



ANNEX 2: TEMPLATE FOR PROPOSAL UNDER DERRI

User-Project Proposal:

Use-Project Acronym	SEM_BAD
User-Project Title	Smart Energy Management for Buildings and Districts
Main-scientific field	Automation and control
Specific-Discipline	Energy management systems

Lead User of the Proposing Team:

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Activity type and legal status* of Organization	Higher Education Institute
Position in Organization	Full Professor

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Position in Organization	Professor

* Higher Education Institution (1) – Public research organization (2) – Private not-for-profit research organization (3) – Small or Medium size private enterprise (4) – Large private enterprise (5) – other (specify)

Additional Users in the Proposing Team:

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DERri
Distributed Energy Resources
Research Infrastructures

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Activity type and legal status* of Organization	Higher Education Institute
Position in Organization	Master Student

* Higher Education Institution (1) – Public research organization (2) – Private not-for-profit research organization (3) – Small or Medium size private enterprise (4) – Large private enterprise (5) – other (specify)

(Repeat for all Users)

Date of submission	30/09/2010
Re-submission	YES _____ NO <input checked="" type="checkbox"/> X _____
Proposed Host TA Facility	RISOE-DTU (DK)
Starting date (proposed)	October 2011

Summary of proposed research (about ½ page)

Prepare a ½ page summary describing the relevance and the scope of the proposed work, and the expected outcome(s)

This project is focused on the design and test of control logics for efficient energy management in buildings and micro-grids. Following CISCO's point of view in [1] we adopt the "layered structure" of a Smart Grid and assume that an ICT infrastructure is available that can provide an everywhere connectivity and support the operation and the management of electrical grids. Our work will focus, then, on setting up efficient control policies that will enable, taking advantages from AMIs (Advanced Measurement Infrastructures), the management of energy consumption in a Smart Grid. Our aim is to develop a framework to design energy manager systems (electrical and thermal) for buildings, districts and, given its scalable architecture, also for homes. This system will enable to perform load peak-shaving thanks to an intelligent remote load-disconnection policy and RES integration, avoiding the network overload during peak-periods.

The energy manager consists basically in a control algorithm and it is independent of the implementation and the platform. It will be integrated in a control environment that will offer different services such as energy consumption profiling, interfacing with a demand/response environment (with the possibility to optimize energy costs), emergency handling and forced remote load

disconnection. A similar approach is presented by P. Stulka et al. in [2].

Given the control logics already partially available, the project aims at exchanging this point of view with industrial and research partners in Europe and at performing a field test in a Micro Grid.

The steps we plan to take include the implementation of the energy management system, testing it in a commercial building setup and interfacing it with a D/R environment and Micro Grid.

The expected outcomes of the project are: 1) a tested set of logics for real-time energy management with peak-load shaving capabilities; 2) an implemented and tested version of this energy manager; 3) demonstration of economic impact of such technology, environmental advantages and energy saving estimation in comparison with a normal “non-smart” building.

State-of-the-Art (about 1 ½ page)

Describe in brief (in about 1½ pages) the current knowledge on the subject, citing recent relevant references. Identify any knowledge gaps and their relevance.

Since the technological revolution started in the 80s, the ICT (Information and Communication Technology) has changed our everyday's life, the way to manage all the processes in our society and intend interpersonal relationships. Now all these technologies are called to help in managing the energy for which global demand is forecasted to triple by 2050 [3]. To avoid overloading the entire grid, not only the scientific community but also many industrial and public sectors are taking steps to upgrade electrical network infrastructures and the related technologies to ensure energy production and delivery in the next century.

In this way, such new grid architecture is termed “Smart Grid” and, beside the name, there is a galaxy of different possible developments of both “hardware” and “software” aspects. Based on what F. L. Bellifemine described in [4], the Smart Grid is “an electrical network able to integrate all the branched customers’ and producers’ actions to distribute electrical energy efficiently, sustainably, at low operating costs and safely.”

As for the key smart grid applications, B. R. Flynn counts in his report for P.E. [5] the values of smart grids, such as Security and Safety, Energy consumption optimization and efficiency, Reliability and Environmental impact reduction of energy production. J. McDonald pointed out that the Smart Grid was essentially a control problem including [6]: Delivery optimization, Demand optimization, Assets optimization, Reliability optimization and Renewable sources integration and optimization.

The control of such a new grid is enabled by communication systems connecting everything in the grid. Of course there will be needs on ICT infrastructure adaptation, upgrades of electrical grids [1], smart metering devices installation, information technology standards, and governmental regulations [1]. Nevertheless though today's ICT technologies are broadly available for supporting the operation of Smart grids, a serious challenge is to develop control strategies which would result in impacts on [6]:

- Operational efficiency: will imply distributed generation integration on the grid, network optimization, enable remote monitoring, improve assets utilization and operate preventive maintenance.
- Energy efficiency: will reduce the system and line losses, improve the reactive load control, enable the peak-load shaving and accomplish with the governmental policies about energy saving.
- Customer satisfaction: the grid will improve the communication between producers and consumers, reduce the outage frequency and duration, improve the power quality, and allow

the customers self-service.

- Green agenda: CO₂ emissions will be reduced, peak shaving can be performed in order to avoid using supplementary (and high polluting) support plants, renewable sources will help to reduce load peaks and the environmental impact, as direct consequence.

The first two points may be seen as monetary benefits while the latter two as environmental and image and/or ethical benefits.

Two key factors to attack the demand optimization problem would be certainly building automation and AMI [5]. Intelligent energy dispatching among the users in the Smart Grid would be a direct application of smart meters, and an optimal consumption profile would be the benefit of having a building energy management system (that perform a cost optimization above the operations). Energy pricing, green power-choices, CO₂ management, usage pattern monitoring and load side voltage changing detection are only some of the possible applications of building automation one can think about. Obviously, the presence of distributed generation (solar, wind, biomass, geothermal, cogeneration) and storage (batteries, fuel cells, PHEVs) will help to create zero net energy buildings and districts [5].

In several EU Countries, combination of market liberalization and DG diffusion is promoting innovative schemes: Italy, for example, is studying a measure such that photovoltaic plants (PV) with a "predictable exchange profile" will get a +20% incentive for their energy production [8].

The EC Recommendation C(2009) 7604 "asks for a closer cooperation between the ICT sector and building and construction sector to improve the environmental and energy performance of new and existing buildings, and to address the existing barriers to the wider use of ICT tools and their relevant applications".

In order to reach these objectives and to achieve a global efficiency in tertiary employ, a complex strategy including not only energy and gas prices but also their specific exploitation, customer preferences and external parameters as seasonal temperature change is required. This strategy may better monitor and control energy performance of buildings, where local generation must be included [9, 10], especially because it could imply a power flow towards the network instead of consumption. In addition, local storage units could improve flexibility in energy management, while their economic benefits should be still identified.

SEM_BAD project is based on different already-existing research works on the low-level control side, and attacks the problem of energy management with a systemic point of view. In fact this latter is the original contribution of the project which development and successful accomplishment would be a relevant achievement in providing practical solutions for efficient energy management from large district to small buildings, confirming its load-side standing point.

References

List relevant References

- [1] V. Pothamsetty and S. Malik, "Smart Grid: Leveraging Intelligent Communications to Transform the Power Infrastructure", *CISCO Systems Whyte Paper*, February 2009
- [2] P. Stluka, D. Godbole, T. Samad, "Optimization and Control for Demand Management in Smart Grid", *Honeywell Corp., CDC Conference, IEEE CDC 2010 Conference*, Atlanta, 15-17 December 2010
- [3] J. Mc Donald, "Leader or follower: developing the Smart Grid Business Case," *IEEE Power and Energy Magazine*, Vol. 6, November-December 2008, pp. 18-90.
- [4] F.L. Bellifemine et al., "Smart Grid: Energia & ICT," *Notiziario tecnico Telecom Italia*, Vol.3 December 2009, pp.15-32.
- [5] B.R. Flynn, "Key Smart Grid applications," *The Protection & Control Journal*, GE, December 2008.
- [6] J. McDonald, "The Smart Grid," *Paris energy summit*, August 23, 2010.
- [7] J. Kleissi and Y. Agarwal, "Cyber-Physical Energy Systems: Focus on Smart Buildings," *Annual ACM/IEEE Design Automation Conference*, January 6, 2010, pp. 749-754

- [8] Decree 129/2010 published 24th August 2010, art 10.
- [9] Luca Ferrarini, Marco Pernice, "Modeling and Control of a Thermal Energy System in a Building Automation Scenario" *INDIN 2009*, Cardiff, 24-26 June, 2009.
- [10] M. de Chirico, S. Esposito, L. Ferrarini, P. Magni, C. Montecucco, S. F. Nicolodi, S. Radaelli, "Bringing efficiency through energy management: The UTILTEC Project", *ANIPLA2006, 1st ANIPLA International Congress on Methodologies for Emerging Technologies in Automation*, 13-15 Nov. 2006, Roma, Italy, paper T115.
- [11] E.Musall et al., "Net Zero Energy Solar Buildings: An Overview and Analysis on Worldwide Building Projects", University of Wuppertal, Department of Architecture, Wuppertal (Germany), 2010.
- [12] G.T.Costanzo, J.Kheir and G.Zhu, "Peak-Load Shaving in Smart Homes via Online Scheduling", *submitted to IEEE International Symposium on Industrial Electronics, Gdansk (PO)*, June 27-30, 2011

Detailed Description of proposed project : Objectives – Expected Outcome – Fundamental Scientific and Technical value and interest (2-3 pages)

Provide a detailed description of the objectives of the proposed activity, the way these objectives will be fulfilled through the proposed work, as well as indications on the expected outcome and the fundamental scientific and technical value and interest of the proposal. Specify the type of TA infrastructure (distributed generation simulator; domotic house; etc.) and the test setup. With the understanding that these aspects will be discussed with the TA infrastructure after approval of the proposal and specified in the Agreement to be signed between the TA infrastructure and the User team, indicate the number of tests to be carried out and their sequence, the response quantities to be measured through the instrumentation, etc. Describe any special requirements for equipment, standards, safety measures, etc. Point out any shortcomings, uncertainties and risks for the fulfillment of the project objectives, as well as the means to mitigate relevant risks.

Going through the technical issues that stay behind the project, we may use the same hierarchy of conventional grids for Smart Grids: production, transport, distribution and consumption. These four layers have proper characteristics and constraints and they will be touched directly by Smart Grids technologies; however, they are too wide and complex to be treated together. Therefore this research will focus mainly on the consumption level, attacking the problems from the consumer point of view. The control aspect is the one we are more interested in, and the dwelling consumption optimization related to the demand/response philosophy will be the main focus of this work. In this fashion we wish to enable the utilities condition the customers' energy absorption and reach zero-net energy status for buildings or districts. To this end, we propose a framework under which the energy efficiency issue is treated by an energy management system that would interact with all other building actors as follows:

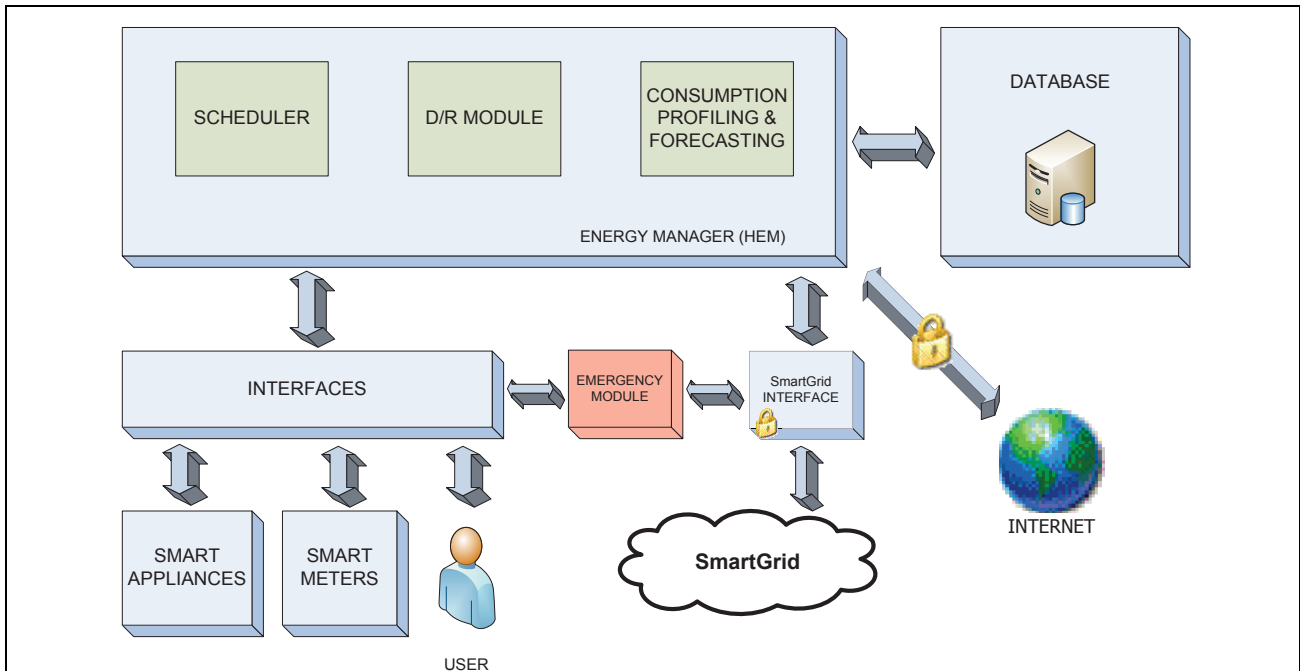


Fig. 1 – Proposed architecture for Smart Buildings energy manger

The previous schematic shows how we imagine the “actors” in a Smart Building interacting within each other. It is intended to give an overall idea about the architecture of every module in the system regardless the actual implementation. This would allow installing in Smart Buildings devices from different producers and integrate them thanks an appropriate interface. Then the user should be able to choose the EM manufacturer and, independently from that, choose the algorithms for energy management. The EM offers different functionalities: optimal activity scheduling (with respect to peak shaving or money saving for example), interaction with the grid in matter of energy pricing (D/R module) and will be able to create and tune up a forecasting models for the building energy consumption (in order to help in the optimal scheduling process). We can leave opened the possibility to integrate more modules in the EM, intending it as an “operative system for the building” in a futuristic vision.

This framework allows the integration of the last two levels in Smart Grid (Home/Building and Micro Grid) and provides for environment modeling, energy management and operations control. From the integration of all these features a high level of energy saving, quality assurance and economical power system operation is enabled, not to mention the positive environmental impact it would have.

After a brainstorm about these issues, our project will proceed into two different and parallel directions: for one side to improve the scheduling algorithm in order to schedule operations ahead in the time while ensuring online-flexibility properties, and for the other side, to define a better system level view in order to enlighten the architecture structure, clarify the layers characteristics and interfaces, give a clear and self-standing approach to smart buildings management system design and interconnection with micro grids.

The optimization would not only touch the electrical consumption, but also the thermal consumption. Actually both are related each other, especially if we think about the modern HVACs systems (heating, ventilating, and air conditioning), and bi-directional energy flow when DG sources and RES are connected to the energy manger.

Our intention is to highlight that the problem of Smart Grid control may be addressed in both centralized and distributed way. For instance a distributed control algorithm might be the best option we can choose: it divides the computational effort among the users, it is scalable, reliable



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and can provide data-mining capabilities. The problem of energy efficiency is addressed both at local level (energy saving and peak shaving) and grid level (optimal energy dispatch). Nevertheless it is mandatory that the two control architectures are well matched and establish a cooperative system.

On top of that, the reason to apply to DERri is to have the possibility to test all these logics and problem approach into a real Micro Grid with Smart Buildings and Demand/Response energy pricing system.

More precisely, the specific objectives of this work include:

- Study and build models for energy demand in smart buildings.
- Apply different scheduling policies for building energy management.
- Tune up models for demand/response optimization and define appropriate cost functions for power consumption optimization.
- Couple building level and micro-grid level control architectures and establish their interaction.
- Run simulation with different scheduling policies and optimizing cost functions.
- Show the direct benefits of this architecture compared to actual grid management policies and power dispatching algorithms thanks to real time simulations and experimental results.

As a direct outcome of implementing and testing these models and optimization algorithms, we would see how integrated energy management and distributed generators facilities in buildings would benefit in creating Zero Net Energy Buildings (ZNEBs) and districts.

The test facilities we need are:

- A real time simulation environment for power networks, possibly with HIL
- Buildings test facilities with the possibility to remotely control the electrical and thermal loads
- Micro grid installation with RE
- Demand/Response simulator or environment
- Communication network deployed
- Platforms to implement the (distributed) energy management system
- Some thermal and electrical energy sources (HVAC, micro-CHP, micro turbines, PV, etc...)
- Data analysis facilities

The experiments themselves don't present high risks since they are not dealing with high voltage equipment and transmission line. The fulfillment of the objectives present uncertainties related on the efficiency of the algorithms: in simulations may be better or worse than in real life since fluctuating behaviour of users would be difficult to model.

Originality and Innovation of proposed research – Broader Impact (1-2 pages)

Demonstrate the originality and innovation of the proposed work and the impact the expected results will have on current and future research or practice, public safety, European standardization, competitiveness, integration and cohesion and on sustainable growth.



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Among the load-peak shaving policies, the scheduling approach seemed to be new and few investigated after a review of about fifty references on Smart Grids, Smart Homes, Smart Buildings, Smart Meters, Demand/Response, Energy efficiency techniques. In this fashion further investigations can be carried out by modifying the basic algorithm in [12] with a stochastic and/or game theory approaches. For instance an immediate end-user application is enabled thanks the EM design presented in [12]. Besides the scheduling approach for energy management, the other contribution this research work aims at is a system point of view of Smart Grids where ICT, power grid, appliances, RES, DG and user interfaces interaction can be treated with the same framework. In addition, special optimization models and techniques will be integrated with the scheduling approach. This latter would allow treating electrical end thermal energies at the same time, enabling bi-directional fluxes and statistics on them; provided a working supervising system, the step toward Smart Grids would be only a matter of implementation (and investments).

Proposed Host TA Infrastructure/Installation – Justification (about one page)

Specify the type of TA infrastructure (e.g. distributed generation simulator; domotic house; etc.) and if possible which one of the 13 TA Infrastructures in DERri may better serve the scope of the proposed research. Justifications should be provided on the grounds of the test set-up, testing method, equipment, past experience in relevant subject, etc. State whether the TA User team intends to deliver to the premises of the TA Infrastructure parts or components to be tested at the TA User's expense and responsibility, or to cover the whole or part of the construction/adaptation cost of the specimens to be tested.

In the previous paragraphs we stated the main test facilities we would need ideally, the presence of more or less facilities would affect the experimental results' reliability compared to real on-the-field implementation possible outcomes.

After an analysis of DERri partners, the laboratories that offer facilities that best match our needs are:

- RISOE-DTU (Denmark) – *“The SYSLAB research facility is a full scale distributed laboratory for experimental testing of distributed intelligent power systems with real power system components in a safe and flexible environment”*. Great interest on the FlexHouse (more details needed)
[http://www.der-ri.net/fileadmin/user_upload/ERSE/transnational_access/10_RISOE.PDF]
- TUS-RDS (Bulgaria) – Possibility for a cross-cooperation between the ACSL, RELS and PEL laboratories.
- USTRAT (United Kingdom) – Possibility to test the logics on a small grid in islanding mode or connected to the grid. More details on the devices should be provided.

Synergy with ongoing research (about ½ page)

Provide information on any concurrent research project with the same or similar subject with the one proposed. Describe the synergy (if any) that will be sought between the existing and the proposed project.

The proposed project is in synergy with the following projects

- UTILTEC. The aim is the design and development of an innovative ICT-based low-cost infrastructure for electrical energy management, monitoring and remote load control for public utilities, residential customers and tertiary field.
- ENERTEC. The aim is the design and development of a management system for any kind of energy sources and exploitations at customer side, including distributed generation, demand response, load

control, and safety issues

- ENERGETICA MENTE [<http://www.energetica-mente.biz/pagine/pagina.aspx?&L=IT>]. The aim is to design and implement an ICT solution for the management and control of the centralised heating system of apartment buildings endowed with distributed accounting system for heat consumption.
- Fifth energy research program of German federal Government toward zero emission buildings, [<http://www.bmwi.de/BMWi/Navigation/Energie/energieforschung.html>]
- Latest European Commission directives on energy performance of buildings, [EU (2010), The Directive 2010/31 of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast). Official Journal of the European Union, accessed 24/06/2010], from [11]
- Canadian National Research Council (NSERC/CRSNG) projects on optimal energy consumption, [http://www.nserc-crsng.gc.ca/Professors-Professeurs/RPP-PP/SPGTargetAreas-SPSDomainesCibles_eng.asp#natural_resources]

Dissemination – Exploitation of results (about ½ page)

Describe the means through which the results to be obtained from the proposed project will be diffused and made broadly known.

- Technical articles for 2011 ANIPLA conference on Energy efficiency (Italian Association for Automation) www.anipla.it
- Dissemination article for “Energia e Automazione” (italian magazine Automation and Energy, published by ANIPLA)
- Technical paper for international conferences/symposia organized by IEEE, such as SmartGridComm, CDC, ISIE, INDIN, and and by IFAC.

Time schedule (about ½ page)

Provide an indicative time-schedule for the proposed work and a target starting date.

Target start date (M1): October 2011

Activity/Month	0	1	2	3	4
State-of-the-art	DONE				
Requirement analysis		X			
Designing		X			
Testing			X	X	
Dissemination				X	X

Description of the proposing team (as long as needed)

Give a short description of each member (organization and persons) of the proposing team including publications, experience in test campaigns and role in the proposed project.

The proposing team is made up of:

- Professor Luca Ferrarini
- Professor Guchuan Zhu
- Marco Pernice (researcher)

- Giuseppe T. Costanzo (Master student)

Luca Ferrarini

Luca Ferrarini received the "Laurea" Degree in Electrical Engineering (summa cum laude) from the Politecnico di Milano, Milan, Italy, in 1988, and a post-Laurea degree in Industrial Process Control, from the Master School CEFRIEL in 1990. In 1994 he was a visiting researcher in Kyoto University, Kyoto, Japan. Since 1990, he has been with the Dipartimento di Elettronica e Informazione, Politecnico di Milano, where he is full professor since 2004, teaching courses on industrial automation and discrete event systems.

He is author of 7 patents (5 Italian and 2 European) in the design and testing of industrial automation systems field, for large complex production plants. He is senior member of IEEE and collaborates with IEC, ISA, IFAC and ANIPLA (Associazione Nazionale Italiana Per L'Automazione), the Italian National Association for Automation of which he was national president in 2003 and 2004. He's author of around 160 scientific contributions, including 4 books, 4 book chapters, 25 journal papers. He has been tutor of 4 PhD students, and a hundredth of Laurea degree final projects (tesi). His research interests include discrete-event systems and Petri nets; control system development methodology for industrial distributed control and automation systems; modeling, simulation and control of manufacturing processes; monitoring and control of electro-thermal energy systems.

Guchuan Zhu

Guchuan Zhu received the M.S. degree in electrical engineering from Beijing Institute of Aeronautics and Astronautics, China, the Ph.D. degree in mathematics and control from the École des Mines de Paris, France, and the graduate diploma in computer science from Concordia University, Montréal, Canada, in 1982, 1992, and 1999, respectively.

Prior to join the École Polytechnique de Montréal, Montréal, Canada, in 2004, where he is currently an Assistant Professor in the Department of Electrical Engineering, he worked as Lecturer in the Department of Electronic Engineering at Beijing Institute of Aeronautics and Astronautics, Postdoctoral Researcher and Research Fellow at the École de Technologie Supérieure, Montréal, Canada, and Software Designer at SR Telecom Inc., Montréal, Canada.

Dr. Zhu has worked on a variety of engineering systems including airborne radar, flight control systems, network-based control systems, communication networks, electrical drive, electrical power networks, and microsystems. He has also worked in industry as Project Manager and Software Designer and has been involved in the development of diverse projects on wireless communication systems in which advanced real-time embedded systems and networking technologies were intensively used.

Dr. Zhu's current research interests include nonlinear and robust system control, distributed parameter system control, optimization, as well as their applications to microsystems, smart grids, and avionics communication systems.

Marco Pernice

He received the degree in Automation Engineering from the Politecnico di Milano, Milano, Italy, in 2009. His final dissertation project is on "Technical-economic simulations of thermal and electric generators for final users", consisting in a software package for automatic design and calculation of thermo-electric high efficiency generators. Currently, he is an assistant professor in the Dipartimento di Elettronica e Informazione (DEI) at Politecnico di Milano, Milano, Italy, focusing on didactic activities and research project of energy management

Giuseppe Tommaso Costanzo

He received the Bsc degree in Automation Engineering from Politecnico di Milano, Milan (IT) in 2008 with a thesis on Pabadi's Promise project. Currently he is master student in Automation Engineering at Politecnico di Milano at "Dipartimento di Elettronica e Informazione" and he is participating in a double degree program with Ecole Polytechnique de Montreal, Montreal (CA). Over there he is attending a Master of Applied Sciences at the department of Electrical Engineering - Control systems section. He worked as research assistant for winter and summer sessions of 2010 at Ecole Polytechnique de Montreal in the field of power generation plants control and he is now assistant at the electrical machines laboratory for the winter session 2011 at Ecole Polytechnique de Montreal. He is native Italian speaker and he can write and speak fluently English, French and Spanish.

Publications

Luca Ferrarini, Marco Pernice, "Modeling and Control of a Thermal Energy System in a Building Automation Scenario" INDIN 2009, Cardiff, 24-26 June, 2009.

M. de Chirico, S. Esposito, L. Ferrarini, P. Magni, C. Montecucco, S. F. Nicolodi, S. Radaelli, "Bringing efficiency through energy management: The UTILTEC Project", ANIPLA2006, 1st ANIPLA International Congress on Methodologies for Emerging Technologies in Automation, 13-15 Nov. 2006, Roma, Italy, paper T115.

Luca Ferrarini and Carlo Veber (editors), "Modeling, Control, Simulation and Diagnosis of Complex Industrial and Energy Systems", ISA series on Distributed Industrial Automation 2008, Product ISBN/ID: 978-1-934394-90-8. www.isa.org/modeling.

L. Ferrarini, J. Carneiro, "Preventing thermal overloads in transmission circuits via model predictive control", IEEE Transactions on Control System Technology, to be published, 2010.

L. Ferrarini, J. Carneiro, "Reliability Analysis of Power System based on Generalized Stochastic Petri Nets" PMAAPS2008, IEEE International Conference on Probabilistic Methods Applied to Power System, Puerto Rico, 25-29 May 2008.