DEVELOPMENT of SIMULATION TOOLS for DISTRIBUTED ENERGY CONVERSION SYSTEMS towards SMART GRIDS

HABILITATION THESIS

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Rezumatul Tezei de Abilitare

Teza de Abilitare cu titlul "Dezvoltarea unor modele și biblioteci de simulare dedicate sistemelor distribuite de conversie a energiei într-o rețea inteligentă", reprezintă principalele cercetări pe care le-am realizat în ultimii zece ani în domeniul surselor regenerabile conectate la rețele energetice de distribuție a energiei. Lucrarea se bazează pe contribuții originale, efectuate în cadrul activităților de cercetare, finanțate de Universitatea Politehnica din Timișoara, Universitatea din Aalborg-Danemarca, Universitatea din Siegen-Germania, Laboratorul Danez National de cercetare/dezvoltare-RISO și Universitatea Tehnică din Danemarca (DTU). Realizările și rezultatele obținute în această teză se bazează pe suportul a 11 granturi obținute prin competiție, de echipele de cercetare cu care am lucrat și pe care le-am coordonat, atât la nivel național cât și internațional, după cum urmează: 7 granturi/proiecte internaționale precum și 4 granturi naționale (CNCSIS). În urma rezultatelor obținute am publicat mai mult de 75 de lucrări, atât în reviste naționale cât și internaționale și în volumele unor conferințe de prestigiu.

Prima parte a tezei de abilitare, care face referire la realizările științifice și profesionale, conține 5 capitole. ***Primul capitol*** oferă o privire de ansamblu asupra structurii tezei, subliniind obiectivele, principalele contribuții, granturi de cercetare și premiile obținute. Scopul celui ***de al-doilea capitol*** este de a dezvolta modele/biblioteci de simulare pentru diferite componente și sisteme ale surselor de energie regenerabilă, ca parte integrantă în sistemele energetice de distribuție, cu ajutorul a două pachete de programe software dedicate, MATLAB / Simulink și DIgSILENT PowerFactory. Aceste modele au fost validate cu ajutorul măsurătorilor/testelor de laborator, utilizând componente reale, și vor fi utilizate în continuare în următoarele capitole pentru dezvoltarea strategiilor de conducere și control a diferitelor scenarii pentru proiectarea și implementarea unei rețele inteligente (*Smart Grid*). Dezvoltarea modelelor de simulare va include panouri și sisteme fotovoltaice, turbine de vânt (generatoare eoliene), sisteme de stocare a energiei și de control al acestora în rețelele de distribuție a energiei, incluzând de asemenea casele inteligente cu diverși consumatori controlați automat. ***Al treilea capitol*** cuprinde trei părți principale și este dedicat strategiilor de control elaborate pentru sistemele energetice de putere având în componență surse regenerabile dintr-o rețea de distribuție. Prima parte a acestui capitol, oferă o imagine de ansamblu asupra strategiilor de control pentru turbine eoliene de puteri mari, folosind generatoare de inducție. De asemenea, sunt descrise și analizate cele mai performante strategii de comandă și control a turbinelor de vânt, atât cu viteză constantă și control activ al paletelor, cât și cu viteză variabilă și controlul unghiului de înclinare a paletelor. În a doua parte a capitolului 3, se prezintă implementarea pe o platformă/micro-controller digital(ă) în timp real a două strategii diferite de control al mașinilor electrice, utilizate în diferitele topologii ale turbinelor eoliene cu viteză variabilă. În ultima parte a acestui capitol au fost implementate și testate cu succes două tipuri diferite de regulatoare/controlere; Unul pentru reglarea tensiunii într-o rețea de distribuție, folosind consumatorii unei case inteligente (birou), si al doilea controler folosind sistemele de stocare

a energiei (diferite tipuri de baterii/acumulatori). Cele două tipuri de controlere/algoritmi de reglare pentru controlul tensiunii, au fost, de asemenea, implementați în MATLAB / Simulink și DIgSILENT PowerFactory și testați experimental cu ajutorul platformei inteligente de tip Smart Grid, descrisă în capitolul 2. ***Capitolul patru*** se axează pe testarea componentelor surselor de energie regenerabile care utilizează dispozitive de stocare și consumatori/sarcini controlați (controlate) în mod activ și, de asemenea, la testarea bateriilor vehiculelor electrice și hibride pentru a studia impactul asupra degradării bateriei în timpul efectuării unor teste de încărcare inteligentă și a unei încărcări rapide (la curenți de ordinul sutelor de amperi). Au fost testate două tipuri diferite de baterii Li-ion dedicate autoturismelor electrice și hibride. Scopul ***Capitolului 5*** este de a proiecta o rețea de distribuție, cu diferite componente ale surselor regenerabile, conectate împreună la aceeași stație de alimentare, și de a identifica situațiile cele mai defavorabile din punct de vedere energetic, punându-se un accent special pe provocările impuse de introducerea unor tehnologii/aparate noi, specifice rețelelor inteligente. Un alt aspect important al acestui capitol este de a identifica cazurile critice de încărcare, maxime și minime (impuse de standardele în vigoare), a rețelelor de distribuție și studiul variațiilor de tensiune generate prin conectarea surselor regenerabile.

Contribuția echipelor/grupurilor noastre în zona de cercetare și dezvoltare, în ultimii zece ani, a avut un impact semnificativ atât în Comunitatea Academică Internațională, precum și în industrie. Publicațiile noastre au primit mai mult de cinci sute de citări în baze de date internaționale. De asemenea, capitol de carte "Modelarea și simularea unui parc eolian de 12 MW", publicat de Editura internațională INTECH în 2011, în cartea intitulată „Studiul Impactului integrării surselor regenerabile în sistemele energetice de putere și alternative pentru a îmbunătăți integrarea acestora” a fost vizualizată și descărcată de peste 5000 de ori. Un alt aspect important pentru recunoașterea activității de cercetare la nivel internațional este premiul al doilea obținut pentru articolul “Wind Turbine Generator Modeling and Simulation where Rotational Speed is the Controlled Variable”, publicat în revista IEEE-IAS Transactions on Industry Applications, în ediția ianuarie/februarie 2004, Vol. 40, No. 1, pp. 3-10, (ISI Journal - ISI Web of Knowledge). Revista are un factor de impact de 2.578, și a primit 50 de citări în baza de date ISI Web of Knowledge, 90 de citări în SCOPUS și peste 150 de citări în Google Scholar.

Cea de a doua parte a tezei, referitoare la planurile de evoluție și dezvoltare a carierei, se bazează pe aptitudinile dovedite de a desfășura și coordona grupuri/echipe de cercetare la nivel înalt și activități de predare la nivel academic și de a iniția colaborări internaționale de succes în domeniul sistemelor de conversie a energiei regenerabile. Ca planuri de viitor vom încerca să accesăm fonduri naționale și Europene (granturi Orizont 2020) pentru a extinde și îmbunătăți laboratoarele departamentului nostru și a centrului de cercetare "Controlul inteligent al conversiei și stocării energiei" de la Universitatea Politehnica din Timișoara, Departamentul de Inginerie electrică, și să extindem cooperarea internațională și rețeaua existentă de cercetare. Un alt aspect important referitor la dezvoltarea carierei academice este de a crea și dezvolta o platformă de tip *Smart Grid*,

similară cu aceia din Danemarca (www.powerlab.dk), unde am petrecut trei ani și de a folosi experiența mea pentru a crea un centru de cercetare cu studenții de la master și doctorat, coordonați ca urmare a obținerii tezei de abilitare.

Abstract

The Habilitation Thesis "DEVELOPMENT of SIMULATION TOOLS for DISTRIBUTED ENERGY CONVERSION SYSTEMS towards SMART GRIDS" points out the main research that I have performed during the last ten years in the area of Energy Conversion Systems with Renewable Energy Resources and Battery Storage Solutions. It is based on original contributions performed during the research activities financed by POLITEHNICA University of Timisoara, Aalborg University-Denmark, Siegen University-Germany, The Danish National Laboratory-RISO and Technical University of Denmark (DTU). The work made in this Thesis has been funded by 7 international grants/projects and by 4 national (CNCSIS) grants, as well. We have also been published more than 70 papers, in national and international journals and conference proceedings, based on the obtained results.

The first part of the Habilitation Thesis, regarding scientific and professional achievements, contains 5 chapters.

The first chapter gives an overview of the research roadmap of the thesis, pointing out the objectives, the main contributions, research grants and awards.

The aim of ***the second chapter*** is to develop simulation models of DER components in Power System, using two dedicated software packages MATLAB/Simulink and DIgSILENT PowerFactory. These models will also be validated against measurements and further used in the next chapters for developing of control strategies and different scenarios for a future smart grid. Development of simulation models will include PV panels and Systems, Wind Turbine Generators, Energy Storage Systems and Demand-Side Control in Distribution Networks with focus on intelligent houses with actively controlled loads.

The third chapter contains 3 main parts and is dedicated to control strategies developed for renewable energy systems in a distribution network. The first part, gives an overview of the state of the art control strategies for large wind turbines using induction generators. An active-stall constant-speed wind turbine controller with its actuator system for variable pitch angle and a control strategy for a pitch-controlled variable-speed wind turbine are described. Afterwards, in the second part, two different control strategies developed for variable-speed wind turbines using induction generators are described and implemented on a real-time digital platform. In the last part of this chapter two different types of voltage controllers in a distribution grid, using active loads/office building appliances and battery energy storage systems, have been implemented and tested successfully. Using the model of an intelligent office building a controller for load shifting has been developed. Two types of controllers for voltage regulation using battery energy systems have also been developed and implemented in MATLAB/Simulink and DIgSILENT PowerFactory.

The Chapter four is focuses on testing of DER components with storage devices and actively controlled loads and also on electric vehicle batteries testing to study the impact of

smart charging and fast charging on the power system and on the battery degradation. Two different types of EV battery packs have been tested.

The purpose of ***the Chapter 5*** is to design a distribution network with different DER Components connected along the feeders and to identify limitations of existing simulation and planning tools, with a particular focus on the challenges imposed by the introduction of Smart Grid technologies. Another important issue of this chapter is to identify critical load cases and voltage variations for the designed scenarios.

Our work in research and development area, during the last ten years, has had a significant impact both in the International Academic Community, as well as in the industry. Our publications have received more than three hundreds of citations in international data bases. Also, our book chapter ***„Modeling and simulation of a 12 MW wind farm"*** published by INTECH in 2011 in the book entitled Wind Farm-Impact in power system and alternatives to improve the integration has reached to more than 5000 downloads.

The second part of the Thesis, regarding to future plans for advancement and career development is based on the proven skills to conduct and coordinate high-level research and teaching activities at academic level and to initiate successful international collaborations in the field of renewable conversion systems. As future plans I am trying to attract national and EU funds (Horizon 2020 grants) to extend and improve our research lab "Intelligent control of energy conversion and storage" from POLITEHNICA University of Timisoara, Electrical Engineering Departments, and to extend our international cooperation and network. Another plan is to create and develop a Smart Grid platform, similar with that one from Denmark (www.powerlab.dk) where I spent 3 years and to use my experience to create a research center for Master and Ph.D. students, coordinated as a result of the Habilitation Thesis.

Contents of the Thesis

Part III: References

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