HABILITATION THESIS

Universitatea Politehnica Timişoara

Contributions to the Optimal Structures of the Electromechanical Systems and the Electric Power Quality

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I. Curriculum Vitae

1. Desired employment / Occupational field

- Politehnica University of Timişoara, Faculty of Electrical and Power Engineering, Dept. Of Electrical Engineering, Timişoara, Associate Professor Ph.D.

2. Education /degrees

- **1987- Engineer -**"Traian Vuia" Polytechnic Institute of Timişoara, Faculty of Electrical Engineering;
- **2000- PhD. in technical sciences -** *Analysis of the behavior of low and medium power three-phase squirrel cage induction motors at their power network supplying through a static frequency converter*. The thesis was carried out under the coordination of the Prof. Ph.D. Eng. Ioan Novac.

3. Work experience

- **1987 - 1990 – Trainee Engineer -** Activity on testing electrical machines – ICM Reşiţa;
- **1989 - 1990 – Head of trial stand on electrical machines;**
- **1990 - 1995 – Engineer -** Electrical machines design, Electromotor SA Timişoara;
- **1990 - 1995 – Associated assistant -** Politehnica University of Timişoara, Faculty of Electrical and Power Engineering;
- **1995 - 2000 – Assistant -** Politehnica University of Timişoara, Faculty ofElectrical and Power Engineering;
- **2000 - 2007 – Lecturer -** Politehnica University of Timişoara, Faculty of Electrical and Power Engineering;
- **2007 - present – Associate Professor -** Politehnica University Timişoara, Faculty of Electrical and Power Engineering.

II. Overview of Activity and Results, 2001 - 2014

1. Teaching and professional development activity

- I conducted seminar, laboratory, and project classes as an assistant professor from 2000 to 2007 and associate professor from 2007 to the present.
- I have taught subjects closely related to my research fields: *Electric drives*, *Electromechanical drives*, *Electric drives and converters*, *Advanced driving systems*, *Electric drives design*, *Electric servomotors and the intelligent motion control*, *Electrical machines*, *The technology of producing electrotechnical products, Computer graphics, Matlab and Simulink*.
- I introduced two new disciplines:
  - *Electrical servomotors and the intelligent motiont control* - Bachelor's degree programme;
  - *Embedded systems- Industry* - Master's degree programme.

Overview of Activity and Results, 2001 - 2014

- I coordinated over 60 diploma projects.
- During 2001-2014, I published:
  - five specialty books specialist;
  - 2 books in electronic format as single author;
  - 2 laboratory guidances;
  - two chapters in international monographis.

Books and chapters

1. Rui Estevez Araujo, **Muşuroi Sorin**, sa., *Induction motor. Modelling and control , Chapter 2. The Behavior in Stationary Regime of an Induction Motor Powered by Static Frequency Converters*, pp. 45 – 72, Editura InTech Europe, Rijeka, Croaţia, ISBN 979-953-307-716-0, 2012.
2. Raul Gregor, **Muşuroi Sorin**, sa., *Induction Motor Drives. Chapter The Scalar Control of Three-Phase Induction Machines*, InTech Europe, Rijeka, Croaţia, ISBN 978-953-51-4314-7.
3. **Muşuroi Sorin,** *Maşina de inducţie alimentată prin convertoare statice de frecvenţă*, Editura Eurostampa, pp. 210, ISBN 978-606-569-815-4, 2014.

4. Valentin Năvrăpescu, Constantin Ghiţă, **Muşuroi Sorin**, Maşini şi acţionări electrice, Editura Academiei Oamenilor de Ştiinţă din România, pp. 149 , ISBN 978-606-837-139-9, 2011.
5. **Muşuroi Sorin**, Popovici Dorin, *Acţionări electrice cu servomotoare*, Editura Politehnica Timişoara, pp. 537, ISBN (10) 973-625-352-X, ISBN(13) 978-973-625-352-2, 2006.
6. Atanasiu Gheorghe, **Muşuroi Sorin**, Popovici Dorin, *Modelare dinamică prin SIMULINK. Maşini electrice. Acţionări electrice. Convertoare statice*, Editura Politehnica Timişoara, pp. 162, ISBN (10) 973-625-351-X, ISBN(13) 978-973-625-351-5, 2006.
7. Bartzer Ştefan, **Muşuroi Sorin**, *Bazele tehnologiei produselor electrotehnice*, Îndrumător de lucrări, Litografia Universităţii POLITEHNICA Timişoara, pp. 180, 1998.
8. Bartzer Ştefan, **Muşuroi Sorin**, *Tehnologia de fabricaţie a produselor electrotehnice*, Îndrumător de lucrări, Litografia Universităţii POLITEHNICA Timişoara, pp. 192, 1997.

- *In recognition of my work with students, I was rewarded with the prize* ***Bologna professor****, in 2009.*

2. Research activity

During 2001-2014 I published a total of 91 works of which:

- 11 in ISI indexed journals and BDI indexed journals;
- 20 in ISI Proceedings;
- 19 in BDI conferences proceedings;
- 11 in international conferences proceedings;
- 30 in volumes of journals, bulletins or national conferences.

I participated in:

- ➢ 2 grants as the representative in charge on behalf of Politehnica University of Timişoara;
- ➢ 3 international projects as a manager;
- ➢ 6 grants and 3 contracts as a member of the research team, of which 1 was international and 2 national.

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Papers

1. **Muşuroi Sorin**, Olărescu Nicola Valeriu, Vătău Doru, Şorândaru Ciprian, *Equivalent parameters of induction machines windings in permanent regime. Theoretical and experimental determination*, Proceedings of the 9th International Conference on POWER SYSTEMS (PS '09), Budapest Tech, Hungary, 3-5 Septembrie, pp. 55-62, ISBN 978-960-474-112-0, ISSN 1790-5117, 2009 – **Indexată ISI**.
2. **Muşuroi Sorin**, Şorândaru Ciprian, Olărescu Nicola Valeriu, Marcus Svoboda, *Mathematical Model of Three-Phase Asynchronous Servomotors in Stationary Non-sinusoidal Regime,* Proceedings of the 9th International Conference on POWER SYSTEMS (PS '09), Budapest Tech, Hungary, 3-5 Septembrie, pp. 123-126, ISBN 978-960-474-112-0, ISSN 1790-5117, 2009 – **Indexată ISI**.

3. **Muşuroi Sorin**, Vătău Doru, Andea Petru, Şurianu Flaviu, Frigură-Iliasa Flaviu, Bărbulescu Constantin, *Analysis of the Magnetic Losses from the Induction Machines Supplied by Inverters,* Proceedings of The International Conference on Computer as a Tool, IEEE Region 8, EUROCON 2007, Warsaw, Poland, 9-12 Septembrie, pp. 1800-1809, ISBN 1-4244-0813-X, Library Of Congress 2006937182, 2007 – **Indexată ISI**.
4. **Muşuroi Sorin**, Svoboda Marcus, Şorândaru Ciprian, Koblara Thomaque, Olărescu Nicola Valeriu, *Deep bar effects produced by PWM power supplies in induction machines: Application to rotor Parameters determination*, Conference Proceeding of International Conference on Computer as a Tool - Joint with Conftele, EUROCON 2011, Lisbon, Code 85630, 27 - 29 Aprilie, art. no. 5929282, 4 pagini, ISBN 978-142447486-8, 2011 – **Indexată IEEE, SCOPUS, INSPEC.**

5. **Muşuroi Sorin**, Şorândaru Ciprian, Greconici Marian, Olărescu Nicola Valeriu, Weinman Martin, *Low-Cost Ferrite Permanent Magnet Assisted Synchronous Reluctance Rotor an Alternative Solution for Rare Earth Permanent Magnet Synchronous Motors*, Proceedings of 39th Annual Conference of the IEEE Industrial-Electronics-Society (IECON), Vienna, 10-14 Noiembrie, pp. 2966-2970, ISBN 978-1-4799-0224-8, ISSN 1553-572X, 2013 – **Indexată ISI.**.
6. Şorândaru Ciprian, **Muşuroi Sorin**, Svoboda Marcus, Olărescu Nicola Valeriu, Popovici Dorin, *Field Oriented Control Drives for Naval Mechanism*, Proceedings EUROCON 2009, EUROCON '09. International Conference of IEEE, Saint Petersburg, Russia, 18-23 Mai, pp. 717-720, ISBN 978-1-4244-3861-6, 2009 – **Indexată ISI**.

7. Olărescu Nicola Valeriu, **Muşuroi Sorin**, Şorândaru Ciprian, Frigură-Iliasa Flaviu, *Scalar control systems with permanent magnet synchronous motors with sinusoidal current control. Calculatin of speed controller parameters*, Revue Roumaine des Sciences Techniques. Serie Electrotechnique et Energetique, Tome 57, Issue 1, pp. 70-79, ISSN 0035-4066, 2012 – **Revistă indexată ISI.**
8. Olărescu Nicola Valeriu**, Muşuroi Sorin**, *Enhanced Simplified Control Algorithm for Surface-mounted Permanent Magnet Synchronous Motors with Sinusoidal Excitation*, Conference Proceedings 4th International Power Electronics and Motion Control, Conference IPEMC 2004, Xi'am, China, 14-16 August, pp. 1049-1053, ISBN 7-5605-1869-9, 2004 – **Indexată ISI**.

9. Olărescu Nicola Valeriu, **Muşuroi Sorin**, Şorândaru Ciprian, Weinmann Martin, Zeh Stefan, *Optimum Current Control for Wide Speed Range operation of PMSM Drive Without regenerative Unit Utilizing PWM-VSI Overmodulation*, Proceedings of 13th International Conference on Optimization of Electrical and Electronic Equipment OPTIM 2012, Braşov, 24-26 Mai, pp. 612-617, ISBN 978-1-4673-1652-1, 2012- **Indexată IEEE, SCOPUS, INSPEC.**
10. Olărescu Nicola Valeriu, Weinmann Martin, Zeh Stephan, **Muşuroi Sorin**, Şorândaru Ciprian, *Optimum Current Reference Generation Algorithm for Four Quadrant Operation of PMSMS Drive System without Regenerative Unit*, IEEE INTERNATIONAL SYMPOSIUM ON INDUSTRIAL ELECTRONICS (ISIE 2010), Conference Proceeding, Bari, Italia, 4-7 Iulie, pp. 1408-1413, ISBN 978-1-4244-6391-6, 2010 - **Indexată ISI.**

3. University management

- 2008 - I was elected the Scientific Secretary of the Faculty of Electrical and Power Engineering for a period of 4 years;
- At the same time, I was a member of the Board of the Faculty;
- 2012 - I was elected Senator of the Politehnica University of Timişoara;
- I activated in three committees of the Senate: the Ethics Committee, the Research Committee and The Education Committee;
- Within the Ethics Committee I was elected chairman, a position that qualified me as a member of the Senate Office of Politehnica University of Timişoara;
- When the Ethics committee became the Senate Ethics Committee of the University, I continued to hold the position of chairman of the Ethics Committee of the University, according to the Rector's decision;

Overview of Activity and Results, 2001 - 2014

- 2012 - I was elected member of the Department Board of Electrical Engineering of the Faculty of Electrical and Power Engineering;
- 2013 - I obtained, through competition, the function of Dean of the Faculty of Electrical and Power Engineering. I currently hold the same position.

The quality of the activity presented above is certified by the following:

- Reviewer in ISI Conferences: Annual IEEE Energy Conversion Congress&Exposition ECCE, 2012, 2013 şi 2014 editions, International Conference on Optimization of Electrical and Electronic Equipment OPTIM 2012;
- Reviewer in BDI Conferences: ICEM 2014
- Member of the editorial board of the following journals: International Journal of Electromagnetic and Applications, since 2010, American Journal of Electrical and Electronic Engineering, since 2011;

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Overview of Activity and Results, 2001 - 2014

- Reviewer in scientific journals indexed in international databases: International Journal of Electromagnetic and Applications, since 2010, American Journal of Electrical and Electronic Engineering, since 2011, International Journal of Engineering and Technology Innovation (IJETI), since 2012;
- Member of the International Steering Committee ACEMP-OPTIM-ELECTROMOTION;
- Member of the Scientific Commitee Regional South-East European Conference (RSEEC 2014) and the 9th International Symposium on ADVANCED TOPICS IN ELECTRICAL ENGINEERING ATEE;
- Member of the editorial board of Eurostampa;
- Member of professional international associations: Institute of Electrical and Electronics Engineers USA (IEEE), Verein Deutscher Ingenieure Germany (VDI).

III. Technical Presentation

Three main research areas have been addressed in my **research activity**:

1. The optimal design of AC motors;
2. The optimal control of electrical drives with AC motors;
3. Single-phase power factor correction converters.

1. The optimal design of AC motors

In the domain of **The optimal design of AC motors** two directions were approached:

(i) the study of the skin effect in the high rectangular bars of the rotors of the three-phase inverter fed induction motors;

(ii) the study of the use of ferrite permanent magnets in designing synchronous machines as an alternative to the version with rare earth magnets.

(i) The study of the skin effect in the high rectangular bars of the rotors of the three-phase inverter fed induction motors

This study aims to analyze the skin effect and the consequences it has on the parameters of the rectangular high bar parameters of the rotor of the three-phase induction motor fed by PWM voltage inverters.

The research will highlight the modifications of the parameters of the rotor bars under the conditions mentioned above, comparing to the sinusoidal supplying regime.

The study aims to clarify the behaviour of the induction machine under the condition of non-sinusoidal power, which will serve as a starting point for further studies to establish the optimal constructive-technological design measures to be taken to improve the parameters and implicitly the functional sizes of motors.

In the first phase of the study, the electromagnetic field equations in the high rectangular rotor bar were analyzed in the case of the non-sinusoidal regime given by the presence of inverters in powering induction machine.

In the second stage, I calculated the particular values of the penetration depth for the two extreme moments of the startup process, corresponding to the zero, respective nominal speed.

Finally, the research presented the calculation of the two factors, the changing factor of resistance in alternative current kr(CSF) and the reactance kx(CSF), corresponding to the situation when the motor is fed by PWM inverters under a global form.

The geometries of the rotor with the high bar of rectangular form were taken into account.

Technical Presentation

$$k_{r(CSF)} = \frac{\sum\limits_{\upsilon=1} \xi_{(\upsilon)} \dfrac{\mathrm{sh}2\xi_{(\upsilon)} + \sin 2\xi_{(\upsilon)}}{\mathrm{ch}2\xi_{(\upsilon)} - \cos 2\xi_{(\upsilon)}} I_{(\upsilon)}^2}{\sum\limits_{\upsilon=1} I_{(\upsilon)}^2} = \frac{\sum\limits_{\upsilon=1} \xi_{(\upsilon)} \dfrac{\mathrm{sh}2\xi_{(\upsilon)} + \sin 2\xi_{(\upsilon)}}{\mathrm{ch}2\xi_{(\upsilon)} - \cos 2\xi_{(\upsilon)}} \dfrac{I_{(\upsilon)}^2}{I_{(1)}^2}}{\sum\limits_{\upsilon=1} \dfrac{I_{(\upsilon)}^2}{I_{(1)}^2}}$$

$$k_{x(CSF)} = \frac{\sum\limits_{\upsilon=1} \dfrac{3}{2\xi_{(\upsilon)}} \dfrac{\mathrm{sh}2\xi_{(\upsilon)} - \sin 2\xi_{(\upsilon)}}{\mathrm{ch}2\xi_{(\upsilon)} - \cos 2\xi_{(\upsilon)}} I_{(\upsilon)}^2}{\sum\limits_{\upsilon=1} I_{(\upsilon)}^2} = \frac{\sum\limits_{\upsilon=1} \dfrac{3}{2\xi_{(\upsilon)}} \dfrac{\mathrm{sh}2\xi_{(\upsilon)} - \sin 2\xi_{(\upsilon)}}{\mathrm{ch}2\xi_{(\upsilon)} - \cos 2\xi_{(\upsilon)}} \dfrac{I_{(\upsilon)}^2}{I_{(1)}^2}}{\sum\limits_{\upsilon=1} \dfrac{I_{(\upsilon)}^2}{I_{(1)}^2}}$$

$$\frac{I_{1(\nu)}}{I_{1(1)}} = \frac{U_{1(\nu)}}{U_{1(1)}} \cdot \frac{1}{\nu f_{1r}} \cdot \frac{1}{x_{sc}^*}$$

The values of the ratio $U_{1(\nu)}/U_{1(1)}$ (line voltage), for $m_a \leq 1$ and m_f odd and 3 multiple

ν \ m_a	0.2	0.4	0.6	0.8	1.0
$m_f \pm 2$	0.082	0.151	0.217	0.275	0.318
$m_f \pm 4$	-	-	-	0.01	0.017
$2m_f \pm 1$	0.95	0.816	0.618	0.391	0.181
$2m_f \pm 5$	-	-	-	0.016	0.032
$3m_f \pm 2$	0.221	0.346	0.337	0.22	0.062
$3m_f \pm 4$	-	0.028	0.079	0.13	0.156
$4m_f \pm 1$	0.819	0.392	0.013	0.13	0.068
$4m_f \pm 5$	-	-	0.057	0.104	0.119
$4m_f \pm 7$	-	-	-	0.02	0.049

During the research conducted in this area, the research team designed a program for the determination of the two factors, entitled CALCMOT.

Technical Presentation

The research results were presented in 14 articles as follows: 4 articles in journals indexed BDI, references [11], [12], [13], [14] from the thesis bibliography, 3 articles issued in volumes of ISI conferences, references [15], [16], [17], 3 articles issued in volumes of BDI indexed conferences, references [18], [19], [20], 1 article at an international conference without indexation [24] and 4 articles in national conferences, [28], [29], [30], [31].

In recognition of the results obtained, I was invited to write a chapter entitled *The Behavior in Stationary Regime of an Induction Motor Powered by Static Frequency Converters* of the book entitled *Induction motor. Modeling and control.*

The book was published in 2012, at InTech Europe Publishing House, under the coordination of Professor Rui Estevez Araujo.

I also published the specialty book *The Induction Motor Fed by Static Frequency Converters,* as a single author.

During the implementation of the study, I participated as a member of a PNCDI 2 grant (partner P2) entitled, *The Optimizing of Electric Hydro-generators Windings to Increase Energy Efficiency*, manager Prof. PhD. Eng. Marius Biriescu.

(ii) The study of the use of ferrite permanent magnets in designing synchronous machines as an alternative to the version with rare earth magnets

In the second domain, together with the team whom coordinator I was, we conducted an extensive study on the possibility of designing a synchronous motor using ferrite permanent magnets to replace the current, more expensive technical solution based on rare-earth magnets.

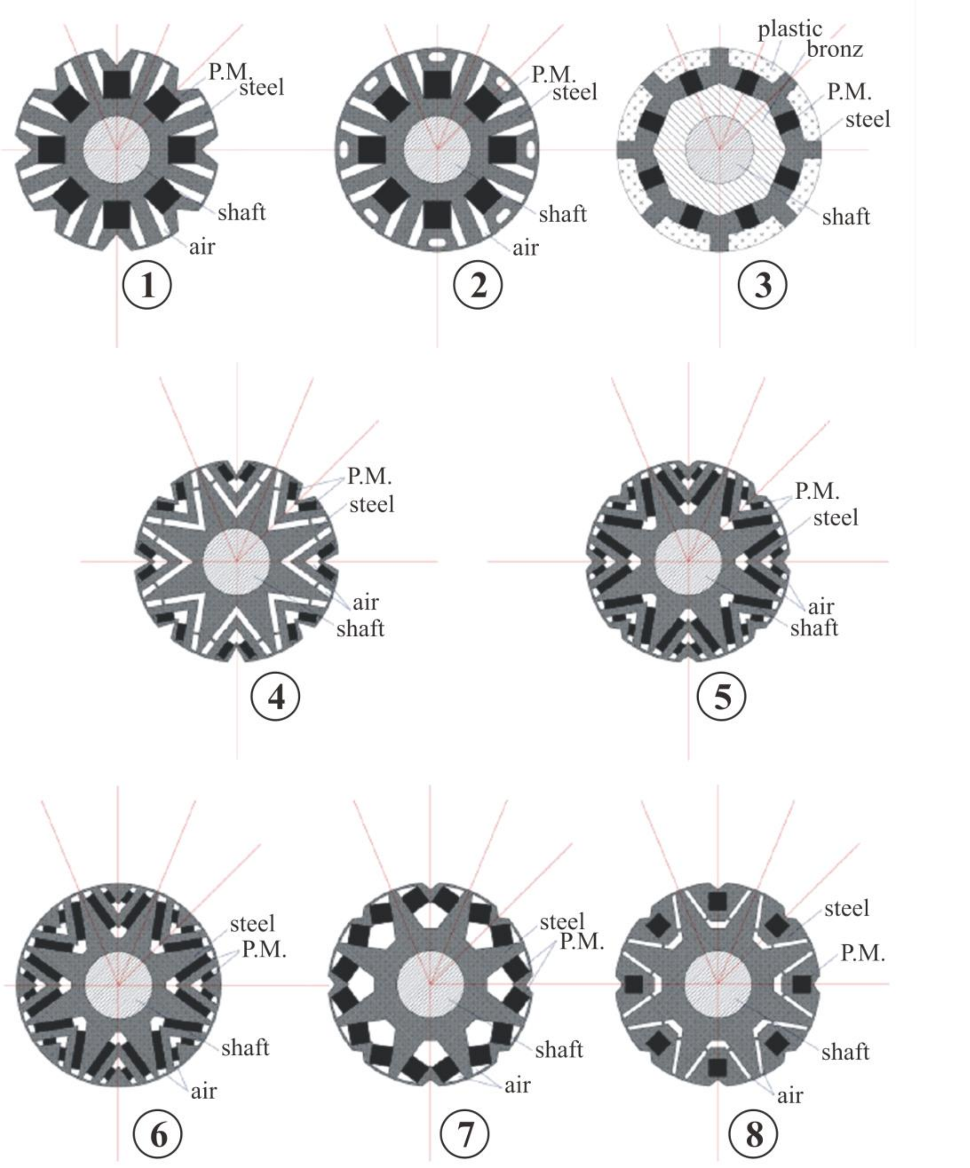
After analyzing the characteristics of ferrite magnets, under a large coercive field to about 265 [kA / m] and a low residual induction up to 0.4 [T], to increase the torque developed by the machine, we adopted as a technical solution a construction in which the rotor presents both permanent ferrite magnets and different magnetic reluctance after the two magnetic axes d and q.

The stator of the machine remains unchanged. Basically, we obtained a much cheaper construction of a variable reluctance synchronous motor with ceramic magnets able to develop the same performance as a synchronous motor with permanent rare earth magnets, characterized by a high cost.

In the research expanded during a period of two years, 8 new variants of rotors were conceived, designed, modeled and simulated.

Of these, seven variants are with variable reluctance having the flux barriers filled with magnets and a rotor topology is with flux concentration. All these designed solutions were designed to be constructed with ferrite magnets.

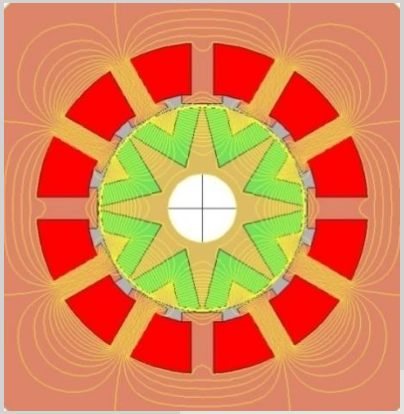
Technical Presentation

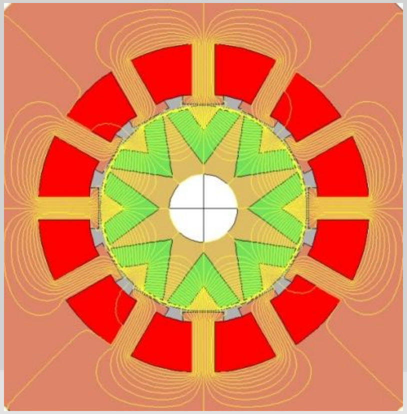


The proposed rotor type variants for PMSynRM .

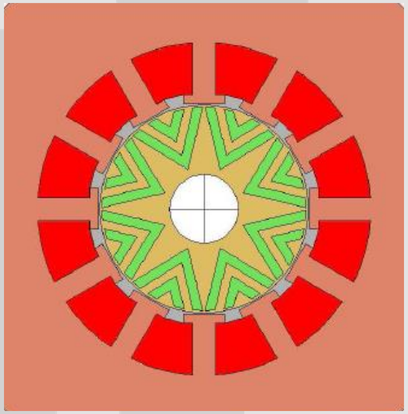
The representative topologies are those in which the rotor is:
- with a row of flow barriers 1V;
- with two rows of flux barriers 2V;
- with flux concentration.

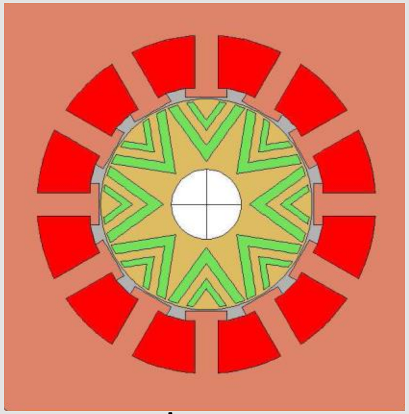
Technical Presentation


a.


b.

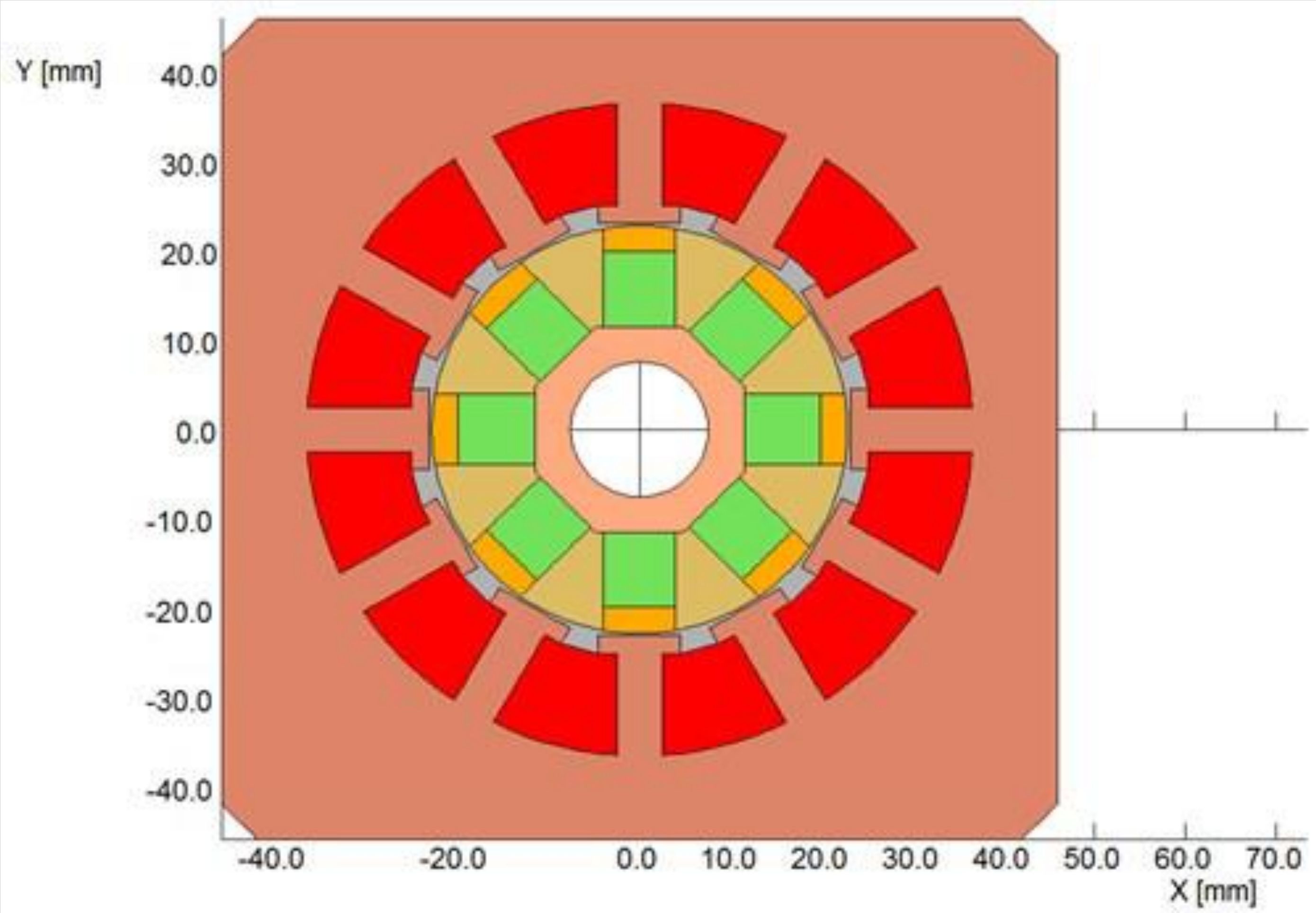
One V flux barrier rotor geometry: *d*-axis PM flux plots, b. *q*-axis PM flux plots.


a.


b.

Two V flux barriers rotor geometry: a. with same width of flux barriers 2V; b. with different widths of the flux barriers 2VU.

Technical Presentation



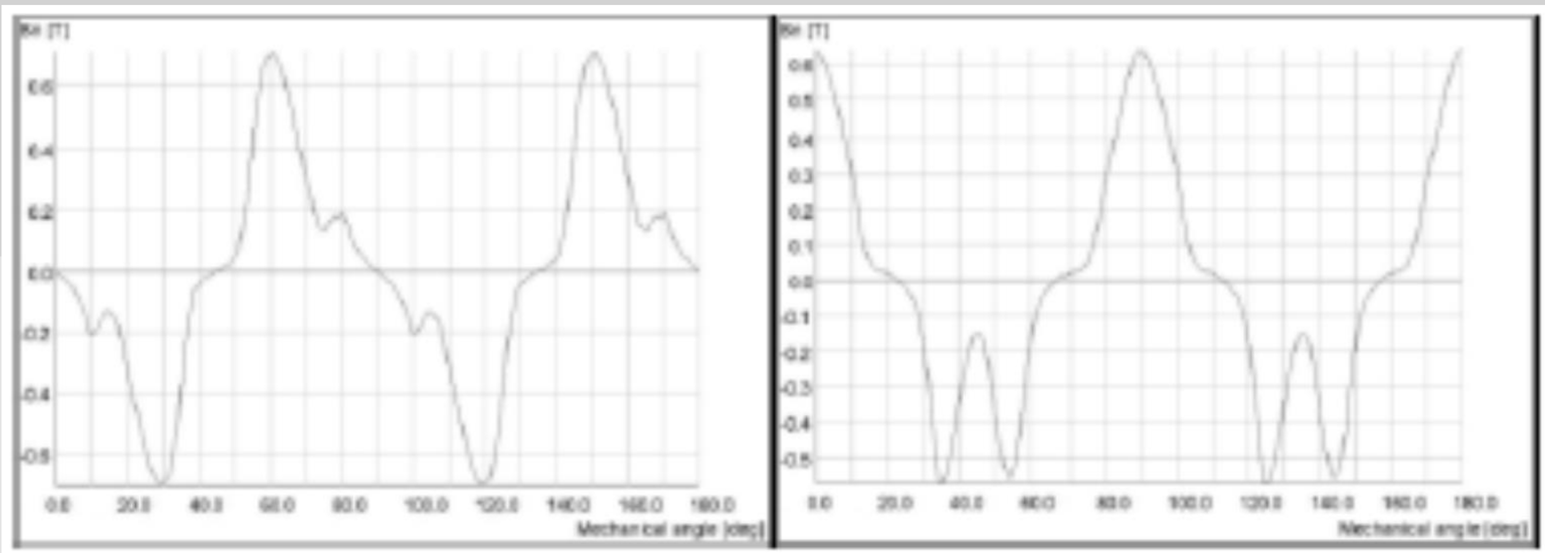
PMSM wit flux concentrator (PMSM-FC).

Simulation results

	Rotor Type			
	Conc. flux	**2V**	**2VU**	**1V**
V_{PM} [mm³]	26481.72	29325.04	24339.78	39587.37
L_d(4A) [mH]	12.76	23.75	~23.75	23.80
L_q(4A) [mH]	15.91	15.8	~15.8	12.1
L_d/L_q	0.8	1.50	~1.50	1.96
ψ_{PM} [Wb]	0.070	0.076	0.070	0,051
T_{av}/I [Nm/Apk]	2.2/4.5	1.9/3,45	~1.9/3.45	2,3/5
T_{ripple} [%]	26.3	26.3	~26.3	26

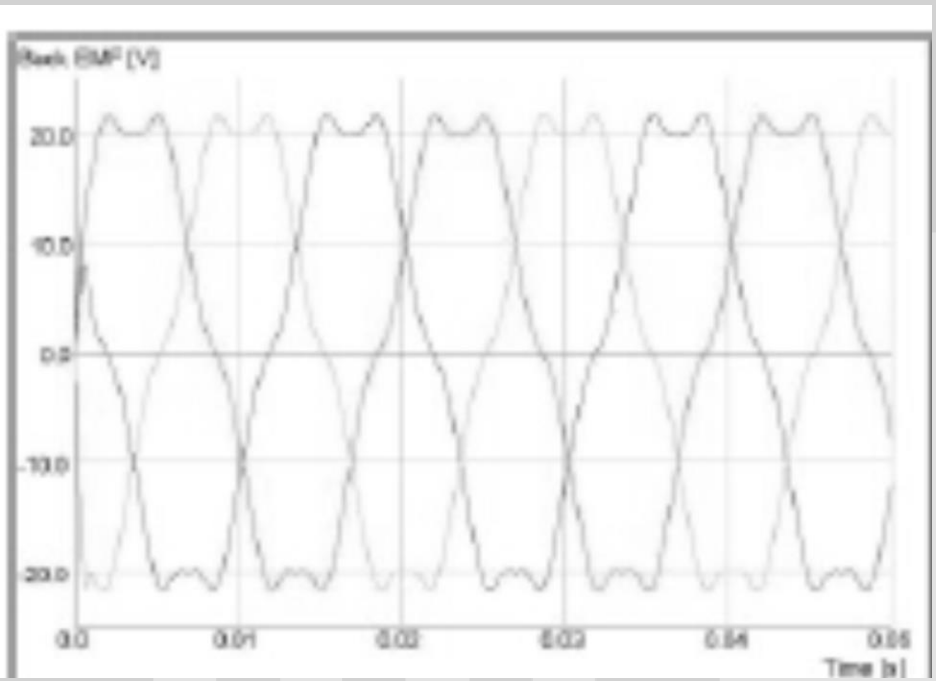
The last solution has been already executed in two constructive variants.

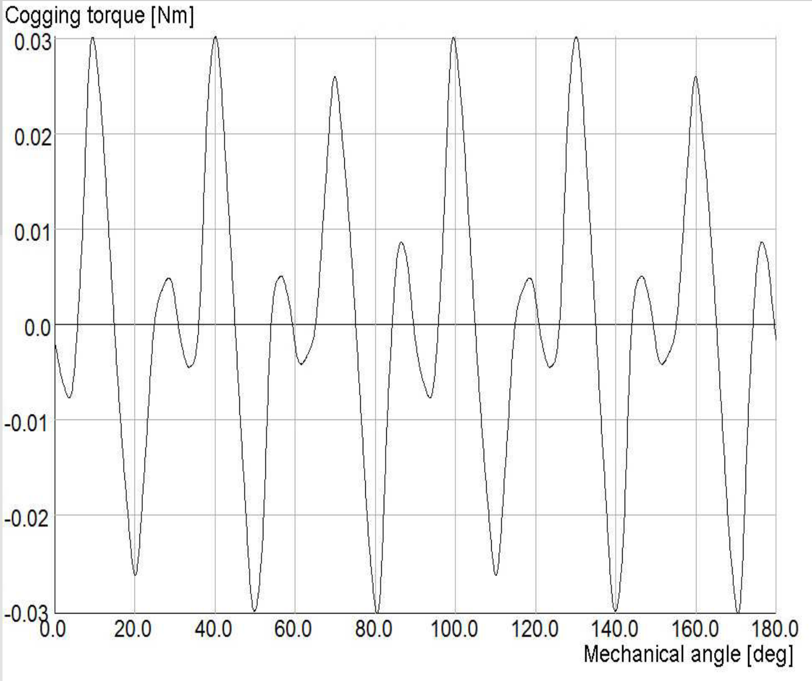
Technical Presentation



a b

Flux density distribution: a *d*-axis, b *q*-axis



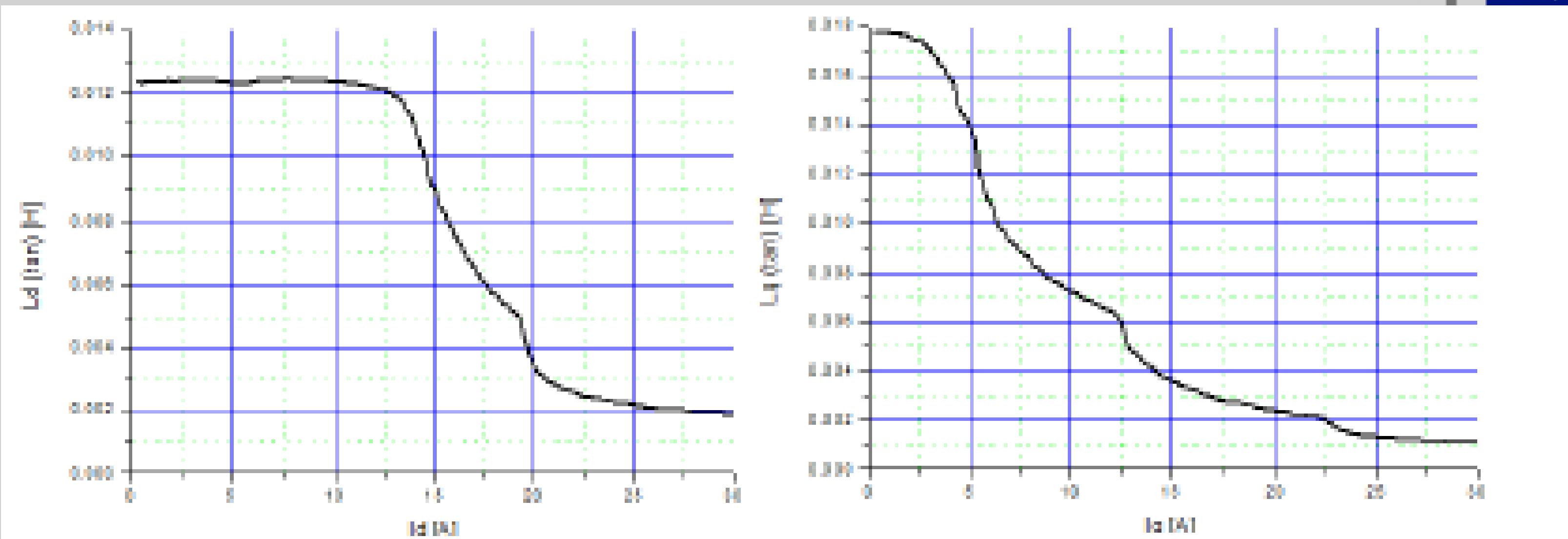


a

b

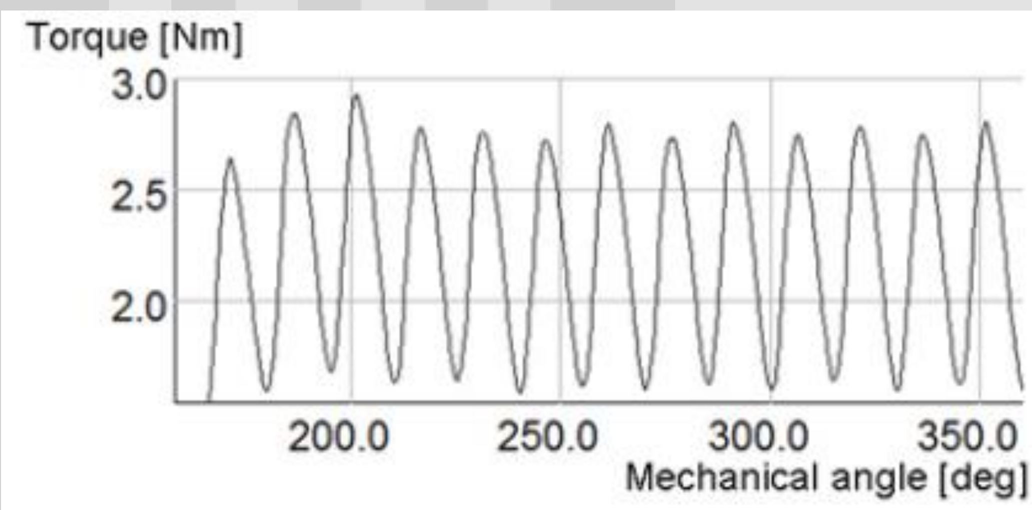
a. Back-EMF, b. Cogging torque.

Technical Presentation



a b

a. Ld and b. Lq inductivities curves vs. currents.



Torque variation at 5.0 [A].

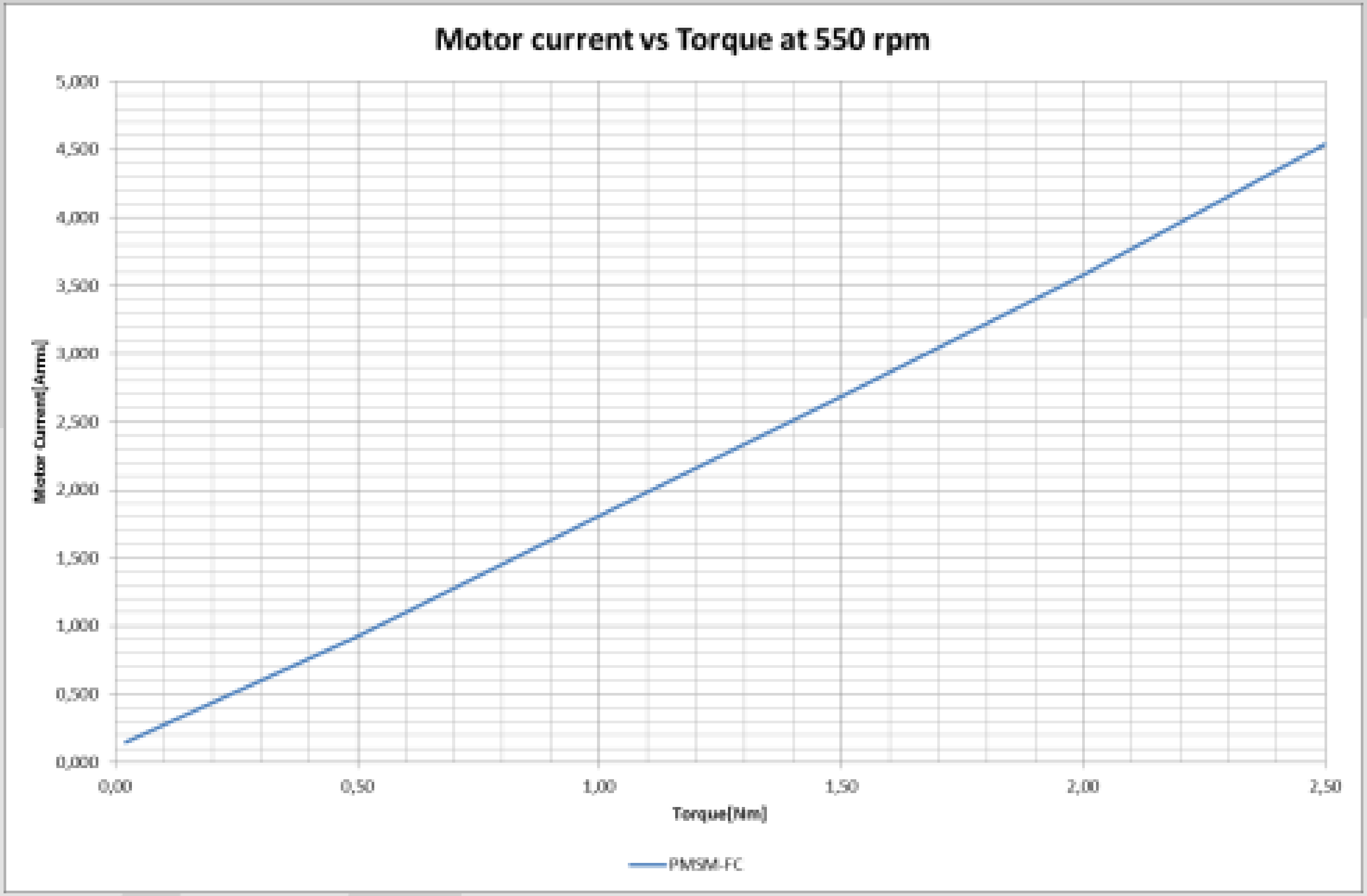
Technical Presentation

The prototypes were made at Electromotor Timişoara. I made the constructive and technological documentation and I coordinated the main phases of the process and the operations of the technological flux.

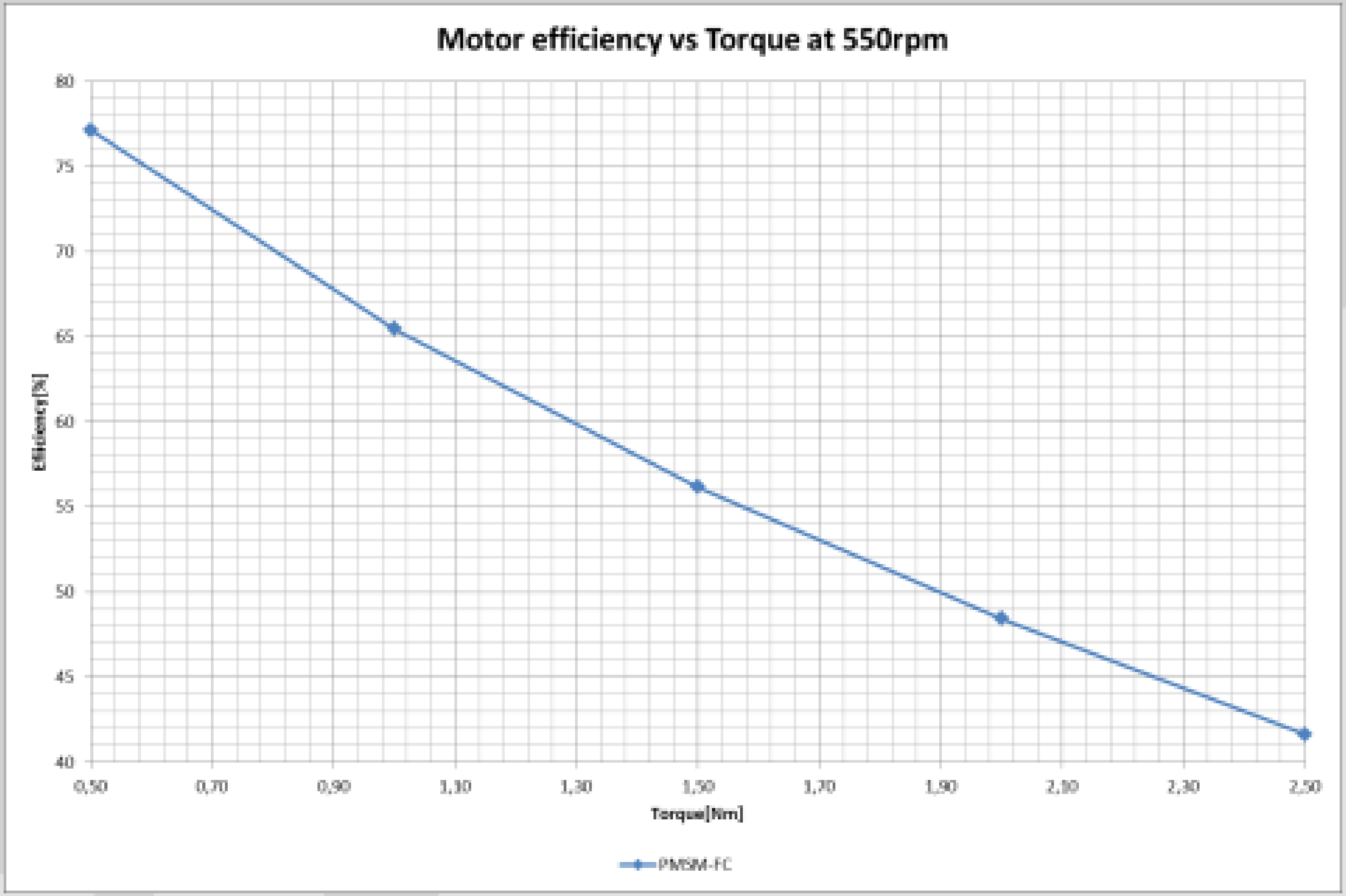
PMSM with flux concentrator rotor PMSM-FC.

The stand tests presented in this thesis were performed in Germany, at Diehl Company.

Technical Presentation



Measured motor performance – Motor current vs. torque.



Measured motor performance – Motor efficiency vs. torque.

The research team addressed this direction in 2010, within the international project *Contract for research-development and consultancy* with Diehl Company from Germany. I participated in this project as a manager.

The recognition of value and practical applications of the study was proved by the published papers. One study was published in the volume of IECON Conference of 2013, from Vienna, under the aegis of IEEE Industrial Electronics Society, an ISI indexed paper [33].

The paper received the Certificate of Acknowledgment for the best work of the section.

Three other works are being under review.

2. The optimal control of electrical drives with AC motors

In the domain of the **Optimal control of electrical drives with AC motors** the research can be grouped into two categories:

(i) *electric drive systems with vector control for induction motors implemented in naval mechanisms;*

(ii) *the development of new algorithms for optimal control of AC motors.*

(i) Electrical drive systems with vector control for the induction motors implemented on naval mechanisms

This domain regards a theoretical and experimental study developed by a joint team consisting of teachers from the Politehnica University of Timişoara, Faculty of Electrical and Power Engineering and from "Mircea cel Bătrân" Naval Academy of Constanţa, Faculty of Marine Military.

The study was conducted within the national grant GR 226 of 2006 entitled *Electric Drives with Vector Control for Induction Motors Implemented in Naval Mechanisms,* project director, Prof. PhD. Eng. Dorin Popovici, in which I participated as the responsible representative in charge of the research team staff, on behalf of Politehnica University of Timişoara.

The study aimed to adopt a solution regarding the implementation of the direct vector control in the torque and flux of the induction machine, for the electric drive systems for naval mechanisms.

This was intended to replace the current technical variant at the time in which for the operation of the loading equipment 3 speed squirrel cage induction motors were used, which were obtained using three separate stator windings in star connection.

The main disadvantages of the variant proposed to be replaced are:

- large gauge and complicated construction of the control machine;
- speed change can be achieved only in steps.

Electric drive systems for naval mechanisms must meet the following requirements:

- to have an appropriate class of protection systems for naval applications;
- to be equipped with mechanical brakes to allow blocking duties in the event of an accidental fall in the supply voltage of the inverter;
- take into account the limited power sources supply ships.

In order to eliminate these disadvantages, along with the research team which I was part of, we proposed a technical solution that maintains the induction machine as part of the execution, but in which the motion control, which involves speed control and/or position control, respectively torque control, is made by direct vector control in torque and flux.

The main advantages that are obtained are:

- a quick dynamic response in torque and operation in a wide range of speeds;
- vector control is robust and relatively simple to implement;
- does not require current regulators and coordinate transformations;
- ensures efficient interference rejection;
- folds very well on numerical control;
- a normal squirrel cage induction motor with a single stator winding can be used;
- eliminates the control panel which comprises sense, acceleration, braking contactors and timing relays.

The ***basic structure of a direct vector control system in classic torque and flux with induction motor and PWM voltage inverter*** is shown in Figure. The machine orientation is made according to the stator flux, this classic scheme being proposed by Takahashi and Noguchi.

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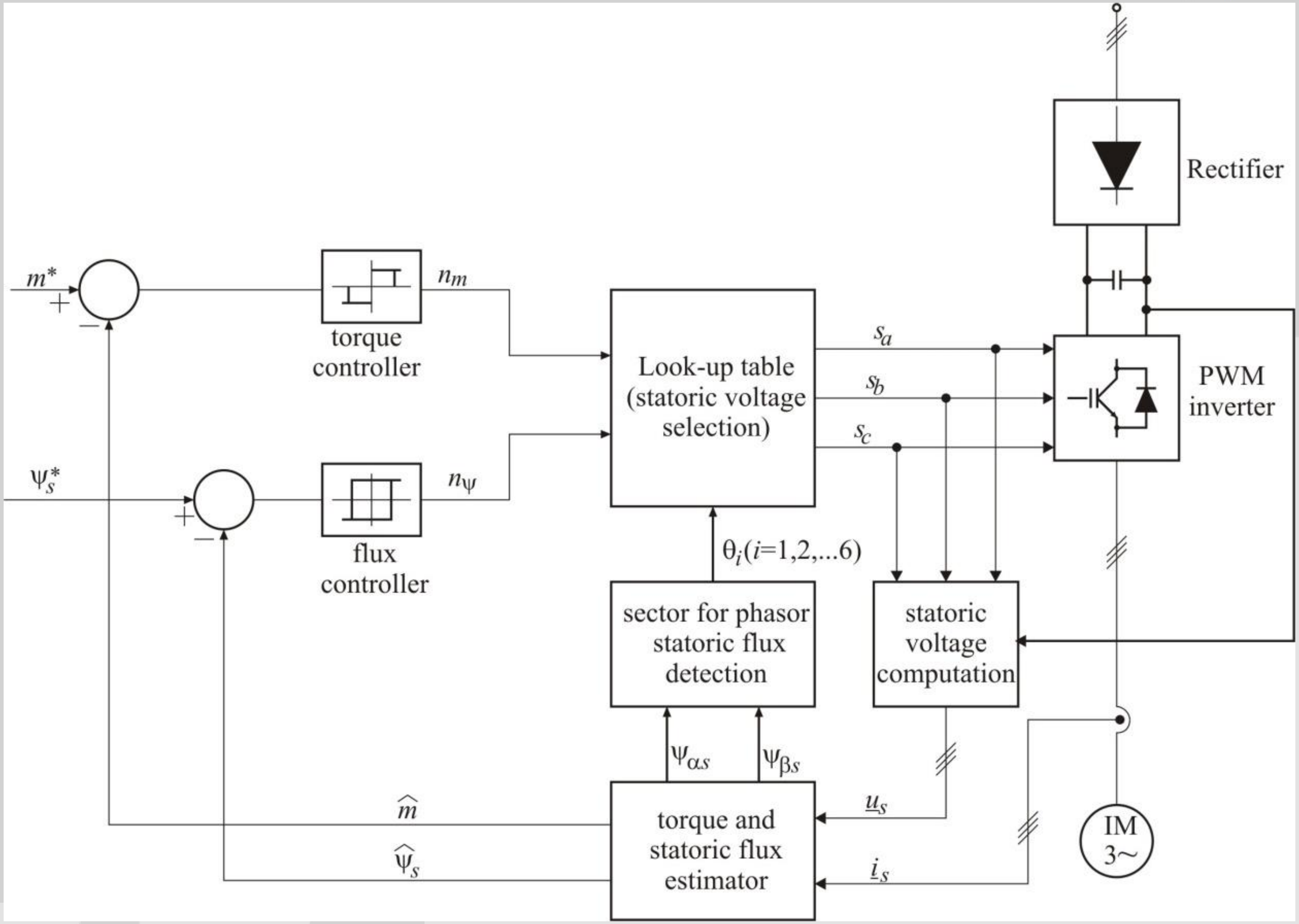
Technical Presentation



Classic DTC stator-flux-oriented induction motor fed by a PWM voltage inverter

Experimental the implementation of the vectorial torque and flux control for the electric drive systems with induction machines serving naval mechanisms was made in two stages.

In the first phase, the implementation was conducted in a model of laboratory developed at the Faculty of Electrical and Power Systems Engineering of Timişoara and then on an experimental stand provided by the Naval Academy of Constanţa.

The main experimental results obtained from the measurements made on this stand are shown in the thesis.

On the designed test stand the two ABB inverters acquired in the research were implemented.

Thus during the experiments conducted at the Faculty of Electrical and Power Systems Engineering of Timişoara, the ACS800 inverter of 4 [kW] was used.

The measurements were performed on the stand of the Naval Academy of Constanta. The ACS800 frequency converter of 11 [kW] was used, executed by naval standards. The used electric drive machine was an asynchronous squirrel cage of 11 [kW] type.

The results were published in 14 articles: 2 in an ISI indexed volume, references [63], [64], 1 in a BDI indexed volume, reference [65], 3 in international conferences [66], [67], [68] and 8 at national conferences [69], [70], [72], [73], [74], [75], [76], [80].

I also collaborated to the publication of three specialty books [6], [61] and [62].

(ii) The development of new algorithms for optimal control of AC motors

This section presents the results obtained after my participation in a research developed during 2004-2013 by a joint team consisting of specialists from the German company Diehl and the teachers from Politehnica University of Timişoara.

The theoretical and experimental study mainly aimed the development of new algorithms for the optimal control of AC motors.

Three of the proposed algorithms are presents, which have significantly improved the existing control strategies while maintaining the same level of their complexity.

The **first algorithm** is presented in section, entitled **Novel Flux Weakening Control Algorithm for PMSM**.

It is an algorithm for wide speed range PMSM drives which are fed by PWM-VSI utilizing overmodulation.

In this research, ***our team proposed an algorithm, starting from the mathematical model of PMSM in per-unit, used to calculate the optimal d- and q-axis reference currents, in the constant torque region and field weakening region taking into account the PMSM with salient-pole or nonsalient-pole***.

The existing constraints for the operation in field weakening region are the maximum output voltage of the VSI and the maximum current of the VSI or the maximum permitted current of PMSM [94], [95].

By using the overmodulation method the installed capacity of the voltage source inverter (VSI) is used better and dynamic and steady-state performance of the control system will be improved.

The ***proposed control has the following advantages***:

- easy to control the motor, with no need of tables for *d*- and *q*-axis reference currents;
- direct limitation of the maximum *q*-axis current for the whole speed range;

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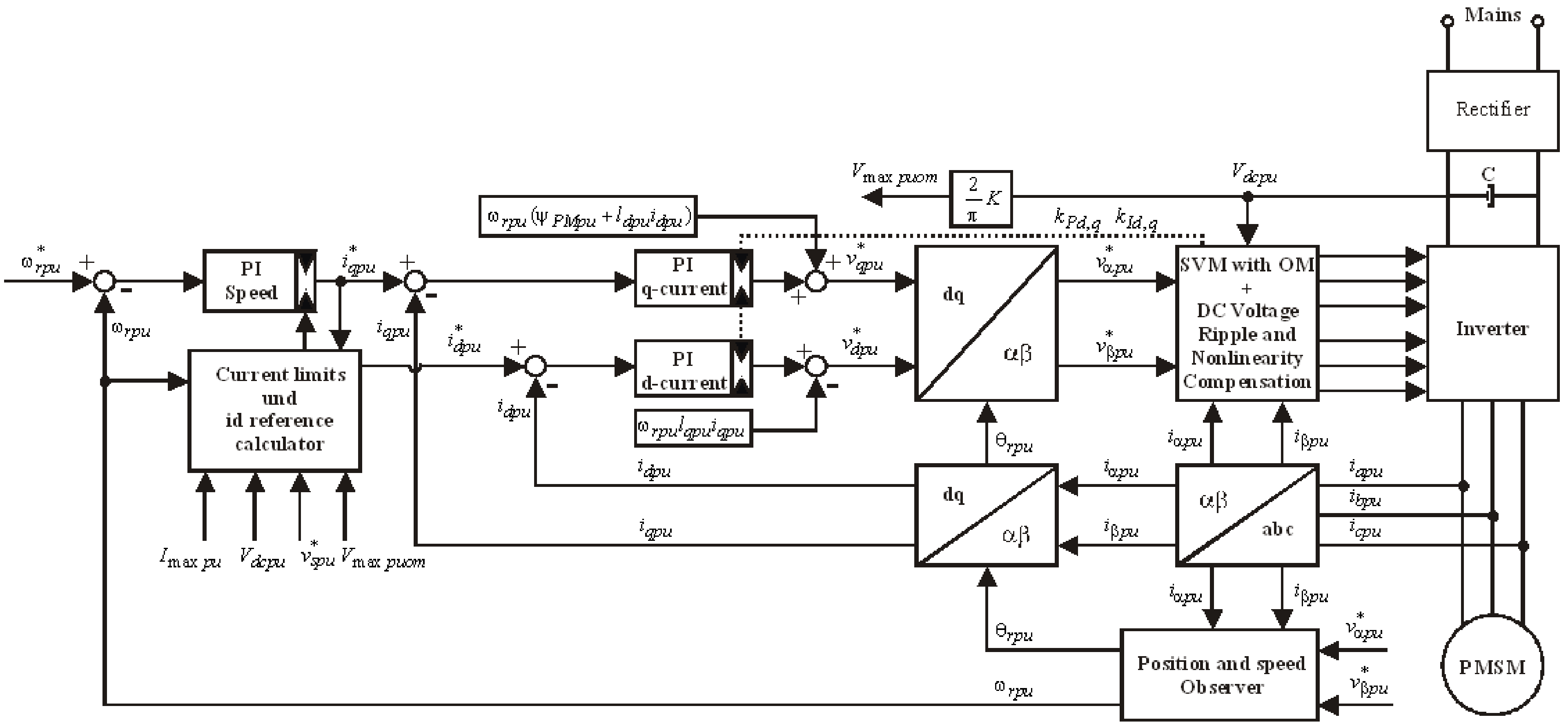
- the flux-weakening area is well exploited;
- the control is stable in the overmodulation region.



Block diagram of the proposed rotor field oriented control

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The PMSM drive system works in generator mode with the proposed algorithm only if the PWM-VSI is equipped with a regenerative unit to the AC power from the mains to DC link.

If the PWM-VSI is not equipped with a regenerative unit, the generator mode operation of PMSM should be avoided by limiting the maximum q-axis current.

- This algorithm allows a smooth transition into and out of the field weakening over the whole speed range.
- The algorithm is not sensitive to the motor parameters.
- It is relative simple and can be implemented with a 16 [bit] microcontroller.
- The dynamic and steady-state performance of the PMSM drive are improved by using the VSI in the overmodulation regions but also the switching losses in the power module will be reduced.

- The control with the proposed algorithm is stable in overmodulation range and it is capable to follow the DC-link variations.
- The experimental results obtained have shown the benefits of the overmodulation despite know issues that involve this method.

The **second study** proposes **an enhanced field oriented drive system for PMSMS**, where the current sensors are eliminated and only two Hall-effect position sensors are used instead of a high-resolution position sensor.

The high performance current control is achieved by use of a state observer for current estimation. The proposed algorithm is capable to generate the optimal d- and q-axes current references in the different operating regions and the limits of the speed controller. This algorithm works in all four quadrants.

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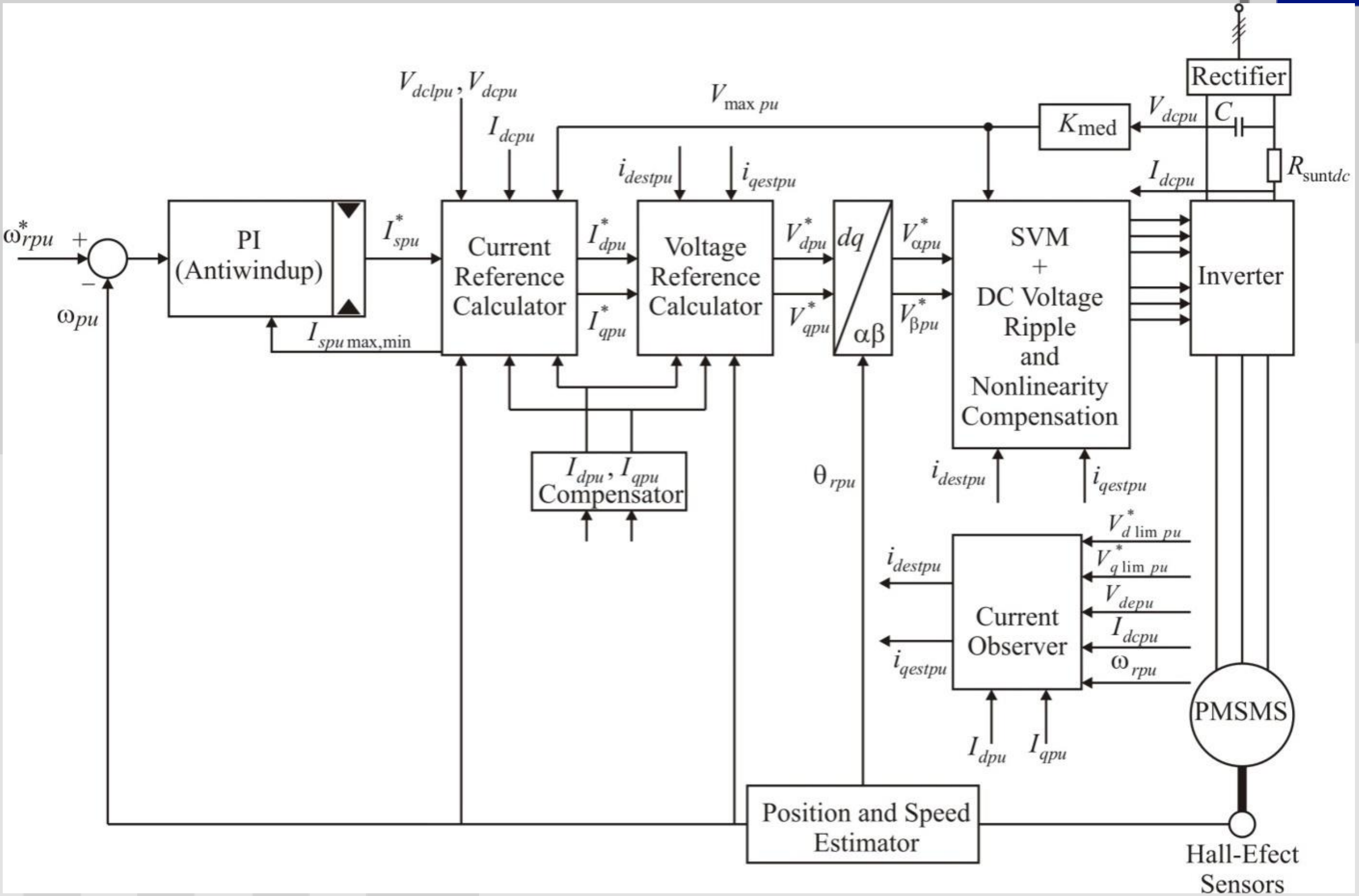

Block diagram of proposal speed control drive system using a state observer for the current estimation and two Hall-effect sensors

The experimental results obtained with the proposed speed control drive system of PMSMS, pointed out that the proposed current observer has a good dynamic and also a good dynamic speed response. The proposed algorithm can be implemented with a 16 [bit] MCU.

The new algorithm allows to calculate the d- and q-axes current references for the whole speed range, which works in all four quadrants, even the power converter has not a regenerative unit.

The third proposed algorithm generates the stator flux reference and q-axis current limit in all four quadrants in an induction motor drive systems, which are fed by PWM inverter equipped with diode rectifier front-end and without any extra braking resistors.

This algorithm allows a smooth transition into and out of the field weakening mode and also a smooth transition from motor mode to generator mode and inverse over the whole speed range.

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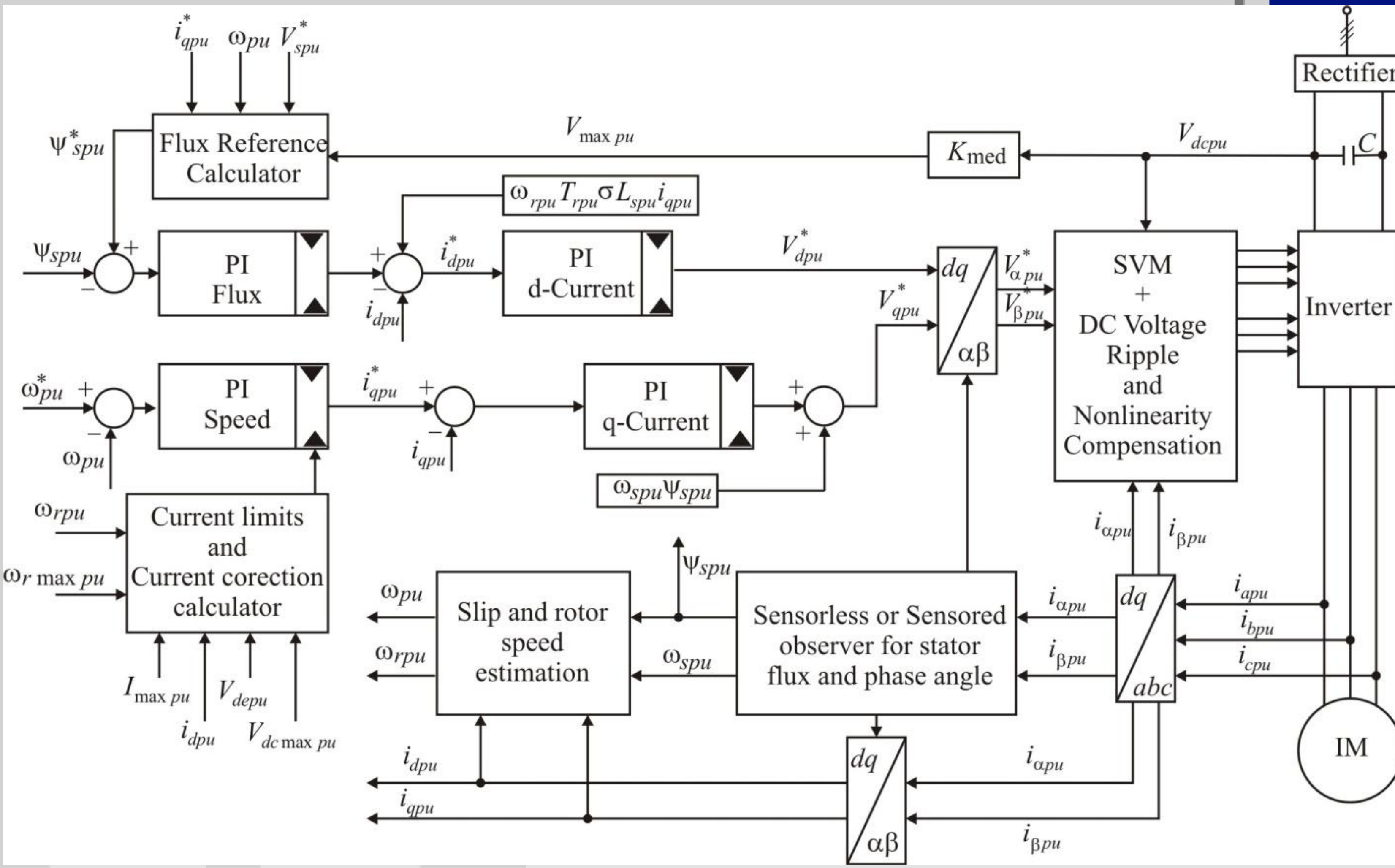

Block diagram of the proposed stator flux oriented control for IM

This algorithm is not sensitive to the motor parameters; it is relative simple and can be implemented with a 16 [bit] DSC.

The experimental results obtained have shown that the proposed algorithm has good dynamic performance and good steady-state performance. Optimum torque capabilities can be developed despite significant changes in dc link voltage and motor parameters.

The results of the developed research resulted in 12 articles as follows: 1 article in an ISI indexed journal, reference [102], 1 in BDI indexed journals [95], 8 in volumes of ISI indexed conferences, references [101], [103], [104], [105], [106], [107], [108], [125] and 2 in volumes of BDI conferences [94], [109].

During this period I participated as a member of two national grants completed in 2003, *Testing, Modeling and Monitoring of Electrical Equipment in Machines Using Acquisition Systems and Data Processing,* code CNCSU 2 and *Variable Frequency Drives Using DSP Signal Processors*, code 115/2001. Both grants were led by Prof. Ph.D. Gheorghe Atanasiu.

3. Contribution to Single Phase Power Factor Correction (PFC) for grid Tied Inverters

The domain of the *Power Factor Correction Converters* was recently approached, in 2013.

The undertaken research was conducted in the two international projects in which I participated as a manager along with a team of teachers from Politehnica University of Timişoara:

a. *Analysis and Evaluation of Current Topologies and Solutions for the Single Phase Power Factor Correction (PFC) for Grid Tied Inverters*, BCI 1/28.01.2013;

b. *Analysis and Evaluation of Current Topologies and Solutions for three phase Power Factor Correction (PFC) for 400 V mains voltage* BCI 1/24.01.2014.

The thesis presents the results obtained in the study conducted in the first project, entirely completed.

The aim of the research consists of selecting the four relevant single phase power factor correction (PFC) topologies currently existing for the power range of 1.5 [kW] up to 4 [kW] and to analyse and evaluate them.

The evaluation has to be done in regards to electromagnetic compatibility (EMC) requirements including radio frequency interference (RFI) which is very important in the residential ambient.

The priority of benchmark parameters, to select topology for prototypes, is:

- low component costs;
- high energy efficiency;
- consideration of potential patent conflicts;
- easy to scale power levels (1,5kW, 2,2kW, 4kW) with the same platform;

- high quality;
- high reliability;
- low field failure probability;
- compact design (kW/dm²).

Conclusion: target is a low cost, high efficient design for high volume production.

A decision matrix was prepared for different topologies including above mentioned criteria. As power density has a low priority, also passive PFC and low-frequency active topologies (100Hz) should be within the decision matrix.

Rough expectation is that there are about 10 different topologies or switching control methods within this matrix. Efficiency versus output power (0-110%) of the different topologies has to be calculated or simulated.

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The investigated topologies are:

- the *conventional boost;*
- *the basic bridgeless PFC converters;*
- *the Boost Interleaved Converters;*
- *the Bridgeless Interleaved Converters*.

The study deals with the design study of the four topologies selected from a state-of-the-art from literature, then with the implementation of their hardware and control parts in Matlab/Simulink, simulation environment and finally with their performances evaluation and electromagnetic interference EMI analysis using comparison.

For the 4 topologies the efficiency versus output power (0-110%) calculation and filter requirement analysis (RFI and harmonics (EN 61000-3-2)) were done in an accurate approach to have a confident decision base.

For these 4 topologies the losses in semiconductors (conduction and switching losses) and passive components (inductors, capacitors and EMI filter) were calculated.

Further, the topologies which are chosen to be investigated are: the boost interleaved PFC and the bridgeless interleaved PFC converters.

In the last two decades, both topologies have been chosen for power application ranges up to 4 kW.

Simulation results, run for the same operation mode, show that the input current is in phase with the input voltage, and its shape is nearly perfectly sinusoidal, as expected, for both topologies, as shown in Figure.

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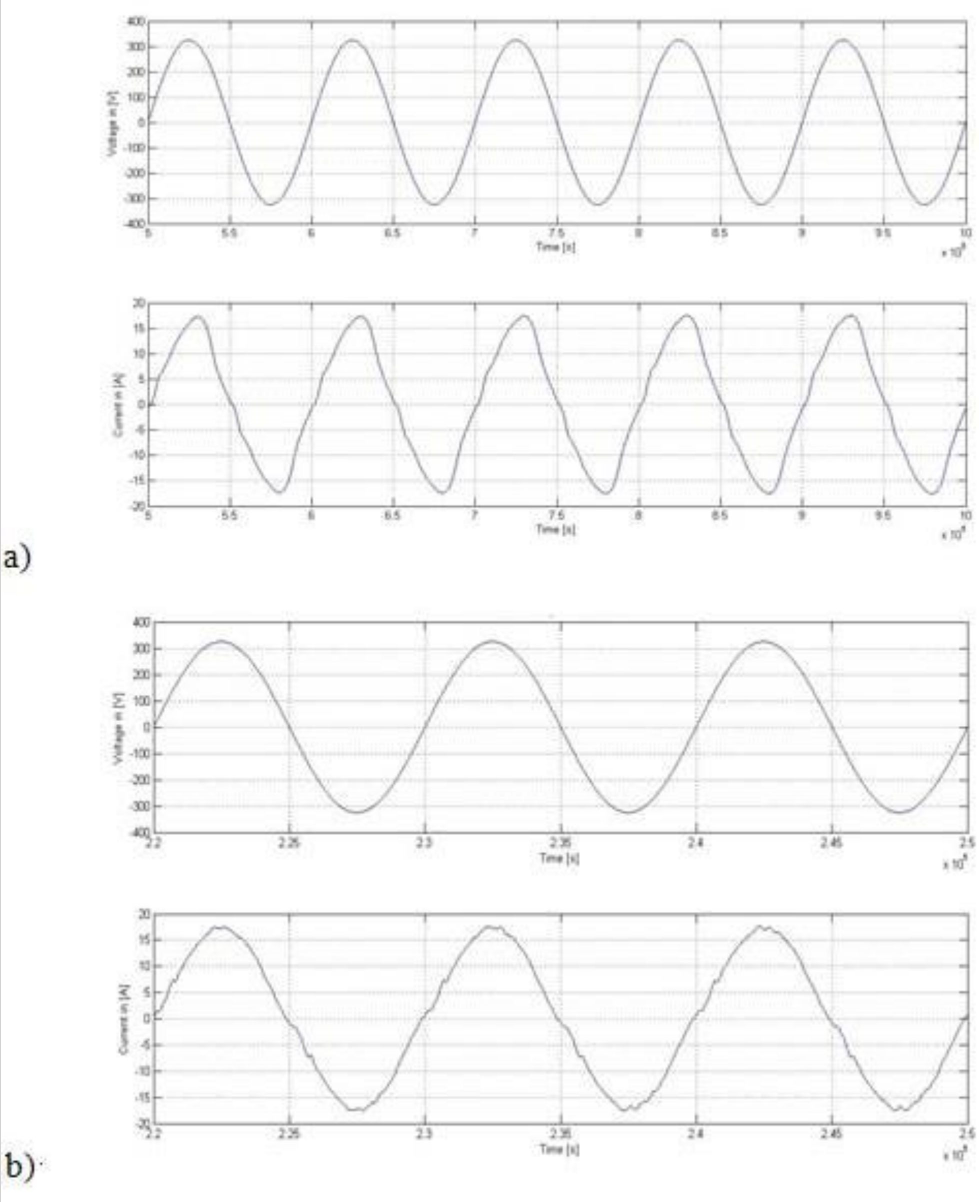

Zoom on input voltage & input current for the BOOST IL topology (a), respectively for the BRIDGELESS IL (b).

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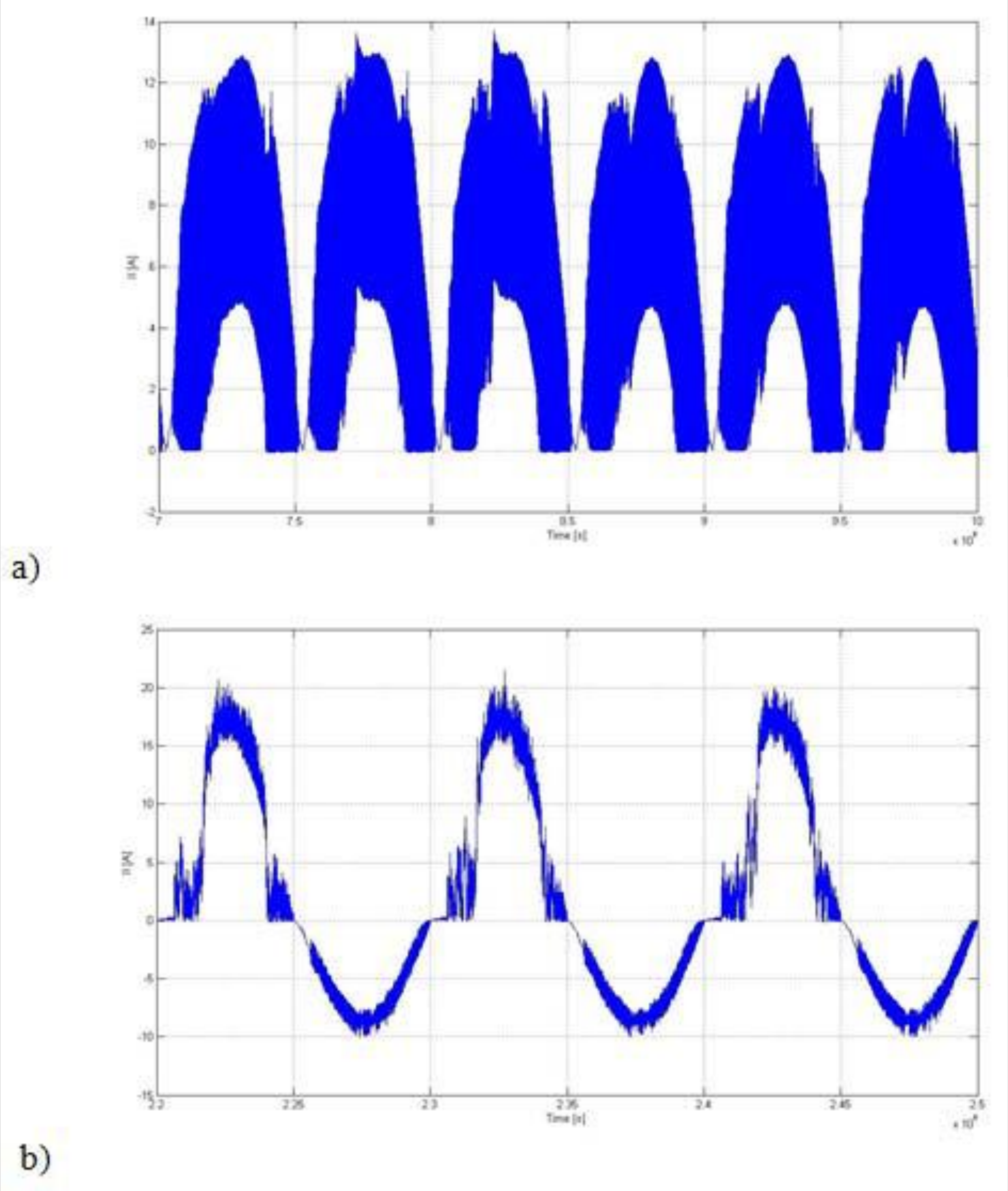

Zoom on inductance current for the BOOST IL topology (a), respectively for the BRIDGELESS IL (b).

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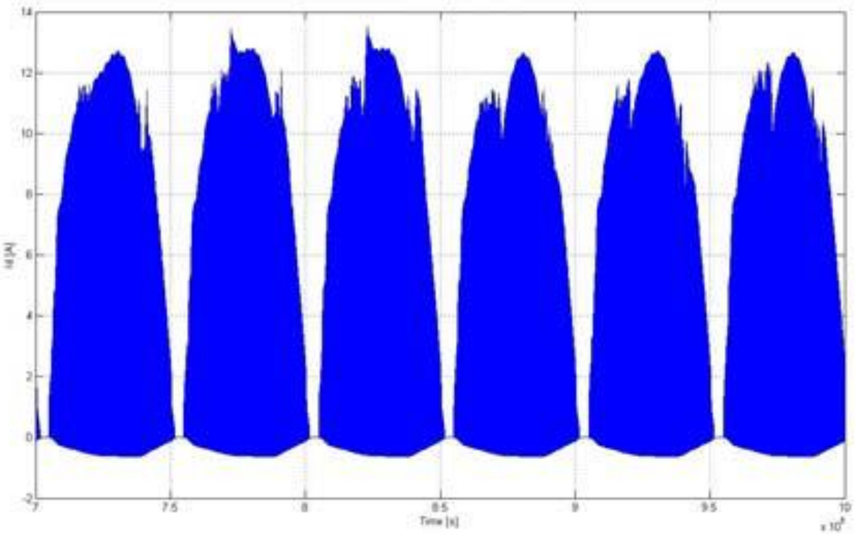
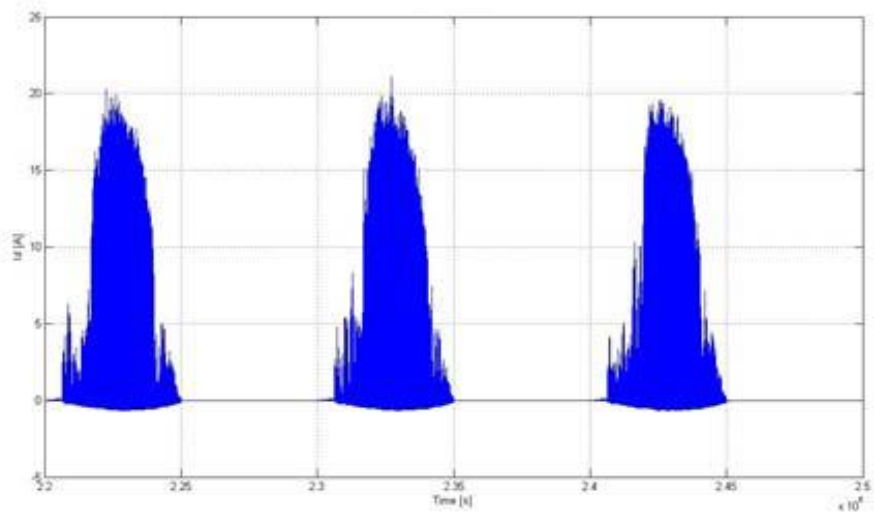


a)



b)

Zoom on diode current for the BOOST IL topology (a), respectively
for the BRIDGELESS IL (b).

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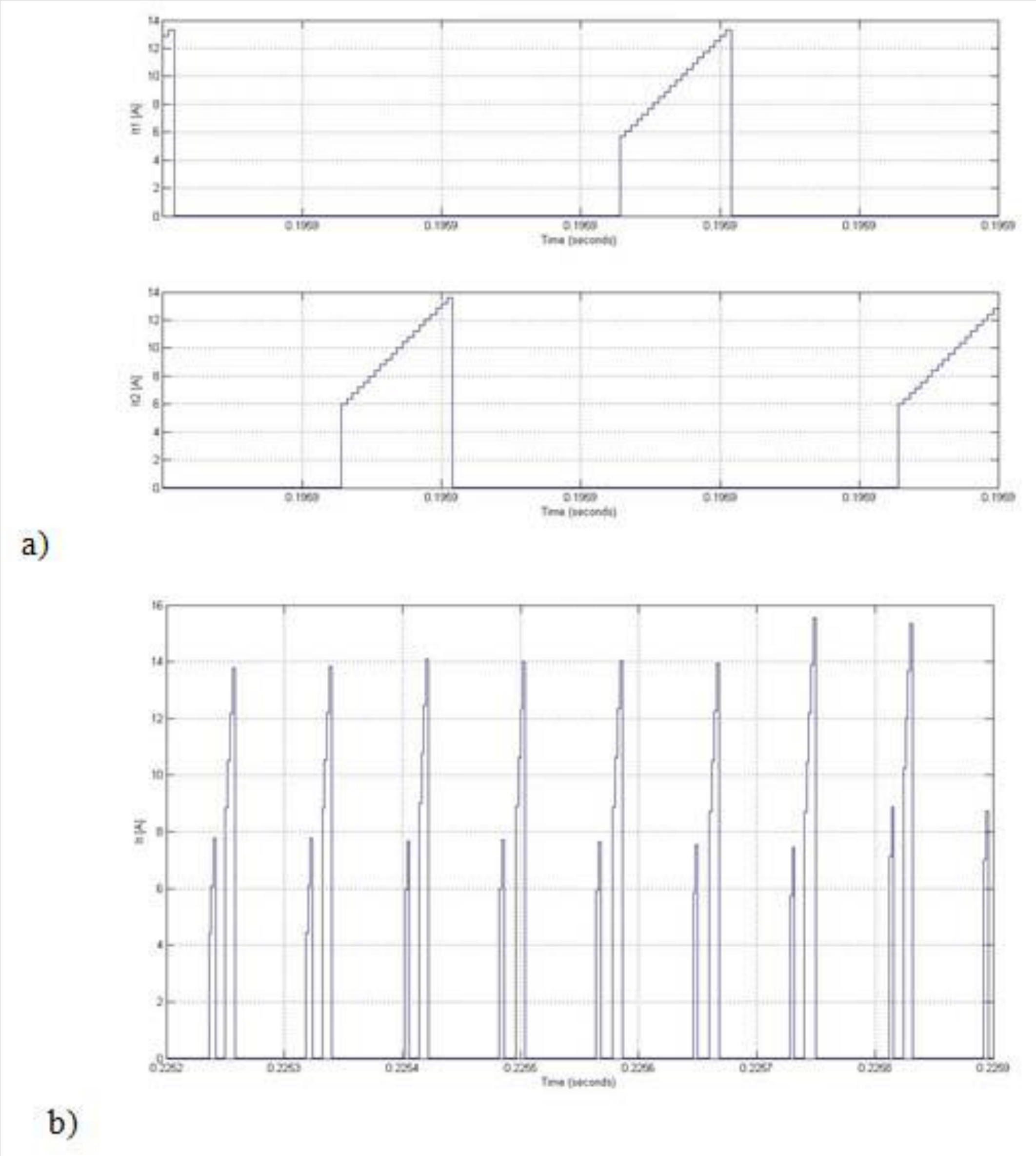

a)

b)

Zoom on Mosfet currents for the BOOST IL topology (a), respectively for the BRIDGELESS IL (b).

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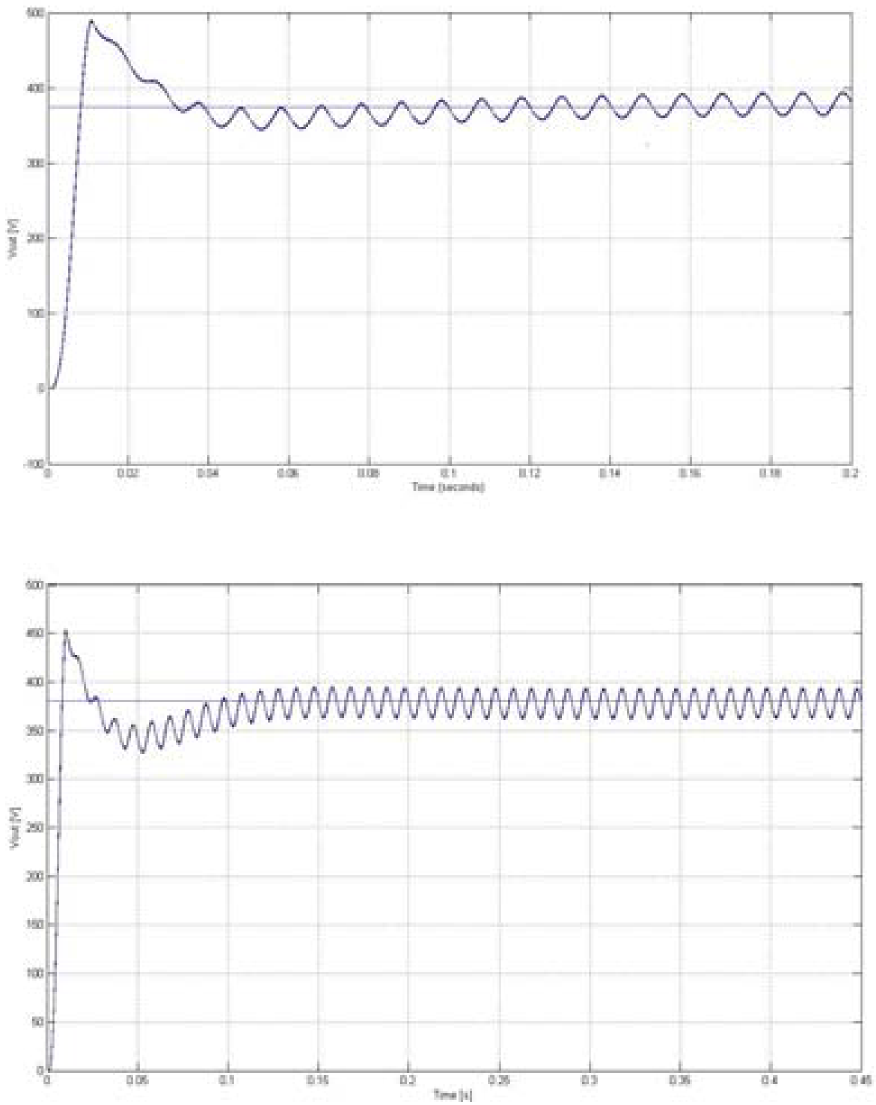
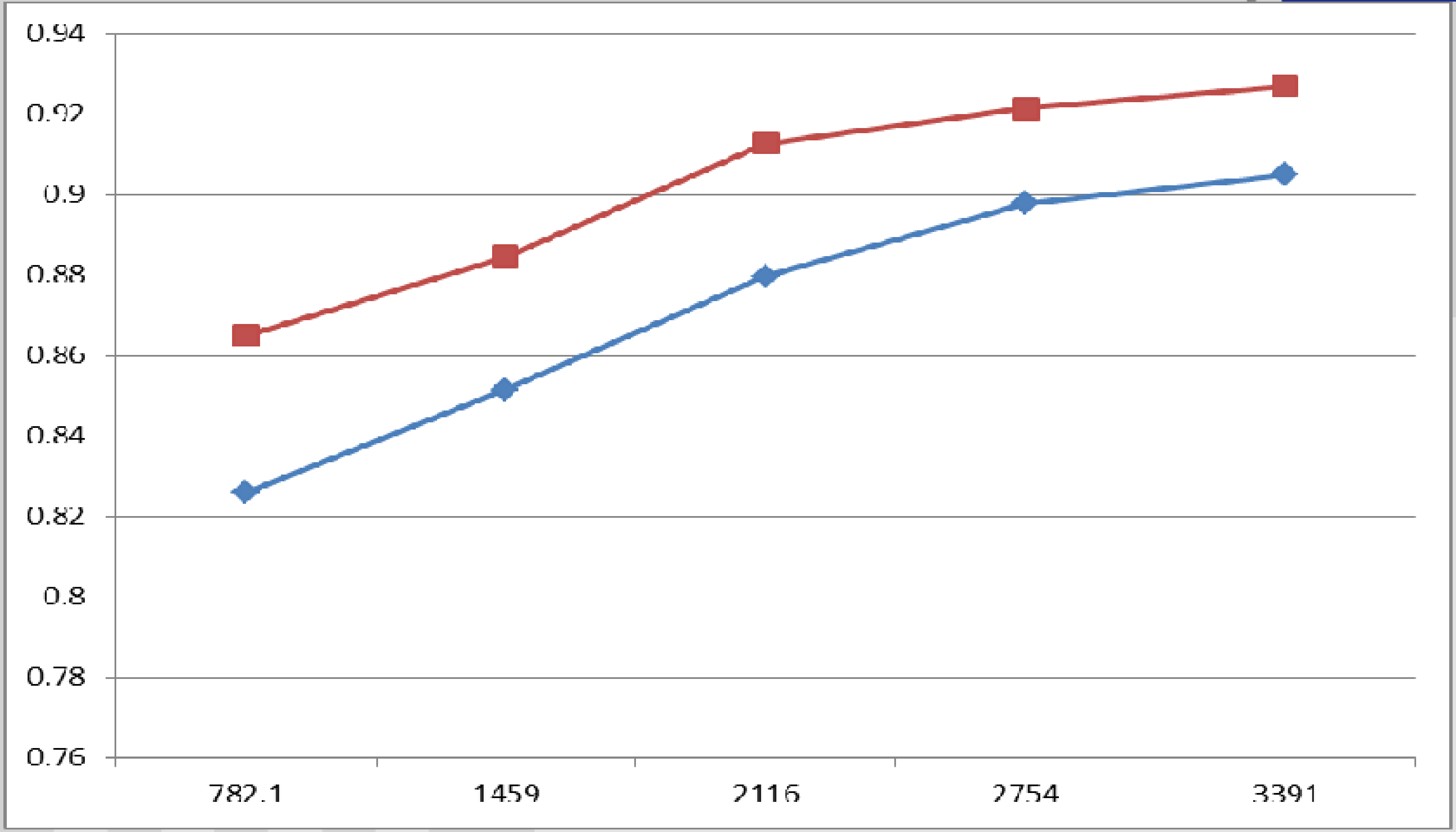


a)

b)

Voltage output for the BOOST IL topology (a), respectively for the BRIDGELESS IL (b).

Technical Presentation



Efficiency versus power curve for the BOOST INTERLEAVED (blue line) and BRIDGELESS INTERLEAVED (red line) topology

Comparing the two efficiency curves versus power for both topologies it results that for the bridgeless interleaved topology there is a slightly gain in efficiency.

So, in conclusion, interleaving and paralleling power converters can increase the efficiency of the power converter; as long as, the inductor ripple currents are kept within reason.

So far three articles have been elaborated, all under review.

IV. Development

In the next period, my activity will focus on the three consecrated directions presented above: *research activity, teaching and professional development, university management activities.*

My future **research activity** will follow three main study areas: *The optimal design of AC motors, The optimal control of electrical drives and* the *Three-phase power factor correction converters*.

In the domain of the *Optimal design of AC motors*, I shall address two areas: *(i) the optimal design of induction machines fed by PWM voltage inverters; (ii) the optimal design of ferrite magnets-assisted variable reluctance synchronous machines.*

The studies in the first area, (i*) Optimal design of induction machines fed by PWM voltage inverters*, will be based on the theoretical and experimental studies conducted so far.

All these results obtained represent a solid starting point for the future research that aims to establish the optimal constructive-technological design criteria and measures to be followed in order to improve the parameters and the functional dimensions of the three-phase induction motors fed by PWM inverters.

The design method that I will study has to satisfy:

- the functional criterion (making a motor with some technical features required by the customer);
- the safety criterion (providing a safe behavior of a machine operating under nominal and short-term overloads conditions);
- and the economic criteria (constructing a machine at a minimum total cost taking into account both the constructive-technological and exploitation expenses).

Development

Considering these requirements, I will continue the implementation of the study in an international project with an machine manufacturer from Slovenia. This project is in the planning stage, based on the request of the manufacturer, at feasible production cost of the final product, using these motors.

The studies in the second domain of the first area of research, (ii) *The optimal design of ferrite magnets-assisted variable reluctance synchronous machines,* will represent the further development of the study undertaken so far, summarized in Thesis.

In the next period, we will develop practical tests of the implemented variants as driving machine in the structure of the washing machine.

The behavior in time of the characteristics of ferrite magnets will be especially monitored.

Development

Future research in this sub domain will focus on optimizing the design of PMSynRM. The design will be carried out using the two-dimensional FEM, using finite element software.

The PMSynRM rotor structure must be designed in such a way that it is possible to achieve the maximum torque per current ratio. This ratio will become the objective function to be applied to the optimization method.

For the computing software that will be developed, Hooke-Jeeves algorithm will be used as appropriate for the given application.

In this research, an FEM approach will be performed to analyze the effects of rotor design variables such as the flux-barrier width, flux-barrier location, insulation ratio, pole-span over pole-pitch ratio, and length of the radial and tangential ribs on PMSynRM performance.

Development

A systematic procedure will be applied to obtain the optimized geometry for rotor flux barriers.

This research direction will be implemented in a new international project concluded with the German company Diehl at their request.

In the second area, *The optimal control of electric drives,* I will address a new research direction in the area of the sensorless control of the Switched Reluctance Motor (SRM).

For the beginning, a flux linkage method and dual layer controller will be developed for an application with a low-voltage Switched Reluctance Motor (SRM) drive.

The basic concept of this application is that of a sensorless speed closed loop with an inner current loop using flux linkage position estimation.

Development

This voltage drop needs to be considered the algorithm which will be also developed. To ensure a sure operation, a startup algorithm will be also included.

The proposed method will be implemented and tested by using a digital signal processor 56F807EVM from Freescale Semiconductor Company and an 8/6 switched reluctance motor coupled with a brushless DC motor as load.

The research in the field of *Power factor correction converters* will continue in an international project, currently in progress. The contract was signed in early 2014 with the German company Diehl, with the theme of *Analysis and Evaluation of Current Topologies and Solutions for three phase Power Factor Correction (PFC) for 400 V mains voltage,* BCI 1/24.01.2014.

The research deals with the design study of actual topologies for the power range of 1.5 [kW] up to 10 [kW], selected from a state-of-the-art from literature.

Development

The publication of the results to be obtained will be oriented towards internationally recognized journals, especially ISI indexed.

The outcomes will be disseminated through international conferences, international events that are intended for information and best practices.

I will continue my activity as a reviewer and member of the editorial staff of the *International Journal of Electromagnetic and Applications* and the *American Journal of Electrical and Electronic Engineering*. In the near future I will respond to the invitation from the Editorial Assistant from the *Scientific & Academic Publishing* (SAP), USA to be the Editor of the Special Issue of the *Journal of Computer & Electrical Engineering*.

Development

My future **teaching activity** will be closely related to the planned research activity.

The confirmed results of my research will represent the foundation of the development of the courses I teach: *Electric drives,* respectively *Electric servomotors and the intelligent motion control.*

The topics of the graduation and master thesis I will coordinate will be in strong connection with the research and teaching activity described so far.

My **managerial activity** will be orientated towards growing up the faculty's human resources focusing on attracting the graduates with didactic and proved research potential and towards the development of the necessary material basis for the research activity.

The research team:

Prof. PhD Dorin POPOVICI

Assoc. Prof. PhD Alexandru HEDEŞ

Assoc. Prof. PhD. Gh. PĂPUŞOIU

Assoc. Prof. PhD. Marian GRECONICI

Lecturer PhD. Ciprian ŞORÂNDARU

Assist.PhD Mihaela Codruţa ANCUŢI

Assist. Marcus SVOBODA

Student Ioan TAMAŞ

Master student eng. Denisa Deaconu

Eng. PhD Nicola Valeriu OLĂRESCU

Eng. Martin WEINMANN

Eng. PhD Stefan ZEH

Eng. Simon BIHLER

Universitatea Politehnica Timişoara

Thank you !