TEMPLATE FOR PROPOSAL UNDER DERRI

User-Project Proposal:

User-Project Acronym	MiWEM
User-Project Title	Microgrid Wireless Energy Management with ESS
Main-scientific field	Distributed Generation system, Energy Management Control
Specific-Discipline	Control in Power Electronics

Lead User of the Proposing Team:

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Activity type and legal status* of Organization	Higher Education Institute
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)

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Activity type and legal status* of Organization	Higher Education Institute
Position in Organization	PhD Candidate

* 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	28/6/2012
Re-submission	YES_______ NO___X____
Proposed Host TA Facility	TA6 - Fraunhofer Institute for Wind Energy and Energy System

	Technology (IWES)
Starting date (proposed)	15th December

Summary of proposed research (about ½ page)

The penetration of renewable energy sources in small-scale power production gives the opportunity parts of the grid to work as microgrids. The microgrid should be able to work both in grid-connected and island mode, while its voltage and frequency deviations follow the EN 50160 standard. The use of energy storage system is recommended in order to absorb the mismatches between the demand and the generation side and to preserve the quality of the microgrid voltage.

While the up to day research is mainly concentrated on energy management based on communication, this team proposes a wireless method for keeping the voltage and the frequency within the limits, using a battery as an energy storage system (ESS). The battery capacity is calculated by a newly-invented analytical method, having as parameters the maximum power of the load and the total duration time of the islanded operation. The active and reactive power sharing among the parallel sources is achieved using (1) the droop control method, (2) an algorithm proportional to droop characteristic and (3) the rated apparent power of each resource. According to the values of frequency and voltage and the State of Charge (SoC) of the battery, the battery is introduced in the microgrid, working in charging or discharging mode. Another operation of the battery inverter is the grid detection and the elimination of the transient effects during the connection with the utility grid. The proposed wireless control method is expected to operate the microgrid with a high quality voltage in both grid-connected and islanded mode under several load scenarios.

State-of-the-Art (about 1 ½ page)

Droop control Method: A method for controlling the output of the inverter of a DER, emulating the function of a synchronous generator. The real and reactive output power is controlled by the frequency and the magnitude of the output voltage respectively [1]. This method can be used as a communication method between different DERs, using the frequency and the magnitude of the output voltage as communication parameters. The droop coefficients are calculated proportional to the apparent power of each DER. [2]

Virtual Impedance: Due to different R/X ratio between the interconnection lines among the several DERs [3], the real and the reactive power will be coupled, inducing the system stability. The traditional droop method is modified by the virtual impedance control [4-7] minimizing the effect of the interconnecting line.

Energy Management with Communication: The energy management is based on communication between the several DERs, loads and usually a central manager, which is placed at the Point of Common Coupling (PCC) [8-10].

Decentralized Wireless Control Method: The power sharing among the several DERs is carried out without communication, based on a decentralized philosophy [11].

ESS: In order to keep the voltage and the frequency within the limits determined by the EN 50160, an Energy Storage System can be added to the microgrid. The ESS can absorb any mismatch between the power production and consumption [12,13] and ensure a seamless transition between the grid-connected and the island mode [14].

Grid-Island detection: Many methods have been proposed for detecting the island condition in the microgrid. They can be divided in three categories: passive methods, active methods and communication-based methods [15]. In the proposed research an active method is selected for detecting the grid, which does not present ant Non-Detection-Zone (NDZ) [16].

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

Scope of this proposal is the evaluation of a new wireless energy management method suitable for microgrids with distributed renewable sources and changeable loads. The proposed microgrid consists of two inverter-interfaced DERs, an inverter-interfaced battery acting as ESS, a constant-power load and the utility grid. The microgrid should be able to work both at grid-connected and island mode, while its voltage profile follows the EN50160 Standard. A switch is necessarily placed on the grid side for isolating the grid and transacting the microgrid function from grid-connected to island mode. The battery is placed at the Point of Common Coupling (PCC) with the utility grid, in order to provide the microgrid with the proper amount of active and reactive power, by absorbing any mismatch between the power production and consumption in case of islanding. Furthermore, the inverter of the battery carries out the grid detection control. This control is based on an active control, which modifies the injected current and measures the disturbance by means of a Phase Locked Loop (PLL). The DERs lack of any other communication connection between them; the energy management is carried out using the voltage magnitude and the frequency as communication parameters. The following figure features the microgrid.

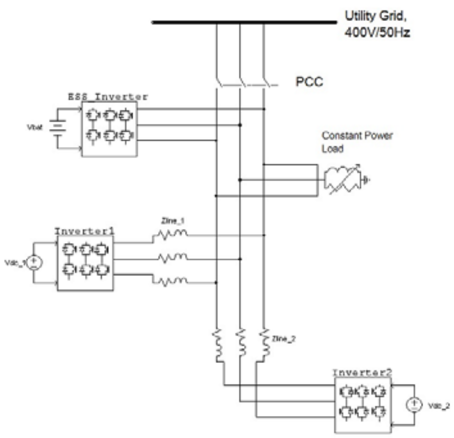

Figure 1 Proposed microgrid with two inverter-based DERs, a battery as ESS and a constant power load

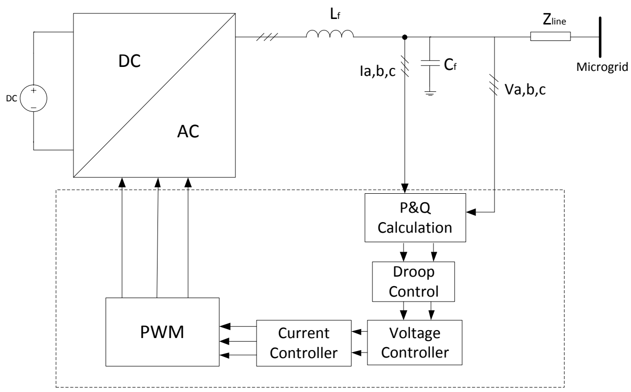

Figure 2 Proposed Microgrid Control System

The inverter of each DER takes as inputs the voltage and the current at the output of the inverter. The control system consists of the following parts:

- Active and reactive calculation block
- Virtual impedance modified droop control block
- Voltage and current control block
- Decoupling control block
- Pulse Width Modulation (PWM) block

The voltage and current control block uses the Park transformation, which are also used to calculate the active and reactive power. The input signals to PWM control are produced by the inverse Park transformation. The control angle in the abovementioned calculations accrues from the frequency – real power droop control, while the input voltage at the voltage control from the voltage – reactive power droop control.

Furthermore, the role of the battery is to ensure a seamless transition between the grid-connected and island mode. The battery is connected to the microgrid through an inverter. The input signals of the inverter are the State of Charge (SoC) of the battery, the voltage and the current at the output. The control system accomplishes the following controls:

- Phase Control Loop (PLL) for the frequency calculation
- Grid/Island detection block
- Current control block
- PWM block

When the utility grid is connected or the load absorbs less power than the power produced by the DERs, the battery operates in charge mode. Instead, its function mode changes to discharge mode, when the load absorbs more power than the aggregated power of the DERs. During the synchronization of the microgrid with the utility grid, the function mode of the battery depends on the voltage magnitude and frequency at the PCC, which are defined by the difference between the power generation and consumption.

The goal is to demonstrate experimentally that the proposed wireless energy management method is able to work under several load scenarios with and without the existence of the grid. Furthermore, the proposed analytical method for calculating the battery parameters will be tested.

Indicative type of TA infrastructure:

- Three completely controllable three-phase inverters
- Tree LCL filters for the output of each inverter
- Two types of generators. As generators can be used photovoltaics, gas engines, wind generators, etc. The nominal apparent power can be a few kWs
- A dc battery having a capacity of few Ahs
- A constant-power load. Such load can be any domestic load, as for example a refrigerator
- A three-phase utility grid with a controllable switch

Number of tests to be carried out:

1. Real time simulation of the microgrid connected with the utility grid, in order to verify the battery charge control algorithm.
2. Same topology as in (1), where the output of the renewable source varies, in order to test the effectiveness of the droop control algorithm. The same topology will also be tested in island operation mode.
3. Real time simulation of the transition between grid-connected mode to island mode and vice versa. The goal of this test is to verify the seamless transition and the effectiveness

of the synchronization control algorithm of the battery.

4. Real time simulation of the microgrid in island mode with different load scenarios. The active and reactive power will change, absorbing more power than the aggregated power of the renewable sources aiming to check whether the voltage profile follows the EN 50160 Standard.
5. In all the previous tests the power line losses will be measured for different line parameters.

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

The proposed work intents to introduce a new wireless energy management method with SoC control of ESS for microgrid applications. The ESS is connected only when the load demands more power than the aggregated generation of the DERs. Furthermore, the several DERs lack of any other communication connection, using the magnitude of the voltage and the frequency as communication parameters. The software simulation results verified that the microgrid can function under several load and renewable source changes, while the voltage profile remains within the limits imposed by the Standard EN 50160.

Moreover, an analytical expression for calculating the battery capacity is also proposed, considering the maximum period of time that the microgrid voltage can remain within the preassigned limits for a certain load increase. By the means of this calculation, the energy manager will be able to dimension the battery capacity correctly and calculate the total period of time, which the microgrid would operate in island mode under a known maximum load.

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

A complete controllable microgrid should be available in the host infrastructure. The test infrastructure will include two inverter-interfaced power sources, an inverter-interfaced battery, a constant power load and the utility grid. The DERs can be any renewable resource, such as photovoltaics, wind generator, solar thermal etc. or any conventional generator (gas or steam generator) with controllable output. The storage device could be a chemical battery, fuel cell, flywheel or supercapacitor. The utility grid should have a controllable switch and have the opportunity to be disconnected, in order the microgrid to be able to work in island mode. Finally, it would be desirable the ability to download the control algorithm from PSIM to the inverter microprocessors, as the proposed control scheme is simulated in PSIM software.

The measurement equipment should be allocated in different places in the microgrid in order to monitor the selected parameters, such as voltage, current, active and reactive power. The power electronics of the inverters should be completely controllable.

The team proposes the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) in Germany.

Synergy with ongoing research (about ½ page)

No other similar project is ongoing in the electrical machines laboratory.

Dissemination – Exploitation of results (about ½ page)

The results will be included to in the upcoming paper for a journal in order to strengthen the results from the simulation software. Among the candidate journals can be included the following:

- IEEE Power and Energy magazine
- IEEE Transactions on Sustainable Energy
- IEEE Transactions on Industrial Electronics
- IEEE Transactions on Power Electronics
- IEEE Transactions on Power Systems
- IEEE Transactions on Energy Conversion
- ELSEVIER Electric Power Systems Research
- ELSEVIER Energy Conversion and Management

Furthermore, part of the results will be presented in an international conference subject to distributed generation and power electronics in the following months.

Time schedule (about ½ page)

Tasks	Time
1. Familiarization with the laboratory infrastructure. All the possible experimental scenarios with the necessary control of the power electronics will be designed.	1st Week
2. The experiments of the microgrid control will be carried out. The microgrid will be tested under grid connected and island operation mode. The transaction from the grid-connected mode to the island mode will also be checked. The measurements will be compared with the simulation results.	2nd Week
3. The Wireless Energy Management control will be tested under several load scenarios. Furthermore, the grid detection control will be tested as a part of the control of the battery. At the end, a final test report will be presented.	3rd Week

Description of the proposing team (as long as needed)

Konstantinos O. Oureilidis was born in 1984. He received the Dipl. in electrical engineering from the Aristotle University of Thessaloniki, Thessaloniki, Greece, in 2008.
Currently, he is a Ph.D student at the Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki. His research interests are in the fields of power electronics, distributed generation and renewable energy sources.

Charis S. Demoulias was born in 1961. He received the Dipl. and Ph.D. degrees in electrical engineering from the Aristotle University of Thessaloniki, Thessaloniki, Greece, in 1984 and 1991, respectively. Currently, he is an assistant Professor in the Electrical Machines Laboratory, Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki. His research interests are in the fields of power electronics, harmonics, electric motion systems, and renewable energy sources. His main published papers are the following:

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The **Electrical Machines Laboratory** belongs to the Energy Section of the Electric and Computer Engineering department of the Polytechnic School of Aristotle University of Thessaloniki and was founded by Professor Ioannis Xypteras in 1984.

The staff of the Laboratory includes two Assistant Professors, two assistants and five Post-Graduate Students. The **Electrical Machines Laboratory** has two main facilities, one in Building D' 5th floor (110 sq.m.) and one in Building E´, 2nd floor (100 sq.m.).

The laboratory serves educational and research needs in the fields of electrical machines (design, modelling, analysis of operation), power electronics (design, construction and design, power converters) drive systems and electrical machinery (control of electric motors and generators, inverters, solar power, wind turbine control systems, etc.).

The Electrical Machines Laboratory serves for:

- Laboratory exercises for six semester courses of the undergraduate studies,
- Laboratory diploma theses
- Doctoral theses
- Research papers and research programs
- Providing services to individuals and organizations

The aim of the research department of the laboratory is to produce new knowledge, which can

be incorporated in the educational process and promote the science of electrical engineering.