DERri
Distributed Energy Resources
Research Infrastructures

PROPOSAL UNDER DERRI

User-Project Proposal:

User-Project Acronym	DEMOC
User-Project Title	Distributed Electricity generation with Multi-Objective Control
Main-scientific field	Electrical Engineering
Specific-Discipline	Operation and Control of Distribution Systems

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Activity type and legal status* of Organization	4
Position in Organization	Senior Research Engineer

* 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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Position in Organization	Researcher

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Date of submission	30 June 2012
Re-submission	NO
Proposed Host TA Facility	TA4: CRES - Pikermi (Greece)
Starting date (proposed)	22 October 2012, or 7 January 2013

Summary of proposed research (about ½ page)

The project aims to implement multi-objective optimal control for distributed energy resources in a portable and accessible manner.

Multi-objective control of distributed energy resources is an approach that can be used to maximise deployment of distributed renewable energy resources in existing distribution networks while ensuring safe operation within system boundaries. The basic idea is to have a dynamic assessment of the distribution system's state by using available measurement devices and a coordinated control approach when limits such as voltage boundaries or thermal capacity limits are approached. Where control priorities conflict, compromises can be made based on a priority weighting set by the operator.

The Multi-OBjective (MOB) controller at the heart of the system is a software application written in the Python programming language, which makes it portable across a wide range of computer hardware and operating systems. Open standards and open interfaces are leveraged for interconnection of the control system and distributed resources. After a test phase using simulation models of distribution grids with varying penetration of controllable resources, the workability of the system is sought to be demonstrated in a real-world test environment.

State-of-the-Art (about 1 ½ page)

Control systems for distribution grids have been developed in many commercial and research projects with a wide range of objectives. Functions always start with the capabilities of DER units and implement a certain set of higher level functionality on top of that. Such functions can be:

- *Peak shaving, managing congestion, helping to avoid network component reinforcement where possible, thus improving efficiency*
- *Voltage control*
- *Virtual power plant operations for active power and reactive power*
- *manage frequency and voltage in island operation*
- *optimized dispatch for loss reduction*
- *optimized dispatch for market interaction/monetary benefit*
- *contribution to ancillary services (frequency control support by providing control reserve)*

Where multiple functions of a different nature are desired at the same time there can be conflicting requirements. For example, an operator in the distribution system may wish to increase reactive power output in response to a request from a transmission system operator, but if the voltage at this point in the grid is already high, the injection of further reactive power could drive the voltage-

controlling scheme close to its limits. Such conflicts are usually resolved by using simple priority schemes, but often do not allow for more sophisticated control where compromises can be made between priorities set by the operator.

References

The Cell Controller is one of the most advanced control systems for DER:

http://energinet.dk/EN/FORSKNING/Nyheder/Sider/Den-ustyrlige-vind-kan-styres.aspx

While it implements many functions that can even operate at the same time, it does not have multi-objective control.

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

The aim of our research at CRES would be to test software developed at Energynautics for the control of distributed generation systems, with a particular emphasis on renewable sources. The Multi-OBjective Controller (MOB Controller) is designed for real-world conditions, where grid operators make multiple, possibly conflicting, demands on the assets under their control. The MOB Controller can take a list of instructions and, when they are not simultaneously realisable, can make the best possible compromise based on a priority weighting set by the user. It also prioritises generation assets with a preference for renewable energy; it only ramps up fossil fuel sources to avoid load-shedding.

The Controller takes multiple set points from the user and then has several modes of operation:

i) voltage control mode, in which it steers the assets to maintain voltage on the grid within a set band;

ii) virtual power plant mode, in which it aims to provide a set active and reactive power to an external grid connection;

iii) a cost control mode, where costs set by the operator for the various assets are minimised, even when this contradicts the preference for renewables;

iv) and finally a mixed multi-objective mode, when it tries to match all of the voltage, power and cost set points as specified by the user. Because these may be conflicting goals, the MOB Controller makes a compromise based on a weighting set by the user as to which goal is more important.

The MOB Controller continuously monitors and steers the assets under its control through an OPC interface. A measure of intelligence is built in, so that the Controller can monitor the response of the assets to its instructions and, if necessary, adjust its behaviour based on past experience.

The goal of our tests at CRES would be to test the software's performance and robustness under increasingly stringent conditions. We would first test the Controller with easy settings, for example that the voltage at all measure points should be within 10% of the default and that no power be fed to the outside grid. With each test we would tighten the conditions to see if the software can cope. The idea would also be to measure the performance of the MOB controller under different priority weightings of its set-points, to see how well it handles conflicting commands.

For equipment we would need a functioning microgrid, including at least:

i) several PV arrays;
ii) batteries;
iii) backup generation, such as a diesel generator;
iv) realistic loads;
v) active and reactive power controls for as many assets as possible;
vi) a realistic network, with impedances to represented longer lines/cables;
vii) sufficient measuring devices to measure the voltage at multiple points;
viii) an OPC server to handle communications between the assets and the MOB Controller.

If any of capabilities i) through iv) is lacking, we will attempt to simulate them as best as possible through the software.

If there is time left at the end, the MOB Controller also has a Multi-Agent setting, where we can model other Controllers in software and see how they interact with our real Controller connected to the real-world assets.

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

The ability to make the best compromises based on multiple objectives is the primary innovation we would like to test at CRES. This functionality is based on the real-world demands of network operators and would be built into a final product that, when in operation, will have a direct impact on the performance and reliability of distributed generation. The MOB Controller is designed specifically to prioritise renewable energy sources when they are available, and we hope it will contribute directly to sustainable growth within Europe. The choices of OPC for the communication interface and Python for the software implementation were made to ensure maximum portability across operating systems and generation assets, so that the Controller can be used in as wide an array of environments as possible.

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

The CRES facility in Pikermi, Greece (TA4) would best serve our testing needs. It has the generation assets we would need for realistic testing, a selection of different dummy loads, some reactive and active power control points, and an OPC server. We have already been in contact with CRES about the finer points of our proposal, in particular the need for impedances to simulate lines/cables, the power setpoint controls and the OPC interface.

Synergy with ongoing research (about ½ page)

We are cooperating with a few German distribution system operators on different projects in the area of Smart Grids and the integration of increasing amounts of distributed generation (mainly based on renewable energy sources).

Testing the MOB controller at CRES will provide us with the real-world test experience that simulation testing cannot provide, and allows us to drive further development ahead in a practicable manner. This will help us approach a state where the system can eventually be tested in a distribution system with real customers.

Dissemination – Exploitation of results (about ½ page)

Test results of the MOB controller in simulation and laboratory testing will be presented in a paper that is to be submitted to the CIRED conference 2013 in Stockholm (10-13 June 2013).

Time schedule (about ½ page)

It is estimated that one week (five work days) will be appropriate to carry out a succession of tests, starting with basic function tests to more elaborate multi-function tests. The following preliminary schedule is proposed:

Day 1 – Basic setup, function tests of communication paths

Day 2 – Verification of remote control and measurement functions

Day 3 – Virtual power plant mode function tests with various set points

Day 4 – Voltage control mode and basic mixed multi-objective mode tests

Day 5 – Buffer (can be used for more advanced multi-objective mode tests if days 1-4 went smoothly)

Proposed starting dates would be either 22 October 2012, or 7 January 2013.

Description of the proposing team (as long as needed)

Nis Martensen received his Dipl.-Ing in Energy Systems Engineering from the Technical University of Clausthal, Germany in 2002. From 2003 to 2008 he worked as a scientific assistant at Technical University of Darmstadt, conducting research on the large-scale integration of small CHP units into virtual power plants. He received his Ph.D. from the Technical University of Darmstadt in 2010. He joined Energynautics in 2008, where he has been responsible for the advanced dynamic modeling and simulation work of the Cell Controller Pilot Project. His fields of interest are power system computing and modeling, energy efficiency, and usage of renewable energy.

In his role in the Cell Controller Pilot Project, he developed test specifications for CHP generators and joined the on-site test team to gather the measurement data. He used this data for validation of the dynamic CHP models. He also took part in field tests of the Cell Controller system. He will be leading the test team in the proposed project.

Stanislav Cherevatskiy graduated from Karlsruhe Institute of Technology in 2010 where he studied electrical engineering. He completed his first practical experience on distributed generation during his internship in the Off-Grid Test Center at SMA Solar Technology. In the diploma thesis that followed at energynautics, he developed black start strategies for electrical grids run by distributed generation units. He continues working in this area as part of energynautics' team since July 2010.

Tom Brown studied Mathematics with Theoretical Physics at the University of Cambridge, England, receiving a BA in 2004 and an MMath in 2005. After a PhD in Physics (2005-2009) and a two-year position as a postdoctoral researcher at the DESY in Hamburg, he joined Energynautics in 2012 as a researcher for the integration of renewable energy in power systems. He is the lead developer of the MOB controller software.