CHALMERS

Annual Report 2009

Division of Electric Power Engineering

Department of Energy and Environment
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Department of Energy and Environment
Division of Electric Power Engineering
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Pictures: Group picture and portrait: Jan-Olov Yxell Laboratories: Magnus Ellsén.

Program Outline and Vision

Electric Power Engineering is a technical field undergoing significant development. The newly created chair in Sustainable Electric Power Systems, which I had the privilege of taking on in January 2009, is an illustration of the importance of the movement of the power system toward renewable solutions.

Current evolution of the electric power system is the result of several contemporary events and developments. For example, the need for reinforcement of the power system, especially the grids; the development of more integrated energy markets in Europe; more intermittent power production; a mixture of large and small scale production; changes among the system actors including the roles of both consumers and producers; and introduction of electricity in the transport sector. One expression of these developments is captured in the words and the concept: Smart Grid. Over the course of the year I have participated in numerous interviews and presentations that communicate about and explain the idea. In short, Smart Grid is the assemblage of solutions building towards a sustainable electric power system. This suggests a system supplied by a large share of renewable energy sources, and one with an intelligent infrastructure for electricity delivery, i.e., incorporating new features for control communication and energy storage including the possibility for connection of electrical vehicles. I believe the overall target should be to find cost-efficient solutions for end users, added value for all actors, and to support the goal of sustainable energy systems involving an increased level of renewable energy sources both for electricity generation and in the transportation sector.

The Division of Electric Power Engineering performs research and offers education in the main areas of this development. Particular focus is placed on wind power generation and its connection to the grid, power delivery systems incorporating a market and consumer perspective, energy storage, and electrical vehicles involving connection to the grid.

My hope and vision in leading the Division is that it shall produce international excellence in research and education within our focus areas. Excellence is the result of hard and dedicated work, and I am confident that we can achieve this together in a joyful and stimulating work environment. Research is always based on team-work, and my wish is that everyone in the Division, our supporting staff from the Department, our steering and reference groups and Elkraftrådet, will feel that they are an important part of our joint vision!

Thanks for the great contributions during the past year and I look forward to an exciting year to come, with many new challenges and possibilities!

Yours,

Lina Bertling
Gothenburg
April, 2010

Contents

Highlights During 2009

The year 2009 was full of highlights at the Division, starting with the arrival of a new head of the Division after a long period of vacancy for this position. It has also been a year when energy has been at the top of the agenda in society, particularly as political meetings were held regarding European climate goals under the Swedish Presidency of the EU, followed by the Copenhagen Accord.

This book is a key result from joint work during the year, formulating a strategy for the research and education within the Division. A brief summary of the most important events during 2009 is listed below.

- Lina Bertling was appointed as Professor in Sustainable Electric Power Systems and Head of the Division of Electric Power Engineering, January 2009. This position is sponsored within an industry consortium including ABB, Göteborg Energi, Svenska Kraftnät and Vattenfall.
- Per Norberg was appointed as Adjunct Professor in Electric Power Systems, February 2009, supported by Vattenfall.
- Division strategy meeting Nösund 23-24 February, 2009.
- 2 PhD theses were presented
    - Abram Perdana, 10th of March 2009.
    - Lena Max, 8th of December 2009.
- 2 Tech Lic theses were presented
    - Tarik Abdulahovic, 17th of April 2009.
    - Andreas Karvonen, 8th of June 2009.
- 33 Master theses were completed by 44 students.
- One new PhD student and one post-doc researcher started during the year.
- ELKRAFTDAGEN (Electric Power Day) arranged by Elkraftrådet was held on March 19, 2009. Around 150 persons attended the event.
- Lina Bertling was appointed Chairman of SEK Svensk Elstandard, April 2009.
- A new ELFACK breakfast event was held, during which industry was invited to the Division for an overview information session prior to the ELFACK main event on May 7, 2009.

- A PhD student course was held in collaboration with KTH on Power Electronics for Transmission System Applications, with course leader at Chalmers, Massimo Bongiorno, in May 2009.
- Lina Bertling was keynote speaker at the Vattenfall 100-year anniversary conference, June 2009.
- A PhD course was held on Wind Energy, modelling, control and grid integration, at Alcala University, by Torbjörn Thiringer, Madrid, June 1-5 2009.
- A research program was formulated and launched as part of the collaboration between E.ON and Chalmers and the program on Future Energy Systems 2009-2012 involving 10 MSEK. The Division is running one project on future electric power system – Smart Grid with Lina Bertling as project leader and funding of 1 MSEK/yr.
- Funding was granted from the Swedish Government within the new strategic funds for research. In total 230 MSEK was approved for the period 2010-2014. Lina Bertling was the project leader for the research proposal with the theme "Large scale renewable and integration to the grid", and the Division also participated in the theme "Plug-in and electrical vehicles", June 2009.
- Torbjörn Thiringer was appointed Professor in Applied Power Electronics in July 2009.
- Division social gathering with wind power and in practice (sailing), August 28, 2009.
- The Division hosted an inaugural member meeting with the renewed IEEE Chapter on Power Systems/Power Electronic September 2009. Lina Bertling was appointed chair of the chapter.
- An application for a new wind power technology centre was approved by the Swedish Energy Agency (Energimyndigheten) with a funding of 60 MSEK during 4 years. Ola Carlson was the project leader during the application process and was appointed as project leader to put the centre into operation in November 2009.
- Lina Bertling was appointed as a member of the scientific board of the Swedish Civil Contingencies Agency (Myndigheten för samhälle och beredskap), November 2009.
- A number of research projects were granted within Vindforsk III and one within Elektra, all for three years, and one EU project on grid for vehicles (G4V).

General Resources

Personnel

The Division of Electric Power Engineering has during 2009 involved the personnel as listed below. Email addresses are composed as firstname.familyname@chalmers.se

Lina Bertling	Professor and Head of Division	(from January 2009)
Valborg Ekman	Administrator	
Tore Undeland	Associated Professor	
Gustaf Olsson	Associated: Professor	
Per Norberg	Adjunct Professor Non-Tenure	(from February 2009)
Torbjörn Thiringer	Professor	(from July 2009)
Ola Carlson	Associate Professor	
Jan-Olov Lantto	Senior Research Engineer	
Magnus Ellsén	Research Engineer	
Robert Karlsson	Research Engineer	
Massimo Bongiorno	Post Doctoral Position	
Katharina Fischer	Post Doctoral Position	(from November 2009)
Tuan Le	Post Doctoral Position	
Stefan Lundberg	Assistant Professor Non-Tenure	
Sonja Tidblad Lundmark	Assistant Professor Non-Tenure	
Abram Perdana	Post Doctoral Position	(until December 2009)
Tarik Abdulahovic	PhD students	
Ghasem Aghdam	PhD student:	
Jens Groot	PhD student	

Saeid Haghbin	PhD student	
Andreas Karvonen	PhD student	
Anders Lindskog	PhD student	(until September 2009)
Lena Max	PhD student	
Ingemar Mathiasson	PhD student	
David Steen	PhD student	
Julia Paixao	PhD student	(until December 2009)
Mohamed Ramadan Wadi	PhD student	
Johan Åström	PhD student	

Economy

The turnover of the Division was approximately 30 MSEK. The grants were supplied by Chalmers (around 11 MSEK) and external sponsors (around 19 MSEK).

Office facilities and laboratories

The Division has modern office facilities at Chalmers Campus in Johanneberg. The building was completely renovated in 1998 and the address is Hörsalsvägen 11. The laboratories are extensive and support in both research and education. The Division also owns a Wind turbine station at Hönö. This section gives more details in these recourses.

IT tools

Information technology (IT) is a very important tool in both education and research at the division. It is used for calculations and simulations, as a base for measurement systems, as a tool to communicate with field measurement systems and of course for general office work. The Division has licenses for several special software systems. These include ARISTO, DIgSILENT, displace, GAMS, Infolytica Magnet, Intel Visual Fortran, OrCAD, Plecs, PowerWorld, PSCAD (EMTDC) and Siemens PSS/E. The latest addition is ANSYS. We also use COMSOL, LabVIEW, MATLAB, Mathematica, SolidWorks and other software that is part of Chalmers site-licenses.

All employees have modern PC's at their office places. There are also many computers used for measurement, control of equipment, heavy calculation, machine laboratory work, master thesis work and other tasks. Our two conference rooms are equipped with data projectors. The data network is 1 Gb/s. Local IT is managed by one of the division's research engineers.

Laboratories

The Division laboratories support test of electrical systems and components, up to a power level of about 300 kW.

Part of the switch room

The in-house variable power sources consist of various rotating converters, transformers and frequency converters located in machine rooms, which are separated from the laboratories. In the laboratories, special outlets for variable voltage sources are available. Any source can be connected to any outlet in any lab. This is achieved by making connections in the separate switch-room. The voltage sources are controlled through a control box in the laboratory. The variable power sources can supply AC voltages in the range of 0 – 690 V, 4 – 400 Hz and DC voltages in the range of 0 – 690 V. The in-house variable power source system is also used by the Department of High Voltage Engineering.

The laboratories are equipped with solid steel test benches for electrical machine setup. The largest bench is equipped with a DC machine (178 kW, 6000 rpm) with a torque meter.

In addition to the electric power sources there is good instrumentation of measurement modules, oscilloscopes, etc. There are also a great variety of passive power components, electrical machines and power electronic equipment available.

Connected to the laboratories is a small workshop where test objects and electrical measurement equipment can be built.

In the Power Systems Laboratory, the Network Model resides. The Network Model is a 400V miniature of the Swedish power system. It consists of:

The power line model

- A synchronous generator driven by a DC machine, which emulates a hydro power station in the north of Sweden
- A power line model, used to emulate a long transmission line, consisting of six identical Π-sections that can be connected arbitrarily. Each Π-section consists of a series inductor and two shunt capacitors. Capacitors between the different phases are also present. The power line model is connected on one end to the synchronous generator and on the other end to the public grid, to emulate an infinite bus
- One induction machine that can be used as a motor load
- Resistive loads
- One dynamic load, constituted by a controllable boiler
- Two tap-changer transformers

The student laboratory

Finally, there is a student laboratory where high-level pedagogical design of the equipment is combined with a very high degree of safety. In this lab, the students can do exercises at 400 V, 4 kW levels, on most of the components they later will encounter in their role as power engineers. A computer-based measurement system with specially developed measurement and presentation applications assists in visualizing different electric power quantities. The student laboratory also contains a 1.3 kW Solar power converter connected to the grid and to solar panels on the south wall of the building.

Experimental Wind Turbine Station

The Division owns a 30 kW wind turbine with an extensive measurement system for research and demonstration. The turbine is situated on the island Hönö, 45 minutes away by car and ferry from Chalmers. The turbine is two bladed, stall controlled, with a direct-driven permanent magnet generator. The power system allows variable speed operation and consists of a diode rectifier and a thyristor inverter connected to the public grid. The station is also occasionally used for tests of small wind turbines in the range 0.5 – 6 kW.

The experimental wind turbine station at Hönö, Gothenburg

During the year, a number of study visits have been arranged. Visitors have been students at Chalmers, but also teachers and students from elementary schools and colleges. The station was also part of the science festival in Gothenburg in May, as an Open House with about 50 visitors during one day of the festival.

Undergraduate and Continuing Education and Communication

The Science Festival

The Division of Electric Power Engineering is involved in both undergraduate and graduate education at Chalmers. The undergraduate courses are offered, either by the divisions itself or in cooperation with other divisions. The main course program is giving within the Master's Program in Electric Power Engineering which is performed together with the Division of High Voltage Engineering. In addition to the courses the Division is involved in several activities to promote the area to the public. In this Section these activities are described in more detail.

Educational program and communication

Master's Program in Electric Power Engineering

The Division offer an international master program which provides students with advanced and state-of-the-art knowledge in electric power engineering, building both on the theoretical fundaments as well as building a good practical and experimental base. The program covers the areas of high voltage engineering, electric machines and drives, power electronics and power systems. The program also covers the department's profile regarding the environment and renewable energy sources.

The overall purpose of the program is to serve society and industry with basic and advanced knowledge in the field of electric power through well-educated engineers. The objective of the master's program is to impart an advanced-level education in Electric Power Engineering to students who already hold basic undergraduate level training in a branch of Electrical Engineering.

Ola Carlson is the coordination for the Master's Program in Electric Power Engineering

The Science Festival

The Division is involved in the yearly Science Festival, which is arranged each spring by the City of Gothenburg. During one week, a number of activities for the public are arranged at different locations in the city. One contribution from the Division was the open house at the Wind Turbine Station at Hönö. The public was invited to the station where they met scientists to discuss and ask about wind power.

Another commitment was the stall "Wind Power is a Breeze", where students were able to construct their own turbines for a miniature wind power station and thereby learn about wind power. There were two turbines, a smaller one intended for younger children and a larger one intended for older ones. The small one was connected to a little model house with a light bulb and the larger one to three lamps connected in parallel plus a voltmeter, ammeter and oscilloscope. The turbines were powered by the strong wind from a large fan. The stall was appreciated by the visitors, young students and researchers alike. It is one of about twenty different stalls in the big experimental workshop, and the experimental workshops welcomed over 10 000 visitors for a period of two weeks. During the weeks, students aged 8-15 visited the workshops and the public joined during the weekends.

Magnus Ellsén is the coordination for Divisions activities within the Science Festival.

Gymnasiumcenter

Every year high school students from Porthälla Gymnasium come to Chalmers to conduct a wind power experiment. They also make a study visit to the Chalmers turbines on Hönö. This cooperation has enabled teachers to expand the wind power knowledge of their students. Their physics course contains project work intended to be carried out in the wind power area. To make this possible they need to have access to suitable learning equipment and facilities.

A master thesis project that involved the production of course material for future wind energy courses was conducted in autumn 2009. This led to several meetings with teachers that resulted in discussions about requests for material, the significance of the project and background knowledge of the pupils. This cooperation has led to a basic wind compendium especially designed for high school students and based on their level of background knowledge.

ELKRAFTDAGEN and ELKRAFTRÅDET

ELKRAFTDAGEN is a yearly event arranged by the Division of Electrical Engineering, the Division of High Voltage Engineering and ELKRAFTRÅDET. The aim of the day is to encourage students to apply to the program in electrical engineering, and to provide a forum for industry, researchers and students with interest in the field of electrical engineering.

ELKRAFTRÅDET is a board of industry representatives, lead by ABB (Carl-Ejnar Sölver), including members from: Vattenfall, ABB, Svenska Kraftnät, Volvo Cars, Saab Technology, Göteborg Energy and EON. The board has a special role to promote and support the educational program within electrical engineering, which includes the two Divisions of Electrical Power Engineering and High Voltage Engineering. The board typically meets twice a year.

This year ELKRAFTDAGEN was held on March 19, 2009. The program was extended into two parts. The first part was held in the facilities of the Division of Electrical Engineering and Division of High Voltage Engineering, at Hörsalsvägen 11. An exhibition was prepared in the entrance hall with industry booths and the presentation of research results. Guided tours were provided to show the laboratory facilities and ongoing student and research projects. The second part was held in a lecture room in the form of a seminar with invited speakers from the industry. Around 150 participants took part. The day concluded with a joint dinner in the Linsen restaurant with entertainment by "Chalmersspexet", the Chalmers Theatrical Comedy Group, performing "Vera". The magazine ERA published an article about the successful event including interviews with students and industry sponsors.

Undergraduate courses

The Division holds an education program in collaboration with the Division of High Voltage Engineering for the international masters program in Electric Power Engineering, as well as courses in the first years in the E-curriculum.

EEK136 Environmental and power technology
(7.5 credits) Yngve Hamnerius

The aim of the course is to give the electrical engineering students knowledge regarding sustainable development. The students approach environmental problems, primarily in electric power engineering. The aim is also to initiate a discussion on sustainable development and assess the measures of society in the area of environment and resources. Another aim is to develop the ability to transfer information in an effective way.

EEK140 Electric power engineering
(7.5 credits) Ola Carlson

The course aims at providing the necessary basic knowledge in electrical power technology that is important for all electrical engineers. The goal of this course is to make the participants understand the basic principles of electrical power components and systems, and know their possibilities and limitations. In addition, the participants become familiar with important concepts and methods of calculation. The course has its main focus on normal operation and steady state.

EEK231 Sustainable energy sources
(7.5 credits) Ola Carlson

The course in Sustainable energy sources deals with the energy production of today and tomorrow. The energy forms that the course covers are heat-energy, electric-energy, and energy for transportation. The main emphasis in the course is on sustainable energy production plants, such as wind power and photo voltage. Further, electrical and hybrid electrical vehicles will be important parts of the transportation system in the future; the technology used for energy transformation between mechanical and electrical systems such as electrical motors and generators, transformation between different voltages, and transformers and converters, are discussed in the course. Systems for distributed heating and heating of single houses is also covered in the course.

EEK565 Electric power engineering
(7.5 credits) Aleksander Bartnicki

After this course students will understand the basic principles of electric power components and systems, as well as know the possibilities and limitations of them. In addition, they will also learn important concepts and calculation methods.

ENM011 Environmental technique & Electric Power Engineering
(7.5 credits, of which 3 Credits is Electric Power Engineering) Johan Boman and Torbjörn Thiringer

This course is given for the automation and mechatronics curriculum, year 2, and is taught in Swedish. The overall purpose of the course is to provide fundamental knowledge regarding the ability to develop environmental-friendly techniques. In the power engineering part of the course the students are provided with knowledge about electrical machines, and how to design a torque and speed controlled system. Moreover, they learn about the operation of basic power electronic circuits as well as power loss and thermal calculation of power electronic semiconductors. Apart from lectures and tutorials there are also computer simulation laboratory exercises as well as an experimental laboratory exercises.

FSP025 Technical communication
(7.5 credits) Torbjörn Thiringer

This course is conducted in cooperation with the High Voltage Engineering Group at Chalmers as well as language teachers from the Language and Communication Group. The goal is to give students a good linguistic foundation and the habit of using the English language, in order to compose, write and present various types of reports and projects as well as to use literature in English. In the course an electro technical problem is also treated. The purpose of the project is to enhance the students' capacity of working in a group, to produce a report and an oral

presentation of their results. This course is given in the first study period of the first year of the Electro-curriculum.

Bachelor theses

ENMX02-09-02 and ENMX02-09-04 Bachelor thesis at the Division of Electric Power Engineering (credit = 15) Examiner Sonja Tidblad Lundmark, Supervisor Robert Karlsson.

14 students worked with projects concerning electrical go-carts and electrical bikes. The students were divided into the following five different sub projects:

- Go-cart drive systems
- Test of a control system for an electric Go-cart
- Implementation of a battery system for an electric Go-cart
- Electric bicycle – Regeneration with BLDC-motor and DC/DC-converter
- Charging of an electric bike by wireless power transmission

Continuing education courses

EEK150 Power engineering, design project
(7.5 credits) Ola Carlson and Aleksander Bartnicki

The course intends to develop creativity and cooperation in approaching a practical problem in the field of electric power engineering, often connected to environmental technology. The students need to apply knowledge from earlier courses as well as seek and obtain the additional information they need for the problem in question. The course should give possibilities to solve problems where creativity is important. Teamwork and collaboration in groups with different compositions are important in the course as well as presentation of the result, both in written and oral form. The projects are not fixed and may vary from year to year. A list of suitable projects is presented before the beginning of the course on the course homepage. The different projects have different aims. The project could consist of experiments, design, construction and testing of prototypes and usage of computers for computation (design & construction) and simulation (experiments & testing).

EEK201 Power market management
(7.5 credits) Tuan Le and Lina Bertling

Power industries in many countries have recently been forced to change their way of doing business since the introduction of deregulation. With deregulation, the power system is “split” into generators, traders, customers and grid owners. These different market actors now act in the power market independently of one another

and in a way that maximizes their respective benefit. In this context, management of power markets to ensure reliable operation of power systems becomes a critical issue, and is the centre of this course. The course brings about the optimal integration of technical requirements of power system operation and the economic principles of power markets. The main focus is on how the markets work, responsibilities of different market actors, management of power system security, requirement on system reserve, pricing for transmission and ancillary services, investment on generation and transmission facilities. Throughout the course, students will gain experience in project work that simulates power markets and their associated problems.

EEK221 Applied computational electromagnetic
(7.5 credits) Yuriy Serdyuk

This course aims to introduce students to fundamental concepts of low frequency electromagnetics with examples from electrical power engineering, to give basic knowledge on numerical techniques and computer software for field calculations. The course focuses on developing practical skills in using computational tools and analyzing results of computer simulations. An essential part of the course is devoted to solving a set of electric, magnetic, thermal and coupled (multiphysics) problems related to different power frequency applications using commercial finite-element software.

ENM050 Power system analysis
(7.5 credits) Tuan Le and Per Norberg

This course covers a wide range of topics in power system analysis. The emphasis is first on development of mathematical models of major power system components (e.g., transmission lines, power transformers, loads). Derivation of network matrices is then treated. The models and network matrices developed earlier are then used in power-flow analysis for large power systems, which is one of the most widely used applications in power system studies. Well-known algorithms for power-flow computation are introduced, and advantages and disadvantages of each algorithm are highlighted. Means to control the power flow and voltages in the network will also be discussed. In addition to analyzing power systems in normal operating conditions, students also learn how to analyze them in faulted conditions (symmetrical and unsymmetrical faults). The course provides students with practical experience in laboratory work related to different topics treated in the course.

ENM055 Electric drives I
(7.5 credits) Sonja Tidblad Lundmark

This course provides an understanding of the design of electric drive systems in general and an ability to choose the relevant drive system for a given application.

The course gives a deep understanding of electric machines: theory, applications, steady-state, and (for the dc brush machine) dynamic performance with speed and current control including relevant theory. The student is encouraged to consider environmental aspects, such as energy-efficient drive systems, and recycling of copper.

ENM060 Power electronic converters
(7.5 credits) Torbjörn Thiringer and Massimo Bongiorno

Sustainable energy technologies such as wind power, photovoltaic, wave energy, utilization of fuel cells and hydrogen as energy carriers all need power electronics converters in the interface to the electrical load. Most of the techniques for energy saving at the electrical load side, such as motor speed control in fans and pumps as in heat pumps and energy saving lamps, also need power electronics. The course presents an introduction to the converter circuits of power electronics used to convert and control electric energy. Methods for designing converters are presented. How to select converter topologies, power semiconductors and passive components is also briefly covered.

ENM065 Power system operation
(7.5 credits) Tuan Le

Power system operation engineers (dispatchers) have one of the most challenging jobs in the electric power industry. They must have a basic understanding of various types of power system generation, plant controls, protective schemes, control of voltage and frequency, overall dynamic behaviours of power systems (transient and voltage stability), and the fundamentals of economic operation. In addition, they must also have the ability to monitor and quickly analyze emergency situations and take appropriate corrective actions promptly. The purpose of the course is to give students knowledge of and exposure to these dynamics. Students will have a better understanding of some of the operating and controlling issues of a power system through laboratory work as well as through simulation software.

ENM070 Power electronic devices and applications
(7.5 credits) Torbjörn Thiringer

This course builds on ENM060. The aim of this course is to enhance students' knowledge regarding the design and application of power electronic converters. Some examples are: design of driver circuits of various qualities and for various applications, design of snubber circuits for improved EMI and loss operation, thermal calculations and considerations. In addition a goal is to explain the concept of soft-switching converters such as resonant and zero voltage current as well as zero voltage switching converters. Moreover an objective is to provide the students with knowledge of power electronic equipment connected to the grid such

as HVDC (both classical and modern VSC-based), FACTS equipment, power factor correctors, UPS and power conditioners. Finally students receive a deeper understanding in the properties and control of power electronic semiconductors.

ENM075 Electric drives II
(7.5 credits) Stefan Lundberg

The overall aim of this course is to provide students with an understanding of how a field-oriented controlled induction machine and PMSM drive is designed and operated. In addition, it gives students the practical ability to construct such a drive in the computer environment Matlab/Simulink, and enables them to interpret and evaluate the performance of the drive constructed. Another goal is to derive dynamic equations as well as equation set-ups appropriate for simulations from the physical construction of the electrical machines. Both induction machines as well as permanent magnet synchronous machines are to be treated for both sensored as well as sensorless (speed and position sensorless) operation.

ENM095 Sustainable power production and transportation
(7.5 credits) Ola Carlson

This course aims to expose students to advanced and state-of-the-art developments in wind power, photo voltages, wave power and hybrid electric vehicles, focusing both on the theoretical fundaments as well as building a good practical and experimental basis. The goal of the course is also to give the students a deep knowledge about the modelling, design and control of the electric system for hydro, wind, wave, and solar power. The electric system in electric or hybrid-electric vehicles will also be treated. The understanding of the grid interaction of these power sources and consumables is also an important goal.

ENM100 Power electronic solutions for power systems
(7.5 credits) Massimo Bongiorno

This is an elective course in the international master program in electric power engineering. The aim of this course is to familiarise students with the use of power electronics both at transmission and distribution level. In particular, the configuration, design and control strategy for the different devices will be covered during the course. At the end of the course the student should have a proper understanding of the different problems that can be encountered at the different voltage levels in the power systems and how to approach and solve them. The course consists of theoretical lectures, tutorials and computer exercises. The course was given the first time in 2008.

MTT035 High voltage engineering
(7.5 credits) Jörgen Blennow

The course starts with fundamental electric field calculations (Laplacian fields) in insulation systems of simple geometries followed by an introduction to gas discharge physics, Townsend's theory of electric breakdown in air and Paschen's law and its implications on gas insulation strength. A central area of the course is experimental techniques, which is applied and put into practice during laboratory work. The concept of insulation coordination connects the different topics in a natural way, and constitutes a theme woven through the course. In addition, knowledge of components in the power system and their characteristics is also of vital importance for a professional engineer and is therefore dealt with both with theoretical practices and during a study visit to a nearby sub-station.

MTT040 High voltage technology
(7.5 credits) Stanislaw Gubanski

This course builds on the knowledge gained during the course in High Voltage Engineering and its aim is to provide deeper understanding of physical phenomena important for proper functioning of insulation systems in high voltage devices, as well as for utilizing high voltages in technological applications. Focus is put on the selection of adequate processes and materials yielding desired electric properties (breakdown strength, ionisation, conduction and polarisation). Based on this understanding the knowledge on design criteria for insulation dimensioning and principles for insulation diagnostics is built, including elucidation of basic differences between insulation systems for ac and dc applications. Furthermore, students gain insight into technologies using electric discharges.

Master theses

During the year 33 master theses projects were presented which were performed by 44 students. The theses and the participating students are presented in the Chapter on publications.

Graduate Education

The PhD students at the Division participate in the following compulsory courses (30/60 credits are required for Licentiate/Doctoral exam):

- TLC102 Teaching, learning and evaluation 3 credits
- TLE206 Ethics, science and society 3 credits
- Science theory 3 credits
- Fundamental environmental theory 4.5 credits

In addition there are a number of courses at other departments at Chalmers, for instance in the area of Control Engineering etc, which the Ph.D. students can also attend, as well as more electric power oriented courses at other universities.

Graduate courses

Wind Energy, modelling, control and grid integration
Conducted at Alcala University, Madrid, 1-5 June 2009 Torbjörn Thiringer

The course dealt with fundamental modelling of wind turbines with a focus on dynamic behaviour. Electric systems as well as their power quality impact and their interaction with the power grid were covered. Furthermore the response of wind energy installations to network disturbances and their ability to ride through these disturbances were covered. Finally, the course dealt with the topic of the stability impact that wind energy installations can have on the grid as well as experiences from measurements.

Power Electronics for Transmission System Applications
Conducted at Royal Institute of Technology, Stockholm, Massimo Bongiorno

This is a three days intensive Ph.D. course, held for the first time at the Royal Institute of Technology (KTH) in May 2009. The aim of the course is to give a deeper understanding of the application of power electronics in power systems, both for AC and DC transmission. The course includes theoretical lectures, computer exercises and laboratory demonstrations. KTH and Chalmers offer the course jointly. The course instructors are Massimo Bongiorno (Chalmers), Lennart Ängquist (KTH) and Staffan Norgga (KTH/ABB).

Graduate theses

Below is a list of the graduate theses that were presented during 2009.

PhD theses

- Lena Max presented her PhD thesis: on Design and control of a DC collection grid for a wind farm, December 8, 2009. External reviewer was Professor Bram Ferriera TU Delft. The thesis was supervised by Ola Carlson and Torbjörn Thiringer with examiner Tore Undeland.

- Abram Perdana presented his PhD thesis: Dynamic Models of Wind Turbines, March 10, 2009. External reviewer was Professor Mark J. O'Malley, University College Dublin. The thesis was supervised by Ola Carlson with examiner Tore Undeland.

Tech Lic theses

- Tarik Abdulahovic presented his Licentiate thesis: on Analysis of High-Frequency Electrical Transients in Offshore Wind Parks, April 28, 2009. External reviewer was Associate Professor Marjan Popov from Delft University. The thesis was supervised by Torbjörn Thiringer with Tore Undeland as examiner.

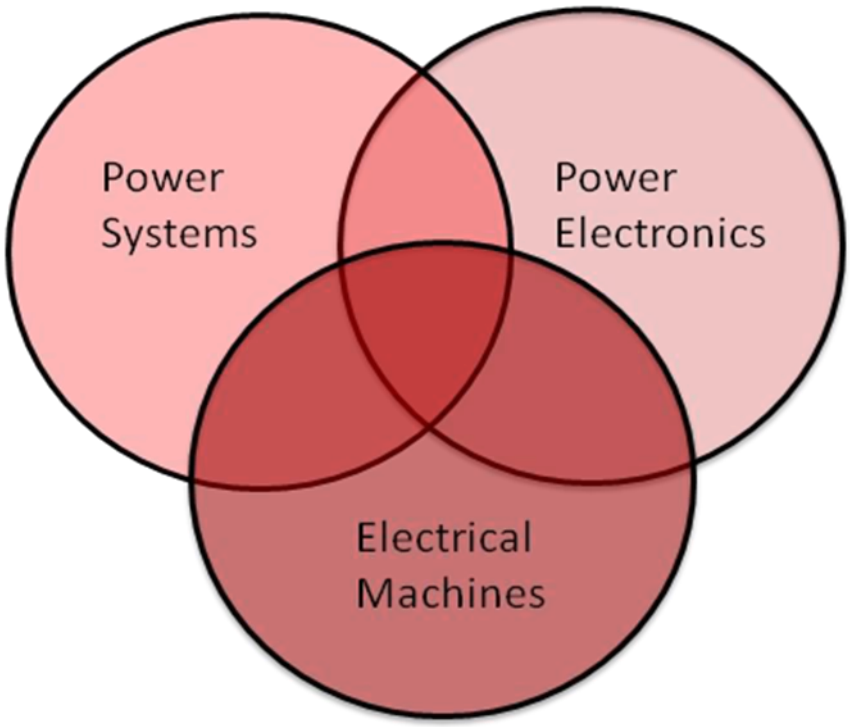
- Andreas Karvonen presented his Licentiate thesis on MOSFET Modelling Aimed at Minimizing EMI in Switched DC/DC Converters Using Active Gate Control, June 8, 2009. External reviewer was Associate Professor Tonny Rasmussen DTU, Copenhagen. The thesis was supervised by Torbjörn Thiringer with Tore Undeland as examiner.

Research Activities

Research scope at the division

The research activities at the Division stem from the following three traditional competence areas: electric power systems, power electronics and electrical machines. Moreover these competence areas are being applied at the Division in several application areas with primary focus on wind power, transmission and distribution, and electrical vehicles. New areas for research are typically found in overlapping competence areas e.g. applied power electronics for the electric power system. In the following section ongoing research projects have been grouped into the following main application areas:

1. Wind power and network integration
2. Electric power delivery system
3. Electrified vehicles and energy efficiency



Wind power and network integration

Wind power and network integration is a main research topic at the Division. Modelling and control of wind turbines are topics that have attracted a great deal of attention. Following on the results of this focus, the research has continued with exploration into fault response from wind turbines as well as study of what wind turbines could do during network disturbances to reinforce the grid. Lately the activities regarding propagation of HF-transients in wind parks as well as reliability issues have attracted more attention, and currently a couple of projects examine this issue. During 2009 the research scope has been extended to include reliability modelling and maintenance management.

General activities

The Division takes part in several related educational and research programs on wind power. The main activities are summarized below. Ola Carlson is the project leader at Chalmers for these different programs.

Power Cluster

The Power Cluster partnership aims to tackle crucial challenges to the further roll-out of offshore wind technology in Northern Europe by cooperating beyond borderlines and sector barriers. Furthermore, the Power Cluster project seeks to develop cooperation between individual countries in order to take advantage of future growth in offshore wind and identify future markets.

The overall project goal is implementation of a transnational offshore wind energy cluster in the North Sea Region. In that respect, the Power Cluster project will contribute to ensuring the North Sea Region's continued leadership in offshore wind energy.

This work will allow Power Cluster to develop comprehensive approaches to meet the strategic challenges of offshore wind energy industry in the North Sea Region and make the region a better place to live, work and invest in.

Swedish Technical Wind Centre

The centre is a collaboration between Chalmers and the Swedish industry and was initiated due to the lack of large-scale production of wind turbines in Sweden. Chalmers and the industrial partners have been working intensely since March 2009 to formulate the research focus and organisational form of this research centre. The centre will concentrate on wind turbines with an output of more than 2 MW, suitable for positioning in open countryside, forests, mountains or off-shore, and the work will be organized within the following themes:

1. Electric power and control
2. Aerodynamic forces and turbine blade design
3. Mechanical drive train and system optimization
4. Supporting structure and foundation

The research will be carried out in project form in close cooperation with industry, with smaller projects for deep research and larger ones covering all themes. The large projects will focus on a complete design: taking the interaction between all components into account as part of the design of an optimal wind turbine.

Power Väst

The project Power Väst is commissioned by the Swedish Energy Agency and is implemented by the Västra Götaland regional authority. The project contains a number of sub-projects which follow the main project description as agreed with Swedish Energy Agency. The main parts are contacts with industry for wind energy development, links with schools, colleges and universities for the planning of wind energy training and development of teaching materials. Chalmers University of Technology has responsibility for the coordination and implementation of the sub-project Training and R&D cooperation, and participation in other sub-projects within Power Väst.

Measurements on a DFIG Turbine in Tvååker, Halland with ride-through ability

Measurements have been conducted on a 2 MW wind turbine located in the county of Halland. Currents and voltages in various locations in the generator and converter system were measured and analyzed. Both steady-state measurements have been conducted as well as transient measurements during fault conditions. A grid fault down to 0% remaining voltage for 100 ms was recorded, and the result showed that the turbine handled this disturbance well, i.e. it succeeded with the ride-through.

Post-doc projects

Wind Turbines and Wind Farms Models for Power System Studies

Participants: Abram Perdana, Ola Carlson
Sponsors: Nordic Energy Research, Vattenfall and Svenska Kraftnät.

Wind power penetration in the power system has reached a level that is no longer negligible. Thus, wind turbine models able to correctly investigate the influence of wind power generation on power system stability are urgently needed. On the other hand, no standardized wind turbine model is currently available, and most proposed wind turbine models are rarely validated. The main purpose of the project is to provide validated generic wind turbine models for power system stability studies. The study will be based on the generic models proposed from the previous concluded study. The project comprises several tasks including:

- Evaluation of existing built-in wind turbine models available in commercial power system simulation tools.

- Validation of the generic wind turbine models against measurement data.
- Grid integration study of wind power. The study focuses on reactive power responses of wind farms during and following faults on the regional network voltage stability.

The project is conducted as a part of a larger project named “Model development for power system analysis with a substantial wind energy capacity installed in the Nordic grid”, which involves Nordic and Baltic countries.

Wind Park Design for HVDC-connected wind park
Participant: Stefan Lundberg
Sponsor: Vindforsk

In this project, a cost-effective solution is proposed for a sea-based wind park located at a substantial distance (>50 km) from a suitable grid connection point. The idea is to utilize the controllability given by a dc-transmission between the wind park and the grid connection point. This solution gives good controllability in the grid connection point. Moreover, this solution makes it possible to use cheap wind turbine systems and still comply with the coming Grid Code requirements. By cheap wind turbine we mean a DFIG wind turbine with an extra small converter and no individual Ride-Through function. Last but not least, the loss reduction possibly achieved by the freedom in setting the local wind turbine grid voltage and frequency will be investigated.

Wind Power Asset Management and Reliability Centred Asset Management
Participants: Francois Besnard (KTH), Katharina Fischer, Lina Bertling
Sponsor: Vindforsk, CSES, Chalmers

Wind power plays a central role for the development of a sustainable power supply system. Ambitious goals have been set to promote the strong increase of wind energy utilization required in view of climate change and limited primary energy resources. Offshore wind power in particular is seen as the most promising new energy technology. However, the present high maintenance costs for wind turbines (especially at offshore sites) impede the growth of wind power necessary to reach the goals. Recent research shows that the present maintenance, both on- and offshore, is not being optimized and there could be large potential savings by reducing (a) the cost for maintenance activities and component failure, and (b) cost due to production losses, especially for large offshore wind parks.

To reach a cost-efficient maintenance management is the objective in the project “Maintenance Management of Wind Power Systems by means of Reliability-Centred Maintenance (RCM) and Condition Monitoring Systems (CMS)”, with post-doc Katharina Fischer as main researcher. For this purpose, the concept of reliability-centred maintenance, which is established and successfully applied in

other industries, is transferred to wind power systems. The focus lies on the utilization of CMS used to continuously monitor the condition of the wind turbine equipment. CMS data is analyzed in order to detect incipient failure and develop methods for optimal condition-based maintenance in a systematic way.

This research project aims to continue on previous research performed at KTH and within the research group of reliability–centred asset management (RCAM) under the direction of Lina Bertling. Within the RCAM group research has been performed within the topics of applied reliability theory for electric power system and equipment from 1997 including three PhD theses: Bertling 2002, Lindquist 2005, Hilber 2005, and several tech lic theses and master theses. The aim of this project is to continue the research track into the field of wind power applications, also involving an ongoing PhD student project within Vindforsk II by Francois Besnard and Lina Bertling. During the autumn a new post-doc project is formulated for Dr. Katharina Fischer to join the group.

Power Cluster – Work package 2 – Business/Grid study of the off-shore wind farms in the North Sea
Participant: Tuan Le
Sponsors: EU - INTERREG IV B North Sea Region Program

When large-scale renewable energy resources are integrated to the power grid of the countries in the North-Sea region, the existing power systems could easily experience overloading and power/voltage fluctuation problems, since they have not been designed to take up as much energy from the remote ends of the grids, (i.e. offshore.) In addition, the fluctuating nature of renewable energy, for example wind energy, could worsen the situation. The grids at these points are often low voltage and relatively weak. They are not ready to take on large-scale renewable power injection. This project focuses on development of a proposal for the off-shore wind power grid and evaluates its effects on the existing on-shore grid in the North Sea region. The project also focuses on evaluation of the surplus benefits when the North Sea Wind Power Grid is connected to the countries around the North Sea, in terms of new opportunities for more energy trading between the countries and other market related issues.

PhD student projects

Analysis of Wind Park High-Frequency Electrical Oscillations
Participants: Tarik Abdulahovic, Torbjörn Thiringer, Ola Carlson,
Sponsor: Vindforsk

This project investigates the generation, presence and propagation of high-frequency disturbances in a sea-based wind park consisting of modern converter-controlled wind turbines.

Both steady-state high-frequency components such as harmonics, as well as transients of irregular nature will be covered. Important components in the wind park treated in the study are: cables, breakers, surge arresters and transformers. An important goal is to compare the theoretically obtained results with measurements.

The results of this project are increased knowledge and understanding about high-frequency disturbances in a wind park. In addition, the results will give concrete indications regarding how future sea-based wind parks should be designed in order to avoid similar problems that have occurred in some wind parks.

The licentiate report was presented in April 2009. Most of the effort during 2009 was put into the modelling and additional case studies in order to identify potentially dangerous transients in medium voltage cable systems equipped with dry-type and/or oil-insulated transformers.

DFIG Wind Turbine Cluster Transients during Disconnections
Participants: Julia Paixao, Ola Carlson, Massimo Bongiorno, Torbjörn Thiringer,
Sponsor: Elektra

The aim of this project is to study the transients occurring in a DFIG-system (doubly-fed induction generator system) with ride-through ability, when the radial circuit breaker is opened. In order to fulfil the emerging grid codes, large installations of DFIG-turbines are equipped with voltage-dip ride-through systems. Harmful over-voltage transients in a DFIG-system with ride-through ability have been reported during events of disconnection/reconnection of the cluster circuit-breaker compromising the reliability of this wind turbine system. The main idea is to investigate and improve the operation of the DFIG wind turbines during a sudden disconnection of the cluster circuit-breaker and the following loss of feeding voltage through simulation models and measurements. The handling of a sudden reconnection of the DFIG wind turbine cluster before the turbines have reached the complete shut-off state is also investigated.

DC wind park module - design, function and control
Participants: Lena Max, Ola Carlson and Torbjörn Thiringer
Sponsor: Vindforsk

In this project, the design and control of a wind farm with an internal dc grid is investigated. The purpose of using an internal dc grid in the wind farm is to decrease the cost since dc cables are cheaper, and the transformers in dc/dc converters are much smaller than ordinary ones. The aim of the project is to further investigate the control of the internal voltage levels in the dc grid and also the control of the wind turbine generators, as well as the choice of voltage levels and grounding system. Normal operating conditions are treated along with

different fault conditions. Both internal faults should be handled as well as the ride-through capability. Further, the characteristics for the wind farm from the grid point of view will be lined out. Lena successfully defended her PhD thesis on December 8, 2009.

Electric power delivery system

The electric power delivery system faces several challenges: need of reinforcement in the power grid, integration between countries, intermittent power production, large and small scale production, and active customers having more information and sometimes being both consumer and producer. Solutions to these changes lay in: new standards and regulations, techniques to control the power, e.g. phase measurement units (PMUs), FACTS (Flexible AC Transmission Systems), HVDC VSC (Voltage Source Converters), support from Information and Communication Technology (ICT), and Digital Signal Processing (DSP), materials for efficient high voltage insulation and technology for energy storage using e.g. electric cars. The idea of Smart Grid connotes the application of such solutions for the development of a sustainable electric power delivery system. The Division has research activities within different sections of these areas presented in more detail below, and several new activities are planned to start in 2010 e.g. within the Chalmers Energy Initiative.

Post-doc projects

Use of Power Electronic Controllers for Power Systems Stability Improvements
Participant: Massimo Bongiorno
Sponsor: Elektra

The aim of this project is to investigate the application of shunt-connected converters (also called STATCOM, both with and without energy storage) to the electric power system. In particular, the final goal is to investigate the impact of active and reactive power compensation on the stability of the power system, as well as on its steady-state performance. Aspects such as ideal placement, control settings (speed of response and droop settings) and the need for active energy input will be investigated. Furthermore, the possibility to use “highly distributed FACTS units” already existing in the power system (for example, wind farms) will be considered.

Future Electric Power System – Smart Grid
Participants: Tuan Le, Lina Bertling
Sponsor: E.ON

The electric power system is changing to meet future demands on the energy infrastructure. This development is getting generally known as Smart Grid. It

implies larger flexibility to manage changes, more integrated systems with less and smarter components, increased optimization and higher availability and lower transmission losses. One of the main changes comes from the large increase in intermittent power production from wind power in the near future, and in a longer perspective in sun and wave power. This project will investigate the strategies to transform the existing power system into a Smart Grid system. The project will look specifically at the development of control and market strategies for the transmission and distribution systems and identify the enabling technologies to optimize the grid. A new post-doc position is being formulated within this project. The project is part of the E.ON Chalmers collaboration involving several projects within the overall topic of Future Energy System.

PhD student projects

Plug-in electric vehicles and the energy supply system in Gothenburg
Participants: David Steen, Ola Carlson, Per Fahlén (at the Division of Building Services Engineering), Lina Bertling
Sponsor: Göteborg Energi AB.

The transport sector faces a major shift towards more energy-efficient vehicles. Already there are several electric hybrid vehicles on the market, powered by both an internal combustion engine and an electric motor. Several of the major vehicle manufacturers will within the next few years launch a new type of hybrid vehicle, known as plug-in hybrid electric vehicle (PHEV), which can be charged from the electrical grid. The purpose of this research project is to investigate how the energy system in Gothenburg is affected by an increasing number of plug-in electric vehicles (PEVs), i.e. PHEVs and electric vehicles (EVs), as the use of energy in buildings is changed.

In a first stage the electric grid in Gothenburg is examined to estimate how well it can handle changes in the energy consumption, such as an increased amount of PEVs or heat pumps etc. and thereafter the market will be investigated to estimate the rate at which PEVs will increase, a distribution map will be produced to show the expected geographical distribution of the vehicles around Gothenburg. Thus the importance of different policy instruments and changes in infrastructure will be included. This information will be used to examine whether and in which sections Göteborg Energi needs to strengthen and expand its electrical grid. By examining how the heat demand looks, how it is expected to change in the future and how heat is produced, future investments in the electrical grid can be optimized in a better way than if only the plug-in vehicles are taken into account. Moreover, the impact on the electric grid, caused by the plug-in vehicles, is to be studied. By controlling the charging of the vehicles to times when the load of the grid is small, an increased peak power is minimized. Variations between the power requirements for electricity and heat over time will be compared to find synergies or solutions to possible problems.

The electric grid in two different areas in Gothenburg, one residential and one commercial have been examined during the year. The maximum power level was found as well as the maximum number of PEVs that could be supported under different charging strategies. Statistical data was then analyzed to find out how and when the vehicles are used. The result will be used to obtain more reliable charging scenarios. Existing measurement data for different heating alternatives will be analyzed in order to examine the effect in the electric grid.

Stability Issues Related to Implementation of Large Wind Farms
Participantes: Marcia Martins, Massimo Bongiorno, Ola Carlson
Sponsors: Vindforsk, Chalmers

This thesis focuses on the impact of voltage stability when introducing large wind farms on the power system. To this end fixed speed wind turbines equipped with conventional induction generators were studied. The investigations have been carried out with respect to short and long term voltage stability. A comparison with field measurements was performed in order to validate the simulation models used for the investigations.

For short-term voltage stability studies, a comparison was made between induction machines operating as a generator or as a motor. Further investigations have been performed to study the behaviour of the system during and after a short circuit fault at the terminals of the wind park. The investigations have examined factors affecting the short-term voltage stability limit such as: generated power, fault types, fault duration, fault clearing time and retained voltage. The voltage tolerance curve was introduced to describe the stability limit of a system connected to a wind farm.

For long-term voltage stability a comparison was made between wind power plants, thermal power plants and a combination of both the production sources. For both wind power and thermal power the requirement of the Swedish grid code was taken into account. Different control strategies of the reactive power production were analysed for the wind park. An important conclusion is that under the normal operation of a wind park, a voltage control mode will be beneficial for the network of which it is part.

Voltage Stability Analysis and Improvement for the South West Network of Libya
Participants: Mohamed Ramadan Wadi, Ola Carlson
Sponsor: The Libyan Government

The project aims to investigate, analyze and suggest improvements for the voltage stability of the south-west electrical network of Libya, which is supplied by different generating regimes and automatic tap-changers operating at maximum network capacity. The research will include the carrying out of a generic analysis of the

voltage stability of the transmission systems using transmission line models. Important relationships for different operating conditions and transmission capabilities will be predicted. Finally, the research will recommend the appropriate improvements for the network.

Electric power production based on combined energy sources
Participants: Ingemar Mathiasson, Ola Carlson
Sponsor: Chalmers

Autonomous electrical power generating systems are the kind of systems that have the ability to work and generate power completely independent from conventional main power grids. The autonomous systems could be of different sizes, depending on the field of application in question. The autonomous systems could be a way to solve the energy requirements for those regions that are far away from the main grid. There are multiple needs, present and future, for these special systems. An example of an application is power generation for small villages in the developing countries. These villages are very often located far from the main grid. One common way to solve the energy problem in these situations is to use diesel operated generators. Of course while these types of electric power generating systems serve their function, they also tend to be harmful to the environment. In the future it is necessary to employ more environmentally friendly solutions that make use of renewable resources e.g. wind and sun. The objective of this research project is to analyze autonomous electrical power generating systems that fulfil these criteria. The systems consist in this case of four subsystems:

- Wind power system(s)
- Sun power system(s) (PV-applications)
- Diesel system(s) (as back up)
- Power accumulator system(s) (e.g. fuel cells)

The project is divided into two main parts, modelling and realization of a test system.

Electrified vehicle and energy efficiency

The research on Electrification of vehicles focuses on better utilization of electric power equipment related to electrified vehicles as well as improved energy efficiency. Projects deal with using the existing propulsion converter and propulsion electric machine for charging of the vehicle, and involve Anders Lindskog, Saeid Haghbin and Sonja Lundmark. Others cover adapting power electronic equipment for electrified vehicles, and involve Ghasem Aghdam and Torbjörn Thiringer. Below follows a detailed description of the projects.

Another important topic for research at the Division is power electronic supply in buildings with an overall goal of energy efficiency. The research activity on this topic involves one PhD student project which is performed in collaboration with the Division of Chalmers Building Services Engineering.

Post-doc projects

Energy efficiency of electrical drive systems
Participant: Sonja Tidblad Lundmark
Sponsor: Swedish Energy Agency.

The aim of this project is to consider the energy efficiency of electrical drive systems; the components of the system should have low energy consumption, low production cost where each part is optimally used, preferably for several different applications, and the parts should be recyclable in a cost effective way. Traditional design and production will be evaluated against more integrated multi-functional methods. Further, the finite element method will be used for modelling electromagnetic and thermal phenomena in order to calculate efficiency of electrical machines.

PhD student projects

Design of power electronic equipment for hybrid electric vehicles
Participants: Ghasem Aghdam, Torbjörn Thiringer
Sponsor: Swedish Energy Agency.

The main objectives of this project are to consider the operational aspects put on the power electronic converters placed in a hybrid electric vehicle, and to study converters fit for this application. In the engine room of a vehicle with a combustion engine, the temperatures are substantially higher than 50°C, the cooling fluids having even higher temperatures, and of course the components in power electronic converters must be able to handle high temperatures. Apart from the high temperatures, there are environmental aspects to consider in the vehicle, for example low temperature, vibrations, dirt and humidity, creating a need for new power electronic converters able to withstand such conditions.

Integrated drive and charging system for a hybrid vehicle
Participants: Saeid Haghbin, Anders Lindskog, Sonja Lundmark, Torbjörn Thiringer, Ola Carlson,
Sponsors: SHC, Swedish Energy Agency and Volvo Car Corporation

The two projects described here are about the design and integration of the electric drive system and the on-board charging system in hybrid plug-in vehicles. Thus the traction circuit parts (i.e. electric machine, inverter and sensors) are used in the charger circuit to make an integrated charger and traction system in order to reduce size, weight, space and total cost of the electrical system of the vehicle.

The PhD students use electric machine design tools as well as modelling, control and optimization methods to study the system, and also construct prototypes/test benches.

Saeid primarily works with the design of a fast (three-phase) charging system with a special electric motor used as an isolator or energy storage device (inductor) in the charger circuit. This sub project “Integrated charger for Plug-in Hybrid Electric Vehicles (PHEV)” is part of the ‘‘Electrical System Design of PHEVs” project inside Swedish Hybrid Vehicle Centre (SHC). The project includes three parallel sections addressed by three parallel groups together at Chalmers, KTH and Lund: Motor Design and Sensorless control (KTH), On Board Integrated Charging (Chalmers) and EMC design (LTH). The latest status of the project is to propose and design an integrated motor/drive/charger based on a three-phase interior permanent machine, with a prototype under development.

Anders’ project is concentrated on 1-phase integrated chargers with a special converter used for traction, charging, and as a battery management system. By using a multi-level converter, the energy transportation can be optimized and the use of different storage components can be introduced. When accelerating, the vehicle’s super capacitors are the most suitable component since they have very low losses, but when driving at a constant speed the energy can be taken from energy optimized cells. The system should also be able to be used as a battery management system in which charges can be moved between the cells during driving. The modelling, control and optimization of the system are to be studied and compared to the traditional method where the charger stands alone. The system will also be verified with a prototype.

State-of-health modelling of Li-ion batteries
Participants: Jens Groot, Torbjörn Thiringer, and external supervisors: Kristina Edström (UU), Göran Lindbergh (KTH),
Sponsors: Volvo AB, Swedish Energy Agency.

In addition to performance in terms of energy power and efficiency, the lifetime of the energy storage is especially important for a successful development of electric and hybrid electric vehicles (HEV). Currently, the most promising energy storage technology is the lithium-ion (Li-ion) battery. Despite good performance compared to other battery technologies, the lifetime of the Li-ion battery is hard to estimate since it is non-linear and strongly dependant on the operating conditions. The scope of this project, run in cooperation between AB Volvo, Scania AB, The Royal Institute of Technology, Uppsala University and Chalmers University of Technology, is to test, investigate and model the most important ageing mechanisms of Li-ion batteries used in HEVs. The project includes a large number of battery cell tests, material analysis, model development and verification. The Swedish Energy Agency funds the project together with the industrial partners AB

Volvo and Scania AB. An industrial PhD-student from AB Volvo is stationed at the department of Energy and Environment at Chalmers with research focus at state-of-health modelling of large-cell Li-ion batteries and battery systems for heavy-duty HEVs.

Initial battery tests were started in 2009 to enable a first characterization of the battery degradation process. Participation in post-graduate courses in electro-chemistry and a literature survey have been parallel activities, as well as the development of test methods and a statistical analysis of battery load cycles. The initial battery tests will be followed by extensive testing and modelling of specific ageing mechanism during 2010.

Modelling Aimed at Minimizing EMI in Switched DC/DC Converters Using Active Gate Control

Participants: Andreas Karvonen, Torbjörn Thiringer,
Sponsors: Vinnova, Volvo Cars, SAAB Microwave Systems, Ericsson AB, SKF

In this project, techniques to reduce the EMI from switched power converters are investigated. The main goal is to directly approach the generation of unwanted signals rather than constructing additional EMI-prevention methods such as additional shielding and filtering.

The goal with the project is to push the technology within the design of voltage conversion units forward using theoretical studies as well as experiments. The main technical focus lies in understanding component functionality and how to control the switching element in an advantageous way by mathematical modelling of the converter. Other important aspects to be investigated are efficiency, robustness, size and cost. The main technique used is shaping of the switching wave-form, but simulations methods to predict the EMI-levels of a converter are also investigated.

During the first half of 2009, the focus of the project was to complete the licentiate thesis. A novel MOSFET model was introduced and verified by measurements and simulations. The model was then used to verify the principle of soft-switching for a low-voltage MOSFET. During the second half of 2009, the focus of the project was aimed at understanding the importance of diode reverse recovery performance for conducted emissions for a 15W isolated DC/DC-converter. Initial simulations and measurements of converters have been performed. In addition to this, an article was extracted from the licentiate thesis and presented at the International Conference on Power Electronics and Drive Systems in Taiwan.

Energy efficiency using power electronics for fan and pump applications in buildings

Participants: Johan Åström, Torbjörn Thiringer
Sponsors: Swedish Energy Agency, Göteborg Energi AB, Formas

The project is a cooperation with Chalmers Building Services Engineering in order to create an interdisciplinary environment of researchers in building service engineering and electro-technology. The overall goal is to provide an assessment of the savings potential as well as to provide recommendations regarding the profitability of new solutions.

Moreover, the project aims to model different motor drive technologies with focus on efficiency determination and analyze the possibilities of improving the efficiency by means of new motor technology and control. An important issue is also to provide an overview of the requirements on the electrical environment and assess the advantages and drawbacks of different types of power electronic control systems for the electric motors.

During 2009 the focus was placed on the modelling of permanent magnet motors. Different FEM programs for modelling motor losses have been evaluated and suitable software was chosen that fulfils all the requirements. FEM models of an inverter fed induction motor and an inverter fed BLDC motor have been developed, and it takes into account the effects of a switched voltage supply. Furthermore, a laboratory setup with a BLDC drive system was built and tested in order to verify the simulation results.

Research programs

The research activities at the Division are typically part of larger research programs at Chalmers or within national or international research collaborations. The following section gives a summary presentation of the main research programs in which the Division is actively involved.

E.ON and Chalmers education and research partnership

The agreement between the E.ON Energy Company and Chalmers relating to a research and education partnership was signed in May 2008. During a period of ten years Chalmers and EON will work together to strengthen and develop research and education within the field of energy. The aim is to further develop knowledge and techniques for safe and environmentally sustainable energy supply, transmission and use. The collaboration also aims at educating competent engineers to meet future demands of the energy industry.

The process of identifying research projects for the collaboration has resulted in four themes containing suitable Chalmers research projects. The themes are: A. Future Energy Systems, B. Efficient use of Biomass, C. Nuclear Reactor Safety and D. Technology Assessment from a Sustainability and Risk Perspective. During 2009 the research program was defined and activities have been focused on recruiting new staff members and preparing/planning for 2010. The Division lead the project: A.2 Future Electric Power System – Smart Grid (with project leader Lina Bertling).

Chalmers Energy Initiative - CEI

Energy is currently one of Chalmers' foremost areas of strength. Starting in 2009, Chalmers launched the new “Chalmers Energy Initiative” to raise the level of Chalmers energy research even higher. The Chalmers Energy Initiative is born out of the increased level of funding for strategically important research areas appointed by the Swedish Government in the Bill “A Boost to Research and Innovation.” The Swedish Energy Agency, responsible for the application process, recommended the Government invest SEK 58 million annually in the Chalmers Energy Initiative. Chalmers has decided to further strongly support the energy area, with at least an extra 50 percent of the sum granted by the Government.

The Chalmers Energy Initiative includes the areas energy combines, electric propulsion systems and hybrid vehicles, and large-scale renewable electricity generation and grid integration. In addition, the Chalmers Energy Initiative provides comprehensive analyses of the conditions under which targeted technologies can expect successfully commercialization.

The Division takes part in the areas of: large-scale renewable electricity generation and grid integration (with program leader Lina Bertling), and the electric propulsion systems and hybrid vehicles.

Chalmers Energy Centre - CEC

Chalmers Energy Centre is a centre for research, education and innovation focusing on the field of energy at Chalmers University of Technology with the aim of developing energy systems for a sustainable society.

The mission of Chalmers Energy Centre is to be an internationally competitive centre for the development of sustainable energy systems as a collaboration among the academic world, civil society, and industry. One important task is to present and market Chalmers University of Technology’s energy-related research and education activities. The initiation and co-ordination of interdisciplinary research relating to energy is another central assignment for Chalmers Energy Centre, together with the application of results associated with technological and systems development in the field.

The programs of Chalmers Energy Centre are funded by Chalmers University of Technology, the Swedish Energy Agency, the Västra Götaland Region, Göteborg Energi AB, E.ON, Preem, Södra, Framtidenkoncernen and Akademiska Hus among others.

Chalmers Energy Centre’s platforms are important tools for research work focusing on the development of sustainable energy systems. The platforms serve as forums for dialogue and initiatives, as well as development of knowledge, technology and expertise for the promotion of innovations and commercialization

of research results. These platforms are designed to strengthen dialogue and interaction with the business community when it comes to market analysis, identification of research needs and priorities, ensuring relevance, and dissemination of results. The Division coordinates one of these platforms: power and heat production (Ola Carlson, project leader).

Swedish Vehicle Hybrid Centre - SHC

The Swedish Hybrid Vehicle Centre (SHC) is a Centre of Excellence established 2007 by the Swedish Energy Agency (Energimyndigheten) with three Swedish universities (Chalmers University of Technology, Royal Institute of Technology, Lund Institute of Technology within Lund University) and six Swedish industrial companies (AB Volvo, Volvo Car Corporation, Saab Automobile AB, GM Powertrain Sweden AB, Scania CV AB, BAE Systems Hägglunds AB) as partners. Chalmers is the host for SHC.

The mission of the Centre is to serve as a strategic knowledge and competence base for education, research and development within hybrid electric vehicles, and to form a framework for cooperation between industry and academia. The focus of the research is divided into three thematic areas:

1. System studies and tools
2. Electrical machines and drives
3. Energy storage

The division of Electric Power Engineering is active within SHC theme 2, electrical machines and drives. Theme 2 contains three projects confronting the challenge of designing cost efficient, energy efficient and reliable traction systems from different perspectives. The project focus is on the design of sensorless operation (KTH), charger integration (Chalmers), EMC and safety optimization (LTH). The persons at the Division involved in this project are Saeid Haghbin, Sonja Tidblad Lundmark, and Ola Carlson.

Pathways

This project is carried out in collaboration with the Energy Technology Division at Chalmers and with Power System Laboratory in ETH-Zurich. The overall aim of the project is to evaluate and propose robust pathways towards a sustainable energy system with respect to environmental, technical, economic and social issues. In this project, a comprehensive modelling package for power generation investment planning, power generation dispatch and detailed representation of European transmission network is developed. The network model of this package focuses on the modelling of current European transmission network in order to evaluate the potential bottlenecks, transmission capacity of interconnections between countries and regions in the grid, as well as propose future network investment solutions in order to accommodate the future generation investment

plan suggested by the investment planning model. The persons at the Division involved in this project are Tuan Le and Lina Bertling.

Vindforsk III

Vindforsk III is a co-funded program for basic and applied wind power research. The Swedish Energy Agency funded 50 percent of the programs costs. Energy companies and other industries associated with wind power are funding the second half. The program is scheduled for a run-time of four years 2009-2012 with a total budget of approximately SEK 80 million.

Elektra

Elektra is a research and development program for doctoral projects at the Swedish technical universities covering the whole electric power system, and focusing on: Electromagnetic systems, Power electronic systems, Electric power systems and Electric power components.

Elektra, run in collaboration between the Swedish Energy Agency, ABB, Banverket and Elforsk (coordinates the industry's joint research and development) is scheduled for a program time of four years 2009-2012 with a total budget of approximately 71 million SEK.

Coordinated Sustainable Electric Power System - CSES

This is a research program supporting two new professor chairs at the Division: one professor chair on Sustainable Electric Power Systems and one in Power Electronics. The program is supported by ABB, Svenska Kraftnät, Göteborg Energi and Vattenfall. The program involves a steering committee and is scheduled for 2009-2013.

Publications and Reports

Listed below are the works published in 2009. The publications are sorted by type of publication and according to the first author's last name.

Ph.D. theses

Max, Lena: Design and control of a DC collection grid for a wind farm, PhD thesis, Chalmers University of Technology, Department of Energy and Environment, Division of Electric Power Engineering, ISBN/ISSN: 978-91-7385-333-0, Gothenburg, December 2009.

Licentiate theses

Abdulahovic, Tarik: Analysis of High-Frequency Electrical Transients in Offshore Wind Parks, Tech Lic thesis, Chalmers University of Technology, Department of Energy and Environment, Division of Electric Power Engineering, Gothenburg, April 2009.

Karvonen, Andreas: MOSFET Modeling Aimed at Minimizing EMI in Switched DC/DC Converters Using Active Gate Control, Tech Lic thesis, Chalmers University of Technology, Department of Energy and Environment, Division of Electric Power Engineering, Gothenburg, June 2009.

Master theses

Ragnar Berglund Frequency Dependence of Transformer Losses

Emma Grunditz, Emma Jansson Modelling and Simulation of a Hybrid Electric Vehicle for Shell Eco-marathon and an Electric Go-kart

Therese Andresen Technical and economical aspects of remote data transmission ways for smart metering

Johanna Gustafsson Analysis and Simulation of Fuel Consumption and Energy Throughput on a Parallel Diesel-Electric Hybrid Powertrain

Kristin Bruhn, Sofia Lorensson, Jennie Svensson Development of Learning Material to Wind Power Courses

Björn Jansson Vakuumbrytare i småskaliga Vattenkraftstationer

Romain Bellut Potential wind power plant development zone

Henrik Elofsson Design and study of the power grid influence of a single-phase 300 W PFC rectifier

Nicholas Rouch Improvement in the Electric Sizing Process for Aircraft applications

Peter Andersson, Olle Collin Parameterization of a 14.5 Ah LiFePO4-battery cell

Anna-Linnea Beckman, Camilla Saltin Development of learning modules for wind and hydropower.

Minh Tuan Tran Definition and Implementation of Voltage Stability Indices in PSS®NETOMAC.

Grenier Mathieu Design of an on-board charger for plug-in hybrid electrical vehicle (PHEV).

Mebtu Bihonegn Beza Multilevel harmonic elimination methods for HVDC.

Lei Zhou Mixed-mode Circuit and Device Simulations of IGBT with Gate Unit Using Synopsys Sentaurus Device.

Adil Mohammed HVDC Transmission System with Medium-Frequency Transformers.

Henrik Lönner Klas Nordqvist Evaluation and improvement proposals of uninterruptible power supply of the electronic system, within the battery system, for X2000 trains at EuroMaint AB.

Pema Yangdon Modelling and Analysis of a Competitive Electricity Market in Bhutan.

Mohammad Seyedi Evaluation of the DFIG Wind Turbine Built-in Model in PSS/E.

Oskar Josefsson, Joakim Karlsson Design and construction of a hybrid vehicle driveline. Developed for an ECO-marathon car

Andreas Bergqvist, Niklas Janehag Modelling of a power system for a new airborne radar system using Saber® Focused on the Multiphase Transformer Rectifier Unit.

Henrik Bengtsson, Magnus Jansson Control of Switch-mode Power Supplies A digital approach for half-bridge converters .

Shehu Abba-Aliyu Voltage Stability and Distance Protection Zone 3.

Annelie Lindeberg Mätning i nätstationer - nyttor och problem.

Héctor A López Carballido Control of a wind turbine equipped with a variable rotor resistance.

Didi Istardi Modeling and Energy Consumption Determination of an Electric Go-kart.

Bahman Kahinpour Modelling, control and investigation of an HVDC transmission for an offshore wind farm

Patrik Ericsson, Ismir Fazlagic Shore-Side Power Supply A feasibility study and a technical solution for an on-shore electrical infrastructure to supply vessels with electric power while in port.

Tomas Hulkoff Usage of Highly Accelerated Stress Test (HAST) in Solar Module Ageing Procedures.

Cuong Duc Le Fault Ride-through of Wind Parks with Induction Generators.

Henrik Påhlsson Analys av högfrekvensstörningar och elnätskommunikation i distributionsnät.

Anders Eliasson Emir Isabegovic Modeling and Simulation of Transient Fault Response at Lillgrund Wind Farm when Subjected to Faults in the Connecting 130 kV Grid

Anders Axelsson Simulering av industriellt distributionsnät

Books

Olguin G., Tuan L., “Optimal Placement in Power System”, in Optimization Advances in Electric Power Systems, Nova Science Publishers Inc., edited by Edgardo D. Castronuovo, 2009, ISBN/ISSN: 978-1-60456-999-5.

Articles in journals

Max L., Thiringer T., Undeland T., Karlsson R., "Power electronics design laboratory exercise for last-year M.Sc students". *IEEE Transactions on Education*, Vol. 52, No. 4, p.524-531, Nov 2009.

Teleke S., Abdulahovic T., Thiringer T., Svensson J.," Dynamic Performance Comparison of Synchronous Condenser and SVC". *IEEE Transactions on Power Delivery,* Vol.23, No.3, p. 1606-1612, July 2008.

Ullah N.R., Bhattacharya K., Thiringer T., "Wind Farms as Reactive Power Ancillary Service Providers-Technical and Economic Issues". *IEEE Transactions on Energy*

Conversion, Vol. 24, No. 3, September. 2009, p.661-672.

Conference proceedings

Haghbin S., Torbjörn T., "Impact of inverter switching pattern on the performance of a direct torque controlled synchronous reluctance motor drive", International Conference on Power Engineering, Energy and Electrical Drives, POWERENG 09, Lisboa, Portugal, March 18-20, 2009.

Lundberg S., Thiringer T., Design considerations for a power electronic converter for series connection of wind turbines. Second EPE- Wind Energy Chapter Seminar, Royal Institute of Technology, Stockholm, Sweden, April 23-24, 2009.

Max L., Thiringer T., "Design and control consideration for a 5 MW DC/DC converter in a wind turbine", Second EPE- Wind Energy Chapter Seminar, Royal Institute of Technology, Stockholm, Sweden, April 23-24, 2009.

Wallnerström C. J., Bertling,L "Risk Management Applied to Electrical Distribution Systems". CIRED 2009 conference, Prague, Hungary, June 2009.

Istardi D., Abba-Aliyu S., Bergqvist A., Rouch N., Abdalrahman A., Tuan L., Bertling L., "Understanding Power System Voltage Collapses Using ARISTO: Effects of Protection", in proceedings of IEEE PowerTech 2009, Bucharest, Romania, June 28 - July 2, 2009.

Besnard F., Patriksson M., Strömberg A.B., Wojciechowski A., Bertling L., "An optimization framework for opportunistic maintenance of offshore wind power system". In Proceedings of IEEE PowerTech 2009 conference, Bucharest, Romania, 28 June - 2 July 2009.

Nilsson J., Patriksson M., Strömberg A. B., Wojciechowski A., Bertling L., "An opportunistic maintenance optimization model for shaft seals in feed-water pump systems in nuclear power plants", In Proceedings of IEEE PowerTech 2009 conference, Bucharest, Romania, 28 June - 2 July 2009.

Setréus J., Arnborg S., Eriksson R., Bertling L., "Components´ Impact on Critical Transfer Section for Risk Based Transmission System Planning", In Proceedings of IEEE PowerTech 2009 conference, Bucharest, Romania, 28 June - 2 July 2009.

Muhamad R., Abdulahovic T., Thiringer T., "Combining MV laboratory and simulation resources to investigate Fast Transient Phenomena in Wind Cable Systems", European Offshore Wind 2009, Stockholm, Sweden, September 14-16, 2009.

Abdulahovic, T., Thiringer, T., "Comparison of switching surges and basic lightning impulse surges at transformer in MV cable grids", Nordic Wind Power Conference 2009, Bornholm, Denmark, September 7-11, 2009.

Aghdam G., Thiringer T., "Comparison of SiC and Si Power Semiconductor Devices to Be Used in 2.5 kW DC/DC Converter", PEDS 2009 - The Eighth International Conference on Power Electronics and Drive Systems, Taipei, Taiwan November 2-5, 2009.

Karvonen A., Thiringer T., "MOSFET Modeling Adapted for Switched Applications Using a State-Space Approach and Internal Capacitance Characterization", PEDS 2009 - The Eighth International Conference on Power Electronics and Drive Systems, Taipei, Taiwan, November 2-5, 2009.

Åström J., Thiringer T., "Modeling and Measurements of Loss Components for Different Switching Schemes in a Three Phase Converter Using CoolMOS Transistors", PEDS 2009 - The Eighth International Conference on Power Electronics and Drive Systems, Taipei, Taiwan, November 2-5, 2009.

Åström J., Thiringer T., "Potential Savings for Induction Motor Drive Systems for HVAC Applications", PEDS 2009 - The Eighth International Conference on Power Electronics

and Drive Systems, Taipei, Taiwan, November 2-5, 2009.

Reports

Deimel C., Wiedermann J., “Plug-In Hybrid Electric Vehicles-A discussion of recent developments regarding grid impacts”, Report at the Department of Energy and Environment, Division of Electric Power Engineering, Chalmers University of Technology, Göteborg, Sweden, January 2009.

Hagbin S., Tuan L., Lindskog A., Lundmark S., “State of the art of Plug-in Hybrid Electric Vehicles (PHEVs)”, report prepared for Göteborg Energi AB, Division of Electric Power Engineering, Department of Energy and Environment, Chalmers University of Technology, Göteborg, Sweden, January 2009.

Haghbin S., Tuan L., Lindskog A., Lundmark S., “State of the art of Plug-in Hybrid Electric Vehicles (PHEVs)” Report at the Department of Energy and Environment, Division of Electric Power Engineering, Chalmers University of Technology, Göteborg, Sweden, January 2009.

Thiringer T., Paixao J., Bongiorno M., Monitoring of the ride-through ability of a 2MW Wind turbine in Tvååker, Halland, Report at the Department of Energy and Environment, Division of Electric Power Engineering, Chalmers University of Technology, Göteborg, Sweden, 2009.

Ellsén M., Carlson O., Drift, utveckling och dokumentation vid Chalmers provstation för vindenergiforskning. Report at the Department of Energy and Environment, Division of Electric Power Engineering, Chalmers University of Technology, Göteborg, Sweden, 2009.

Rova E., Wedlund J., Ellsén M., (editor). Wind power is a Breeze, Report at the Department of Energy and Environment, Division of Electric Power Engineering, Chalmers University of Technology, Göteborg, Sweden, 2009.

Conferences and Visits

This section shows on **participation** from the Division at different conferences, seminars and performed external visits during 2009.

Conferences and seminars

- Meeting with SKF on wind power. Discussions on wind energy research in general, but specifically focusing on the reliability of wind power components, Lina Bertling, Ola Carlson, February 6, 2009.
- Annual meeting of the National Swedish Committee of the World Energy Council (WEC). Lina Bertling, Stockholm, March 4, 2009.
- Energitinget, Lina Bertling, Stockholm, March 11-12, 2009.
- Annual customer day of Svenska Kraftnät, Lina Bertling, Stockholm, March 26, 2009.
- Review meeting with the scientific board for the Swedish Research Council Formas, Lina Bertling, Sigtuna, March 26-27, 2009.
- Annual meeting of SEK Svensk Elstandard. Lina Bertling, Stockholm, April 22, 2009.
- Smart grid meeting with focus on solar energy, Lina Bertling, Copenhagen, May 4, 2009.
- Reference group meeting with the Reliability-Centred Asset management group (RCAM), Lina Bertling, KTH, Stockholm, May 5, 2009.
- Annual meeting and seminar with the Swedish Society for members of parliament and researchers (RIFO) and Royal Academy of Science (KVA), Lina Bertling, Stockholm, May 5, 2009.
- Strategy meetings with the senior researchers at the Division, Lina Bertling, Ola Carlson, Torbjörn Thiringer, Sonja Lundmark, Stefan Lundmark, Tuan Le, Massimo Bongiorno, Led by Socratia, May 12, 2009.
- Licentiate thesis seminar by Johan Setréus, KTH, Lina Bertling (examiner), Stockholm, May 15, 2009.
- Seminar about future challenges for the Swedish energy system organized by the Swedish society for members of parliament and researchers (RIFO), The Swedish Parliament, Lina Bertling (moderator), March 18, 2009, Stockholm.

- PhD thesis seminar “On Power-system Benefits, Main-circuit Design, and Control of StatsComs with Energy Storage”, KTH, Lina Bertling (reviewer), Stockholm, May 26, 2009.
- Nordic Grid 2 – Project and Reference Group Meeting, Helsinki, Tuan Le, June 2009.
- PhD thesis seminar “Conducted and Radiated Electromagnetic Interference in Modern Electrified Railways with Emphasis on Pantograph Arcing”, KTH, Lina Bertling (reviewer), Stockholm, June 1, 2009.
- Summer break meeting, Department of Energy and Environment, Division, June 1, 2009.
- Vattenfall International Energy & Climate Week, Lina Bertling, Stockholm, June 9, 2009.
- PowerCircle, Smart Grid meeting, Lina Bertling, Stockholm, June 17, 2009.
- IEEE PowerTech meeting, Lina Bertling, Tuan Le, Bucharest, Romania, June 28 - July 2, 2009.
- IEEE Power & Energy General Meeting, Lina Bertling, Calgary, July 27-30, 2009.
- Cigré Wind power session, Lina Bertling, Calgary, July 30-31, 2009.
- IVA and KVA seminar on how to communicate research, invited national researchers, Lina Bertling, Stockholm, August 25, 2009.
- Meeting with Kraftelektronik AB. Kraftelektronik AB manufactures DC power supply for low voltage but also gas heaters that requires high-voltage direct current. Torbjörn Thiringer, Lina Bertling, August 27, 2009.
- EPE 2009, European Power Electronic Conference, Torbjörn Thiringer, Barcelona, Spain, September 8-10, 2009..
- Seminar on EU ECR grants, Lina Bertling, Gothenburg, September 8, 2009.
- Off shore conference, Lina Bertling, Francois Besnard, Stockholm, September 14, 2009.
- Conference meeting with the board at the Department of Energy and Environment, Lina Bertling, Varberg, September 16-17, 2009.

- Seminar on smart grid, and (joint meeting IEEE, Cigré and Ciréd), Elforsk, Lina Bertling, Stockholm, September 17, 2009.
- Power Cluster Regional Meeting, Tuan Le, September 17, 2009.
- IVA project Vägval Energi, final presentation of the project, Lina Bertling, September 29, 2009.
- Cigre conference “Operation and Development of Power Systems in the new Context” in Guilin China, Per Norberg, October 2009.
- KVA Seminar on Energy, Lina Bertling, Stockholm, October 19-20, 2009.
- IVA Annual member meeting, Lina Bertling, Stockholm, October 23, 2009.
- Licentiate thesis seminar by Julia Nilsson, Royal Institute of Technology (KTH), Lina Bertling (examiner), November 5, 2009.
- First seminar with the new Swedish Wind Power Technology Centre, Ola Carlson, Lina Bertling, November 16, 2009.
- Chalmers seminar on how to prevent and detect alcoholic dependence at work, Lina Bertling, November 17, 2009.
- Vindforsk seminar, Lina Bertling, Francois Besnard, November 25, 2009.
- IVA Industry Research Group Annual Symposium, Lina Bertling, November 25, 2009.
- Licentiate thesis seminar by Francois Besnard, Royal Institute of Technology (KTH), Lina Bertling (examiner), December 4, 2009.
- Workshop on Optimization of Maintenance Activities Models, Methods and Applications at Chalmers Applied Mathematics, Lina Bertling, Francois Besnard, Katharina Fischer, December 10, 2009.
- Strategy meetings with the senior researchers at the Division, Lina Bertling, Ola Carlson, Led by Harald Haegermark, December 16, 2009.

Visits

- Lina Bertling joined a study trip organized by the Royal Swedish Academy of Engineering Sciences (IVA), within the IVA project Vägval Energi, including visits at Vattenfall ”Schwarze Pumpe” and Volkswagen, Wolfsburg, March 23-25, 2009, Berlin, Germany.

- Lina Bertling, Tuan Le, visited with ETH for research discussion on electric power delivery system and the pathway project, April 19-21, 2009, Zurich.
- Torbjörn Thiringer, Stefan Lundberg, joined the second EPE- Wind Energy Chapter Seminar, April 23-24, 2009, Royal Institute of Technology, Stockholm, Sweden
- Lina Bertling visited Sandviken with IVA and the Industry Research Group (IFG), May 6, 2009, Sandviken.
- Lina Bertling visited ABB Corporate Research, research discussion, May 27, 2009, Västerås.
- Lina Bertling visited Accenture with IVA and the Industry Research Group (IFG), May 29, 2009, Stockholm.
- Tuan Le visited SINTEF/NTNU during June 1-3, 2009 for the work in Nordic Grid – 2 project, Trondheim.
- Lina Bertling visited Volvo AB, Research discussion, June 11, 2009, Gothenburg.
- Tuan Le visited Aalborg University, June 15, 2009 for the work in Power Cluster project, Aalborg.
- Tuan Le visited ETH-Zurich during August 10-14, 2009 for the work in Pathways project, Zurich.
- Lina Bertling and Francois Besnard visited Lillgrund wind power station and farm for study on maintenance management, August 20-21, 2009, Malmö.
- Lina Bertling visited Vattenfall Wind power, research discussions, Råcksta, August 26, 2009, Stockholm.
- Tuan Le, David Steen, Lina Bertling, Massimo Bongiorno, visited E.ON Nät, Malmö in September 2, 2009 for research discussions, Malmö.
- Lina Bertling and Francois Besnard visited IFN, research discussions, September 11, 2009, Stockholm.
- Lina Bertling visited GE Healthcare with IVA and the Industry Research Group (IFG), September 28, 2009, Uppsala.
- Lina Bertling, Tuan Le, Massimo Bongiorno, David Steen visited E.ON research discussion within the project on future electric power system – smart grid, October 5, 2009, Malmö.

- Lina Bertling joined the IVA Study trip to Russia within Industry Research Group (IFG). Including visits at: Exportrådet Moscow State University ,Russian Academy of Engineering, International Science and Technology Centre, MEPhI , AEB - The voice of European Business in Russia, the Cristall Vodka factory, October 12-16, 2009, Moscow.
- Lina Bertling, Vindforsk at Elforsk, Research discussion, October 23, 2009, Stockholm.
- Lina Bertling, ABB Corporate Research, research discussion, Västerås, November 13, 2009.
- Lina Bertling, NTNU research review and visit, November 22-23, 2009, Trondheim.
- Lina Bertling, Vattenfall Wind power, research discussions, Råcksta, November 26, 2009, Stockholm.

Seminars and Lectures

This section shows on **contributions** from the Division providing lectures, seminars or giving interviews etc. during 2009.

Media

Several Division highlight activities during the year have been seized upon by the media, with reporting examples available in the Chalmers news calendar, on the Department's web pages, or through Karin Ljungklint who works with the information services at the Department of Energy and Environment. Published interviews and contributions to debates includes: Future by Semcon (no.1), ERA (no.2 and no 4.), SEK Member Magazine (no. 3), Chalmers Magasin, Nordisk Energi, DI (Sept), DinEl, Metro ("Framtidens El", March 3), Energivärlden (No. 3) and NyTeknik (20 May).

Seminars and lectures at Chalmers

- Lina Bertling was invited to present on "Sustainable electric power systems", at a Vattenfall evening seminar for students at Chalmers to promote the new master program on nuclear power engineering, February 24, 2009.
- Lina Bertling was invited to present on "Electric Power Systems with Smart grids", Organized within Chalmers Energy Seminar Series, March 5, 2009.
- Lina Bertling held a presentation on "Optimal maintenance plans for increase reliability of wind power turbines – with use of condition monitoring systems" at the Vindforsk III workshop, March 5, 2009.
- Lina Bertling was invited to present on "Electric Power Systems with Smart grids", Chalmers Energy Seminars, Gothenburg, March 5, 2009.
- Lina Bertling held presentation on "Future Electric Power System- Smart grid", Kick-off for the Chalmers and E.ON. collaboration, May 14, 2009.
- Lina Bertling hosted a workshop together with STRI (Math Bollen) on operational risk assessment, June 16, 2009.
- Lina Bertling held a presentation on "Involvements in IEEE and about the PE/PEL Chapter, at an IEEE PE/PEL Chapter meeting with external guest, September 3, 2009.
- Lina Bertling invited to lecture "On sustainable power system – smart grid" for the faculty club at Chalmers, September 21, 2009.

- Tuan Le gave a presentation on Modelling of Germany Electricity Networks, at Pathways project seminar, September 29, 2009.

- Lina Bertling, Francois Besnard held presentations at a workshop with SKF and Göteborg Energi on wind power asset management, November 2, 2009.

- Lina Bertling invited to present on “Intelligent electric power systems and electrical vehicles - Smart grid”, Energy Day at Chalmers with E.ON. Gothenburg, November 18, 2009.

- Lina Bertling invited to present on “Maintenance Management of Sustainable Electric Power Systems”, at a Workshop on Optimization of Maintenance Activities Models, Methods and Applications, December 10, 2009.

Seminars given outside Chalmers

- Lina Bertling invited to present on “Smart grids with wind power – challenges for reliability in power supply”, March 12, 2009, Energitinget, Stockholm.

- Torbjörn Thiringer held a presentation on “Electric Power Engineering for wind energy installations – methods for a more cost-effective electrical system as well as improved power quality impact”, March 12, 2009, Energitinget, Stockholm.

- Lina Bertling acted as moderator in a seminar about future challenges for the Swedish energy system organized by the Swedish society for members of parliament and researchers (RIFO), The Swedish Parliament, March 18, 2009, Stockholm.

- Torbjörn Thiringer held a symposium and a PhD course on Wind Power. The Alcala University in Madrid traditionally invites researchers from other universities to lecture a 1-week course and to hold a related symposium presentation of one’s unit’s activities. This summer the course was held by Electric Power on the theme of wind. Electrical Power also participated about 4 years ago on the theme of regulation of electric power systems, June 1-5 2009, Madrid.

- Lina Bertling was keynote speaker at the Vattenfall International Energy & Climate Week, on “smart power system”, June 9, 2009, Stockholm.

- Ola Carlson was an invited speaker at the IEEE meeting in Stockholm to describe the electro-technical wind energy research in Sweden, September 14, 2009, Stockholm.

- Torbjörn Thiringer held a lecture on Wind Power in Sweden. The presentation considered an addition to an initial part of wind power in Sweden with focus on Lillgrund, also wind energy research at Chalmers, with special focus on offshore placement, October 17, 2008, Trondheim.

- Lina Bertling held an invited presentation on “Framtidens eldistribution – smart grid” for the Rotary club Örgryte, November 10, 2009, Gothenburg.

- Ola Carlson was invited participant to IVA Swedish - Chinese exchange in renewable energy. Presentation of Chalmers wind power activity within Electric Power and discussions about exchange of experiences, November 23, 2009, Stockholm.

- Lina Bertling held an invited presentation at NTNU on “Bærekraftig elektrisitetsproduksjon og distribusjon – sustainable electric power delivery”, November 24, 2009, Trondheim.

- Lina Bertling invited to present on “A Swedish perspective on maintenance of wind farms: challenges and innovative solutions”, December 3, 2009, UK – Sweden Wind Power Forum, The Residence of the British Ambassador, Stockholm.

- Lina Bertling invited to present at the producers meeting on “Hållbart elkraftssystem” (Sustainable electric power system), Göteborg Energi DinEl, December 14, 2009, Bjertorp Slott.

Other Activities

This section shows on **assignments** for different appointments and memberships within the Division during 2009. It also shows on the mobility of the researchers and list visiting international guests.

National assignments

- Lina Bertling was appointed as a member of the new Scientific Board of the Swedish Civil Contingencies Agency (MSB).
- Ola Carlson was a member of the organisation committee of Swedish Wind Power Conference 2010. Taken part of the planning meetings during 2009.
- Lina Bertling was elected as chair of the IEEE Sweden Chapter of Power Engineering and Power Electronics PE/PEL.
- Tuan Le was a member of the board of the IEEE Sweden Chapter on Power Engineering and Power Electronics.
- Lina Bertling was a member of the Royal Swedish Academy of Engineering Sciences (IVA) and the Industry Research Group (IFG) during 2007-2009, and a member of the IVA project Vägval Energi 2008-2009.
- Lina Bertling was Chairman of SEK Svensk Elstandard (responsible for standardization in Sweden in the field of electricity, co-ordinating Swedish participation in European and other international standardization work as a member of the IEC and CENELEC).
- Lina Bertling was a member of the Swedish National Committee of Ciréd (*Congrès International des Réseaux Electriques de Distribution).*
- Lina Bertling was part of the scientific board for the Swedish Research Council Formas.
- Torbjörn Thiringer was the coordinator within the research program Vindforsk III and the research project package on high-frequency phenomena related to wind power installations.
- Lina Bertling was a member in the evaluation committee for the Ph.D. dissertation and thesis on “Kunskap i resonans”, “Knowledge in resonance”, by Johan Svahn, KTH, Tuesday February 17, 2009.

- Lina Bertling was a member in the evaluation committee for the Ph.D. dissertation and thesis “On Power-system Benefits, Main-circuit Design, and Control of StatsComs with Energy Storage” by Hailian Xie, KTH, Tuesday May 26, 2009.
- Lina Bertling was a member in the evaluation committee for the Ph.D. dissertation and thesis on “Conducted and Radiated Electromagnetic Interference in Modern Electrified Railways with Emphasis on Pantograph Arcing” by Surajit Midya, KTH, Monday June 1, 2009.
- Lina Bertling was in the board of the Swedish Society for members of parliament and researchers (RIFO).
- Lina Bertling was a member of the board of the Chalmers Energy Centre (CEC).
- Lina Bertling was a member of the steering group of the Department of Energy and Environment.
- Lina Bertling was member of the Swedish standard association and the working group TK56 for the Swedish reliability standards.
- Lina Bertling was member of UTEK Swedish Maintenance Society.
- Lina Bertling was the representative of Chalmers in Power Circle.

International assignments

- Lina Bertling was reviewer for the National Research Foundation, South Africa, February 2009.
- Torbjörn Thiringer participated in EPE Wind Power Chapter. EPE (European Power Electronics) is, together with an American organization, the largest organization of Power Electronics in the world. To carry out important key activities, so called Chapters were created. Two years ago, "EPE/Windpower Chapter" was formed and had its first conference in Delft. Chalmers/Electrical Power participated in the organization of this event. In the spring of 2009 the Wind Conference was held in Stockholm. Participation in the organization includes, in addition to organizing conferences, dissemination of information about the conference and evaluation of the articles presented at the conference, Spring 2009 ending April 23-24, Stockholm.
- Ola Carlson was a member of the Scientific committee for Nordic Wind Power Conference, September 10-11, 2009. Evaluating the incoming abstracts and planning of the scientific program.

- Torbjörn Thiringer was censor for the Ph.D. dissertation and thesis on “Wind power integration: from individual wind turbine to wind park as a power plant” by Yi Zhou, Delft University, Delft, The Netherlands, October 2009, with main supervisor Prof. Pavol Bauer).

- Lina Bertling was “the second” external reviewer for the Ph.D. dissertation and thesis on “Norwegian value creation beyond oil and gas – Strategic opportunities in sustainable Norwegian energy production to secure European energy supplies” by Per Ivar Karstad, at NTNU, Trondheim, Monday November 23, 2009.

- Lina Bertling is a Swedish national member of the World Energy Council.

- Lina Bertling, Torbjörn Thiringer. Per Norberg are members of Cigré (International Council on Large Electric Systems).

- Per Norberg is the Swedish member of Cigré Study Committee C1.

- Lina Bertling was the Vice Chair of the Reliability Risk and Probability Applications (RRPA) Subcommittee of the IEEE Power & Energy Society.

- Lina Bertling was the Chair of an IEEE PES Task Force on Test systems for distribution system, and Chair of a Working Group on Coordinating activities on test system developments.

- Lina Bertling has been a reviewer for the following journals: International Journal of Electrical Power and Energy System, Electric Power Systems Research, IET Generation, Transmission & Distribution, IEEE Transactions on Power Delivery, IEEE Transactions on Power Systems, and IEEE Transactions on Energy Conversion. (Around 2 papers for each journal).

- Lina Bertling has been a reviewer for the following periodical conferences: The IEEE PES general meeting, the IEEE Power Tech conference (around 5 papers for each).

- Lina Bertling was member of the Technical Programme Committee for the Power Systems Computation Conference (PSCC).

- Lina Bertling was a member of the International Technical Advisory Committee for the International Conference on Probabilistic Methods Applied for Power Systems (PMAPS).

- Lina Bertling was a member of the International Advisory Committee of the IEEE PowerTech Conference.

- Tuan Le has been the reviewer for the following journals: International Journal of Electrical Power and Energy System, Electric Power Systems Research, IET Generation, Transmission & Distribution (IEEE Transactions on Power Delivery, IEEE Transactions on Power Systems.

- Tuan Le has been the reviewer for the following periodical conferences: the IEEE Power Tech conference.

Mobility and visitors

International visitors to the Division

- Professor Matti Lethonen, Helsinki University of Technology, May 6-7, 2009.
- Professor Trevor Gaunt, University of Cape Town, June 12, 2009.
- Professor Chen-Ching Liu, University College Dublin, September 3, 2009.

- PhD student Papaemmanouil Antonis, Power Systems Laboratory ETH Zürich, 11-19 November 2009.

Mobility

- Torbjörn Thiringer was on part time leave for a position at Volvo Cars.

- Lina Bertling was the main supervisor and examiner at the Royal Institute of Technology (KTH), and the School of Electrical Engineering, and for three Ph.D. students within the research group on Reliability – Centred Asset management (RCAM) who all finalized their Licentiate thesis during 2009.

    - Johan Setréus on May 15, 2009 with external reviewer, Tech Lic. Lars Wredenberg (former Vattenfall Power Consultant). Johan continues his research studies at KTH.

    - Julia Nilsson, on November 5, 2009 with external reviewer Adjunct professor Ulf Sandberg Vattenfall and Luleå Technical University. Julia finalized her research studies.

    - Francois Besnard, on December 4, 2009, with external reviewer Senior specialist and Adjunct professor Lars Gertmar ABB and Lund Technical University. Francois continues his studies with the Division from 2010

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