TEMPLATE FOR PROPOSAL UNDER DERRI

User-Project Proposal:

User-Project Acronym	D.I.R.E.C.T.
User-Project Title	Development of Innovative Renewable Energy Conversion Techniques
Main-scientific field	Electrical Engineering
Specific-Discipline	Wind Energy

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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 Institution
Position in Organization	PhD Candidate

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status* of Organization	
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	
Re-submission	YES_______ NO_______
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)

The proposed research work studies the interconnection methods of small and medium scale Wind Energy Conversion Systems to the utility grid through a three phase power converter. The research will study the inverter hardware structure and control strategy, and evaluate the performance of the inverter under certain operating conditions.

The studied system consists of a Wind Turbine mechanically coupled to a generator, which can be either squirrel cage induction generator, wound rotor, or permanent magnet synchronous generator and a rectifier that transforms the AC voltage at the generator output to DC. The DC link is connected to the utility grid by means of a power converter that converts the DC voltage to AC with appropriate frequency that corresponds to the network frequency, and injects the produced energy to the grid.

The proposed research studies the performance of the inverter at certain conditions, including the connection methods of an inverter to the grid during the start up of the wind turbine, the performance and the ride-through capability of the system during grid faults, such as single and three phase short circuits and loss of a phase. Furthermore, the operation of the converter will be examined and evaluated, regarding the efficiency, current and voltage total harmonic distortion and reactive power control strategy. Several control schemes will be tested and the collected data will be used as reference and for comparison with experimental data acquired from the experimental system established in our laboratory.

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.

The interconnection of Wind Energy Conversion Systems to the grid has been studied in the literature in the past. In [1] the performance of a voltage source inverter on grid voltage disturbances and voltage dips is examined. It is concluded poor performance of the inverter on unbalanced dips is located on the current controller loop, due to the negative sequence component of the grid voltages. The authors propose the use of two controllers, one for each voltage sequence; however this increases the hardware needs of the inverter and the computing power needed for the control. In [2], the effects of symmetrical and unsymmetrical voltage sags on induction machines are examined. In [3] a dead beat controller is proposed that improves the performance of dead beat control of voltage source converters at saturation. In [4, the effect of balanced and unbalanced voltage sags on adjustable speed drives is examined, however, there is no concern on the performance in case the machine operates as a generator. In [5], the effect of balanced and unbalanced voltage sags onlarge scale wind turbines utilizing DFIG is examined, and the in [6] and [7] the ridethrough capability of large scale wind energy conversions systems utilizing synchronous and doubly fed generators respectively is discussed; however there is no concern of the behavior of the system when squirrel cage induction generators are used on small and medium scale wind energy conversion systems. In [8], a reactive compensation technique is discussed that improves the ridethrough capability of wind turbines during grid disturbances, and a control strategy is proposed in [9], in order to improve grid fault ridethrough capability of DFIG wind turbines. Finally, the improvement of fault ridethrough capability of wind farms with series dynamic braking resistors is discussed in [10].

The self excitation of an induction generator has been investigated in [11] and [12], based on the remnant magnetism of the induction generator rotor. The authors propose the use of capacitors and demonstrate the startup capability of the proposed control schemes. An extensive overview of the self excitation methods of an induction generator has been conducted in [13]. However, further investigations on cost effective and reliable self excitation capabilities of induction generators driven by wind turbines need to be conducted, in order to achieve optimum operation and interconnection of the wins energy conversion system in the utility grid.

References

List relevant References

[1] Saccomando, G.; Svensson, J.; Sannino, A.; , "Improving voltage disturbance rejection for variable-speed wind turbines," Power Engineering Society Summer Meeting, 2002 IEEE , vol.1, no., pp.502 vol.1, 25-25 July 2002

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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.

Aim of the proposed work is to evaluate the operation of a grid connected inverter that works with a wind energy conversion system. The activities that will be carried out include study several control schemes regarding the start up of the wind turbine and the connection of the inverter to the grid, operation and performance of the inverter on several wind speed conditions, including several wind speed levels and transients, measuring the total harmonic distortion of the inverter current and voltage output, as well as operation of the inverter with different reactive power control schemes. Finally measurements will be performed for the evaluation of various control strategies for the detection of grid faults and control schemes on fault occurrences, such as short-circuits or loss of a single phase at the grid side and the ride through capability of the wind energy conversion system under these faults and excess electrical energy dissipation on system faults.

An experimental setup including a wind turbine coupled to an induction generator will be required. The system should have a generator side converter, for the conversion of the alternating voltage output of the generator to DC and the control of the generator-turbine system speed, and the output should be connected to the utility grid through a three phase converter and a power filter for the reduction for the injected current and voltage harmonics. An emulated wind turbine system by a controlled motor with specified wind speed and various wind speed profiles is preferable. The equipment of the infrastructure should be able to measure wind speed, torque at the turbine shaft, rotational speed of the generator, voltage and current outputs of the generator, DC-Link voltage, inverter voltage and current outputs as well as grid side current and voltage outputs at the point of common coupling.

Firstly, the system will be used for the examination of the start up and self excitation methods of an induction generator. Various control schemes will be applied and their performance will be observed and evaluated. The evaluation criteria include the stability of the proposed control strategy, especially with high wind speeds during startups, efficiency of the proposed control method, safety risks that are included with each one, cost, etc. Aim of the specified test is to produce an extensive report on the performance of every control scheme and control methods that will produce the best results will be proposed.

The proposed test is of importance, as wind energy conversion systems suffer of frequent breaks due to low wind speeds. Therefore, the wind turbines are often forced to stop their operation when the wind speed drops below the production limit, and then connect again when the wind becomes sufficiently strong. Therefore, frequent connections and disconnections of the wind energy conversion system occur during; consequently, a control scheme for the connection of the system to the grid is important, as an optimized connection scheme will raise the produced energy, reduce the grid side faults that occur due to improper connection and improve the system stability.

Further tests are intended, regarding the operation of the wind energy conversion systems under various wind speed levels and during transients. An experimental setup as described above is required. The wind speed will be set on different levels, from low wind speeds up to the nominal wind speed of the wind turbine, and the performance of the system will measured and recorded. Furthermore, several wind profiles will be supplied to the system for the examination of the system on transients. The wind speed, the wind turbine shaft torque, the rotational speed of the generator are the mechanical variables of the system that will be recorded. The electrical variables include the generator output voltage and current values, the DC link voltage and current, and the inverter voltage and current outputs, as well as the voltage and current values at the point of common coupling with the utility grid. The control techniques used for the system and the inverter will be evaluated, regarding the quality of the power injected to the grid. The total harmonic distortion of the current and voltage at the point of common coupling will be measured and the operation of the inverter under different wind speed conditions and transients will be evaluated. Moreover, the inverter reactive power control will be tested, by injecting reactive power into the grid and measuring the performance of the system, as well as the voltage level at the grid side.

The measurements mentioned above are of great importance, as inverters suffer from high emission of harmonics, mainly at the current injected to the grid. This can lead to electromagnetic compatibility problems due to electromagnetic noise emission, which affects nearby electronic equipment, causing telecommunication problems, faults at electronic devices etc. Moreover, voltage harmonics can pollute the grid, causing increased distortion which is a reason of failures on electronic devices connected to the utility grid. Therefore, the grid manager imposes limits on the emitted harmonics of the output current and voltages of inverters. The tests will also measure the performance of the inverter with variable reactive power output, which is demanded for modern inverters. In order to prevent voltage drops or excessive voltage raise, the inverter can regulate the reactive power injected to the grid according to the demands of the grid manager with the power factor of the inverter capable of being adjusted as leading or lagging. However, low power factor reduces the ability of the inverter to inject the produced power to the utility grid, due to the limits imposed by the maximum current of the inverter bridge. A correct control technique should be applied, that achieves optimum performance of the inverter and maximum active power injected into the grid, while keeping the voltage level limits imposed by the utility grid manager by regulating the reactive power of the inverter accordingly.

Finally, a set of tests will be carried out that will examine the performance of the inverter fault prevention techniques. Various grid side fault conditions will be examined, including short circuit of a single or all three phases, line voltage drops, loss of one or more phases. During the tests, fault conditions will be reproduced on various operating conditions of the wind energy conversion system and the inverter response will be recorded and evaluated. When a grid fault occurs, the normal operation of the inverter is disrupted and actions need to be taken in order to maintain control of the system, otherwise undesirable effects may occur, such as loss of synchronization to the grid frequency, overvoltages, excessive currents that may damage the system. Moreover, during faults, the inverter loses its ability to inject the produced power into the grid. As a result, certain actions need to be taken to dissipate the excessive electrical energy produced by the generator. As a result, overvoltages on the DC link may occur which can damage the system. Fast detection of the fault is crucial as it allows actions to be taken to prevent the system from being damaged. Such actions include dissipation of the produced electrical energy on a resistor coupled to the DC link side of the converter in order to prevent overvoltage of the DC link. In case of phase loss or short circuit the inverter should detect the fault and respond accordingly, in order to prevent damage from overcurrents. Moreover, the system should rarely come to a stall during faults, as it needs to be reconnected and return to its normal operation as soon as the network is restored and the fault is corrected. Therefore, proper control of the system is needed, that achieves protection from faults and restores the operation of the wind energy conversion system immediately when the faults are corrected.

The above tests will be conducted on the TA test site, with equipment provided by the host. Various control methods will be tested and the results will be recorded. The obtained measurements will be used as reference and comparison with the data acquired from tests conducted on our laboratory will be conducted.

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 proposed research is part of an extensive research of our team on small and medium scale wind energy conversion systems. The research aims at setting the grounds on cost effective, efficient and reliable power generation from the wind. The part of the research that investigates the interconnection of the wind energy conversion system to the grid is of great importance, as it investigates new and more efficient control methods for the system connection during start up. This can lead not only to increased power production of the system, but also reduced number of startups and shut downs, as well as more efficient interconnection of the system, with less transients and avoidance of overvoltages and overcurrents, which can lead to grid faults, lower power quality and safety issues.

The improvement of the ride through capability of the system leads to better grid integration of the wind energy conversion systems, and the capability of staying on line even during grid faults improves the network stability and the quality of power provided to the end users. Furthermore, fault ride through specifications specify that wind turbine generators must remain connected to the grid during voltage sags. Proper control of the wind energy conversion system should be applied, not only to ensure the successful connection to the grid, but also protection of the system from excessive currents, which are results of the voltage sags caused by grid faults, such as single or three phase short circuits. Lack of the proper control strategy and fault detection from the converter can lead to system malfunction or even destruction of the 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.

The research facility that most probably meets the needs of the proposed tests is believed to be the Fraunhofer Institute for Wind Energy and Energy System Technology IWES, DeMoTeC, as the facilities incorporate the necessary equipment needed for the performance of the tests. The infrastructure includes a 20 kVA Variable Speed Genset which uses an inverter at its output, as well as a 80 kVA WEC/ Grid Simulator and a 15kVA Mini Grid / WEC Simulator that can be used for the tests. Moreover, the test facilities include a Control and Visualization unit that can be used for the observation and record of the needed variables during the test.

Moreover due to the relevance of the facilities to the studied subject of Wind Energy Conversion Systems, the team reckons it is the most suitable facility that can accommodate the intended tests, and the staff can more efficiently comprehend the needs of the application.

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.

Currently, the team is conducting research regarding the design of a complete Wind Energy Conversion System, aimed at small and medium scale wind turbines using induction machine generators. The members of the team are studying the operation of the system in order to improve the efficiency of the generator and expand the exploitable wind speed region towards the lower wind speeds. The proposed research will supplement the current research allowing the team to study the integration of the Wind Energy Conversion System in the utility grid and develop methods of efficient interconnection of the system with increased safety and efficiency.

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.

The obtained results will be used as a reference and will be compared and used along with measurements taken in our laboratory. The collected data will aid the ongoing research by providing reliable measurements that will support our research. The collected data may also be used for a publication of an announcement on scientific conference.

Furthermore, the collaboration of our team with the institution that will be visited, may lead to an establishment of a long term cooperation that will aid both parts in producing quality scientific research.

Time schedule (about ½ page)

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

Our team, consisting of two persons, Mr Mesemanolis and Mr Karakasis, plans on visiting the test site around the 9^{th}- 17^{th} of April 2012. The indicative time schedule of our visit is as follows:

- Day 1 : Arrival in the host city, settlement, and familiarization with the local and facility premises, acquaintance with the local collaborating team.
- Day 2 and 3 : On site scheduling of the performed test, familiarization with the equipment, planning of the tests that will performed
- Day 4 and 5: Performance of the tests, collection of data
- Day 6 and 7 : Evaluation of the collected data, discussion of the results with the local collaborating team

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.

Lead member of the team is Dr. Christos Mademlis, Assistant Professor at the dept. of Electrical and Computer Engineering, Polytechnic School of Aristotle University of Thessaloniki. Dr. Mademlis has a long experience on electric machines and drives and he has conducted extensive research regarding the subject. He has published various articles in scientific journals, and has extensive experience with research projects, being the scientific director of a number of projects in the pasts. Currently, he is leader of a project regarding Wind Energy Conversion Systems. He will be the coordinator and scientific director of the proposed project.

Mr Athanasios Mesemanolis is a graduate of the dept. of Electrical and Computer Engineering of Polytechnic School of Aristotle University of Thessaloniki and is currently working towards his PhD thesis on Wind Energy Conversion Systems. On the proposed project, he will visit the infrastructures in order to conduct the tests and process the measurements.

Mr Nektarios Karakasis is a graduate of the dept. of Electrical and Computer Engineering of Polytechnic School of Aristotle University of Thessaloniki and is currently working towards his PhD thesis on Wind Energy Conversion Systems. Along with Mr Mesemanolis, he will visit the infrastructures and perform the needed tests.

Publications:

[1] Mademlis, C.; Xypteras, J.; Margaris, N.; , "Loss minimization in synchronous motors," *Industrial Electronics, 1995. ISIE '95., Proceedings of the IEEE International Symposium on* , vol.1, no., pp.297-302 vol.1, 10-14 Jul1995

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