ELECTRIMACS 2002

7th International Conference on Modeling and Simulation of Electric Machines, Converters and Systems

Proceedings

7th International Conference on Modeling and
Simulation of Electric Machines, Converters and Systems
Montreal, August 18-21, 2002

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A WARM INVITATION TO ELECTRIMACS 2002

Following the last successful ELECTRIMACS of Lisboa (Portugal) in 1999, the 7th International Conference on Modeling and Simulation of Electric Machines, Converters and Systems will be held in the beautiful city of Montreal, Canada, August 18-21, 2002. On behalf of the Conference Committee, I sincerely invite all of you to come to Montreal to explore and admire its myriad of facet, wealth of activity and excitement of life while enjoying our popular professional meeting and exchanges. This event is organized by the École de technologie supérieure (ETS). Our sponsors are Hydro-Québec TransÉnergie, RTDS Technologies, Opal-RT Technologies inc., Manitoba HVDC Research Institute, the ministère Recherche Science et Technologie du Québec, Bombardier Transport and the Hydro-Québec Research Institute.

For the first time, an Electrimacs conference will host an exhibition. Four high tech companies will exhibit their power system simulation products.

Our technical program committee (TPC) has accepted over 200 technical papers from 30 countries in the areas of electrical machines and transformers, electronic power converters, electrical drives, applications of new materials (power semiconductors, magnetics, superconductors, etc.) and emerging electric technologies. The 3-days technical presentations consist of 1 plenary session, 29 regular sessions and 2 poster sessions, which will be held in the ETS conference floor (first floor). Three invited sessions are also scheduled to highlight new developments. Among them, one special session is planned by Professor Damien Grenier on the Modeling and Control of Power Electronic Systems while another invited session is organised by Professor Bernard de Fornel and Mr Alain Bouscayrol on the Multimachine Multiconverter Systems. Finally, a third invited session is organised by Mr Jean Bélanger on the real-time simulation of electric drives and power systems. For detailed and the latest information, please visit the ELECTRIMACS 2002 web site at www.electrimacs2002.com.

Montreal has been considered as one of the richest and most diversified cultural cities in the world, and it offers everything to everyone. It has been one of the most important international gateways. You can find some useful information of Montreal city at www.tourism-montreal.org. Attendees and their families should seriously consider the opportunities for many extended-vacation options, which naturally arise from the Montreal area.

We are looking forward to welcoming you in Montreal. We hope that you will enjoy this unique international event in the field as well as the Montreal festivities during this special season of the year.

Professor Louis-A. Dessaint
Chairman, ELECTRIMACS 2002

PROGRAM OVERVIEW

Monday August 19, 2002				
8:30 – 10:10	Welcome and Plenary Session : Room 1150			
10:10 – 10:40	Coffee Break : Main Hall			
	Room 1150	Room 1160	Room 1170	Room 1300
10:40 – 12:45	MA-1A	MA-1B	MA-1C	MA-1D
12:45 – 14:15	Lunch : Main Hall			
14:15 – 16:20	MP-1A	MP-1B	MP-1C	MP-1D
16:30 –	Departure for Hydro-Québec Research Institute Main Entrance			

Tuesday August 20, 2002				
8:30 – 10:35	TA-1A	TA-1B	TA-1C	TA-1D
10:35 – 11:05	Coffee Break : Main Hall			
11:05 – 12:45	TA-2A	TA-2B	TA-2C	TA-2D
12:45 – 14:15	Lunch : Main Hall			
14:15 – 16:20	TP-1A	TP-1B	TP-1C	TP-1D
16:20 – 16:50	Coffee Break : Main Hall			
16:50 – 18:50	Poster Session I : Rooms 1422 and 1752			
19:30	Banquet and Concert : Main Hall			

Wednesday August 21, 2002				
8:30 – 10:35	WA-1A	WA-1B	WA-1C	WA-1D
10:35 – 11:05	Coffee Break : Main Hall			
11:05 – 12:45	WA-2A	WA-2B	WA-2C	WA-2D
12:45 – 14:15	Lunch : Main Hall			
14:15 – 16:20	WP-1A	WP-1B	WP-1C	WP-1D
16:20 – 16:50	Coffee Break : Main Hall			
16:50 – 18:50	Poster Session II : Rooms 1422 and 1752			
18:50 – 19:00	Closing Ceremony : Room 1150			

MONDAY AUGUST 19TH

8:30 – 10:10	**Welcome and Plenary Session** **Room 1150**			
10:10 – 10:40	**Coffee Break** **Main Hall**			
10:40 – 12:45	**MA-1A** **Room 1150**	**MA-1B** **Room 1160**	**MA-1C** **Room 1170**	**MA-1D** **Room 1300**
12:45 – 14:15	**Lunch** **Main Hall**			
14:15 – 16:20	**MP-1A** **Room 1150**	**MP-1B** **Room 1160**	**MP-1C** **Room 1170**	**MP-1D** **Room 1300**
16:30 –	**Departure for Hydro-Québec Research Institute** **Main Entrance**			

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Room 1150
Plenary Session –

8:30 – **Welcome**

8:40 – **Digital Simulation Tools for the Design, Simulation and Testing of Power Electronics and Controls for Power Systems**
G. Sybille, Hydro-Québec Research Institute (Canada)

9:10 – **Tools for the Simulation of Large-Scale Power Electronic Systems**
A.M. Gole, University of Manitoba (Canada)

9h40 – **New Advances in the Simulation of Transients with EMTP: Computation and Visualization Techniques**
J. Mahseredjian, Hydro-Québec Research Institute (Canada)

Back to the Monday program

MA-1A – Room 1150
Power Systems I

Session Chair:

L.A. Snider (China)

10:40 – **Calculation of Eddy Current Losses in the Stator Clamping System of Large Hydro-Generator**

Erich Schmidt, Georg Traxler-Samek

Abstract – The eddy currents in the clamping plates of large hydro-generators generate additional losses and can cause local heating problems. Thus, an accurate determination of these losses is a matter of particular interest in the machine design. The paper presents an analytic method for the determination of these losses. Thereby, the 3D time harmonic diffusion equation will be solved. Additionally, the 3D nonlinear finite element analysis of the end region of a 500 MVA hydro-generator for the calculation of these losses is shown. The results of both methods are compared with the values obtained from measurements on the 500 MVA hydro-generator.

11:05 – **A Novel Current and Voltage Sensor in Power Transmission Lines**

Mitsunori Kawano, Eiji Nishiyama, Kenshi Kuwanami, Toyonori Matsuda, Ichiro Oota

Abstract – We propose portable equipment that monitors current and voltage of high-potential power transmission lines. In the equipment, a current and voltage sensor are attached to a polymer insulator that supports a power transmission line: A current of a power line is detected by an air-core solenoidal coil clamped to the power line and the detected current signal is transmitted to the ground station by a wireless optical link using Voltage-Frequency conversion of light; a voltage on a power transmission line is detected by a high resistance element, zinc oxide (ZnO), that acts as a potential divider between the power line and the ground. We make an experimental device for 6.6KV power lines and demonstrate that it can monitor currents ranging from 0 to 600 A and potentials up to 6.6 KV. The proposed equipment is small-sized, light, and inexpensive in comparison with the conventional CT (current transformer) and PT (potential transformer) since it does not require high potential insulators and magnetic cores. Further, the equipment is easily installed owing to its small size and its simple structure.

11:30 – **The Linkage Between Power Transmission Development and Simulation**

John P. Bowles

Abstract – The development of power transmission technology, particularly in the areas of high voltage direct current (hvdc) and flexible alternating current transmission systems (facts) has paralleled and been dependent on improvement and the evolution of power transmission simulation. This paper considers the evolution of these technologies in the period from the early sixties to the present day, a particularly rich period, and the linkages between simulation and real power system development.

11:55 – **Development of a Broadband Real-Time Fully Digital Simulator for the Study and Control of Large Power Systems**

Laurence A. Snider, H.T. Su, Kevin K.W. Chan, Do Van Que

Abstract – While transient stability programs can represent very large systems, they are unable to model power electronic devices in detail since they use relatively large time steps and balanced representation of the network. Electromagnetic transients simulators, on the other hand, can model relatively small systems in detail using small time steps. By interfacing both simulation tools, it will be possible to develop a broadband simulator capable of modeling large systems, but including detailed representation where required. The simulator would provide for studies ranging from fast transient to transient, dynamic, and voltage stability, with applications including closed-loop protection and control studies, as well as on-line dynamic security assessment. In this paper we present the latest development work related to the realization of a broadband fully digital simulator, which would be capable of meeting the challenge obtaining real-time solutions of very large networks using sufficiently small integration time steps such that power electronic devices (FACTS or HVDC) could be modeled at the device level with sufficient time resolution.

12:20 – **Analysis of an Electric System Polluted Under Fault Conditions**

Maria Isabel Cuenca Alegria, Francisca A. de Camargo Pires

Abstract – The harmonic distortion in power system under conditions operational normal they were wide and deeply studied, but there is still little knowledge of the effects of these distortions under short-circuit conditions. A harmonic distortion of voltage or current under normal operational conditions can give place the currents fault harmonicas considerably discharges. This is due to eventual resonance's that can appear under fault conditions, could determine the incorrect intervention of the protection devices. In this article it is made an analysis of a power system under fault conditions with a load producing of harmonic installed in the network of medium voltage, tends as objective to study the behavior of the protections of the system in the short-circuit occurrence in the bus.

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MA-1B – Room 1160
Synchronous Machine

Session Chair:

M. El-Kahel (Canada)

10:40 – **Iron Losses in Synchronous Generators**

A.S. Abdallah, R.M. Hamouda, A.I. Alolah

Abstract – This paper reports the measured iron loss of two synchronous machines (salient-pole and cylindrical rotor). Mathematical equations describing the iron loss components in salient-pole machines due to d-axis ampere-turns P_{cq}, q-axis ampere-turns P_{cd}, no-load component P_{co} and load component P_{cL} have been formulated. Furthermore, the effects of the loading conditions such as terminal voltage, load angle, active and reactive output powers on the iron loss have been investigated. In salient-pole machines, the total iron loss is found to increase with the increase of the machine terminal voltage, output power and load angle. Also, for leading power factors, the iron loss is found to be higher than lagging power factors. Moreover, the iron loss reached a maximum value at loading angle $\delta = 90^{o}$ (theoretically). In cylindrical- rotor machines, the iron loss is increased with the increase of terminal voltage and did not depend on the other operating conditions.

11:05 – **Parameter Estimation of a Synchronous Generator**

Antoine Launay, J.D. Gabano, G. Champenois

Abstract – The aim of this work is to present a method capable of estimate the dynamic behavior of a synchronous generator. This knowledge is necessary to design a proper stator voltage regulation during variations of the load. We have developed a model of the machine, including the effect of the dampers. The model parameters are estimated by an output error optimization algorithm taking in account all the available measurable outputs. We describe the state model used, including the load connected to the machine and the principle of optimization algorithm. Finally, we present experimental results obtained from an industrial testing bench.

11:30 – **Specifics and Applicability of AC-Drives Technology Usage in the Static Excitation Systems of Synchronous Generators**

Gorislav Erceg, Romina Erceg

Abstract – This paper points out specifics and applicability of the developed transistor (IGBT) converters' usage for AC-Drives in the synchronous generators' excitation systems. Basic characteristics of the control circuits in generators' excitation systems are shown. Static excitation systems with the transistor converters developed for AC-Drives have to be adapted. Hardware (input/output modules) has to be adapted considering the needs of the generator's static excitation. With the developed software package for AC-Drives new algorithms for control and voltage control of the generator are written. The transistor converters with mentioned adaptations can be successfully used in the excitation systems of the generators.

11:55 – **Transient Performance of a Salient-Pole Synchronous Generator Using Phase-Domain Model**

Jawad Faiz, Afshin Rezaei-Zare

Abstract – Transients performance of a salient-pole synchronous generator is simulated using phase-domain equations where saturation has been taken into account. In this analysis, machine quantities, such as flux of windings, are obtained based on time and position of the windings, in the place of dqo orthogonal axes. These are the actual quantities and it is possible to relate parameters of the machine and power system easily. Thus, it is a suitable tool for simulation of a power system. In addition, application of nonlinear equations and studying internal phenomena, such as changing the resultant flux path and internal faults, are made more easily and accurately compared to dqo model. Consequently, a better realization of the phenomena during the transient operation of the synchronous generator is possible.

12:20 – **Simplified Simulation Method for Polyphase Brushless DC Motors**

José Roberto Figueroa-Barnier, Charles Brocart, Jérôme Cros, Philippe Viarouge

Abstract – This paper presents a general simulation method for polyphase brushless DC motors. It is based upon an estimation of the average value of voltages and currents on each PWM period. The simulation speed is improved. Different inverter structures and machine winding connections can be studied. It is also possible to evaluate different modulation techniques and drives control strategies. The simulation method is validated by a comparative analysis with experimental results obtained with a prototype of seven-phase brushless dc motor.

Back to the Monday program

MA-1C – Room 1170
Fault Detection and Diagnosis I

Session Chair:

V.Q. Do (Canada)

10:40 – **On-Line Fault Diagnosis in Synchronous Generators by Stator Current Harmonics Analysis**

Elham Khosrowshahli, Ali Mohammad Ranjbar, Hessam Mirabedini

Abstract – Short circuits in the field windings of large synchronous generators are difficult to detect. This paper presents a methodology in which stator current harmonics analysis is applied to detect this fault. In order to calculate stator current harmonics, CFE/SS (Coupled Finite Element/State Space) method, which is a combination of finite element and state space model, is used. It can be seen that stator current harmonics are changed significantly, when a fault occurs. As stator current is one of the generators' accessible on-line parameter, this method seems to be useful to on-line fault detection. In some cases fault can be localized, as well.

11:05 – **Neural Networks Application for Induction Motor Faults Diagnosis**

Czeslaw T. Kowalski, Teresa Orlowska-Kowalska

Abstract – The paper deals with diagnosis problems of the induction motors in the case of rotor, stator and rolling bearing faults. For diagnostic purposes two kinds of neural networks were pro-posed: multilayer perceptron networks and self organizing Kohonen networks. Neural networks were trained and tested using measurement data of stator current and mechanical vibration spectra. The efficiency of developed neural detectors was evaluated. Feedforward NN with very simple internal structure used for the detection of all fault kinds gave satisfactory results, what is very important in practical realization. Experiments with Kohonen networks indicated that they could be used for initial classification of motor faults, as a introductory step before proper neural detector based on multiplayer perceptron. Based on obtained results it can be concluded that neural detectors for rotor and stator faults as well as for rolling bearings and supply asymmetry faults can be developed based on measurement data acquired on-line in the drive system.

11:30 – **New Parameter Estimation Method Applied to Broken Rotor Bars Detection in Induction Machine**

Smaï Bachir, Slim Tnani, Gérard Champenois, Erik Etien

Abstract – I n this paper, authors give a new model of squirrel cage induction motors under rotor faults. In the first time, we propose a new faulty model dedicated to broken rotor bars detection. In the last one, new diagnosis procedure based on parameter estimation of the rotor faulty model is proposed. The estimation technique is performed by taking into account prior information available on the safe system operating in nominal conditions. A special three-phases induction machine has been designed and constructed in order to simulate true faulty experiments. Experimental test results show good agreement and demonstrate the possibility of detection and localization of previous failure.

11:55 – **Simulating Transient Fault Currents due to Internal Winding Faults in Synchronous Machines**

D. Muthumuni, P.G. McLaren, R.P. Jayasinghe, J. Nordstrom

Abstract – This paper deals with issues related to simulation of internal winding faults in different windings inside a synchronous machine. It is shown how the inductances of the faulted winding sections are calculated. With these inductances, the faulted machine can be modeled and simulated in PSCAD, an industry standard electromagnetic transient simulation program. Results comparing recorded and simulated fault current waveforms are presented. The consideration of the winding design is important in internal fault calculations. Numerical integration issues such as the selection of a suitable time step when the inductances are rotor position dependent and the reason for deviating from the conventional d-q-0 transformation are also addressed briefly.

12h20 – **Modelling, Simulation and Signal Processing With Application to Electric Machine Fault Diagnostics and Condition Monitoring**

Marian Negrea, Sanna Poyhonen, A. Arkkio, J. Pover, H. Hyotyniemi

Abstract – Correct evaluation of faulty motor performance is very significant part of condition monitoring and diagnostic procedure in modern supervision systems of electrical drives. Numerical magnetic field analysis is used for predicting the performance of an induction motor having different faults implemented in its structure. Virtual measurement data provided by the numerical magnetic field analysis and real measurement data are analysed using modern signal processing techniques in order to get a reliable indication of the fault. Support vector machine (SVM) based classification is applied to fault diagnostics. Different parameters are used as media of fault detection, and their suitability and capability to accurately diagnose a faulty operation is discussed. The circulating currents between parallel stator branches, forces between the stator and rotor, forces acting on the stator teeth and the outside stator yoke search coils placed over two poles pitches are found to be the most accurate fault indicators.

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MA-1D – Room 1300
Static Power Converters I

Session Chair:

J. Faucher (France)

10:40 – **Multiple Model Control of a Buck DC/DC Converter**

D. Alejo, P. Maussion, J. Faucher

Abstract – This paper describes a new method for algorithms commutation between two linear laws, for the voltage control of a buck converter with variable loads. A multiple model control (MMC) is the generated, based upon the fusion of only two traditional IP controllers outputs. This strategy improves the performances of the step input responses.

11:05 – **Distributed Model of Insulated Gate Bipolar Transistor Applied to Power Electronic**

G. Bonnet, P. Austin, J.L. Sanchez

Abstract – In this paper, a new one-dimensional (1D) Insulated Gate Bipolar Transistor (IGBT) model is presented. The heart of this model is based on the analogical resolution of the ambipolar equation of diffusion. Indeed, transport of loads to broad areas and little doped power components of a distributed nature. Approximation of the localised constants is not longer a valid solution. By taking into account, in the model, the side current into the P/P+ well, the 2D phenomenon, IGBT latch-up can be reviewed. The complete model developed under SABER as well as the static, dynamic results of simulation and the use in current converter are presented and compared to Hefner's IGBT model. Simulation results of a current inverter will be also presented to show the good behaviour of this IGBT model.

11:30 – **Development and Applications of Power Converter Discrete Models Based on Difference Equations**

Mikhail Borodulin

Abstract – This paper discusses development and applications of power converter discrete models in the form of a set of difference equations. As an example considered is the three-phase six-pulse Graetz bridge. All variables and parameters in the models developed are expressed either in the per unit system or based on a generalized parameter representation. Digital firing control is described by a set of difference equations with respect to control non-linearity and delays. Because of a small dimension, these models allow effectively using most of dynamics and stability analysis techniques. Shown are small stability regions along with examples of unstable converter performance. Instability usually occurs when control gains are too large, and frequency of unstable oscillations is tens of hertz. However, there exist unstable regimes with small gains and regimes with unstable oscillations whose frequency is several hertz only. Stability regions are reproduced by digital simulation with almost no discrepancy. Converter discrete models can also be used in calculating converter non-linear dynamics, in synthesis of tracking control, and studies of chaotic behavior.

11:55 – **Use of State Graph Theory in Power Components Modeling**

Faiza Charfi, Mohamed Ben Messaoud, Bruno François, Kamal Al-Haddad, Fayçal Sallami

Abstract – In this paper we present a novel extended model of power electronic components using the state graph theory. Our methodology is based on the functional decomposition of the power electronic component in a control part, defining the temporal functions of the structure, and an operative part describing the topological functions. The IGBT model is given as an example of application. Simulations are carried out by Simulink combined with Stateflow toolboxes of Matlab™. The model is evaluated in several application tests. The results of simulations are compared to those obtained with the IGBT model of Matlab Power Blockset. The advantage of the proposed model is its evolutionary structure, which allows possible extension to extreme operating modes.

12:20 – **Simulation Tool for the Control Circuit for a Static Converter**

M. Allain, F. Tourkhani, M. Ghribi, P. Viarouge

Abstract – This paper presents the basic principles underlying the creation of a software tool allowing both the visual drawing and the simulation of the control circuit of a static converter. After having presented the principles needed to create a visual interface used for the drawing of electronic circuits, we will present the application of the interface to defining a control circuit capable of generating control impulses for a power converter. Then we will discuss in general terms the algorithm that is used to calculate the impulse signals for a given control circuit drawn with the graphical interface. Finally, we will demonstrate how the graphical interface was coupled with the simulation tool SUPRA in order to provide the possibility of closed-loop control.

Back to the Monday program

MP-1A – Room 1150
Power Systems II

Session Chair:

G. Scott (Canada)

14:15 – **Object Oriented Power Flow With UPFC in Matlab**
Graham Rogers, Fernando Alvarado, Jean Mahseredjian
Abstract – This paper describes the development of a full capability object oriented power flow program using MATLAB and its integral class structure. The power flow solution uses scaled vectorized Newton-Raphson iterations to solve the nonlinear equations describing power flow in the interconnected power system network. The sparse jacobian of the real and reactive power injections into each bus is augmented by the jacobian of the controlled variables, and is reformed at each solution iteration. This allows additional models to be added relatively easily. The addition of a unified Power Flow Controller (UPFC) model is illustrated in detail, and examples of its use are shown using small and medium sized systems.

14:40 – **Parameterized Eddy Current Model of a Power Transformer**
Joseph El Hayek
Abstract – In order to introduce the winding losses distribution in a thermal model of a power transformer, a geometrical parameterized model has been realized on a finite elements software (Flux2D), which allows the simulation of different parts of the transformer. The results of the magnetodynamic study are obtained by the mean of a circuit link between the geometry and the different winding turns. Three geometrical cases have been studied with the aim to deduce a similitude law permitting to gain on the simulation time and memory size. To facilitate the data input in the thermal model program, actual results are expressed in percent of the transformer geometrical dimensions, then simplified and grouped according to a maximum error that the user can define.

15:05 – **Hybrid Electric Buses: Dimensioning the Intermediate Electric Storage Stage**
Jorge Esteves, F. Vale, N. Teixeira, Ines Santos, Pedro Granchinho Matos, T. Farias, R. Stüssi
Abstract – Electric buses could contribute for solving the environmental negative impact of transportation. However, limited autonomy allowed by available batteries imposes seeking other solutions in the definition of the electric driven powertrain. A thermal motor and an electric alternator or a solution including a fuel cell are two hybrid solutions actually considered by all the teams involved in electric buses design. A correct dimensioning of the several enrolled components of the driven powertrain (thermal motor and electric alternator versus fuel cell stack, batteries, power electronics converter and electric motor) can allow an optimised solution in the use of the power source, reducing its environmental impact. A methodology using a bus simulation model is proposed as a tool for helping design and dimensioning. Experimental results validate the simulation model.

15:30 – **Hysteresis Modeling: A Closed Loop Approach**
E. Etien, L. Rambault
Abstract – A new model to characterize the hysteresis phenomenon is presented. The model is based on a closed loop allowing to take into account the output delay. A non linear least square algorithm is used to identify parameters. The characterization of a magnetic circuit is proposed as application. The property of reversibility is then used to obtain an input estimation from output datas.

15:55 – **Transient Design Studies of Neutral Reactors for Single-Phase Auto-Reclosing on the Peruvian 220-kV Double-Circuit Series-Compensated Interconnection**

Que Bui-Van, Danielle McNabb

Abstract – In October 2000, the TransMantaro double-circuit 604-km lines were put in service interconnecting the Northern (SICN) and the Southern (SIS/REDESUR) regional subtransmission systems in Peru. During the first months of operation, severe temporary over-voltages (TOV) were experienced following single-phase tripping and auto-reclosing (SPAR) due to line flashovers caused by lightning storms. Although there was no failure of the interconnection equipment, these disturbances caused unsuccessful line reclosing, temporarily resulting in a separation of the SIS/REDESUR system from the SICN system. In order to prevent damage to equipment and to improve service continuity, it was decided to investigate an effective mean to avoid dangerous TOV that could appear on the interconnection. This paper summarizes the results of electromagnetic transient (EMTP) studies for the design of four 350-. neutral reactors that are to be implemented in the Cotaruse substation to suppress TOV following a single-phase line tripping and auto-reclosing. The efficiency of neutral reactors for secondary arc current extinction and the transient performance of SPAR systems on double-circuit 220-kV lines were thoroughly investigated. Finally, the impacts of these neutral reactors on transient recovery voltages (TRV) across 220-kV line circuit breakers as well as on energy stresses imposed to 156-kV line surge arresters have also been analyzed.

Back to the Monday program

MP-1B – Room 1160
PM Synchronous Machines

Session Chair:

P. Viarouge (Canada)

14:15 – **Magnetic Field Analytical Solution of an Axial Flux Permanent Magnet Synchronous Machine**

J. Azzouzi, G. Barakat, B. Dakyo, C. Nichita

Abstract – An exact two-dimensional (2D) analytical solution of the magnetic field in an axial flux permanent magnet synchronous machine (AFPMSM) is presented. This solution is based on the use of separation of variables method to solve a magnetic vector potential formulation resulting from Maxwell equations. The obtained solution allows rapid parametric studies of airgap magnetic field as well as cogging torque. Results issued from the proposed model in the airgap are compared with a good agreement with those stemming from a 3D finite elements method (FEM) simulation.

14:40 – **Modeling of Non Sinusoidal Permanent Magnet Synchronous Machines With the Aim of Control**

L. Gasc, M. Fadel, S. Astier, L. Calegari

Abstract – The control of surface-mounted permanent magnet synchronous are based either on the three phase model or on the use of the Park's transformation. These models apply only to the machine with sinusoidal flux distribution and do not take account of the real electromagnetic characteristics of the motor such as the ripple torque caused by the interaction of the permanent magnet field with the stator emf distribution harmonics or the cogging torque caused by the interaction of PM field and stator slotting. We propose in this paper two models. The first one is dedicated to the analytical model of PM motors in three phase, we show that this model makes it possible to reproduce the electromagnetic characteristics and the torque oscillations and this in agreement with an approach lead by calculations of fields. The second model is based on extension of the Park's transformation. We define a new transformation which permits to find the properties of Park's transformation such as the electromagnetic torque depends only "q" like component of the stator current.

15:05 – **Torque Evaluation of Direct Drive PM Disc Motor for Electric Vehicle**

Goga V. Cvetkovski, Lidija B. Petkovska, Milan D. Cundev

Abstract – In this paper a torque calculation of a permanent magnet disc motor (PMDM) by using FEM data and by an analytical approach is going to be performed. For the FEM calculation of the torque a 2D FEM magnetic field calculation, as very suitable for this type of geometry, is performed. Therefore a proper modelling of the motor is required. The method used for the torque calculation using FEM data is the Maxwell stress method. The necessary data for the calculation of the torque is provided by calculating the magnetic vector potential for rated current load, for all five segments and for different rotor displacements. The analytical approach for torque calculation is based on the phasor diagram of the motor. The values of the electromagnetic torque for rated load calculated by the Maxwell stress method and the analytical approach show good agreement compared to the measured ones.

15:30 – **A Modulation Method to Determine the Magnetic Field in PM Motors**

Miroslav Markovic, Marcel Jufer, Alain Cassat

Abstract – An analytical modulation method to determine the magnetic field created by permanent magnets PM), in a PM slotless motor is presented. It is based on the resolution of Poisson's equations using the Fourier's series. A first step is to determine the magnetic field created by two current sectors in the air gap. Then, the magnetic field due to PM equivalent currents is calculated. The corresponding results are compared with those obtained by FEM analysis.

15:55 – **On-Line Identification of Stator Resistance for Sensorless Control of PMSM: Back-emf Based Techniques and Extended Kalman Filter**

Babak Nahid Mobarakeh, Farid Meibody-Tabar, François-Michel Sargos

Abstract – A new on-line identification method of a PMSM stator resistance is proposed in this paper. The machine is controlled without mechanical sensor. The proposed method is easy to implement. A stability analysis based on the first method of Lyapunov shows the stability of the closed-loop system with the proposed estimator combined to the sensorless algorithm. This approach make the sensorless control more robust with respect to the stator resistance variations at low speeds. The same problem is resolved by a Kalman filter extended to the stator resistance. The simulation and experimental results are used to compare the proposed method with the EKF and illustrate the validity of the analytical approach and the efficiency of the proposed method.

Back to the Monday program

MP-1C – Room 1170
Power Quality and Active Filtering I

Session Chair:

E. Ngandui (Canada)

14:15 – **Assessment and Mitigation of Voltage Dips**

Ibrahim O. Habiballah

Abstract – Voltage dips are the worst power quality problem facing many of the modern industrial and commercial customers. They are much more frequent than interruptions. The combination of voltage dips (also known as voltage sags) and sensitive equipment may cause significant production outages. Voltage dips are short duration reduction in voltage due to short circuits, overloads, starting of large motors, etc. They can cause problems to sensitive equipment such as solid state electronic relays, contactors and adjustable speed drives. This paper presents the characterization of voltage sags. It also presents the most important methods to assess this power quality event. It gives an overview of the major existing solutions to improve the equipment performance that are sensitive to voltage sags.

14:40 – **Power Quality and its Fuzzy Evaluation and Management**

Liang Cai, Hui Huang

Abstract – The paper first indicates a fuzzy measurement concept based on the consideration of the deviation from rated value. From this basic concept it takes the membership for fuzzy property of quality indices. Then the paper gives some representations for indices by different approaches to the membership. So the membership of a detailed quality can be its evaluation simply. Then in order to discussing the further fuzzy evaluation of power quality, the paper makes applications both on item quality and general quality. The former is using fuzzy comprehensive evaluation and the latter is multi-grades advanced evaluation. For enhancing the accuracy of evaluation, the paper also makes some improvements on the fuzzy comprehensive evaluation. From the application case, it is not difficult to see that the paper realizes an effective evaluation of power quality, especially on general quality. And the fuzzy representations can also be successful for power quality studies. In the second part of quality management, first the authors suggest a regulation of memberships before management. Then the paper introduces the fuzzy relations cluster application to quality management as guidance for decision via a case study. It is not difficult to see that the application results for management are quite reasonable that hold the preliminary expectation.

15:05 – **Performance Evaluation of Adaptive Techniques for a Power System Harmonic Neural Network Estimator Method**

Salma Aït Fares, Éloi Ngandui, Daniel Massicotte, Pierre Sicard

Abstract – This paper presents a combined adaptive technique based on artificial neural networks to estimate simultaneously the power supply frequency variations and the time varying power system harmonics. The main feature of the estimation is that it enables robust real-time tracking of time varying harmonic components. The proposed estimation is compared to existing artificial neural networks methods based on adaptation of the stochastic least mean square (LMSS), normalized least mean square (LMSN), and the recursive least square (RLS). Simulation results and Comparison with respect to speed of convergence and accuracy of current harmonic amplitude and phase angle estimation, signal-to-noise ratio and distortion show the superiority of the proposed method.

15:30 – **Fixed Frequency Driving Signals for a Shunt Active Filter**

Antonio Dell'Aquila, Agostino Lecci

Abstract – An active filter has been proposed to compensate harmonic distortion, line neutral current and reactive power in three-phase four-wire systems. Focus has been addressed to current control in order to achieve an optimum current tracking by means of fixed frequency driving signals. The effectiveness of proposed control has been proved in simulation where the harmonic pollution and unbalance caused by a highly distorting load have been drastically reduced.

15:55 – **Optimal Operation of a Generator Connected to a Network Using FACTS Devices**

E. Gholipour, S. Saadate

Abstract – The aim of this paper is to analyze the effect of an Unified Power Flow Controller (UPFC) in optimal operation of a generator connected to a network via transmission lines, by using an Electromagnetic Transient Program (EMTP) simulation package. The UPFC consists of two solid-state Voltage Source Inverter (VSI) which is connected with a transformer at its output. The exchanged real power at the terminal of one inverter with the line flows to the terminals of the other inverter through the common DC link capacitor. Each inverter can exchange reactive power at its terminal, independently. After modeling the UPFC, the optimal values of generator reactive power (Qs) for each value of generator active power demand (Ps), was also calculated. Then by using nonlinear programming (Newton method), the proper values of injecting shunt current and series voltage of UPFC was calculated and applied to the system. The simulation results are presented in the last section.

Back to the Monday program

MP-1D – Room 1300
Real-Time Simulation (Invited Session)

Session Chair:

J. Bélanger (Canada)

14:15 – **A Fully Digital Real-Time Power System Simulator Based on PC-Cluster**

C. Larose, S. Guerette, F. Guay, A. Nolet, T. Yamamoto, H. Enomoto, Y. Kono, Y. Hasegawa, H. Taoka

Abstract – Many benefits come with the real-time simulation of electric machinery and drives. HYPERSIM, a fully digital real-time power system simulator, originally based on large parallel supercomputer, is now adapted to a new hardware platform, in order to increase its flexibility and accessibility. This paper presents a new hardware architecture, called PC-Cluster, for real-time simulation of complex power system networks, including power electronics. A PC-cluster consists of several commodity PC interconnected with high-speed network. This new hardware platform for the HYPERSIM simulator is completely based on components-off-the-shelf (COTS) such as commercial motherboard, PCI input/output board and communication board. The general implementation of the real-time parallel simulator is introduced in this paper. All aspects of the simulation, such as communication, calculation, synchronization, I/O access and acquisition, are presented in detail. To evaluate the performance of the new hardware platform in a real simulation, a complete application of electric machine drive is presented. This new hardware technology is bringing interesting benefits to power system engineers. It is now easier to have access to powerful simulation tools, in order to perform precise and complete power system studies.

14:40 – **RT-Lab Based Real-Time Simulation of a Direct Field-Oriented Controller for an Induction Motor**

M.A. Ouhrouche, N. Léchevin, S. Abourida

Abstract – Field-Oriented Control, introduced first by Blaschke in 1972, allows high performance speed and torque response to be achieved from an induction motor. When driven by a field-oriented controller, an induction motor behaves like a separately excited DC machine, which is, as its flux and torque are controlled independently, traditionally and for a long time used in electrical drives. Thanks to the advances of industrial computers and DSP technologies, the field-oriented control strategy for an induction motor can now be easily implemented for real-time applications. In this paper, the authors present a real-time PC-based simulation of a direct field-oriented controller (DFOC) for an induction motor using RT-LAB software package[TM1]. The use of a real-time simulator to achieve Hardware-in-the-Loop (HIL) simulation allows rapid prototyping of this kind of complex system in particular, and the development and testing of embedded systems in general. The implemented system presented in this paper consists of an induction motor with its static converter and speed, torque and flux controllers. These controllers are designed to take into account the variations of the rotor resistance.

15:05 – **Real-Time Simulation of Electric Drives**

Roger Champagne, Louis-A. Dessaint, Handy Fortin-Blanchette

Abstract – This paper presents a real-time simulation of an AC electric drive. The main purpose of this type of simulation is to provide an efficient, cost-effective and secure way of testing the control part of an electric drive. Therefore, the electric motor and the electronic converter of the drive are simulated using a time-step of about 50 microseconds and an external controller is tested by interfacing it to the real-time simulation. Note that the distribution system and the motor mechanical load can be also conveniently included in the real-time simulation. This new way of testing drive's controllers avoids the need for bulky and expensive test benches equipped with high power motors, converters and measurement devices. The real-time simulation results are validated by comparing them to their off-line version.

15:30 – **Real-Time Computer Control of a Multilevel Converter Using the Mathematical Theory of Resultants**

John Chiasson, Leon Tolbert, Keith McKenzie, Zhong Du

Abstract – The mathematical theory of resultants is used to compute the switching angles in a multilevel converter so that it produces the required fundamental voltage while at the same time cancels out unwanted order harmonics. Experimental results are given for the three DC source case. It is shown that for a range of the modulation index m_I, the switching angles can be chosen to produce the desired fundamental $V_1 = m_I\ (s4V_{dc}/\pi)$ while at the same time 5^{th} and 7^{th} harmonics are identically zero.

15:55 – **An Efficient Saturation Algorithm for Real Time Synchronous Machine Models Using Flux Linkages as State Variables**

Trevor Maguire

Abstract – This paper presents an efficient method of calculation concerning D-axis saturation in a synchronous machine model when winding flux linkages are the state variables. A method is presented for calculation of a saturation indicator S based on a linear combination of the flux linkages in the D-axis windings. A method is then presented for developing a look-up curve F(S) which is dependent on the saturation indicator. The product of S times F(S) produces ψ_{md}, the main mutual magnetizing flux linkage for the D-axis. The component of flux linkage due to leakage in each winding on the D-axis can be obtained by subtracting ψ_{md} from the flux linkage of the particular winding. D-axis winding currents are subsequently obtained by multiplying the components of winding flux linkages due to leakage by the pre-calculated inverse of the leakage inductance matrix.

Back to the Monday program

TUESDAY AUGUST 20TH

8:30 – 10:35	**TA-1A Room 1150**	**TA-1B Room 1160**	**TA-1C Room 1170**	**TA-1D Room 1300**
10:35 – 11:05	**Coffee Break Main Hall**			
11:05 – 12:45	**TA-2A Room 1150**	**TA-2B Room 1160**	**TA-2C Room 1170**	**TA-2D Room 1300**
12:45 – 14:15	**Lunch Main Hall**			
14:15 – 16:20	**TP-1A Room 1150**	**TP-1B Room 1160**	**TP-1C Room 1170**	**TP-1D Room 1300**
16:20 – 16:50	**Coffee Break Main Hall**			
16:50 – 18:50	**Poster Session I Rooms 1422 and 1752**			
19:30	**Banquet and Concert Main Hall**			

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TA-1A – Room 1150
Power Systems III

Session Chair:

E. Pagano (Italia)

8:30 – **Influence of Hydraulic Turbine on Power Dynamic Stability**

A. Ahmed-Chaouch, Georges Gaba, Serge Lefebvre

Abstract – The purpose of power system dynamic stability analysis is to study oscillation modes and their relationship with controllers variables and parameters in order to identify instability sources and to develop solutions witch ensure a satisfactory operation of the system for the small perturbations. The concept of small signal justifies the hypothesis of linearity and enables the linearization of the system equations around the operating point, allowing the use of linear system analysis techniques. The hydraulic turbines are supposed to have a considerable influence on power system dynamic stability; therefore their modeling must be reliable and accurate. A method is presented for the accurate modeling of hydroelectric power generating systems for dynamic stability analysis. A detailed model, which takes into account the dynamic of water flow in the hydraulic pipes and where the turbine is presented by its static characteristics, is developed. The detailed model is validated by load rejection test. A linear model is derived for James Bay LG2 and validated with simulated frequency-response tests on detailed model.

8:55 – **Comparison of Different Numerical Approaches for the Calculation of Eddy Current Losses in Large Synchronous Generators**

Erwin Schlemmer, Franz Klammler, Franz Mueller

Abstract – The paper describes the use of numerical techniques for the calculation of eddy current losses in the end region and in the poles of large synchronous generators. End region heating is one of the design limiting factors of large generators. Predominantly, the finite element method (FEM) is employed for more detailed investigations of end region behaviour. Although affordable computing power has increased considerably during the last years, the exigencies for processor time are still preventing the everyday use of fully 3D FEM solutions including non-linearity and rotational motion. Therefore, besides semi-analytical methods, approximations for the fully fledged 3D solutions are sought for. In the paper, we compare the 3D rotational solution with 3D time-harmonic solutions for cylindrical rotor machines. The next step of approximation is to sacrifice non-linearity for the sake of the faster and better converging linear 3D solutions. Furthermore, comparisons are made between 2D solutions for damper currents and their 3D counterparts in salient pole generators. Additionally, some calculation examples of smaller permanent magnet generators are given.

9:20 – **Generator Operations of Asynchronous Induction Machines Connected to Either AC or DC Active/Passive Electrical Networks**

D. Iannuzzi, E. Pagano, L. Piegari, O. Veneri

Abstract – The paper analyses generator operations of asynchronous machines when they are connected to a passive electrical network either directly or by an intermediate static power converter. The analysis is performed by taking into account the saturation phenomena of the main magnetic circuits of the machine. Mathematical models of both physical configurations are given and their non-linearities are evidenced. The paper investigates the existence of periodical solutions related to stable operations of the systems. Numerical and experimental results support the theoretical analysis.

9:45 – **Using Multilevel Flow Modeling for Power Substation Control**

A.R. Aoki, G. Lambert-Torres, L.E. Borges da Silva, J.G. Borges da Silva

Abstract – The intelligent system proposed in this paper has been implemented for helping the Piratininga Power and Light's technicians in the system operational occurrences. It allows the operator to go through the ways for problem solving. The use of hybrid systems with artificial intelligence techniques, together with correctional numeric techniques, make possible to solve non-systematic problems and to show to the user the reasoning path used for the problem solving. This last factor is very important in a learning process, one of the aims of this system, once it make possible for the operator to understand the way the specialist in the area uses for solving one problem.

10:10 – **Thermal Model of a Power Transformer**

Samuel Marguet, Joseph El Hayek, Philippe De Werra

Abstract – In order to predict the hot spots in a transformer winding, a thermal model of the latter is presented. Equations system is implemented in Matlab environment. The temperatures obtained from this model are compared to those measured by optical fiber wound within a real winding. A first approach based on a simplified model gives acceptable results. Several ways to improve this model are presented including investigations on fluid and heat transfer physical phenomena.

Back to the Tuesday program

TA-1B – Room 1160
Asynchronous Machine I

Session Chair:

B. Davat (France)

8:30 – **Neural Network Speed Controller for Induction Motor Based on Field Oriented Control**

Ghasem Ahrabian, Mohammad Reza Banaei

Abstract – A simple structure feed forward neural network (NN) is presented to control the speed of the induction motor in this paper. The scheme consists of a neural network controller, a reference model, and an algorithm for changing the NN weights in order that the speed of the drive can track of the reference speed. To apply the induction motor drives for high performance applications, rotor flux and motor speed must be controlled independently. Field oriented theory is used to decouple the rotor speed and the flux amplitude. The proposed controller, without using state space dynamics and by employing only the input-output information can produce the control input for motor. However, the NN controller is robust to the bounded parameter variations and external disturbances. A qualified speed tracking and load regulating responses can be obtained by the proposed controller. structure can control the dynamics of the system, it should receive all of the state variable some of which may not be available. In the neural network used in this paper for control of motor speed only speed error and derivative of speed error is used and error reduction is independent of complicate and dynamics of system that should be controlled.

8:55 – **Operation of Three-Phase Self-Excited Induction Generator Under Unbalanced Load**

A.M. Alsalloum, A.I. Alolah, R.M. Hamouda

Abstract – A general model of a delta-connected three-phase self-excited induction generator (SEIG) feeding a delta-connected load is presented. This model may be used to analyze the performance of the SEIG under any type of three-phase loads with any degree of unbalance. The models for other combinations of SEIG and load are also derived and listed. The SEIG performance has been investigated for balanced and unbalanced loading conditions. Single capacitor excitation case was also studied. The results have good agreement with those published in the literature.

9:20 – **Evaluation of Three-Phase Induction Motor Maintenance by a Hybrid Intelligent System**

L.E. Borges da Silva, G. Lambert-Torres, R. Rossi, L.O.M. Reis

Abstract – The paper describes an on-going research about Rough Sets based classifier applied to Induction Motors fault diagnosis. The knowledge acquisition and further manipulation in order to obtain useful information about the fault is actually an important research working out in predictive maintenance. Depending the number of variables acquired and the complexity of the system under analysis, the experts can have a hard time to analyze and get it in a compact and comprehensible form in order to reach a diagnosis in a reasonable amount of time. This fact may result in a wrong analysis and misevaluation of the information available. The problem is getting worst when superfluous, incomplete or noisier set of information is acquired and put inside the database. This paper presents a contribution to help knowledge engineers to manipulate and reduce knowledge bases for Induction Motor Fault Diagnosis using a systematic approach. The approach is based on Rough Set Theory. An illustrative example is presented in this paper.

9:45 – **An Accurate Model of Squirrel Cage Induction Machines Under Stator Faults**

Vincent Devanneaux, Bruno Dagues, Jean Faucher

Abstract – A substantial portion of squirrel cage induction motor faults are stator related. An accurate transient model of squirrel cage induction machines under stator faults is presented here. A coupled magnetic circuits approach is used and very few restrictive assumptions are made. All parameters are calculated from the actual geometry and winding layout of the machines rather than from transformed or equivalent variables. The detailed depiction of the procedure needed to implement such an accurate model with simulation results is the subject of this paper.

10:10 – **The Coupled Electrothermal Model of an Induction Machine**

M. Broussely, Y. Bertin, P. Lagonotte

Abstract – The network topology reduction is based on an exact mathematical tool. The principle is a reduction of the problem matrix to a few lines and columns. The original reduction method developed in this study is an extension of this technique implemented to transient heat diffusion problems. The finite volume model is hence reduced to a few chosen nodes and a new type of element appears in the associated network, the compensation capacitance. This element, discussed in [1], links every node of the model and improves the dynamic behaviour of the model. Two steps of optimisation, concerning the choice of the nodes and the value of the compensation capacitances, are discussed. The method is implemented to the thermal model of an industrial object, a 5.5 kW squirrel cage induction machine.

Back to the Tuesday program

TA-1C – Room 1170
Multimachine Multiconverter Systems (Invited Session)

Session Chair:

A. Bouscayrol (France)

8:30 – **Control Structures for Multi-Machine Multi-Converter Systems With Upstream Coupling**

A. Bouscayrol, B. Davat, B. B. De Fornel, François, J.P. Hautier, F. Meibody-Tabar, E. Monmasson, M. Pietrzak-David, H. Razik, E. Semail, M.F. Benkhoris

Abstract – A multi-machine multi-converter system formalism has been proposed to describe systems composed of several electrical machines and converters. This description points out coupling elements, which have to distribute energy. Control structures have already been proposed for systems with downstream coupling. This paper is focused on control structures for systems with upstream coupling. Several solutions can be found by moving control blocks.

8:55 – **The DUOMOTOR® - A Novel Double Rotor Machine Construction and Control**

Manfred Schrödl, Erich Schmidt, Stephan Ojak

Abstract – The DUOMOTOR consists of one stator and two unilateral beared rotors which are controlled independently of each other. The utilized rotors are either squirrel-cage induction or permanent magnet synchronous types. The paper describes the space phasor model, the field oriented control and the losses of the machines with two possible rotor combinations. The utilization of digital signal processors and modern power electronics allow for an innovative low cost electrical drive for a wide range of applications such as heating pumps and electrical stepless gears.

9:20 – **Torque Control of a Field Oriented Doubly Fed Induction Machine**

Ragi Ghosn, Claude Asmar, Maria Pietrzak-David, Bernard De Fornel

Abstract – In previous works we defined a control strategy for a stator-field oriented Doubly Fed Induction Machine (DFIM), that divides the electrical power between stator and rotor. We also presented a new control method that gives better decoupling between d and q axis, and then higher performances for flux, torque and speed responses. This method is almost insensitive to the variations of the stator and rotor resistances. In these studies, we have considered at first that a mechanical sensor of speed or position is used. After that, we have shown that it is possible to maintain good performances in sensorless operation by using a method, based on MRAS which gives good simulation results. We now present experimental results which show good behavior while the torque is controlled and a mechanical sensor is used.

9:45 – **Six-Phase Induction Machine With Third Harmonic Current Injection**

Renato O.C. Lyra, Thomas A. Lipo

Abstract – The use of a six-phase induction motor for industrial drives realizes advantages over the conventional three-phase drive, such as increased reliability, reduction in the power ratings for the static converters and reduction in the harmonic content. For these reasons, six-phase induction motors are increasingly used in high power applications. A typical construction of six-phase induction motor drives includes a stator with a dual three-phase connection, where two three phase groups are spatially shifted thirty electrical degrees, a six leg inverter and control circuit. By controlling the phase currents of the machine, harmonic elimination and torque ripple reduction techniques can be implemented. Furthermore, performance is improved with the injection of stator zero sequence third harmonic currents. This paper describes the modeling of the induction machine in a dq0 synchronous reference frame that includes the effects of the third harmonic currents. The model is verified through simulation and experimental results.

10h10 – **Series Connection of Supercapacitors: Comparative Study of Solutions for the Active Equalization of the Voltages**

P. Barrade

Abstract – Because of their low voltage level, supercapacitors need arrangement with series connection in order to obtain voltage levels from few dozen to few hundred of volts. As for batteries, devices have then to be defined to balance the voltages across each series connected components. This paper presents the problematic of voltage sharing in a series connection of supercapacitors. It is generally described the way the balancing of the voltages can be obtained, with the main design rule. It is also introduced how the voltage balancing can be obtained easier with a coherent arrangement of the supercapacitors in their tank. Then, the main solutions for sharing the voltages with active devices are presented, detailed and compared, using a global modeling approach.

Back to the Tuesday program

TA-1D – Room 1300
Static Power Converters II

Session Chair:

M.P. Kazmierkowski (Poland)

8:30 – **Frequency Domain Analysis of Digital Pulse Width Modulators**

David M. Van de Sype, Koen De Gussemé, Jan A.A. Melkebeek

Abstract – As the performance of digital signal processors has increased rapidly during the last decade, there is a growing interest to replace the analogue controllers in low power switching converters by more complicated and flexible digital control algorithms. Compared to high power converters, the control loop bandwidths for converters in the lower power range are generally much higher. Because of this, the dynamic properties of the digital pulse width modulator used in low power applications become an important restriction for the maximum achievable bandwidth of control loops. After the discussion of the most commonly used dig-ital pulse width modulators, a frequency domain model for the dynamics of the digital pulse width modulator is derived using both theoretical analysis and simulation. The results obtained are verified by means of experiments using a test setup.

8:55 – **Simulation of Voltage Source Converter – Application to a STATCOM**

Guillaume de Préville

Abstract – Flicker, caused by large fluctuating loads as arc furnace, is one of the power quality problems that include interruptions, voltage sags and dips, harmonics. The state of the art technology to reduce flicker is shunt compensation using Static Var Compensator with thyristors. However, this kind of technology has an intrinsic limited flicker mitigation capability. Voltage Source converters can be used as shunt compensation device. Simulations of VSC converter with its control as STATCOM device has been done in Matlab/Simulink and VSC structure was introduced in a complete arc furnace installation. Topological simulations of different Voltage Source converters are presented in this paper and VSC could be expressed in state space equations for easy implementation in a real time simulator and results of these simulations for a 4 Level Flying capacitors Voltage Source are shown. Simulation of a complete arc furnace installation is presented too, using MATLAB/Simulink.

9:20 – **PWM-Switch Modeling of Converters Including Semiconductor Device Non-Linearities**

Anis Ammous, Youssef Ounajjar, Moez Ayedi, Kamal Al-Haddad, Fayçal Sellami

Abstract – The accurate simulation of power electronic systems is possible when including accurate models of the semiconductor devices, but practically not affordable. Classical ideal averaged models of the system are not suitable either. Hence, averaged models including the non-linear effects of the power semiconductor devices appear quite efficient. The proposed non-ideal PWM-switch model is a useful method for modeling pulse width modulated converters operating in the continuous conduction mode. The main advantages of the proposed averaged model are the takes into account of the non-linear effects of power devices and the possibility to estimate the dissipated power in the different circuit devices. The proposed model can be applied to bi-directional converters and allows the electrothermal simulations of the power electronic system. A simple technique to evaluate the different static and dynamic parameters of the devices is presented.

9:45 – **Numerical Phenomena When Applying the Trapezoidal Rule in Simulations of Power Electronics**

Mikhail Borodulin

Abstract – This paper discusses numerical phenomena observed when the trapezoidal rule (TR) or TR-based algorithms are applied in simulations of networks with power electronics. Their specific features, including initialization of a new free motion after each switching operation, require accurate reproduction of this motion. Intolerant mode distortion results in incorrect reproduction of bus voltages, valve voltages, and extinction angles. Distortions can also misrepresent harmonic spectra of network currents and voltages. To perform the analysis, used is an approach based on evaluating distortions of the free and forced motion modes. The phenomenon of TR oscillations is analyzed in terms of damping and frequency distortions. Another distortion mechanism results in transforming high frequency modes into phantom low frequency modes. Discussed are TR-based algorithms proposed to enhance simulations, including those generalized by the Liniger-Willoughby method. Given are formulas for companion models associated with TR-based algorithms.

10:10 – **Review and Comparative Study of Control Techniques for Three-Phase PWM Rectifiers**

Mariusz Malinowski, Marian P. Kazmierkowski, A. Trzynadlowski

Abstract – Control techniques for PWM rectifiers in ac adjustable speed drives are presented. In particular, the so-called virtual-flux oriented control (VFOC) and virtual-flux based direct power control (VF-DPC) schemes are described and compared with their voltage based counterparts, that is, the voltage oriented control (VOC) and voltage-based direct power control (V-DPC) techniques. Theoretical background is provided, and results of computer simulations and laboratory experiments are given, documenting advantages and disadvantages of the individual control strategies.

Back to the Tuesday program

TA-2A – Room 1150
Static Power Converters III

Session Chair:

H. Buyse (Belgium)

11:05 – **Conducted EMI Reduction Techniques for Power Converters**

C. Semet, N. Idir

Abstract – Permanent progress of insulated gate transistor technologies (like MOSFET and IGBT) increased their utilization in the power converters functioning at higher frequencies. The utilization of this switch induces rapid variations of the current (di/dt) and voltage (dv/dt) produced conducted and radiated emissions in wide frequency bands. To reduce these perturbations as well as those linked by the control electronics, there exist various solutions. We propose here an approach associating two EMI reduction methods. A direct method that allows to reduce perturbations to the source by acting directly on the gate control voltage of the power switches, and a passive filtering method allowing to reduce conducted emissions up to 30MHz. The advantages of the association of these two methods are to allow an optimization of the passive filtering installed. The waited benefit is a cost and weight of the converter what is a mainly advantage for the embarked equipment. In this study, the proposed method is applied to 6 kW converter.

11:30 – **Two Time Scale Global Dynamical Modelling of Power Electronic Systems**

S. Gusia, F. Labrique, D. Grenier, H. Buyse

Abstract – Global dynamical models of power electronic systems allow to compute their dynamics in a very easy way as they replace the switching behavior of the power electronic converter by a continuous process [1],[2]. But they are unable to predict the ripples induced by the switching behavior of the power semiconductor switches. The aim of this paper is to show for power electronic systems using a power electronic converter working in a PWM mode, how it is possible to define a global dynamical model including a dynamical model of the ripple effects.

11:55 – **Identification and Reduction of Common Mode Currents in PWM Inverter Motor Drives**

N. Idir, J.J. Franchaud

Abstract – In the last years, Adjustable Speed Drives (ASDs) manufacturer's uses Insulated Gate Bipolar Transistors (IGBTs) as the power switching devices. However, the advent of fast power devices has generated several unexpected problems, such as premature deterioration of ball bearing and high levels of electromagnetic emissions, caused by flowing of parasitic capacitive currents known as common mode (CM) currents. In order to reduce these currents, a suitable modeling of an AC motor is obtained by the identification of the spreading paths. By connecting the model of the cable with a proper high frequency model of the motor and the equivalent model of the converter, a representation of the whole ADS is developed. In this paper, first the simulations are carried out using the proposed model and compared with experimental results. In the last part, a CM choke method is used allowing to reduce de CM current in the ASD.

12:20 – **A New Nonlinear Single-Loop Bipolar Control Law Applied to an Active-Current-Injection Three-Phase Rectifier**

Hadi Youssef Kanaan, Kamal Al-Haddad

Abstract – This paper presents a new nonlinear bipolar control technique applied to a three-phase rectifier operating with an auxiliary current injection circuit. The proposed control scheme uses a single current loop and is implemented based on the input-output feedback linearization technique. The control law is elaborated on the basis of a single-input-single-output low-frequency state model of the converter, which is obtained using the states-pace-averaging method. The control system performances are analyzed in both steady state and transient regimes. Numerical results, obtained on a simulated version of the converter, emphasize the high performance of the proposed control law in terms of line-current Total Harmonic Distortion (THD) and output voltage ripple. Furthermore, the robustness of the control scheme to load changes and supply-voltage disturbances is analyzed. The considered control law is finally compared, analytically and numerically, to other single-loop control techniques yet applied to the converter, and its superiority over these techniques is consequently highlighted.

Back to the Tuesday program

TA-2B – Room 1160
Magnetic Materials I

Session Chair:

R.Le Doeuff (France)

11:05 – **Magnetization of Composite Ferrite Magnets for 42 V Brushless Electrical Fan**
S. Sraici, C. Espanet, T. Péra, J.-E. Torlay, A. Miraoui, J.M. Kauffmann
Abstract – The present work concerns the magnetization of composite ferrite magnets used in a 42 V brushless DC motor for electrical fan. First the authors explain the design of the magnetizing coil, which is based on both analytical and finite element models. In a second part they present the experimental performances of a prototype realized by the L2ES in collaboration with the company Faurecia.

11:30 – **A 3-D and 2-D Computations of the Magnetic Field in a Permanent Magnet Synchronous Machines**
S. Yaïci, L. Adjout, R. Ibtiouen
Abstract – In this paper, the authors deal with the tri-dimensional and bi-dimensional computations of magnetic field in permanent magnet devices. Application to the modeling of a slotless and slotted permanent magnet synchronous machines (PMSM) are presented. The obtained results using the developed method are compared to these issued from a finite element computation and to experimental ones.

11:55 – **Optimization of SMES and Superconducting Magnets With a Derivative Free Deterministic Method**
Vincent Picaud, Patrick Hiebel, Jean-Marie Kauffmann
Abstract – This article presents a constrained optimization method which does not need the gradients. The method is used to optimize superconducting devices. In order to reduce the computing effort the initial optimization problem is divided into two coupled optimization problems one managing the geometrical parameters, the other finding the best current densities for a given geometrical configuration.

12:20 – **Ferromagnetic Material Modeling and Field Computation**
S. Clénet
Abstract – In this communication, we present different kinds of models which enables to represent the ferromagnetic materials: one based univoc B(H) and ones which takes hysteresis phenomenon into account. Their implementation in field computation code is also developed. Then, a simple example of an iron core coil is presented and the conditions of utilization of these models in field computation are discussed.

Back to the Tuesday program

TA-2C – Room 1170
Power Quality and Active Filtering II

Session Chair:

A.M. Sharaf (Canada)

11:05 – **Power Quality Enhancement and Harmonic Reduction Using Dynamic Power Filters**

A.M. Sharaf, Pierre Kreidi

Abstract – The paper presents a low-cost dynamic switched/modulated power filter to enhance power quality, reduce waveform distortion and waveform flickering effect. These effects are introduced by the nonlinear digital type switching associated with converter-type loads such as in process-industry, motor- drives and common controlled thyristor rectifier type loads.

11:30 – **Assessment of the Harmonic Contribution of the Supplier and the Consumer at the Point of Common Coupling**

P. Guérin, D. Herbreteau, F. Auger

Abstract – The number of non-linear loads don't stop increasing as well as the injection of the harmonic currents into the electrical distribution system. This paper presents several methods to assess the harmonic contribution of the supplier and the consumer at the point of common coupling. During 24-hours, a survey was carried out on two electrical installations: a mechanical enterprise and a lighting shop. Thus, these measurements allow evaluating techniques to be to applied on practical cases with real operating conditions.

11:55 – **A Hybrid Power Filter With Improved Control Algorithm Based on LMS Estimation**

N. Mendalek, K. Al-Haddad, L.-A. Dessaint

Abstract – In this paper a new control technique based on the Least-Mean-Square (LMS) algorithm is applied to a Hybrid Power Filter (HPF) that is capable of compensating current harmonics and regulating the voltages on radial lines. The hybrid filter inherits the efficiency of already installed shunt passive filters and the improved compensation characteristics of an active power filter. The active filter is composed of a three-phase PWM voltage-source inverter connected in series to the passive filters. The hybrid device is discussed in terms of principle of operation and the proposed control based on the LMS algorithm is designed with stability considerations. Simulation results demonstrate the expected behavior of the proposed control and the overall hybrid power filter performance during both steady state and transient operations.

12:20 – **A New PWM Control Technique Applied to Single-Phase Shunt Active Power Filter**

Salem Rahmani, Kamal Al-Haddad, Farhat Fnaiech

Abstract – In this paper, the authors present an analysis of a single-phase shunt active power filter in order to simplify and linearize the system. A linear model with the average values of the alternative variables allows to consider the inverter transfer function between the converter output voltage v_f and the controls ϑ as a pure gain. The PWM control technique adopted is based on two comparisons:

i) Between low frequency signal $+\vartheta$ and a triangular high frequency carrier and,

ii) Between low frequency signal $-\vartheta$ and the same carrier. The minimization of the harmonic distortion lead to good power-factor. Lastly, the simulation results are presented using the Matlab software and of its toolboxes. These results highlight the performance of the voltage and current regulation controllers.

Back to the Tuesday program

TA-2D – Room 1300
Simulation Methods I

Session Chair:

A. Monti (USA)

11:05 – **Symbolic Treatment of Dynamic Model for the Simulation of Electrical Actuators**

Loig Allain, Laurent Gerbaud, Christian Van Der Schaeghe, Benoit Delinchant

Abstract – The paper deals with a symbolic treatment, which aims to structure equation based models. This one is planned to be used in different simulation environments. In the field of electromechanical actuator sizing, and especially for actuators that associate machines, power-electronics and control, quick and efficient simulation methods have to be used. This is especially true, when they take place in an optimization process, to size the corresponding application. In order to take into account such systems, a model mixing discrete and continuous equations is also required. The main difficulty encountered by designers with such an approach, is that existing solvers may have different capabilities (MATLAB[1] for simulation or EDEN[2] for optimization). As a consequence, designers have to use several simulation environments, with the same model. Thus, designers are facing with a difficult choice: they have to find an optimal compromise, using either an easy way of description (visual building with box association like in Simulink[1] or SABER[3]), or a "procedural" description of the model (S-Function[1], or MAST for SABER[3]). The final goal of this work is therefore to help designers to describe complex models, as well as to automate as much as possible their translation from a "declarative" description into a "procedural" one. In this way, an object oriented structuration of the model, its automatic reorganization and the corresponding state system reduction are proposed here. This leads to a new process description, which allows model calculation.

11:30 – **Causality Assignment Using Evolutionary Algorithms**

Tony Wong, Pascal Bigras, Robert Sabourin

Abstract – The causality assignment problem is central to physical modeling by bond graphs. The traditional SCAP and MSCAP are algorithms that may fail if the bond graph has loops or contains junction causality violations. The RCAP algorithm focuses on the generation of differential algebraic equations to take into account junction violations caused by nonlinear multiport devices. We present a formulation of the causality assignment problem by casting it as a constrained optimization problem. We then solve the resulting optimization problem by the use of a genetic algorithm. Results from trial runs indicate that this formulation is capable of solving the causality assignment problem with or without junction violations.

11:55 – **Dissociated Equation Sets for the Optimization of Switched Circuit Simulation**

Bruno De Kelper, Louis-A. Dessaint, Kamal Al-Haddad, Harbans Nakra

Abstract – The equation set update required after a switching is the most intensive computation effort in the simulation of circuits containing switches. Some optimization methods have been proposed to reduce it, but each of these methods are specific to one simulation approach and are largely dependent on the topology of the circuit. The proposed dissociated equation sets method reduces the computation effort by separating the calculation of the switches from the calculation of the circuit. Thus, the updating calculations are confined to the much smaller equation set of the switches. Once the current of the switches has been computed, it is injected back into the circuit. Hence, the method is independent of circuit topology. Also, since the dissociation between the switches and the circuit is done in the modelling phase, the proposed method is independent of the simulation approach, as shown by its implementation into the nodal and state space approaches. Finally, the performance gain was evaluated with a simple 12 pulse rectifier circuit in both simulation approaches.

12:20 – **A Co-Simulation Approach for Legacy Models**

Fabio Ferraro, Antonello Monti, Marco Riva, Enrico Santi, Roger A. Dougal

Abstract – The objective of this project was to demonstrate the multi-language capabilities of the Virtual Test Bed (VTB), specifically the ability to use legacy ACSL models and the ability to augment a legacy simulation by adding new elements of the system topology as native models in the VTB. One of the unique characteristics of VTB is its ability to import simulations created in other simulation environments such as ACSL, MATLAB Simulink, and Spice. This multi-language capability facilitates reuse of existing simulations and reduces duplication of modeling and simulation efforts. In this project the VTB was used to develop a system-level simulation of the Healy icebreaker by reusing a ACSL language simulation model of the electric propulsion system that had been independently developed over many years. A significant feature of this use of the ACSL model was that the legacy ACSL application was coupled to the augmented system at the physical terminals of the electric network according to nature coupling laws. Thus the ship service load and the bow thruster were easily added as native models. This is believed to be the first major demonstration ever of nature coupling in a co-simulation environment. It was then possible to explore interactions and propagation of disturbances from one subsystem to the other.

Back to the Tuesday program

TP-1A – Room 1150
Power Systems IV

Session Chair:

V.K. Sood (Canada)

14:15 – **Distributed Control Architecture of a Multipaddle Wave Generator for Hydraulics Studies**

Joâo Palma, Franciso Carvalhal, Paulo Morais

Abstract – A solution is proposed for the control of multipaddle serpentine wave generators, with individual electrical drives for the position control of each paddle, by using commercially available ac machine drives. The architecture consists of decentralised microcontroller units each having the dedicated control task of a group of drives. These units are networked together as slaves having a PC as the master where all the position references are established in order to synthesise the desired wave profiles with smooth transitions. The linear motion of each paddle is created by a spindle drive actuated by a motor having an integrated pulse encoder. The solution described herein, mostly based on industry grade material, was devised to be economical though adequate and reliable for the application and was accompanied by an especially light mechanical design of the wave generator. Some design guidelines are presented for hydromechanical force calculation and for motor and drive rating according to given hydraulics specifications.

14:40 – **Stochastic Optimization of Hydroelectric Generators and Benefit-Risk Analyses in Generator Upgrading**

Erwin Schlemmer, Friedrich Gillmeier, Franz Klammler, Franz Mueller

Abstract – A two-step method for determining generator uprating potentials and performing the associated risk-benefit analyses and conducting the subsequent fine-tuning of hydroelectric generator design optimization is presented. Decision making for plant refurbishment is a very complex task requiring the assessment of the condition of existing plant components and the evaluation of the cost versus generation capability situation. Several scenarios have to be investigated and an arbitration between the different options has to be made. Based on data from previous refurbishment projects and on experience, the manufacturer can state the most economically feasible variants of upgrading. However, not all of these approaches are the same in terms of risk associated. Therefore, in order to reduce the danger of backfire of major design decisions, a standardized method for balancing risks and benefits has been developed. After the main design decisions have been taken, the generator is usually optimized using the deterministic design programs. In order to make this optimization more robust against unavoidable jitter around the nominal input parameters, a method driven by a genetic algorithm with an additional Monte Carlo loop is used.

15:05 – **Performance Evaluation of Harmonics Detection Methods Applied to Harmonics Compensation in Presence of Common Power Quality Problems**

Sanae Rechka, Éloi Ngandui, Jianhong Xu, Pierre Sicard

Abstract – Harmonics estimation methods are analyzed in presence of different power quality problems, namely voltage sags, voltage unbalance, voltage distortion and variations of power supply frequency. The harmonics detection algorithms are based on the instantaneous reactive power (IRP) theory, the Discrete Fourier transform (DFT), the Recursive Discrete Fourier transform (RDFT) and the Kalman filtering (KF) approach. Simulation results obtained with Matlab/Simulink/Power System Blockset are presented to compare their performance in term of precision and transient response and for harmonics compensation by a power active filter.

15:30 – **Comparative Study of HVDC System With Capacitor Commutated Converters**

A. Mazumder, V.K. Sood

Abstract – A comparative study of the performance of an HVDC system with three types of converter configurations is reported in this paper. The three converter configurations are: (a) the conventional line commutated converter (LCC), (b) the capacitor commutated converter (CCC), and (c) the hybrid commutated converter (HCC) which is a combination of a CCC and LCC. The HVDC system employed for the study is based on the CIGRE HVDC Benchmark model traditionally used for dynamic performance studies. The simulation study is performed using the EMTDC-PSCAD program. Details of control systems for the three converter options are also provided.

15:55 – **Prediction of Electrical Parameter of the Hydro-Generators With Using finite Element Method**

Arezki Merkhouf

Abstract – This paper presents a transient model of the salient-pole synchronous machine based on a 2-dimensional time-stepping finite element method. Simulation no-load and sudden three phase short circuits are performed in rotation, the simulation take into account the saturation effects and the eddy current in solid conductors. The end effects are also included by the use of external circuit elements. The results obtained from the simulation provide the voltage waveform, telephone influence factor and dynamic reactances. Comparison between calculations and measurements for large existing hydro-generator are presented.

Back to the Tuesday program

TP-1B – Room 1160
Asynchronous Machine II

Session Chair:

P. Sicard (Canada)

14:15 – **Consideration of Rotor Bar Skewing in a Transient Two-Dimensional Equivalent Circuit Model of the Induction Machine**

Thomas M. Wolbank, Reihnard Woehrnschimmel, Juergen L. Machl

Abstract – In recent years, a lot of effort has been undertaken to omit the sensor in field oriented AC-Machine drives since this would increase its reliability and decrease the costs. Most promising are methods which evaluate the machines response during a high frequency or transient excitation and make parasitic effects visible. These effects are mainly due to saliencies induced by saturation and rotor slotting, so that it is possible to track the desired flux- or rotor position. Simulation of these parasitic saturation and slotting effects is important in order to investigate the high frequency or transient machine behavior on which the suitability of different machines in a sensorless control scheme depends. For that task, the magnetic equivalent circuit model appears to be a tool requiring only reasonable calculation time. Finite element programs are so far not capable to calculate transients in saturated machines. But since the magnetic equivalent circuit model is a two dimensional model, attention has to be paid to a correct modeling of rotor bar skewing. It will be discussed that mainly the zig-zag permeance determines the transient machine behavior with respect to rotor slotting and that it is highly dependent on rotor bar skewing. How this effect in the third dimension is accounted for in a two dimensional model is presented further on. Simulation and measurement results are then compared and verify the applicability of the suggested simulation method.

14:40 – **A Dynamic Model for Studying the Behaviour of Induction Generators**

Afshin Majd Zarringhalam, Mehrdad Kazerani

Abstract – Induction generators are well known for their rugged structure and tolerance of shaft speed variations, while operating at constant terminal frequency. This makes them a good candidate for integration into variable-speed energy recovery systems based on wind-turbines and micro-turbines. A good mathematical model can help in studying the behavior of the induction generator under different conditions and selecting the appropriate machine for a specific application. In this paper, the dynamic equations originally derived for the induction motor are used as a model for the induction generator. The model can be used for steady-state or transient analysis, in stand-alone or grid-connected mode, and for squirrel-cage or wound-rotor structure. The model is very general and can be used to study induction motor behavior, start-up as an induction motor and transition from motoring to generating mode, and operating as a generator. In this paper, the model is used to study the effects of the machine size and parameter values on its dynamic performance. Digital simulation results are presented and compared against the well-known characteristics of the induction generator to validate the model.

15:05 – **AI Techniques in Speed Tracking Control of Induction Motor**

Abdelmajid Rahmouni, Gérard Lachiver

Abstract – This paper presents a novel neural network-based control architecture, which use continual on-line training to identify and control the nonlinear, time varying induction motor dynamics with unknown parameters. The objective of this controller is to force the rotor speed to follow an arbitrarily prescribed trajectory. The architecture incorporates two ANN and a fuzzy logic controller. The first ANN identifies the current-fed induction machine model in order to indirectly train the second ANN which control the rotor speed via manipulation of the slip frequency. The fuzzy controller is used to model adaptively the stator currents. The scheme is self-commissioning, robust, and adaptive. Simulated results are presented to validate the proposed architecture indicating that speed control is stable, rapid to stabilize, and insensitive to parameter uncertainty and load disturbance.

15:30 – **Thermal Effects of Nonsinusoidal Supply on Three-Phase Induction Motor Behavior**

Gabriel Rakotonirina, Jianhong Xu, Anatole Sévigny, Pierre Sicard

Abstract – This paper proposes a simple polynomial approach to evaluate distribution of core losses in induction motors under distorted voltage supply. The polynomial functions are obtained by curve fitting using experimental loss data for the motor operating under several typical distorted voltages supply. Standard loss segregation and temperature-time methods are combined to obtain these data. The increase of the core losses and the stray load losses within all parts of the induction motor are considered. Once determined, the polynomial functions are used as input function in a finite element thermal model of the induction motor. The operation of the induction motor under various distorted power supplies can then be investigated by numerical methods and interpolation of motor behavior under nonsinusoidal supply from sinusoidal cases becomes possible. The temperature results obtained by simulation are compared to experimental measurements.

15:55 – **Magnetic Oscillations and Rotor Surface Heatings in an Induction Machine**

Jean-François Trigeol, Marc Broussely, A. Marino, Patrick Lagonotte

Abstract – The goal of this paper is to present a study on the rotor surface heatings of an induction machine. We first present the instrumentation of the machine that is both thermal and magnetic. Thermal measurements are presented with oscillations for a very low slip. Magnetic measurements show the correlation between the magnetic oscillations and the temperature rise. By integration of the induced voltage curves we obtain the induction curves. The oscillation magnitude in zones under field is three times more important than the ones in zones out of field. The magnitude of the oscillations is proportional to the supply voltage.

Back to the Tuesday program

TP-1C – Room 1170
Power Quality and Active Filtering III

Session Chair:

V. Rajagopalan (Canada)

14:15 – **Study of Two Current Control Techniques Applied to a Shunt Active Power Filter**

Mongia Labben-Ben Braiek, Farhat Fnaiech, Kamal Al-Haddad, Loubna Yacoubi

Abstract – This paper deals with a comparative study of the performance of two current control techniques for shunt active power filter namely the direct current control (DCC) based on a PI regulator and the DCC based on a sliding mode control with prediction (SMC-P). These two types of commands were employed to generate the peak supply reference current. The comparison criterion is based on the current total harmonic distortion (THD). Simulation results are presented using Power System Blockset (PSB) of Matlab.

14:40 – **Network Voltage Profile Correction by Discrete Shunt Compensation**

P.J. Lagacé, L.-A. Dessaint

Abstract – Efficient methods are needed to evaluating discrete shunt control actions required for maintaining acceptable voltage levels following changes in loads and after network contingencies. Evaluating all possible shunt combinations would involve an excessive amount of computation. An algorithm has been developed to restrict the cases considered so that optimization is done on a subset of discrete shunt combinations. Results are presented for voltage control following changes in load level and after contingencies.

15:05 – **Thyristors Controlled Series Compensator With Protection System**

Maricel Adam, Adrian Baraboi, Catalin Pancu

Abstract – FACTS devices, among which is and TCSC, allows to realise an AC Transmission System more performed through the control of the power flow and through the increasing of the transmission capacity. This work presents a modelling of TCSC with protection system for dynamic analysis. It is shown the influence of the inductive component, respective resistive for the TCSC behaviour and for the electric line where is placed. Its are shown the evolutions of different parameters (the voltage on capacitor, the current through the capacitor and inductance, the current through the transmission line) depending on the thyristor firing angle, the resistive component of the TCSC and the presents or not of the protection system. The paper presents an analysis of the TCSC with protection system placed into a 400 kV electrical network. The numerical simulation it is done with the EMTP/ATP 2000 software.

15:30 – **Load Flow Control in the Interconnected Networks by Means of FACTS Devices**

Shahrokh Saadate, Kalid Belacheheb

Abstract – This paper presents a numerical simulation of an electrical system with production groups with different characteristics, notably in term of kWh production cost. The main aim is to control the power flow in the different lines by use of FACTS (Flexible Alternate Current Transmission System) devices in order to minimize the total production cost. Several compensation cases with one group of parameters are studied and the obtained results discussed. All simulations are performed by using SABER numerical code.

15:55 – **A Fuzzy Controlled Three-Phase Four-Wire Shunt Active Filter**

Antonio Dell'Aquila, Agostino Lecci

Abstract – An active filter has been proposed to compensate harmonic distortion, line neutral current and reactive power in three-phase four-wire systems. Focus has been addressed to current control in order to achieve an optimum current tracking by means of fixed frequency driving signals. Duty cycle of driving signals has been computed by means of a fuzzy control, based on a design equation. Simulation tests have been presented to prove the effectiveness of proposed control.

Back to the Tuesday program

TP-1D – Room 1300
Electric Drives I

Session Chair:

B. Robyns (France)

14:15 – **A Simulation Model for a Linear Drive of a Magnetic Levitating Transportation Vehicle**

Dirk Brakensiek, Gerhard Henneberger

Abstract – In this paper a simulation model for a linear drive of a magnetic levitating, autonomous transportation vehicle is presented. The vehicle is optionally supplied with a contactless energy- and information transmission. At the test bench of the vehicle measurements are made. The results of the model are verified by these measurements. According to this the model is used to develop a strategy of driving through horizontal curves only by controlling the motors. The commercial software Matlab/Simulink was used to build both, the model and the controller of the test bench. A dSPACE DSP controller board executes the real-time controller application. The transportation system, the motor and the structure of the controller are explained. The results of the simulations driving on a straight line and comparisons to the measurements are given. Finally the simulation results of the curve-driving strategy are depicted.

14:40 – **Variable Rate Artificial Neural Network Adaptive Control of a Flexible Joint With Hard Nonlinearities**

Hicham Chaoui, Pierre Sicard, Orfan Aboulshamat

Abstract – This paper proposes a control strategy based on artificial neural networks (ANN) for flexible mechanisms with hard nonlinearities. The model of the positioning system includes a flexible shaft and Coulomb and static friction for both motor and load. For this structure, the inverse model is unrealizable. The ability of ANNs to approximate nonlinear functions is exploited to obtain an approximate inverse model for the positioning system. Two control structures are analyzed, both using a reference model and variable learning rate in the adaptation process to impose desired system dynamics, namely inverse model based feedforward neural network (NN) controller with and without a NN feedback control law. Simulation results show the performance of the controller, and its fast response to mismatch in initial conditions.

15:05 – **Comparative Study of a Synchronous Motor Current Control Loop Stability, Implanted on Mono and Multiprocessor Architectures**

Henri de la Vallée Poussin, Damien Grenier, Francis Labrique, Jean-Didier Legat

Abstract – Classically, the control algorithms of high performance motor control systems using PMSM synchronous actuators are today implemented on DPS's. In previous papers [1][2], we have presented a multiprocessor architecture for such applications. The aim of this paper is to investigate how moving from a single processor to a multiprocessor architecture influences the stability of the motor current control loop. It is shown that, with a multi-processor architecture, higher loop gain can be used and that the damping of the response is much better.

15:30 – **Control Based on Fuzzy Logic of a Flywheel Energy Storage System Associated With Wind and Diesel Generators**

Ludovic Leclercq, Benoit Robyns, Jean-Michel Grave

Abstract –The aim of this paper is to propose a control strategy of a flywheel energy storage system associated with a diesel generator and a fixed speed wind generator. To control the power exchanged between the flywheel energy storage system and the AC grid, a fuzzy logic based supervisor is proposed with the aim to minimize variations of the power generated by the diesel generator. The interesting performance of the proposed supervisor is shown with the help of simulations.

15:55 – **A Multi-Machine Multi-Inverter DTC Strategy**

Jamel Belhadj, Ilhem Slama-Belkhodja, Maria Pietrzak-David, Bernard De Fornel

Abstract – A Multi-motor Multi-inverter system needs a complex control, due to the strong internal variables and the external electrical and mechanical coupling. This control will be more complicated when the motors have not the same in parameters and powers. In this paper the authors investigate a Direct Torque Control (DTC) method for two induction motors fed by one voltage inverter. The aim is to determine an equivalent motor for the best control. Two methods are studied, the Master-Slave Control (MSC) and the Mean Control (MC). Comparisons between the two methods are developed. Finely an average model control is required to an adequate control.

Back to the Tuesday program

Rooms 1422-1752
Poster Session I

16:50 – 18:50

Session Chair:

A. Chandra (Canada)

P1 – **Simulation and Experimental Investigations on a 3-Phase 4-Wire Shunt Active Power Filter for Power Quality Improvement**
Shailendra Kumar, Pramod Agarwal, H.O. Gupta
Abstract – Paper presents simulation and experimental investigations on a shunt active power filter for 3-phase, 4-wire system, which is capable to compensate harmonics, reactive power, neutral current and load balancing. Two configurations of 3-phase, 4-wire shunt active power filter, a four-leg four switch-pole topology and a standard 3-phase converter with a mid point capacitor are considered and compared. The control scheme is simple and easy to implement which is based on sensing line currents only. Various simulation and experimental results are presented.

P2 – **Using Artificial Neural Networks for the Thrust Developed by a Sector Motor**
Luciana Cambraia Leite, Carlos Rodrigues de Souza
Abstract – The purpose of this paper is to analyse the characteristics of the thrust developed by a particular configuration of linear machine. The sector motor is a type of rotary induction machine, which owing to its particular, present the end-effects usually found in the linear motors. Also considering that the operation under variable frequency is required in this study, the modeling via the usual machine equations is questionable. Therefore, artificial neural networks are used in this research as mathematical tools to render a machine model for the simulations. Several tests were carried out in the laboratory for different conditions regarding the stator voltage, current and frequency. Transient and steady state conditions are considered. The main purpose of this work is to obtain an artificial neural network architecture that represents the sector motor under the required operating conditions. As for the machine-developed thrust, the case studies presented in this paper show that the chosen neural network topology is able to reproduce it quite well.

P3 – **Benefits of Component Methodology Applied to Electrical Engineering Software**
Benoit Delinchant, Frederic Wurtz, Eric Atienza, Jean Bigeon
Abstract – This paper deals with the encapsulation of electromagnetic software into component. Although software development take advantage of many methodologies, the reuse of software is generally considered as a patching task. We will expose encapsulation issues as well as software requirements that allow integration. A process of simulation software encapsulation is presented through an example. The benefits of this process, based on distributed technology and component paradigm, are then highlighted.

P4 – **Power Management of a Series Hybrid Electric Vehicle**

D. Diop, Y. Ait-Amirat, J.M. Kauffmann

Abstract –This paper presents a Control Strategy and a Power Management of a series Hybrid Electric Vehicle (HEVs). The configuration in study uses as main powers a battery and two diesel engines driving each a generator. The HEV retained uses independent four traction motors. An optimization method allows to determine the best sharing between the powers delivered by the diesel engines. The state of charge (SOC) of the battery must be maintained within a band which authorizes different operating modes and a regenerative braking and to maintain lifetime. Simulations show the sharing of the generation for a given load.

P5 – **Analysis of the Electromechanical Vibrations in Induction Motor Drives Due to the Imperfections of the Mechanical Transmission System**

Hadi Youssef Kanaan, Kamal Al-Haddad, Gilles Roy

Abstract – Mechanical vibrations become a serious concern in drive applications when they adversely affect the dynamic performances of these applications and may end with physical deterioration of their structures. In many process applications, such perturbations must be detected and assessed in order to take the appropriate action to preserve the reliability of the operation. This paper presents a method of detection of one of the major causes of mechanical vibrations in asynchronous motor drive applications. The study, which involves linearized dynamic modeling of the asynchronous motor associated with its multi-mass load, shows the dependence of the vibrations frequencies on both the electrical and mechanical system parameters. Numerical simulations using Matlab/Simulink are performed using the set of parameters of a prototype drive system. The simulation results confirm the validity of the proposed method of detection.

P6 – **The Rigorous Thermal Reduced Model of Electric Machine**

J.-F. Trigeol, F. Soulier, N. Dollinger, Patrick Lagonotte

Abstract – After presenting the different commonly used methods of model reduction commonly used, we will study thoroughly the nodal modeling and the corresponding matrices of impedances [Z] and admittances [Y]. The method of models reduction based on the Kirchhoff network theory directly uses the properties of these matrices. We will establish by a theoretical way the structures of the models reduced successively to 1 node, 2 nodes, 3 nodes, and 4 nodes to make clearly appear the polyhedron structure. We will generalize these structures with the theory of the continued fractions to obtain models with a wanted bandwidth.

P7 – **Reduction of Over-Voltage Transients Resulting from PWM AC Motor Drive Using Long Cables**

Stefan Laurentiu Capitaneanu, Bernard de Fornel, Maurice Fadel, Fabrice Jadot, François Malrait

Abstract – The main problems that appear when using a long cable connection between a Variable Frequency Drive (VFD) and the AC motor are over-voltages and bearing currents. The last one concerns especially EMC, while the over-voltages transients can be fatal to the motor in long motor duties. Using LF/HF models the paper investigates the behaviour of this motor and drive system concerning over-voltages. As a result of the theoretical study of over-voltages problem, a PWM algorithm that decreases the amplitude of the over-voltages transients is proposed. It is based on an online identification of the cable. Experimental results are shown.

P8 – **Identification of the Time-Varying Current Behaviour by a Discrete Fourier Transform**

L. Miègeville, P. Guérin

Abstract – With the widespread use of power electronics equipment and other non-linear loads since the last twenty years, current and voltage waveforms are becoming highly distorted. Considering the effects of harmonics on the performance and life expectancy of electrical devices, prediction of harmonic levels is important to prevent the risks of their disturbances and to optimise the size of equipment. For this purpose, an estimation tool using a discrete Fourier transform to model time evolution of harmonics and thermal behaviour of electric equipment has been developed. The harmonic phenomenon is then considered as a time-dependent stochastic process. This model has been applied to the identification of the harmonic currents drawn by an institutional building which presents a weekly load pattern. The results obtained from the proposed method are compared to those from a model based on time-series. The long term objective is to use these models to predict the temperature rise of the main transformer.

P9 – **Rapid Control Prototyping of a Controller for Inverters: Comparison by Modeling and Testing of Two Strategies in Stand Alone Mode**

Samuel Nguefeu, Laurent Bou Gebrael

Abstract – Decentralized Generation Systems often include inverters in their power electronics interface. The need for optimizing efficiency is justified by the fact that, unlike some UPS devices, converters operate continuously. However the efficiency improvement should not be obtained at the expense of the wave quality. After theoretical calculations and simulations carried out under Simulink/PSB to compare two strategies (SVPWM and GDPWM) usable to control the dispersed generation inverters, tests were carried out, in stand alone mode, to validate the results. The extrapolation of the curve shows that beyond 13 kW, the GDPWM efficiency shall be systematically higher than with SVPWM, even if, below 13 kW, measurements seem better with SVPWM. In addition, the difference between the linearity limits (10% in favor of GDPWM), was found much larger than envisaged from the simulations and the THD on the GDPWM current was 20% smaller than the SVPWM one. We also came across a limit in the PSB utilization, consistent with the way the IGBT switching times are modeled.

P10 – **Artificial Blood Pump Motor Design With Global Parametric Optimization Method**

Yves Perriard

Abstract – Voltage converters occupy a very important rank as actuators in modern industry, which explains the large number of works done in this field from both design and control point of view, having as a goal the reach of a better performances. This study describes the design and control of a new direct minimal AC-AC converter structure. This converter allows the supply of single phase loads with variable frequency and amplitude, presenting an unit power factor at the network. In order to keep a certain level of performances, we shall use an adaptive control associated to a dynamic state feedback. We have also used a Clamping bridge for closed loop control of intermediate voltages of the capacitor filter.

P11 – **Deliberate Introduction of Anisotropy in the Sheet of Electrical Steel**

Alexandre Pulnikov, Philippe Baudouin, Roumen Petrov, Jan Melkebeed

Abstract – Texture is one of the key factors for which continuous improvements are required and especially in the case of transformers. A new technological procedure that introduces a desired anisotropy pattern is developed. Experimental results after partial rolling and annealing of a 2.98% Si steel are reported.

P12 – **Contactless Energy Transfer Optimisation Using a PCB (Printed Circuit Board) Air Transformer**

Hicham Sadki, Mohammed Hamzaoui, Alain Jaafari, Thierry Capitaine, André Lebrun

Abstract – In many industrial applications (transport, light automatic vehicles, electronic badges, automatic tolls, tramways, etc.), energy transfer and control by induction is preferable for reasons of space, reliability and cost. The device we use for energy transfer is a printed circuit air transformer. The primary of the transformer is fixed. The secondary is mobile. We present in this article the approach we have adopted to characterise and optimise the energy balance.

P13 – **Solutions to Typical Motor Load Emulation Control Problems**

Hassania Baibanou, Pierre Sicard, Abdellfattah Ba-Razzouk

Abstract – Mechanical load emulation is a powerful tool that permits good design and analysis of high performance controlled electrical machines driving complex non linear industrial loads, in laboratories and at low cost. This paper presents a comprehensive formulation of dynamic emulation problems of mechanical loads. The dynamometer and the electrical drive under test can be coupled with flexible or rigid coupling. Control solutions to the emulation problem are also proposed. The emulation control laws are developed in the SIMULINK environment to impose desired behaviors to the motor-load set. Controllers are designed using simplified linear models of the drive-emulator and validated using detailed non linear models of the Power Systems Blockset and SIMUPELS block libraries. Simulation results for systems with rigid-to-rigid and flexible-to-rigid couplings are presented to illustrate the dynamic performance of the proposed emulation control laws.

P14 – **Characterization of Sensitivity to Voltage Sags of Mechanically Coupled Induction Motors**

Pierre Sicard, Nourdine Elouariachi, Sylvain Lahaie

Abstract – Voltage sags represent the most serious power quality problem in terms of losses of production. This paper presents the development of a simulation model and the characterization of the sensibility of mechanically coupled drives in presence of voltage sags, in particular of two drives in a material transfer process, e.g. winding process. Each drive is composed of an induction motor supplied by an IGBT inverter and the drives share a common diode rectifier and dc-link capacitor set. In addition to the standard torque, flux and velocity control loops, tension control is considered. The sensitivity of the system to type A, B and C voltage sags is characterized primarily by their effect on the product, in this case by the variation of tension in the material. Secondary indices of performance are used such as dc bus voltage and inrush current.

P15 – **Current Density Computation Inside a Capacitor by Inverse Problem**

T. Talbert, L. Nativel, C. Joubert, N. Daudé, D. Gasquet, M. Castagné, C. Glaize

Abstract – Over the past three decades, there has been a significant miniaturization of power electronics converters, as a consequence the switching frequency increases. The resulting electric constraints lead to a low reliability of the system because of the decrease of the life-time of the passive components particularly the capacitor. For a better understanding of the electromagnetic behavior of a capacitor we have investigated non destructive measurements such as the measurement of the scattered magnetic field B near the boundary of the component. From this measurement we are able to reconstruct the current density inside the capacitor responsible of the decrease of the life-time.

P16 – **Application of a Quasi Waveform Relaxation Method for the Analysis of Power Electronic Circuits**

Yasutoshi Yoshioka

Abstract – A new circuit-oriented time-domain analysis method of power electronic circuits is presented. The method is based on relaxation methods. The predictive-corrective nature of the relaxation methods is used to speed up numerical integration of switching network equations. The piecewise-linear switch model that consists of a current source in parallel with a two-valued resistor is applied. The modified nodal formulation is used to generate circuit equations. The convergence condition of relaxation methods can be met by handling the current source of the switch model as an unknown variable in a modified nodal equation. The relaxation method is applied for the entire given time interval, and specific circuit topology for the time interval can be obtained automatically during the relaxation process. An example circuit is used to illustrate application of the proposed method, and the accuracy of the method is demonstrated based on the comparison of simulation results obtained from other integration techniques.

P17 – **Investigation of the Local Magnetic Effects in the Sheets of Rotational Electrical Machines**

Alexandre Pulnikov, Philippe Baudouin, Jean Melkebeek

Abstract – The local magnetic effects caused by punching are investigated. Experimental data regarding the direct magnetic measurements are presented. A comparison with microhardness measurements is made. The application of these results to rotating electrical machines is discussed.

Back to the Tuesday program

WEDNESDAY AUGUST 21ST

8:30 – 10:35	**WA-1A** Room 1150	**WA-1B** Room 1160	**WA-1C** Room 1170	**WA-1D** Room 1300
10:35 – 11:05	**Coffee Break** Main Hall			
11:05 – 12:45	**WA-2A** Room 1150	**WA-2B** Room 1160	**WA-2C** Room 1170	**WA-2D** Room 1300
12:45 – 14:15	**Lunch** Main Hall			
14:15 – 16:20	**WP-1A** Room 1150	**WP-1B** Room 1160	**WP-1C** Room 1170	**WP-1D** Room 1300
16:20 – 16:50	**Coffee Break** Main Hall			
16:50 – 18:50	**Poster Session II** Rooms 1422 and 1752			
18:50 – 19:00	**Closing Ceremony** Room 1150			

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WA-1A – Room 1150
Transformers

Session Chair:

S. Casoria (Canada)

8:30 – **Modeling and Simulation of Non-Linear Inductances Using Matlab/Power System Blockset**

Richard Gagnon, Gilbert Sybille, Jérôme Cros, Jean Lemay, Philippe Viarouge

Abstract – This paper describes a general method for the modeling of multi-phase coupled inductances including the magnetic saturation of the core. The method is developed in the Matlab/Power System Blockset (Matlab/PSB)simulation environment. The reluctance network of the magnetic circuit is modeled as an equivalent non-linear electric circuit. The modeling approach uses the capability of Matlab/PSB to edit the electric and the magnetic circuits of the device to be modeled and to solve the corresponding equations. A 3-phase 3-leg transformer is used to describe the modeling method. Two illustrative examples of the simulation of the transformer are presented. With the proposed modeling method, it is now more easy to simulate the behaviour of multi-phase coupled inductances and transformers in a realistic distribution and transmission power system network.

8:55 – **Modeling Tool Based on the Frequency Response for Transformers Maintenance**

Jorge Pleite, Emilio Olias, Andrés Barrado, Antonio Lazaro, Juan Vazquez

Abstract – The deregulation of the electric supply market is pushing the electric companies to improve their supplying quality. As far as transformers are one of the main devices in the utility grids, some advanced maintenance techniques have been developed in recent years in order to improve the transformer life assessment. FRA (Frequency Response Analysis) Techniques are nowadays widely used by the electric utilities as one of them. They are specially suitable to detect winding displacements inside the transformer. The main problem about FRA Techniques is to interpret the observed evolution of the frequency response in order to identify both failures and failure tendencies in the transformer. In order to solve this problem, a Modeling Aided Analysis is proposed in this work, which is based on the development of a Modeling Tool that takes into account the frequency response measured at the transformer.

9:20 – **Analytical Model of a T – Connected Three-Phase Transformer**

Guy Olivier, Radu Cojocaru, Anthony Lefèvre

Abstract – Three-phase transformers usually consist of three sets of windings connected in Wye, delta or zigzag on three individual cores or on a single three-phase one. Two single-phase transformers can also be used in a less than well-known way called the T-connection. Depending on the actual connection, as in conventional three-phase transformers, secondary voltages are in phase or displaced by ±30°. Due to the reduced number of windings, the T-connected transformer can be economically produced. However, since it is an asymmetrical connection, the short-circuit impedances of the individual phases are not identical, leading to unbalanced load voltages and short-circuit currents. An analytical model of the T-connected transformer has been developed to evaluate the effects of the impedance unbalance. This model based on single-phase short-circuit tests can be used to determine voltage unbalances, active and reactive transformer losses and short-circuit impedances.

9:45 – **The Influence of Correlated Functional Parameters on Transformer Thermal Loss of Life**

M.J. Resende, L. Pierrat, J. Santana

Abstract – International Standards regarding power transformers thermal aging, consider idealized load and ambient temperature profiles to estimate thermal loss of life. In realistic terms, no transformer operates under these conditions since these profiles present both seasonal and random behaviors. One of the aspects not considered in International Standards is the possible correlation that load and ambient temperature do present in realist term. Being the adopted aging model a strongly non-linear one, correlation between input profiles can be determinant on loss of life estimation. In order to illustrate this situation we propose to examine the influence of correlated load and ambient temperature profiles, on the estimation of thermal loss of life of a distribution transformer; both deterministic and probabilistic approaches will be considered.

10:10 – **Hysteresis Modeling in the Matlab/Power System Blockset**

Sylvano Casoria, Patrice Brunelle, Gilbert Sybille

Abstract – This paper presents a static hysteresis model for the saturable transformer blocks in the Power System Blockset (PSB), a MA TLAB/Simulink -based simulation tool. The model defines a relation between the flux (F) and the excitation current measured in dc (when the eddy current losses are not present). It is useful under transient conditions and can represent minor loops. The model exhibits all the main features of hysteresis and is extended to represent also the saturation characteristic. A hysteresis design tool consisting of graphical user interface (GUI) allows precise adjustment to any major loop or saturation characteristic. An example case is described to illustrate the application of the model.

Back to the Wednesday program

WA-1B – Room 1160
Renewable Energy

Session Chair:

R. Gagnon (Canada)

8:30 – **PEM Fuel Cell Models for Supply of an Electric Load**

W. Friede, S. Raël, B. Davat

Abstract – Different modeling approaches for PEM fuel cells are presented. For integration in a full system description, the model must not be too complex, so a monodimensional simulation is used. The model takes into account mass flow in the different fuel cell regions as well as electrochemical reactions. For a model validation, impedance spectroscopy is presented permitting in-situ measuring of the membrane resistance. The test bench in our laboratory is described including a new type of electronic load permitting computer controlled steady state measurements, dynamic testing as well as impedance measurements with only one device. Simulation results are presented and compared to measurements on a 500 W PEM fuel cell stack.

8:55 – **A Novel Comprehensive Energy Saving System for Oil Well Induction Motor Driving**

Dai Guangping, Liu Xiaofang, Zhang Jianhua, Cui Xueshen, Luo Yingli

Abstract – Beam pumping motor is of the type of induction motors applied to drive beam pump in oil fields. A complete working circle of the beam pump motor includes heavy load working condition, light load working condition and asynchronous generator working condition. The relationship between the energy loss for each component and the slip is firstly studied in this paper. Then the energy saving methods of ˜-Y dynamic conversion for the winding connections and the dynamic Var compensation are studied. Moreover, the control strategy about how to achieve the best effect for energy saving is also discussed.

9:20 – **Control Strategy for Stand Alone Wind-Diesel Hybrid System Using a Wind Speed Model**

Mostafa El Mokadem, Christian Nichita, Georges Barakat, Brayima Dakyo

Abstract – In this paper we propose a control strategy model for a wind-diesel hybrid system based on the analysis of a wind turbine and diesel subsystems. In our study, we use a wind speed model that describes both the long-term component and the turbulence component which is assumed to be dependent of slower component evolutions. The wind-diesel hybrid power systems are required to provide an optimal power under various conditions of the electric networks. The proposed structure is based on the following elements: a permanent magnet synchronous aerogenerator, a diesel generator unit with synchronous generator, a static storage unit (batteries), a power conditioner, a dump load and a variable passive load. Numerical results developed on Matlab-Simulink and implementation aspects are also discussed.

9:45 – **Modeling Optimum Charging of an Ultra-Capacitor by an Alternator**

Carl Klaes

Abstract – A DQ model of a synchronous alternator is presented. Implementation of the model in PSPICE is explained. Sudden short circuit test data is used to verify the model. Operation of an ultra-capacitor in a vehicle regeneration cycle is explained. The maximum power curve of the alternator is explained. An algorithm is derived to set the duty cycle of a DC-to-DC converter so that the alternator operates on this maximum power curve while charging the ultra-capacitor. Test data verifies simulation results.

10:10 – **Feasibility and Stability Analysis of a Photovoltaic Pumping System for Deep Wells – Simulations and Experiments**

Thierry Martiré, Charles Joubert, Christian Glaize

Abstract – Developing countries suffer from a lack of energy and water to improve the agricultural production by irrigation. As an approach to ameliorate this situation we suggest the use of solar-powered centrifugal pumps. The pumping group is powered by a standard induction machine. In order to feed the system we suggest two approaches, the first one is made of a single three phase power inverter connected to a high voltage photovoltaic generator. The second system is based on a multi converter system with parallel DC/DC converters feeding the inverter and enforcing a correct operation at optimal power. Both systems were simulated with Matlab/Simulink and Maple. Instability threats have been tracked down and solved. Finally, the first system has been industrialized and tested in different developing countries.

Back to the Wednesday program

WA-1C – Room 1170
Electric Drives II

Session Chair:

A. Kaddouri (Canada)

8:30 – **Torque Controller for a BLDC Motor With Non-Sinusoidal Back-emf Waveform**

Jawad Faiz, B. Rezaei-Alam

Abstract – This paper presents a control structure including a variable-structure current controller with a reference frame that coincides on the instantaneous rotor flux. To transfer currents to this reference frame, a Park's-like transformation is used. A variable-structure current controller does not require the conventional PWM and it operates similar to the space vector modulation. The recommended technique is applied to simulate the performance of a BLDC motor with non-sinusoidal Back-emf. The obtained results are compared with that of the optimal current profile technique and reduction of the torque ripples using the recommended technique are emphasized.

8:55 – **Electric Machines Test Bench as Contribution for the Study of Automobile Electrical Active Suspension System**

Paulo Gambôa, Elmano Margato, Isménio Martins, Jorge Esteves

Abstract – The primary function of vehicle suspension is to isolate the vehicle body and passengers from the oscillations created by the road irregularities and produce a continuous road-wheel contact assuring security. Typically, current automobiles use passive suspensions where performance is reasonable but oscillations are only reduced. An alternative is to use active suspensions; however, due to the cost and energy consumption, it is only used in top models from cars manufacturers. Use of electromagnetic actuators can be a solution for solving the problem: to use linear electromagnetic actuators applied directly in the system or to use a rotating electric machine with a rotation transformation into linear movement. As a first approach to the implementation of this last alternative, a classical test bench with two electric drives was used (one drive simulating the actuator system in test and the other actuating as disturbance element) allowing to implement a position controller able to answer to the disturbance torque for different control algorithms, that after could be implemented in the vehicle electromagnetic suspension system.

9:20 – **Adjustable Speed Drive Based on Fuzzy Logic for a Dual Three-Phase Induction Machine**

A. Kalantari, M. Mirsalim, H. Rastegar

Abstract – The main objective of this paper is devoted to a fuzzy speed controller for a multiphase induction machine. The previous schemes in this field mostly achieved by space vector PWM (SVPWM) techniques, despite of obtaining relatively good results, had special problems in design and implementation phase. In the proposed approach of this paper, by using a simple and flexible structure of a fuzzy controller, worthy results such as, high accuracy in regulating speed for any conditions, fast reaction to the variation with minimum offset, minimum pulsation in the output torque, and minimum distortion in the phase current are obtained. Moreover, this approach significantly reduces the complexity of the control process with respect to the previous schemes.

9:45 – **Computer Aided Design of Control Systems for Electric Machines Based on the Genetic Algorithm**

Adrien Dupuis, Mohsen Ghribi, Azeddine Kaddouri

Abstract – In order to eliminate the difficulties encountered when designing multi-loop DC motor control, a method based on the genetic algorithm is proposed. The genetic algorithm is used to estimate the gains of the controllers for current and speed regulation. The Routh-Hurwitz criterion for stability is incorporated into the genetic algorithm in order to ensure a stable solution and accelerate the convergence by reducing the search space. Simulation results show that the method generates controller gains for the DC motor that respect stability constraints and enable the system to reject disturbances while following the specified transient response.

10h10 – **Dynamical Properties of Sensorless Vector-Controlled Induction Motor Drive With New Neural Speed Observer**

Teresa Orlowska-Kowalska, Marcin Pawlak

Abstract – Sensorless control of the induction motor drives requires knowledge of the instantaneous value of the rotor speed. Various methods of the rotor speed estimation were recently used, based on the mathematical models of the induction machine, on nonlinear phenomena of the motor and based on neural networks. This paper deals with the application of neural speed estimator based on neural modeling approach in the vector-controlled IM drive system. The sensitivity of the proposed estimator to motor parameter changes was tested by simulation. The neural speed estimator was implemented in the real drive system using TMS320C31 digital signal processor and tested in the open and closed-loop operation. Experimental results are presented and the speed estimation quality is evaluated.

Back to the Wednesday program

WA-1D – Room 1300
Modeling and Control of Power Electronics Systems (Invited Session)

Session Chair:

D. Grenier (Belgium)

8:30 – **Equivalent Continuous Dynamic Model of Renewable Energy Systems**

Benoit Robyns, Yann Pankow, Ludovic Leclercq, Bruno François

Abstract – An equivalent continuous dynamic model of a renewable generating system is proposed in this paper. The models of a variable speed wind generator and of a solar generating system are particularly detailed. It is shown that these models are interesting for analyzing the dynamic behavior of the system and for designing the control strategy. The proposed global model is simulated with the help of Matlab-Simulink™, by considering a 4.5 kW wind generator and a 3.6 kW solar generator. This hybrid system is connected to a distribution network which is simulated with the help of the Power System Blockset™ (PSB) toolbox.

8:55 – **Modelling and Control of a Three-Phase Single-Phase System for Feeding AC Catenaries**

D. Telteu, D. Grenier, F. Labrique, J. Bonal, O. Akhrif

Abstract – This paper deals with modeling and control of a three-phase single-phase system for feeding AC catenaries (supply substation). The proposed system is characterized by a perfect balance of the mains, independently of load variations. A direct application of this system is to feed high-speed trains catenaries in low-density population zones. An equivalent continuous model is proposed in order to perform the system control. The system being strongly non linear, its control is performed using input-output linearisation techniques.

9:20 – **Unified Symbolic Modeling of Mechatronic Systems – Implementation and Applications**

Laurent Sass, Dan Telteu, Damien Grenier, Paul Fisette

Abstract – This paper presents a generic way to model electromechanical systems in a unified manner. Our strategy is to generate separately the electrical and mechanical dynamical equations, under the same standard Lagrange form, and to couple these equations afterwards in a unique global model. Our approach is also fully symbolic, increasing both the portability and the time-efficiency of our models. The efficiency of this approach will be demonstrated through applications having mechanical and electrical time constants of the same order.

9:45 – **Advanced Control Methods for Power Electronics Systems**

J. Fernando Alves da Silva, V. Fernao Pires, Sonia Ferreira Pinto, J. Dionisio Barros

Abstract – The application of modeling methods suitable for control and simulation of power electronic systems is outlined as a self-contained approach to solve the simulation and control problems of novel structures of power electronics converters. The straightforward non linear modeling for controller design and simulation uses switched state space models avoiding the averaging task, needs few linear control concepts, derives the stability study from geometric properties and leads to an integrated design of the control, modulators and simulation tasks. On-line sliding mode control techniques are well suited to power converters as they are inherently variable structure systems. Obtained controllers are robust concerning converter parameter variations, semiconductor non ideal characteristics, load and line disturbances. Main modeling and design steps are summarized and some examples given. Results show fast dynamics, no steady state-errors and robustness against semiconductor non idealities and dead times.

10:10 – **Reduction of Torque Undulation and Extension of the Park's Transformation Applied to Non-Sinusoidal Saturated Synchronous Motors**

Guy Sturtzer, Damien Flieller, Jean-Paul Louis

Abstract – This paper present the principle of an extended field oriented control. This control strategy follows from an extension of the Park transformation, suitable for non-sine synchronous motors with salient poles. In particular, we highlight that the structure of the classical field oriented control is kept in the case of non-sine motors provided minor modifications. The presented method allows to regulate constant values in steady state while applying non-sine currents to the motor. The shape of these non-sine currents is predetermined so as to minimize the steady state torque undulation.

Back to the Wednesday program

WA-2A – Room 1150
Magnetic Materials II

Session Chair:

G. Olivier (Canada)

11:05 – **Global Actuator Design Methodology – Application to Reluctant System**

Christoph Kuert, Valérie Nguyen, Yves Perriard

Abstract – To be able to calculate the performance of a linear actuator or to design it, it is essential to perform an efficient model. Using programs based on finite elements and executing calculations is difficult and is time consuming, but normally offers increased precision. 3D finite elements are used to better understand some phenomena and helps establishing an analytic modeling based on magnetic equivalent scheme. Force calculation is therefore much faster and permits to easily optimize a given structure. Finally finite elements may be used to confirm the optimization in a more precise way.

11:30 – **Finite Element Based Electromagnetic Analysis of Hydrogenerator With Fractional Winding**

Milutin Pavlica, Zlatko Maljkovic

Abstract – The paper deals with electromagnetic analysis of the hydrogenerator with fractional winding. General purpose FEM based software and its built in automation support were used to automate the analysis. Generator has been modeled as a true magnetic symmetry element and not by one or two pole pitches as it has been done in the past. The no-load characteristic, reactances, short circuit field current and rated load field current have been determined. The results have been compared to those acquired by classical, analytical methods and measurements in case of one real generator. FEM based analysis also shows the difference in magnetic flux distribution in rotor poles for different positions of the rotor.

11:55 – **Influence of Magnetic Saturation and Brushes Geometry on the Air-Gap Flux of a DC Motor**

M. Fassenet, T. Pera, C. Espanet, J.M. Kauffmann

Abstract – An analytical model for the evaluation of air-gap magnetic field on load is presented. The model, which is adapted for permanent magnet direct current motor, takes into account the geometry and position of brushes and the saturation phenomena. The theoretical results given by analytical model is compare with corresponding finite element analysis. Analytical approach is able to predict the air-gap flux values with weak errors. These values are significant data for the estimation of mechanical torque or more globally for the evaluation of motor electromechanical performances.

12:20 – **Inverse Design Methodology Applied to MRI Magnets**

S. Bégot, E. Artioukhine, P. Hiebel, J.M. Kauffmann

Abstract – This paper deals with the design of MRI magnets using an inverse methodology. The authors compute the current density that produces a homogeneous magnetic field, then they adapt these results to obtain magnets with a constant current density. In order to have stable solutions, the authors use numerical methods that have been developed to solve inverse problems of experimental data treatment. These methods enable us to achieve a compromise between the stability of the computed solutions and the accuracy of the computed magnetic field. The authors show that the use of the iterative regularization method and the use of the decrease in the unknown number yield to this compromise. The final magnet is obtained by a nonlinear optimization of the geometrical parameters of the coils. In this paper, the authors present the used methodology and numerical results.

Back to the Wednesday program

WA-2B – Room 1160
Switched Reluctance Motors

Session Chair:

C.R. De Souza (Brasilia)

11:05 – **Induction Machine Modeling by Reluctance Network for Fault Diagnosis**

Nikola Jerance, Gilles Rostaing, Jean-Pierre Rognon, Albert Foggia

Abstract – A model of induction machine based on a reluctance network is developed. The machine model includes machine faults – air-gap eccentricities, short circuits of stator winding and broken rotor bars. The model was established directly from the machine geometry data. Machine fault diagnosis is performed by using stator current spectrum. Faulty machine dynamic behavior was investigated. The presented model was validated through comparison with experimental data and with previous publications.

11:30 – **Design and Performance Prediction of a Low-Power Single-Phase Switched Reluctance Motor**

Jawad Faiz

Abstract – The design, principle of operation and performance prediction of a single-phase switched reluctance motor are described and considered. The motor initial dimensions are first calculated using a simple design method and semi-empirical formulas taking into account the saturation of iron, and they are then used as input of the specially developed PC based finite element design package. A prototype single-phase switched reluctance motor has been manufactured and its predicted and measured performance is compared and a good agreement is achieved.

11:55 – **Modeling the Synchronous Reluctance Motor**

C.A.M.D. Ferraz, C.R. de Souza

Abstract – A conventional three-phase reluctance synchronous machine is analyzed and a model for the determination of its steady state and dynamic characteristics is presented. As the machine behavior and also its control are affected by the iron losses, those ones are considered in the analysis. To achieve this purpose the d-q dynamic models of cage-rotor synchronous reluctance motor are developed. The iron losses are incorporated to the model. The models allow developing expressions for the control objectives and are suitable for simulation in steady state and transient conditions. Theoretical developments and experimentation are required. The machine general equations are presented and the experimental determination of some performance characteristics were carried out. The theoretical expressions and the corresponding experimental results are compared in way to verify the validity of the model under synchronous operations.

12:20 – **Performance Simulation of Switched Reluctance Motor Drive System Operating With Fixed Angle Control Scheme**

Hamid Ehsan Akhter, Virendra K. Sharma, A. Chandra, K. Al-Haddad

Abstract – This paper presents the performance of a 4kW 8/6-pole configuration SRM drive with fixed turn-off angle control scheme. Turn-off angle plays an important role in developing electromagnetic torque in Switched Reluctance Motor (SRM) and leads to stable or unstable operation of the drive. The value of turn-off angle is usually variable and depends upon the motor speed and other parameters of the inverter that excites the SRM. However, this study is conducted for full-load and partial load starting and operation of the drive with fixed turn-off angle control scheme. The simulated performance of SRM drive system is presented to analyze the effect of fixed value of turn-off angle on transient and steady state performance of the drive in terms of speed, current and torque response. The advantages inherent in fixed turn-off angle control scheme are emphasized.

Back to the Wednesday program

WA-2C – Room 1170
Fault Detection and Diagnosis II

Session Chair:

T. Lipo (USA)

11:05 – **Simulation of Internal Faults in Synchronous Machines Using Winding Function Approach**

X. Tu, L.-A. Dessaint, M. El Kahel, A. Barry

Abstract – In this paper, a model for simulation of the internal faults in synchronous machines is proposed. The method is based on the winding function approach (WFA), which makes no assumption as to necessity for sinusoidal symmetrical distribution of the machine windings and therefore accounts for the all magnetomotive force (MMF) harmonics. The machine inductances are calculated directly from the geometric data and windings arrangement. With this method, any internal fault of synchronous machines can be simulated and the effects of the MMF harmonics on the machine faulty currents can be investigated. The paper gives details of machine models under the normal condition and under the various internal fault conditions.

11:30 – **Analysis and Simulation of Induction Motor Drives Behavior Under Terminal Fault Conditions**

M.V. Aware, D. Sutanto, S.G. Tarnekar

Abstract – Variable Speed drives with front-end inverter are widely accepted and established technology. Operational reliability depends on the weak link, such as converter-inverter in the system. The reliability of the power electronics devices is of paramount importance in industrial, commercial, aerospace and military applications. The faults in the inverter are attributed to misfiring, short circuit of the device or missing pulse. These abnormal behavior causes to change the motor terminal variables. The motor performance parameters such as speed and torque are subjected to vary. Such variations may lead to the abnormal process behavior and heavy loss. Reliability can be improved by using the fault redundant systems. The fault redundant systems can be built to work under post fault conditions. Therefore it is important to know the machine behavior under terminal fault condition. In this paper, induction motor simulation is presented to study the performance under terminal faults. Different terminal faults are categorized to co-relate the actual failure condition in the front-end converter-inverter of the induction motor. Pre fault operating conditions, such as load torque are also important while building the fault redundancy in to the system. The basic control variables such as speed, torque, current and flux are observed during post fault condition. This simulation is carried out in SIMULINK with actual motor data. The fault profile of for a given machine is obtained. This can be used in fault tolerant protection systems.

11:55 – **Reconfiguration of Stator Windings in Large AC Electrical Machinery for Rapid Internal Fault Detection and Reduction**

Stephen B. Kuznetsov, Allen Levien

Abstract – Reconfiguration of stator windings combined with Internal Fault Detection (IFD) pertains to high-power synchronous and induction propulsion electric machinery in the range of 1 - 60 Megawatts. The IFD comprises a virtual instrument winding fault detection system including apparatus for classification/identification of winding faults. Each phase is grouped into subphases that are individually switched by thyristors or IGBTs into or out of the excitation supply or load on a sub-cycle interval during the de-energization sequence to mitigate unbalanced magnetic pull. The internal fault detection system is able to isolate selected segments of the stator responsive to the magnitude of stator faults detected and derive the mode with the lowest magnetostrictive induced acoustic signature using a spatial attenuation pattern of airgap radial flux. A design example is shown for a 21 Megawatt PM propulsion generator. A 275 kVA, 4160 Volt, 12-pole generator has been fitted with IFD diagnostics.

12:20 – **Fuzzy Diagnosis Model of Fuel Cell Power Generators for Automotive Applications**

D. Hissel, S. Jemeï, M.C. Péra, J.M. Kauffmann

Abstract – Main auto manufacturers are investigating fuel cell generators in order to design a zero or low emission vehicle. Despite of the numerous prototypes already unveiled, many hurdles have still to be overcome, particularly in terms of reliability. Predictive maintenance is then one of the milestones to be reached. The fuzzy diagnosis model of fuel cell power generator presented in this paper is a contribution to achieve this aim. Two types of faults have been studied: temperature below the nominal value (vehicle starting) and air supply fault. It has been tuned using a genetic algorithm and validated with an experimental test bench of low power (500We).

Back to the Wednesday program

WA-2D – Room 1300
Simulation Methods II

Session Chair:

B. de Fornel (France)

11:05 – **Accurate Simulation of a 6-Pulse Inverter With Real Time Event Compensation in ARTEMIS**

Christian Dufour, Jean Bélanger, Simon Abourida

Abstract – This paper presents new simulation software that allows the efficient and accurate fixed-time-step simulation of complex event-based electrical systems. The software, named ARTEMIS™ (Advanced Real-Time Electro-Mechanical Transient Simulator), accurately simulates time-segment linear systems with discontinuities occurring anywhere between time-steps. The new software is used for the simulation of energy and power system dynamics, and is implemented in the ARTEMIS Add-On for Simulink's Power System Blockset. With ARTEMIS' Real Time compensation of switching Events (RTE), the between-step events are transparently taken into account and compensated for in the simulation results. This eliminates sub-synchronous jitter while causing only minor increase in both the average time-step and real-time time-step (typically less than 10%), making ARTEMIS with RTE suitable software for real-time simulation of precision-critical hardware-in-the-loop (HIL) electromechanical and drives systems. The RTE algorithm is very good at handling difficult fixed-step simulation cases, like multiple single time-step discontinuities encountered in the simulation of electric drives and power converters.

11:30 – **Two Software Implementations for State-Space Simulation of RLCM Networks**

Rendong Lin, Jeffrey S. Mayer

Abstract – When analyzing systems comprised of power electronics, electric machines and control systems, simulations based on state-space modeling offer two important advantages over simulations based on the now-conventional combination of companion modeling and modified nodal analysis. In particular, state-space modeling provides a more natural representation of complex multi-terminal components and the freedom to choose among various integration algorithms at run time. These advantages are accompanied by the disadvantage of a more complex procedure for establishing the overall network/system equations and implementing software for their solution. With advances in object-oriented and generic programming languages over the last 20 years, however, the implementation of state-space simulation methods in software is no longer as formidable as it once was. We have investigated two implementations of a simulator for switched RLCM networks. The first is based on numerical evaluation of the symbolic formulation in [1]. The second is generalization of the "A-matrix" method in [2][3].

11:55 – **On the Stability of Hardware in the Loop Simulation**

Saffet Ayasun, Antonello Monti, Roger A. Dougal, Sean Vallieu, Robert Fischl

Abstract – We describe analytical and computational approaches for evaluating the stability of simulations that include Hardware in the Loop. The parameters that influence the system performance are analyzed and specific stability criteria are stated. We describe a simulation platform that can be used to analyze the stability of complex systems where analytical approaches are unwieldy. The relation between the analytical approach and the simulation is discussed.

12:20 – **Communication Structure Between Electrical Design Software**

Vincent Fisher, Jean Brigeon, Eric Atienza, Benoit Delinchant

Abstract – In this paper, a communication structure between electrical design software is proposed. This structure allows the designer to transfer data from one application to another without using a new intermediary software, but a plug-in added to the application. The transferred data is encoded in XML and adapted from one application to another with a syntactic translator, XSLT.

Back to the Wednesday program

WP-1A – Room 1150
Asynchronous Machine III

Session Chair:

A. Chandra (Canada)

14:15 – **Using Discrete Difference Kalman Filters for Flux and Velocity Estimation of Induction Motors**

T. Saheb, F. Auger, L. Loron

Abstract – This paper reviews some recent state estimation techniques for nonlinear discrete-time systems that are based on first- and second-order Stirling approximations. Based on a thorough study of the error of these approximations in the scalar case, an intermediate approximation is proposed that is also computationally efficient. The relevance of the application of these algorithms to the estimation of flux and velocity of induction motors is finally studied.

14:40 – **Identification of Induction Machine Parameters Using the Continuous Model: LP and TF Methods**

N. Tali Maamar, M. Aït-Ahmed

Abstract – The objective of this paper is to present some identification methods for the determination of parameters of an induction machine of weak power with the aim of its vector control. From the current and voltage measure, we reconstitute physical parameters of the machine. We are going to use the least squares (LS) method applied on the continuous model of the machine transformed by a linear product or by a filtering with an aim of avoiding the calculations of the derivative of a noised signals.

15:05 – **A Coupled Magnetic Circuit Based Global Method for the Simulation of Cage Induction Machines Under Rotor and Stator Fault**

G. Houdouin, G. Barakat, B. Dakyo, E. Destobbeleer, C. Nichita

Abstract – This paper deals with a global method enabling the simulation of the squirrel cage induction machines under rotor and stator faults. This method is based on the coupled magnetic circuit theory. The system of differential equations describing the induction machine in presence of different rotor and stator faults is given. The machine inductances are calculated by means of the magnetic energy stored in the airgap. This task is performed by the use of the winding functions method and a previously developed airgap permeance analytical model. Because of the inductances calculation is highly time consuming, a numerical representation method of the inductances is also proposed avoiding the calculation of the inductances during the differential equations system integration. The proposed model allows a precise study of several machine faults signature in various machine main quantities. Finally, some simulation results illustrate the proposed global method in the case of some common defaults such as stator inter-turn short circuits, broken rotor bars or airgap eccentricity.

15:30 – **Design of Novel Winding Configurations for VSI Fed Dual-Stator Induction Machines**

D. Hadiouche, H. Razik, A. Rezzoug

Abstract – The major drawback of usual dual-stator AC machines supplied by a voltage source inverter (VSI) is the occurrence of large stator circulating harmonic currents. These ones induce extra losses in the machine and require larger semiconductor device ratings. In order to minimize their amplitude, novel winding configurations for safe operations of VSI fed dual-stator induction machines (DSIM) are proposed in this paper. A dynamic model of DSIM, including detailed analysis of stator slot leakage inductances, is developed. Simulation results are presented and show the advantages of the proposed winding configurations.

15:55 – **Stray-Load Losses Analysis in Copper Squirrel Cage Induction Machine**

L. Doffe, C. Paris, O. Walti

Abstract – Our study aims at showing the importance and the influence of stray losses in copper squirrel cage induction machine's dynamic behaviour. Its operates an important role on the machine's efficiency but also on electromagnetic torque characteristic's look. First, the question is to know the origin of these stray losses and after, identify the effects on the torque in terms of speed characteristic and on the efficiency in terms of effective power characteristic. Finally it could be interesting to see how to make it optimal.

Back to the Wednesday program

WP-1B – Room 1160
Static Power Converters IV

Session Chair:

T. Meynard (France)

14:15 – **PWM Control Methods for Five-Level Flying Capacitor Multilevel Converters**
Chunmei Feng, Vassilios G. Agelidis
Abstract – Different PWM control methods suitable for a three-phase five-level flying capacitor multilevel converter are discussed in this paper. Specifically, the phase-shifted sinusoidal PWM technique, the carrier disposition methods, a hybrid one and the carrier sinusoidal PWM technique that includes a third harmonic injected on the reference signal are presented. The analysis is based not only on the way switching control signals are derived but also on the resulting total harmonic distortion, the harmonic spectrum of the output voltage, and the complexity of implementation. The ability of each technique to deal with the voltage unbalance of the flying capacitors, which is considered to be a challenge, is also discussed. Finally, simulation results are presented to confirm the performance of the said converter under the above named different control methods.

14:40 – **Optimization Design of a DC-DC Power Converter for Ultracapacitors Energy Management**
J.-N. Marie-Françoise, A. Djerdir, A. Berthon
Abstract – The aim of this work is to find the optimal solution for a proposed DC-DC power converter for ultracapacitors energy management in an electrical vehicle (power flowing during a time interval under voltage and current constraints). The DC/DC converter is based on the boost/buck chopper topology. So, the proposed optimization methodology highlighting the needed requirements is presented and its algorithm is given. Thus, an optimal design example will be treated. Some simulation results checking the validity of the proposed methodology will be also exposed. At this time, a non optimal experimental test bench has been made and we are in the way of its optimization.

15:05 – **Digital Emulator and Observer of Multicell Converter**
Régis Ruelland, Guillaume Gateau, Thierry Meynard, Jean-Claude Hapiot
Abstract – This article presents the design of a digital real-time emulator dedicated to the simulation of four-level multicell converter. The design has been made using a new tool: the co-simulation. Co-simulation results are presented in this paper and an experimental setup has been realised on a FPGA (Field Programable Gate Array) in order to validate this new tool. In the final part, we present the test of an observation loop using this emulator.

15:30 – **Improving the Space Vector PWM for the Three-Level Flying-Capacitor Inverter**
Marcos A. Severo, Paulo F. Seixas, Zélia M. Assis Peixoto, Antonio M. Lima, Bruno G. de Andrade
Abstract – This paper presents an improved space vector PWM method for a 3-level flying-capacitor inverter. Simple algebraic equations are used to calculate the pulse widths of the gate signals from the sampled reference voltages. This feature makes easy the implementation in real time. At low voltage levels, asymmetric modulation is introduced to reduce harmonic distortion. The voltage on the flying capacitors are regulated by simple ON-OFF controllers independently of the output voltage control. The main features of the proposed technique are analyzed by computer simulations. The algorithm was implemented using a commercial DSP without any external logic. The experimental tests obtained confirm the expected results.

15:55 – **Nonlinear Control of a Three-Phase NPC Boost Rectifier Operating Under Severe Disturbances**

Loubna Yacoubi, Farhat Fnaiech, Louis-A. Dessaint, Kamal Al-Haddad

Abstract – This paper proposes a new nonlinear control of three-phase three-level Neutral Point Clamped (NPC) boost rectifier operating under severe disturbances. The nonlinear control strategy is employed to take into account the essential nonlinearities of the system and it totally differs from the common approach of linearizing the nonlinear system around a nominal operating point. In order to apply this technique, a nonlinear state space mathematical model of the rectifier is developed. An input/output feedback linearization is then designed and the linearizing control law is derived. The resulting model is linearized and decoupled. Afterwards, the stabilizing controllers are designed based on linear techniques to control power factor, output and neutral point voltages. This control uses a 3kHz Pulse Width Modulator (PWM). Simulation results are performed using Simulink / PSB. The controllers' performance has been evaluated under diverse parameter variations and input and output disturbances.

Back to the Wednesday program

WP-1C – Room 1170
Electric Drives III

Session Chair:

J.P. Louis (France)

14:15 – **A LMI Approach to Feedback Path Control for an Articulated Mining Vehicle**
Pascal Bigras, Plamen Petrov, Tony Wong
Abstract – This paper proposes a feedback path controller for an articulated (LHD) mining vehicle. First, we develop a kinematic model of the vehicle in error coordinates expressed in a moving reference frame, which is partially linked to the vehicle. We give a change of coordinates and input combined with a new variable instead of the time-index that transform the original system into a form that can be viewed as a nonlinear time-invariant system. The nonlinear terms in system can be transformed in linear s-variant one by using mean values theorem. Subsequently, linear control feedback is applied to the full nonlinear system and local general stability of the closed-loop system is achieved by using Linear Matrix Inequality (LMI) approach. Simulation results illustrate the effectiveness of the proposed controller.

14:40 – **LSM Design and Motion Control of ME02 on Steep Slope of Water-Land Transition**
Kinjiro Yoshida, Abderrahmane Nafa, Yusaku Nakamura
Abstract – Marine Express is a Linear Synchronous Motor vehicle intended to run both on land and underwater over a long continuous guideway using combined linear motors and magnetic levitation technologies. In real operating conditions, Marine Express will have to transit from sea to land and from land to sea situated at different horizontal levels. This paper presents the design of the guideway and simulation of water to land transition using the underwater model vehicle ME02.

15:05 – **Control of a Direct-Drive DC Motor by Fuzzy Logic**
T. Nasser, M. Cherkaoui, M. Maaroufi, A. Essadki
Abstract – This paper presents a study on the application of fuzzy logic theory to control a direct-drive dc motor. The design of fuzzy logic controller for speed of a DC motor is presented. Control performance of the fuzzy logic controller is studied by simulation. The simulation results with fuzzy control are compared with those of the conventional controller.

15:30 – **Presentation of a Control Law for IM Drive Based on the Dynamic Reconfiguration of a DTC Algorithm and a SVM-DTC Algorithm**
E. Monmasson, J.P. Louis
Abstract – In this paper, the authors present an original control law for induction motor drive. It is based on a dynamic reconfiguration of a basic Direct Torque Control (DTC) algorithm and a Direct Torque Control algorithm associated to Space Vector Modulation (SVM-DTC). The criterion of reconfiguration concerns the state of the machine. Indeed, during transient states DTC algorithm is activated in order to get the best torque dynamic. Then, at steady-state, a SVM-DTC algorithm is preferred because it allows to reduce significantly the torque ripples. Besides, an original and well-adapted modelling based on a polar representation of the state variables is also introduce. Finally, experimental results are presented that confirm the interest of this solution.

15:55 – **Space Vector Control of 5-Phase PMSM Supplied by 5 H-Bridge VSIs**

J.P. Martin, E. Semail, S. Pierfederici, A. Bouscayrol, F. Meibody-Tabar, B. Davat

Abstract – The use of polyphase PMSM supplied by H-bridge VSI allows on one hand to segment the power transferred from the electrical source to the mechanical load and on the other hand to operate in degraded operating mode, with one or several non-supplied phase. Nevertheless, for an independent current control of the H-bridge VSI the magnetic coupling between each phase winding leads to high phase current ripples. In this paper a global current control method of the H-bridge VSIs, based on an adapted space vector control method is proposed. The proposed method allows a considerable reduction of the current ripple rate in the case of 3-phase and 5-phase non-salient PMSM supplied by H-bridge VSIs.

Back to the Wednesday program

WP-1D – Room 1300
Electromechanical Systems

Session Chair:

H. Le-Huy (Canada)

14:15 – **Modeling and Simulation of FPGA-Based Variable-Speed Drives Using Simulink**
Francesco Ricci, Hoang Le-Huy
Abstract – This paper presents a novel approach for the design and simulation of variable speed drives when the control algorithm is to be implemented in an FPGA. The specialized Simulink tools used and the design procedure are presented. An application example using a DTC induction motor drive is presented and discussed.

14:40 – **Simulation of Permanent Magnet Synchronous Generator Based Wind Energy System Conversion Under Stochastic Wind**
E.J.R. Sambatra, G. Barakat, C. Nichita, B. Dakyo
Abstract – This paper presents the study of the dynamic behaviour of permanent magnet synchronous generator (PMSG) directly coupled to the wind turbine shaft of the wind energy conversion chain. Firstly, the modeling of the different conversion chain components from the wind to the electrical load is exposed. The global model of simulation is then implemented in the Matlab environment. The simulation results allow the authors to determine generator's safe operation regions for a given electrical load and given wind dynamic characteristics.

15:05 – **Numerical Modelling Method for Electromagnetic Forces Computation in AC Brushless Motor With Outer Rotor**
R. Tirnovan, A. Miraoui, R. Munteanu
Abstract – The paper proposes a method for modelling electromagnetic forces and analysing the vibrations, in synchronous motors with permanent magnets. Ac brushless synchronous motor with outer rotor construction makes difficult to measure the vibration's acceleration of the rotor. So a theoretical numerical model (based on finite element analysis of magnetic field and MATLAB/SIMULINK uses) was developed permitting to study the electromagnetic forces and the effects of the motor feed on it.

15:30 – **A Simulation-Based Design Study for a Locomotive Electric Power System**
Fu Zhang, Raul G. Longoria, Robert Thelen, Doug Wardell
Abstract – This paper presents a model and simulation for a conceptual locomotive power system consisting of a gas turbine driven synchronous alternator coupled to a rectifier – dc link – variable frequency inverter configuration. This system drives four induction traction motors and is integrated with a flywheel energy storage system (FESS). Such a system is meant to meet demands for rapid acceleration, speed maintenance on grades, recovery of braking energy and overall improved fuel efficiency. This system is under investigation at the Center for Electromechanics (CEM) at the University of Texas at Austin as part of its Advanced Locomotive Propulsion System (ALPS) project. In this paper, a modular, system level simulation of the ALPS prototype is presented, with emphasis placed on the use of power flow management.

15:55 – .Hysteresis and Eddy Current Loss in an Axial Large Scale Permanent Magnet Superconductor Bearing

R. Zickermann, H.W. Lorenzen, D. Schafer

Abstract – This article describes the applied loss determination of a large scale axial permanent magnet superconductor bearing for levitation forces beyond 1000 N. The experimentally determined brake torque can be used to calculate the power loss. The power loss can then be split into a hysteresis part and an eddy current part. This paper describes the set-up of the arrangement and the measured results.

Back to the Wednesday program

Rooms 1422-1752
Poster Session II

16:50 – 18:50

Session Chair:

P.J. Lagacé (Canada)

P1 – **Validation on a Large Frequency Range of an Iron Losses Model by a Thermal Method**
B. Ben Abdallah, R. Glises, J.P. Masson, J.M. Kauffmann
Abstract – This paper presents an experimental test of a local magnetic losses model by thermal measurements. First this model is tested in the classical homogeneous losses distribution assumptions of an Epstein frame. In order to obtain a more realistic evaluation, we develop a specific device where high loss gradients can be observed. This article presents briefly the device structure and shows the results obtained for several frequencies of a sinewave voltage applied on the excitation coil.

P2 – **A New 3-Phase Shunt Active Power Filter for the Compensation of Only Customer Generated Harmonics**
Pramod Agarwal, Shailendra Kumar Jain, H.O. Gupta
Abstract – This paper presents a new control algorithm for 3-phase shunt active power filter to compensate only those harmonics, which are generated by the customer using harmonic generated loads. Therefore, the resultant source current will have the same waveform as that of the supply voltage. Due to similar shape of source voltage and current, reactive power has been compensated completely. The proposed scheme provides an additional feature of compensation of either harmonics only, or the compensation of both harmonics and reactive power simultaneously, based on the desired capacity of the APF. Various simulation results are presented with distorted mains.

P3 – **Superconducting Coils Adiabatic Quench 2D Simulation on an Unstructured Simplicial Mesh**
Vincent Picaud, Patrick Hiebel, Jean-Marie Kauffmann
Abstract – This article describes a new numerical method which analyses adiabatic quench of superconducting coils. The winding region is discretized by an unstructured simplicial mesh. This method generalizes the Wilson's older method. The evolution of the resistive front is efficiently managed by the resolution of an Hamilton-Jacobi equation, a methodology inspired by the Level-Set method

P4 – **Design and Simulation of a Magnetic Levitation Conveyor Vehicle**

J. Van Goethem, L. Schober, G. Henneberger

Abstract – Design of a new transportation system presup-poses a thorough understanding of the dynamics of the system. This paper presents a simulation environment to analyse the dynamic behavior of a magnetic levitation vehicle designed to convey luggage at airports. The simulation environment is built in a modular way so that it can easily be extended. The conveyor vehicle is modeled as a rigid body with 6 degrees of freedom. The Newton/Euler equations of motion provide the basis of the mechanical model. Two models of the support magnets are presented: a simple analytic model and an accurate model based on finite element calculations. The levitation controllers, based on a state control algorithm, complete the simulation environment. Simulations with different air gaps and/or loads as well as rides through curves are possible. Extensive simulation results prove the usefulness of the simulation environment in designing a new transportation system.

P5 – **Approximation and Simulation of Circularly Symmetric Two-Dimensional Los-Pass Discrete Filters**

V. Ramachandran, S. Sitaram, C.S. Gargour

Abstract – An algorithm has been developed and implemented which tests for the approximation of circularly symmetric two-dimensional discrete filters. The starting point is the product-separable two 1-D Butterworth filters in each dimension. A configuration is given which implements such 2-D filters.

P6 – **Modeling and Simulation of a Multivariable Process Control**

Ernesto Cornieles, Maarouf Saad, Guy Gauthier, Hamadou Saliah-Hassane

Abstract – This paper presents a comparative survey of different multivariable techniques applied to process control. The modeling of the physical system and real time simulations are also presented using different PID structures and applied for the regulation of level and the temperature of a water reservoir control process. The structure of the multivariable control system has been implanted using LabView® software. This structure uses two control loops, the first for the level regulation and the second for the regulation of temperature. Five different PID controllers are included in this paper (Ziegler_Nichols, ITAE, IMC, poles placement and dual loop) and real time results are presented.

P7 – **Laboratory Implementation of an Artificial Neural Network for Online Tuning of a Genetic Algorithm Based PI Controller for IPMSM Drive**

Nasir Uddin, Casey Butt, M.A. Rahman, M.A. Abido

Abstract – This paper presents an artificial neural network (ANN) for online tuning of a genetic based proportional-integral (PI) controller for interior permanent magnet synchronous motor (IPMSM) drive. The proposed controller is developed for accurate speed control of the IPMSM drive under system disturbances. In this work, initially different operating conditions are obtained based on motor dynamics incorporating various uncertainties. At each operating condition genetic algorithm (GA) is used to optimize PI controller parameters in a closed loop vector control scheme. In the optimization procedure a performance index is developed to reflect the minimum speed deviation, minimum settling time and zero steady-state error. A radial basis function network (RBFN) is utilized for online tuning of the PI controller parameters to ensure optimum drive performance under different disturbances. The proposed controller is successfully implemented in laboratory using a digital signal processor board DS1102 for a 1 hp IPMSM. The efficacy of the proposed controller is verified by simulation as well as experimental results at different dynamic operating conditions.

P8 – **The Analytical Modelling of a Bimorph Beam Piezoelectric Transformer**

Dejan Vasic, Emmanuel Sarraute, François Costa

Abstract – This paper presents a new type of piezoelectric transformer functioning in flexion mode. Structures such as beams, bridges or membranes are concerned with this new principle. The structure presented herein is a bimorph beam embedded at one end and free at the other. This symmetric bimorph beam is made up of three layers: two oppositely polarized piezoelectric layers and one conductive middle shim layer. Thanks to a 4x4 chain matrix connecting the efforts and velocities of one end to the other end for each element of the beam (primary and secondary), we can establish the dynamic behavior of the transformer made up of this two elements. We have also established the shape of the deformation and the axial stress as well as the input electrical admittance and the voltage gain, according to the frequency. At last, these analytical results are compared to experimental ones.

P9 – **Modeling and Simulation of Variable Speed Centrifugal Pump**

Gabriel Rakotonirina, Pierre Sicard, Thangavelu Vetrivel Sivakumar

Abstract – This paper presents the development of a detailed model of a centrifugal pump using few measurements and nameplate or constructor information only. Full development of the model is presented along with its implementation in a software package. Simulation results demonstrate the usefulness of the model to study the transient and steady state behaviour of a system consisting of a centrifugal pump coupled to an induction motor by a flexible shaft.

P10 – **Modeling and Identification of Parameters on Saturated Induction Machine**

K. Dakhouche

Abstract – Many papers on variable speed drives of induction machine use, in their analyses, conventional representations of the machines such as those based on Park's equations suitable for transient but suffers on determination of parameters or the classical T-form of linear equivalent circuit used only in steady state. This paper attempts to propose appropriate model for use in transient or steady state analyses of induction machines This work presents modeling and parameters identification of saturated induction machine.

P11 – **Steady-State Finite Element Analysis of a Salient-Pole Synchronous Machine in the Frequency Domain**

J. Gyselinck, L. Vandevelde, J. Melkebeek, W. Legros

Abstract – In this paper the authors study the steady-state finite element simulation of synchronous machines. A recently proposed harmonic balance method is briefly described and applied to a salient-pole synchronous at noload. The frequency domain approach is shown to produce results that agree well with those obtained with plain time stepping, however with a reduction of the computation time. Particular attention is paid to the damping effect of the eddy currents in the solid poles.

P12 – **Analytical Computation of the Mechanical Deformation of Two Rectangular Conductors Embedded in a Slot**

Christian Grabner, Erich Schmidt

Abstract – The mechanical deformation of two rectangular conductors embedded in a slot mainly depends on the acting electromagnetic volume force density inside the conducting regions, the mechanical properties of the used materials and the applied mechanical slot wedge fixing. With this problem, the behavior is completely different between mechanical loose and mechanical fixed conductors inside a slot. Loose conductors can only be shortened or stretched due to the acting electromagnetic volume forces, whereby the mechanical behavior of fixed conductors additionally depends on the mechanical pre-load. The mechanical stress distribution and the accompanied deformation are calculated in an analytical way separately for both cases of loose and fixed electrical conductors.

P13 – **A New Model of the Induction Motor in Dynamic Regime With Variable Parameters for the Electric Vehicle**

M. Ghariani, S. Feki, R. Trigui, N. Masmoudi, L. Kamoun

Abstract – The conventional modelling of asynchronous machine takes in account many simplifying hypotheses that drive to a "scale model". In the case of high strengths applications, as the case of the traction machine, the physical phenomena so neglected invoke modelling mistakes that generate in their part command mistakes. We study in this paper the physical phenomena involved as well as their effect on the machine model. We propose an observer who takes account the parameter variations. Thereafter, simulations are conducted to compare its performance with respect to a conventional observer.

P14 – **Towards Real-Time Simulation on a PC-Cluster of Mechanically Coupled Induction Motors in a Material Transfer Process**

Pierre Sicard, Nourdine Elouariachi, Nicolas Léchevin, Abdellfattah Ba-Razzouk

Abstract – Real-time simulation of electromechanical systems is an important tool with applications in system and controller design and development, for real-time emulation of dynamical motor loads and for model based real-time control. With the small time constants and the presence of high frequency switching devices in power systems, achieving real-time is a real challenge, in particular on low cost computer systems. This paper presents a model separation scheme for distributed processing for a material transfer process composed of two AC variable speed drives with strong electrical and mechanical coupling. The model of the system is implemented in RT-Lab using ARTEMIS to separate the model. The use of dynamic matrix calculation of the state-space matrices of the subsystems, with a buffer of stored matrices for each power converter, resulted into the best time performance.

P15 – **Transverse Flux Linear Induction Catapult Machinery for Electromagnetic Aircraft Launch Systems**

Stephen B. Kuznetsov, Allen Levien

Abstract – Transverse flux linear electric machines (TF-LEM) for aircraft catapults combine an efficient magnetic structure with reduced core depth and lower overall machine weight for high-speed propulsion in the range of 50-150 m/s end-speed. The change in spatial orientation of the magnetic and electric circuit in this type of linear induction machine results in a reduction in the primary conductor material for a given thrust rating and more efficient use of the reaction rail driving the catapult assembly. Traditional longitudinal flux linear induction machines (LF-LIMs) are restricted in efficiency and have a lower power density by having a large primary core depth as a result of large pole-pitch design for speeds in excess of 50 m/s. The LF-LIM has the additional disadvantage of a high end-winding leakage reactance and consequent high reactive kVA requirement for the inverter power supply. The TF-LEM by allowing a more compact magnetic and electric structure results in a lower reactive kV burden on the inverter for a specific thrust and speed requirement. The paper describes the specific design of a 95 MJ output, 200 knot TF-LEM for electromagnetic aircraft launching of 20-30 ton payloads. A comparison with conventional LF-LIMs is given for performance and electrical design aspects; the transverse flux machines are shown to be 27% higher in power density at the 200 knot rating.

P16 – **Modeling and Simulation of an Electromechanical System for its Diagnosis**

Houda Ben Attia, Bruno Dagues, Jean-Claude Hapiot, Ilhem Slama Belkhodja

Abstract – This paper is interested in the modeling of a gear driven by an induction machine and operating under healthy and faulty conditions. The defaults that are studied concern a wear affecting the whole or a party of the meshing teeth, considered at their contact point. The behaviours of the healthy and the faulty gear are examined and compared through the stator current of the induction machine. The electric signatures of these mechanical load defaults are determined via a Fourier spectral analysis carried out on the supply current. The study is completed by the influence of the gear meshing stiffness on the detectability of the considered defaults while basing on the current signals.

P17 – **Analysis and Experimental Validation of Various Photovoltaic System Models**

O. Gergaud, B. Multon, H. Ben Ahmed

Abstract – A photovoltaic conversion chain is classically composed of flow-through photovoltaic panels, by means of a converter, on a continuous voltage bus bar. In the present case, it has also been fitted with instrumentation for measuring weather conditions. In this article, we propose the modeling set-up for such a chain, in the aim of estimating its energy production. In order to characterize the photovoltaic panels, we have applied and compared the models available in the literature. The characteristic of converters equipped with an MPPT (Maximum Power Point Tracking) function is determined on the basis of experimental readings. All meteorological data recorded by the system are then averaged; we have also analyzed the impact of averaging frequency on the energy output of the derived model.

Back to the Wednesday program