DERri
Distributed Energy Resources
Research Infrastructures

ANNEX 2: TEMPLATE FOR PROPOSAL UNDER DERRI

User-Project Proposal:

Use-Project Acronym	W&S_IC
User-Project Title	**W**ind power and **S**torage modeling and **I**ntegrated **C**ontrol in electric distribution systems
Main-scientific field	electrical engineering – power system operation
Specific-Discipline	Power system control

Lead User of the Proposing Team:

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Activity type and legal status* of Organization	Higher Education Institution (1)
Position in Organization	Assistant 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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Activity type and legal status* of Organization	Higher Education Institution (1)
Position in Organization	PhD student 3rd year

* 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___X____
Proposed Host TA Facility	RISO (DK)
Starting date (proposed)	January 2011

Summary of proposed research

The project is aimed at describing the models of generation sources and storage systems for implementing integrated control strategies of a renewable generation park composed by wind turbines and batteries. The storage system is characterized from an electrochemical and thermal perspective, while the wind turbines have an electro-mechanical characterization. The purpose of the energy storage system is to be coupled to the wind generation system in order to realize different tasks: to have the generation output power smoothed and to grant no power transfer, for a certain period on Distribution System Operator (DSO) request, at the point of common coupling in any battery state-of-charge condition.

The goal of the activity (still in progress in the national context) is to develop simulation models for MV grids with renewable and Distributed Generation (DG) for different operation conditions: interconnected to the distribution grid, islanding mode with privileged loads supplied and in transient conditions (when the plant forms an intentional island and when it is connected again to the public grid). These simulations also aim to verify the most critical automation strategies before implementing them and to test them in test facilities available in large research centers. These models are likely to become simulation instruments used to support the electric utilities in the forecasting of their grid behaviours in case of a significant DG penetration.

The main aim of the project is to validate models of wind turbines and storage systems and integrated control strategies of the whole resulting system thus describing and testing the benefits that the storage system can provide.

State-of-the-Art

The electric power system is facing an evolution from the traditional concept of energy generation by few localized power plants interconnected through a meshed system to distributed medium and small scale generators [1], [2], [3], [4].

Moreover some typologies of these generators embedded into the distribution network are fed by renewable sources like wind and sunlight. Their main drawback is their hardly predictable behaviour and uncontrollable output. This means having for example maximum production during minimum demand period or excess of generation in congested parts of the electric network, thus causing bottlenecks and overvoltage situations in some critical sections of the grid [5], [6], [7].

The presence of energy storage systems may allow a better management of the electric system allowing the full exploitation of renewable energy sources. Nowadays the cost per stored energy is quite high and so it might not be economically feasible to install huge amount of batteries. The size of the storage systems can considerably vary and, depending on their sizes, different tasks can be performed as shown in Fig. 1 [8].

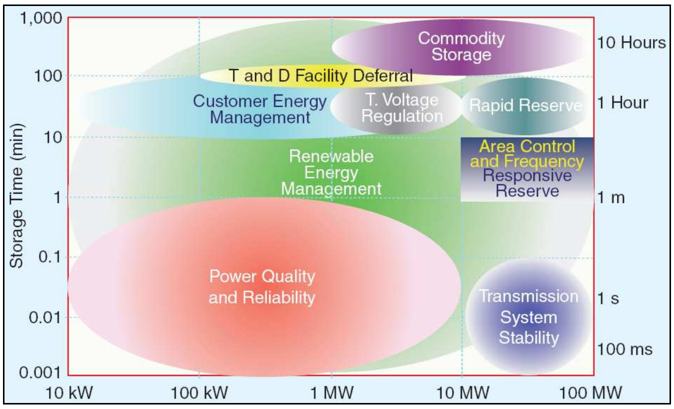

Fig. 1. Storage power requirements for electric power utility applications

Hence the possible duties range from short-term fluctuation levelling and power quality improvement to primary frequency-power regulation and, in case of large storage sizing, compliance to day-ahead generation dispatching [9]. Distribution companies start to recognize that storage has the unique ability to act as a buffer between the grid and generation that is either intermittent or not controlled by the utility. Although electricity storage technologies have changed substantially over the past decade, making them economically feasible remains the greatest challenge for utilities. Besides its strategic value, electricity storage offers many more tangible values that, if added up, would exceed the cost of deployment.

References

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Detailed Description of proposed project : Objectives – Expected Outcome – Fundamental Scientific and Technical value and interest

Detailed description of the proposed project

The modeling of wind park and the relative control architectures are an important part for the introduction of relevant quantity of renewable energy in the future smartgrids. Therefore there is a strong necessity to have proper validated models to help operators to perform better studies and to be more confident with the results.

In order to fully exploit wind generation capabilities, there is a great attention to couple wind generation to storage systems. The storage model proposed below is suited for electrical studies and has a general validity. For this activity it has been tuned on the specification of a Vanadium Redox battery. The analyzed dynamic regards the SOC (State of Charge) behaviour, the electrochemical one and the thermal one.

The wind turbine model is suited for a full converter direct drive equipped generator. This typology of wind turbine is characterized by the absence of gearbox and the presence of ac/dc/ac converter sized for the whole power. The dynamic analyzed regards the aerodynamic efficiency of blades, the maximum power tracking characteristic and the blade pitch control. Since the model is not intended to analyze dynamics faster than a fraction of second, there is no need to characterize in a detailed way the generation/conversion system, which thus is modelled as a negative load.

Because of the interest in studying the fluctuation induced in the turbine power output it is also necessary to have appropriated wind speed data.

For the considered wind generation storage system, the idea is to control the battery charging and discharging in order to control the whole plant output. The park controller sets the reference power that the storage system has to accomplish. This controller is equipped with a PI regulator and is sensible to the error between the power produced by the all wind turbines and the expected reference power. Moreover it is present in the control loop another contribution sensible to the SOC level of the battery. This control reduces or increases the battery reference power with the purpose to keep the SOC in an adequate range so that storage is always available.

Objectives

The proposed project will have the following objectives:

1. Validate models for wind turbine and controllers
2. Validate models for storage systems and relative controllers
3. Implement and test control strategies for the combined system

These objectives require the following components from the testing infrastructure:

1. Wind turbine
2. Electrochemical storage
3. Measurements of the most significant electrical and mechanical parameters, power flows and environmental properties
4. Assistance in the development of functionality in the SCADA system for the interaction of the controller with the equipment (i.e. OPC link, etc.).
5. User training on safety procedures would be expected. Health and safety assessment will be performed before the beginning of the experimental work.

A series of testing and operational scenarios will be run, during which the performances of the single models and of the overall system will be evaluated. In particular different operational scenario will be tested for validation:

- stand-alone single model validation for parameter tuning
- smooth the wind power output
- no power transit at the PCC (Point of Common Coupling) for a certain period (i.e.30 min)
- power and energy controller

Power flows, other typical characteristics of the system (i.e. pitch angle, SOC, battery voltage, ecc.) and environmental conditions (wind speed, temperature, atmospheric pressure, ecc.) will be recorded and analyzed. The effect of wind fluctuation compensation operated by the storage will be tested.

The most significant challenge about the project development will be the unexpected difficulties that are usually present in experimental campaign.

This will be taken into consideration with a correct planning and allocating sufficient time for each task.

The experience of laboratory staff to implement control algorithm on the infrastructure would be extremely important to complete the project.

Expected Outcome and Value

The expected outcome is the validation of the model for the analysis of short and long term dynamics. Moreover the demonstration, on a laboratory scale, of the coupling between wind generation and storage will be measured and documented in detail. Indication will be reached on the ability of storage to effectively compensate wind fluctuations and on the number of charge-discharge cycles necessary to perform such task.

The results and conclusions will be reported and also disseminated in the scientific community and in relevant publications.

Originality and Innovation of proposed research – Broader Impact

The proposed project addressed the issues related to wind power turbulent output and to the medium voltage electric network overloading. The coupling with a storage system can grant some benefits in term of controllability of wind park output.

If controlled in the right way the storage system can in fact smooth the turbulent output of wind turbines and allows to store wind power in case of orders by the DSO to reduce or to have zero power output at PCC. A detailed model of storage as well as a model of a wind turbine will be validated.

These experimentations also aim to verify the most critical automation strategies before implementing them in real contest.

Moreover this project will indicate the charge-discharge cycles to be performed by storage, that is actually the most critical aspect of these components.

These models are likely to become simulation instruments used to support the electric utilities in the forecasting of their grid behaviours in case of a significant DG penetration.

Proposed Host TA Infrastructure/Installation – Justification

As described above, the proposed project requires micro-grid installation which includes renewable energy sources and specifically wind turbines. The proposed host TA is RISO in Denmark, for the following reasons:

- presence of wind turbines to validate single model and to test the wind park controller algorithm
- presence of a Vanadium flow battery of comparable size with respect to wind turbines
- the SCADA system should provide all the relevant information necessary for model tuning and provide a good architecture (Ethernet based) to test new controller
- the infrastructure staff has extensive experience in aspect design, development and operation of VPP (Virtual Power Plant) controller

For the above reasons, it is assumed that the infrastructures offered by RISO are very qualified for the scope of the research.

No significant additional costs would be expected, as the measuring requirements are not too much stringent and a complete SCADA system is present.

Synergy with ongoing research

A national project on smart grid, starting in November 2010, will be focused on the definition of a DMS (Distribution Management System) architecture for the inclusion of renewable energy sources.

Dissemination – Exploitation of results

The results of the tests performed in TA would be disseminated in national and international appropriate per-reviewed journals and conferences.

Time schedule

	Week					
Planning for proposed project	1	2	3	4	5	6
Introduction to the infrastuctures, definition of requirements and measurements, develop safety procedures						
Adaptation of wind park controller to equipment:						
- definition of SCADA interface and testing						
- definition of metering						
Stand alone testing for model validation						
- wind turbine						
- storage system						
Whole system testing						
Analysis of results						

Description of the proposing team (as long as needed)

The **IEES** Lab operates within the Department of Naval and Electrical Engineering (DINAEL) in the University of Genova. IEES is contributing in the following scientific and industrial sectors: Management and optimization of the electric system and of the energy and ancillary services markets. Power system monitoring and preventive-corrective Control. Analysis, modelling and simulation of power system components and controls. Decision support systems and artificial intelligence (AI) applications to the planning and control of large power systems and industrial systems. Advanced technologies and methodologies for power systems protection. Electric distribution systems with distributed generation (DG). Innovative technologies for electric power microgeneration. Real time load monitoring and management for consumption rationalization and energy saving. Systemistic and design aspects of lighting engineering and domotics. The testing methodologies make use of integrated traditional simulation procedures and informatics techniques derived from AI, such as expert systems and neural networks.

The research group has well-established links with the industrial and scientific world with which it co-operates tightly in the definition and development of its own activities. Moreover **IEES** is represented in national and international normative and research coordinating Bodies in the sector. The **IEES** Lab is strongly involved into the industrial world through several and significant research contracts with sector industries and EU Frameworks.

The IEES Lab is equipped with software tools for the analysis of large power systems and of industrial electric systems through advanced calculation tools in the context of decision support systems and neural networks development (Gensym G2), of static and dynamic network studies, such as load flow, stability, short circuits, harmonics, protections coordination, electromagnetic transients and control systems analysis (DigSILENT, PSCAD/EMTDC, ATP, MATLAB). The Lab has carried out studies related to small and medium size, and renewable, Distributed Generation and their relevant validations on test grids of EU project co-partners.

The Lab has activated a real time Monitoring and Intelligent Control system of the electric consumptions of the Genova University (annual estimable consumption about 23 GWh); this system consists of 19 measurement points at MV electric energy meters and in the automatic collection of the consumptions every 15 minutes. These consumptions are transmitted to a centralized server, they are analysed and assembled into load curves aimed to operate evaluations for energy saving and for loads optimal management.

Samuele Grillo was born in Alessandria, Italy, in 1980. He received the "Laurea" degree in electronic engineering in 2004 and the PhD degree in electrical engineering 2008, both from the University of Genoa. His research interests regard optimization, automatic control, neural networks and machine learning and their application to power systems.
Stefano Massucco received the Doctor degree in electrical engineering at the University of Genoa, Italy, in 1979. From 1979 to 1987, he had been working at the Electrical Engineering Department of Genoa University, at CREL - the Electrical Research Center of ENEL (Italian Electricity Board) in Milano, Italy, and at ANSALDO S.p.A. in Genoa, Italy. He has been Associate Professor of Power Systems at the University of Pavia and since 1993 at the Electrical Engineering Department, University of Genoa, as Full Professor since 2000. His research interests are in power systems and distributed generation and smartgrids modelling, control, and management. Member of CIGRE Working Group 601 of Study Committee C4 for “Review of on-line Dynamic Security Assessment Tools and Techniques”.
Mattia Marinelli was born in Genova, Italy, in 1983. He received the "Laurea specialistica" degree in electrical engineering in 2007 and is currently pursuing the PhD degree in electrical engineering, both from the University of Genova. His research interests regard wind and solar data analysis, distributed generators (mainly wind turbines and storage systems) electromechanical modeling and integration studies of renewable energy sources in power systems.
Andrea Morini was born in Milano in 1964. He obtained his Laurea Degree in Electrical Engineering cum laude in 1990 and his PhD in Electrical Engineering – Electric Power System in 1994. From 1994 to 1999 he had been with Gensym Corporation working on Artificial Intelligence applications to Industrial Processes. Since 1999 he has been Assistant Professor at the Electrical Engineering Dept. University of Genova. He is Regional Responsible for AIDI – Italian Association for Lighting. Scientific Responsible for National Projects, Member AEIT, IEEE – PES.
Andrea Pitto was born in Genoa on March 2, 1981. He received his Doctor degree in Electrical Engineering at the University of Genoa, Italy, in 2005. He also received a PhD in Electrical Engineering at the same university in 2009. He is currently a research assistant at the Electrical Engineering Department of the University of Genoa. His area of interest includes probabilistic and deterministic approaches to power system security assessment, DG modelling, control and interface with distribution networks, application of bifurcation theory techniques to power systems analysis.
Federico Silvestro received the degree in electrical engineering from the University of Genoa in 1998 and a Ph.D. in electric power systems in 2002, with a dissertation on artificial intelligence applications to power system management and control. He is now a Research Assistant at the Electric Engineering Department, University of Genoa, where he is working in distributed generation and smartgrids, dynamic security assessment, knowledge based systems applied to power systems.