



POLITEHNICA University of Timisoara

Faculty of Electrical and Power Engineering

Habilitation Thesis

Teza de abilitare

Advanced Measurement, Command, Control and Protection Equipment for Power Systems

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Part A. ABSTRACT

In the frame of the habilitation thesis are presented the most important personal achievements on scientific, professional and academics plan that I've obtained in the period of time January 2001 – June 2016. This period follows to my public presentation of the PhD thesis which took place on November 10th 2001 (later confirmed by the Order of the Ministry of Education No. 5285 from December 28th, 2001).

The habilitation thesis is structured in three parts: the abstract, the technical presentation and the bibliographic references.

The habilitation thesis starts with an abstract that includes the synthesis of the habilitation thesis typed in English, as well as in Romanian language.

The second part of the thesis named „Technical Presentation” and includes ten sections.

In the first section are presented briefly the remarkable achievements obtained through research and educational activities (list with publications and grants classified on three research directions, new disciplines introduced in the education plans, taught courses, contributions brought to the development of the syllabus, invited professor, practice activities with students, conducting license and dissertation theses, endowed laboratories and library, international cooperation, management activities, etc.). It has to be mentioned that in the period of time 2001 - 2016 I've published a number of 83 scientific articles, I've participated in the frame of 14 research grants / contracts won through competition (at 5 of them I was project director) and I've elaborated 7 books in the fields connected to the present thesis.

The main research directions are:

- A. Measurement, Command, Control and Automation Equipment;
- B. Materials, Equipment, Methods and Work Techniques for Power Commutation;
- C. Devices, Apparatus and Techniques for Power Systems Protection.

The second section presents the contributions adequate to all research directions. The most important scientific achievements are classified in 10 chapters, all three domains being mixed.

The first chapter is related to automation issues based on PLCs. This kind of particular embedded system is replacing traditional electric equipment based on relays and similar devices. Some applications, developed on the Low Voltage Apparatus Laboratory are presented as well.

The second chapter is describing some SCADA systems applied in district heating and power plant facilities. They are result of a project with COLTERM S.A. Timisoara and ELSACO Electronic S.R.L. Some of these software applications are already in use at the Freidorf District Power Plant, in Timisoara or other similar companies.

The third part presents some issues about ferromagnetic forces in computational apparatus which are computed based on a new theory related to Maxwell's tensors. All theoretical aspects are verified by some practical measurements.

The fourth chapter presents some mathematical models applied in order to obtain an excellent interpolation of measured signals which are submitted to DSP's inside digital measurement systems. The B-Spline functions taken in consideration offer an excellent response, mostly to sinusoidal functions, belonging to standard power measurements. This response is certified by a set of experiments.

The fifth part of the research involves fuzzy logic. This modern approach in automation, control, as well as in predictive maintenance is widely used today. I present some results belonging to a Permanent Magnet Synchronous Machine driving strategy (applied for different mechanisms of power apparatus, such as compressors, actuators) which are part of a more complete research, involving a bigger fuzzy logic set of techniques for reliability.

Another major aspect in command, control and automation, inside power networks, located on thousands of square kilometers is data transmission. The sixth chapter presents the assessment of some data security appliances belonging to WLAN networks in Power Systems. It proves that increased security issues are reducing all network times.

Chapter seven is about a new material and some new design algorithms belonging to the area of Metal Oxide Varistors (ZnO based). These devices are the most important part of modern overvoltage surge-arresters. A new and simple method to test their quality is briefly described too. All researches were performed together with some teams from VARSI d.o.o. Slovenia and Paul Sabatier University in Toulouse, France. The works presented refer to the results obtained on the study of varistors (the influence of the manufacturing technology on their quality, the reliability of the ZnO based varistors during exploitation).

The eighth chapter presents an original method for the increase of the heat absorption capacity for a varistor based on ZnO. This method based on additional masses acting like heat absorbers is patented in Romania by the author and helps dissipating the overheat inside the varistor, avoiding destruction. All experiments made in order to confirm this idea were performed at the Paul Sabatier University in Toulouse.

Chapter nine is another independent research carried out in the field of ZnO varistors. It wants to verify the functional limits of certain varistors, on different environmental temperatures. All theoretical parts are followed by experimental ones, made at the LAPLACE Laboratory in Toulouse.

The last chapter presents an overvoltage protection module, called BMS 01, conceived, designed, achieved, tested, homologated and afterwards marketed by the author, as technical manager of PROTENERGO S.A. Timisoara. At the respective moment, it was the first protection module class D entirely designed and achieved in Romania. It still remains the single one entirely designed and produced in Romania, having an original electric shema. It is a true example of technological transfer.

The last section presents the evolution and development plan regarding the professional, scientific and academic career, as well as exact methods of putting them into practice.

The conceived action plan includes three directions of research / teaching / practical applications that are almost the same as previous ones:

- A. Command, Control and Measurement Equipment;
- B. Materials, Equipment, Methods and Work Techniques for Power Commutation;
- C. Devices, Apparatus and Techniques for Power Systems Protection.

There are proposed a series of actual studies, such as: the study of the behavior of insulation systems to external loads (high temperature and/or high electric fields and/or high magnetic fields); studies of the electrical equipments destined to the work under high voltage (LST), new strategies and devices for power systems protection. There are presented, as well, some methods for reaching these targets (objectives).

The third part of the habilitation thesis is dedicated to the bibliographic references grouped into: general references for each chapter as well as grants and research contracts.

The habilitation thesis ends with an annex regarding the overvoltage protection module, class D, manufactured by S.C. Protenergo S.A. from Timișoara, company where I was technical director, and some details about the other grants/contracts.

Part A. REZUMAT (RO)

În cadrul tezei de abilitare sunt prezentate cele mai importante realizări personale în plan științific, profesional și academic pe care le-am obținut în perioada ianuarie 2002 – iunie 2016. Această perioadă urmează susținerii publice a tezei mele de doctorat, care a avut loc în 10 noiembrie 2001 (confirmată ulterior prin Ordinul ministrului învățământului nr. 5285 din 28 decembrie 2001).

Teza de abilitare este structurată pe trei părți: rezumatul, prezentarea tehnică și referințele bibliografice.

Lucrarea debutează cu un rezumat ce cuprinde sinteza tezei de abilitare redactat atât în limba engleză cât și în limba română.

Partea a doua a tezei, denumită „Prezentare tehnică” cuprinde zece secțiuni.

În prima secțiune sunt prezentate sumar realizările remarcabile obținute în activitățile de cercetare și didactică (listă de publicații și granturi clasificate în trei direcții de cercetare, discipline nou introduse în planurile de învățământ, cursuri predate, contribuții aduse la dezvoltarea syllabusurilor, profesor invitat, activități de practică cu studenții, conducerea lucrărilor de licență și disertație, dotare laboratoare și bibliotecă, cooperare internațională, activități de management etc.). De menționat că în perioada 2002 - 2016 am publicat un număr de 83 de articole științifice, am participat în cadrul a 14 granturi/contracte de cercetare câștigate prin competiție (la 5 dintre ele fiind director de proiect) și am elaborat 7 cărți în domenii conexe prezentei teze.

Principalele direcții de cercetare sunt:

- A. Echipamente pentru măsurări, comandă, control și automatizare;
- B. Materiale, echipamente, metode și tehnici de lucru pentru comutație de putere;
- C. Aparare, echipamente și tehnici pentru sisteme de protecție în electroenergetică.

Cea de a doua secțiune prezintă contribuțiile specifice pentru toate direcțiile de cercetare. Cele mai importante realizări științifice sunt clasificate în 10 capitole, toate cele trei domenii definite anterior fiind vizate aleatoriu de către fiecare capitol.

Primul capitol este legat de problemele de automatizare bazate pe PLC-uri. Acest tip de sistem dedicat permite înlocuirea echipamentelor electrice tradiționale, bazate pe relee și dispozitive similare. Anumite aplicații, dezvoltate în cadrul Laboratorului de Aparare electrice de joasă tensiune sunt prezentate, de asemenea, în cadrul capitolului.

Al doilea capitol descrie unele sisteme SCADA aplicate în instalațiile de termoficare și centrale electrice. Ele sunt rezultatul unui proiect dezvoltat împreună cu COLTERM S.A. Timisoara și al unor proiecte pentru Elsaco Electronic S.R.L. Unele dintre aceste aplicații software sunt deja utilizate la centrala termoelectrică Freidorf, în Timișoara sau alte companii similare din țară.

Cea de a treia parte prezintă unele probleme cu privire la forțele feromagnetice care apar în nișele în aparatele de comutație, care sunt calculate pe baza unei noi teorii care ia în considerare tensorii lui Maxwell. Toate aspectele teoretice sunt verificate prin unele măsurători practice.

Al patrulea capitol prezintă câteva modele matematice aplicate în scopul de a obține o interpolare excelentă a semnalelor electrice măsurate care sunt achiziționate prin sisteme de măsurare digitală și prelucrate în interiorul DSP-urilor. Funcțiile de B-Spline luate în considerare oferă un răspuns excelent, mai ales pentru funcții sinusoidale, aparținând măsurătorilor standard din sectorul energetic. Acest răspuns este certificat printr-un set de experimente.

Cea de a cincea parte a cercetării implică logica fuzzy. Această abordare modernă în automatizare, control, precum și în mentenanța predictivă este utilizată pe scară largă în prezent. Sunt prezentate câteva rezultate care aparțin unei strategii de acționare cu mașină sincronă cu magnet permanent (aplicată pentru diferite mecanisme de la aparatele electrice, cum ar fi compresoare, elementele de acționare, etc.) Dar această cercetare face parte care fac parte dintr-una și mai completă mai completă, care implică un set mai mare de logică fuzzy, adaptată tehnicilor de fiabilitate.

Un alt aspect important în zona comandă, control și automatizare pentru rețelele electrice, amplasate pe mii de kilometri pătrați este transmisia de date. Al șaselea capitol prezintă evaluarea unor dispozitive de securitate a datelor care fac parte rețele WLAN din electroenergetică. Acest lucru dovedește că elementele de securitate sporite reduc toți timpii de transfer din rețea.

În capitolul șapte este descris un material nou și noi algoritmi de proiectare care aparțin domeniului varistoarelor cu oxizi metalici (pe bază de ZnO). Aceste dispozitive sunt cea mai importantă parte a echipamentelor moderne de protecție împotriva supratensiunilor. O metodă originală și simplă pentru a testa calitatea lor este descrisă pe scurt, de asemenea. Toate cercetările au fost efectuate împreună cu echipe de la Varsi d.o.o. Slovenia și Universitatea Paul Sabatier din Toulouse, Franța. Aspectele

prezentate se referă la rezultatele obținute pe studiul varistoarelor (influența tehnologiei de fabricație a acestora asupra calității și fiabilității varistoarelor pe bază de ZnO în timpul exploatării).

Capitolul al optulea prezintă o metodă originală pentru creșterea capacității de absorbție a căldurii pentru un varistor bazat pe ZnO. Această metodă bazată pe mase suplimentare care acționează ca și absorbanți de căldură este brevetat în România de către autor și ajută la disiparea căldurii acumulate în interiorul varistor, evitând distrugerea acestuia. Toate experimentele realizate în scopul de a confirma această idee s-au efectuat la Universitatea Paul Sabatier din Toulouse.

Capitolul nouă este o altă cercetare independentă realizată în domeniul varistoarelor pe bază de ZnO. Se dorește să se verifice limitele funcționale ale anumitor varistoare, la diferite temperaturi de mediu. Toate aspectele teoretice sunt urmate de experimente, efectuate la Laboratorul LAPLACE din Toulouse.

Ultimul capitol prezintă un modul de protecție la supratensiune, numit BMS 01, conceput, proiectat, realizat, testat, omologat și apoi comercializat de către autor, în calitate de director tehnic al PROTENERGO S.A. Timisoara. La momentul respectiv, aceasta a fost primul modul clasă de protecție D proiectat și realizat integral în România. Dispozitivul încă rămâne unicul proiectat și produs în România în întregime, având o schemă electrică originală. Este un adevărat exemplu de transfer tehnologic.

Ultima secțiune se prezintă planul de evoluție și dezvoltare în ceea ce privește cariera profesională, științifică și academică, precum și metodele exacte pentru punerea acestor obiective în practică.

Planul de acțiune conceput include trei direcții de cercetare / predare / aplicații practice, care sunt aproape la fel ca și cele anterioare:

- A. Echipamente pentru măsurări, comandă și control;
- B. Materiale, echipamente, metode și tehnici de lucru pentru comutație de putere;
- C. Aparatură, echipamente și tehnici pentru sisteme de protecție în electroenergetică.

Sunt propuse o serie de studii de actualitate precum: studiul comportării sistemelor de izolație la solicitări extreme (temperatură înaltă și/sau câmpuri electrice mari și/sau câmpuri magnetice mari); studii asupra echipamentelor electrice destinate lucrului sub înaltă tensiune (LST), noi strategii privind echipamentele de protecție. Sunt prezentate, de asemenea, unele modalități de atingere a acestor planuri.

Partea a treia a tezei de abilitare este dedicată referințelor bibliografice grupate în: referințe generale pentru fiecare capitol precum și lista granturilor-contractelor derulate în intervalul 2002 - 2016.

Teza de abilitare se încheie cu o anexă, referitoare la modulul de protecție contra supratensiunilor, clasa D, produs de către S.C. Protenergo S.A. din Timișoara, firmă la care am fost director tehnic, precum și detalii privind unele granturi-contracte.

Part B. TECHNICAL PRESENTATION

1. Overview of Activity and Results

On November 10th, 2001 I've publicly defended my PhD thesis titled „Contributions to the Improvement of Energy Performance of ZnO Varistor based Surge Arresters” Afterwards, by the Order of the Ministry of Education No. 5285 from December 28th, 2001, I've obtained the title of „Doctor Engineer”.

The personal achievements in the scientific, professional and academic plane shall be presented below, only for the period of time from January 2002 – May 2016. During this period of time, as a member of the teaching staff at Politehnica University of Timișoara I've asserted a series of disciplines, correlated with the local and international standards, like:

- Electrical apparatus and equipment (3rd year, Electrical Engineering, Faculty of Electrical and Power Engineering);
- Electrical energy use and large consumers 3rd year, Power Engineering, Faculty of Electrical and Power Engineering);
- Materials and technologies (2nd year, Economical Engineering, Faculty of Management in Production and Transport);
- Materials used in electrical engineering (2nd year, Electrical Engineering, Faculty of Electrical and Power Engineering);
- Materials used in power engineering (2nd year, Power Engineering, Faculty of Electrical and Power Engineering);
- Electrical and Non-Electrical Measurements part I (2nd year, Power Engineering, Faculty of Electrical and Power Engineering);
- Electrical and Non-Electrical Measurements part II (3rd year, Power Engineering, Faculty of Electrical and Power Engineering);
- Reliability and Industrial Risk (3rd year, Power Engineering, Faculty of Electrical and Power Engineering);
- PLCs and Embeded Systems (1st Master year, Power Engineering, Faculty of Electrical and Power Engineering);

The assimilation of the mentioned disciplines, the development of analytic programs and their assertion was possible only by a full correlation between the teaching and research activity. The special results registered in the frame of the research activity were found also in the elaborated teaching materials.

The research activity, accomplished in the framework of the University Politehnica Timișoara, as well as at other universities (University „Paul Sabatier” of Toulouse, University of Chemical Technology and Metallurgy of Sofia, sothampton Institute for Higher Education-U.K., Nigde University Turkey a.o.) and companies (S.C. Protenergo S.A. in Timișoara – where I was Technical director from 2001up to 2010), was structured on following research domains, related to apparatus and equipment applied in power and electrical engineering:

- A. Measurement, Command, Control and Automation Equipment;
- B. Materials, Equipment, Methods and Work Techniques for Power Commutation;
- C. Devices, Apparatus and Techniques for Power Systems Protection.

In each of these three research directions I've had important contributions during this period of time.

Due to the interconnection between these research directions, belonging mostly to apparatus and equipment area, it is very hard to separate them in distict chapters or independent directions. All the 10 significant results described below could be easily integrated in 2 or all 3 domains.

The contributions concerning **Measurement, Command, Control and Automation Equipment** are presented in almost all sections. In order to emphasize this, I've made reference to a series of results obtained from researches performed in this field, results presented in:

- 2 specialty books published at publishing companies of the country, recognized by CNCSIS, among them being one typed in French language, [2.7.6], [2.9.12] ;
- 3 electronic courses on the POLITEHNICA University site [EC1], [EC2], [EC3].
- 5 articles published in the volumes of international scientific manifestations (proceedings), quoted ISI, [2.2.12], [2.4.1], [2.4.4], [2.4.5] [2.5.6], [2.9.5] ;
- 1 article published in specialty journals, indexed ISI, [2.1.3]
- 1 article published in specialty journals, indexed in international data basis (BDI), [2.1.2];
- 6 articles published in the volumes of some international scientific manifestations (proceedings), indexed in international data basis (BDI), [2.2.8], [2.3.7], [2.4.6], [2.4.7], [2.5.7], [2.5.8];
- 9 articles published in the volumes of some international scientific manifestations organized in Romania (with scientific referents), not mentioned as references.

A great part of the published results that treat problems specific to automation and measurement issues in the electrical and power engineering were obtained as a result of researches performed in the framework of:

- 3 international research grants won through competition [IG1], [IG4], [IG5];
- a national research grant (CNCSIS) won through competition, [NG2];
- 4 research contracts / consultancy unfurled on the demand and under the financing of some companies in Romania, [CC1], [CC2], [CC3] and [CC4].

I mention that, as grant director, I've coordinated the research activities performed in the frame of 3 international research grants that are:

- BROKINNOVOUCHER – Support for Innovative Crossboard Cooperation for SMEs located in Romania and Hungary, financed by PHARE CBC [IG1];
- „Système de formation continue par la recherche dans le domaine de la maintenance des installations électriques”, grant ruled with the financial support of the University Agency of Francophony, [IG5].

The contributions concerning **Materials, Equipment, Methods and Work Techniques for Power Commutation** are presented, like in previous case, in almost all sections. In order to emphasize this, I've made reference to a series of results obtained from researches performed in this field, results presented in:

- 3 specialty books published at publishing companies inside the country, recognized by CNCSIS, among which one was published in French language, [2.1.9], [2.7.11] [2.7.4];
- 6 articles published in the volumes of some international scientific manifestations (proceedings), indexed ISI, [2.3.9], [2.7.5], [2.9.6], [2.9.8], [2.9.11] and [2.10.10];
- 5 articles published in the volumes of some international scientific manifestations (proceedings), indexed in international data basis (BDI), [2.7.7], [2.8.3], [2.8.5], [2.8.7], [2.8.8];
- 1 article published in specialty journals, indexed ISI, [2.5.15]
- 1 article published in specialty journals, indexed in international data basis (BDI), [2.3.4];

- 22 articles published in the volumes of some international scientific manifestations organized in Romania (with scientific referents), not mentioned as references.

A part of the published results, regarding different problems connected to the power apparatus was obtained as a result of researches performed in the framework of:

- 2 international research grants won through competition [IG2], [IG3];
- a national research grant (CEEX) won through competition, [NG1].

I mention that, as grant director, I've coordinated the research activities unfurled in the frame of the CEEX grant [NG1]:

- "Improvement of Energy Performance of ZnO Varistor based Low Voltage Surge Arresters", [NG1];

Devices, Apparatus and Techniques for Power Systems Protection is another research direction correlated with the other two. In some chapters I've made reference to a series of results obtained from researches performed in this field, results presented in:

- 2 specialty books published at publishing companies of the country, recognized by CNCSIS, [2.3.5], [2.10.2] ;
- 6 articles published in the volumes of international scientific manifestations (proceedings), quoted ISI, [2.7.5], [2.8.1], [2.10.3], [2.10.6] [2.10.8], [2.10.9] ;
- 1 article published in specialty journals, indexed ISI, [2.9.10]
- 6 articles published in the volumes of some international scientific manifestations (proceedings), indexed in international data basis (BDI), [2.6.5], [2.6.6], [2.6.7], [2.6.8], [2.6.9], [2.6.10];
- 11 articles published in the volumes of some international scientific manifestations organized in Romania (with scientific referents), not mentioned as references.

A part of the published results that treat problems regarding the impact of electrical installations on the environment was obtained as a result of researches performed in the frame of:

- one international research grant won through competition [IG6];
- a national research grant won through competition, [NG2].
- 1 research contracts / consultancy unfurled on the demand and under the financing of some companies in Romania, [CC5].

In the period of time 1997 – 2014, by filling in the things mentioned above, I've unfurled a series of other teaching and scientific activities, such as:

- I've contributed to the development of the research resources of the laboratories of Electrical apparatus and equipment. Measurements and Electrotechnic materials, by: the modernization of the computation technique, by the acquisition of some kits of devices and equipments specific for these laboratories, the acquisition of samples of electrotechnic materials and the endowment of the laboratories library with new prospects, standards and specialty books.
- I've participated to the optimal derulement of 6 programs POSDRU. I underline only activities regarding the professional improvement in the scientific activity unfurled in the frame of the project POSDRU/21/1.5/G/13798 „Doctoral school to the support of the research under the European context”.

In the frame of this project I've guided next to the doctorate coordinator Prof.Dr.Eng. Petru Andea, the activity of an active doctorate student (Florin Solomonesc) in the field of „Engineering sciences – Power engineering”.

- I've received 4 citations in specialty journals and in the volumes of some scientific manifestations (proceedings), indexed ISI, respectively 10 citations in specialty journals and volumes of some scientific manifestations (proceedings), indexed ISI BDI. It must be remarked also the fact that two of my books published in the French language („Considerations sur la qualité de l'énergie électrique” and „Matériaux pour le génie électrique”) were chosen for the 25th prize Roberval at the category „Enseignement Supérieur”.
- I've asserted 3 invited presentations in the plenum of some international scientific manifestations, respectively 4 invited presentations in the plenum of some national scientific manifestations.
- I was member of the publishing teams or scientific committees of some journals and national and international manifestations: 1 indexed ISI, 1 indexed in other BDI and 12 not indexed.
- I was member in the management of some international and national professional associations:
 - Long time expert at the Regional bank of Experts at the Francophone University Agency – Office for Central and Eastern Europe in Bucharest, expertise field D 122 – electrical and power engineering;
 - Long time expert in the field of electrical and power engineering of the Agency of Credits and Study Scholarships (with the old denomination National Center for Study Scholarships Abroad);
 - Long time expert for TEHIMPULS, the Regional Center for Innovation and Technological Transfer.
- I was member of different international and national professional associations:
 - Institute of Electrical and Electronics Engineers (United States of America);
 - Association for Multidisciplinary Research in West Region / Romania (President);
 - The Society of Power Engineers in Romania;

In the period of time between 2002 and 2016 I've occupied a series of managing and administrative activities on the support of the teaching, research-development process, etc., among which I mention following:

- I was the coordinator of 1 bilateral agreement with the Nigde University in Turkey, in the framework of the Erasmus program concerning the mobility of students and teaching staff;
- I was technical (R&D) director (2001-2010) at S. C. Protenergo S. A. in Timișoara, a private Company that valued a part of the achievements obtained in the field of the protection of electric low voltage installations against overvoltages;
- Member in the Council of the Department of Power Engineering (2012 - present) at the Faculty of Electrical and Power Engineering;
- Member of the Council of the Faculty of Electrical and Power Engineering (2016- nowadays).
- Member of the „Center for Students Information and Counselling” (at the Rectorate of University Politehnica Timisoara) starting with the year 2012.
- Member of the „Research Center for the Analysis and Optimization of Power Systems Regimes (University Politehnica Timisoara)” starting with the year 2012.
- Member of the board of specializations in the field of Power and Electrical Engineering.

Considering all performances obtained and presented summary above, the request of the habilitation attest in Power Engineering represents, from my point of view, a natural continuation of the personal activity, with the aim of the future development of a research and university career as doctorate coordinator.

2. Research Results

2.1. The Integration of PLCs in Command and Control of Different Industrial and Power Applications

Monitoring and control of all industrial processes is an important issue in our era. During the last few years we assist to an increased number of control equipment based on PLC's. PLC's (Programmable Logic Controllers) are today the most common technical solution applied to such equipment due to some obvious advantages [2.1.8]:

- the electrical scheme of the whole equipment could be easily modified by changing only some program instructions;
- increased flexibility;
- safety in exploitation;
- improved liability;
- reduced volume;
- it not requires special and periodical maintenance;
- it could be easily programmed by any electrical engineer or technician;
- any control sequence could be virtually verified without any costs or risks.

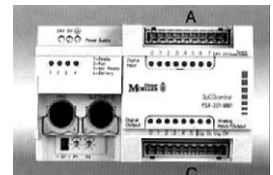


Fig. 2.1.1:
the PS 4-201
PLC basic type

When the price of all classic electrical equipment replaced is higher than PLC's price, this piece of equipment becomes even economically justified, being cheaper than the old parts changed. In fact, a PLC is a small industrial computer specialised in simultaneously treatment of both combinational and sequential logic instructions. It is a piece of equipment which allows connections between a large number of inputs and another large number of outputs [2.1.4].

It simulates the classical wire structure by using logical ports disposed in a flexible and complex structure. Figure 2.1.1. shows us such a PLC type PS4-201 MM1 produced by the German manufacturer Klöckner MOELLER, belonging to the Low Voltage Equipment Laboratory of the POLITEHNICA University of Timisoara [2.1.9].

The proposed piece of equipment has 6 digital inputs (marked with an A) and 8 digital outputs (marked with a C). All digital inputs and outputs are 24 V DC and maximum current of 100 mA. This current allows enough power to control a semiconductor device, relay or micro-contactor connected to that output. It also disposes of two analogical inputs and one analogical output all offering an array of 0 - 12 V DC at maximum 100 mA. This PLC disposes of a serial RS 232 communication port which allows program downloading from an external program source (PC or panel) [2.1.1]. It also has a RS 485 serial communication connector used for PLC connections and an extension module connector for multiplying all the inputs and outputs needed.

According to IEC 1131-3, it accepts all languages compatible with:

- ◆ **IL** (Instruction list);
- ◆ **LD** (Ladder Diagram);
- ◆ **FB** (Function Block).

Next, we will present two original applications taking from the industrial and agricultural environment: command of a conveyor sequence and of a silage facility [2.1.2].

2.1.1. Conveyor Band Command Sequence

The process controlled by this sequence is a normal conveyor belt used for cereal transport, located in each storage areas. The most important aspect is the refurbishment of existing equipment, without any considerable modification.

Figure 2.1.2. shows the main application panel for this conveyor band sequence. As we notice in Figure 2.1.2., this panel refers to an agricultural conveyor band sequence made of 3 different segments called **Band1**, **Band2**, **Band3**, each of them driven by a squirrel-cage induction motor. Those engines are directly connected to the power supply network by using 3 main contactors called **K1**, **K2** and **K3**,

The cereal grains are loaded on the first conveyor segment in order to be transported to the storage area at the end of the third segment. The proper functioning of the 3 contactors is shown by 3 LED's located on the panel. On the up-right corner of the same panel, there is a button set used to activate all PLC inputs (process outputs) [2.1.3].

They are:

- **S0** is the STOP button;
- **S1** is the button used to start the first segment in manual mode;
- **S2** is the button used to start the second segment in manual mode;
- **S3** is the button used to start the third segment in manual mode.
- **S4** is the start button for the automatic sequence.
- **S5** is the button reserved to simulate a fault caused by an overload.

There are 4 other LED's located in the same area:

- the **H1** LED indicates the appropriate operation of **Band 1**, no matter manual or automatic mode.
- the **H2** LED indicates the appropriate operation of **Band 2**, no matter manual or automatic mode.
- the **H3** LED indicates the appropriate operation of **Band 3**, no matter manual or automatic mode.
- the **H4** LED indicates the appropriate operation of all equipment in automatic mode. When it flickers, a fault is detected.

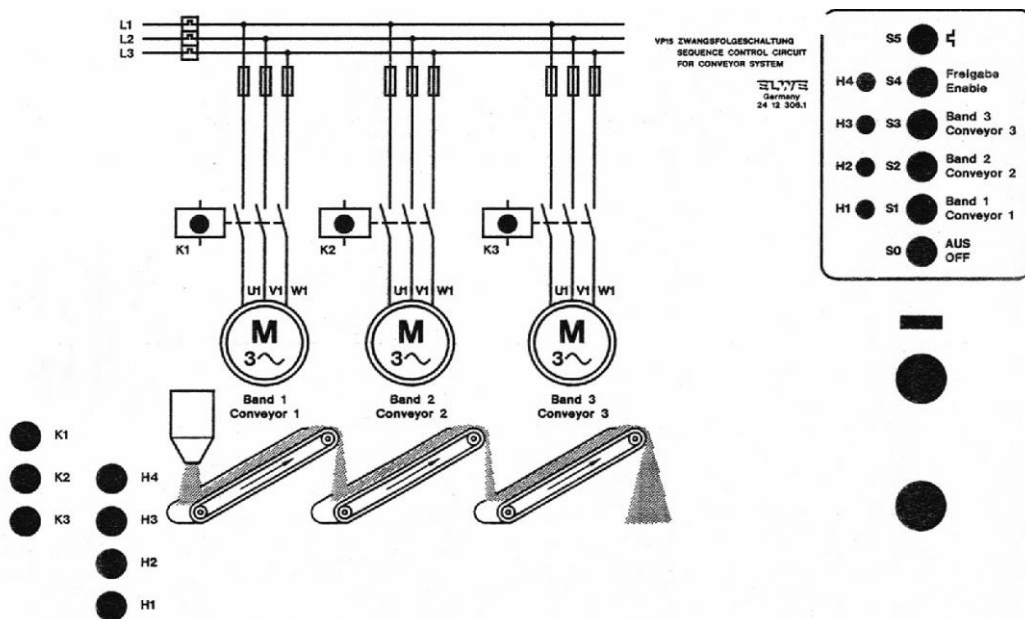


Fig. 2.1.2: Conveyor band sequence. Monitoring and control panel

The control algorithm is, as follows:

- The conveyor band sequence starts automatically when pressing the **S4** button. Automatically mode selection is confirmed by the **H4** LED.
 - ✓ Then, after 2 seconds (time for feeding the start point with cereal grains), the first segment, **Band 1**, starts by activating the **K1** contactor. This situation is indicated by the **H1** LED showing the operational status of the first engine.
 - ✓ After 5 seconds from **Band 1**'s start through the **K1** contactor, (the necessary time for all cereals to pass through that segment), the second segment will be activated, through the **K2** contactor. The function status of the **K2** contactor is indicated by the **H2** LED.
 - ✓ After another 5 seconds from **Band 2** through **K2**, (the necessary time for all cereals to pass through that segment), the third segment will be activated, through the **K3** contactor. The function status of the **K3** contactor is indicated by the **H3** LED.
 - ✓ During service, for each segment, **K1**, **K2**, **K3** and **H1**, **H2**, **H3**. LED's will rest on. The **H4** LED will indicate automatic mode selection.
- **Band 1**, starts independently from the others (in manual mode) when pressing the **S1** button. The **K1** contactor will be connected as well as the corresponding LED indicator **H1**.
- **Band 2**, starts independently from the others (in manual mode) when pressing the **S2** button. The **K2** contactor will be connected as well as the corresponding LED indicator **H2**.
- **Band 3**, starts independently from the others (in manual mode) when pressing the **S3** button. The **K3** contactor will be connected as well as the corresponding LED indicator **H3**.
- Those operations are not permitted when the automatic mode is selected. One, two and even all three conveyor band segments could operate simultaneously during manual mode, depending on the given control modes.
- All equipment stops when the **S0** button is pressed, no matter the operational mode.
 - ✓ If the automatically mode is selected, all engines running at that time will be disconnected through the **K1**, **K2**, **K3** contactors. The corresponding LED's **H1**, **H2**, **H3** and, obviously, **H4** will be shut off.
 - ✓ If the manual mode is selected, all engines running at that time will be disconnected through their dedicated contactors. The corresponding LED's will be shut off.
 - ✓ Overload simulation is made by pressing the **S5** button.
 - ✓ That fault could occur no matter if automatic or manual mode is active.
 - ✓ All segments running will be shut down. The corresponding LED's will be shut off, as well as, of course, all active contactors.
 - ✓ The **H4** will blink during 15 seconds, time needed for short engine and relay cooling, indicated fault mode.
 - ✓ No re-connections are permitted during this period.
 - ✓ After 15 seconds manual or automatically mode selection is permitted.

After describing all functional requirements for the conveyor band, the necessary control program write into the **Sucosoft S40** dedicated language [2.1.7], which does all those operations through the PLC, is shown below.

```

VAR (variable declaration section)
K2 AT %Q0.0.0.0.2 : BOOL ;
K1 AT %Q0.0.0.0.1 : BOOL ;
K3 AT %Q0.0.0.0.3 : BOOL ;
S1 AT %I0.0.0.0.1 : BOOL ;
S2 AT %I0.0.0.0.2 : BOOL ;
S3 AT %I0.0.0.0.3 : BOOL ;
S0 AT %I0.0.0.0.0 : BOOL ;
S4 AT %I0.0.0.0.4 : BOOL ;
S5 AT %I0.0.0.0.5 : BOOL ;
avarie : TP ;
stav : BOOL ;

```

```

p1 : TP ;
p2 : TP ;
p3 : TP ;
avarie : TP ;
stav : BOOL ;
p1 : TP ;
p2 : TP ;
p3 : TP ;
timp1 : TIME := t#2s ;
timpav : TIME := t#15s ;
timpsem : TIME := t#0.5s ;
nosemn : TP ;
stpor1 : BOOL ;
stpor2 : BOOL ;
stpor3 : BOOL ;
timp2 : TIME := t#5s ;
timp3 : TIME := t#5s ;
semn : TP ;
stsemn : BOOL ;
stnosemn : BOOL ;
man1 : BOOL ;
po1 : BOOL ;
auto : BOOL ;
oprire : BOOL ;
H1 AT %Q1.1.0.0.1 : BOOL ;
H2 AT %Q1.1.0.0.2 : BOOL ;
H3 AT %Q1.1.0.0.3 : BOOL ;
H4 AT %Q1.1.0.0.4 : BOOL ;
man2 : BOOL ;
man3 : BOOL ;
END_VAR

```

Main program section

```

ld          S4
r          oprire
ld          S4
andn       avarie.q
s          H4
s          auto
st         stpor1
cal        p1(in:=stpor1,pt:=timp1)
ldn        p1.q
and        auto
andn       oprire
andn       avarie.q
s          k1
s          H1
st         stpor2
cal        p2(in:=stpor2,pt:=timp2)
ldn        p2.q
and        auto
andn       oprire
andn       avarie.q
and        k1
s          k2

s          H2
st         stpor3
cal        p3(in:=stpor3,pt:=timp3)
ldn        p3.q
and        auto
andn       oprire
andn       avarie.q
and        k1
and        k2
s          k3
s          H3
ld         S0
s          oprire
ld         oprire
and        auto
r          k1
r          k2
r          k3
r          H1
r          H2
r          H3
r          H4
ld         S5
st         stav
st         stsemn
s          oprire
r          k1
r          k2
r          k3
r          H1
r          H2
r          H3
r          H4
cal        avarie(in:=stav,pt:=timpav)
cal        semn(in:=stsemn,pt:=timpsem)
ld         avarie.q
and        semn.q
s          H4
ld         avarie.q

```

```

andn      semn.q
r          H4
st        stnosemn
cal       nosemn(in:=stnosemn,pt:=timpsem)
ld        avarie.q
andn      nosemn.q
st        stsemn
cal       semn(in:=stsemn,pt:=timpsem)
ld        S1
r         auto
r         H4
r         oprire
ld        S1
andn      avarie.q
andn      auto
andn      oprire
s         k1
s         H1
s         man1
ld        S2
r         auto
r         H4
r         oprire
ld        S2
andn      avarie.q
andn      auto
andn      oprire
s         k2
s         H2
s         man2
ld        S3
r         auto
r         H4
r         oprire
ld        S3
andn      avarie.q
andn      auto
andn      oprire
s         k3
s         H3
s         man3
ld        S0
s         oprire
ld        oprire
and       man1
r         H1
r         k1
ld        oprire
and       man2
r         H2
r         k2
ld        oprire
and       man3
r         H3
r         k3

```

The process controlled by this programming sequence is a normal silage used for cereal storage, located in each ceareal process areas. The most important aspect is the refurbishment of existing equipment, without any considerable modification of the electrical installtion allready on place .

2.1.2. Silage Facility Command Sequence

Figure 2.1.3. shows the main application panel for this silage command sequence. As we notice in Figure 2.1.3., this panel refers to agricultural silage both for filling and discharge sequence made of 4 different levels called **Level 1**, **Level 2**, **Level 3**, **Level 4**, progressive as volume, each of them having a level positioning sensor, called **S6**, **S7**, **S8** and **S9**. Filling of the silage is made throughout a **M1** pump and discharge is made by using an **Y1** electric valve. On the simulation panel there is a switch contact called **mode**, which switch between standard speeds of filling/discharge and manual set speeds.

When selecting **mode**, it switches all sequences from automatic to manual and reverse. Speeds in manual mode are preset by the two regulator switches called **M1-supply rate** and **Y1-discharge rate** located both on the right side of the control panel. All the other commands are the same, both manual and automatic; it only allows a different desired speed respecting the command logical sequence when manual.

All equipment starts when selected a desired cereal level and an operation (supply or discharge) and stops only when the desired cereal level is attended.

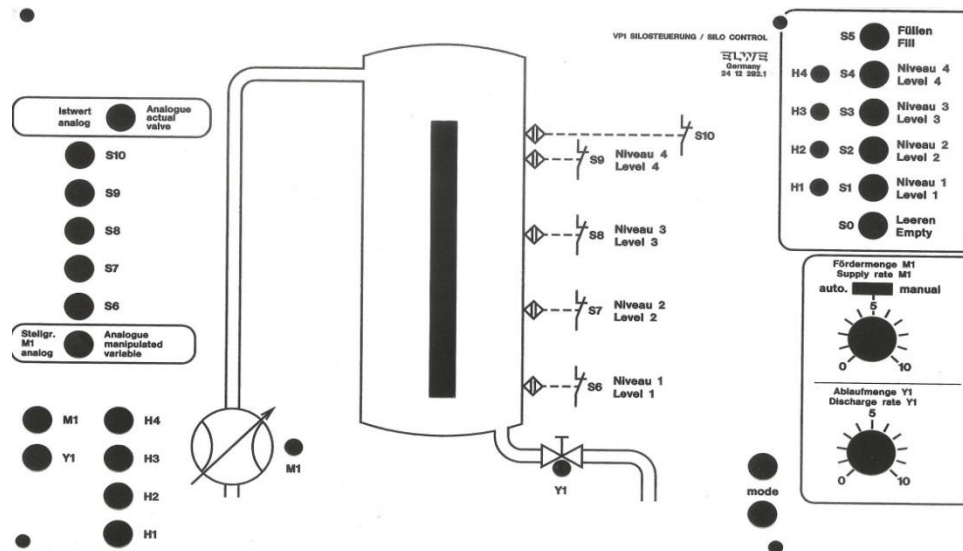


Fig. 2.1.3. Cereal Silage Simulation Panel

The cereal grains inside are simulated by a red LED column located in the center of the panel, continuously lighted, depending on the real level. **Maximum Level** sensor is given by the **S10** contact. The proper functioning of the 4 levels is shown by 4 LED's located on the right side command panel. On the up-left corner of the same panel, there is a button set used to activate all PLC inputs (process outputs). They are:

- **S6** is **Level 1** sensor;
- **S7** is **Level 2** sensor;
- **S8** is **Level 3** sensor;
- **S9** is **Level 4** sensor.
- **S10** is **Maximum Level** sensor.
- **Y1 analog** is the input connection for analog discharge in manual mode;
- **M1 analog** is the input connection for analog supply in manual mode.

These are basically are PLC inputs coming from the process.

The whole process has other PLC inputs, coming from the main panel, as user commands. Those additional command inputs are (no matter manual or automatic mode):

- **S0** is the setting button for silage discharge;
- **S1** is the setting button for **Level 1**;
- **S2** is the setting button for **Level 2**;
- **S3** is the setting button for **Level 3**;
- **S4** is the setting button for **Level 4**;
- **S5** is the setting button for silage filling.

Due to the higher number of PLC inputs, we will use a separate extension module type EM 4-101 DD1, also made by Moeller and compatible with the PLC. This device has to be declared in the Project Configuration sequence of the software.

There are 4 other LED's located in the same area of the user control panel:

- the **H1** LED indicates the appropriate cereal stock position on **Level 1**, no matter manual or automatic mode;
- the **H2** LED indicates the appropriate cereal stock position on **Level 2**, no matter manual or automatic mode;

- the **H3** LED indicates the appropriate cereal stock position on **Level 3**, no matter manual or automatic mode;
- the **H4** LED indicates the appropriate cereal stock position on **Level 4**, no matter manual or automatic mode.

The control algorithm is, as follows:

- There are two major situations for the silage command and control sequence: *filling* and *discharging* the cereals from the storage facility. The filling operation is selected by pressing the **S5 Fill** button once. Discharging is made when pressing the **S0 Empty** button. When one of them is pressed, the other operation is canceled. When selecting the manual **mode**, in connection with **Analog manipulated variable** and **Analogue actual valve**, the supply or discharge rate is given by the **M1** and **Y1** speed selectors.
- The cereal level is shown on the command panel by lighting the corresponding level LEDs **H1**, **H2**, **H3** or **H4** (depending on the cereal colon height 1,2,3 or 4 LEDs).
- The level is signaled to the PLC by the level sensors **S6**, **S7**, **S8**, **S9** and **S10**. The first sensors are related with cereal level LEDs described before. **S10** is activated only when the silage is full and charging has to be stopped.
- Starting and stopping the whole command panel (and silage command sequence) are made independently by simply turning power on or off, for the command panel, on a different selector.
- After selecting the filling or discharge procedure (**M1** or **Y1**) the silage manager has to select the desired level. The procedure works only if the desired level could be reached (it doesn't work, for example, if you want to fill the silage at a lower level then the real existing one or if you want to discharge the silage at an upper level). This procedure stops when the desired level is reached. Of course, the unnecessary LEDs of the discharged levels shut down as well as the new level LEDs of the filled areas are lighting up. Existing level LEDs are lighting without interruption on the command panel. Filling is stopped automatically when **S10** maximum level is reached and discharging is stopped automatically when **S6** minimum level is reached. Cereals are simulated by a continuously lighting column inside the silage facility.

After describing all functional requirements for the conveyor band, the necessary control program write into the **Sucosoft S40** dedicated language, which does all those operations through the PLC, is shown below [2.1.6].

```

VAR (variable declaration section)
M1 AT %Q0.0.0.0.1 : BOOL ;
Y1 AT %Q0.0.0.0.0 : BOOL ;
K3 AT %Q0.0.0.0.3 : BOOL ;
S1 AT %I0.0.0.0.1 : BOOL ;
S2 AT %I0.0.0.0.2 : BOOL ;
S3 AT %I0.0.0.0.3 : BOOL ;
S0 AT %I0.0.0.0.0 : BOOL ;
S4 AT %I0.0.0.0.4 : BOOL ;
S5 AT %I0.0.0.0.5 : BOOL ;
S6 AT %I1.1.0.0.1 : BOOL ;
S7 AT %I1.1.0.0.2 : BOOL ;
S8 AT %I1.1.0.0.3 : BOOL ;
S9 AT %I1.1.0.0.0 : BOOL ;
S10 AT %I1.1.0.0.4 : BOOL ;
H1 AT %Q1.1.0.0.1 : BOOL ;
H2 AT %Q1.1.0.0.2 : BOOL ;
H3 AT %Q1.1.0.0.3 : BOOL ;
H4 AT %Q1.1.0.0.4 : BOOL ;
umplere : BOOL ;
golire : BOOL ;
END_VAR

Main program section

ld          S5
r           S0
s           umplere
r           Y1
ld          S0

```

```

r          S5
s          golire
r          M1
ld         S6
s          H1
ld         umplere
and        S2
andn       S7
s          M1
ld         S7
r          M1
s          H2
ld         umplere
and        S3
andn       S8
s          M1
ld         S8
r          M1
s          H3
ld         umplere
and        S4
andn       S9
s          M1
ld         S9
r          M1
s          H4
ld         umplere
andn       S10
and        S9
s          M1
ld         S10
r          M1
ld         golire
and        S10
and        S4
s          Y1
ld         S9
r          Y1
ld         golire
and        S9
and        S3
andn       S10
s          Y1
ld         S8
r          Y1
r          H4
ld         golire
and        S8
and        S2
andn       S9
s          Y1
ld         S7
r          Y1
r          H3
ld         golire
and        S7
and        S1
andn       S8
s          Y1
ld         S6
r          Y1
r          H2

```

PLC's are fully recommended for monitoring and control of such equipment located in agricultural areas (silages, cereal conveyors). A small program sequence introduced to a PLC could replace many electrical devices involved in a classic structure, reducing equipment costs. It could increase safety and reliability of all units involved at a lower maintenance cost, with interchanging possibilities. No major changes have to be made in the control scheme in order to apply these technical solutions. The program sequences could be easily verified virtually. They are totally suitable for agriculture/industrial equipment due to the simplicity of operation process too.

It could be applied without major changes to all existing equipment, as a refurbishment, with an updating and energy saving effect.

2.2. Human Machine Interface for a SCADA System applied on a District Heating Power Plant

District heating is largely used today in many Romanian cities. But, having an efficient heating system on such a large area, it needs an adequate command, control and measuring system, too. Due to the continuous limitation of resources and also due to the high price of the energy, the measurement and the management of the heating agent is a real priority for the power plants and also for the heating distribution companies from Romania. There is a huge trend in the Romanian district heating industry to introduce as many as possible IT and TC solutions, or excellent measuring capacities. This chapter presents a human-machine interface, conceived by the authors and applied in the case of the small Power Plant located in Freidorf-Timișoara and applied to other facilities, too. Starting from computer science, computer graphics and thermal engineering, to electronics and electrical engineering, this is a true example of a multidisciplinary research [2.2.2].

A few hundred Romanian towns have their own district heating facility. That's why all activities relating to its maintenance are so important in our country, which has a climate with excessive winters, with temperatures up to -35 degrees Celsius, and around -10 degrees normally in all regions.

This kind of activities consists in:

- establishing the right measurement solution, choosing and assembling all the measurement equipment;
- doing the design, selecting the supply companies, producing or executing all the systems involved;
- making all the metrological tests needed, offering service, spare parts;
- training clients' engineers and technicians;
- using a quality assurance system (ISO 9001 compatible).

Any technical solution presented requires some specific particularities imposed by customer's technical conditions. It means that every application is unique and it's made only to satisfy a certain client for a certain application.

That's why, in our University, we make not only the necessary technical transfer but also it looks for specific customer needs. The most important intelligent thermal energy measurement, control and resource management systems made by me are [2.2.1]:

- electronic measurement, control and management system of heating energy for a standard Romanian block of flats' stair;
- electronic measurement, control and management system of heating energy for a standard Romanian district thermal exchange station;
- automatic measurement, control and payment system of heating energy for a standard Romanian block of flats' stair, using a portable terminal and inductive transducers;
- semi-automatic measurement, control and payment system of heating energy for a standard Romanian block of flats' stair, using a portable terminal and inductive transducers.
- any other type of dedicated intelligent measurement solution applied for District Heating.

For the next future, many other Romanian Heating Distribution Companies have the intention to integrate such automatically systems adapted to their needs, in order to improve the quality of their services, to reduce some costs and to calculate and reduce all the loses [2.2.5].

2.2.1. The Architecture of the SCADA System

The implementation of such a system, applied for district heating networks, can be solved by a multi-level organization [2.2.3]:

The first level (level 0) consists of primary elements that collaborate within the process. At this level takes place an automation of the process, which requires accomplishing some functions of adjustment of the primary characteristic variables, as well as the taking over and measuring of some important values. The “0” level consists of:

- sensors and translators (flow, temperature, pressure, and so on)
- electronic devices for local processing (thermal integrators, frequency invertors, flow computers, and so on)
- execution elements (ordered tap, adjustment gates with 2 or 3 ways, pumps, boilers, heat modifiers, pressure differential adjusters, and so on)

The second level (level 1) is realized with the automation logic, and the data acquisition equipment. This level realizes:

- the over taking of the signals from the sensors and from the primary elements. This can be analogical (0-10V or 4-20mA) or binary (voltage impulses, contacts), in order to control the principal parameters of the central;
- it can also have the purpose of the automatic running mode of the central, through ordering and adjusting signals of the execution elements.

The information can be locally surveyed for the efficient management of the central. Also, at this level takes place the management and the automatic data centralization taking in counter the long distance data broadcasting from the local broadcaster.

This level consists from the following equipment:

- Controllers for automation and spreading the boilers, controllers for temperature adjustment of the thermal agent and the hot water for every leaving circuit.
- The acquisition and data centralization for the efficient management at the level of the central.
- The communication interface has a superior level.

The third level consists from the Central Point (the Broadcaster), which surveys and can well manage the functioning of all thermal centrals. Level 3 is made of:

- PC Broadcaster station
- PC network, specialized for various operations for broadcasting (efficient running – diagnosis – alarms, information management regarding the consumptions registered and automatic client invoicing, server specialized for managing the communications with thermal central and of various public institutions).
- The communication system (adjusted with the transmission medium – telephonic line (dedicated or rented) radio-channels, GSM or optical wire).

The broadcaster surveys in real time all available values in the process computers from the centrals and has the possibility of long distance control for limit and adjustment parameters. It has the possibility of communication with other component elements of the first level having the „master” role in this system. The central computer can gather important information. The information is referring to the process history and to all the essential values that can be controlled or supervised.

Such kind of an intelligent system consists in [2.2.4]:

- **The automation subsystem (LCS & PCS):**

- controller for process automation – has as a ground principle the architecture of the Excel controller series 500 made by Honeywell (in our case), specialized in boilers automation, pumps command and temperature compensation from the leaving circuits for heating and hot water. This controller has the advantage of being able to bear full changes in structure and is free to be programmed, having the possibility to be further spread with modules and supplementary functions;
- the temperature and pressure sensors necessary to the automation;
- the gates with 3 adjustment ways.

- **The control and operative central (PCS & SCS) subsystem:**

It is made of measuring and displaying equipments, like:

- An industrial process computer – which has as a starting point a PC / EAD system, model AR2000 developed by Elsaco Electronic specially designed for:
 - Process data acquisition (from the pressure sensors, temperature sensors, cold water indicators thermal energy and CLU fuel present in the central, hot water indicators and thermal energy assembled at consumers),
 - Processing, managing, archiving and displaying the useful information at the level of the human operator from the central;
 - Interaction with the human operator;
 - Communication with the common equipment level.
- The appropriate process interfaces, accessories (MBUS/RS232 inverter for data acquisition from the CT indicators, the supplying source of the temperature and pressure sensors)
- Temperature and pressure sensors.
- Thermal energy and cold water indicators.
- Fuel indicator.
- Thermometers and hand meters.

- **Connection equipment and communication subsystem:**

- PC common equipment station.
- Needle printer for alarms.
- Laser printer for reports.
- The communication system between PC common equipment and the process computers (Ethernet protocol).
- Optical wire network (or wireless/GSM network).
- Switch-hubs for assuring the communication capacity at 7 thermal centrals.
- Network boards, environmental interfaces (FO/UTP) and appropriate accessories for computer communication.

The equipment for automation, command, control, protection and supplying will be included in one unique panel for automation and force.

Below, we present the systems' architecture:

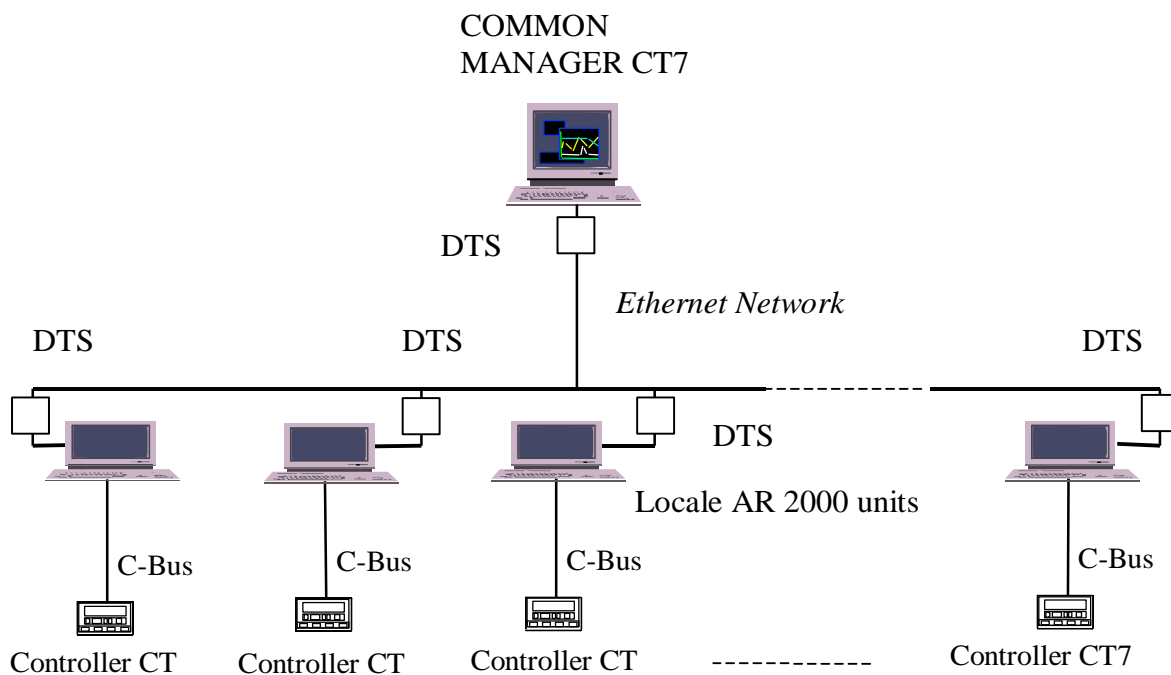


Fig. 2.2.1. System's architecture

This architecture is applied to many district heating companies around Romania, like in Bucharest, Timișoara, Iași, Oradea, and many other small cities, in collaboration with ELSACO Electronic S.R.L., one of the top Romanian companies in this area.

2.2.2. Human-Machine Interface (HMI)

The implementation of such a system, which needs an efficient human-machine interface, applied for district heating networks, can be solved by a multi-level organization:

- **The first level** (level 0) consists of primary elements that collaborate within the process.
- **The second level** (level 1) is realized with the automation logic, and the data acquisition equipments.
- **The third level** consists from the Central Point (the Broadcaster), which surveys and can well manage the functioning of all thermal centrals and plants.

The human operator interacts with the followed process through a graphical interface and through input devices (mouse, keyboard). The graphical interface is very powerful related with the used operating system and with the used software package.

The central computer can gather important information quantities. The information is referring to the process history and to all the essential values that can be controlled or supervised [2.2.6].

Lately is unanimous accepted the fact that the graphical interface is operating under Windows. This offers certain advantages from which the most important one is the familiarity of the users with this environment and the many programs existing for the after-dates processing (the most common example is Microsoft Excel). This programming environment classifies the information with the help of some screen windows that are acting disregarding their content.

Any window has buttons for minimizing, maximizing, restoring, title bar, shapeable or not margins, and so on. In this context, we can define a very large number of types of windows from which we can aspect to be available in a human-operator modern interface as well as the minimum functions that it must be implemented.

Synoptic maps

One synoptic map represents very briefly a technological installation. On this map are being represented under text form or graphical way the values of the values which were read from the process. This kind of representation offers the advantage of an very good overlook on one installation. The graphical display of the values is dependent to the value, exceeding of the alarming limits take to displaying with other colors (e.g. yellow = preventive alarming, red = general alarm) allowing to the human operator to notice from a simple glance the abnormal working situations [2.2.8].

A particular case of a synoptic map can be represented from displaying the general scheme of the system on which is represented the functioning status of all devices and communication interfaces which take part at the process.

Figure 2.2.2 shows such a map of a small heating plant located in the south part of Timișoara, Romania. It has two diesel engines, five boilers, pumps, valves, a storage tank, meters, etc.

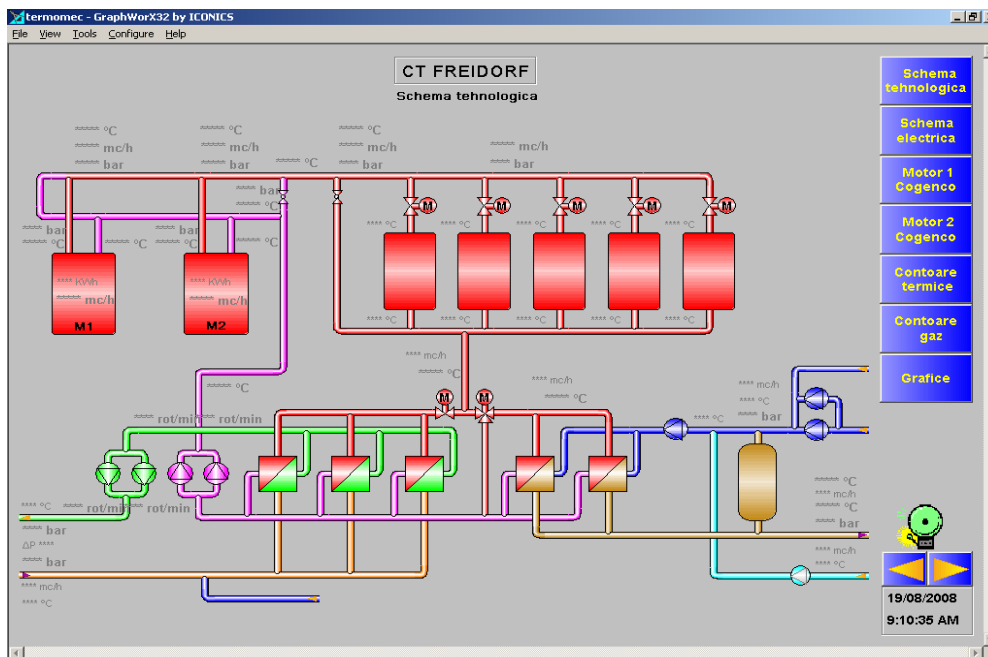


Fig. 2.2.2 Synoptic map of a small power plant located in Freidorf-Timișoara

Next, we will present a command sequence written in Visual C, performed in order to navigate on these synoptic maps:

```
//-----
// Functia de navigare cu mouse-ul pe scheme sinoptice
//
void CSchWnd::OnLButtonDown(UINT nFlags, CPoint point)
{
    // TODO: Add your message handler code here and/or call default
    CString sNumFerIni;
    CRect rd;
    char wname[50];
    char bf[15],cx[40];
```

```

char nume[50];
int rez;
genbd_type *ap,*apm;

wname[0]=0;
for(int ai=0;ai<nrAna;ai++)
{
if(rc[ai].PtInRect(point))
{
if(NULL==(ap=pWBDate->atm_find_off(ida[ai]/*,val,stare,modif*/))) {
break; // poate este necesar sa intre in adancime
}
CWnd *pDsk=GetDesktopWindow();
if(pDsk!=NULL)
pDsk->GetClientRect(&rd);
if (nFlags & MK_CONTROL) {
char mes[100];
id_type idm;
CRect r(point.x+10,point.y,point.x,point.y);
CMainFrame* pM=(CMainFrame*)pMainWnd;
if(pM->fii)
pWndLim->DestroyWindow();
pWndLim=new CLim;
switch (ida[ai].lista) {
case aA:
case AA:
r.right+=330;
r.bottom+=220;
pWndLim->lim_adm_inf=ap->wa.mi;
pWndLim->lim_adm_sup=ap->wa.ms;
pWndLim->lim_avarie_inf=ap->wa.lia;
pWndLim->lim_avarie_sup=ap->wa.lsa;
pWndLim->lim_prev_inf=ap->wa.lip;
pWndLim->lim_prev_sup=ap->wa.lsp;
pWndLim->lim_conv_inf=ap->wa.litr;
pWndLim->lim_conv_sup=ap->wa.lstr;
pWndLim->canal=ap->wa.canal;
pWndLim->id=ap->wa.id;
pWndLim->tscan=ap->wa.tscan;
pWndLim->atrib=ap->wa.atrib;
pWndLim->prel_inst=ap->wa.prel_inst;
idm.lista=ap->wa.id_placa.lista;
idm.echidx=ap->wa.id_placa.echidx&0xffc0;
if(idm.lista==MA){
if (NULL!=(apm=pWBDate->atm_find_off(idm))
strcpy(pWndLim->ech_name,apm->wm.name);
else
strcpy(pWndLim->ech_name,"Neconfigurat");
idm=ap->wa.id_placa;
if (NULL!=(apm=pWBDate->atm_find_off(idm))
strcpy(pWndLim->module_name,apm->wm.name);
else
strcpy(pWndLim->module_name,"Neconfigurat");
}
else{
strcpy(pWndLim->ech_name,"Neconfigurat");
strcpy(pWndLim->module_name,"Neconfigurat");
}

strcpy(mes,ap->wa.name);
strcat(mes," (analogica)");
break;
case cA:
case CA:
r.right+=330;
r.bottom+=140;
pWndLim->lim_adm_inf=ap->wc.di;
pWndLim->lim_adm_sup=ap->wc.ds;
pWndLim->lim_avarie_inf=ap->wc.lia;
pWndLim->lim_avarie_sup=ap->wc.lsa;
pWndLim->lim_prev_inf=ap->wc.lip;
pWndLim->lim_prev_sup=ap->wc.lsp;
pWndLim->id=ap->wc.id;
pWndLim->atrib=ap->wc.atrib;

```



```

        pWndLim->prel_inst=ap->wc.prel_inst;
        strcpy(mes,ap->wc.name);
        strcat(mes," (calcul)");
        break;
    default:
        CMDIChildWnd::OnLButtonDown(nFlags, point);
        return;
    }
    ClientToScreen(&r);
    if(r.right>rd.right){
        r.left-=r.right-rd.right+5;
        r.right=rd.right-5;
    }
    if(r.bottom>rd.bottom-20){
        r.top-=r.bottom-rd.bottom+20;
        r.bottom=rd.bottom-20;
    }
    pMainWnd->ScreenToClient(&r);
    pWndLim->Create(NULL,mes,WS_CHILD | WS_VISIBLE |
        WS_BORDER | WS_CAPTION | WS_SYSMENU,r,NULL);
    CMDIChildWnd::OnLButtonDown(nFlags, point);
    return;
}

switch(ida[ai].lista){
    case AA:
    case aA:
        strcpy(wname,ap->wa.name);
        break;
    case CA:
    case cA:
        strcpy(wname,ap->wc.name);
        break;
    case TA:
        strcpy(wname,ap->wt.name);
        break;
    default:
        CMDIChildWnd::OnLButtonDown(nFlags, point);
        return;
}

    CTime t = CTime::GetCurrentTime();
    strcat(strcpy(ume,DirArhiva),"\\");
    strcat(ume,Luni[t.GetMonth()-1]);
    sprintf(bf,"\\%d",t.GetDay());
    strcat(strcat(ume,bf),"\\");
    strcat(strcat(ume,Id2Str(ida[ai],cx)),".his");
    struct _stat st;
    rez=_stat(ume,&st);
    if(rez!=0){ // Nu exista arhiva cu date
        MessageBox("Nu exista date pentru grafic in arhiva!","Scuze dar...",MB_ICONEXCLAMATION);
        CMDIChildWnd::OnLButtonDown(nFlags, point);
        return;
    }
    else {
        CRect r(point.x+10,point.y,point.x+560,point.y+350);
        CWnd *pDsk;
        CRect rd;
        pDsk=GetDesktopWindow();
        if(pDsk!=NULL)
            pDsk->GetClientRect(&rd);
        ClientToScreen(&r);
        if(r.right>rd.right){
            r.left-=r.right-rd.right+5;
            r.right=rd.right-5;
        }
        if(r.bottom>rd.bottom-20){
            r.top-=r.bottom-rd.bottom+20;
            r.bottom=rd.bottom-20;
        }
    }
    pMainWnd->ScreenToClient(&r);
    CGraf2 *pGLWnd = new CGraf2;
    strcat(strcpy(ume,wname)," , azi");
    pGLWnd->zua=t.GetDay();
    pGLWnd->luna=t.GetMonth();

```

```

pGLWnd->anul=t.GetYear();
pGLWnd->actualizare=1;
pGLWnd->m_indg=ida[ai];
strcpy(pGLWnd->numew,wname);

if (!pGLWnd->Create(nume,WS_CHILD | WS_VISIBLE | WS_OVERLAPPED | WS_CAPTION |
                  WS_SYSMENU | WS_THICKFRAME | WS_MINIMIZEBOX | WS_MAXIMIZEBOX,
                  r,pMainWnd)){
    CMDIChildWnd::OnLButtonDown(nFlags, point);
    return;
}
return;
}
}
}

for(int b=0;b<nrBin;b++)
{
if(rcbin[b].PtInRect(point)) {
    genbd_type *ap,*apm;

if(NULL==(ap=pWBDate->atm_find_off(idbin[b]))) {
    break; // pentru a permite intrarea in adancime
}
if (nFlags & MK_CONTROL) {
    char mes[100];
    id_type idm;
    CRect rd,r(point.x+10,point.y,point.x,point.y);
    CWnd *pDsk;
    pDsk=GetDesktopWindow();
    if(pDsk!=NULL)
        pDsk->GetClientRect(&rd);
    CMainFrame* pM=(CMainFrame*)pMainWnd;
    if(pM->fii)
        pWndLim->DestroyWindow();
    pWndLim=new CLim;
    switch (idbin[b].lista) {
        case DA:
        case BA:
        case bA:
            r.right+=340;
            r.bottom+=170;
            pWndLim->canal=ap->wb.canal;
            pWndLim->id=ap->wb.id;
            pWndLim->tscan=ap->wb.filt;
            pWndLim->atrib=ap->wb.atrib;
            idm.lista=ap->wb.id_placa.lista;
            idm.echidx=ap->wb.id_placa.echidx&0xffc0;
            if(idm.lista==MA){
                if (NULL!=(apm=pWBDate->atm_find_off(idm)))
                    strcpy(pWndLim->ech_name,apm->wm.name);
                else
                    strcpy(pWndLim->ech_name,"Neconfigurat");
                idm=ap->wb.id_placa;
                if (NULL!=(apm=pWBDate->atm_find_off(idm)))
                    strcpy(pWndLim->module_name,apm->wm.name);
                else
                    strcpy(pWndLim->module_name,"Neconfigurat");
            }
            else {
                strcpy(pWndLim->ech_name,"Neconfigurat");
                strcpy(pWndLim->module_name,"Neconfigurat");
            }
            strcpy(mes,ap->wb.name);
            strcpy(pWndLim->diag_norm,ap->wb.diag_norm);
            strcpy(pWndLim->diag_anorm,ap->wb.diag_anorm);
            strcat(mes," (binara)");
            break;
        default:
            CMDIChildWnd::OnLButtonDown(nFlags, point);
            return;
    }
}
ClientToScreen(&r);
if(r.right>rd.right){

```

```

        r.left-=r.right-rd.right+5;
        r.right=rd.right-5;
    }
    if(r.bottom>rd.bottom-20){
        r.top-=r.bottom-rd.bottom+20;
        r.bottom=rd.bottom-20;
    }
    pMainWnd->ScreenToClient(&r);
    pWndLim->Create(NULL,mes,WS_CHILD | WS_VISIBLE |
                    WS_BORDER | WS_CAPTION | WS_SYSMENU,r,NULL);
    CMDIChildWnd::OnLButtonDown(nFlags, point);
    return;
}
//grafic marime binara
switch(idbin[b].lista) {
    case DA:
    case BA:
    case bA:
        strcpy(wname,ap->wb.name);
        break;
    default:
        CMDIChildWnd::OnLButtonDown(nFlags, point);
        return;
}

    CTime t = CTime::GetCurrentTime();
    strcat(strcpy(ume,DirArhiva),"\\");
    strcat(ume,Luni[t.GetMonth()-1]);
    sprintf(bf,"\\%d",t.GetDay());
    strcat(strcat(ume,bf),"\\");
    strcat(strcat(ume,Id2Str(idbin[b],cx)),".his");
    struct _stat st;
    rez=_stat(ume,&st);
    if(rez!=0){
        MessageBox("Nu exista date pentru grafic in arhiva!","Scuze dar...",MB_ICONEXCLAMATION);
        CMDIChildWnd::OnLButtonDown(nFlags, point);
        return;
    }
    else {
        CRect r(point.x+10,point.y,point.x+560,point.y+350);
        CWnd *pDsk;
        CRect rd;
        pDsk=GetDesktopWindow();
        if(pDsk!=NULL)
            pDsk->GetClientRect(&rd);
        ClientToScreen(&r);
        if(r.right>rd.right){
            r.left-=r.right-rd.right+5;
            r.right=rd.right-5;
        }
        if(r.bottom>rd.bottom-20){
            r.top-=r.bottom-rd.bottom+20;
            r.bottom=rd.bottom-20;
        }
        pMainWnd->ScreenToClient(&r);
        CGraf2 *pGLWnd = new CGraf2;
        strcat(strcpy(ume,wname)," azi");
        pGLWnd->ziua=t.GetDay();
        pGLWnd->luna=t.GetMonth();
        pGLWnd->anul=t.GetYear();
        pGLWnd->actualizare=1;
        pGLWnd->m_indg=idbin[b];
        strcpy(pGLWnd->numew,wname);
        if(!pGLWnd->Create(ume,WS_CHILD | WS_VISIBLE | WS_OVERLAPPED | WS_CAPTION | WS_SYSMENU |
                        WS_THICKFRAME | WS_MINIMIZEBOX | WS_MAXIMIZEBOX,r,pMainWnd)){
            return;
        }
        return;
    }
}
}

for(int ri=0;ri<nrRect;ri++) {
    if(rct[ri].PtInRect(point)) {

```

```

CSchWnd *pSchemaW;
    CRect rect,rect1;
    int fh,result,xbmp,ybmp;
    line_type lin;
    char fname[64];
        char numebmp[32];

    strcat(strcat(strcpy(fname,DirBdate),"\\"),"grafic.ini");
    if (-1 != (fh=topen(fname,O_RDONLY | O_TEXT))) {

        up_case(szNumeF[ri],numebmp);

        if (find_line(fh,numebmp,"BITMAP",lin)) {
            copy_par(lin,MAXPAR,TabelPar,result);
            if (result || (strlen(TabelPar[1])==0)) {
                MessageBox("Linie incorecta in .ini","Eroare!",MB_ICONSTOP);
                tclose(fh);
                return;
            }
            xbmc=ini_integer(TabelPar[2],result);
            ybmp=ini_integer(TabelPar[3],result);
            tclose(fh);
        }
        else {
            MessageBox("Nu este specificat numele bitmap-ului!\n","Eroare!",MB_ICONSTOP);
            tclose(fh);
            return;
        }
    }
    else {
        MessageBox("Nu exista fisierul grafic.ini!\n","Eroare!",MB_ICONSTOP);
        tclose(fh);
        return;
    }
    GetWindowRect(&rect1);
    pMainWnd->GetClientRect(&rect1);
    rect.left=xbmp;
    rect.top =ybmp;
    rect.right=rect1.right;
    rect.bottom=rect1.bottom;
    Mod=1; //S-a modificat pozitia ferestrei parinte, deci nu o distrug.
    if((pSchemaW=ListaFer.IsInList(szNumeF[ri]))==NULL)
    {
        pSchemaW=new CSchWnd;
        if (!pSchemaW->Create(szNumeF[ri],WS_CHILD | WS_VISIBLE | WS_BORDER | WS_SYSMENU | WS_CAPTION |
WS_MINIMIZEBOX ,rect,NULL))
        {
            CMDIChildWnd::OnLButtonDown(nFlags, point);
            return;
        }
    }
    else
        pSchemaW->BringWindowToTop();
    CMDIChildWnd::OnLButtonDown(nFlags, point);
    if(Mod!=1)
    {
        if(strcmp(NumeFerIni,szNumeFer)!=0)
            DestroyWindow();
        return;
    }
    }
    CMDIChildWnd::OnLButtonDown(nFlags, point);
}

```

Figure 2.2.3. shows us the mouse handler function obtained for that synoptic map, by navigating on different map elements.

Next, the Visual C procedure for that application will be provided:

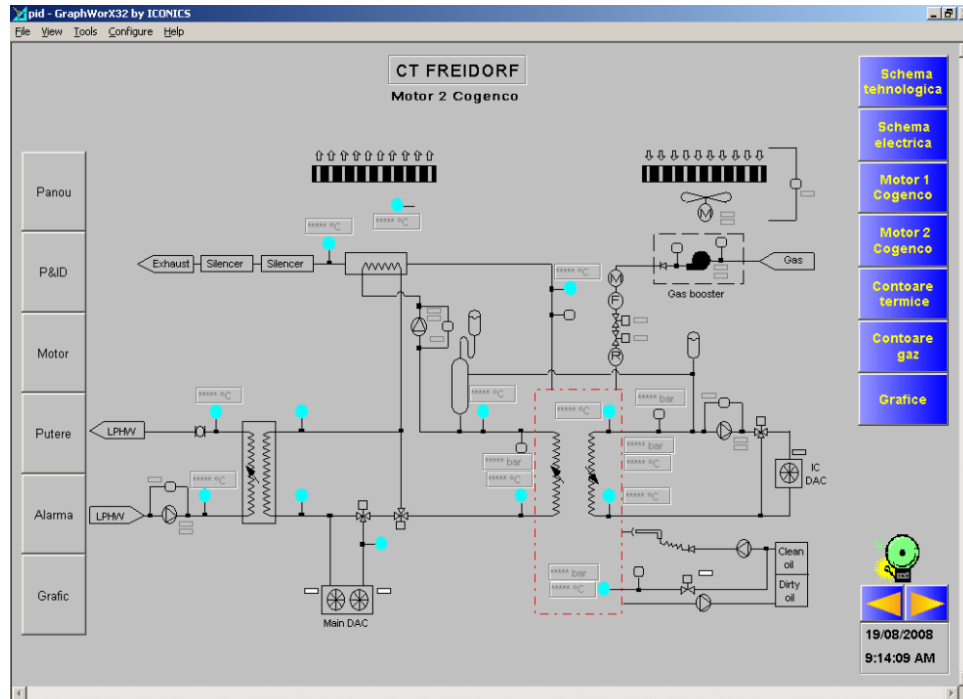


Fig. 2.2.3. Data on Synoptic Map

```
//-----
// Handler pentru click mouse
//
void CBargraf::OnLButtonDown(UINT nFlags, CPoint point)
{
    // TODO: Add your message handler code here and/or call default
    CRect r;
    char wname[50];

    wname[0]=0;
    for(int i=0;i<data->nr_marimi;i++)
    {
        r.left=m_coord[0]+1;  r.top=(i+1)*sp-sp/20-m_coord[2]+1;
        r.right=m_coord[1]-1;  r.bottom=(i+1)*sp-sp/20-1;
        if(r.PtInRect(point))
        {

            char bf[15],cx[40];
            char nume[50];
            int rez;
            genbd_type *ap,*apm;

            if(NULL==(ap=pWBDate->atm_find_off(data->marime_bargraf[i].id))) {
                CMDIChildWnd::OnLButtonDown(nFlags, point);
                return;
            }
            CRect rd;
            CWnd *pDsk=GetDesktopWindow();
            if(pDsk!=NULL)
                pDsk->GetClientRect(&rd);
            if (nFlags & MK_CONTROL) {
                char mes[100];
                id_type idm;
                CRect r(point.x+10,point.y,point.x,point.y);
                CMainFrame* pM=(CMainFrame*)pMainWnd;
                if(pM->fii)
                    pWndLim->DestroyWindow();
                pWndLim=new CLim;
                switch (data->marime_bargraf[i].id.lista) {
                    case aA:
                    case AA:
                        r.right+=330;
                        r.bottom+=220;
                        pWndLim->lim_adm_inf=ap->wa.mi;
                }
            }
        }
    }
}
```

```

pWndLim->lim_adm_sup=ap->wa.ms;
pWndLim->lim_avarie_inf=ap->wa.lia;
pWndLim->lim_avarie_sup=ap->wa.lsa;
pWndLim->lim_prev_inf=ap->wa.lip;
pWndLim->lim_prev_sup=ap->wa.lsp;
pWndLim->lim_conv_inf=ap->wa.litr;
pWndLim->lim_conv_sup=ap->wa.lstr;
pWndLim->canal=ap->wa.canal;
pWndLim->id=ap->wa.id;
pWndLim->tscan=ap->wa.tscan;
pWndLim->atrib=ap->wa.atrib;
pWndLim->prel_inst=ap->wa.prel_inst;
idm.lista=ap->wa.id_placa.lista;
idm.echidx=ap->wa.id_placa.echidx&0xffc0;

if(idm.lista==MA){
    if (NULL!=(apm=pWBDate->atm_find_off(idm)))
        strcpy(pWndLim->ech_name,apm->wm.name);
    else
        strcpy(pWndLim->ech_name,"Neconfigurat");
    idm=ap->wa.id_placa;
    if (NULL!=(apm=pWBDate->atm_find_off(idm)))
        strcpy(pWndLim->module_name,apm->wm.name);
    else
        strcpy(pWndLim->module_name,"Neconfigurat");
}
else{
    strcpy(pWndLim->ech_name,"Neconfigurat");
    strcpy(pWndLim->module_name,"Neconfigurat");
}
strcpy(mes,ap->wa.name);
strcat(mes," (analogica)");
break;
case CA:
case CA:
    r.right+=330;
    r.bottom+=140;
    pWndLim->lim_adm_inf=ap->wc.di;
    pWndLim->lim_adm_sup=ap->wc.ds;
    pWndLim->lim_avarie_inf=ap->wc.lia;
    pWndLim->lim_avarie_sup=ap->wc.lsa;
    pWndLim->lim_prev_inf=ap->wc.lip;
    pWndLim->lim_prev_sup=ap->wc.lsp;
    pWndLim->id=ap->wc.id;
    pWndLim->atrib=ap->wc.atrib;
    pWndLim->prel_inst=ap->wc.prel_inst;
    strcpy(mes,ap->wc.name);
    strcat(mes," (calcul)");
    break;
default:
    CMDIChildWnd::OnLButtonDown(nFlags, point);
    return;
}
ClientToScreen(&r);
if(r.right>rd.right){
    r.left-=r.right-rd.right+5;
    r.right=rd.right-5;
}
if(r.bottom>rd.bottom-20){
    r.top-=r.bottom-rd.bottom+20;
    r.bottom=rd.bottom-20;
}
pMainWnd->ScreenToClient(&r);
pWndLim->Create(NULL,mes,WS_CHILD | WS_VISIBLE |
                WS_BORDER | WS_CAPTION | WS_SYSMENU,r,NULL);
CMDIChildWnd::OnLButtonDown(nFlags, point);
return;
}
switch(data->marime_bargraf[i].id.lista){
case AA:
case aA:
    strcpy(wname,ap->wa.name);
    break;
case CA:

```

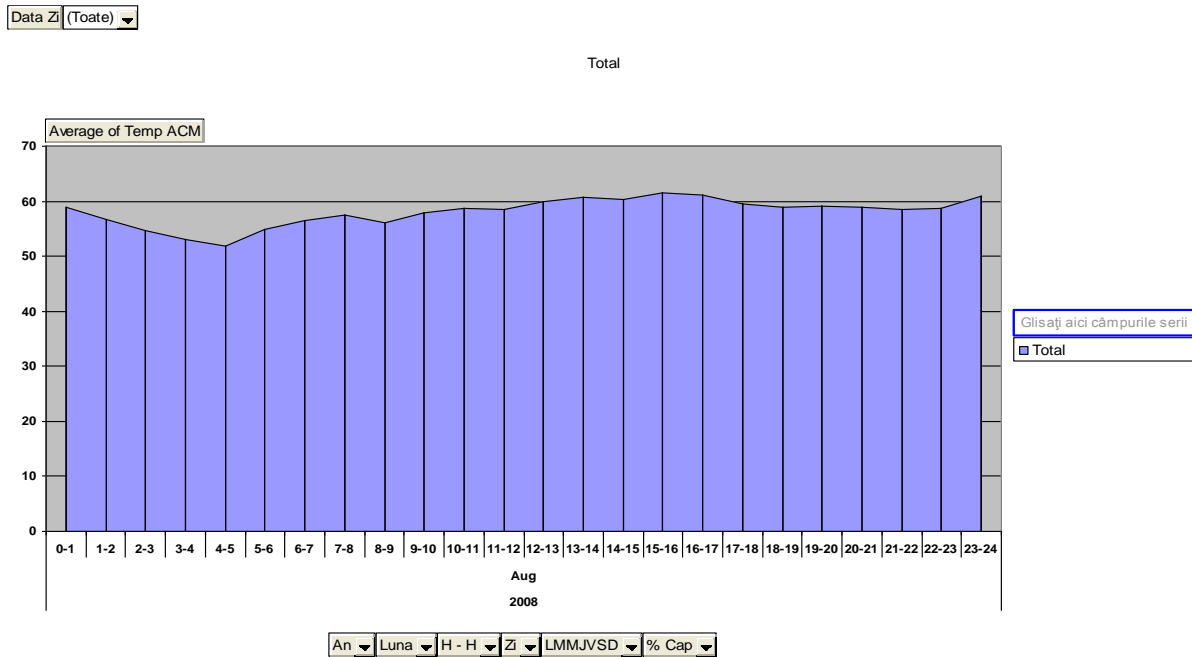



Fig. 2.2.4: Bar-graph representation of a boiler's temperature

```
//-----
// Trasare Diagrame
//
void CGrafX::Diagrame(CDC *pdc, RECT *r) {

    int i,j,x,y; //litr,lstr;
    short v,tmax,pas=1;
    float vf,px,py; //vf1,cic,di,ds;
    char diag[32]="";
    BOOL prim;
    genbd_type *ap;
    CTime t=CTime::GetCurrentTime();
    CPoint pnt[2];
    struct tm *timp=t.GetLocalTm(NULL);
    if (timer)
        tmax=timp->tm_hour*60+timp->tm_min;
    else
        tmax=24*60;
    py=(float)(m_coord[1]-m_coord[3])/m_nrgraf;
    for(j=0; j<m_nrgraf; j++) {
        HPEN pOldPen = (HPEN)SelectObject(pdc->m_hDC,hpen[indcul[j]]);
        ap=pWBDate->atm_find_off(ids[j]);
        px=pas * (m_coord[2]-m_coord[0]) / (float)(24*60);
        SetGetVal(GV_MINUT,buf[j],bufflen[j]); //pregateste variabilele pentru GetVal
        prim=TRUE;
        for (i=0; i<tmax; i++) {

            if(v>=0){
                x=(int)(m_coord[0]+i*px);
                vf=1-v;
                if(vf==1)
                    y=(int)(m_coord[1]-(j*py+py*0.8));
                else
                    y=(int)(m_coord[1]-(j*py+py*0.2));
                if (prim) {
                    pdc->MoveTo(x,y); //pentru primul punct se face numai pozitionare
                    prim=FALSE;
                    pdc->SetPixel(x,y,indcul[j]);
                    oldx=x;
                    oldy=y;
                }
            }
            else
                if((oldx!=x)|| (oldy!=y)){
```



```

        pdc->LineTo(x,oldy);
        pdc->LineTo(x,y);
        oldx=x;
        oldy=y;
    }
}
else {
    vf=V_GOL;
    prim=TRUE;
}
}
if (v==VL_B_NORMAL)
    strcpy(diag,ap->wb.diag_norm);
else
    strcpy(diag,ap->wb.diag_anorm);
    SelectObject(pdc->m_hDC,pOldPen);
if (i>0) SetValCurenta(pdc,j,vf,diag,r); // daca in buffer (fisier) era macar o valoare
}
}
}

```

Time-evolution graphics

The graphics could be shown in two ways:

- real time graphics, which allows the graphical representation of the values evolution on one time period around the present moment (usually the current day or hour) and which have one single displayed value [8]
- historical graphics which are allowing the representation of a high number of values (in order to be compared) and on any period of time.

Real time graphics are usually used at the short term drift quest and can include a high number of points as well as the generalization till the level of second of the data evolution. Figure 2.2.5. shows a time-evolution representation of temperatures.

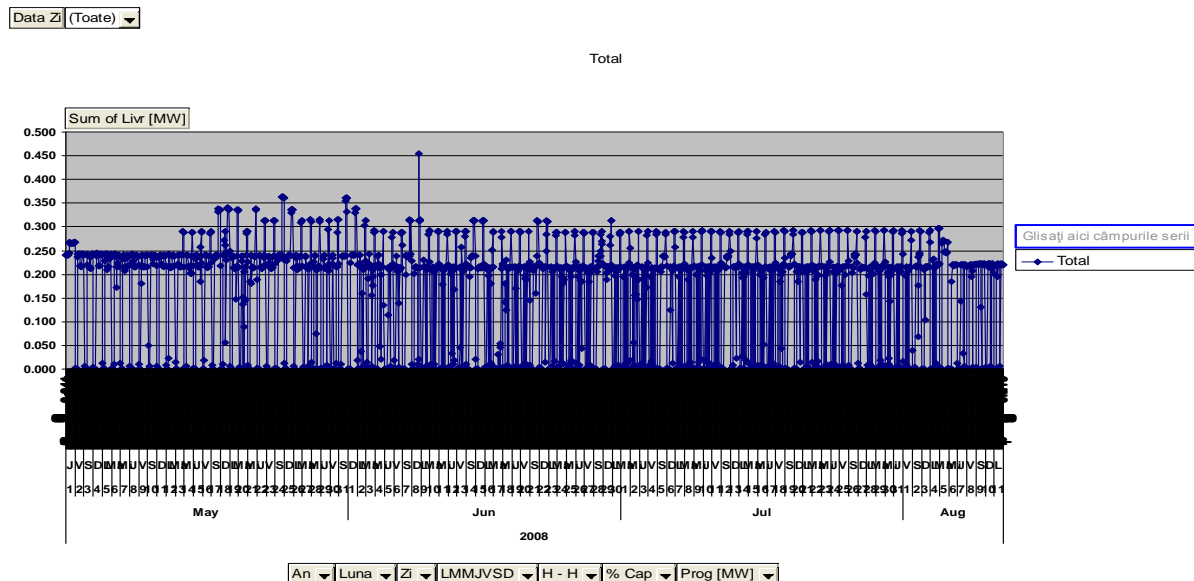


Fig. 2.2.5: Time-evolution graphics

Next, the Visual C procedure for that application will be provided, in order to present the results:

```

//-----
// Afisare grafice
//
void CGrafX::OnPaint()
{

```

```

        CPaintDC dc(this); // device context for painting
        CRect r;
        GetClientRect(r);
        if((stfocus==1)&&(actlin==1)){
            marclinie(antpoint);
            actlin=0;
        }
        DesenPaint(&dc,&r);
        // Do not call CMDIChildWnd::OnPaint() for painting messages
    }

//-----
extern HPEN hpen[13];
void CGrafX::DesenPaint(CDC *pdc,RECT *r) {
    pMyApp->DoWaitCursor(1);
    height=(r->bottom-r->top)*heighti/Hi; //noua inaltime a fontului
    width=(r->right-r->left)*widthi/Wi; //noua latime a fontului
    H=r->bottom-r->top; //noua inaltime a ferestrei
    W=r->right-r->left; //noua latime a ferestrei
    //coordonate zona utila grafic
    if(flana) {
        int lung;
        char sir[10];
        int lg,lg1;
        sprintf(sir,"%0f",m_limval[0]);
        lg=strlen(sir);
        sprintf(sir,"%0f",m_limval[1]);
        lg1=strlen(sir);
        if(lg>lg1) lung=lg;
        else lung=lg1;
        if (lung<5) lung=5;
        m_coord[0]=r->left+(lung+5)*width;
    }
    else
        m_coord[0]=r->left+W/30;
    m_coord[1]=r->bottom-H/20-(m_nrgraf+1)*height-(m_nrgraf+1)*H/100;
    m_coord[2]=r->right-W/30;
    m_coord[3]=r->top+height+height/4;

    TrasareAxe(pdc,nr_ore/24,10); //24 gradatii pe x, 10 gradatii pe y
    ValGrafice(pdc,r,nr_ore/24,10);
    if(flana)
        Curbe(pdc,r);
    else
        Diagrame(pdc,r);
    pMyApp->DoWaitCursor(-1);
}

//-----
// Trasare curbe
//
void CGrafX::Curbe(CDC *pdc, RECT *r) {
    int i,j,x,y,litr,lstr,tipc;
    short v,tmax,pas=1;
    float vf,vf1,cic,px,py,di,ds;
    BOOL prim;
    genbd_type *ap;
    CPoint pnt[2];
    time_t ltime;
    time (&ltime);
    struct tm *timpcrt;
    timpcrt=localtime(&ltime);
    if (timer)
        tmax=timpcrt->tm_hour*60+timpcrt->tm_min;
    else
        tmax=24*60;
        tmax=nr_ore;
    for(j=0; j<m_nrgraf; j++) {
        HPEN pOldPen = (HPEN)SelectObject(pdc->m_hDC,hpen[indcul[j]]);
        ap=pWBDate->atm_find_off(ids[j]);
    }
}

```

```

switch (ids[j].lista) {
    case AA: case aA:
        ds=ap->wa.ms;
        di=ap->wa.mi;
        litr=ap->wa.litr;
        lstr=ap->wa.lstr;
        if (ap->wa.prel_inst==PI_A_LIN) {
            tipc=0;
            cic=(ds-di)/(float)(lstr-litr);
        }
    else {
        tipc=1;
        cic=(ds-di)/(float)sqrt((double)(lstr-litr));
    }
    break;
    case CA: case cA:
        ds=ap->wc.ds;
        di=ap->wc.di;
        litr=0;
        lstr=4096;
        tipc=0;
        cic=(ds-di)/(float)(lstr-litr);
        break;
    case TA:
        ds=ap->wt.ds;
        di=ap->wt.di;
        litr=0;
        lstr=4096;
        tipc=0;
        cic=(ds-di)/(float)(lstr-litr);
        break;
}
px=pas * (m_coord[2]-m_coord[0]) / (float)nr_ore; //(float)(24*60);
py=(float)(m_coord[1]-m_coord[3])/(m_limval[1]-m_limval[0]);
prim=TRUE;
for (i=0; i<tmax; i++) {
// extrage urmatoarea valoare din buffer
    vf=buff[j][i];
    if (vf==V_GOL)
        v=-2;
    else
        v=1;
    if (v>=0) { // valoare existenta (v=-2 daca e inexistentă)
        if (tipgraf) vf1=vf;
        else vf1=100*(vf-di)/(ds-di); //conversie in procente
        if (vf1>m_limval[1]) vf1=m_limval[1];
        if (vf1<m_limval[0]) vf1=m_limval[0];
        x=(int)(m_coord[0]+i*px);
        y=(int)(m_coord[1]-(vf1-m_limval[0])*py);
        if (prim) {
            pdc->MoveTo(x,y); //pentru primul punct se face numai pozitionare
            prim=FALSE;
            pdc->SetPixel(x,y,indcul[j]);
            oldx=x;
            oldy=y;
        }
        else
            if((oldx!=x)|| (oldy!=y)){
                pnt[0].x=oldx;
                pnt[0].y=oldy;
                pnt[1].x=x;
                pnt[1].y=y;
                pdc->Polyline(pnt,2);

                oldx=x;
                oldy=y;
            }
        if (i==tmax-1) //sint la sfirsit
        {
            pnt[0].x=oldx;
            pnt[0].y=oldy;
            pnt[1].x=oldx+px;
            pnt[1].y=oldy;
            pdc->Polyline(pnt,2);
        }
    }
}

```

```

    }
    else {
        vf=V_GOL;
        prim=TRUE;
    }
}
SelectObject(pdc->m_hDC,pOldPen);
if (i>0) SetValCurenta(pdc,j,vf,"",r); // daca in buffer (fisier) era macar o valoare
}
}

```

Events windows

The information stored here has the on/off/out-of order type of equipment and the status changes. Each such event is registered with the time moment at which it takes place. For the easy following of the events, this colour code can be used [2.2.9]:

- **yellow** – informative type event, specifying that the equipment is functioning under proper conditions;
- **black** – an event that specifies the nonfunctioning status of an equipment (off/out-of-order);
- **green** – a binary element which can be encountered at a normal status (e.g. an normal off light);
- **red** – a binary element is encountered in the functioning status opposed to its status.

This colour schema is only an example of how those windows are made.

Figure 2.2.6 shows an example of an event window. Each window is generated by using a Visual C specific program, developed by us.

Data are collected from the process by using a SCADA System, dedicated to district heating applications. Dialogs are carried out in Romanian.

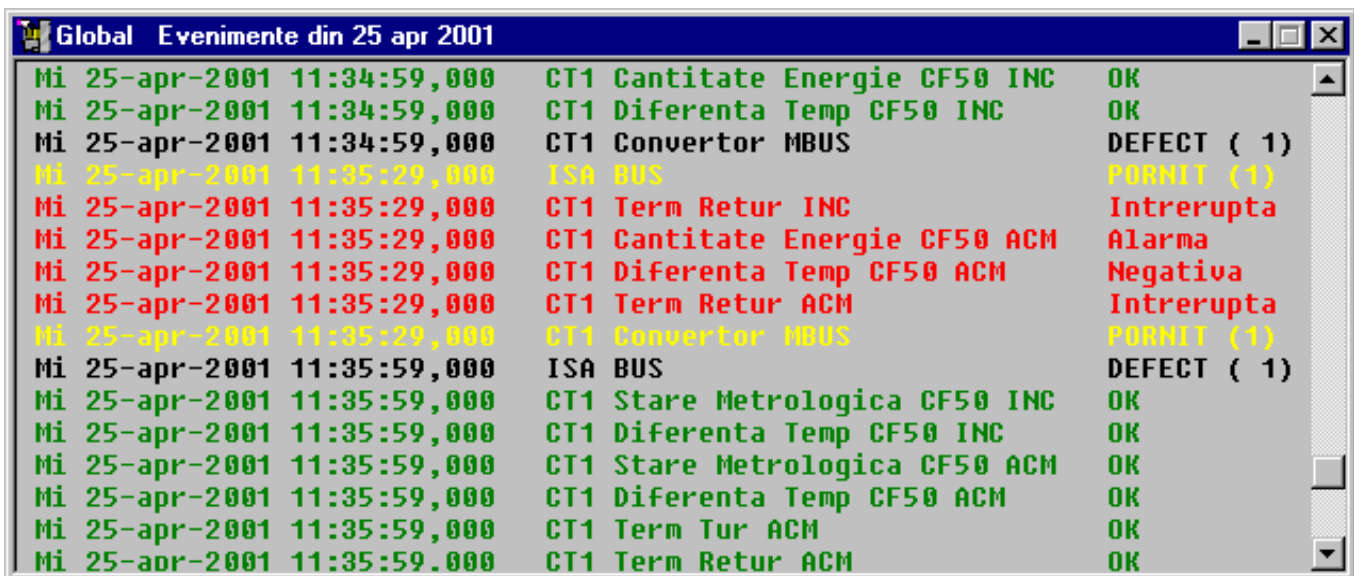


Fig. 2.2.6.: Event type window

Next, the Visual C procedure for that application will be provided, in order to present the results [2.2.7]:

```

//-----
// Desenare fereastră evenimente
//
void CEvFis::OnPaint() {
    int i;
    eventl str;
    CPaintDC dc(this); // device context for painting
}

```

```

// TODO: Add your message handler code here
CRect rct;
CBrush br( RGB(255,255,0) );
GetClientRect( &rct );
ninceput=max(0,nVscrollpos+rct.top/nychar);
nsfirsit=min(nnrlnii,nVscrollpos+rct.bottom/nychar+1);

HGDIOBJ hfont=GetStockObject( SYSTEM_FIXED_FONT );
SelectObject( dc.m_hDC, hfont );
for( i=ninceput; i<nsfirsit; i++ ) {
    str=buff[i];
    if( str.atrib==AT_ACTIV ) {
        if ( str.stare==VL_B_DEF )      dc.SetTextColor( RGB(183,193,192) );
        else if( str.stare==VL_B_NORMAL ) dc.SetTextColor( RGB(33,130,0) );
        else if( str.stare==VL_B_ANORMAL ) dc.SetTextColor( RGB(255,0,0) );
        else if( str.stare==4 )         dc.SetTextColor( RGB(255,255,0) );
        else if( str.stare==5 )         dc.SetTextColor( RGB(0,0,0) );
    }
    if( str.atrib==AT_PASIV )           dc.SetTextColor( RGB(0,0,0) );
    dc.SetBkColor( RGB(192,192,192) ); //fondul
    dc.TextOut( 0, (i-nVscrollpos)*nychar, szbuffer, sprintf( szbuffer, " %s", str.stri ) );
}
// Do not call CMDIChildWnd::OnPaint() for painting messages
}

void CEvFis::OnSize( UINT nType, int cx, int cy ) {
    CMDIChildWnd::OnSize( nType, cx, cy );

    // TODO: Add your message handler code here
    nyclient=cy;
    nVscrollmax=max(0, nrlnii-nyclient/nychar);
    nVscrollpos=min( nVscrollpos, nVscrollmax );
    SetScrollRange( SB_VERT, 0, nVscrollmax, FALSE );
    SetScrollPos( SB_VERT, nVscrollpos, TRUE );
}

void CEvFis::OnVScroll( UINT nSBCode, UINT nPos, CScrollBar* pScrollBar ) {
    // TODO: Add your message handler code here and/or call default
    switch( nSBCode ) {
        case SB_LINEUP:
            ninc=-1;
            break;
        case SB_LINEDOWN:
            ninc=1;
            break;
        case SB_PAGEUP:
            ninc=min(-1, -nyclient/nychar);
            break;
        case SB_PAGEDOWN:
            ninc=max(1, nyclient/nychar);
            break;
        case SB_TOP:
            ninc=-nVscrollpos;
            break;
        case SB_BOTTOM:
            ninc=nVscrollmax-nVscrollpos;
            break;
        case SB_THUMBTRACK:
            ninc=nPos-nVscrollpos;
            break;
        default:
            return;
    }
    ninc=max(-nVscrollpos, min( ninc, nVscrollmax-nVscrollpos ) );
    nVscrollpos+=ninc;
    ScrollWindow( 0, -nychar*ninc );
    SetScrollPos( SB_VERT, nVscrollpos, TRUE );
    UpdateWindow();
    CMDIChildWnd::OnVScroll( nSBCode, nPos, pScrollBar );
}

```

Alarm Windows

In case of complex processes surveying with a highly danger rate, an abnormal functioning mode in the system must be promptly signaled in every possible way.

Receiving some information on an abnormal functioning status of an alarm generator value is being signaled by a front page window in which is being specified the type of the error. This window could not be closed and does not disappear except in the case of normal functioning mode of the value or its acceptance from the operator. If the system has a sound board, excepting the warning window, a sound warning is also possible. Figure 2.2.7 shows us an alarm window.

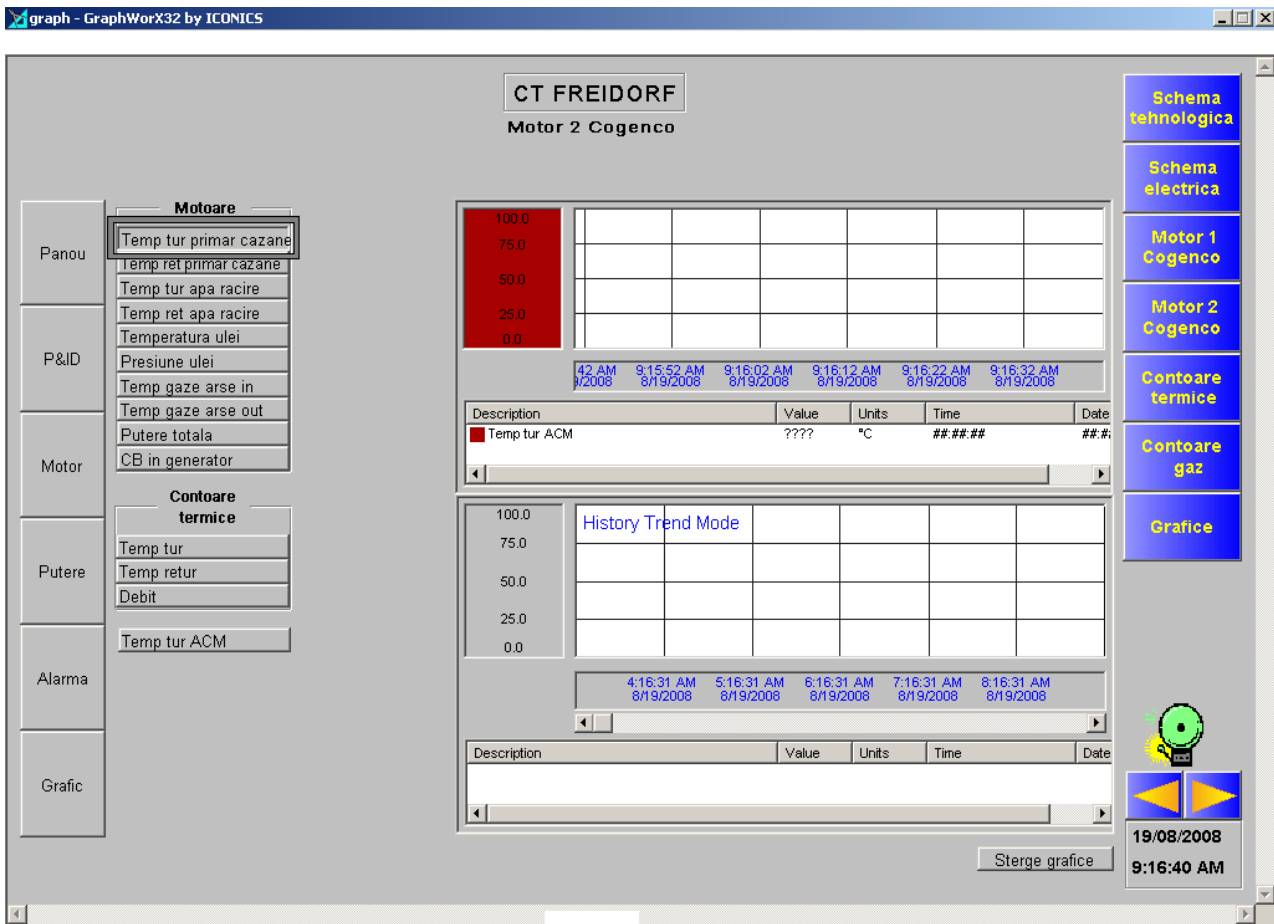


Fig. 2.2.7. Alarm (warning) window

Next, the Visual C procedure for that application will be provided, in order to present the results:

```
//-----
// Functia de desenare a tabelului pentru raportului
//
void CReport::DeseneazaTabel(CPaintDC *dc)
{
    POINT capete[2];
    int i;
    CPen myPen,*oldPen;
    COLORREF color=dc->GetTextColor();
    myPen.CreatePen(PS_SOLID,0,RGB(0,0,0));
    oldPen=(CPen*)dc->SelectObject(&myPen);

    capete[0].x=capete[0].y=0;
    capete[1].x=xi0;capete[1].y=yi0;
```

```

dc->Polyline(&capete[0],2); //linia oblica

//scrie prima coloana
oldFont=dc->SelectObject(&myfont);
CRect r(0,0,xi0,yi0);
dc->DrawText(" Per",-1,&r,DT_LEFT | DT_BOTTOM | DT_SINGLELINE);
dc->DrawText("Den",-1,&r,DT_RIGHT | DT_TOP | DT_SINGLELINE);

dc->SetTextColor(RGB(0,0,255));
char text[20];
for (i=0;i<nrlin0;i++)
{
    r.top=yi0+i*yinc0;
    r.bottom=r.top+yinc0;
    switch(Cels[i].tip)
    {
        case 'n':
        case 'u':
            text[0]='\0';
            break;
        case 'm':
            strcpy(text,"m");
            break;
        case 'M':
            strcpy(text,"M");
            break;
        case 'v':
        case 'f':
            if (Cels[i].req==0)
                strcpy(text,"T");
            else
                if (tiprap0=='Z') //pe zi
                    sprintf(text,"%02d-%02d",Cels[i].req-1,Cels[i].req);
                else
                    sprintf(text,"%02d",Cels[i].req);
    }
dc->DrawText(text,-1,&r,DT_CENTER | DT_VCENTER | DT_SINGLELINE);
}

dc->SetTextColor(RGB(255,0,0));
//desenez titlurile coloanelor
r.top=0;r.bottom=yi0;
for (i=0;i<nrcol0;i++)
{
    r.left=xi0+i*xinc0;
    r.right=r.left+xinc0;
    dc->DrawText(capcoloana[i],-1,&r,DT_CENTER | DT_VCENTER | DT_SINGLELINE);
}
dc->SelectObject(oldFont);

//partea de desenare efectiva a liniilor
capete[0].x=capete[0].y=capete[1].y=0;
capete[1].x=nWidth;
dc->Polyline(&capete[0],2); //linia din cap
//deseneaza liniile
for (i=0;i<nrlin0+1;i++)
{
    capete[0].x=0;
    capete[0].y=capete[1].y=yi0+i*yinc0;
    capete[1].x=nWidth;
    dc->Polyline(&capete[0],2);
}

capete[0].x=capete[1].x=capete[0].y=0;
capete[1].y=nHeight;
dc->Polyline(&capete[0],2); //linia din stanga
//deseneaza coloanele
for (i=0;i<nrcol0+1;i++)
{
    capete[0].y=0;
    capete[0].x=capete[1].x=xi0+i*xinc0;
    capete[1].y=nHeight;
}

```

```

        dc->Polyline(&capete[0],2);
    }

    dc->SelectObject(oldPen);
    dc->SetTextColor(color);
}
// -----
// functii ajutatoare pentru implementarea unei liste cu alarme
//
CListAlm::CListAlm()
{
    lst=NULL;
    act=0;
}

CListAlm::~CListAlm()
{
    lalarm *al;
    al=lst;
    while(al!=NULL){
        lst=al;
        al=al->next;
        delete lst;
    }
}

lalarm *CListAlm::first_msg()
{
    return(lst);
}

lalarm *CListAlm::last_msg(int *n)
{
    lalarm *tt;
    int i=0;
    tt=lst;
    if(tt==NULL){
        *n=i;
        return NULL;
    }
    while(tt->next!=NULL){
        i++;
        tt=tt->next;
    }
    *n=i+1;
    return tt;
}

lalarm *CListAlm::next_msg(lalarm *poz)
{
    if(poz==NULL)
        return NULL;
    return poz->next;
}

lalarm *CListAlm::prev_msg(lalarm *poz,int k)
{
    int i;
    if(poz==NULL)
        return NULL;
    for(i=0;i<k;i++)
        if(poz->ant==NULL)
            return lst;

    if(poz->ant==NULL)
        return lst;
    return poz->ant;
}

BOOL CListAlm::StergeId(id_type idalm)
{
    lalarm *pntr,*delalm;
    pntr=lst;
    if((lst->aid.echidx==idalm.echidx)&&(lst->aid.lista==idalm.lista)){
        delalm=lst;
        if(delalm->blk<2){
            delalm->blk=2;
            repaint=1;
        }
    }
}

```



```

    delalm->cul=IDCUL_VERDE;
}
if(delalm->blk==3){
    repaint=1;
    lst=lst->next;
    if(lst!=NULL)
        lst->ant=NULL;
    repaint=1;
    delete delalm;
}
return TRUE;
}
while(pntr->next!=NULL){
    if((pntr->next->aid.echidx==idalm.echidx)&&(pntr->next->aid.lista==idalm.lista)){
        delalm=pntr->next;
        if(delalm->blk<2){
            delalm->blk=2;
            repaint=1;
            delalm->cul=IDCUL_VERDE;
        }
        if(delalm->blk==3){
            pntr->next=delalm->next;
            if(delalm->next!=NULL)
                delalm->next->ant=pntr;
            repaint=1;
            delete delalm;
        }
        return TRUE;
    }
    pntr=pntr->next;
}
return FALSE;
}

lalarm * CListAlm::InLista(id_type idalm)
{
    lalarm *pntr;
    pntr=lst;
    while(pntr!=NULL){
        if((pntr->aid.echidx==idalm.echidx)&&(pntr->aid.lista==idalm.lista)){
            pntr->act=act;
            return pntr;;
        }
        pntr=pntr->next;
    }
    return NULL;
}

BOOL CListAlm::AdaugaId(id_type idalm,st_val_type st,time_t tp)
{
    lalarm *pntr,*ant,*nalm;
    pntr=lst;
    ant=lst;
    repaint=1;
    if(lst==NULL){
        lst=new lalarm;
        if(lst==NULL)
            return FALSE;
        lst->aid=idalm;
        lst->timp=tp;
        lst->act=act;
        lst->blk=0;
        mesaj_alm(lst,st);
        lst->next=NULL;
        lst->ant=NULL;
        return TRUE;
    }
    while(pntr!=NULL){
        if(tp<pntr->timp){
            nalm=new lalarm;
            if(nalm==NULL)
                return FALSE;
            nalm->aid=idalm;
            nalm->timp=tp;
            nalm->act=act;

```

```

    nalm->blk=0;
    mesaj_alm(nalm,st);
    nalm->next=pntr;
    nalm->ant=pntr->ant;
    pntr->ant=nalm;
    if(pntr==lst)
        lst=nalm;
    else
        nalm->ant->next=nalm;
    return TRUE;
}
ant=pntr;
pntr=pntr->next;
}
pntr=new lalarm;
if(pntr==NULL)
    return FALSE;
pntr->aid=idalm;
pntr->timp=tp;
pntr->act=act;
pntr->blk=0;
mesaj_alm(pntr,st);
pntr->next=NULL;
pntr->ant=ant;
ant->next=pntr;
return TRUE;
}
}
BOOL CListAlm::mesaj_alm(lalarm *alm,st_val_type st)
{
    char name[50];
    char nmc[30];
    genbd_type *ap;
    id_type idalm;
    time_t t;
    struct tm cev;
    float val;

    idalm=alm->aid;
    t=alm->timp;
    if((ap=pWBDate->atm_find_off(idalm))==NULL){
        strcpy(alm->amsq,"ALARMA PENTRU O MARIME NECUNOSCUTA!");
        return FALSE;
    }
    cev=*localtime(&t);
    sprintf(nmc,"%s %02d %s, %02d:%02d ",Zi[cev.tm_wday],
        cev.tm_mday,Luni[cev.tm_mon],cev.tm_hour,cev.tm_min);
    strcpy(alm->amsq,nmc);
    switch(idalm.lista){
        case AA:
        case aA:
            nrmodul(ap->wa.id,nmc);
            adaugmsg(alm->amsq,ap->wa.name,20);
            switch(ap->wa.prel_inst){
                case PI_A_LIN:
                    val=(st.val-ap->wa.litr)*(ap->wa.ms-ap->wa.mi)/(ap->wa.lstr-ap->wa.litr)+ap->wa.mi;
                    break;
                case PI_A_SQR:
                    val=(float)(sqrt(st.val-ap->wa.litr)/sqrt(ap->wa.lstr-ap->wa.litr))*(ap->wa.ms-ap->wa.mi)+ap-
>wa.mi;
                    break;
                default:
                    val=0;
            }
            alm->cul=IDCUL_ROSU;
            sprintf(nmc,"% .2f",val);
            if(st.stare!=ST_VAL_OK){
                strcpy(nmc," ??????");
                alm->cul=IDCUL_GRI;
            }
            strcpy(alm->stare,nmc);
            adaugmsg(alm->stare,ap->wa.um,12);
            break;
        case DA:
        case BA:

```

```

case bA:
    nrmodul (ap->wb.id,nmc);
    adaugmsg (alm->amsg,ap->wb.name,20);
    strcpy (alm->stare," ");
    switch (st.stare){
        case ST_ALR_AN:
            strcat (alm->stare,ap->wb.diag_anorm);
            alm->cul=IDCUL_ROSU;
            break;
            case ST_ALR_DM:
            strcat (alm->stare,"Defect masura");
            alm->cul=IDCUL_GRI;
            break;
        }
        break;
    if (st.stare!=ST_VAL_OK){
        strcpy (nmc," ??????");
        alm->cul=IDCUL_GRI;
    }
    strcpy (alm->stare,nmc);
    adaugmsg (alm->stare,ap->wc.um,12);
    break;
case TA:
    adaugmsg (name,ap->wt.name,20);
    sprintf (nmc," %.2f",ap->wt.value);
    alm->cul=IDCUL_ROSU;

    if (st.stare!=ST_VAL_OK){
        strcpy (nmc," ??????");
        alm->cul=IDCUL_GRI;
    }
    strcpy (alm->stare,nmc);
    adaugmsg (alm->stare,ap->wt.um,12);
    break;
default:
    alm->amsg[0]=0;
    alm->cul=IDCUL_ROSU;
    return FALSE;
} return TRUE;
}

int CListAlm::Actualizare()
{
    act=(act+1)%500;
    return act;
}

void adaugmsg(char *dest,char *sursa,unsigned int n)
{
    unsigned int i;

    if (strlen(dest)<n)
        for (i=strlen(dest);i<n;i++)
            dest[i]=' ';
    dest[n]='\0';
    strcat (dest,sursa);
}

```

Many Romanian heating distribution companies have made improvements concerning their technical base, in order to improve the quality of their services.

This paper presents only some aspects concerning the human-machine interface of some applications developed by our university in collaboration with some heating distribution companies across Romania. There are many other partnerships and results, but for reason of volume limitation, we cannot present all of them. Many applications are developed together with ELSACO Electronic S.R.L.,[2.2.3] one of the top Romanian companies in this area, and most of them were developed when orking as consultant for COLTERM Timisoara.

Our intentions are to realize new even more efficient resource management systems with partners from all over Romania.

2.3. New Design Features for Power Apparatus and Equipment

This chapter will present some new computational issues deduced in order to improve the functioning and the design of power apparatus

2.3.1. Forces Applied to Electric Conductors Located close to Ferromagnetic Walls inside Power Apparatus

Electric conductors are often placed nearby ferromagnetic walls or inside ferromagnetic slots. Knowing exactly the forces which appear in those situations is mandatory in order to insure an adequate design of all machines, apparatus and power equipment. This chapter presents a more generalized method to compute these forces, based of Maxwell’s tensors, and taking in consideration the asymmetry of the conductor placement between the walls.

As we know from literature, electric conductors crossed by different electric currents, are often located or placed nearby ferromagnetic walls [2.3.1].

They are even placed inside ferromagnetic slots or compartments. In all these locations, they are subjected to attraction forces.

The computational methods found in literature are treating those situations in some particular cases like [2.3.2]:

- the electric conductors are placed exactly in the symmetry axis or plan belonging to that geometrical structure;
- the length of the ferromagnetic wall is considered as infinite;
- the ferromagnetic slots are rectangular or triangular ones only;

This research presents a more generalist case, where the electric conductor is placed asymmetrical between two finite length ferromagnetic walls or in such a ferromagnetic slot [2.3.3].

2.3.2. Electric Conductor Placed in the Symmetry Axis of a Ferromagnetic Slot

We consider an electrical conductor crossed by a certain current, “*i*”.

First, it is placed in a rectangular ferromagnetic slot. The geometrical dimensions are those represented in Figure 2.3.1. a,b [2.3.4]

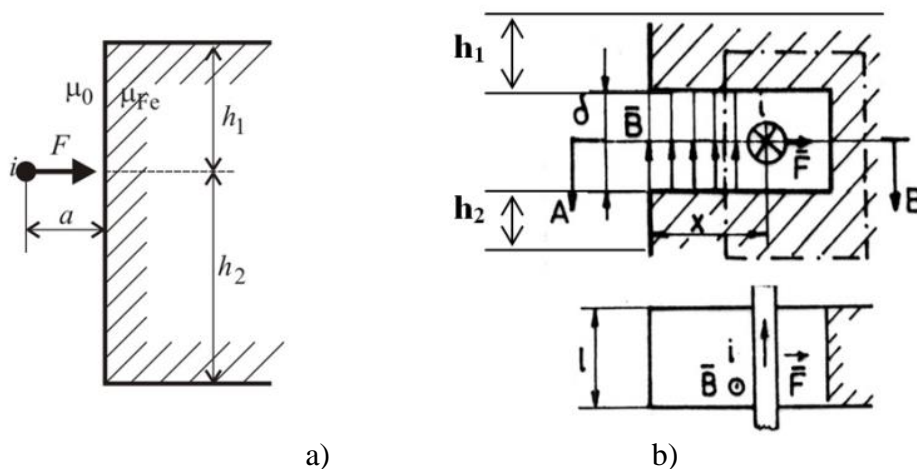


Fig.2.3.1. Electric conductor placed close to a ferromagnetic wall a) or inside a ferromagnetic slot b)

By applying the generalized forces theorems for a specific case when the conductor is placed symmetrical inside the slot and the exterior walls are extended up to infinite ($h_1=h_2=\infty$), we will obtain the relation for the \overline{F} force which tries to push the conductor to the ferromagnetic wall [1], as shown in Fig.2.3.1b.

$$F = \left(\frac{\partial W_m}{\partial x} \right)_{i=ct.} = \frac{\mu_0}{2} \cdot \frac{\ell}{\delta} \cdot i^2 \quad (2.3.1)$$

where W_m is the magnetic energy.

Next, we consider that the length of the upper and lower ends of that slot are finite, considered as h_1 and h_2 .

When we use the Maxwell Tensors Method in order to compute the same force, taking in consideration the magnetic induction B , we will obtain this relation:

$$F = F_1 + F_2 = \frac{\mu_0 \cdot \ell}{2 \cdot \delta} \cdot i^2 \cdot \left(\frac{h_1}{2 \cdot h_1 + \delta} + \frac{h_2}{2 \cdot h_2 + \delta} \right) \quad (2.3.2)$$

In Fig. 1a. the conductor is placed close to a ferromagnetic wall. By using the electrical image method, we obtained a relation for the specific attraction force [1]:

$$f_\infty = \frac{F}{l} = \frac{\mu_0}{4 \cdot \pi \cdot a} \cdot i^2 \quad (2.3.3)$$

where l is the length of the conductor and the heights h_1 and h_2 are extended to infinite.

When h_1 and h_2 are finite, (3) becomes:

$$f = f_\infty \cdot \varphi_{h_1} \cdot \varphi_{h_2} \quad (2.3.4)$$

where φ_{h_1} and φ_{h_2} are shape coefficients which took in consideration the heights h_1 and h_2 . They are given by:

$$\varphi_{h_1} = \frac{\pi \cdot h_1 - 2 \cdot a}{\pi \cdot h_1 + 2 \cdot a} \quad (2.3.5)$$

$$\varphi_{h_2} = \left(1 + \frac{2 \cdot \pi \cdot a}{\pi \cdot h_1 - 2 \cdot a} \cdot \frac{h_2 - h_1}{\frac{3 \cdot \pi}{2} \cdot h_2 + 2 \cdot a - \frac{\pi}{2} \cdot h_1} \right) \quad (2.3.6)$$

All relations starting from (2.3.1) up to (2.3.6) are particular cases, where the conductor is placed close to a ferromagnetic wall.

2.3.3. Electric Conductor Asymmetrically Placed between two Ferromagnetic Walls

We also consider an electrical conductor crossed by a certain current, “ i ”. It is asymmetrically placed between two ferromagnetic walls A and B, as shown in Fig. 2.3.2.

We appreciate that, with the right approximation that the magnetic lines are closing according to Fig 2.3.2. The two walls are extended up to infinite.

The length of an ordinary field line, starting from A, continuing in air, which does not rich wall B (shape Γ on Fig. 2) is given by:

$$l_\Gamma = 2 \cdot a + \pi \cdot r \quad (2.3.7)$$

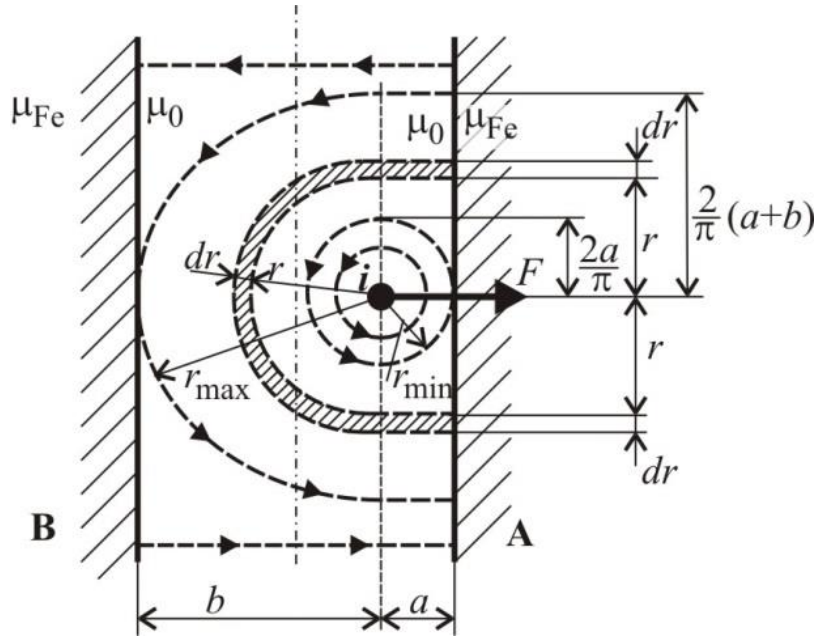


Fig.2.3.2. Electric conductor placed between two ferromagnetic walls

By applying the magnetic circuit law for the closed loop Γ , we will obtain the magnetic field's intensity H_m as well as the magnetic field's induction B_M , normal in point M, on the A surface.

$$B_M = \mu_0 \cdot H_M = \frac{\mu_0}{\pi \cdot r + 2 \cdot a} \cdot i \quad (2.3.8)$$

By consequent, the Maxwell tensor around point M, normal on A is [1]:

$$f_M = \frac{\mu_0}{2} \cdot \frac{i^2}{(\pi \cdot r + 2 \cdot a)} \quad (2.3.9)$$

The force applied by the ferromagnetic wall on the electric conductor is the sum of all Maxwell tensors generated by that field lines starting on wall A and not reaching wall B.

We consider that the minimum radius r_{min} of a field line reaching wall A is:

$$\pi \cdot r_{min} = 2 \cdot a \quad (2.3.10)$$

And the maximum radius of a field line which does not reach wall B, r_{max} , is satisfying the next relation:

$$\pi \cdot r_{max} = 2 \cdot (a + b) \quad (2.3.11)$$

We consider an elementary surface dS_A , on wall A, given by:

$$dS_A = l \cdot dr \quad (2.3.12)$$

The integration limits are from r_{min} up to r_{max} . Taking in consideration the conditions established by (10) and (11), the F force could be written as:

$$F = 2 \cdot \int_{r_{min}}^{r_{max}} f_m dS_a = \int_{\frac{2a}{\pi}}^{\frac{2(a+b)}{\pi}} \frac{\mu_0 \cdot l}{2} \cdot i^2 \cdot \frac{dr}{(\pi \cdot r + 2 \cdot a)^2} \quad (2.3.13)$$

After computing the integral, we will obtain:

$$F = \frac{\mu_0 \cdot i^2 \cdot l}{4 \cdot \pi \cdot a} \cdot \frac{b-a}{b+a} \tag{2.3.14}$$

And the specific attraction force:

$$f = \frac{F}{l} = \frac{\mu_0 \cdot i^2}{4 \cdot \pi \cdot a} \cdot \frac{b-a}{b+a} = f_\infty \cdot \varphi_{ab} \tag{2.3.15}$$

where:

$$\varphi_{ab} = \frac{b-a}{b+a} \tag{2.3.16}$$

and f_∞ is given by the same relation (2.3.13).

Relations (2.3.14) and (2.3.15) allow us to make some significant observations:

- We observe that the presence of a second infinite ferromagnetic wall, called B in this case, diminishes the attraction force applied on the conductor by the ferromagnetic wall A, with a diminution coefficient φ_{ab} given by relation (2.3.16).
- If the conductor is placed symmetrical ($a = b$), then the attraction force becomes zero, which is logical, because the attraction forces applied by both walls are canceling each other.
- If dimension “ a ” becomes greater than “ b ”, the attraction force changes its sign, and the conductor will be attracted by the B wall, instead of A, which is also a logic thing [2.3.9].
- If wall B is taken away ($b \gg a$), then $\varphi_{ab} \rightarrow 1$ and relation (2.3.15) becomes relation (2.3.3), which is the one deduced for a single wall.
- If we look at the integration limits, relations (2.3.14) and (2.3.15) are not necessary applied for infinite walls. They are used for walls having a minimum height equal to $2(a+b)/\pi$.

2.3.4. Electric Conductor Asymmetrically Placed Inside a Ferromagnetic Slot

We consider an electrical conductor asymmetrically placed in a ferromagnetic rectangular slot, as shown in Fig.2.3.3 a and b.

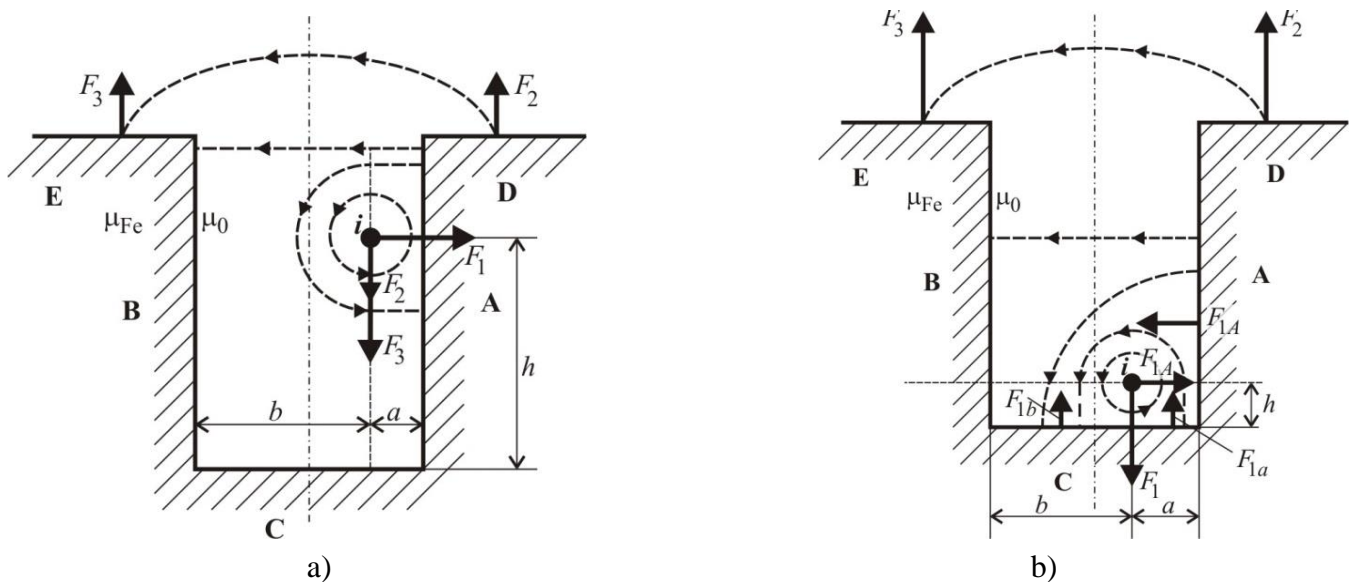


Fig.2.3.3. Electric conductor placed inside a ferromagnetic slot.
a. Placed far from the bottom; b. Placed close to the bottom

Situation described in Fig.2.3.3a could be treated starting from the case previously presented, when the conductor was placed between two ferromagnetic walls. The main condition is that the “h” distance between the conductor and the bottom of the slot, named as C, must fulfill the condition given by (2.3.11), which means to be at least equal to $2(a+b)/\pi$.

In this case, the attraction force F_1 , exerted by the A wall on the conductor, is given by a relation similar to (14), which is:

$$F = \frac{\mu_0 \cdot i^2 \cdot l}{4 \cdot \pi \cdot a} \cdot \frac{b-a}{b+a} \quad (2.3.17)$$

Forces F_2 and F_3 , generated by Maxwell’s tensors are also applied on the conductor. They are produced on the exterior D and E surfaces of the slot, and they are pushing the conductor to the bottom C of the slot. If we consider surfaces D and E extended to infinite, according to (2.3.1), the forces are:

$$F_2 = F_3 = \frac{\mu_0 \cdot i^2 \cdot l}{4 \cdot (a+b)} \quad (2.3.18)$$

By consequent, the total force F , which is pushing the conductor up to the bottom C of that slot, is given by:

$$F = F_2 + F_3 = \frac{\mu_0 \cdot i^2 \cdot l}{2 \cdot (a+b)} \quad (2.3.19)$$

We noticed that if $a = b$, then F_1 becomes zero, so only the F force is applied to the conductor. We are finding relation (2.3.1).

Case b in Fig.2.3.3 does not satisfy the relation from which the distance between the conductor and the bottom must be higher than $2(a+b)/\pi$.

In this situation, the conductor will be attracted to the bottom of the slot with a F_1 force and it will be supplementary pushed by a force $F = F_2 + F_3$. It will be also attracted by the A wall with an additional F_{1A} force [2.3.6].

Because forces F_2 and F_3 are the same like in case a), they are given by relation (2.3.18).

The F_1 force is given by the sum of F_{1a} and F_{1b} , forces that appear on the surfaces having an “a” and a “b” length, belonging to the C wall [2.3.8].

By using the Maxwell’s tensors on the field lines having the specified shape like in Fig.2.3.3b, we will obtain:

a. For the F_{1a} force, the average field line is considered as:

$$l_{1a} = 2 \cdot h + \pi \cdot r \quad (2.3.20)$$

By repeating all computational procedures like previously described, it results:

$$\begin{aligned} F_{1a} &= 2 \cdot \int_{r_{\min}}^{r_{\max}} f_m dS_C = \int_{\frac{2h}{\pi}}^{a-h} \frac{\mu_0 \cdot l}{2} \cdot i^2 \cdot \frac{dr}{(\pi \cdot r + 2 \cdot h)^2} = \\ &= \frac{\mu_0 \cdot l \cdot i^2}{4 \cdot \pi \cdot h} \cdot \frac{\pi(a-h) + 2h}{\pi(a-h) + 2h} \end{aligned} \quad (2.3.21)$$

b. For the F_{1b} force, the average field line is considered as:

$$l_{1b} = h + \frac{\pi}{2} r + a \quad (2.3.22)$$

and the integration limits of the Maxwell’s tensors are:

$$\begin{aligned} r_{\min} &= a-h \\ r_{\max} &= b-h \end{aligned} \quad (2.3.23)$$

It results:

$$\begin{aligned}
 F_{1b} &= \int_{a-h}^{b-h} \frac{\mu_0 \cdot l \cdot i^2}{2} \cdot \frac{dr}{\left(\frac{\pi}{2}r + h + a\right)^2} = \\
 &= \frac{\mu_0 \cdot l \cdot i^2}{2} \cdot \frac{b-a}{\frac{\pi}{2}(a-h) + h + a} \cdot \frac{b-a}{\frac{\pi}{2}(b-h) + h + a}
 \end{aligned} \tag{2.3.24}$$

c. The F_{1A} force is equal to F_{1b} , but oriented like in Fig. 2.3.3b. On Fig.2.3.4, we can distinctly represent the composition of all forces applied on the electric conductor placed inside the ferromagnetic slot, like in Fig. 3b.

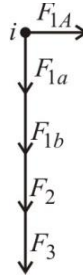


Fig.2.3.4. The forces applied on the electric conductor asymmetrically placed near the bottom of the ferromagnetic slot.

According to (2.3.24), we still notice that if $a = b$, then $F_{1b} = 0$ and $F_{1A} = 0$, which is perfectly logical.

The situation of the electrical conductors placed nearby ferromagnetic walls (or inside ferromagnetic slots) is a case frequently seen inside all the electrical machines and apparatus, as well as transformers and power equipment.

Knowing exactly the forces acting in these cases is a priority for all designers of such equipment.

The computational method based on Maxwell's tensors offers a more precise point of view by comparing the classical methods based on the magnetic energy and using many simple models.

All the computational processes are carried out by considering a more general case, when the electric conductor is placed asymmetrical between two ferromagnetic walls [2.3.7].

The new formulas deduced by using those considerations are perfectly compatible with the older cases, all simplified older formulas are particular cases of the newest ones.

2.4. New Algorithms used for Signal Interpolation in DSP Techniques

There are a huge number of applications where a lot of samples of a digital signal are given and there is necessary to estimate the values between them. In present time, the interpolation problem is also on the spot, although many great mathematicians with hundred years ago approached it from different points of view. Those algorithms could be improved and then used in other DSP domains, like measurements and virtual instrumentation.

All the measurement techniques involved are applied in Power Quality Assessment especially in case of Active/Reactive Power/Energy Measurements.

Signal interpolation is an old problem that could be resolved by filtering techniques. This type of technique is applied when a dedicated filter is used to determine the coefficients from the input samples and another filter is applied in order to obtain the interpolated values. In this research is presented a new technique for coefficients determination. The approximation function is a cubic B-spline one. We are presenting the results for signal interpolation by a factor $m=2^r$. The algorithm is implemented for some well known signals (like sine, cosine and triangle functions) and the results are discussed at the end.

The problem of interpolation is one of the most actual in technical sciences. It was discussed since old times, first in astronomy. For generations, great mathematicians approached the problem from different angles. The traditional methods are improved and always are searched new ways to obtain better results with minimum costs. Nowadays, the interpolation is still an important issue in signal processing, especially for digital signal and image processing.

To perform digital processing are needed divers operations like acquisition, sampling, analog to digital conversion, approximation, reconstruction, interpolation or translation. In this section we present a new method for determine the B-spline coefficients in the generalized interpolation approach. We started with an algorithm described in the specialty literature that has some disadvantages. The new algorithm that will be presented can be used to perform interpolation for signals represented by uniformly spaced samples.

In Section II are presented the concepts of general and traditional interpolation and an algorithm for B-spline interpolation that uses some modern techniques. In Section III are determined the relations for the coefficients using the properties of the spline functions: polynomial on short intervals, continuous and differentiable. The coefficients are determined from the input samples and from the function derivative values in the knots. This method eliminates the signal extension necessary for the algorithm toke from the literature. Section IV presents the new interpolation algorithm for an interpolation factor $m=2$ and a way to extend the process for $m=2^r$. Some practical results for implementing this one are discussed in Section V.

Traditionally, the interpolation is performed using polynomial functions. For a set of data you have to determine a polynomial function that passes through all the given points.

For a signal $y = \{y(k)\}$, $k = 0, N-1$, we have to find a polynomial function $f(x)$, that in the knots: $f(k) = y(k)$ for any $k \in \{0, N-1\}$. There were utilized systems of equations and matrix computation methods to determine the interpolation function. In these procedures are necessary many numerical calculations and is hard to make algorithms ready to implement on digital systems.

In problems of signal processing, the traditional approach supposes to use a basis function $\varphi_i(x-k)$ and the input samples to determine the values for the interpolation function:

$$f(x) = \sum_{k \in Z} y(k) \varphi_i(x-k)$$

The function $\text{sinc}(x)$ is used as basis function to perform the interpolation.

Usually, is not necessary to determine the exact structure of this function. There is enough to find the values of the function in some certain points, determined with a good approximation. That permits to do a good approximation with minimum computational costs, instead to perform an exact interpolation with greater efforts.

A larger view on the problem is provided by the concept of generalized interpolation. This method requests to perform 2 steps. The first is to determine a set of coefficients $c(k)$ from the input samples $y(k)$. For the second step, the interpolated values $f(x)$ are obtained by convolving the coefficients vector with a basis function:

$$f(x) = \sum_{k \in Z} c(k) \varphi(x-k).$$

The generalized interpolation allows the use of a larger class of potential basis functions. We have a traditional interpolation if the coefficients are equal to the input samples $c(k) = y(k)$.

This method can be implemented by digital filtering techniques. First, a solution for some applications in image processing was published by H. Hou and H. Andrews in 1978. Later, the idea was developed in multiple studies with direct applications in digital image processing.

2.4.1. B-Spline Functions

Spline functions are piecewise polynomials of degree n with continuity of the spline and its derivatives up to order $(n-1)$ at the knots. Only functions with uniform knots and unit spacing are used in this research [2.4.1].

A spline function $f^n(x)$ is uniquely characterized by the B-spline coefficients $c(k)$, where:

$$f^n(x) = \sum_{k \in \mathbb{Z}} c(k) \beta^n(x-k) \quad (2.4.1)$$

$\beta^n(x)$ is the B-spline function of degree n constructed from the $(n+1)$ -fold convolution of a rectangular pulse β^0 :

$$\beta^0(x) = \begin{cases} 1, & -1/2 < x < 1/2 \\ 1/2, & |x| = 1/2 \\ 0, & \text{otherwise} \end{cases} \quad (2.4.2)$$

For $n = 3$ we have the cubic B-spline function which is often used for performing high-quality interpolation [2.4.2]:

$$\beta^3(x) = \begin{cases} 2/3 - |x|^2 + |x|^3/2, & 0 \leq |x| < 1 \\ (2 - |x|)^3/6, & 1 \leq |x| < 2 \\ 0, & 2 \leq |x| \end{cases} \quad (2.4.3)$$

The B-spline interpolation problem is traditionally solved by using matrices and classic numerical techniques. The algorithms are long and many operations are necessary in order to determine the solutions. There is a faster way to solve the problem, by using simpler digital filter techniques. Unser uses the discrete B-spline functions and define the indirect and direct B-spline transforms. The B-spline coefficients can be obtained by linear filtering. Having a set of data the spline coefficients are calculated such that the function goes through the data points exactly. The interpolated values of the signal are obtained also by digital filtering.

In order to perform an interpolation process for a set of N samples, it is necessary to find the interpolation function in (2.4.1). The input data are lettering by $\{s(0), s(1), s(2), \dots, s(N-1)\}$. For that we have to calculate the B-spline coefficients. A solution proposed by M. Unser is mandatory to apply, for the input signal, a digital filter, called direct B-spline filter [2.4.3]:

$$(b_1^3)^{-1}(k) \leftrightarrow [B_1^3(z)]^{-1} = \frac{6}{z+4+z^{-1}} \quad (2.4.4)$$

$b_1^3(k)$ is the discrete B-spline function of degree $n=3$ (cubic). The coefficients can be calculated by "direct B-spline transform".

This filter is implemented by 2 filters: first a causal filter and the second anti-causal. A recursive algorithm is given to compute the B-spline coefficients:

$$c^+(k) = s(k) + z_1 c^+(k-1), \quad k = 1, \dots, N-1 \quad (2.4.5)$$

$$c^-(k) = z_1 (c^-(k+1) - c^+(k)), \quad k = N-2, \dots, 0 \quad (2.4.6)$$

where: $z_1 = -2 + \sqrt{3}$ and $c(k) = 6c^-(k)$.

For achieving this, it is necessary to establish some initial conditions. To recover exactly the initial samples by convolving $c(k)$ with $b_1^3(k)$, we use mirror-symmetric boundary conditions: $s(k) = s(1)$ for $(k+1) \bmod (2N-2) = 0$.

The resulting signal is periodic with period $2N-2$. For the first recursion we have the next initialization [2.4.4]:

$$c^+(0) = \sum_{k=0}^{+\infty} s(k)z_1^k \quad (2.4.7)$$

Practically is not simple and efficient to calculate this. For the periodic signal, resulted by mirroring the input data, the relation became:

$$c^+(0) = \frac{1}{1-z_1^{2N-2}} \sum_{k=0}^{2N-3} s(k)z_1^k \quad (2.4.8)$$

The author propose, for current use in practice, the formula (2.4.9), with $k_0 > \log \varepsilon / \log |z_1|$, where ε is the desired level of precision. In the literature it is not pointed out the exact signification and how ε have an effect on the calculating the coefficients process [2.4.5].

By taking different values for ε , it was observed that only a few coefficients are affected at the beginning and at the end of the data string. For a given signal, the intermediate values are the same for different values of ε .

$$c^+(0) = \sum_{k=0}^{k_0} s(k)z_1^k \quad (2.4.9)$$

For the second recursion, it is used:

$$c^-(N-1) = \frac{z_1}{(z_1^2 - 1)} (c^+(N-1) + z_1 c^+(N-2)) \quad (2.4.10)$$

Having the B-spline coefficients, the signal interpolation by an integral factor m it is completed by $f^m(x/m)$, denoted by $f_m^n(x)$. From (2.4.1) we obtain:

$$f_m^n(x) = \sum_{k \in Z} c(k)b_m^n(x - km) \quad (2.4.11)$$

This operation is called “indirect B-spline transform” and it is implemented by means of digital filtering techniques.

The presented algorithm was implemented; we have calculated the B-spline coefficients and the recovered signal in some particular cases. We used more arrays of initial data with N samples of sine or cosine functions.

The samples $s(k)$ are defined by $s(k)=\sin(2\pi k/M)$ or $s(k)=\cos(2\pi k/M)$ with $k=0, \dots, N-1$, were $M=12, 50, 100$ or 120 . The N samples represent 1, 3 or 5 periods of the functions for different sampling frequencies. The case of a straight line signal was also analyzed. The value for k_0 in (2.4.9) was set to $k_0=7$. From these results, several observations could be revealed.

The B-spline coefficients are following the signal variation and they are closed to the sample values. In figure 2.4.1., the differences between the coefficients and the input data values for $s(k)=\sin(2\pi k/120)$ with $N=361$, are presented. In all studied cases the values of the B-spline coefficients are almost equal with the sampled values. In the case of cardinal spline functions the coefficients are exactly the input data. But those functions are no longer compactly supported. There is lost the advantage of calculating any value of the interpolation polynomial by using maximum $(n+1)$ B-spline functions (for the sampling points, only n functions are necessary).

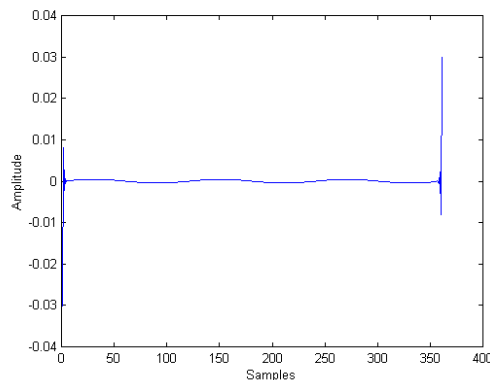


Fig. 2.4.1. Differences between B-spline coefficients and input data

For sine and cosine functions, the B-spline coefficients for different sampling frequencies have been calculated. There were taken one period of the signal and then three periods. In each case we obtained different values for the coefficients. Generally $c(k)$ depends on the signal sampling frequency (sampling unit). Table 2.4.1. are compares the coefficients $c(k)$ for different sampling frequencies in case of sine function: $\sin(2\pi k/M)$. The values are obtained on the same points α of the input function characteristic.

Table 2.4.2. presents the same coefficients, but for the cosine function: $\cos(2\pi k/M)$. The values depend not only of the shape of the function, but also of the sampling frequency.

TABLE 2.4.1.
COEFFICIENTS FOR $s(k)=\sin(2\pi k/M)$, $\kappa_0=7$

| α | M | First period | | Second period | | Third period | |
|----------|-----|--------------|---------------|---------------|---------------|--------------|--------------|
| | | k | $c(k)$ | k | $c(k)$ | k | $c(k)$ |
| 0 | 12 | 0 | -0.3021395140 | (M+0) | -0.0000000413 | (2M+0) | 0.0000000413 |
| | 120 | 0 | -0.0302443872 | (M+0) | 0 | (2M+0) | 0 |
| $\pi/6$ | 12 | 1 | 0.6043309293 | (M+1) | 0.5233729016 | (2M+1) | 0.5233727360 |
| | 120 | 10 | 0.5002284575 | (M+10) | 0.5002285152 | (2M+10) | 0.5002285152 |
| $\pi/3$ | 12 | 2 | 0.8848157966 | (M+2) | 0.9065084347 | (2M+2) | 0.9065090142 |
| | 120 | 20 | 0.8664212038 | (M+20) | 0.8664212038 | (2M+20) | 0.8664212038 |

TABLE 2.4.2.
COEFFICIENTS FOR $s(k)=\cos(2\pi k/M)$, $\kappa_0=7$

| α | M | First period | | Second period | | Third period | |
|----------|-----|--------------|--------------|---------------|--------------|--------------|--------------|
| | | k | $c(k)$ | k | $c(k)$ | k | $c(k)$ |
| 0 | 12 | 0 | 1.0467677172 | (M+0) | 1.0467457811 | (2M+0) | 1.0467457811 |
| | 120 | 0 | 1.0004237020 | (M+0) | 1.0004570305 | (2M+0) | 1.0004570305 |
| $\pi/6$ | 12 | 1 | 0.9065025600 | (M+1) | 0.9065084377 | (2M+1) | 0.9065084377 |
| | 120 | 10 | 0.8664212037 | (M+10) | 0.8664212038 | (2M+10) | 0.8664212038 |
| $\pi/3$ | 12 | 2 | 0.5233744655 | (M+2) | 0.5233728905 | (2M+2) | 0.5233728905 |
| | 120 | 20 | 0.5002285152 | (M+20) | 0.5002285152 | (2M+20) | 0.5002285152 |

Studying the case of sine and cosine functions it is clearly that for greater sampling frequencies the values of $c(k)$ and $s(k)$ are very close (differences of maximum 10^{-4} order for $M=120$). At smaller sampling frequency the differences are increasing (10^{-2} for cosine and 10^{-1} for sine functions when $M=12$).

In case of the odd functions, by performing the mirror extension for the input signal, the functions derivatives are no longer continues. The coefficients obtained for one or more periods are not the same. For the second period, the coefficients are different in comparison with the first period, but they are almost equals with the ones obtained in the next periods. In Table 2.4.1 and Table 2.4.2 we notice the differences between $c(0)$ from the first period and his correspondents in the second and the third period. Those last ones are almost equal.

For the intermediary periods the values are the same and some differences are presented at the beginning of the first period and at the end of the last. The first and last few coefficients have values closer to the others, but not equal.

Between the first and the last coefficients there is a sort of symmetry. It can be said that we have a “side effect”. This side effect can be due to the initial conditions.

Those coefficients introduce some errors at the beginning and the end of the sequence in the signal reconstruction.

In the case of the sine function we observe that the difference between $c(0)$ and $c(M)$ is greater than in the case of cosine function. For the odd functions the mirror-symmetric conditions introduce bigger errors. For the signal reconstruction and interpolation, in all cases studied, we observed those side effects. At the beginning and the end of the data sequence the errors are higher than the others.

Considering the input signal $s(k) = \sin(2\pi k/120)$ we calculated the B-spline coefficients and completed the interpolation by factor 2. For the first and last few points the errors are $e=10^{-3}$ and decrease fast to $e=10^{-8}$ in the interpolated points. The algorithm has excellent properties of convergence. At the input data points, the values obtained are exactly the same, excepting the 2 extremely points. For calculating every interpolated value, we need the coefficient for the current point $c(k)$ and some anterior and posterior coefficients. For the first and last 2 points of the string, some of those coefficients are not known (example $c(-1)$) and considered zero. This is one of the causes for the side errors that appear in every cases when we perform interpolation.

For $s(k) = \cos(2\pi k/120)$ the results are comparative. The interpolation was done by 2 and the errors at the beginning and the end of the results array are smaller, starting from 10^{-6} and decay faster than for the above function. Similar results have been obtained in the cases of the studied signals with other sampling unit ($M=50, 100$). The errors for the B-spline coefficients have a real significance in the interpolation process.

For initializing $c^+(0)$ are used a finite number k_0 of samples. Extending the signal by mirroring it was calculated $c^+(0)$ in the relation (2.4.8). The results for coefficients, signal reconstruction and interpolation by 2 are better than in the case of using (2.4.9) for initialization, with $k_0=7$. For the cosine signal $\cos(2\pi k/120)$ the interpolation errors at the beginning and the end of the string are much smaller than for $k_0=7$. Compared with the same case of initialization for $\sin(2\pi k/120)$ the results are better too. But the errors decay slower compared with the cosine function case. It can be said that the mirror extension present disadvantages for the odd functions.

The coefficients for the extended signals are similar with the values obtained in the second and third period of the signals for $k_0=7$. We can say that the values for $c(k)$ corresponding to the second period in Table 2.4.1 and Table 2.4.2 (where $k_0=7$), in fact, represent the coefficients for $k_0 = \infty$. If we can take the coefficients values from the intermediary period, then the initialization is not necessary to be very precise. But in this case, an increased amount of numerical operations are necessary.

If the input samples correspond to a straight line $s(k) = 1$, $N=50$, the B-spline coefficients $c(k)$ are calculated and presented in Table 2.4.3. At the beginning and at the end, the coefficients have values different from 1. But they converge fast to 1. We perform the interpolation of the signal by the integral factor 2 and obtain the values $y(k/2)$ presented in the third column of Table 2.4.3.

Excepting the first and last values, in data points, the signal is exactly recovered. Between those points, the interpolated values have errors for certain positions. This proves again that the algorithm has a good convergence due to polynomial spline properties. But, for some oscillations in the sequence of coefficients, we obtain oscillations in the interpolated signal. This could be an inconvenient if the input signal has a small number of samples.

For all the errors that appear in the determination process of the B-spline coefficients, a possible cause is, on principle the input signal, which is considered of infinite duration (extended to $k \in \mathbb{Z}$). In practice, for the recursive algorithm, the initialization is done for $k = 0$ and is limited to a k_0 . If a signal extension on both sides is done and the interpolation is performed, in the center area the results are very good. By doing this, the middle area is the interval where the input samples are defined and the side errors are not relevant.

TABLE 2.4.3
INPUT SIGNAL $S(K)=1, K_0=7$

| k | c(k) | y(k/2) |
|-----|--------------|------------------------------|
| 0 | 0.999637023 | 0.8333107558 0.9791538800 |
| 1 | 1.0000097259 | 1 1.0000026699 |
| 2 | 0.9999973939 | 1 0.9999992845 |
| 3 | 1.0000006982 | 1 1.0000001916 |
| 4 | 0.9999998128 | 1 |
| ... | ... | ... |
| 30 | 1 | 1 1 |
| 31 | 1 | 1 |
| ... | ... | ... |
| 49 | 1 | 1 0.9791666666 |
| 50 | 1 | 0.8333333333 |

In case of the straight line, we took for input much more samples. For calculating $c^+(0)$, we use the relation (2.4.7):

$$c^+(0) = \sum_{k=0}^{+\infty} s(k)z_1^k = \sum_{k=0}^{+\infty} z_1^k = \frac{1}{1-z_1} \quad (2.4.12)$$

All the values for B-spline coefficients are equal to 1. The samples obtained for the interpolated signal by the integral factor 2 are presented in Table 2.4.4, along with the coefficients.

TABLE 2.4.4
INPUT SIGNAL $S(K)=1, K_0=\infty$

| k | c(k) | y(k/2) |
|-----|------|------------------------------|
| 0 | 1 | 0.8333333333 0.9791666666 |
| 1 | 1 | 1 1 |
| 2 | 1 | 1 1 |
| 3 | 1 | 1 1 |
| 4 | 1 | 1 1 |
| ... | ... | ... |
| 30 | 1 | 1 1 |
| 31 | 1 | 1 |
| ... | ... | ... |
| 49 | 1 | 1 0.9791666666 |
| 50 | 1 | 0.8333333333 |

We see that still exists a side effect due to the 2 coefficients that are not known at the beginning and at the end of the data string.

In conclusion, to reduce the side effect it is necessary to perform a signal extension on both sides, but it is essentially to establish the right way to do it. The presented examples show that the extension of a signal by using its mirror image it is not an optimal solution in all the cases. The extension can be performed for the string coefficients too. We searched another approach for calculate the B-spline coefficients.

2.4.2. A New B-Spline Interpolation Algorithm

The interpolation algorithm can be implemented by digital filtering. The input samples are brought at the input of a pre-filter, and the coefficients are obtained at its output. In the previous section we determined a relation between the coefficients and the input samples (2.4.12). From this one is deduced the transfer function for the pre-filter [2.4.7]:

$$H_{1p}(z) = \frac{(z^{-2} - z^2) - 8(z^{-1} + z^1)}{6(z - z^{-1})} \quad (2.4.16)$$

This is the first step of the interpolation: to determine the coefficients by pre-filtering. The second step is to determine the interpolated values using these coefficients. To perform the interpolation by a factor $m=2$, the coefficients string is expanded by 2 and brought as input for the filter $B_2^3(z)$. The expansion is made by filling with zero the intermediary values.

The interpolated signal $yin(k)$ is obtained at the output of the system presented in figure 1.

The interpolation by a higher factor m can be done in the same way: the coefficients string is expanded by m and brought as input for the filter $B_m^3(z)$. The process is presented in figure 2.4.2.

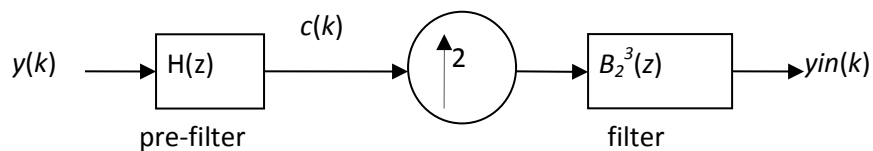


Fig.2.4.2a Signal interpolation for $m=2$

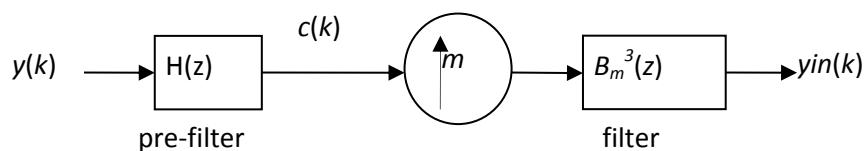


Fig.2.4.2b. Signal interpolation for $m>2$

An important matter is to determine the transfer function for the filter $B_m^3(z)$. This process can be difficult. We can use an important property of digital filters: any filter with a high order can be decomposed in filters of second degree connected in cascade [2.4.8]. If we want to perform the interpolation by a factor $m=2^r$ we can use r systems that make the interpolation by 2 (presented in fig.1), one after another. The output of the first system will be input for the next one. In this way, it can be done for higher m .

The algorithm presented was used to perform the interpolation for some well known signals. The coefficients were determined by pre-filtering with $H_{IP}(z)$. The signal was reconstructed for $m=1$ in order to be compared with the original. After, we performed the interpolation by $m=2$, using the system presented in figure 2.4.2. For other values of the interpolation factor ($m=4$, $m=8$ or $m=16$), we used recursively the same system (2, 3 or 4 times). Some results are presented further [2.4.9].

For this algorithm and for the ones presented in literature, we observe that the coefficients follow the signal variation and are close to the samples values.

As input signals, we took samples from the sine or cosine functions: $y(k)=\sin(2\pi k/M)$ or $y(k)=\cos(2\pi k/M)$, $k = 0, \dots, N-1$. We have analyzed multiple situations: different values for M (various sampling frequencies) and N (the total number of input samples). For the periodic signals the input vector has a small number of samples ($M=12$ and $N=13$) corresponding to one period or an increased number of samples equivalent to more than two periods (example: $M=120$ and $N=361$).

We have analyzed also the situation in which the input samples correspond to a triangle wave.

The values for the interpolated samples and the interpolation errors for a sine function, for some distinctive points α on the function characteristic are presented in Table I. The input samples are given by $y(k)=\sin(2\pi k/M)$, were $M=12$ (for a low sampling frequency). There were performed the signal reconstruction and signal interpolation by 2, 4, 8 and 16.

Analyzing all the data in this case, the interpolation errors are of maximum 10^{-3} order. We used extended precision to perform the operations and we considered zero any value minor than 10^{-8} order. Only at the beginning and the end of the signals, the interpolation errors are greater, due to the so called "side effect". When increasing the interpolation factor m , the interpolation errors are not increasing and hang about the same order. This represents an accepted result for a lot of applications.

TABLE 2.4.5.
 $Y(K)=\sin(2\pi K/12), H_{IP}(Z)$

| α | m | y_{in} | e_{in} |
|----------|-----|-------------|-----------------------|
| $\pi/3$ | 1 | 0.49999999 | 10^{-8} |
| | 2 | 0.49999999 | 10^{-8} |
| | 4 | 0.49966113 | $3.39 \cdot 10^{-4}$ |
| | 8 | 0.49962400 | $3.76 \cdot 10^{-4}$ |
| | 16 | 0.49956933 | $4.30 \cdot 10^{-4}$ |
| π | 1 | 0.00129537 | $-1.29 \cdot 10^{-3}$ |
| | 2 | 0.00129537 | $-1.29 \cdot 10^{-3}$ |
| | 4 | 0.00235947 | $-2.23 \cdot 10^{-3}$ |
| | 8 | 0.00242814 | $-2.42 \cdot 10^{-3}$ |
| | 16 | 0.00238661 | $-2.38 \cdot 10^{-3}$ |
| $3\pi/2$ | 1 | -0.99627848 | $-3.73 \cdot 10^{-3}$ |
| | 2 | -0.99627848 | $-3.73 \cdot 10^{-3}$ |
| | 4 | -0.99511226 | $-4.89 \cdot 10^{-3}$ |
| | 8 | -0.99500357 | $-4.99 \cdot 10^{-3}$ |
| | 16 | -0.99504869 | $-4.96 \cdot 10^{-3}$ |

In figure 2.4.3 we present the interpolation errors for an input signal $y(k)=\sin(2\pi k/12)$ interpolated by a factor $m=16$.

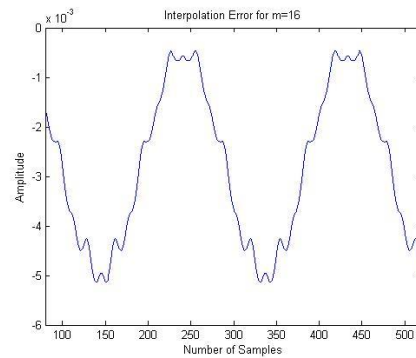


Fig.2.4.3. Interpolation errors for $\sin(2\pi k/12)$ interpolated by $m=16$

If the input signals are sampled at greater rates, then the interpolation errors are significantly reduced. The same operations were performed for $y(k)=\sin(2\pi k/120)$ ($M=120$ samples per period) and the results showed that the interpolation errors are negligible (10^{-7} or 10^{-8} order).

The same interpolation algorithm was performed also if the input signal is $y(k)=\cos(2\pi k/M)$. We obtained comparable results. We tested both \sin and \cos to analyze the errors introduced by the initial conditions. For $y(k)=\cos(2\pi k/M)$, at the beginning of the interpolated signal the errors are larger by one order of magnitude [2.4.9].

For a triangle wave, the interpolation errors were greater, especially in the points where the signal presents discontinuities. We took the case of a signal that presents 5 samples per period. The coefficients and the interpolated values were computed in the same manner as for the sine and cosine functions. In figure 4 is presented the output signal for interpolation with a factor $m=16$.

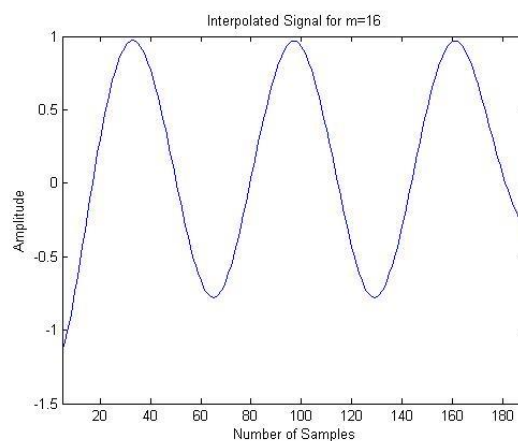


Fig.2.4.4. A triangle wave interpolated by $m=16$

As it can be seen, a smoothing effect appears, as for all the cases when a discontinuous signal is interpolated. We have analyzed the resulting values for interpolation by a factor 2, 4, 8 or 16. The interpolation errors are increasing when increasing the interpolation factor for this signal.

2.4.3. Another New Interpolation Algorithm for Digital Signal Processing

In this part of the research, we will present a way to initialize the spline coefficients without performing the signal extension on Z .

For the new coefficients it is used the notation: $c_n(k)$. For a given set of data $\{s(0), s(1), s(2), \dots, s(N-1)\}$ we consider $f(x)$ as the interpolation function. We impose for that one function to be a cubic spline function. An important property of those functions is that they are piecewise polynomial functions.

From the convolution of the coefficients with the cubic B-spline function in formula (2.4.1) we can write the next relation:

$$6f(k) = 4 c_n(k) + c_n(k-1) + c_n(k+1) \quad (2.4.17)$$

This is happening in the function knots. Also in the sample points, the relations between the function derivatives and the B-spline coefficients are:

$$f'(k) = 0 c_n(k) - \frac{1}{2} c_n(k-1) + \frac{1}{2} c_n(k+1) \quad (2.4.18)$$

$$f''(k) = -2 c_n(k) + c_n(k-1) + c_n(k+1) \quad (2.4.19)$$

Those relations help us to evaluate the properties and the values for the B-spline coefficients. For $k = 2$ it can be deduced:

$$c_n(2) = f(2) - f''(2)/6 \quad (2.4.20)$$

$$c_n(0) = c_n(2) - 2f'(1) \quad (2.4.21)$$

$$c_n(1) = \frac{6f(1) - c_n(0) - c_n(2)}{4} \quad (2.4.22)$$

The problem is how to calculate $f'(1)$ and $f''(2)$ from the known samples. The interpolation function is a B-spline (piecewise polynomial), so we can approximate $f(k)$ by a polynomial function on short intervals. With this polynomial function and his derivatives we calculate the values for the first 3 coefficients.

Consider f a polynomial function of 4-th order (pass trough 5 points):

$$f(x) = a + b x + d x^2 + e x^3 + g x^4 \quad (2.4.23)$$

The function and the function derivatives of order 1 and 2 have been evaluated on the interval $[0;4]$, and we obtain the next relations:

$$f'(1) = \frac{-3f(0) - 10f(1) + 18f(2) + f(4)}{12} \quad (2.4.24)$$

$$f''(2) = \frac{-(f(0) + f(4)) + 16(f(1) + f(3)) - 30f(2)}{12} \quad (2.4.25)$$

The main condition is that the interpolation function has to pass through the input samples: $f(k)=s(k)$ for $k=0,1, \dots, N-1$. By using (2.4.20) and (2.4.21) in relations (2.4.16), (2.4.17) and (2.4.18) are calculated the initial coefficients $c_n(0)$, $c_n(1)$ and $c_n(2)$ without performing any signal extension.

Those 3 coefficients have been calculated for the previous studied signals. Some results are presented in Table 2.4.6 for sine functions and Table 2.4.7 for cosine functions. The coefficients calculated with the new relations (in the last column) are compared with the corresponding coefficients in Unser's algorithm, for $k_0=7$ and $k_0=\infty$.

The coefficients for $s(k)=\sin(2\pi k/M)$ are presented in Table 2.4.7 for two situations: $M=12$ and $M=120$. As it can be seen, the new values are much closer to the ideal values than the ones for $k_0=7$. The differences between $c_n(k)$ and $c(k)$ for $k_0=\infty$ are in the order of 10^{-3} for $M=12$. For a higher sampling frequency the differences decrease to 10^{-7} ($M=120$).

TABLE 2.4.6.
COEFFICIENTS FOR $s(k)=\sin(2\pi k/M)$

| M | k | | $c(k)$ | $c_n(k)$ |
|-----|---|--------------|---------------|---------------|
| 0 | 0 | $k_0=7$ | -0.3021395140 | -0.0035163260 |
| | | $k_0=\infty$ | -0.0000000413 | |
| 12 | 1 | $k_0=7$ | 0.6043309293 | 0.5244880516 |
| | | $k_0=\infty$ | 0.5233729016 | |
| | 2 | $k_0=7$ | 0.8848157966 | 0.9055641193 |
| | | $k_0=\infty$ | 0.9065084347 | |
| 0 | 0 | $k_0=7$ | -0.0302443872 | -0.0000000544 |
| | | $k_0=\infty$ | 0 | |
| 120 | 1 | $k_0=7$ | 0.0604638345 | 0.0523598917 |
| | | $k_0=\infty$ | 0.0523598753 | |
| | 2 | $k_0=7$ | 0.1024047866 | 0.1045762250 |
| | | $k_0=\infty$ | 0.1045762359 | |

In case of $s(k)=\cos(2\pi k/M)$ the values are presented in Table 2.4.7. The results are similar: differences of order 10^{-7} for $M=120$.

TABLE 2.4.7.
COEFFICIENTS FOR $s(k)=\cos(2\pi k/M)$

| M | k | | $c(k)$ | $c_n(k)$ |
|-----|---|--------------|--------------|--------------|
| 0 | 0 | $k_0=7$ | 1.0467677172 | 1.0495366943 |
| | | $k_0=\infty$ | 1.0467457811 | |
| 12 | 1 | $k_0=7$ | 0.9065025600 | 0.9059470100 |
| | | $k_0=\infty$ | 0.9065084377 | |
| | 2 | $k_0=7$ | 0.5233744655 | 0.5228276880 |
| | | $k_0=\infty$ | 0.5233728905 | |
| 0 | 0 | $k_0=7$ | 1.0004237020 | 1.0004569306 |
| | | $k_0=\infty$ | 1.0004570305 | |
| 120 | 1 | $k_0=7$ | 0.9990948692 | 0.9990859898 |
| | | $k_0=\infty$ | 0.9990859389 | |
| | 2 | $k_0=7$ | 0.9949740293 | 0.9949763183 |
| | | $k_0=\infty$ | 0.9949764222 | |

Having calculated the initial B-spline coefficients, the next step is to establish the algorithm for calculating the others. It has to perform the interpolation with those new coefficients and compare the results with the existing ones.

The algorithm use known techniques combined in new manner [2.4.10]. The main advantage of this one is that the input signal does not have to be extended to establish the initial conditions. The coefficients are calculated using the input samples and the values for the first derivative of the input function in the sampling points. The presented method offers good results for the interpolation.

The algorithm offers simplicity of implementation. It was applied on input signals for different sampling frequencies. The presented methods will be tested on other types of signals to see if the results are as good as the presented ones. We analyze the possibility to modify the algorithm to be used also for unequally sampled signals.

The main disadvantage of this method is that every coefficient is determined using also the value of a previous coefficient. Any errors of calculating a coefficient can influence the others value.

2.5. Speed Control for a Permanent Magnet Synchronous Motor based on Fuzzy Logic with Reduced Perturbations on the Supply Network

Fuzzy logic controllers, FLCs, are elements of the artificial intelligence, and, today, they are widely use in command and control of many industrial processes. It involves the acquisition of better signal wave forms at the output and the reduction of all oscillations (in

case of electric drives, we consider speed variation, torque variation, current variation for all the three phases ore more) in comparison with the classic control procedures [2.5.1].

This research presents two case studies of two FLCs applied for some exterior permanent magnet synchronous machines, PMSM. One fuzzy logic algorithm has 25 rules and the other has 49 rules.

These FLCs are developed for less computational issues, which make them suitable for real time implementation. The permanent magnet synchronous machines are used today in state of the art drives due to their dynamic performances. It is known that PMSM has a high torque density, with reduced losses/torque rates, a high power factor and a quick torque and speed time response. All the references concerning the real time implementation are made on the digital signal processor controller board type DS1104.

The electric machine prepared for our fuzzy control is a brushless DC motor, which is a PMSM with an inverter and a position sensor attached. All characteristics are similar with those of the DC motors.

Permanent magnet synchronous machines do not need electric drives on variable speed in a wide range. PMSM are controlled by using one of these methods [2.5.2]:

- open loop control with no feedback reaction, mostly used for simple applications (pumps, fans);
- closed loop control with feedback reaction, used for complex drives, with encoders or transducers.

The control of PMSM by using a fuzzy regulator is considered to be a closed loop control method, based on the elements of the fuzzy logic (FL).

FL is a type of artificial intelligence with a very recent history and application. Lotfy Zadeh invented the theory of fuzzy logic, and, from the beginning, in 1965, he argued that human thinking is more like fuzzy, vague, or imprecise by its own nature, and, therefore, it cannot be represented by using only yes (1) or no (0). The fuzzy control is also nonlinear and versatile by nature, having an excellent response under parameter variations. In our days modern control techniques based on uncertainty and vagueness have an important position, supporting all non-linear design techniques.

A standard fuzzy logic-based controller adapt the system input in order to get a specific output by just looking at the output, without having any mathematical model for the controlled system That's why it could be used in motor control drive applications. Each fuzzy set of instructions is defined by a so-called linguistic variable (low, large) which is practically defined by a multi valued membership function (MF) [2.5.3].

An MF has values between 0 and 1 and could take a range of shapes. The simple and logical operations on fuzzy sets and crisp sets are the classic ones, like *and* (intersection), *or* (reunion), *not*, *sum*, *prod*.

The fuzzy inference systems (FIS), in case of our electric drive presented in figure 2.5.1, are:

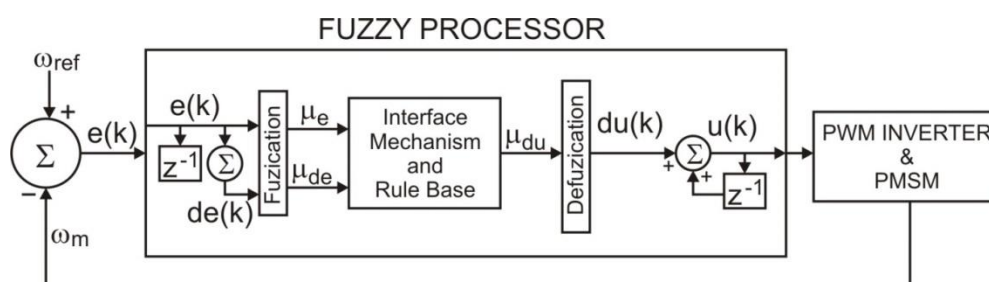


Fig.2.5.1. Fuzzy Inference System for a PMSM drive

- the so called fuzzification of all input variables;
- the application of the fuzzy operators in the IF area of the rules;
- the implication, starting from the antecedent to the consequent which are part of the rule;
- the aggregation of the consequents across all the rule;
- the defuzzification.

The fuzzy systems we used in this control drive of our PMSM motor have a set of 49 rules, two inputs and one single output. The linguistic variables we used for the inputs and outputs are: 1. Negative Very Big (NVB), 2. Negative Big (NB), 3. Negative Medium (NM), 4. Negative Small (NS), 5. ZERO (in center), 6. Positive Small (PS), 7. Positive Medium (PM), 8. Positive Big (PB), 9. Positive Very Big (PVB).

The fuzzification defines a clear correlation between a crisp real value and one or more linguistic values [2.5.4].

The conversion of fuzzy outputs in a fuzzy system into a crisp and real output is defined in literature as defuzzification. The fuzzy output is built by superimposing the outputs of each individual rule. The most usual method applied for defuzzification is the centroid method, which involves some integrations covering the outer envelope [2.5.5].

2.5.1. The Fuzzy Logic Controller applied for tests

All the inference rules are composed with linguistic variables in order to better describe the behavior of the process.

In the situation of a more complex description of that process, it is necessarily to start with a brief and summary description which could be completed during the implementation of the control sequence.

Mainly, we have to determine the variation domain for all the parameters involved, during the transient process, taking into account the reach of all the real functional points.

In order to clearly describe the dynamic response of the whole process, we need as many indices as we can find on the considered process, like the number of the time values and their approximately limits. All these specifications are mandatory for the evaluation of the sampling time and for the establishment of all membership functions.

By starting with the description of the controlled process, we will chose the type structure of the regulator. It involves to establish the number and the nature of the considered input values. In our case, of the electric drive, one of the most visible input value is the adjustment error, which is the difference between the preset value and the adjusted value. In many cases, we have two input values. For a larger number of input values, the inference rules are bigger and harder to define. We could use a control structure with many regulators placed in cascade or a more complex control structure if requested by the process. In some cases, when reaching this level it is mandatory to go at the initial level in order to finish the description of the process.

Another important step is the selection of the fuzzification method, in fact the definition of the membership functions, both for the input and the output parameters. Now, we will chose the number of the fuzzy terms involved for every value, their type/shape and the distribution of the considered membership functions.

In practice, 3 or 4 fuzzy terms are fair enough. A larger number of fuzzy terms could be used only if it is necessarily to obtain specific or accentuated nonlinear effects. Also, a large number of fuzzy terms will increase the number of inference rules used and the run time.

In order to have a linear characteristic of the considered fuzzy regulator (RF), we use a triangular membership function with an uniform distribution. An issue could appear when we select the scale factors (C1 and C2 in Fig.2.5.2.), somewhere between the normalized domain $-1 \leq x \leq 1$ and the corresponding real/physical value. We notice, in figure 2.5.2., that these scale factors are corresponding to some reaction coefficients which are determined by taking in consideration the dynamic behavior of the control system.

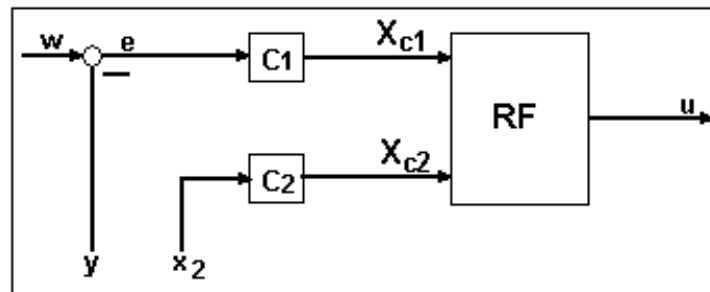


Fig. 2.5.2. A Fuzzy Regulator having 2 Scale Factors

It is obvious that, this two scale factors aren't determined before, but it is recommended that the implementation has to be made by using the structure in figure 2.5.2. When testing the equipment, we can modify this scale factors until they reach correct values for the transitory process. The modification of the dimensions and the distribution of the membership functions aren't mandatory in this case.

In case of the output values, there are no issues concerning the definition of the scale factors. The considered normalized field corresponds in fact with the maximum admitted variation of the command signal u .

Going from the definition of the controlled process, and using linguistic variables and membership functions, we can establish all the inference rules. These rules are, in the most of cases, incomplete. The rules applied can't be in contradiction. A graphic representation of the inference matrix makes the verification easier.

When performing certain tests on the equipment, maybe there is necessary to modify the inference rules. In many cases, it has to reduce their number or to add some complementary rules.

The selection of the inference rules could be made by taking into consideration the implementation model of the regulator involved, with the help of a dedicated program or a dedicated piece of equipment, when the running time is specified.

When the control system is briefly (or not) described with a model of the process, the tests on the installation are carried out by making simulations on a PC. All the adjustments could be performed on the simulation. Only minor adjustments have to be made on the equipment at implementation.

2.5.2. A fuzzy logic control having 25 rules

One fuzzy logic algorithm performed for the PMSM is specified by having as two input variables: the error (E/er) and the coefficient error (CE/der), as described in figure 2.5.3. The standard inference method used is Mamdani and the defuzzification method involved is the centroid method.

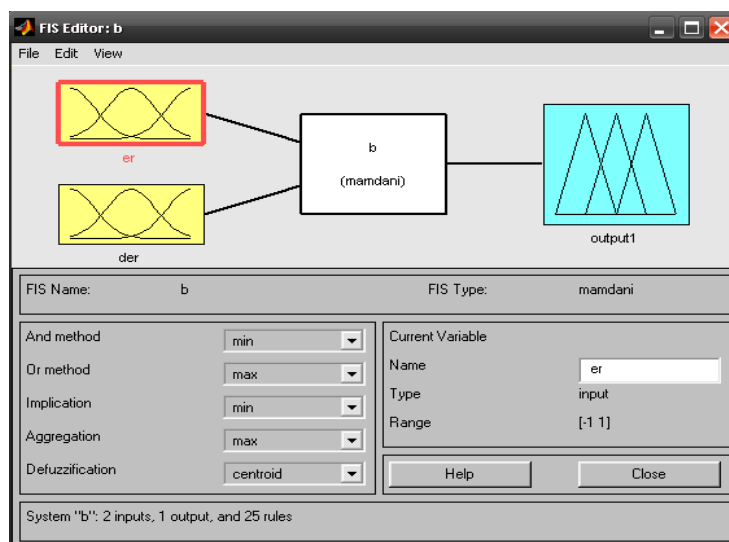


Fig. 2.5.3. Editing the Fuzzy Inference System

When all the input variables are clearly defined, the next step is the conception of the rule base in order to obtain the specific results. Table 2.5.1. shows us the rule base for the implementation of the first FLC with 25 rules. Inside the rule base, there are different groups of rules which are different as validation. The first group of rules is centered. It could cause only small deviations around zero value which gives, in fact, a stationary regime. By doing this, the adjustment error is almost zero [2.5.14].

TABLE 2.5.1.
THE RULE BASE ALGORITHM WITH 25 RULES

| Error/ Δ Error | PB | PS | ZERO | NS | NB |
|--------------------------|----|----|------|----|----|
| PB | NB | NB | NS | NS | ZE |
| PS | NB | NS | NS | ZE | PS |
| ZE | NS | NS | ZE | SP | PS |
| NS | NS | ZE | PS | PS | PB |
| NB | ZE | PS | PS | PB | PB |

Inside the other areas (with different colors) the error and the error coefficient are clearly different by zero, it means that the regulator command could be faster and efficient for error reduction.

A rule example is built like this: on the first line and in the first column, there are the linguistic terms for that error and the error coefficient (from PP to NB). On the intersection between one specified line with one specified column, there is the linguistic term for the resulting output variable. By doing this, the representation of all the rules is more compact, effective, and easy to read, and to compute [2.5.15].

2.5.3. A fuzzy logic control having 49 rules

The other rule base, designed for the case of a 49 rules is built similar, on a table, like the one for the 25 rules, and is defined in table 2.5.2.

TABLE 2.5.2.
THE RULE BASE ALGORITHM WITH 49 RULES

| Error/ $\Delta Error$ | PB | PM | PS | ZE | NS | NM | NB |
|--------------------------|----|----|----|----|----|----|----|
| PB | PB | PB | PB | PB | PM | PS | ZE |
| PM | PB | PB | PB | PM | PS | ZE | NS |
| PS | PB | PB | PM | PS | ZE | NS | NM |
| ZE | PB | PM | PS | ZE | NS | NM | NB |
| NS | PM | PS | ZE | NS | NM | NB | NB |
| NM | PS | ZE | NS | NM | NB | NB | NB |
| NB | ZE | NS | NM | NB | NB | NB | NB |

In this situation, not like in the 25 rules one, the output variable has more linguistic terms (9 terms, from PB to NB instead of 7 terms, from PB to NB as above), having the values for the output command as described in figure 2.5.4.

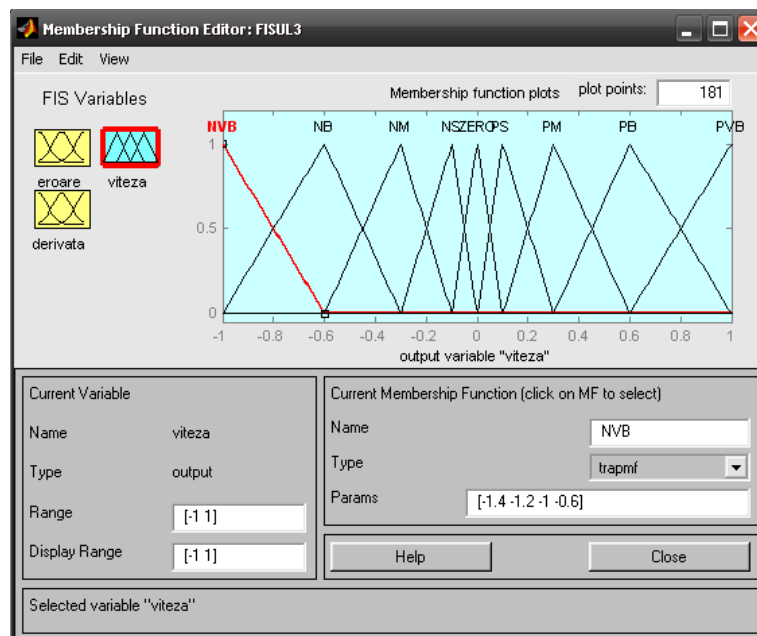


Fig. 2.5.4. Editing the fuzzy inference system with 9 terms for the output variable

2.5.4. Implementation of the fuzzy logic control using Matlab/ Simulink

The simulation model was performed under Matlab 6.1 with the help of the Matlab/Simulink specific blocks dedicated to motor drives [2.5.10]. This schema is presented in Figure 2.4.5.

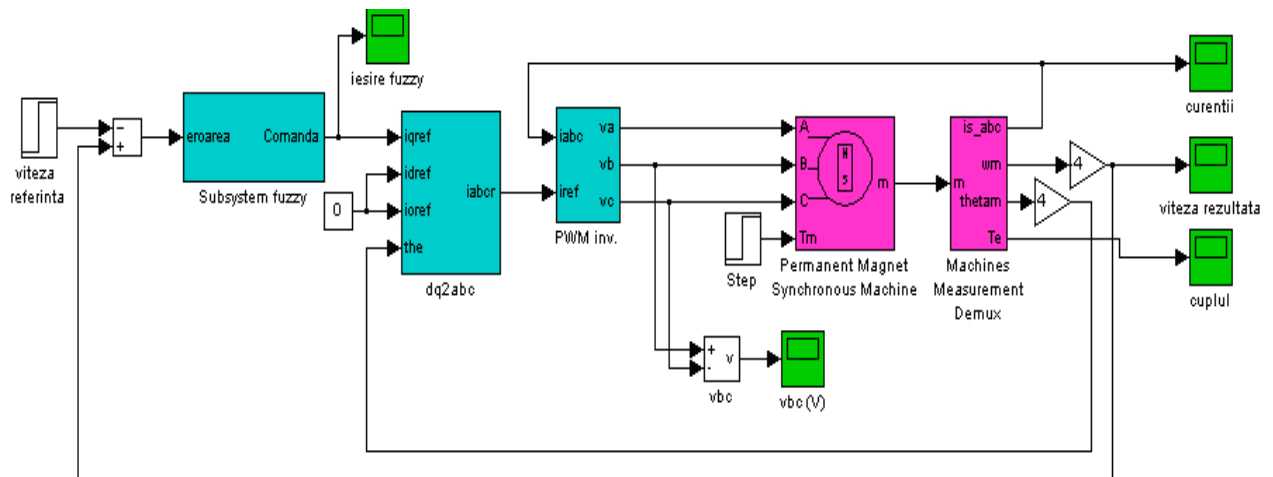


Fig. 2.4.5. The Simulink model.

Main input variable is the reference speed, compared with the output speed, in order to offer the input variable for the FLC subsystem. The fuzzy control is made both with 25 and 49 rules.

All the simulations parameters considered were set in the same way as in all cases.

Another important step is obtaining some experimental results comparative both for the fuzzy control with 25 and 49 rules. The measurements were carried out in 4 cases: constant speed and step type variation for the torque, step type variation for the speed and constant torque, both input variables of the system set constant and step type variation for both variables.

Next, we will be present only the situation where the speed and the torque are considered as step type.

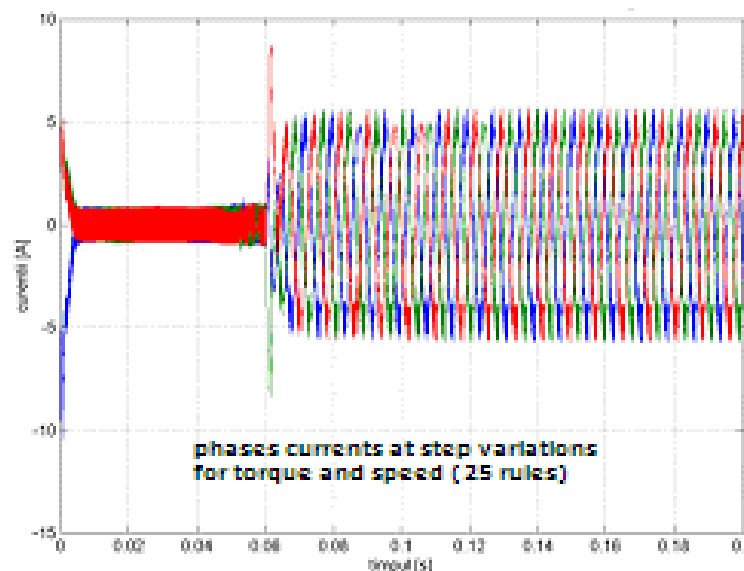


Fig .2.4.6a.. The time variation of the currents (25 rules)

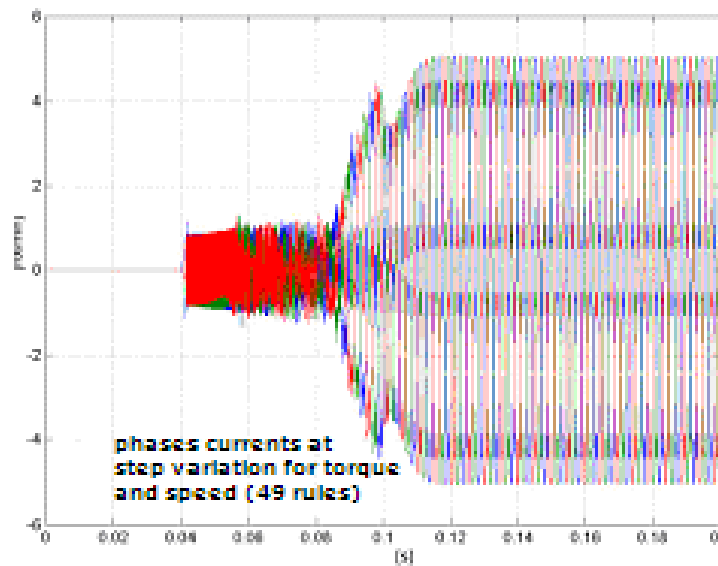


Fig .2.4.6b. The time variation of the currents (49 rules)

We considered that the reference speed is step type, and it could appear from 100 to 850 [rot/min] after a time of $t=0,04$ [s] as well as the reference torque which is also of step type taking a rate from 0 to 5 [Nm] after the same given time t . In figure, 2.4.6, we can notice a difference between the signals obtained at the output, for the two methods of fuzzy control involved.

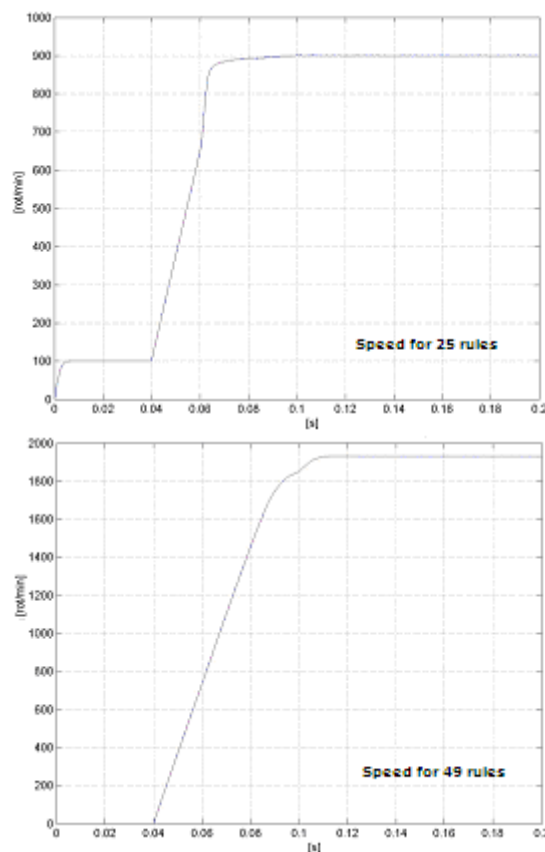


Fig.2.4.7. The time variation of speed (25 rules, 49 rules).

For the fuzzy control with 49 rules, the three currents have a 0 value until the moment ($t=0.04$ [s]) when the speed takes the value of 850 [rot/min]. After $t=0.04$ [s] we notice that the currents progressively oscillate around the 0 axis [2.5.8].

For the 25 rules controller, the currents always oscillate around the 0 axis, going to a value of 10 [A], as we can see in the figure 2.4.8.

The speed value, when the output speed, at the exit, is stabilized, is slightly bigger in the situation of the FLC with 49 rules comparative with the one with 25 rules. Reaching the maximum value of the output speed, 1900 [rot/min], is possible only after a longer time $t_1=0.12$ [s], in the situation of the one with 49 rules, comparative with $t_1=0.06$ [s] for the 25 rules one. The output speed, in case of the 25 rules controller, has a value of 100 [rot/min] for time $t=0.04$ [s] and it comes to a value of 900 [rot/min] for $t=0.06$ [s].

The output torque is stabilized for a value of 5 [Nm] in all two cases. In case of the 25 rules controller, we notice sudden oscillations of the torque for $t=0.001$ [s] and at $t=0.06$ [s], and in the situation of the 49 rules, the torque has a 0 value for $t=0.04$ [s]. When establishing the system at a value of 5 [Nm], the time output is different $t=0.06$ [s] for 25 rules and $t=0.11$ [s] for 49 rules (as in figure 2.4.8) [2.5.13].

This research presented a technical solution for a drive control with fuzzy logic, in case of a PMSM motor. The system was analyzed and studied exclusively through means of simulations with the purpose of validating the theoretical concepts. The simulation results show a clear superior performance of the fuzzy logic control, which is very versatile and adaptable to the specified model [2.15].

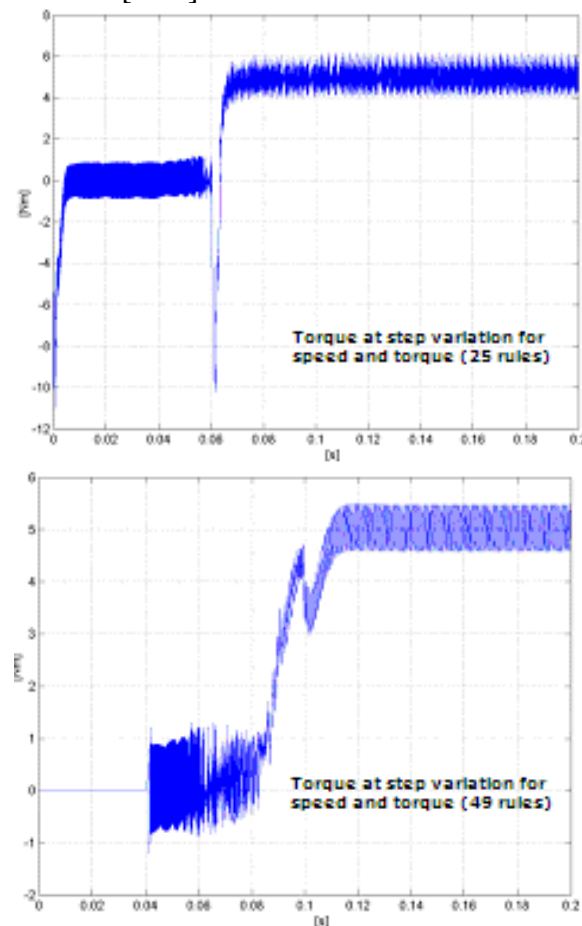


Fig. 2.4.8. The time variation of torque (25 rules, 49 rules).

This fuzzy logic based control method, using 25 rules for control, could be easily applied in the situation of selected rotations of hundreds of rpms. The rules set was assessed experimentally in both situations. This number of rules was adopted only after some position measurements available for this PMSM machine.

Further and maybe more accurate measurements could produce more fuzzy rules, which is a benefit for the whole drive. The 49 rules controller prove this idea, obtaining a more versatile response [2.5.12].

Another advantage of the fuzzy control is that it does not necessarily request a detailed knowledge of the PMSM model, and could be performed based on the experience and measurements carried out by the programmer [2.5.9].

Power quality for the supplying grid is not affected by the use of this model.

2.6.A Few Aspects about WLAN Security Tests for Data Transmission inside SCADA Networks

Wireless networks became very used in today communications. They offer internet access points in a simple and comfortable way, with a reasonable speed, for many users. This research will present a case study of how security mechanisms work on a standard IEEE 802.11g wireless network based on classic server-client architecture. The measurements will quantify how some additional security precautions will influence the whole network performance. It's a real proof of how much does security cost.

The introduction of the IEEE 802.11b norm made wireless LANs more accessible. Flexible connections for mobile users are today usual and even mandatory. Wireless LANs are everywhere installed in offices, conference centres, stations, hotels, airports, universities and even home.

The IEEE 802.11 – based wireless LANs are sometimes a nightmare for security and network administrators worldwide [2.6.1]. More security issues could easily decrease network performance. This performance is given by certain parameters such as a time delay, system throughput, packet loss, speed connection, etc.

All wireless networks are today vulnerable to many types of cyberattacks starting from a simple interception and data loss. Anyone could physically access the wireless network due to their inherent classic broadcast nature and shared air medium. In order to insure a minimal level of network performance it is crucial to assess the performance impact caused by security improvements on wireless networks. Of course, from the beginning, wireless security requires authentication and encryption of data. Today, all wireless networks use many security features for data protection.

For the first generation of 802.11 networks, the WLAN security was performed on two directions: the Service Set Identifier (SSID) and the Wireless Equivalent Privacy (WEP), as mentioned in standards. Some weaknesses of WEP were identified and IEEE proposed a new variant for the standard, IEEE 802.1X, which offers a possibility to improve traditional strong authentication mechanisms like RADIUS Server in a wireless network. The new IEEE 802.1x standard presents a new mechanism for port-based network access control, based upon an Extensible Authentication Protocol (EAP, as defined in standards) to insure compatible authentication and authorization mechanisms for all devices interconnected throughout an IEEE 802.11 protocol [2.6.2].

The IEEE 802.1x authentication system described above has many parts: supplicant, authenticator and authentication server. In a standard WLAN, *supplicant* usually, there is an AP (Access Point) that means an *authenticator*. Authentication, Authorization, and Accounting (known as AAA) server such as the RADIUS server are used as the *authentication server*. The *port* in 802.1x means an association between the supplicant and the authenticator. Both supplicant and authenticator have a *Port Access Entity (PAE)* that operates the algorithms and protocols associated with the authentication mechanisms. The authenticator's *controlled port* is in unauthorized state. Messages will be directed only to the *Authenticator PAE*, which will further direct 802.1x messages to the authentication server.

This authenticator PAE will have to close the controlled port after the supplicant was authenticated successfully. IEEE 802.1X tells us how to run the EAP directly over a link layer protocol. EAP is a transport protocol that can be used in a large variety of different authentication types known as EAP methods [2.6.3].

Figure 2.6.1. is presenting the 802.1X–EAP Message Protocol for an authentication process. Between the EAP principles applied specifically for wireless networks, there is a set of principles base on the public key certificates and the Transport Layer Security (TLS) protocols. They are EAP-TLS, EAP-TTLS and EAP-PEAP.

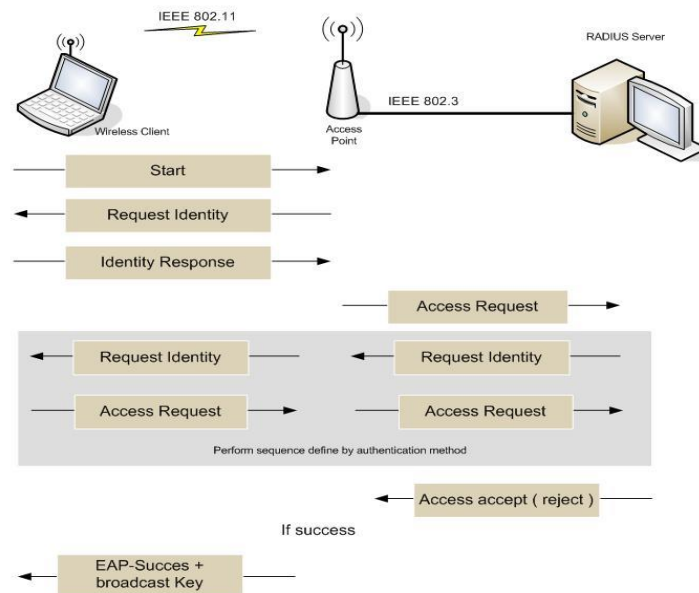


Fig.2.6.1. The 802.1X – EAP Protocol

Network physical configuration

All tests were carried out on a small WLAN made of an access point, an authentication RADIUS server, a local area network, a wireless laptop and a PC station. This topology is shown in Figure 2. It is the testbed architecture used for all tests [2.6.7].

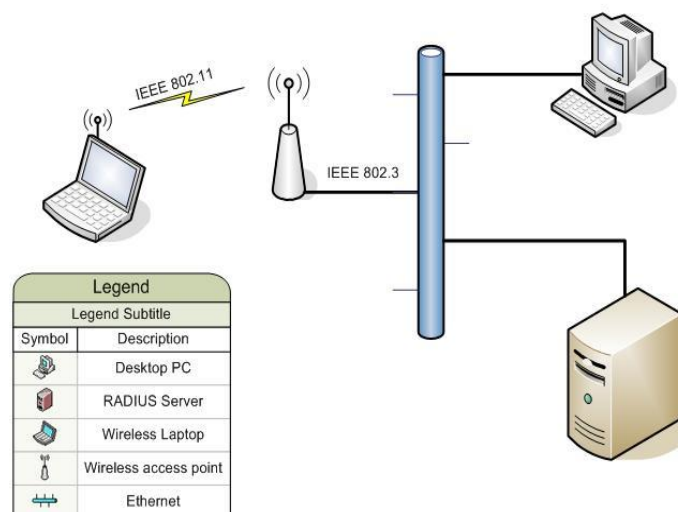


Fig.2.6.2. Topology and configuration

Hardware configuration

The access point (AP) configured in tests is a D-link DWL 2100AP [10]. To this access point, there are wireless connected a wireless client with a simple HP Laptop (basic configuration) and a D-link wireless adapter. For making the RADIUS Server we used a desktop PC (basic configuration) and for PC station another desktop PC (same configuration as the first one). All the Ethernet adapters are faster adapters [2.6.5].

Software configuration

For simplicity, all the systems have installed Windows XP Home Edition as an operating system. Some software components for various protocols involved have to be installed, too: RADIUS server is implemented with open-source software FreeRADIUS, X.509. Certificates (CA, Server, and Client) are issued with open-source software OpenSSL; Capturing packets are performed with Ethereal packet analyser, TCP / UDP tuning and throughput measurement are made with Iperf and Qcheck [2.6.6].

2.6.1. Experimental procedure

A lot of different factors are affecting network performance and some of them interact together in order to provide overall performance results. Performance indicators depend on the choice of hardware device, software application, security policy and network topology. On the same topology or conditions (hardware, software and network configuration) we have counted the authentication time, throughput and response time for all different types of security policy.

The authentication time is well defined, as the time involved in an authentication phase of the security protocol.

The throughput refers to the actual measured bandwidth, at a specific time of day, using specific routes, and while a specific set of data is already transmitted on the network. All these have to be clearly specified.

The response time (as shown here) is a measure of the simple delay in transmission of data between a sender and a receiver for a specific packet size.

For this experimental analyse we have used the “Iperf”, “Qcheck” and “Ethereal” software programs [2.6.4].

Security configuration

The IEEE 802.11 protocol provides two mechanism of security: authentication and encryption. Authentication may be made with Shared key authentication mechanism and with different type of authentication mechanism run over the EAP protocol.

In our research we used the EAP based on 802.1x family protocol for authentication (EAP – TLS, EAP – TTLS, EAP – PEAP).For data encryption we used WEP (40 and 128 bits), TKIP and AES encryption protocol.

Measurement methods

For each security service configured, experimental data were collected in two phases, in a not congested network (normal situation). The first phase collects measurements from authentication protocols. The second phase focuses on generating different traffic and measurement the throughput and response time.

In the first phase of the experiments, we used “Ethereal” packet analyser to capture all the packets exchanged during authentication process. Data obtained here were used to compare the measured authentication time for different authentication protocols,.

On the second phase of our tests, we used “Iperf” and “Qcheck “ for generate the whole TCP and UDP traffic between Wireless Laptop and PC station for measuring the throughput and the response time [2.6.16].

For all performed tests, the wireless link rate was at a constant level of 54 Mbps with a level for the radio signal higher than 95% [2.6.8].

2.6.2. Main Results

Authentication Time

Figure 2.6.3 show the measured authentication time (in sec) for EAP – TLS, EAP–TTLS, EAP–PEAP authentication protocols.

As we specified in our research, before, this research was based only on the 802.1x protocol authentication principles. The shared key authentication taken in consideration does not achieve the mutual authentication and, when the authentication is considered to be completed, it does not result a in simple session key.

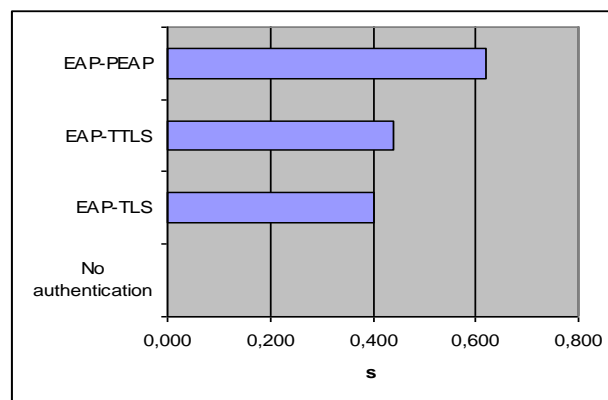


Fig.2.6.3. Comparison for the authentication time

Authentication time for all the Certificates based protocol mention above is, mostly, about the same. We can see that the authentication process is performed in less than 1 sec and appears after association phase [2.6.22].

Throughput

Figure 2.6.4. presents the throughput of TCP traffic for different types of encryption protocols applied. Performance measures were obtained by running a total of seven repetitive tests on each encryption protocol involved. The resulted throughput is smaller than one produced if we use the AES instead of TKIP (RC4) which is cipher. If we apply the same protocol, the throughputs decrease when increasing the secret key length [2.6.17].

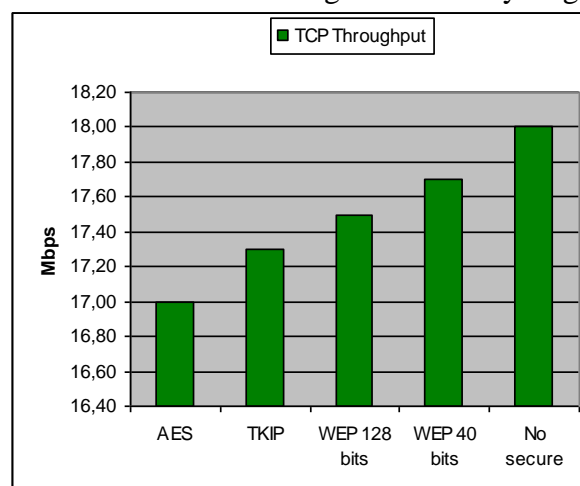


Fig.2.6.4. The throughput rate for TCP

Figure 2.6.5. illustrates the throughput rates of UDP traffic for different encryption protocols involved. In this situation, the “trend” is the same as the one noticed in TCP traffic, but the corresponding throughput rate is around. 20% lower [2.6.18].

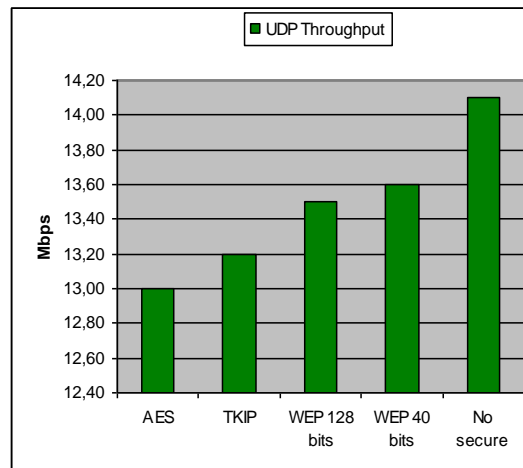


Fig.2.6.5. The throughput rate for UDP

Response time

Figure 2.6.6. illustrates the response time measured for the TCP and the UDP traffic. In this case, we count the response time for 1K byte packet size (in a not congested network) [2.6.19].

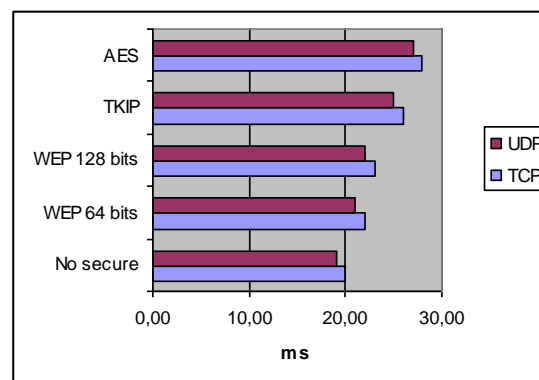


Fig.2.6.6. Comparison for the per packet response time

In this part of research, we presented some experimental results concerning the impact of security policies on system performance in a normal and not congested network [2.6.21].

The obtained (and shown) results demonstrate clearly that the WEP policies cause least overhead, while AES and TKIP cause significantly more overhead, but, of course, they provide a stronger security for the network. The authentication process on 802.1x protocol, with EAP-TLS, causes lesser overhead than 802.1x with EAP-PEAP. The delay produce by the authentication process is smaller than 1 sec. Because the WLAN isn't very mobile (WLAN is implemented in relative limited area – college campuses, airports, shops) the need for authentication is not very frequent and the benefits of that is evident. The requested authentication delay time is bigger for EAP-PEAP towards other authentication Certificate based protocols [2.6.20].

Using AES as encryption protocol as described, we have obtained a smaller throughput and, by consequent, the possibility of delivery less amount of data in a certain time than in case of using classic TKIP or WEP, but this is the ‘price’ we have to pay for having a higher security.

2.7. Some Contributions concerning the Semiconductor Materials used to Varistors for Overvoltage Protection Equipment

Metal Oxide based varistors are basically ceramic n – semiconductors, having a polycrystalline and complicated structure. The main application of them is in for construction of overvoltage protection equipment (for every voltage level), because of some advantages like: an increased level of non-linearity between the current and the voltage characteristic, a high energy adsorption capacity and an excellent good response time, which make them ideal for protecting other sensible electronic devices, as well as large segments of power lines. This research presents a new material and some manufacturing technology aspects for a Metal Oxide Varistor based on a new mixture of oxides used in order to obtain a new ceramic with higher non-linear electric properties. The two oxides involved are Cr_2O_3 and MnO_2 as dopants or additives. The new varistor material has a smaller electrical capacity, suitable even for IT and electronic applications. This new technology is easy to apply by any ceramic manufacturer. A new and simple method for testing the electric capacity of a certain varistor is also presented, based on the oscilloscope measurements at various frequencies [2.7.1].

Metal Oxide Varistors (also named ZnO varistors, due to their most important component, more than 60%) are today used for making the most performant surge arresters for all voltage levels, from domestic low voltage to high voltage power lines. Their main purpose is to protect any piece of sensitive electronic equipment against all types of over voltage which occurs on the power supplying network (technical incident, induced overvoltages or lightning stroke). They are applied in many modern surge arresters technologies due to some important advantages like: a high level of non-linearity for the current-voltage characteristic, a high energy (heat) absorption capacity and an excellent nanosecond response time. They are ceramic materials having a poly-crystalline structure and acting as n – semiconductors. These ceramics are made from a mixture of many metal oxides such ZnO (more than 90 %), Sb_2O_3 , MnO_2 , Bi_2O_3 , Cr_2O_3 , Co_3O_4 and many others. Depending on their application, not all the ingredients presented below are necessary. This research wants to confirm this [2.7.3].

If we present ZnO only, in his natural form, it is an excellent native semiconductor. Generally, there are more Zn^{2+} ions inside his crystal structure. By introducing other metal oxides (doping), Zn^{2+} ions are substituted in some positions, inside the crystal structure only by the bivalent metal ones. The other ions will be placed between the remaining ZnO fragments and they will act like a supplementary potential barrier.

Fig. 2.7.1. shows us the microstructure of a metal oxide varistor, as observed on the electronic microscope. We notice the large ZnO crystal grains and the inter-granular layer of other oxides, which, in fact, gives the varistance effect by introducing a supplementary potential barrier. This micro-structure looks like a stone-wall having ZnO grains as stones and other oxides acting as cement [2.7.4].

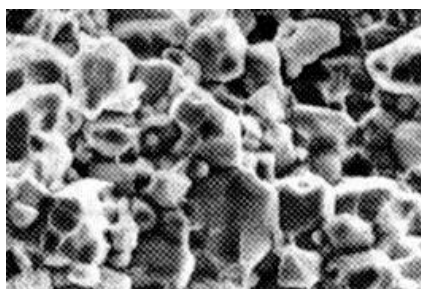


Fig. 2.7.1. Micro-structure of a ZnO varistor

The varistance principle (or effect) consists in a highly non-linear (non-ohmic) relation between the crossing current (the crossing current density) and the voltage applied (the electric field intensity, when speaking about the material). In practice, for low voltages, the varistor acts as an insulator and when exposed at higher voltages, it acts like a normal conductor material. So, it makes him ideal for any protective device made for voltage suppression (surge arresters) [2.7.2].

The most important additives, Cr_2O_3 and MnO_2 , are used in order to obtain different crystal structural phases during the whole elaboration process. It's obvious that the amount of Cr_2O_3 and MnO_2 used during the manufacturing stage has a high influence over all electrical and thermal proprieties of that varistor. The main objective of this research is to determine the influence of the concentration of Cr_2O_3 and MnO_2 (and of other dopants, too), over the electrical capacity of that varistor, as well as to find a new and easy to made material, excellent for low voltage lines.

All phases of the manufacturing process for a certain varistor type will be described bellow:

At the beginning, all metal oxide powders are carefully weighed using an electronic device. After weighing, all components are mixed together and also grinded by using pure water and some organic solvents, for at least a few hours. Water and organic solvents are totally removed by slowly heating that mixture. Another grinding operation is absolutely necessary after removing those solvents. The resulting powder mixture is sifted in order to avoid the formation of other large pieces. The resulting powder is putted into dedicated moulds and carefully exposed to higher pressure (on the order of hundreds of barrs). After this pressing operation, the resulting piece of varistor is gradually submitted to an extreme heating (at different temperatures higher than $1000\text{ }^\circ\text{C}$) for a few hours (depending on several thermal procedures). Next, the varistor will be naturally cooled down. When the varistor reached at the environmental temperature, a small layer of Ag, in an organic compound, is applied to both ends, as electrodes. The Ag based mixed compound is a semi liquid paste which has to be completely dried before any other action could be performed (by slowly heating again at around 100 degrees). Then, the final phase belonging to the technological procedure consists in submerging the heated piece into an epoxy resin powder in order to obtain the uniform and rapid polymerization of that organic insulator [2.7.10].

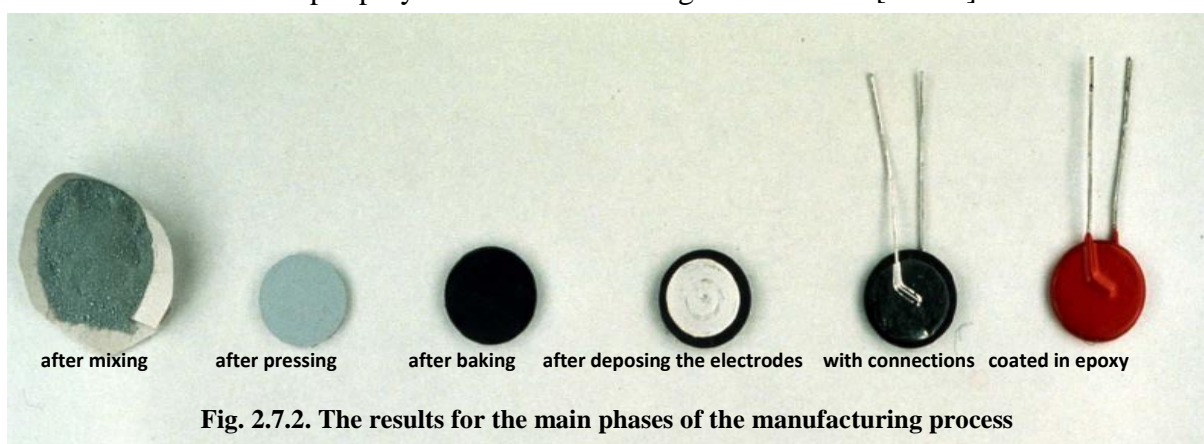


Fig. 2.7.2. The results for the main phases of the manufacturing process

2.7.1. Main Chemical Compositions of the Varistor Materials

It is well specified that all physical and electrical proprieties of the varistor material are depending of the chemical composition.

First of all, weighing all ingredients (after establishing a certain composition) is an important manufacturing operation. This operation is performed by using a standard METTLER electronic sensitive balance, for weights having more than 0.1 mg in precision. This manufacturing operation is relatively simple, because, for this first step, all the ingredients required are delivered as powders, having, by factory specifications, a very uniform and well determined granulation [2.7.8].

The initial chemical composition of a standard varistor having 5 additional oxides (highlighted in yellow shade rows) is shown in table 1, according to a standard technology developed, a few years ago, by the Génie Electrique Laboratory in Toulouse, France. All computed masses are reported to a total of 500 g mixture. The role played by each component is totally different. There are many oxides introduced inside this material during processing, but the roles of the last 4 oxides (blue rows) are not very important, from the electrical point of view, because they are used only for grain growth [2.7.9].

| Substance | Percentage [%] | Mass [g] for 500 g mixture |
|-----------------------------------|----------------|----------------------------|
| ZnO | 82.25 | 411.28 |
| MnO ₂ | 0.75 | 3.75 |
| Cr ₂ O ₃ | 1.32 | 6.601 |
| Co ₃ O ₄ | 2.09 | 10.457 |
| NiO | 0.648 | 3.244 |
| Bi ₂ O ₃ | 4.047 | 20.235 |
| Sb ₂ O ₃ | 8.862 | 44.345 |
| B ₂ O ₃ | 0.0756 | 0.378 |
| MgO | 0.0438 | 0.219 |
| Al(NO ₃) ₉ | 0.0260 | 0.130 |

Table 2.7.1. The initial composition of a standard varistor (having 5 additive oxides)

The author has developed, during his research stages at the Génie Electrique Laboratory from the PAUL SABATIER University of Toulouse, in France, another totally new varistor material which could be successfully used for telecommunication applications, due to its reduced electrical capacity. It is based only on 2 additive oxides (having a reduced electrical capacity) MnO₂ and Cr₂O₃. This initial chemical composition is presented in Table 2.7.2. (all masses are reported to 500 g of mixture, as before). By comparing this with the initial composition, we notice that only the Sb₂O₃ amount has been slightly modified.

| Substance | Percentage [%] | Mass [g] for 500 g mixture |
|-----------------------------------|----------------|----------------------------|
| ZnO | 87.45 | 437.25 |
| MnO ₂ | 1.843 | 9.215 |
| Cr ₂ O ₃ | 1.515 | 7.575 |
| Sb ₂ O ₃ | 9.0466 | 45.233 |
| B ₂ O ₃ | 0.0756 | 0.378 |
| MgO | 0.0438 | 0.219 |
| Al(NO ₃) ₉ | 0.0260 | 0.130 |

Table 2.7.2. The initial composition of a new varistor (having only 2 additive oxides)

It is important to notice that this is only the initial chemical composition of the varistor. It will be changed after passing throughout all the phases and operations of the manufacturing process, mostly because of the vaporization and chemical decomposition of many supplementary oxides.

Practically, only the first two useful oxides will remain non-degraded inside the electrical material, when finishing [2.7.5].

The roles of the two remaining oxides are:

- Cr_2O_3 is used mostly for grain growth limitation, as well as doping;
- MnO_2 is used only as a doping element.

After precision weighing, all ingredients have to be carefully mixed by using a standard mixing ball machine. The mixing operation can last for more than 36 hours, in order to obtain a very homogeneous powder, which could be pressed in molds after [2.7.7].

As we mentioned, the other four oxides will be slightly decomposed after passing through all the phases of the manufacturing process. Only traces of them could be found inside when finishing.

At the end, the resulting piece of semiconductor material will be carefully put to mechanical tests and electrical measurements in order to determine all its main parameters

2.7.2. Electrical Measurements

In case of telecommunication equipment (such as digital phone centers or switches), or other sensitive electronic consumers, supplied from the industrial low voltage power network, it is necessary to measure the electrical capacity of the varistor at 50 Hz, in order to avoid perturbations. We will present an original, simple and efficient method, described below, which could be applied by using a standard digital oscilloscope and other usual devices.

The testing method described below is based on the simple observation that the varistor is a non-linear electronic device, having, at this low (industrial) frequency, an important capacity. First of all, we must check the opening voltage of a certain varistor, V_N is the DC voltage measured between the ends of the varistor, when a 1 mA DC current is established through that varistor. It is one of the first measurements performed before, and it has to be compliant with the voltage level involved, but it doesn't make the object of this research.

The varistor is considered as equivalent to a parallel electrical schema having a capacity C_V and a resistance R_V (variable with the applied voltage, but constant for a certain voltage). This schema, together with the main schema used for carrying out measurements is presented in Figure 3. A simple SEFRAM 5064DC digital oscilloscope, with two channels was used for measurements. The PC/laptop is recommended, but not mandatory.

One of the channels is reserved only to the varistor voltage and the other is reserved for measuring, by using the R_d resistance, the current passing through the varistor. The varistor was connected to a 250 V AC source (U_{MCOV} , which is the maximum RMS voltage value applied in normal conditions). If the supplying voltage is higher, the varistor is a conductor and the resistive part of the current is higher. If the voltage is lower, that varistor acts normally like an insulator, and the capacitive component is higher than the resistive one. All measurements are made at 50 Hz AC and they were performed at the Faculty of Electrical Engineering in Timisoara.

Experimentally, we can separate easily these two current components, I_r , which is the resistive one, in phase with the main supply voltage, and I_c , which is the capacitive one, with a 90 degrees delay.

We have to measure only the maximum capacitive current $I_{c_{max}}$, obtained, obviously, for the maximum 90 degrees delay, when the main supply voltage reaches 0.

When determinate this value, we can easily use this relation necessary for the varistor capacity C_V :

$$C_V = I_{c_{max}} / (V_{max} \cdot \omega) \quad (2.7.1)$$

It is known that $V_{max} = 250 \cdot 1.41 = 352 \text{ V}$, $\omega = 314 \text{ rad/s}$

After computing the C_V capacity at 50 Hz, we can easily measure its relative permittivity, ϵ_r at this 250 Vef voltage and 50 Hz frequency. The necessary computing relation is given below:

$$\epsilon_r = (4 \cdot h \cdot C_V) / (\epsilon_0 \cdot \pi \cdot d^2) \quad (2.7.2)$$

where:

$h = 2.8 \text{ mm}$ is the height of the varistor (for the 230 Vef classic varistors);

d is the diameter;

$\epsilon_0 = 8.854 \cdot 10^{-12} \text{ F/m}$ is the absolute air permittivity.

All measured results are detailed in Table 2.7.3:

| Diameter of the classic 230Vef varistor | $I_{c_{max}}$ [A] | C_V [nF] | ϵ_r |
|---|----------------------|------------|--------------|
| 7 mm | $1.32 \cdot 10^{-5}$ | 0.12 | 1046 |
| 20 mm | $1.13 \cdot 10^{-4}$ | 1.03 | 1039 |
| 30 mm | $2.57 \cdot 10^{-4}$ | 2.33 | 1048 |

Table 2.7.3: AC performed measurements at 250 V, 50 Hz

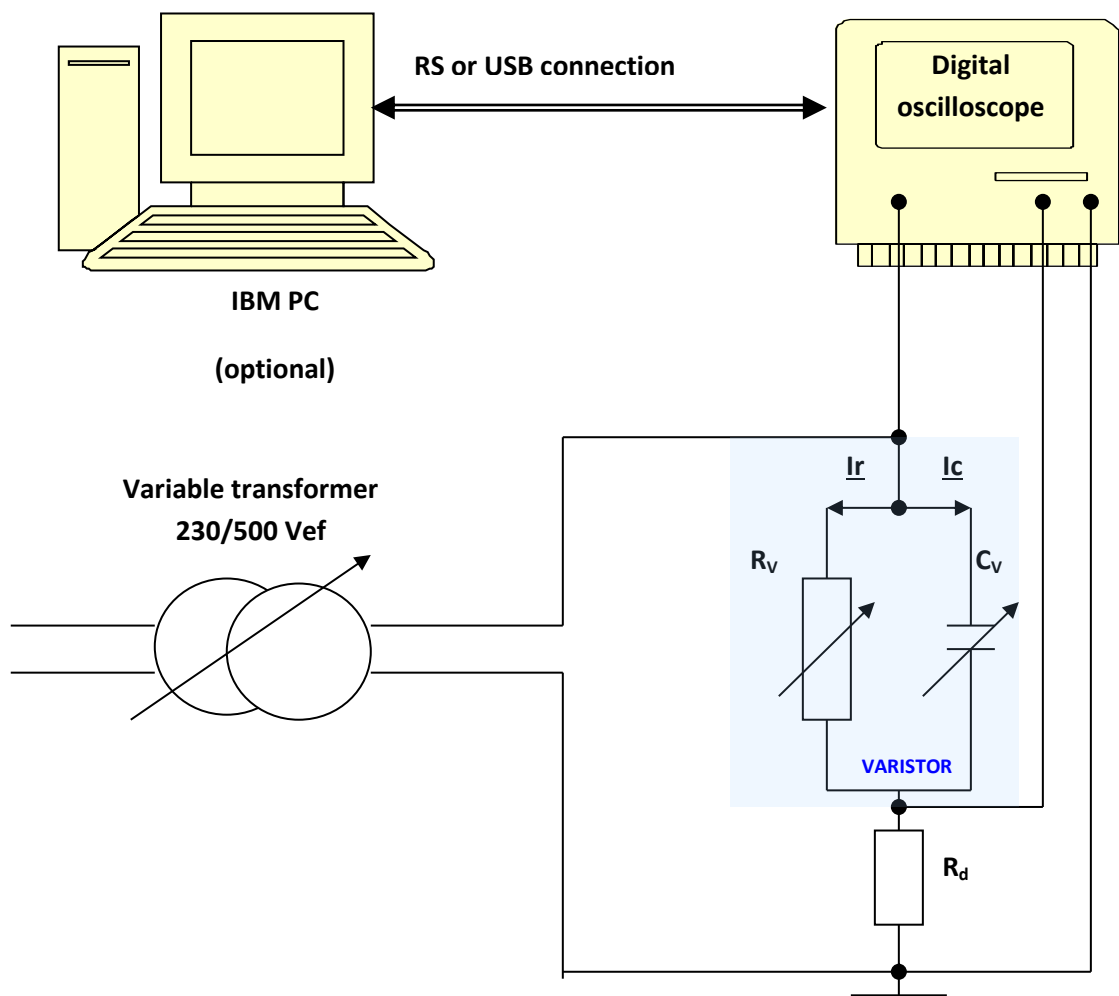


Fig. 2.7.3. The electrical schema for alternative measurements

All measurements were executed at an standard environmental temperature of 20-22 °C.

In Table 2.7.3., we notice that the average value for ϵ_r is higher, around 1040, for a classic material having 5 additive oxides, used in common AC applications.

Using the new proposed material, which could be easily applied to telecommunication lines, having only the two additional oxides, only varistors for 48 Vdc telecom lines were made. They have a significantly reduced ϵ_r . The maximum RMS value of the voltage (in AC regime) is about 65% from the opening voltage (aprox. 40 Vef, not 38.9).

In all computing, we considered $V_{max} = 0.65 \cdot 59 \cdot 1.41 = \text{aprox. } 56.4 \text{ V}$, $\omega = 314 \text{ rad/s}$

Relations (2.7.1) and (2.7.2) are applied in the same conditions as before, by knowing:

$h = 0.9 \text{ mm}$ (the height of the 48 Vcc varistor);

$d = 7 \text{ mm}$ (diameter);

All results are presented as Table 2.7.4.

| Type of the new 48 Vdc Varistor (d) | $I_{c_{max}}$ [A] | C_v [nF] | ϵ_r |
|-------------------------------------|----------------------|------------|--------------|
| 7 mm | $3.01 \cdot 10^{-6}$ | 0.17 | 468 |

Table 2.7.4: AC measurements for the new varistor, at 40 V, 50 Hz

As we can notice in Table 2.7.4, the average value for ϵ_r is around 470, for this new material having only two additive oxides, which could be easily made and used in common telecommunication applications. It offers a reduced electrical capacity and a higher capacitive reactance for the useful signals, so it can be used as a filter sometimes.

The two oxides material performs very well, having a reduced electric capacity at the industrial 50 Hz frequency and is easy to made. It could be used for analogic filters, too, depending on the frequencies required.

Another issue described in this research is a new method used in order to assess the parameters of the new material. This method is simple, clear, easy to use, with unexpensive equipment, available in almost any electrical engineering laboratory, and it could be performed by medium qualified persons. It gives information about the performances of all those materials involved and gives also some suggestions for their future applications.

All the results obtained by using this method are simple, clear, and they are confirmed by obtaining an ϵ_r which is 2.2 times lower than the one for the two oxides material by comparing with the classic five oxides one, which has a 2.11 higher granulation. They were also confirmed by the very close range of values obtained for 230 V AC varistors. Generally, on literature and on practice, for this classic material, only values of 1000-1500 are shown, confirmed this time.

2.8. Some Technical Consideration about Thermal Sytability of ZnO based Varsitors

As we mentioned in the last chapter, Metal Oxide Varistors are successfully used for overvoltage protection equipment at an industrial scale.

Metal Oxide Varistors are applied in overvoltage protection equipment, at any voltage, being one of the most common power electronic devices in use. They have a high non-linear dependence between voltage and current, and a relatively high heat adsorption capacity in case of normal overvoltage shocks. Their current is mostly activated by temperature, so overheating can cause a major damage. Researches could be carried out both for a new material as well as for technical solutions for a new design of this piece of equipment, by studying heat extraction and transfer inside a new varistor device.

This research propose a simple new device, used for low voltage applications, based on some supplementary brass masses added to the varistor, shaped as cylinders. They act like heat pumps at the beginning and as radiators at the end of the thermal process caused by a transitory overvoltage. A finite element model followed by some experimental measurements is also presented in order to confirm the new design, for permanent and transitory regimes. Including additional brass masses inside a new varistor structure could easily add heat pumping and dissipation in order to reduce temperature stress and aging effect [2.8.2].

Low voltage sensitive electronic devices are today exposed to a lot of overvoltage phenomena, caused mostly by lightning (a transitory overvoltage regime) or caused by internal power network faults (permanent overvoltage regime). Metal Oxide Varistors are made of a semiconductor ceramic material.

Their current versus voltage relation is highly non-linear and their response time is very accurate, faster than a dielectric breakdown caused by a lightning stroke. They have also a high level of energy adsorption capacity, limited by the risk of overheating. That's why the limitation of their temperature is crucial for keeping them in service.

The main electric current passing inside a varistor is highly depending on temperature, like for all known semiconductor materials. In case of a violent lightning stroke applied to the power grid, or a long time over voltage, there is an increased risk of overheating. When temperature increases (even from simple and natural/environmental causes), the current increases too, due to the reduction of the electrical resistance. A chain reaction occurs that time, with devastating and expensive consequences both for the protection and the protected equipment.

The heat quantity produced inside the varistor is important in any scenario. Designing an adequate topology/configuration, in order to control heat dissipation, is mandatory in case of any varistors involved.

The thermal adsorption/dissipation capability of a Metal Oxide Varistor has to be assessed in two situations [2.8.3]:

- In permanent regime, when the varistor is exposed to a long time accidentally overvoltage, moderated, but enough destructive for the sensitive protected equipment;
- In voltage impulse (shock) regime, when the varistor is exposed to an extremely quick overvoltage, but with a very high voltage value (like a lightning stroke), destructive for any sensitive protected equipment.

In practice, there are many simple technical solutions applied to increase the energy absorption capacity in case of a lightning temporary pulse (radiators, epoxy coating, etc.). Metal Oxide Varistors acts mostly in conformity to manufactures' specifications, but the real lightning caused overvoltages are not like standard ones. No analytical model known today could describe such an incident; the experimental procedure is the only one able to characterize this type of electric incidents. This research will present only models and measurements performed for the permanent over voltage regime [2.8.4].

Permanent (long term) over voltage regime is not very well described in today's literature.

The heat (power, per time unit) produced inside the varistor (by Joule effect) is given by:

$$P_{dez} = U \cdot I = U \cdot A(U) \cdot T^2 \cdot e^{-\frac{q_e \cdot \Phi(U)}{k \cdot T}} \quad (2.8.1)$$

The heat dissipated by convection and radiation to the environment is given by :

$$P_{dis} = \alpha \cdot S_l \cdot (\theta - \theta_a) \quad (2.8.2)$$

where:

- S_l – is the whole external heat exchange surface;
- $\Phi(U)$ – is the voltage height of the semiconductor's junction potential barrier;
- q_e – is the nominal charge of an electron;
- T_e – is the absolute temperature, on Kelvin scale;
- k – is Boltzmann's constant;
- α – is the convective+radiative heat exchange coefficient;

The typical intersection of the two graphs (P_{dis} and P_{dez}) given by (2.8.1) and (2.8.2), could be done by one or two equilibrium points. The situation in which they do not intersect at all is the situation of a permanent catastrophic overheating regime (when the heat produced inside the varistor is too great to be dissipated in the environment).

Thermal stability (and energy adsorption), for a specified varistor, was analyzed only by taking in consideration the temperature of that varistor as the main perturbation, as a direct consequence of the overvoltage exposure.

2.8.1. The principle of additional masses on varistors

As we noticed before, the most important aspect of heat adsorption capacity is keeping the varistor inside the thermal stability area, by limiting its temperature.

The exposure of a certain varistor to a W-energy shock wave, caused by a short-time overvoltage, (process considered as adiabatic, due to its extremely short time), means that the whole energy $Q=W$, produced by heat generation effect remains stored inside its own mass, causing an important increase of its natural temperature $\Delta\theta_1$. It's necessary that this temperature increase does not over-pass the temperature stable equilibrium limit, so all heat existing inside the varistor could be dissipated in the environment [2.8.5].

The relation for the varistor temperature difference $\Delta\theta_1$ after having that extra Q heat stored inside, is:

$$W = Q = m_v \cdot c_v \cdot \Delta\theta_1 \quad (2.8.3)$$

It means that, after that short adiabatic process, the whole heat Q is stored and kept inside the varistor mass m_v , having the c_v specific mass heat. Q is given by the overvoltage specificity, so it could not be changed, and c_v is a specific material parameter, which could be slightly increased, but with bad consequences on the material, especially in the area of the electrical properties of that material. It is considered as a constant for a certain varistor type/ material.

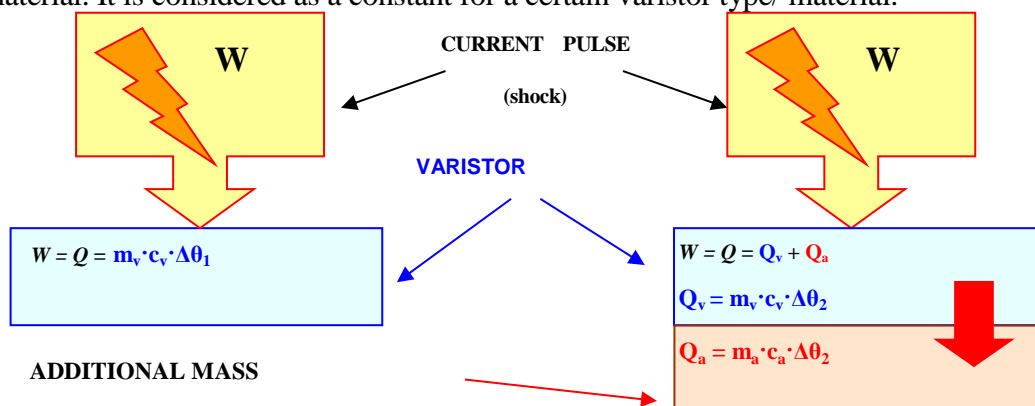


Fig. 2.8.1. The Additional Masses Principle

A simple and original technical solution (patented in Romania, by the author), recommended for thermal stability control of a certain varistor consists in attaching some additional masses (made of a conductor material) on the varistor. These additional masses must have an excellent thermal and electrical contact with the varistor. The main principle of this technical solution is described in Fig. 2.8.1.

The additional masses principle consists in dividing the heat quantity produced inside the active part of the varistor, $Q=W$, in two fractions. One fraction, called Q_v ($Q_v = m_v \cdot c_v \cdot \Delta\theta_2$) remains stored inside the varistor, and the other fraction, called Q_a ($Q_a = m_a \cdot c_a \cdot \Delta\theta_2$) is naturally sent inside the additional mass which is well thermo-coupled with the varistor. Of course, m_a is the additional mass and c_a is its own specific mass heat.

In this situation, the corresponding relation is:

$$W = Q = Q_v + Q_a = (m_v \cdot c_v + m_a \cdot c_a) \cdot \Delta\theta_2 \quad (2.8.4)$$

Relation (2.8.4) is validated because:

- The electric resistance of the mounted additional mass is nine times smaller than the smallest varistor resistance, when in conduction mode, and, as consequent, the additional mass is electrically passive, and does not modify any electric behavior, the heat produced by electric conversion (Joule effect) inside this mass is totally negligible, by consequent the varistor is considered the only heat source.
- The thermal contact between the varistor and the brass additional mass is very well made, so heat is changed very fast and uniform between those two pieces. By consequent, both pieces involved will have the same increment of temperature, $\Delta\theta_2$.
- The process is considered as fully adiabatic and we can easily apply the energy conservation principle.
- We can notice that $\Delta\theta_2$ is smaller than $\Delta\theta_1$, as given by (2.8.4). The additional mass is, in fact, acting like a “heat pump”, taking instantaneously a part of the heat stocked inside the varistor and, by this way, decreasing its temperature and placing the whole assembly inside a possible thermal stability area.

It is necessary to explain that, because of the supplementary masses geometry, the heat dissipation surface is increasing (not as much as in the case of large dedicated radiators). During the permanent regime, these additional masses could be assimilated to radiators (not their main role), but with a reduced effect on the heat dissipation balance. Considering this, we can reduce, with a few degrees Celsius, the varistors' temperature. But, using a reduced additional heat dissipation surface, we cannot consider them as radiators [2.8.11].

2.8.2. Model Validation of Additional Masses Principle

The advantages of placing additional masses welded on the varistors could be proved only by using some numerical models, combined and veified with experimental results, in order to perform confirmation of the proposed modeling hypothesis [2.8.10].

All modeling procedures were performed done during the last year at the POLITEHNICA University of Timisoara, Romania.

The experiments were performed at the LAPLACE Laboratory, from the PAUL SABATIER University in Toulouse, France.

All simulations and measurements presented in this research were carried out by using regular 30 mm diameter commercial disk varistors. This devices have a small 3 mm height and they are used mainly for standard 230 V European low voltage (domestic or similar) power supply grids. The varistors considered are not fully covered in epoxy resin, having only the lateral edge coated with insulator, for 1 mm.

Metal Ag electrodes are deposited by a special technique on both sides. This configuration with a single varistor alone is called the “A” configuration.

The additional mass used was a small cylinder made of brass, with a 20 mm diameter and a height of 5 mm. The new configuration proposed in this research, with a varistor and an additional mass on one side, centered, is called the “B” configuration.

Finite elements software made analysis is, nowadays, is a powerful tool for modeling heat transfer, as well as electric/magnetic field problems. For complete modeling, we have used the FLUX 2D software, which offered excellent results for cylindrical symmetry pieces.

The finite elements mesh for each configuration is shown in Fig. 2.8.2 and Fig.2.8.3.

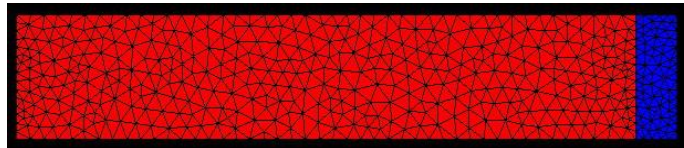


Fig. 2.8.2. Finite elements mesh for configuration A

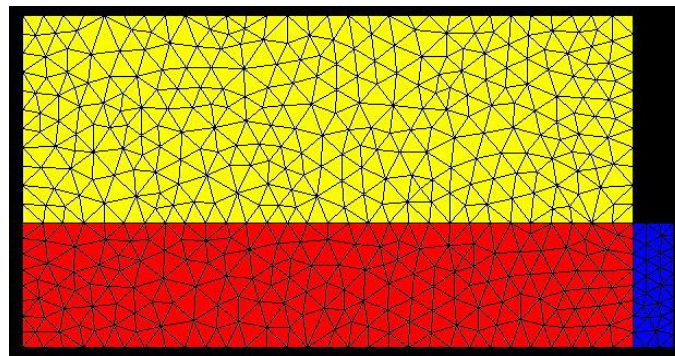


Fig. 2.8.3. Finite elements mesh for configuration B

The finite elements mesh was generated by the software. We can easily see the geometrical properties of each configuration.

In order to perform all computing procedures, some material parameters have to be specified, for all pieces involved. Those parameters are:

For the varistor itself:

- the thermal conductivity [$\text{cal}/(\text{cm} \cdot \text{s} \cdot ^\circ\text{C})$]: $\lambda = 0.0136$
- the radiation heat exchange coefficient: $\varepsilon_r = 0.85$
- the linear relation between the heat convection exchange coefficient and the temperature θ [$\text{W}/(\text{m}^2 \cdot ^\circ\text{C})$],: $\alpha_c = 9 \cdot (1 + 0.0166 \cdot \theta)$
- the linear relation between the volume specific heat and temperature θ , [$\text{J}/(\text{m}^3 \cdot ^\circ\text{C})$]: $c_v = 3.516 \cdot 10^6 \cdot (1 + 8.33 \cdot 10^{-3} \cdot \theta)$
- the mass density [kg/m^3]: $\rho = 5660$

For the epoxy resin:

- the thermal conductivity [$\text{cal}/(\text{cm} \cdot \text{s} \cdot ^\circ\text{C})$]: $\lambda = 0.15$
- the radiation heat exchange coefficient: $\varepsilon_r = 0.9$
- the linear relation between the heat convection exchange coefficient and the temperature θ [$\text{W}/(\text{m}^2 \cdot ^\circ\text{C})$], similar to the varistor: $\alpha_c = 9 \cdot (1 + 0.0166 \cdot \theta)$
- the volume specific heat (constant ,because the resin is not exposed to temperature variation), [$\text{J}/(\text{m}^3 \cdot ^\circ\text{C})$]: $c_v = 1.9 \cdot 10^6$
- the mass density [kg/m^3]: $\rho = 1300$

For the brass additional mass [2.8.4]:

- the thermal conductivity [cal/(cm · s · °C)]: $\lambda = 0.26$
- the radiation heat exchange coefficient: $\varepsilon_r = 0.2$
- the linear relation between the heat convection exchange coefficient and the temperature θ [W/(m² · °C)]: $\alpha_c = 5 \cdot (1 + 0.02 \cdot \theta)$
- the volume specific heat (constant ,because the additional mass is not exposed to temperature variation), [J/(m³ · °C)]: $c_v = 3.224 \cdot 10^6$
- the mass density [kg/m³]: $\rho = 8400$

Simulations for configuration A were made for an environmental temperature θ_a of 25 °C, and for configuration B, at 26 °C. The simulation were performed by considering that a certain impulse energy $Q = 90$ J (given, in fact, by a real shock generator) is transformed in heat, producing the rapid increase of temperature for each configuration (as we said before, this process is fully adiabatic) [2.8.6]. After absorbing that energy, each configuration is cooled down naturally, performing temperature estimation at any moment, in any point, until reaching the environmental temperature [2.8.5].

For configuration A, the overheating, τ_e , [°C], is:

$$\tau_e = \frac{Q}{m_v \cdot c_v} = \frac{90}{12 \cdot 0.7534} = 9.95$$

where: $m_v = 12$ g is the mass of the varistor; $c_v = 0.7534$ [J/(g · °C)], is the mass specific heat.

The maximum estimated temperature for configuration A is:

$$\theta_e = \theta_a + \tau_e = 25 + 9.95 = 34.95 \text{ °C} \quad (2.8.5)$$

For configuration B, the overheating, τ_e , [°C], is:

$$\tau_e = \frac{Q}{m_v \cdot c_v + m_{al} \cdot c_{al}} = \frac{90}{12 \cdot 0.7534 + 29.68 \cdot 0.383} = 4.40$$

where: $m_v = 12$ g is the mass of the varistor; $c_v = 0.7534$ [J/(g · °C)], is the mass specific heat; $m_{al} = 29.68$ g is the mass of the brass; $c_{al} = 0.383$ [J/(g · °C)], is the brass specific heat.

The maximum estimated temperature for configuration B is:

$$\theta_e = \theta_a + \tau_e = 25 + 4.4 = 29.40 \text{ °C} \quad (2.8.6)$$

The maximum estimated temperature on the model for configuration A was:

$$\theta_e = \theta_a + \tau_e = 25 + 9.95 = 34.95 \text{ °C} \quad (2.8.7)$$

The maximum estimated temperature on the model for configuration B is:

$$\theta_e = \theta_a + \tau_e = 26 + 6.38 = 32.38 \text{ °C} \quad (2.8.8)$$

In Fig.2.8.4. and Fig.2.8.5. we present the finite elements results, at 60 s after the overvoltage, for each configuration considered:

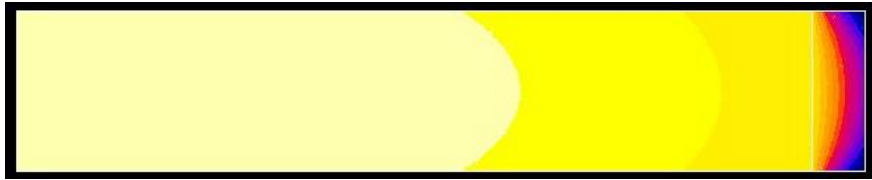


Fig.2.8.4. Temperature repartition for configuration A

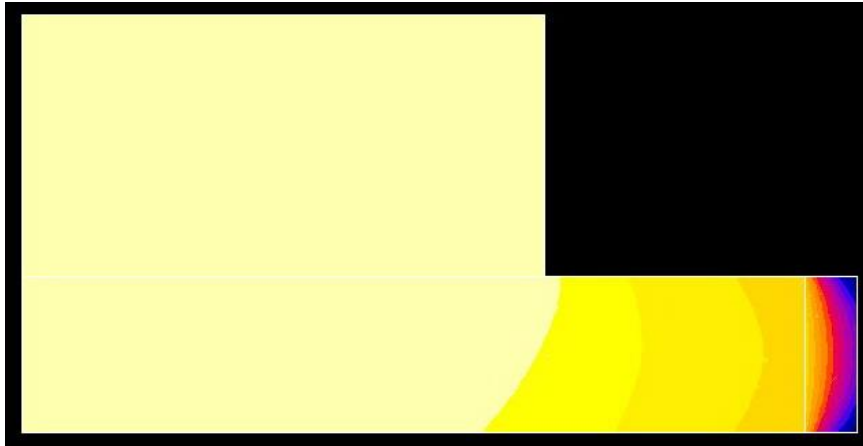


Fig. 2.8.5. Temperature repartition for configuration B

The maximum temperature obtained for configuration A was $32.84\text{ }^{\circ}\text{C}$ and the minimum one was $31.77\text{ }^{\circ}\text{C}$, with a step of $0,09$ degrees Celsius for each colour, from yellow to magenta. The time variation graph of the temperature, for a certain point located on the top side where $H = 3$ mm and having a $R = 12$ mm radius, on the configuration A, is shown in Fig.2.8.6.

The maximum temperature obtained for configuration B, in the same conditions, was around $31.41\text{ }^{\circ}\text{C}$ and the minimum was around $30.62\text{ }^{\circ}\text{C}$, with a step of $0,07$ degrees Celsius for each colour, as previous. The time variation of the temperature for a specified point located on the top side ($H = 3$ mm) having a $R = 12$ mm radius, on the configuration B, is shown in Fig.2.8.7.

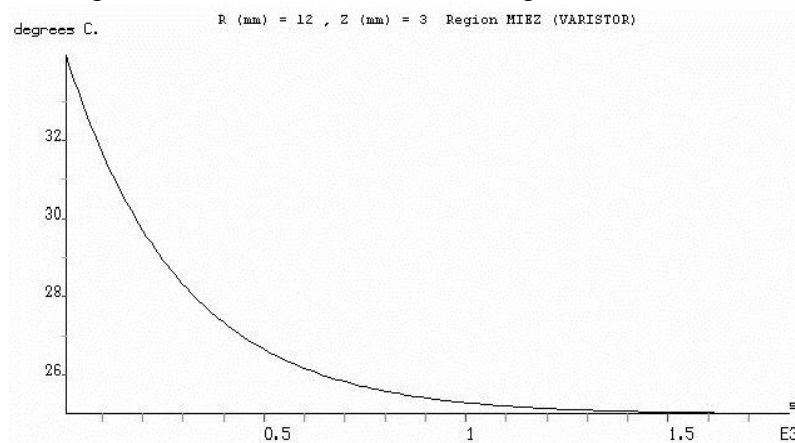


Fig. 2.8.6. Time variation graph of the temperature for a point located on configuration A

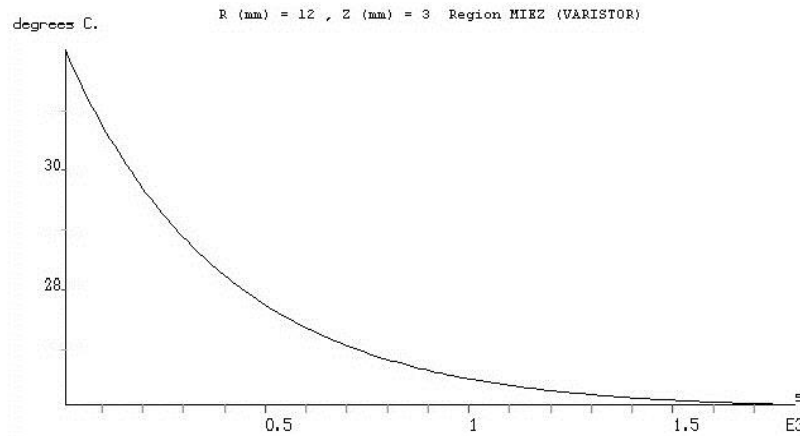


Fig.2.8.7. Time variation graph of the temperature for a point located on configuration B

These graphs are only software estimations for the temperature. They must be verified in practice.

2.8.3. Experimental Validation of the Additional Masses Principle

Each configuration considered was submitted to an overvoltage test shock, by using a standard 8/20 shock generator, located at the LAPLACE Laboratory, in Toulouse France.

The maximum real measured temperature θ for the same point considered before (3 mm, 12 mm), belonging to the first configuration A was:

$$\theta = 34,44 \text{ } ^\circ\text{C} \quad (2.8.9)$$

We notice that relation (2.8.5) offers a very good estimation compared to (2.8.7). The time evolution of the temperature, during the after shock cooling process, for the same point as before, is shown in Fig.2.8.8. The same point as before was considered for the new configuration B.

The maximum real and measured temperature θ for the same considered point (3 mm, 12 mm), belonging to configuration B was:

$$\theta = 32,13 \text{ } ^\circ\text{C} \quad (2.8.10)$$

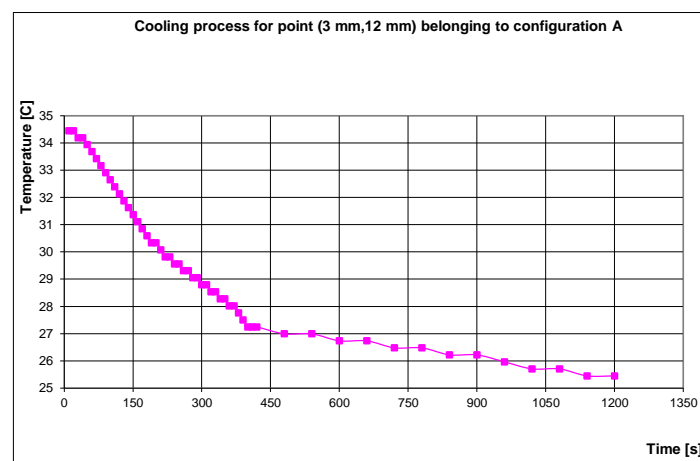


Fig.2.8.8. Cooling process time graph for a point located on configuration A

Relation (2.8.10) offers a very good estimation when compared to (2.8.8). The evolution of the temperature during the cooling process, considered for the same point is shown in Fig.2.8.7. There is an excellent correspondence between the estimated values and the measured results.

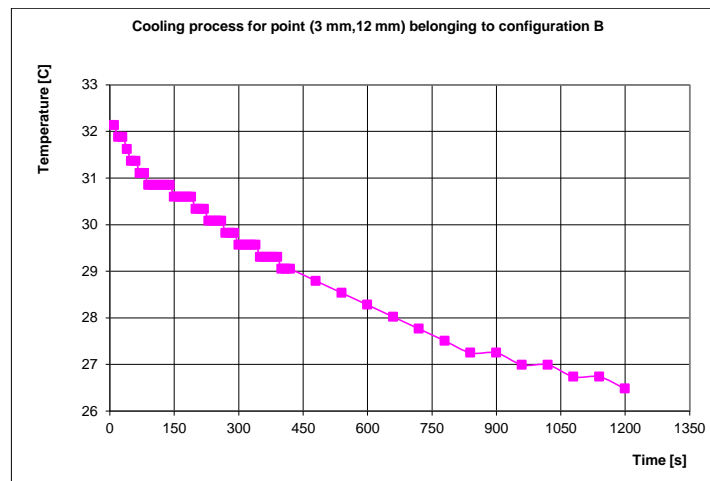


Fig.2.8.9. Cooling process time graph for a point located on configuration B

All measurements were performed by using the shock generator is shown in Fig. 2.8.10. It is located at the LAPLACE (Génie Electrique) Laboratory, from the PAUL SABATIER University in France.



Fig. 2.8.10. Shock generator

Temperature was measured by adding Pt sensors soldered with silicone gel (a very good thermal conductor).

The main schema of the shock (pulse) generator, as used for these measurements, is presented in Fig.2.8.11. All equipment belongs to LAPLACE Genie Electrique Laboratory at the PAUL SABATIER University in Toulouse, France.

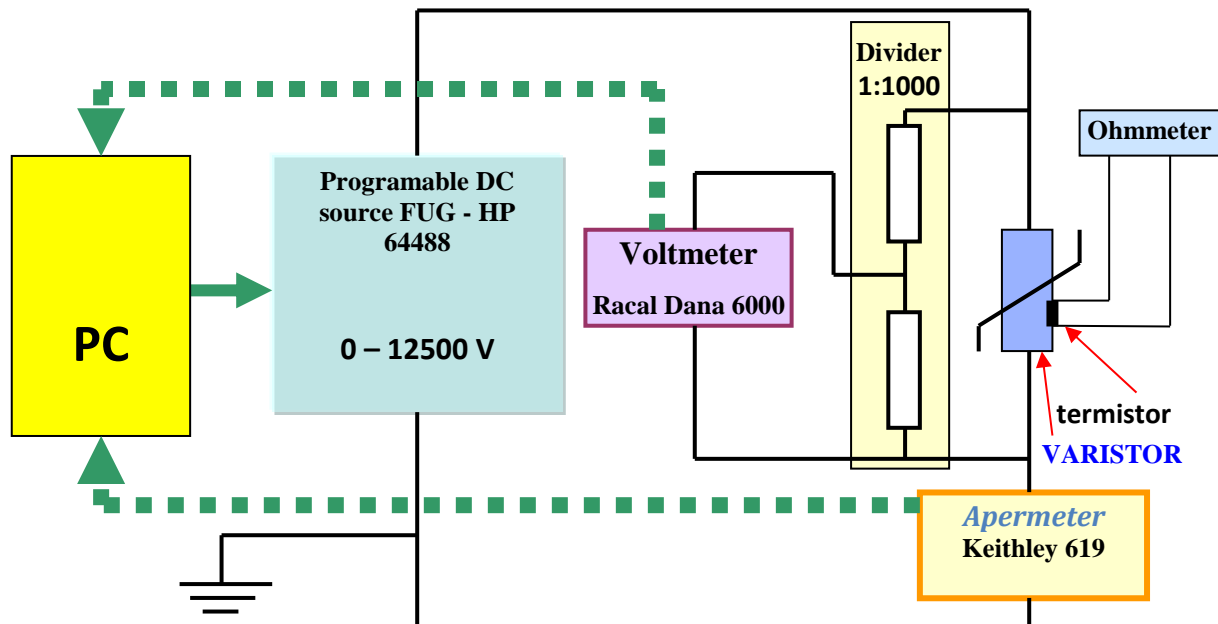


Fig. 2.8.11. Electric Schema for Shock Generator

2.8.4. Patented High Energy Voltage Suppression Capacity Varistor

The patented invention RO 117052 B/1999 [2.8.12] relates to a zinc oxide (Metal Oxide) varistor with increased capacity to limit surges in all electrical networks intended to limit overvoltages on long-term or high frequency, regardless of polarity and nature. The fundamental aim of this invention is the elimination of the destruction risk caused by heating in case of a standard varistor [2.8.9].

The technical problem solved by this invention is to provide an assembly which is based on a zinc oxide varistor which has an increased capacity to absorb and release the energy dissipated by Joule effect on varistor's mass.

The zinc oxide varistor with increased capacity to limit surges, according to the patent mentioned above, eliminates the heating drawback mentioned before, in order to limit overvoltage on long-term or high frequency and it consists of a zinc oxide varistor, ring-shaped, slightly curved inwards and two metal electrodes acting as thermal buffer having a dome-shaped inwards, which are glued to the ends of the varistor by a thin layer of metal alloy and the inner space of the whole occupied by an epoxy resin.

It has the following advantages [2.8.12]:

- With the same amount of mixed metal oxide can be obtained a single ring with a diameter of a classic pill (or a cylinder), so there is a greater cooling surface area (heat transfer by convection to the environment);
- Shape ring is more appropriate compared to the cylindrical shape filled because under pulse (having a fundamental high frequency), there is the skin effect and the electrical current is pushed to the outside, the central area of the cylinder contributing to a low extent of the electric conductivity;
- Metal electrodes ensure an uniform electric field and they are a thermal buffer having a high transient heat absorption capacity, maintaining varistor at a temperature that does not lead to thermal runaway, creating an increased reserve limit for long-term surges or high frequency ones;

- Shaped and curved inward varistor, the electrode contributes to uniform temperature inside the assembly, so, it has a faster heat transfer to the environment;
- The assembly is designed to be modular to various voltage levels.

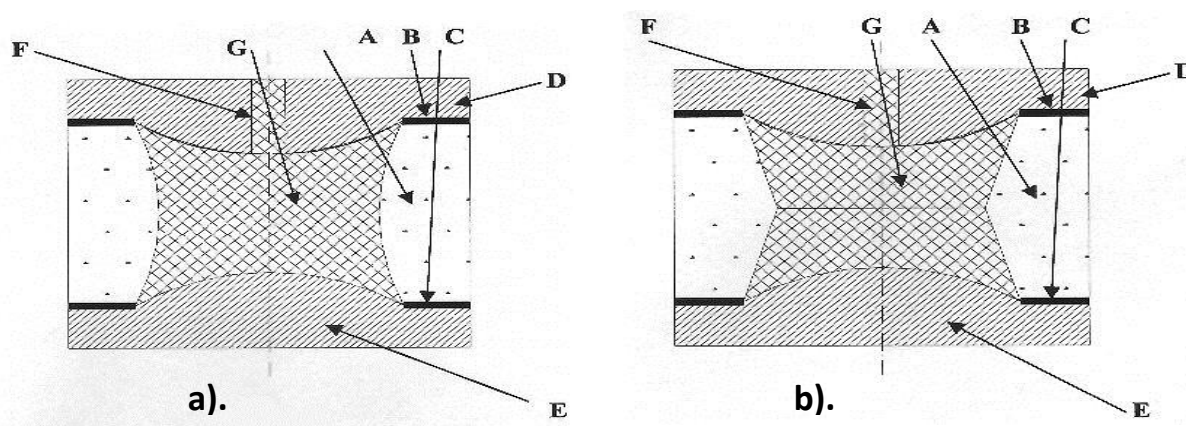


Fig.2.8.12. High Energy Voltage Suppression Capacity Varistor on two technical solutions (shapes)

The zinc oxide varistor with increased capacity for limitation of overvoltages, according to the embodiments of the invention, consists of a zinc oxide varistor itself (A), ring-shaped, on the inner face being slightly convex. At the ends of the varistor (a) apply two thin and uniform layers of solder or other alloy with similar properties, (B) and (C). Over these layers are installed two metal electrodes (D) and (E), brass or other appropriate alloy properties. Electrodes (D) and (E) are also bombs inward. The electrode (D) has applied a channel (F) which can inject the insulating resin (G), which fills the interior of the assembly, for example polyurethane or epoxy.

The assembly is mounted between the electrodes. Some Medium Voltage surge arrester devices or other low voltage protection modules may include these electrodes inside their structure.

Convex shape of the varistor (A) provides a more uniform distribution of temperature inside the assembly (as demonstrated following an individual computer numerical modeling). It offered two variants, with the inner face-sectional shape of an arc as shown in 2.8.12.a or two line segments, as shown 2.8.12.b, easier to achieve than the first in terms of technology.

Regardless of embodiment, these assemblies are maintaining the varistor + additional mass at a lower temperature value than the same version functioning without additional weight.

We noticed that there is a major risk of overheating during permanent or shock (overvoltage) regime, because the current inside that varistor is activated by temperature,.

The thermal stability concept is important in the assessment of the quality of a certain varistor. In order to avoid any potential risk of overheating, the experiments described in this research, placed the varistor inside the thermal stability area, in order to avoid complete destruction and, also, to verify the efficiency of the newly proposed technical solution of additional masses.

There are many practical technical solutions concerning the overheating risk reduction. In our opinion the most efficient ones involves working to improve the quality of the varistor material itself, a job basically for chemical/material specialists [2.8.7].

This original solution proposed in this chapter, which is dedicated only to existing materials and equipment, consists, basically, in an additional mass welded on the varistor surface, which acts like a heating pump, extracting heat from the electrical active part of the varistor and relocating this heat in fractions between the two pieces of equipment.

This original solution, part of a patent, proved to be efficient, reducing the temperatures compared to the single varistor one. This technical solution gives us a high energy absorption capability, placing the varistor inside the stability reserve area, for all normal overvoltage shocks [2.8.8].

We observed a good correspondence between the estimated and the measured results.

The principle of additional masses could be successfully used in order to manufacture high energy absorption capacity low voltage varistors, suitable mostly for low voltage applications.

2.9. Researches for Establishing the Functional Limits of ZnO based Varistors

Metal Oxide Varistors (also named ZnO varistors, due to their most important component) are today used for making state of the art surge arresters for all voltage levels, from domestic low voltage to high voltage transport lines. Their main goal is to protect any piece of electrical equipment against any type of over voltage which occurs on the power supplying network (technical incident, induced voltages or lightning stroke).

ZnO varistors are essentially ceramic poly-crystalline n – semiconductors [2.9.3].

They are applied in modern technologies due to some important advantages such as: a high level of non-linearity for the current-voltage characteristic, a high energy absorption capacity and an excellent response time [2.9.4].

Like many other semiconductor devices, the current passing through that varistor is thermal activated. So, for a high energy short time shock (like a violent lightning stroke) or for a long time over voltage (a technical incident), there is an increased risk of overheating. As long as the temperature increases (even the environmental temperature increases), the passing through current increases due to the diminution of the electrical resistance. An avalanche phenomenon could occur any moment, with devastating consequences both for the surge arrester as well for the protected equipment too [2.9.2].

Knowing the service limits for a certain varistor included into protection equipment is important in order to obtain maximum performance and safety for a long term use of that protection equipment. This goal could be achieved only by making some experiments to evaluate the thermal limits of a certain varistor. This chapter presents some original experiments made by the author at the LAPLACE“Genie Electrique” Laboratory of the “Paul Sabatier” University in Toulouse, France. These experiments are original because they are taking in consideration the environmental temperature too, and they provide technical solutions for an optimal service of that equipment.

As a consequence of the thermo-activated current, the thermal stability of a ZnO based varistor could be analyzed in two different cases:

- the permanent service regime, when the varistor is exposed to a long time accidentally over voltage, not very high, but destructive for the protected equipment;
- the shock (voltage impulse) regime, when the varistor is exposed to an extremely short time over voltage, but with a very high value (like a lightning stroke), obviously destructive for any protected equipment.

The shock regime is generally specified by the surge arrester manufacturer by marking the energy absorption capacity of that device at a certain maximum voltage, in the case of a standardized shock wave form. Of course, that parameter is informal, no lightning stroke is like in standards and there are many other parameters involved (the environmental temperature, the varistors' temperature, the wave form, etc.)

There are many technical solutions to increase the energy absorption capacity in case of a voltage impulse (new materials, radiators, other cooling systems, etc.).

Generally, ZnO varistors behaves according to manufactures specifications, due to large series of experimental tests made before. No mathematical model could predict such an incident; the experimental method is the only one to characterize that type of electrical faults. In this research we will not discuss about the shock regime, but only about the long term over voltage regime [2.9.1].

The long term over voltage regime is generally not very well described.

This research presents a method used to determine the maximum continuous operating voltage of a ZnO varistor, based on experimental results.

A parameter called “the load coefficient, C ” is involved, in order to obtain some information about the voltage applied.

It is defined as:

$$C = V / V_N \quad (2.9.1)$$

Where V is the applied voltage and V_N is the nominal voltage for that varistor.

Our goal is to determine the maximum value of this coefficient (in fact the maximum continuous operating voltage V) for a certain varistor at a certain environmental temperature, different from the standardized one. This study could be made only in an experimental way.

2.9.1. Experimental Procedure

All the measurements were made by the author at the LAPLACE “Génie Electrique” Laboratory of the “Paul Sabatier” University in Toulouse, France. All the experiments were performed by using the same type of domestic appliance varistors, made by the Slovenian company VARSIS - ISKRA D.O.O. The catalog data for a disk varistor type **ISKRA V250D32S**, having a diameter of 32 mm and a height of 3 mm, are, according to the manufacturer [2.9.5]:

$$V_{RMS} = 250 \text{ V}, V_{DC} = 320 \text{ V}, P_{max} = 1,2 \text{ W}, I_{max(8/20\mu s)} = 25000 \text{ A},$$

$$W_{max(2ms)} = 340 \text{ J}, V_N = 390 \text{ V}, \Delta_N = \pm 10\%, V_C = 650 \text{ V}, I_n = 200 \text{ A}, C = 2200 \text{ pF}.$$

We notice that the producer already offers a maximum continuous operating voltage (a maximum value for the “ C ” coefficient) at an environmental temperature of 25 °C, defined, in permanent DC regime, as:

$$C_{max} = \frac{V_{DC}}{V_N} = \frac{320Vd.c.}{390Vd.c.} = 0,82 \quad (2.9.2)$$

The first step is to verify this value provided by the manufacturer [2.9.6.].

The experimental equipment is shown in Fig. 1 and the electrical schema of that device is shown in Fig. 2.9.2. The tested varistor is connected through two wires in order to avoid any thermal transmission. Two Pt high sensitive temperature sensors, with low delay, are placed on the two disk faces, near to the center of that disk. All experiments are made in a thermo – insulated controlled chamber shown in Fig. 2.9.1.

The elements of the experimental equipment are, as shown in Fig. 2.9.2:

- A FUG-HP 64488 DC voltage source, programmed by a PC 486 computer, which can supply any DC voltage between 0 and 12500 V DC at a maximum current of 25 mA;
- A Keithley 619 DC digital micro ampere-meter which allows measurements between $1,9 \cdot 10^{-9}$ and $1,9 \cdot 10^{-3}$ A, having a precision class of 0,5%;

- A Racal Dana 6000 digital memory voltmeter used to measure the voltage difference between the faces of that disk varistor through a 1:1000 resistive voltage interface, having a precision class of 0,1%;
- Two usual portable multi meters (not shown in Fig. 2.9.2) used to measure the resistance of the Pt temperature sensors in order to obtain that temperature values.



Fig.2.9.1. The experimental equipment

That varistor was polarized at three different voltage levels [2.9.10]:

- 312 V DC, corresponding to $C = 312/390 = 0,8$, a value under the manufacturer limit;
- 320 V DC, corresponding to $C = 320/390 = 0,82$, the manufacturer limit;
- 345 V DC, corresponding to $C = 345/390 = 0,884$ – value over that limit.

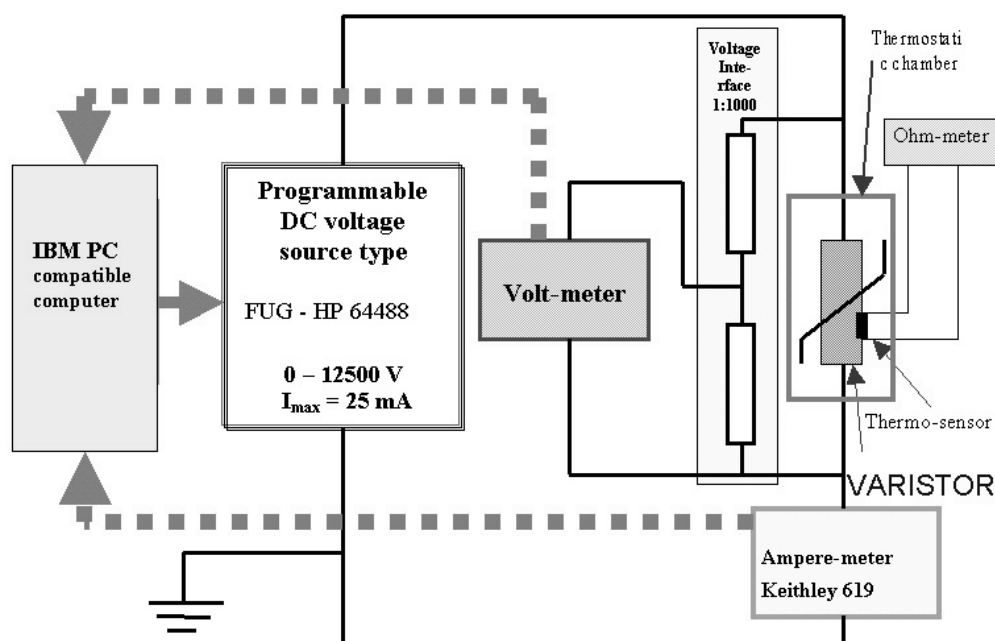


Fig. 2.9.2. The electrical schema of the experimental equipment

The main purposes of these measurements were:

- to evaluate the thermal avalanche;
- to establish the maximum voltage for a certain environmental temperature;
- to verify the thermal behavior of that varistor;
- to determine the critical current density for that temperature.

The evolution of varistors' supra-temperature (related to the environment one, $t_a = 25$ °C) is shown in Fig. 2.9.3, for all values of C .

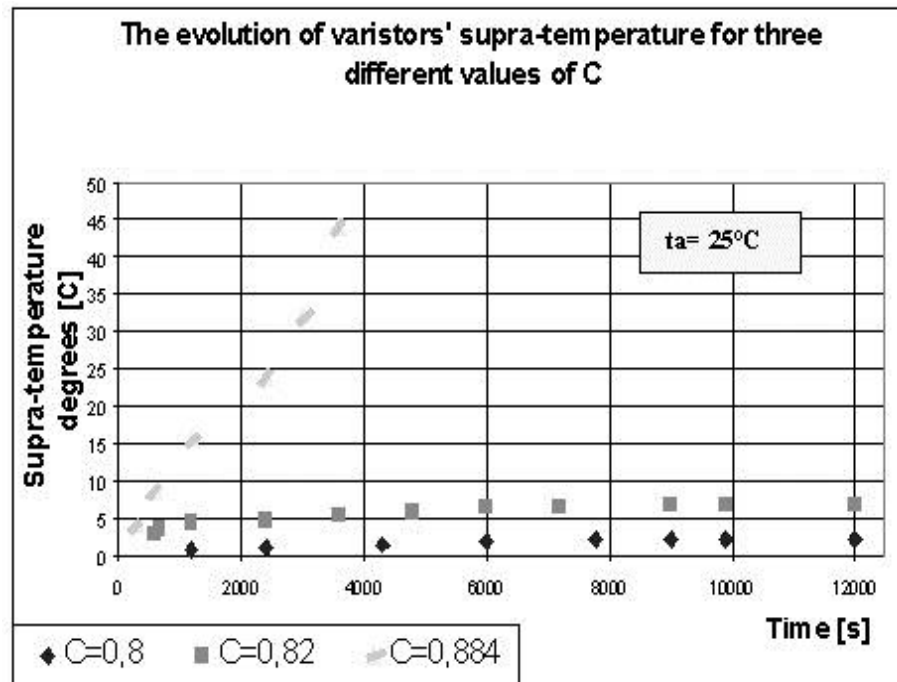


Fig.2.9.3. Time evolution for supra-temperature

We notice that for the producer recommended value $C = 0,82$, a steady regime is obtained with a supra-temperature of only $6,8$ °C [2.9.9].

For a higher value of the C coefficient, at the same value of the environmental temperature $t_a = 25$ °C, the increase of the supra-temperature of that varistor is exponential, in avalanche. The varistor was disconnected after 1 hour (3600 s) to avoid its destruction. It was having a supra-temperature of $44,1$ °C at that moment.

The time related evolution of the crossing current (at $t_a = 25$ °C) is shown in Fig. 2.9.4, for all values of C .

We noticed that:

- for a coefficient $C = 0,8$, under the limit $C = 0,82$, the current is maintained constant around 10^{-4} A;
- for a coefficient $C = 0,884$, over the limit, the current increases exponentially, with a higher risk of overheating and degradation.
- for a coefficient $C = 0,82$ ($V = 320$ V DC), the limit prescribed by the producer, the current remains stable around $7,1 \cdot 10^{-4}$ A, even starting from $2 \cdot 10^{-4}$ A (value specified in its voltage-current chart).

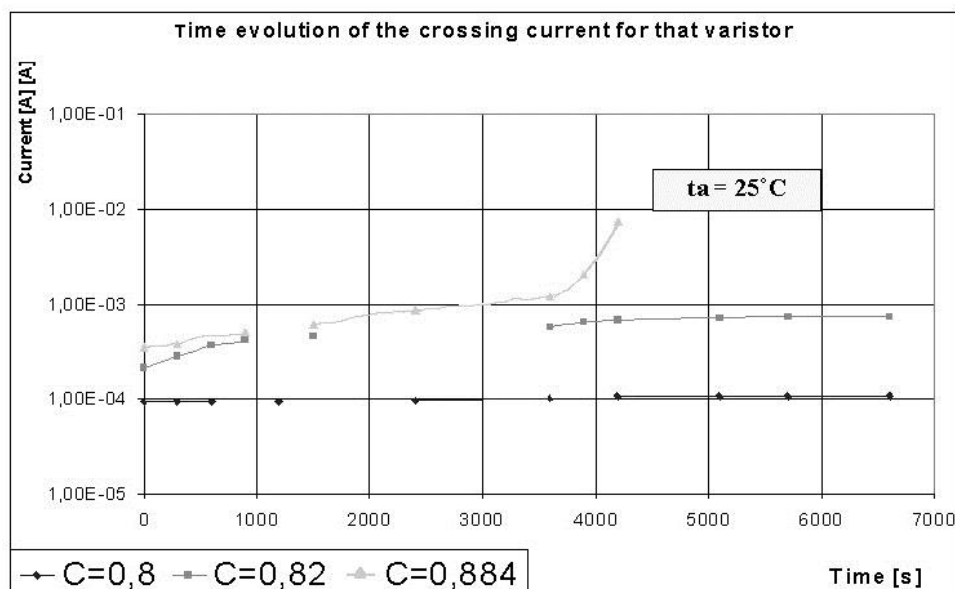


Fig. 2.9.4. Time evolution of the crossing current

The limited value for the voltage (the limited coefficient C) provided by the manufacturer does not represent the voltage necessary to obtain the critical current density, being in fact inferior to that value. The critical current density, at an environmental temperature of 25 °C, is obtain for a load coefficient around 0,83 ...0,85, depending on the geometry of that varistor and his composition and structure [2.9.8].

According to some experimental data, for that specified varistor, we have some important values:

- $\rho_a = 3,6 \cdot 10^5$ [$\Omega \cdot m$] (electrical per unit resistance);
- $\alpha_R = 3 \cdot 10^{-3}$ [$degrees^{-1}$] (thermal resistance factor);
- $d = 3 \cdot 10^{-2}$ [m] (diameter).

For a temperature of 25°C, $\alpha \approx 17$ [$W/(m^2 degree)$] (thermal transmittance).

The calculated critical density is obtained by using this equation:

$$J_{cr} = \sqrt{\frac{\alpha \cdot l_p}{\rho_a \cdot \alpha_R \cdot A}} = \sqrt{\frac{4 \cdot \alpha}{\alpha_R \cdot \rho_a \cdot d}} \quad (2.9.3)$$

And it has a value of:

$$J_{cr} = 1,448 \text{ [A/m}^2\text{]} \quad (2.9.4)$$

By analyzing the expression of the critical current density, J_{cr} , gave by (3), we can observe that its value is influenced only by the de heat dissipation conditions by changing α by changing the diameter of the ZnO varistor disk [2.9.3].

The critical current density will be the same for all series of varistors of the same diameter, the absorbed energy being proportional with the volume (the height) of the varistor (cylinder or disk).

The evolution of the supra-temperature for the considered varistor for two different environmental temperatures $t_a = 25$ °C and $t_a = 55$ °C is shown in Fig.2.9 5.

All the measurements were made at a voltage value of 320 V DC, which corresponds to the limited value for the “C” load coefficient, recommended by the producer as being $C = 0,82$.

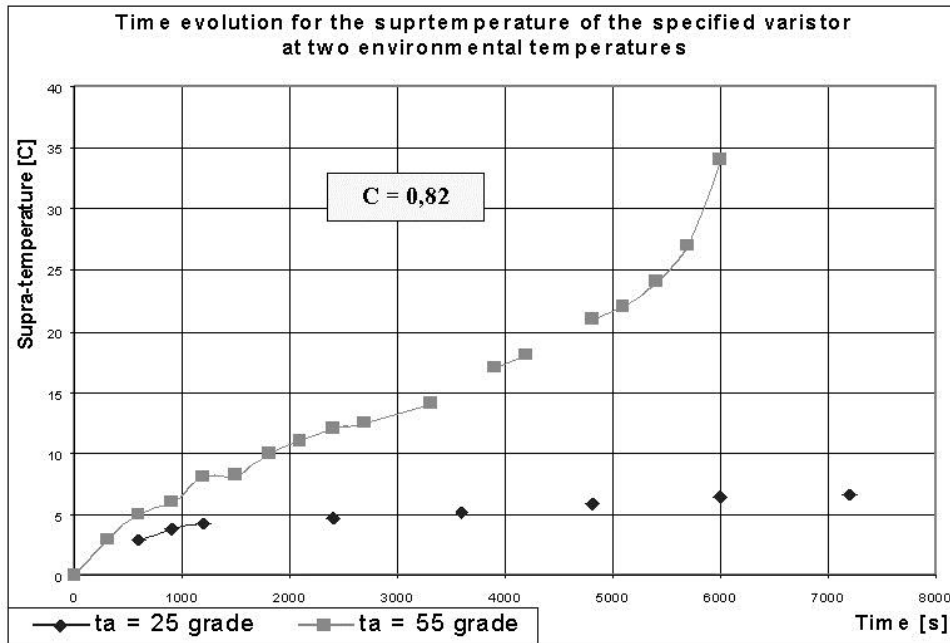


Fig. 2.9.5. Time evolution for the supra-temperature for the considered varistor for two environmental temperatures

The first value is placed under the environmental temperature limit and the second is placed over that. The limited value of the environmental temperature for a load coefficient $C = 0,8$ is about $40-45\text{ }^{\circ}\text{C}$. Over this value, the risk of thermal racing is higher. For a continuous service at the nominal voltage level ($C < 0,65$) there are no risks of thermal racing, overheating and fault even for an environmental temperature $t_a = 85\text{ }^{\circ}\text{C}$ (direct solar exposure of that piece of equipment).

The time evolution of the crossing current for the two values of the environmental temperature is shown in Fig. 2.9.6.

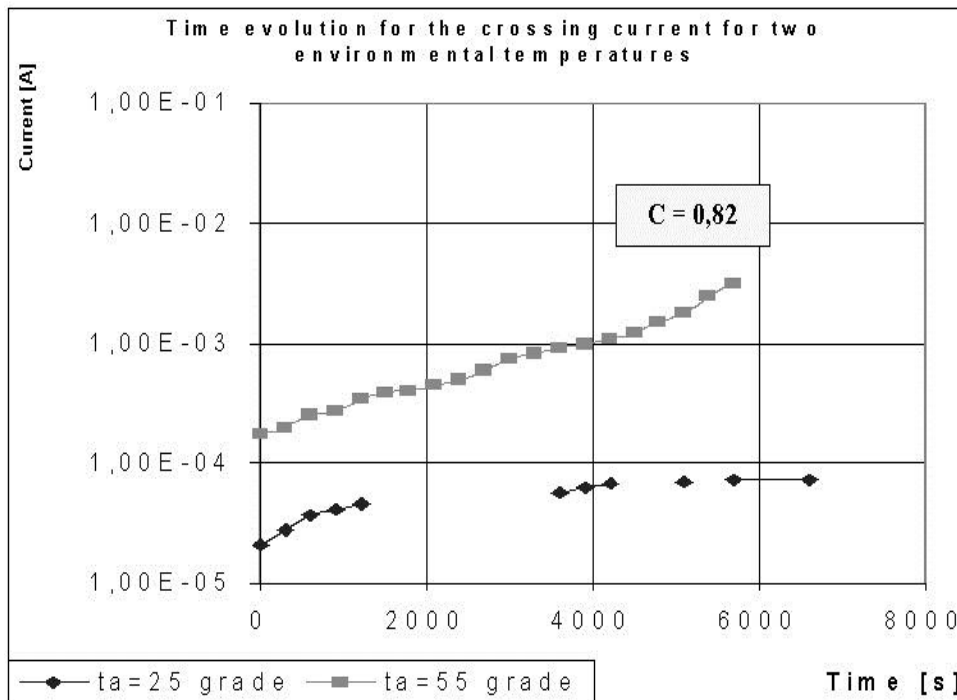


Fig. 2.9.6. Time evolution of the crossing current for two environmental temperatures

We can observe that, in this case of a higher environmental temperature, the thermal racing occurs even for a load coefficient $C = 0,8$. The critical load coefficient is located around $C = 0,75$ for an environmental temperature of $55\text{ }^{\circ}\text{C}$. When passing over that value, the risk of over heating increases dramatically.

After performing all specific measurements, the values of the critical load coefficient C_{cr} for an usual range of environmental temperatures t_a are shown in Table 2.9.1. We notice, in Fig.2.9.7, that, for this normal environmental temperatures between $25\text{ }^{\circ}\text{C}$ and $55\text{ }^{\circ}\text{C}$, there is a linear relation between those two parameters.

It could be synthesised as $C_{cr} = a_0 + a_1 \cdot t_a$. This is happening because the electrical resistance of the varistor is linearly decreasing with the temperature, at the same voltage level (as we mentioned before). So, in order to maintain the same critical current (critical current density), which is causing thermal runaway, we have to reduce the applied voltage (the load coefficient). The new critical load coefficient then appears, smaller than the low temperature old one [2.9.10].

| $t_a\text{ [}^{\circ}\text{C]}$ | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
|---------------------------------|------|------|------|-----|------|------|------|
| C_{cr} | 0,84 | 0,82 | 0,81 | 0,8 | 0,79 | 0,76 | 0,75 |

Table 2.9.1 Critical load coefficient measured for usual environmental temperatures

The equation of that line was numerically determined as:

$$C_{cr} = 0,915 - 3 \cdot 10^{-3} \cdot t_a \quad (2.9.5)$$

It was obtained after solving the equation system gaved by [4]:

$$\begin{cases} s_0 \cdot a_0 + s_1 \cdot a_1 = t_0 \\ s_1 \cdot a_0 + s_2 \cdot a_1 = t_1 \end{cases} \quad (2.9.6)$$

Where :

$$\begin{aligned} s_0 &= 7 \text{ (the number of points);} \\ t_0 &= \sum_{i=1}^7 C_{cr_i} = 5,57; & s_1 &= \sum_{i=1}^7 t_{a_i} = 280 \\ t_1 &= \sum_{i=1}^7 C_{cr_i} \cdot t_{a_i} = 220,75; & s_2 &= \sum_{i=1}^7 t_{a_i}^2 = 11900 \end{aligned} \quad (2.9.7)$$

This line is presented in Fig. 2.9.7. For all points having the plan coordinates (C, t_a) located over the line (C is bigger than C_{cr}), the thermal racing at that applied voltage V (load coefficient C) and that environmental temperature is inevitable. For all points having the plan coordinates (C, t_a) , (C is smaller than C_{cr}), located under that line, the thermal racing does not occur, because the critical current density is not over passed. All the points obtained before were represented in Fig. 2.9.7.

This linear relation between the critical load coefficient and the environmental temperature was verified not only for this type of varistors, but also for another low voltage varistors [2.9.11].

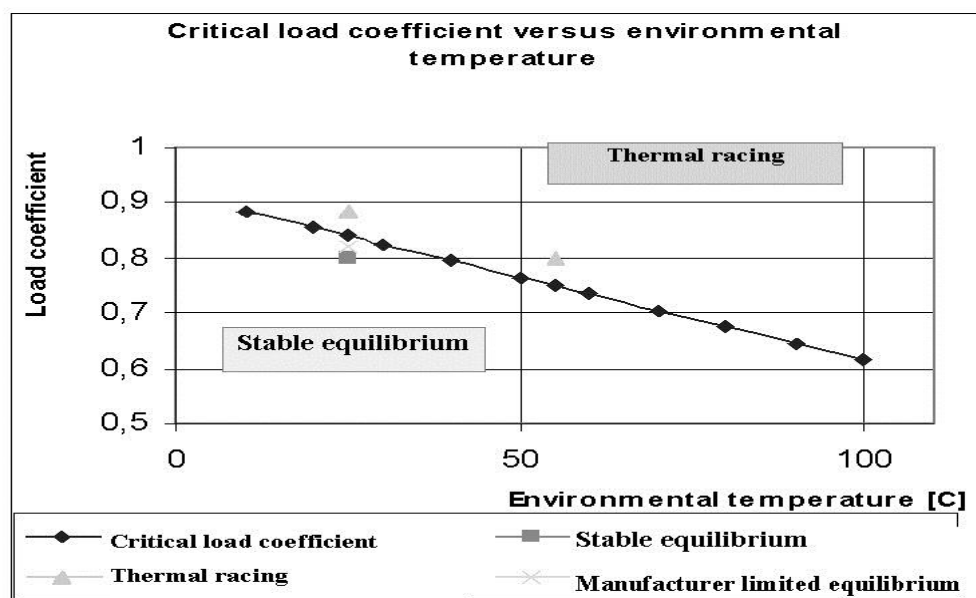


Fig.2.9.7. The relation between the critical load coefficient and the environmental temperature

It gives an answer to the question: “What is the maximum continuous DC operating voltage for a certain varistor at a certain environmental temperature?”. The designer, the producer or the simply user of a varistor could know its limits only by evaluating the equation (2.9.5) for a certain environmental temperature.

Not every varistor manufacturer offers data related to the environmental temperature of that device. Generally, all manufacturers gave data only for measurements made at an environmental temperature of 20 or 25 degrees Celsius.

Surge arresters have to perform very well even at higher temperatures, due to excessive climate or direct solar exposure on embedded capsulated devices. This kind of measurements is not standardized.

2.9.2. Conclusions

This research presents an experimental method used to determine the maximum continuous operating DC voltage for a ZnO based varistor at a certain environmental temperature.

This kind of technical data is not always specified by the manufacturer but is necessary when using that device. We introduced a so-called “load coefficient” in order to obtain a much simplified expression for that relation. By studying a certain disk type varistor we obtained a very simple linear equation which offers an answer to that question. This equation was verified for many other types of low-voltage ZnO based varistors, made by other producers and with other dimensions.

All the experimental procedures and all results are original and they are already applied by the Romanian low-voltage surge-arresters manufacturer PROTENERGO S.A. from Timisoara.

This equation gives a solution concerning the long term thermal stability of a varistor at a certain environmental temperature with no other further measurements and testing procedures, reducing the design time and costs for a low voltage surge-arresters made by using ZnO based varistors.

This study must be continued with an evaluation of the impulse regime thermal stability for completing all tests concerning the low voltage ZnO based varistors. These conclusions could be used even for medium and high voltage ZnO based varistors.

2.10. A New Solution for a Domestic Low Voltage Surge-Arrester

This article presents a new product, developed by the author, which made the object of a research contract and a technological transfer, from university to industry and mass production. It is a low voltage class D surge-arrester, based only on metal-oxide varistors, a state of the art electronic device used to protect domestic and similar consumers against any type of overvoltage (pulse or long time). On the first stage, it was developed after some research studies carried out by the authors at the UPS/Laplace Laboratory in Toulouse, France in partnership with the Politehnica University in Timisoara.

The applicative research was transferred, in order to be produced at PROTENERGO S.A., a local electronic products manufacturer in Timisoara [2.10.14]. It has some original ideas which make this product cheaper, easy to use and adapted to any low voltage installation existing even in ancient buildings.

2.10.1. Overvoltage Protection Equipment

Nowadays, there are on the market a lot of low voltage (domestic) electric consumers, most of them being extremely sensitive to any electric perturbation like flickering and overvoltages (especially electronic ones). Power quality is now an issue for each power/electricity provider, and there is a real need on the market for finding state of the art technical solutions in order to protect these sensible pieces of equipment against any electromagnetic disturbances which can appear inside the power supply grid.

Those protecting devices are known as surge-arresters because they are making an efficient cut of the overvoltage shock wave, absorbing its energy.

Today, the general protection of low voltage consumers against any type of overcurrents is practically solved, by means of simple, cheap and versatile devices (protection switchers, fuses, relays), all researches are now conducted towards getting protective systems against overvoltages. Modern electric low voltage consumers such as: IT/communication electronics, electronic equipment for measurements and control, medical electronics, home appliances, audio-video apparatus, power electronics (and practically any other piece of electric/electronic equipment supplied directly from a socket, for domestic, office, medical and industrial use) are expensive and very sensitive. By consequent, we notice an increase users' interest that these electronic pieces of equipment must work properly [2.10.12].

From the point of view of the power suppliers, efficient overvoltage protections are an additional cost and a supplementary investment not always accepted. By consequent, not many surge arresters are present on the power supply network.

From the point of view of the producer/manufacturer of electronic goods or home appliances, overvoltages are really a source of benefits. Destroyed items have to be replaced, service and maintenance must be carried out, or, in a worst scenario when no replacement or fixing is possible, consumer has to buy another new electronic product, which is clearly the normal intent of the manufacturer.

By consequent, not many overvoltage protective devices are placed inside an electronic product [2.10.3].

As a principle, the overvoltage protecting systems are needed only by the electronic goods consumers, people or organizations which wants to protect their investments in electronic goods, as well as to increase safety in service. By consequent, a new generation of surge arresters, working at low voltages in power supply installations, located in buildings, having the role of completing the already existing ones, is going to entry on the market. By using these complementary equipment (located mostly in the socket area), the co-ordination and selectivity of protections could be achieved.

Although all over the world, (EU included) there is a clear strategy concerning protection against overvoltages of low voltage consumers, there is a lack of clear, simple and effective standards to normalize the presence and the construction of such protecting systems. We can say that, except 2 or 3 standards, which are not mandatory, this policy is practically absent worldwide.

There is also a lack of consumers' technical culture in the field of overvoltage protection.

This study wants to present some useful information for both companies and common people, about modern overvoltage protecting systems.

An overvoltage protection device must comply the following requirements: to not allow the dielectric breakdown of the existing insulation of the protected electric circuit or electronic equipment, to avoid any type of accidental discontinuities in power supply, to limit the risk of human operator electrocution due to voltage potential increase of some parts of the equipment and to prevent fires or emergency situations caused by electric arc or overheating.

Nowadays, the protection of power systems against overvoltage is made by lightning rods, protective passive conductors, LC circuits, automatic speed circuit breakers and spark gap based parallel protections, diodes and varistors.

All types of such parallel protections are building a temporary connection by having a very low impedance between the high voltage protected equipment and earth, which is effective only for a relatively short period of time, but long enough in order to conduct the transitory overvoltage produced by the direct or indirect atmospheric discharges, or by the accidental connections inside the power networks. Those connection times have to be limited to a certain value which is inferior to the maximum level of protection required by the protected installation [2.10.1].

This type of parallel protections used in power systems include spark gaps, simple dischargers, gas dischargers and variable resistance dischargers (surge arresters). Modern surge arresters are based on SiC, semi-conductor Si or Se Zenner diodes, semi-conductor ceramics made of ZnO and other metal oxides (MOV surge arresters).

MOV surge arresters have some clear advantages, when compared with other similar devices, like short response time, high energy absorption capacity, excellent voltage calibration. Due to those advantages, today, state of the art surge arresters are made with MOV varistors, sometimes called ZnO varistors, due to their main ingredient. First used for high and medium voltage surge arresters, they have recently been used in the area of low voltage devices, too, mostly for protecting sensitive electronic equipment against any type of overvoltage.

2.10.2. A New and Original Overvoltage Protective Module for Low Voltage Applications

In order to protect the low voltage electric installations and equipment against overvoltage, ZnO varistors, in many situations, are not integrated alone, but together with other specific electronic devices, forming an overvoltage protection module.

Generally, a MOV based protection module includes [2.10.5]:

- Some (one or two) varistors used for absorbing quickly the electromagnetic power of the voltage pulse, as internal heat, that dissipates completely into the environment;
- A spark-gap gas discharger capsule, which disconnects (one or all) varistors when the protected installation is working in normal permanent regime and for fixing the value of the opening voltage when long time overvoltages appear;

- A simple thermo-bimetal element used to disconnect the varistor if its temperature increases after a voltage shock pulse, in order to avoid its temperature increase;
- A fuse element which is the last line of defense when limiting the leakage currents, avoiding the complete thermal destruction of the varistor;
- An adequate body, insulated for at least 6 kV;
- A wired circuit on a standard electronic SMD board;
- Some LED or bulb lamps indicating the working state of that protecting module.

According to IEC 61643, protecting modules of this type are produced world wide in five different protection classes, in order to co-ordinate the level of overvoltage protection in buildings. We will present a standard Class D (or 4) – protecting module placed in the plug/socket area, before the entrance in the electronic sensible consumers [2.10.6].

Figure 2.10.1 shows us the electric schema of a classic module used on the plugs of domestic and similar consumers produced by DEHN & SOHNE GmbH from Germany, only as a case study [2.10.12].

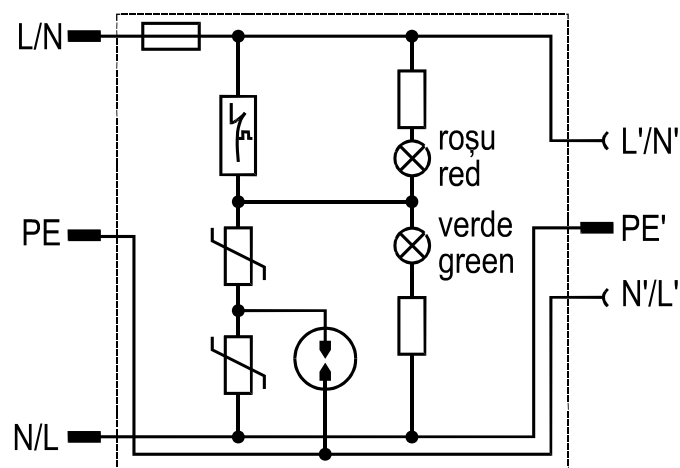


Fig. 2.10.1: Protecting modules of class D

We observe that it involves a very complicate structure of the module, with reduce liability. In many situations, the use of such overvoltage protecting modules in low voltage distribution networks is convenient only for class A, B, and C, where a lot of equipment will be protected. By consequent, we will take into account the costs, because these apparatus are not affordable for every appliance. When speaking about this class D protecting module, we notice this electric schema which could be applied only to perfectly symmetrical and balanced low voltage networks. By consequent, their application in certain low voltage networks which are unbalanced and non-symmetrical, in most cases showing a strong neutral voltage deviation, is not always efficient [2.10.7].

This market and technical case study imposed the idea of designing and producing an original overvoltage protecting module, which should answer the requirements of a low voltage distribution network and, at the same time, has to be affordable to a number of consumers as large as possible, with at least 3-5 years of complete liability. This original module was designed by the authors at the POLITEHNICA University in Timisoara and then produced on a large scale by S.C. PROTENERGO S.A. Timisoara, Romania. Product code is MPS-01 and it has a very simple electric schema with three ZnO varistors which realize phase-neutral, phase-earth and neutral-earth protection, as shown in Figure 2.10.2.

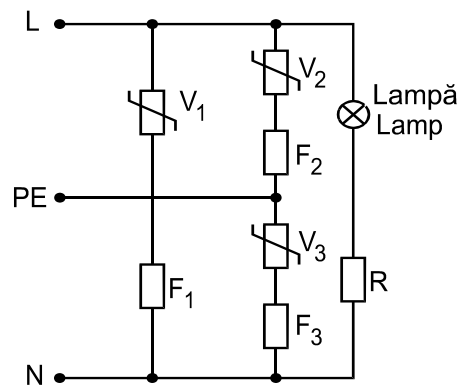


Figure 2.10.2: The electric schema of the overvoltage protecting module MPS-01

The circuit was made on a printed-plate on a classic glass silk texture. It includes 3 V250K20 type varistors produced by VARSİ Varistor d.o.o. Ljubljana, called V1, V2, V3, 3 fuses called F1, F2, F3 designed to work at a peak current of maximum 8 kA in order prevent varistors from excessive over-heating and avoid any phase-neutral or phase-earth short circuits, a neon bulb lamp which signals the presence of voltage on the terminals of the module and a resistor R which limits voltage on the neon lamp, for a proper function. The simple conception and design of this electric schema practically eliminates the possibility of varistor overheating, because no matter the origin and the terminals where an overvoltage occurs, all varistors are working in parallel. It offers the possibility of eliminating both the thermo-bimetal block and the gas discharger, reducing the cost price of the module, and making it more liable, strong and calibrated.

This MPS-01 overvoltage protection module can work as an E class module imbedded at the supply entrance of the protected electronic consumer or as a D class one being a component part imbedded in an electric plug type unit (placed inside or outside the wall) or of a multi-plug standard lengthener [2.10.8].

A product unit called 'Multi-plug Block Protected from Overvoltage – BMS-01' was equipped with this MPS-01 protecting module, after being mass produced and marketed by PROTENERGO S.A. company in Timisoara. It is presented in Figure 3. The conception and the design of this original product was made by the authors, and PROTENERGO S.A. Timisoara is one of the spin-off companies belonging to the industrial innovation park of the University. BMS-01 can be used up to a power of 2,500 W (even larger when changing the plug conductors).



Fig. 2.10.3. Multi-plug Block Protected from Overvoltage – BMS-01

2.10.3. Experimental Part and Quality Control

The Multi-plug Block Protected from Overvoltage – BMS-01 product has been homologated according to SF 16/2011 internal production standard and first, it has been tested at the High Voltage Laboratory of the Electrical Engineering and Power System Faculty of U.P. Timisoara and at LAPLACE Laboratory of the University 'Paul Sabatier' of Toulouse - France, where it has got the Certificate of Conformity in Electromagnetic Compatibility for electric domestic equipment.

All laboratory tests were performed on the whole apparatus and they endorsed both tests of mechanic resistance for the carcass and the electric bonds as well as dedicated overvoltage tests concerning the response at the voltage step and current signal with 8/20 μ s standard waves having a peak voltage of 4 kV, according to the IEC 61000 norms. Figure 4 shows an example of the response wave form of the product. It is known that, in most industrial buildings, there are many domestic consumers, which, in normal work regime, through inductive disconnections, they can produce overvoltage 'wandering waves' which travel through the distribution network. One of the main issues of the authors' was to determine the behavior of this BMS-01 block when exposed to such 'wandering waves'. A test stand, presented in fig. 5, has been conceived, made of a sparking-coil supplied, in primary, at the 230V AC network, which produces, in secondary, a combined train of overvoltage waves having about 1.35 kV, which are discharged on plugs B1 and B2 as intermittent electric discharges of 50 Hz.

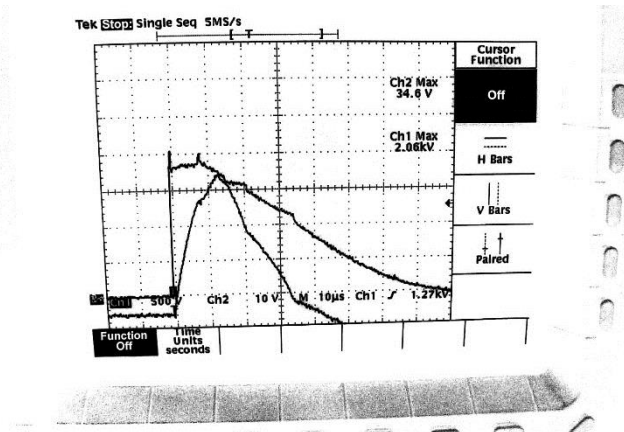


Fig. 2.10.4: Response of BMS-01 to an 8/20 μ s standard pulse

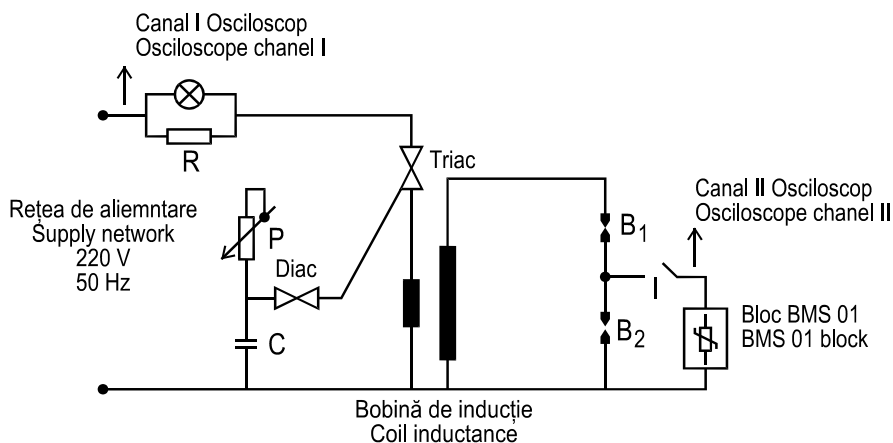


Fig. 2.10.5: Test stand for studying the behavior of the BMS-01 block for a train of overvoltage wandering waves

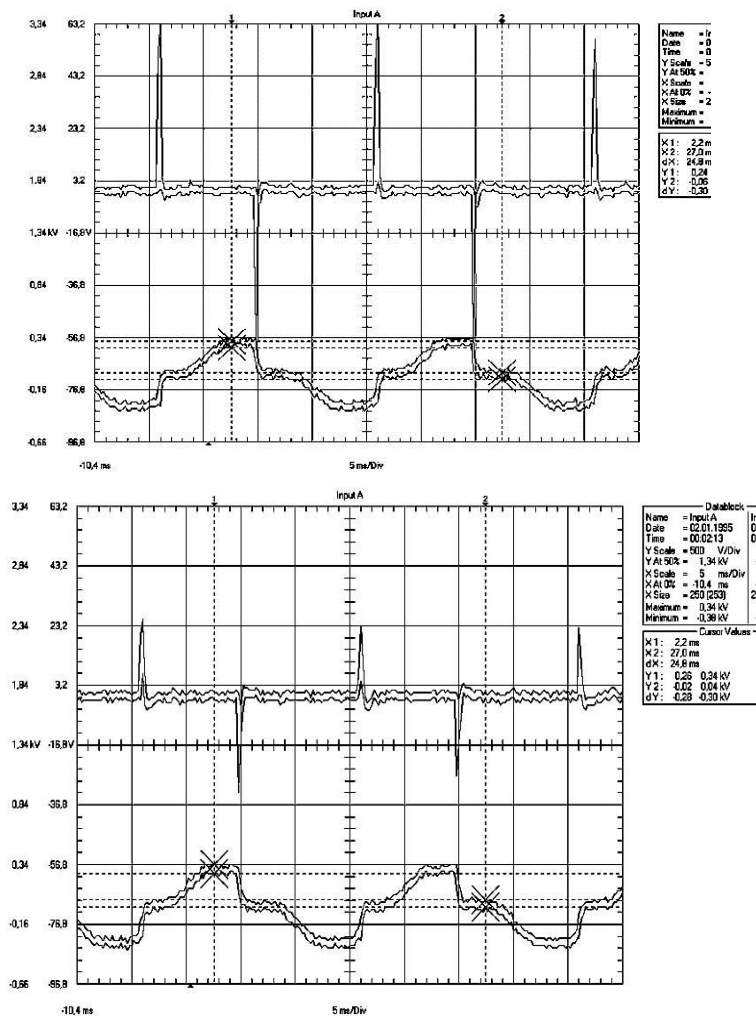


Figure 2.10.6: Diagrams for a train of overvoltage wandering waves applied to a domestic consumer: a) without any overvoltage protection; b) with overvoltage protection

When switch no. I is off, by applying the 230 V AC voltage of the supplying network to the equipment, we can easily see electric discharges on both sparking plugs. If switch no. I is on, by connecting the BMS-01 (or MPS-01) to the sparking plug B2, we can notice that the electric discharge appears on sparking plug B1 only. The measurements of the phenomena, provided by using a simple digital oscilloscope, are presented in fig. 2.10.6. It shows that the train of wandering waves is practically cut by the presence of BMS-01 at a third of its initial peak value, so, by consequent, its effect is not felt any longer by the sensitive protected domestic consumer. Another benefit is that, using this multi-plug block BMS-01 for supplying the electric home consumers which generate voltage inductive disturbances, the whole electric network of the building is protected against any bad effect of the overvoltage wandering waves like the premature fatigue of condensers inside the electronic domestic apparatus, the degradation of the 'economic' electric bulbs, the precocious aging of some isolations, etc.

2.10.4. Conclusions

Quality of power delivered to consumers requires some protecting measures to be adopted at consumers' low voltage, too. All these requirements are fairly common described in Europe, but not very applied on the market. There are not many companies producing overvoltage protecting systems using MOV (ZnO) varistors [2.10.11].

The first Romanian product of this kind, engineered and built in Timisoara, has demonstrated through the tests that it meets the European standards and regulations existing in this field. Designed for the specificity of the low voltage distribution network, this product has a good price/quality ratio, being affordable to a large number of domestic users and consumers.

The original technical solution described above use only 3 varistors, with no gas-discharge or thermo-bimetal elements, which increase time response and calibrated even better that element. There is an increased liability, proved during the last 4 years, where a few ten thousands BMS-01 were produced, with no warranty or post-warranty complains.

All these performed experiments shown the benefits of the use of BMS-01 and the correct choice of the technical solution applied.

2.11. Future Developments

For the development of my own professional, scientific and academic career I've designed a plan of actions that I've started even some years ago. The evolution and development plan of my own professional, scientific and academic career includes 3 research/teaching/practical application directions, which are, based on apparatus and equipment from the Power Systems area:

- A. Command, Control and Measurement Equipment;
- B. Materials, Equipment, Methods and Work Techniques for Power Commutation;
- C. Devices, Apparatus and Techniques for Power Systems Protection.

A. The first research direction concerning **Command, Control and Measurement Equipment** includes 4 types of action:

- New and updated applications of SCADA/Expert Systems;
- Virtual measurements and virtual Human/Machine Interfaces;
- Techniques for data processing;
- Sensors and Automation.

Here are some actual solutions proposed in the frame of this research direction:

- Fundamental specific problems that appear in the modeling SCADA systems, in the meaning of simplifying their structure;
- Increasing power conversion efficiency by an intelligent energy measuring system, both for electricity as well as for steam and hot water in power plants;
- The energy losses measurement, at all levels (production, transport and distribution of electricity and heat);
- Energy management tools (hardware and software);
- New semiconductor ceramic sensors for gases, based on metal oxydes;
- The integration of small cogenerative units.

For the good unfurling of these researches I shall make appeal to the material base of COLTERM S.A. (the Local Heat Provider for Timisoara) ENEL S.A. Banat (the Local Electricity Provider in the West Region) and I shall base myself on the excellent cooperation relations with ELSACO Electronic S.R.L., AEM S.A. and other dedicated companies in this field of power measurements.

In the frame of this first research direction I've received already a series of results, as team leader expert for COLTERM S.A., in the framework of their environmental refurbishment project, for CET Sud, CET Freidorf and CET Centru Power plants, by working on the SCADA systems applied there.

B. The second research direction makes reference to **Materials, Equipment, Methods and Work Techniques for Power Commutation** and includes 3 types of actions:

- The study of materials used in electrical and power engineering;
- Researches on electrical equipment for high voltage commutation;
- Power electronics for electrical and power engineering.

In the framework of this research area, I propose a series of actual studies, such as:

- The determination of the material properties in the electric field;
- The valuation of the life span of electric insulated materials by using the techniques of artificial intelligence;
- The elaboration of new materials, respectively the study of the behaviour of new materials (mostly semiconductor ceramics);
- The behaviour of insulation systems at extreme loads (high temperature and/or high electric fields and/or high magnetic fields);
- Design and/or computer-aided optimization of electrical equipment for high voltage working;
- Development of a new single class of surge-arresters combined with a change in the European Standards (object of a large European project for the next years);
- Measurements and special high voltage tests.

The success of these researches shall depend on the maintaining of cooperation relations with LAPLACE Laboratory in Toulouse, the University of Chemical Technology and Metallurgy in Sofia or with companies like DEHN GmbH in Germany, VARSİ d.o.o in Slovenia or EETest in Romania. The National Institute for Electrochemistry and Condensed Matter in Timisoara

C. A third research direction regarding the **Devices, Apparatus and Techniques for Power Systems Protection** includes 2 types of actions:

- Researches concerning new embedded systems for protective devices ;
- Studies sanctioning the valuation of the impact of high voltage installations on the environment with the aim of its minimization.

Among actual studies in this area, I want to mention:

- The assessment of existing protection equipment on 110 kV lines and the proposal of new technical solutions;
- New protection strategies for 400 kV lines and substations;
- Overvoltage protection equipment for all voltage lines.

In order to achieve these research goals, it is strongly recommended to maintain and improve the existing excellent cooperation relations with TRANSELECTRICA S.A., Enel Distribuție Banat, CEZ Distribuție Oltenia and the Society for Transmission Network Maintenance Service (SMART), Sibiu subsidiary.

Parts of the research shall be, as well, included in courses that I teach at the University Politehnica Timișoara at different disciplines, compatible with the mentioned research directions, like:

- „Electric and Non-Electric Measurements” (research direction A);
- „Reliability and Industrial Risk” (research direction A and C);
- „Materials used in Power Engineering” (research direction A, B and C);
- „Power Apparatus” (research direction B and C);
- „Power Equipment” (research direction B and C);
- „Automation and Protection of Power Systems” (research direction A and C);

A series of actual subjects specific for the mentioned research directions shall be proposed to be studied at the doctoral school level.

The development of future researches will focus, as before, on the participation in dedicated and specialized international and national events, publishing and disseminating the results of research, collaboration with other entities and development of new methods and results in the field of research projects.

More specifically, to increase the relevance and impact of my scientific work I propose the following:

- Publication of a minimum of three articles per year on international conferences (2) and Thompson Reuters-indexed journals (1) in the field of electrical engineering and power engineering.
- Publication of a minimum of two (2) articles per year, indexed in databases other than Thompson Reuters, but worldwide recognized (IEEE Exxplore, SCOPUS and others);
- I will pursue participation in conferences, particularly internationally, conducted both in Romania and abroad (minimum 2 per year, indexed in different data bases). Participation in conferences provide, in addition to dissemination of results, the opportunity to exchange experiences and information with other institutions in the field, things that can lead not only to my development as a researcher, but also to the prestige of the department (or faculty, and university) in that field of interest;
- Participation in the networks/clusters of national and international research entities and access to international grants or national ones (including the establishment of a consortium with the Paul Sabatier University in Toulouse, University of Chemical Technology and Metallurgy in Sofia Technical University of Ljubljana, VARSİ d.o.o Slovenia and Dehn Germany in order to access a complex project within the Horizon 2020, in order to achieve a high performance surge protection device for low voltage applications;
- The development of a partnership with the Advanced Research Institute of the Nigde University, in Turkey, and with the National Institute for Electrochemistry and Condensed Matter in Timisoara, in the field of advanced semiconductor materials (ceramics), with a large domain of applications (overvoltage protection, sensors, power electronic devices);
- Publication of specialized books, particularly on foreign publishers or recognized national publishing houses.

Future actions will aim at developing means of mathematical, statistical and numerical interpretation in the service of fundamental phenomena and processes applicate, especially in the management of industrial risk and reliability study.

I am the President of the Association for Multidisciplinary Research in the Western Region of Romania (ACMV) and its representative on the board of the Tehimpuls Association (The Regional Centre for Research, Innovation and Technology Transfer). From this position (ACMV is a professional association with more than 400 persons as members, 6 universities and 2 research institutes), I have one of the best perspective on the innovation potential of the Western Region and on the opportunities for technology transfer, R & D in companies and research entities located in 4 counties (Arad, Caras-Severin, Hunedoara and Timis).

Future research results will be included in books and articles which I will publish as well as research projects which I coordinate. In future projects will encourage master students to participate in research and to disseminate the results through their participation in various conferences and symposiums.

By obtaining the habilitation attestation I shall have the possibility to create (and afterwards to coordinate) a strong research team in order to contribute to the level of the doctoral school of the Politehnica University in Timișoara.

My plan for career development is correlated with the Development Plan of the Faculty of Electrical Engineering, the Strategy of the Politehnica University in Timisoara and I intend to realize as many imperative measures are necessary in order to accomplish some of their objectives. I want to build an academic career and an excellent professional reputation, ensuring the success and increased visibility of the Department of Power Systems and, in this way, of the Electrical and Power Engineering Faculty.

The instruments used in carrying out the development plan will both maintain and increase the standards of academic excellence.

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IG - International Grants/Projects

| Nr. crt. | Echipa de cercetare | Tip grant (proiect) | Denumire grant (proiect) | Nr. grant (proiect) / An | Valoare grant (proiect) [€] | Nr. ani | Beneficiar | Poziția în cadrul echipei | |
|----------|--|---------------------|--|------------------------------|-----------------------------|---------|---|---------------------------|--------|
| | | | | | | | | Director | Membru |
| 1 | CIBU-BUZAC Raluca, FRIGURA-ILIASA Flaviu Mihai, MATIU-IOVAN Liliana, COROIU Felicia, VATAU Doru, FARBAS Nicolae, POP Ana, FRIGURA-ILIASA Mihaela, ALBU Adriana, VLADUT Dana, VASIU Radu, STEFEA Petru, MUNTEANU Valentin | PHARE CBC | BROKINNOVOUCHER - Sprijin pentru cooperarea si inovarea intreprinderilor mici si mijlocii din zona Romania-Ungaria | 018 / 446.01 | 161000 | 2 | U.P.T., intreprinderi din Romania si Ungaria | DA | NU |
| 2 | Bui Ai, Ionescu Florin, Vasilevici Alexandru, Moldovan Lucian, Buta Adrian, Vatau Doru, FRIGURA-ILIASA Flaviu Mihai | INCO-Copernicus | HIPOVAR, Varistance haute puissance a base d'oxyde de zinc | 15-CT96-0749/1997 | 20,000 | 3 | U.P. din Timișoara; U.P.S. din Toulouse; U.P. Bucuresti | NU | DA |
| 3 | VĂTĂU Doru, FRIGURA-ILIASA Flaviu Mihai, ȘURIANU Flavius Dan, ILYEV Iliia, CAMBRONNE Jean-Pascal | AUF | Modélisation et caractérisation des propriétés thermiques dans des fluides contenant des nano inclusions anisotropes de forme différente | 6301PS521/2007 | 12,000 | 2 | U.P. din Timișoara; U.P.S. din Toulouse; U.T.C.M. din Sofia. | NU | DA |
| 4 | VĂTĂU Doru, FRIGURA-ILIASA Flaviu Mihai, ȘURIANU Flavius Dan, CHOYLEV Nicola | AUF | La qualité de l'énergie électrique transférée entre l'Europe de l'Est et l'Europe de l'Ouest | 1PS426/20 | 14,000 | 2 | U.P. din Timișoara; U.P.S. din Toulouse; U.T.C.M. din Sofia. | NU | DA |
| 5 | Vatau Doru, FRIGURA-ILIASA Flaviu Mihai Surianu Flavius Dan, Cambronne Jean Pascal, Choylev Nicolas, Ursa Dana, Iliia Iliiev | AUF | Système de formation continue par la recherche dans le domaine de la maintenance des installations électriques | A.U.F.-6301PS320 (2005/2007) | 14,000 | 2 | U.P. Timisoara, U.P.S. Toulouse, U.T.C.M. Sofia, F.R.G. Timisoara | DA | NU |
| 6 | FRIGURA-ILIASA Flaviu Mihai | AUF | Grant pour Perfectionnement et formation individuelle dans le domaine des matériaux électriques | 02201PF380/2005 | 2,400 | 1 | Universite PAUL SABATIER Toulouse | NU | DA |

NG - National Grants/Projects

| Nr. crt. | Echipa de cercetare | Tipul grantului | Denumirea grant (proiect) | Nr. grant (proiect) / An | Valoare grant (proiect) [€] | Nr. de ani | Beneficiar | Poziția în cadrul echipei | |
|----------|---|-----------------|---|---------------------------|-----------------------------|------------|-------------------------------|---------------------------|--------|
| | | | | | | | | Director | Membru |
| 1 | FRIGURA-ILIASA Flaviu Mihai, POPA Cristian, MĂȚIU-IOVAN Liliana, ZENG Eva | CEEX | Îmbunătățirea performanțelor funcționale ale echipamentelor de protecție împotriva supratensiunilor cu varistoare pe baza de ZnO pentru aplicații la joasă tensiune | ET33 5908-18.09.2006/2008 | 28,400 | 3 | U.P.T. | DA | NU |
| 2 | BIRIESCU Marius, MOȚ Marțian, FRIGURA-ILIASA Flaviu Mihai | PNCDI | GENEX - Studiul excitației generatoarelor sincrone | 21040/2007/2009 | 30,000 | 2 | U.P.T., U.E.M., Univ. Craiova | NU | DA |

CC - Consultancy Grants

| Nr. crt. | Echipa de cercetare | Denumirea contractului | Nr. contract / An | Valoare contract [€] | Nr. ani | Beneficiar | Poziția în cadrul echipei | |
|----------|---|---|--|----------------------|---------|---|---------------------------|--------|
| | | | | | | | Director | Membru |
| 1 | Moga M., Surianu F.D., Vuc G., FRIGURA-ILIASA Flaviu Mihai. s.a. | Asistență tehnică pentru traducerea și redactarea documentațiilor tehnice referitoare la echipamentele destinate stațiilor electrice de 400 kV | 625/02.04.2001 AD1/09.01.2002 | 49400 | 3 | CONEL STD Timisoara | NU | DA |
| 2 | Moga M., Surianu F.D., Vuc G., FRIGURA-ILIASA Flaviu Mihai. s.a. | Asistență tehnică pentru traducerea și redactarea documentațiilor tehnice referitoare la echipamentele destinate stațiilor electrice de 400 kV | 94/23.06.2004 AD1: 2005 | 35700 | 3 | TRANSELECTRICA STD Timisoara | NU | DA |
| 3 | FRIGURA-ILIASA Flaviu Mihai, VĂTĂU Doru, ȘURIANU Flaviu Dan, MOGA Mihai | Evaluarea viabilității sistemelor de securitate și de tip SCADA aplicabile în cazul rețelelor de termoficare | 87/ 26.05.2008 | 2121 | 1 | S.C. ELSACO Electronic S.R.L. Bucuresti | DA | NU |
| 4 | FRIGURA-ILIASA Flaviu Mihai, VĂTĂU Doru, ȘURIANU Flaviu Dan | Inercarea a 18 buc. DRV-uri | 36/2005 | 2207 | 1 | S.C. SMART S.A. | NU | DA |
| 5 | FRIGURA-ILIASA Flaviu Mihai, VĂTĂU Doru, ȘURIANU Flaviu Dan | Verificarea caracteristicilor statice ale unui lot de microîntrerupătoare electrice de joasă tensiune | 1205 / 2003 | 2268 | 1 | TRANSELECTRICA STD Timisoara | NU | DA |
| 6 | FRIGURA-ILIASA Flaviu Mihai, coordonator, precum și alții, conform listei: http://www.colterm.ro/application/media/upload/user/files/termoficaretm/termoficaretm/expert.html | „Re tehnologizarea sistemului centralizat de termoficare din Municipiul Timișoara în vederea conformării la normele de protecția mediului privind emisiile poluante în aer și pentru creșterea eficienței în alimentarea cu căldură urbană” | POS MEDIU, Axa Prior. 3 SMIS 16828 | 58.346.720 | 3 | COLTERM S.A. Timisoara | DA | NU |

Anexes

1. S.C. Protenergo S.A. Timisoara

ROMANIA
CAMERA DE COMERT SI INDUSTRIE
TIMIS
Județul
OFICIA REGISTRULUI COMERTULUI

CERTIFICAT DE ÎNMATRICULARE

Firma * PROTENERGO * S.A.

cu sediul în TIMISOARA

str. CONSTANTA nr. 3 bloc

sc. et. apł. județul / sectorul TIMIS cod postal 1900

este înmatriculată în registrul comerțului sub

Nr. J.35/ 132 din 06.02.2001

Cod SIRUELS 3293567

seria A 367186 Data eliberării 07 FEB. 2001

OFICIUL REGISTRULUI COMERTULUI TIMIS

Director
Ec. FLOARE BISCA

ROMANIA
CAMERA DE COMERT SI INDUSTRIE

CERTIFICAT DE ÎNREGISTRARE

Firma: PROTENERGO S.A.

Sediul social: Timisoara, B-dul VASILE PARVAN, Nr. 2, Județul Timis

Activitatea principală: 3162 - Productia altor componente electrice

Cod Unic de Înregistrare: 13693618

Statut fiscal: R

Nr. de ordine în registrul comerțului: J35/132/06.02.2001

Data emiterii certificatului: 22.08.2002

Seria A 183975

Presedinte
Emil Mateescu

MINISTERUL FINANTELOR

CERTIFICAT DE ÎNREGISTRARE FISCALA

PROTENERGO SA

TIMISOARA județ: Timis cod postal :1900
CONSTANTA nr.3
Autorizație: J35/132/2001 2/72888

Codul dvs. de înregistrare fiscală este: R13693618

Emitent - Director General
Semnatura

Data emiterii: 09.02.2001
Data emiterii documentului 09.02.2001



S.C. PROTENERGO S.A. Timișoara
 Str. Constanța nr. 3, tel. 056-165667
 B-dul V. Pârvan nr. 2D, tel./fax 056-204364
 1900 TIMIȘOARA, România

TECHNICAL CARD

Product **OVERVOLTAGE PROTECTED MULTIPLUG BLOCK**
 Type: **BMS 01**

BMS 01 is formed from a protection module against overvoltages which is using metal oxide based varistors, included in a multi-plug block.

It is made to assure either the household consumers on any type of overvoltages, which can accidentally appear in the electric supplying network, by a direct or indirect thunder stroke applied to the network or by an intern overvoltage.

Among the consumers that can be protected by **BMS 01** supplying system can be mentioned: calculation technique (PC, printers, monitors), TV video, audio, equipments, electro-household consumers (cooking machines, microwave ovens, refrigerators, washing machines).

The product is realized in accordance with the National and European standards (DIN VDE 0675, NFC 61740/07/95), taking in counter the D protection group, protecting the stacker-plug contact. The **BMS 01** product can work in electric installation systems together with the surger-arresters of A, B and C classes, accordingly to DIN VDE 0675, assuring in this way a consumers complete protection.

Permanent functioning regime id indicated by a neon lamp assembled on the module. The illuminating lamp power can indicate a supra-voltage.

This module is not assuring a supplementary overcurrent or short circuiting currents protection, being an overvoltage protection. It acts only if appear supra-currents generated by the voltage supplying wave increase. It is electromagnetic compatible.

It is being plugged in and by it can be supplied four, eight consumers maximum, which summed total power cannot overcome 2500 W.

Technical dates:

| | |
|---|-----------------------|
| Nominal voltage: | 220 – 250 V |
| Maximum nominal current: | 10 A |
| Nominal supplying frequency: | 50 – 60 Hz |
| Leaking current (permanent regime): | < 20 μ A |
| Protection level (8/20 μ seconds wave): | 2,5 kV |
| Response time: | < 20 ns |
| Energy absorption capacity (8/20 μ seconds wave): | 5 kA, 520 J |
| Exploiting temperature: | -20°C...+40°C |
| Dimensions: | 250 x 65 x 40 mm |
| Mass: | 350 g |
| Carcass: | Monokroussos (UL94VO) |
| Cable length: | 1,5 m (\pm 5%) |



S.C. PROTENERGO S.A. Timișoara
 B-dul V. Pârvan nr. 2D, tel./fax 0256-204364
 Mobil: 0722-294648
 1900 TIMIȘOARA, România
 e-mail: surianu@et.utt.ro
<http://www.protenergo.ro>

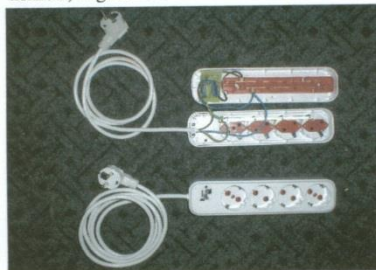
Către,

OFERTĂ

Pentru achiziționarea produsului:

BLOC MULTIPRIZĂ PROTEJAT LA SUPRATENSIUNI BMS 01

BMS 01 este destinat asigurării protecției consumatorilor electrici de joasă tensiune (220 – 250 V) la variațiile de tensiune care pot să apară în rețeaua electrică de alimentare. Protejează consumatorii electrici, atât la șocurile de tensiune produse de descărcările electrice atmosferice (fulgere, trăsnete), cât și la cele care apar la efectuarea unor manevre sau lucrări în rețeaua electrică de alimentare. Totodată, în funcționare normală, asigură filtrarea tensiunii de alimentare.



Blocul multipriză protejat la supratensiuni tip BMS 01. Vedere de ansamblu și detaliu constructiv.

Consumatorii electrici care pot fi protejați alimentându-i prin **BMS 01** sunt: tehnică de calcul (calculatoare, imprimante, monitoare etc.), televizoarele, aparatura electronică medicală echipamentele audio, video, aparatura de măsură și control, consumatori electrocasnici (mașini de gătit, cuptoare cu microunde, frigidere, mașini de spălat, aspiratoare, roboți electrici de bucătărie, centrale termice de apartament, instalații de climatizare etc.).

Produsul **BMS 01** este alcătuit dintr-un modul de protecție împotriva supratensiunilor, echipat cu trei varistoare pe bază de ZnO, care este introdus într-un bloc multipriză cu patru sloturi și care are un cablu prelungitor de 1,5 – 2 m. Concepția și execuția produsului sunt conforme cu standardele europene (DIN VDE 0675, NFC 61740/07/95). **BMS 01** are clasa de protecție D, protejând contactul fișă – priză, dar poate funcționa în instalațiile electrice și împreună cu modulele de protecție la supratensiuni, clasele A, B și C, asigurând astfel o protecție totală a consumatorilor electrici. Schema electrică a modului de protecție ține seama de situația rețelei electrice de distribuție din România, fiind realizată cu trei varistoare, care protejează complet consumatorii sensibili la supratensiunile ce pot să apară între fază fază și neutru, fază și pământ, și între neutru și pământ.

BMS 01 este un echipament de protecție la șocuri de tensiune complementar surselor autonome de tip UPS, surse care asigură, în general, printr-un acumulator, numai menținerea alimentării consumatorului un anumit timp, după întreruperea tensiunii rețelei. Prin funcția sa de protecție, **BMS 01** protejează la supratensiuni inclusiv sursele autonome de tip UPS, iar dacă sursele tip UPS au înglobate dispozitive de protecție, **BMS 01** asigură acestora un nivel de protecție suplimentar.

Este compatibil electromagnetice. Prin intermediul său se pot alimenta mai mulți consumatori electrici, cu condiția ca suma puterilor acestora să nu depășească 2500 W.

BMS 01 este primul modul de protecție contra supratensiunilor, clasa D, proiectat și fabricat în România, de către S.C. PROTENERGO S.A. Timișoara, unicul producător de asemenea echipamente pe plan național, la calitate și preț competitive pe piața europeană.

Date tehnice:

| | |
|--|------------------|
| Tensiune nominală: | 220 – 250 V |
| Curent nominal maxim: | 10 A |
| Frecvența nominală de alimentare: | 50 – 60 Hz |
| Curent de scurgere (în regim permanent): | < 20 μA |
| Nivel de protecție (undă 8/20 μs): | 2,5 kV |
| Timp de răspuns: | < 20 ns |
| Capacitate de absorbție în energie (undă 8/20 μs): | 5 kA, 520 J |
| Temperatură de exploatare: | -20 °C...+40 °C |
| Dimensiuni: | 225 x 55 x 45 mm |
| Masă: | 350 g |
| Carcasă: | ELBI (UL94VO) |
| Lungime cablu: | 1,5 + 2 m (± 5%) |

Prețul de vânzare cu amănuntul este 21 EURO/buc. (25 EURO/buc cu T.V.A. inclus), la cursul BNR din data achiziționării.
 La achiziționarea produsului tip **BMS 01** în cantități mai mari, S.C. PROTENERGO S.A. oferă următoarele prețuri promoționale:

| Cantitate (bucăți) | Preț (EURO) | |
|--------------------|-------------|-----------|
| | Fără T.V.A. | Cu T.V.A. |
| 11 ÷ 75 | 20 | 23,8 |
| Peste 75 | 19 | 22,6 |

PROTENERGO S.A. oferă 12 luni garanție pentru orice echipament achiziționat. Se asigură și service postgaranție.

Director General S.C. PROTENERGO S.A. Timișoara
Prof. dr. ing. Flaviu Dan ȘURIANU



UNIVERSITE PAUL SABATIER

LABORATOIRE DE GÉNIE ÉLECTRIQUE

ASSOCIE AU C.N.R.S.


118, route de Narbonne
31062 Toulouse Cedex (France)U. F. R. Physique - Chimie
Automatique

Toulouse, le 29/06/01

N/Ref.

V/Ref.

Prise de PROTENERGO SA
Timisoara le 6.07.2001
au nr 044/6.07.2001



Rapport d'essais effectués selon la norme NF 61-740 (Juillet 1995)
Sur le module de protection BMS-01
Fabricant : SC PROTENERGO SA Timisora-Roumanie

Date : 29/06/01
Opérateur : Talhi
Nombre de feuilles : 2

I-(26.2.1) -Essai de vérification de la tension résiduelle au courant nominal de décharge.

| Bornes essayées | Nombre de chocs- Onde 8/20 microseconde | Tension mesurée (Volt) | Courant mesuré (Ampère) | Tension Norme (Volt) |
|-----------------|---|------------------------|-------------------------|----------------------|
| Phase/neutre | 2 | 1200 1225 | 4960 5020 | <1500 |
| Phase/terre | 2 | 1110 1125 | 4890 4900 | <1500 |
| Neutre/terre | 2 | 1145 1140 | 4960 4950 | <1500 |

II- (26.3)- Essai de fonctionnement au courant nominal de décharge

- Après 4 séries de 5 chocs à $I_d=5kA$, aucun signe de dégradation n'est apparu sur le module.



U. F. R. Physique - Chimie
Automatique

UNIVERSITE PAUL SABATIER
LABORATOIRE DE GÉNIE ÉLECTRIQUE

ASSOCIE AU C.N.R.S.
118, route de Narbonne
31062 Toulouse Cedex (France)

Toulouse, le
N/Ref.
V/Ref.

**RAPPORT D'ESSAIS EFFECTUES SELON LA NORME
NF C 61 740
SUR PROLONGATEUR type BMS-01 230V-10A**

Nom du fournisseur : S.C PROTENERGO S.A Timisora

Date : reçu le 10/05/2003
Opérateur : C.TALHI
Nombre de feuille : 02

Marque : prolongateur type BMS-01 protection contre les surtensions.
Tension : 230V
Courant nominal: 10A

RESULTATS DES EXAMENS

I-26.2.1 Essai de vérification de la tension de seuil au courant nominal de décharge

Sanction : Conforme

II-26.3 Essai de fonctionnement au courant nominal de décharge

Sanction : Conforme

Directeur

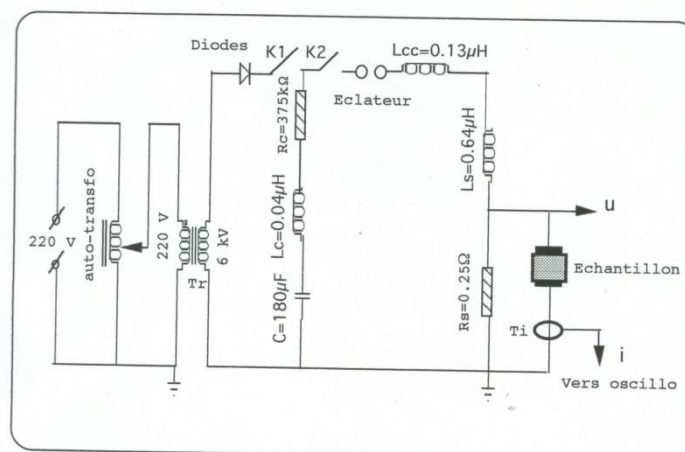
Mr. BUI AI

UNIVERSITÉ PAUL-SABATIER
Laboratoire de Génie Électrique
associe au C.N.R.S.
118, route de Narbonne
Bât. : 3R3 - H. Brunet
31062 TOULOUSE CEDEX

Responsable des Essais

Mr.C.TALHI

Bât. Recherche de Physique III R3 - Tél. (33) 05 61 55 67 97 - e-mail : secretariat@iget.ups-tlse.fr - Télécopie (33) 05 61 55 64 52



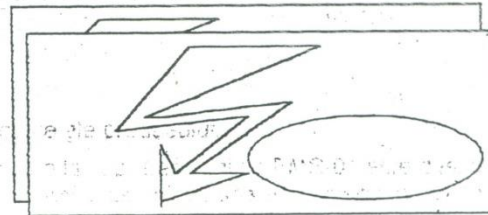
Laboratorul de INALTA TENSIUNE**Catedra de Electroenergetică**

Facultatea de Electrotehnică
 Universitatea Politehnică Timișoara
 1900 Timișoara B-dul Vasile Pârvan Nr.2

Numar FAX : 056 - 204.364

E-mail: viorel@et.utt.ro

Data: 14.05.2001

**BULETIN DE INCERCARE Nr.01/2001**

1. Produsul: Bloc multipriză cu protecție la supratensiuni tip BMS-01.
2. Solicitant: S.C. PROTENERGO Timișoara
 Convenție de consulting și Know – How Nr. 1 /14.05.2001
3. Încercări efectuate: Verificări și încercări privind caracteristicile electrice:
 - 3.1. Verificarea tensiunii de prag;
 - 3.2. Încercarea cu tensiune de impuls de trăsnet standardizat.

4. Încercări executate de către:

Conf.dr.ing.Viorel Titihăzan
 Sef lucr.ing.Anton Chirleşan
 Conf.dr.ing.Mariana Titihăzan
 Sef lucr.ing.Ana Nicolaescu

de la:

Fac.Electrotehnică
 Fac.Electrotehnică
 Fac.Electrotehnică
 Fac.Electrotehnică

Semnătura:

Titihăzan
Anton
M. Titihăzan
Nicolaescu

5. Concluzia: se comunică rezultatele - vezi Cap.3.

6. Buletinul

Intocmit de: conf.dr.ing.Viorel Titihăzan
 Verificat – Sef Colectiv TTI – Prof.dr.ing.Viorel Negru

Titihăzan
Negru

7. Aprobat

Sef de Catedră EE - Prof.dr.ing.Stefan Kilyeni

Decanul Fac.Electrotehnică - Prof.dr.ing.Dumitru Toader
 Buletinul conține 2 pag.



1. Tema:

1.1. Verificări și încercări privind caracteristicile electrice ale produsului.

1.2. Domeniul de utilizare – Blocul multipriză cu protecție la supratensiuni tip BMS-01 este destinat alimentării cu tensiune alternativă 220 V, $f = 50$ Hz a tehnicii de calcul, aparaturii electronice, FAX-ur și aparaturii de măsură care necesită o protecție suplimentară la supratensiuni.

1.3. Norme de încercare:

Caiet de sarcini Bloc multipriză cu protecție la supratensiuni tip BMS-01;

Catalog "Power Development" LTD Cheshunt Grande Bretagne;

Norme Francaise NF C 41-101 Techniques des essais a haute tension Part.I;

Norme Francaise NF C 41-102 Techniques des essais a haute tension Part.II;

STAS 6669/1, 2, 3-86 Incercări la înaltă tensiune;

2. Programul verificărilor și încercărilor:

2.1. Verificarea tensiunii de prag;

2.2. Incercarea cu tensiune de impuls de trăsnet standardizat.

3. Rezultatele verificărilor și încercărilor:

3.1. Verificarea tensiunii de prag s-a efectuat cu o sursă de 10 kVcc tip SIT 5040 RV produsă de Institutul de Fizică Atomică, iar măsurarea tensiunii și curentului s-a efectuat cu aparate tip DU 20 seriile 6801319, 9085893 rezultând pentru curentul $I_{prag} = 1$ mA, tensiuni de prag $U_{prag} = 395$ V, 400 V și respectiv 405 Vcc.

Rezultat: corespunde.

3.2. Incercarea cu tensiune de impuls de trăsnet standardizat s-a efectuat cu un Generator de impulsuri repetat cu tiristoare – Brevet OSIM România Nr. 115.583 B – ITA 1,2/50 μ s, 9,6/400 μ s : respectiv ITC 250/2500 μ s, iar măsurătorile au fost efectuate cu Osciloscopul Hameg Instruments HM 303-4, cu două canale rezultând pentru tensiuni maxime de impuls: $U_{aplicat} = 800$ Vmax... 1100 Vmax, tensiunile reziduale pe varistorul din ZnO Urez = 440 Vmax...490 Vmax .

Rezultat: corespunde.

3. Observatii și concluzii: Blocul multipriză cu protecție la supratensiuni tip BMS-01 limitează valorile supratensiunilor și a corespuns la verificările și încercările menționate în prezentul buletin.

Laboratorul de înaltă Tensiune al Universității Politehnica Timișoara a fost fondat în anul 1927 de către prof.dr.ing.Plauțius Andronescu – a primit Autorizarea de funcționare Nr.44/80 și ar aparatura de măsură și încercare atestată metrologic - Buletinele de verificare metrologică Nr.1070/ 27.03.1997 Laboratorul 1 Timișoara, Biroul Român de Metrologie Legală, Inspectia Interjudețeană de Metrologie Timiș, Buletine de verificare metrologică Nr.TM 0491119, TM 0491120/15.10.1999, TM 0491128/ 12.11.1999 unitatea emitentă - SC ELECTRICA SA S.D. Timisoara, Laboratorul de Metrologie Sectia PRAM Tc.

BULETINUL DE INCERCARE NU POATE FI REPRODUS TOTAL SAU PARTIAL, FARA
ACORDUL SCRIS AL L.I.T. - Laboratorul de înaltă Tensiune Politehnica Timișoara.

Laboratorul de INALTA TENSIUNE**Catedra de Electroenergetică**

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Universitatea Politehnică Timișoara

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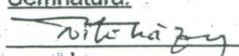

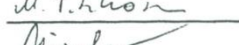

Numar FAX : 056 - 204.364

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Data: 14.05.2001

BULETIN DE INCERCARE Nr.01/2001

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2. Solicitant: S.C. PROTENERGO Timișoara
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| <u>4. Încercări executate de către:</u> | <u>de la:</u> | <u>Semnătura:</u> |
|---|--------------------|---|
| Conf.dr.ing.Viorel Titihăzan | Fac.Electrotehnică |  |
| Sef lucr.ing.Anton Chirleşan | Fac.Electrotehnică |  |
| Conf.dr.ing.Mariana Titihăzan | Fac.Electrotehnică |  |
| Sef lucr.ing.Ana Nicolaescu | Fac.Electrotehnică |  |

5. Concluzia: se comunică rezultatele - vezi Cap.3.

6. Buletinul

Intocmit de: conf.dr.ing.Viorel Titihăzan

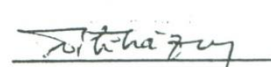

Verificat – Sef Colectiv TTI – Prof.dr.ing.Viorel Negru

7. Aprobat

Sef de Catedră EE - Prof.dr.ing.Stefan Kilyeni

Decanul Fac.Electrotehnică - Prof.dr.ing.Dumitru Toader

Buletinul conține 2 pag.




Proiect Brokinnovoucher



**CENTRUL REGIONAL
DE INOVARE ȘI TRANSFER TEHNOLOGIC**
Str. Proclamația de la Timișoara nr. 5, Timișoara 300054, România
Tel: +40-356-178753 Fax: +40-356-178753
e-mail: office@tehimpuls.ro, website: www.tehimpuls.ro

Atestat

| | |
|---------------------|-------------------|
| ASOCIAȚIA TEHIMPULS | |
| INTRARE TESIRE | NR. 383 |
| ZIUA 23 | LUNA 05 ANUL 2016 |

Se atestă prin prezenta că Dl. Dr. Ing. Flaviu Mihai FRIGURĂ – ILIASA a desfășurat, în perioada 2008-2009 o laborioasă activitate în cadrul Proiectului *BROKINNOVOUCHER – Sprijin pentru cooperarea și inovarea întreprinderilor mici și mijlocii din zona România – Ungaria*, cod RO – 2006/018 – 446.01.01.01.25, finanțat prin Programul Phare CBC România-Ungaria, având o valoare totală de 161.000 Euro.

Dumnealui a fost responsabil de proiect în relația cu Universitatea POLITEHNICA Timișoara (U.P.T.), din partea Asociației pentru Cercetare Multidisciplinară din Zona de Vest (A.C.M.V.), fiind coordonatorul unei echipe cercetători-cadre didactice din cadrul Universității POLITEHNICA Timișoara, formată din: Doru Vătău, Felicia Coroiu, Constantin Bărbulescu, Liliana Mățiu-Iovan, Marius Rangu și Adriana Albu, având ca obiectiv implementarea a 9 vouchere de inovare bazate pe cercetări avansate din U.P.T., către mediul economic din România și Ungaria.

Președinte al Asociației TEHIMPULS - Centrul Regional de Inovare și Transfer Tehnologic

Manager Proiect BROKINNOVOUCHER

Raluca CIBU-BUZAC

Timișoara,

23 mai 2016

POS Mediu - Colterm

www.colterm.ro/application/media/upload/user/files/termoficaretm/termoficaretm/experti.html



Acest site este cofinanțat din Fondul de Coeziune prin Programul Operational Sectorial Mediu 2007-2013



Retehnologizarea sistemului centralizat de termoficare din Municipiul Timisoara

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Obiective

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Opinii

Echipei Proiectului

Implementarea proiectului este asigurată printr-o echipă de 16 experți:

- 6 Experți principali
- 10 Experți secundari

Experți principali:

1. Coordonator de Echipa (Team Leader): **Flaviu Mihai FRIGURA**
2. Expert în termoficare: **Rodica FRUNZULICĂ**
3. Expert în publicitate și comunicare: **Oana ISLAM**
4. Expert în achiziții: **Violeta SIMIONESCU**
5. Experți financiari: **Elena VELICU/ Denisa POPESCU**
6. Expert protecția mediului: **Iulia DINU**

Experți secundari:

1. Expert energetică : **Irina DUICĂ**
2. Experți instituționali: **Silviu STOICA/ Laura NENA**
3. Expert instruire: **Liliana CHIRILĂ**
4. Expert financiar pentru rambursarea cheltuielilor: **Dan DIMA**
5. Jurist: **Laura SMARANDA**
6. Expert IT: **Eugen NISTOR**
7. Expert grafică și design : **Nadia MUTU (PINTOIU)**
8. Experți PR: **Raluca GRIGORAS/ Cristian NICULAE**
9. Expert licitare - contractare: **Ileana FĂLCESCU**
10. Expert desulfurare: **Moldoveanu Bogdan Grig**

Calendar activitati

20160612:
Nici un eveniment azi

Lunie 2016

| D | L | M | Mi | J | V | S |
|----|----|----|----|----|----|----|
| | | | 1 | 2 | 3 | 4 |
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Statistica