User-Project Proposal:

Use-Project Acronym	SREI-MG
User-Project Title	Smart buildings and Renewable Energy Integration in Micro Grids
Main-scientific field	Automation and control
Specific-Discipline	Energy management systems, Intelligent energy 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	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)

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Activity type and legal status* of Organization	Higher Education Institute
Position in Organization	Ph.D. 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	
Re-submission	YES_______ NO___X___
Proposed Host TA Facility	
Starting date (proposed)	

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 Smart Buildings integration in micro-grids, which may host distributed generation from renewable energy sources. Followingthe point of view in [1] we adopt the “layered structure” of a Smart Grid and assumethat 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 Micro Grid under the Demand/Response paradigm.

Our aim isto develop a set of techniquesfor energy management (electrical and thermal) inbuildings and districts in the context of demand side optimization. Such a system enables customers to adjust their electric consumption so as to participate in the grid stability preservation. Therefore, this technology enables to augment local generation from renewable sources and integrate them with smart buildingsand distributed energy storage facilities.

The aforementioned system consists in a micro grid Energy Manager that can 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 at building level already partially available, the project aimsat exchanging design ideas for Micro Grid Energy Managers with industrial and research partners in Europe and at performing a field test in a MicroGrid.

The steps we plan to take include: assessment and refinement of the building energy management system the team designed and implemented during summer 2011 in collaboration with RISØ-DTU under the SEM-BADDERri project. Design and implement a Demand/Response system for energy pricing,test the demand-side management systemit in a commercial buildingand interface it with the D/R environment.

The expected outcomes of the project are: 1) a tested set of logics for real-time energy management in smart buildings and micro grids;2) a D/R manager for local energy market; 3)an implemented and tested version of an energy manager for micro grids. The project scopes include also feasibility assessment of such a technology, in the particular aim of integrating different DG sources and storages with residential and commercial customers.

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. Identifyanyknowledge gaps and theirrelevance.

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 inthe next century. In this context, building automation enables active collaboration between customers and utilities, which represent the basics of a new electrical grid paradigm, termed as "Smart Grid".

Beside the name "Smart Grid" there is a galaxy of different possible developments on either "hardware" and "software" aspects of power systems. Based on whatF. L. Bellifemine described in [4],the SmartGrid 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 andoptimization.

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 impactson [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 SmartGrid 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, CO_2 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]. Indeed, this latter subject is one of the most investigated scenarios that smart building technologies would enable.

D. Crawlery and collegues [13] define a Zero Net Energy Building as a “building that offset all its energy use from renewable energy sources available within the footprint.” This imply that all this kind of buildings have to reduce their energy consumption at first and then produce on site at least as much electric energy as they require in a year using demand-side load control and renewable energy technologies, such as daylight heating, advanced HVAC, solar panels, insulation, ground-source heating pumps, ocean water cooling, evaporative cooling, etc. In this article it is pointed out that, even though many simulations and studies support the feasibility of a ZNEB, in general the majority of these dwellings achieve to be “near” to the zero-net energy buildings. This is mainly due to optimistic assumptions about the tenants’ lifestyle and the solar radiation level. The penetration of ZNEBs addresses also a stability issue on power networks because, during low solar radiation, the energy peak-consumption in ZNEBs is even more pronounced than in typical buildings. Therefore, energy storage facilities should be integrated to limit this problem.

References such as [14] and [15] offer an economic feasibility point of view of ZNEBs, presenting studies for Newfoundland and Florida regions respectively, while [11] summarizes the state-of-the-art in regulations and active projects on ZNEBs. This latter reference is particularly interesting because it is up to date with the latest information coming from the 2010 European Commission directives on Smart Buildings.

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 objectivesand 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.

SREI-MG project is based on different already-existing research works on the demand-side management, and attacks the problem of Smart Buildings integration in micro grids through proper energy management. In fact this latter is the contribution of the project, which development and successful accomplishment would provide practical solutions for effective zero-net energy districts design.

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”, *IEEE International Symposium on Industrial Electronics, Gdansk (PO)*, June 27-30, 2011

[13] D.Crawlery et al., “Getting to Net Zero”, National Research Laboratory, Journal Article NREL/JA-550-46382.

[14] M. Iqbal, “A feasibility study of a zero energy home in Newfoundland.” Renewable Energy Review n.29, Elsevier, pp. 277-289.

[15] S. Kadam, “Zero net energy buildings: are they economically feasible?” Technical report, Massachussets Institute od Technology.

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 SmartGrids: 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 distribution level, attacking the problem of how to integrate local generation in the distribution grid by the means of demand-side optimization.The control aspect is the one we are more interested in, and the dwelling consumption control through 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:

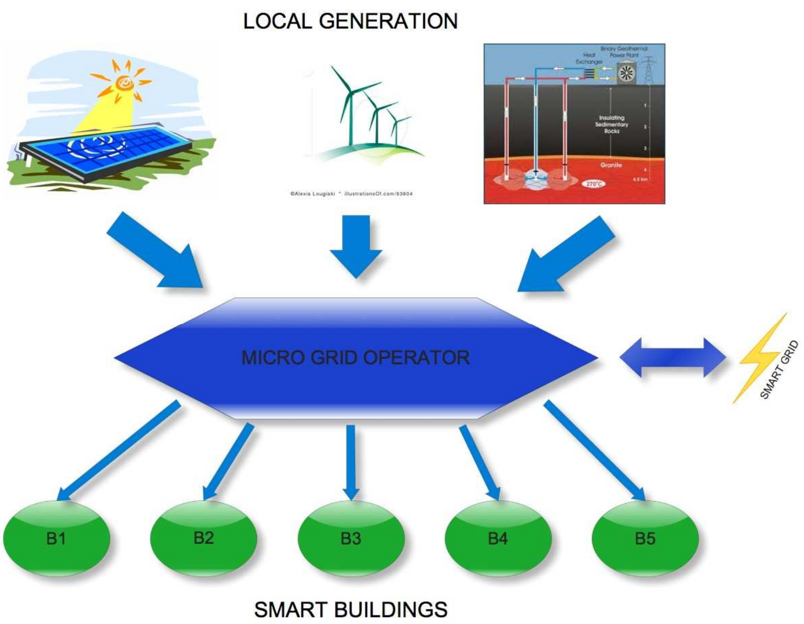

Fig. 1 – Micro Grid energy management structure

The previous schematic shows how we imagine the "actors" in a Micro Grid interacting within oneanother. It is assumed that DSM system in Smart Buildings is fairly operative, such as this project is oriented to the design of the modules at micro grid level and implementation. We leave open the possibility to integrate more modules in the grid manager, intending it as an “operative system for the micro grid” in a futuristic vision.This architecture 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.

Our project will follow two different and parallel directions: on one side to improve the scheduling algorithm in order to dispatch loads ahead in time while ensuring online-flexibility properties, and on 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 micro gridmanagement system design and interconnection with Smart Buildings and local generation facilities.

Operative steps will includethe integration of the Demand-Side load Management with the Micro-Grid by the means of Demand/Response, so as to test the behavior of this latter system in a real environment and show the benefits of using autonomous DSM as a mean for micro grid stability enhancement. In this context, the main actors are the following:

1. Customers (power sinks)
2. Utility (micro grid manager)
3. Power sources

Customers: are the energy sinks physically connected to the Micro Grid. Their consumption can be partially controlled.

Utility: is a software entity that manages all the devices branched in the micro grid in order to maintain the power production/consumption balance. Such a *grid manager* embeds a Demand/Response pricing system with a Proportionally Fair Price (PFP) method.

Power sources: we need flexible energy sources in order to test the DSM system performances in controlling the energy demand so as to follow the energy production. Renewable energy sources and diesel generator would do the job. Eventually a battery can be added, which would act as both energy source and sink.

The basic idea is to collect the power coming from the different sources and dispatch it to the clients using D/R. In this context each client is allowed to absorb a certain power so as the total instantaneous consumption should balance the production. The connection with the power grid will balance the energy gap (excess or lack of power in the micro grid). The expected outcome of these experiments is a proof of concept for the benefits of using such a DSM system as a mean of interfacing smart buildings with a micro grid with distributed renewable energy sources.The optimization would not only touch the electrical consumption, but also the thermal consumption.

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 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.

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"*.
- 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.

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
- Some thermal and electrical energy sources (HVAC, micro-CHP, micro turbines, PV, etc...)
- Data analysis facilities

The experiments themselves donot present high risks since they are not dealing with high voltage equipment and transmission lines. 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.

The scheduling approach is quite new as a technique for load-peak shaving policies.The basic algorithm is shown 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 within 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.

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]
- CASSANDRA Eu Project (2011-2014). It aims to build a platform for the realistic modeling of the energy market stakeholders,also involving small-scale consumers. CASSANDRA main outcomes will be the aggregationmethodology and the framework of key performance indicators for scenario assessment, as well as anexpandable software platform that providing different energy stakeholders with the ability to model the energymarket, in order to assess scenarios for their own purposes.

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 stat date (M1): ----

Activity/Month	**0**	**1**	**2**	**3**	**4**
State-of-the-art	DONE				
Requirement analysis		X			
Designing		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 (Full Professor, Politecnico di Milano)
- Giuseppe Tommaso Costanzo (Master Student, Politecnico di Milano)
- Marco Pernice (Researcher, Politecnico di Milano)
- Giancarlo Mantovani (Ph.D. Student, Politecnico di Milano)

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 (AssociazioneNazionaleItaliana 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.

Giuseppe Tommaso Costanzo

He received the BSc degree in Automation Engineering fromPolitecnico 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 EcolePolitechnique de Montreal, Montreal (CA). Over there he is attending a Master of Applied Sciences at the department of Electrical Engineering - Control systems section. He took part in DERri Project (SEM-BAD) in partnership with RISO-DTU and carried out the experiments in the FlexHouse installation (August 2011). He worked as research assistant for winter and summer sessions of 2010 at EcolePolytechnique de Montreal in the field of power generation plants control and he worked as assistant at the electrical machines laboratory for the winter session 2011 at EcolePolytechniqe de Montreal. He is native Italian speaker and he can write and speak fluently English, French and Spanish.

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

Giancarlo Mantovani

Giancarlo Mantovani received a MSc summa cum laude in Automation Engineering at Politecnico di Milano (July 2010), a MSc in Mechatronic Engineering at Politecnico di Torino (June 2011) and the Alta ScuolaPolitecnica (ASP) Diploma (June 2011), the school of excellence of Politecnico di Milano and Torino. He has been employed for six months in Enertech Solution, a start-up born from Politecnico di Milano, where he worked on the development of innovative monitoring systems for energy management. He is now a PhD Student at Politecnico di Milano, working in the field of ICT technologies for energy efficiency and smart grids.

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.

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G. T. Costanzo, A. M. Kosek, G.Zhu, L. Ferrarini, M.Anjos and G.Savard, “An Experimental Study on Peak-Load Shaving in Smart Homes by Means of Online Admission Control”, paper submitted for ACC2012 – American Control Conference, June 27-29, 2012, Montreal (CA).