UNIQUE VIRTUAL POWER SYSTEM TECHNOLOGY USED IN A LOW POWER NETWORK TO PROVIDE SOLUTION TESTING FOR DISTRIBUTED GENERATION

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INTRODUCTION

To fully test electrical machines, it is desirable to have full control over the network to which they are connected. Control of the networks impedance, voltage, and frequency, and the ability to be able to test machines under network fault conditions are all desirable attributes for a test facility. There is particular interest in testing machines at present, since the machine parameters for generating electricity from intermittent renewable sources are unlike those parameters from gas or steam turbines, and there are concerns relating to grid stability under scenarios with high penetrations of renewable generators.

ELECTRICAL EQUIPMENT DEVELOPMENT ROUTE

Traditional approach

The traditional development route for electrical equipment is to develop software models of the equipment performance and simulate its performance using packages like MathCAD and Simploter; build a prototype which is subjected to extreme testing regimes in test labs such as the Clothier laboratories in the UK to prove the product’s safety performance; and to fit the equipment into a network under controlled conditions to monitor its performance.

Simulation has a number of drawbacks. The software models of the device and the network are only as good as the assumptions behind them so errors in the representation of the device being modelled, the network to which it is attached or the conditions under which it is being modelled can all lead to imperfect results. Granularity of the results relies on the detail within the models so to get extremely accurate results needed to study areas such as transient performance, the model, modelling package and assumptions are tested severely. There is evidence that different modelling packages running the same models [1] can give slightly different results. Simulation is also difficult where unbalanced transient performance is being studied since most elements in packages assume balanced conditions so many of the results can become distorted.[2]

Fitting electrical devices in a network is in some ways the ideal step. Demonstration in a network allows confidence to be built, real network conditions to be experienced and a range of practical issues to be resolved. There are however a number of drawbacks to this approach. The jump from simulation to full scale prototype can incur a relatively large cost hike in terms of production of the prototype. Further the resources involved in getting a prototype to the area of network to be installed, the installation itself and the operation of the test all imply a major cost penalty compared to laboratory operations.

The level of risk increases when accessing a distribution network. There is a financial risk to the prototype and to the network, were the prototype to fail. Prototype mal-installation or failure could also lead to a safety risk to the network operator’s staff or the public. Installation of prototypes is clearly a higher risk activity since there is no experience on which to build. Risk to quality of supply in terms of power loss, power factor, harmonics or flicker are all risks that are undertaken when testing a prototype on a network. Further the impact of the network on the device under extreme conditions and on the network from the device under extreme conditions are risk areas which need to be addressed.

Access to networks and safety issues may impact to delay the project, leading to cost overrun or failure to hit the market in time. Testing on networks also carries a risk to the information being sort. If extreme conditions on networks are sort then these can be may not arrive in a timely fashion. Network tests to get field experience may not lead to representative data, for example it is possible to test 50 micro combined heat and power units and not have a single representative sample.

NaREC Approach

The New and Renewable Energy Centre (NaREC) in Blyth, Northumberland, UK has built their EnergyLINK laboratory to compliment their other testing facilities for marine energy, 70m wind turbine blades, Clothier high voltage testing and photovoltaic cells. The EnergyLINK laboratory is aimed to address the problems of embedded generation; comprises a flexible range of facilities targeted at micro-generation, power train optimisation and evolving active networks. The power train optimisation market is served in part by an intermediate test area where software model simulations can be translated into hardware model emulations. This allows scale models of the principle generation technologies to be run in configurable networks where, for example, faults can be thrown and the physical response of the generator running a control algorithm under test can be measured. The simulation code can
therefore be tested in a safe, easy access environment when compared to a real network.

Improvements in the experimental process are therefore in the areas already stated in terms of lower financial, safety, network performance and failure to capture information risks. Further the boundary between experimental planning and field prototype can then be blurred to allow configuration options to be explored in a low risk but physical environment.

**Physical equipment**

The EnergyLINK laboratory has a number of physical pieces of equipment including a doubly fed induction generator, a pair of synchronous generators one with a variable inertia, a DC generator and diesel generator. While this covers several of the dominant technologies, new technologies are always being developed. To keep abreast of these, NaREC in conjunction with the University of Newcastle-Upon-Tyne, UK has developed Virtual Power System (VPS) technology in the form of fully controllable current and voltage sink/sources.

**VIRTUAL POWER SYSTEM TECHNOLOGY**

VPS technology builds upon the concept of the Virtual Machine (VM) [3,4]. The VM allowed electric drives to be tested at full power levels without the need for a real machine to be present during the testing and development of the inverter. The VM contained a real-time simulation model of the machine, and this was used to control the currents drawn from the inverter under test to match the currents which would be drawn if it were connected to the real machine. The VPS takes this idea further and is a real time, real power level, controllable sink/source which is capable of emulating a full range of power systems and loads via the appropriate real time simulation model. In this way, the VPS can be used to emulate any generator, motor or mechanical load system. This allows a full range of machine types to be tested or provided for network testing. At NaREC, VPS technology is primarily designed to test renewable energy inverter systems and how these integrate into networks. The generator that will test the inverter’s operation is played by the VPS.

The VPS is designed around a standard Control Techniques® inverter drive system capable of regenerative braking which has been modified to allow control by external state of the art dSpace® DSP equipment. A block diagram of the VPS is shown in Figure 2.
As an example of its application, we will assume that the VPS is representing a wind turbine driven 48 pole permanent magnet machine (Figure 4 and Figure 5). Under these conditions, the operation of the VPS is summarised by the following steps:

1. The VPS is provided with statistical and parametric data taken from an actual wind turbine.
2. The VPS contains a real time simulation of the 48 pole permanent magnet machine. With the wind turbine data included, it is possible for the VPS to determine turbine speed and torque signals. (Figure 4).
3. The VPS representation of the 48 pole permanent magnet machine converts the speed and torque into voltage and current signals. (figure 5).
4. The VPS takes mains power (400V, 50Hz) from the NaREC supply. This is converted into controllable current waveforms (at a variable frequency) that represent the real permanent magnet machine currents produced when connected to the inverter under test. For the VPS to determine the current waveforms, inverter under test output voltage and inductor current feedback is required.
5. The inverter under test output voltage is a Pulse Width Modulated waveform (Figure 6). Since the VPS is microprocessor controlled it is a sampled system. It is therefore necessary to determine the average applied voltage of the inverter under test over the sampling period of the VPS. Custom built voltage measurement equipment is used to feedback this average output voltage of the inverter under test to the VPS.
6. The inductors at the output of the VPS, linking the VPS to the inverter under test, allow current flow between the two inverter systems by filtering of the current waveform. (Figure 7).

The VPS Technology can also work in reverse, representing a motor or any balanced load. This allows NaREC to also use it integrated in network circuit as a power sink. Since the VPS regenerates back into the grid system, it is a very economic load bank.

**GENERATOR MODELS**

NaREC have built a 15kW Doubly Fed Induction Generator (DFIG) which has a dSpace controller capable of running a variety of control algorithms. The rotor converter is fully rated to allow flexibility in determining the optimum configuration, and the crowbar is also capable of control rather than a straight switch. There is significant interest in making DFIG generators ride through faults with the same characteristics as a synchronous generator riding through faults.
The England & Wales Transmission system requires generators to ride through network faults [5] where the voltage drops and recovers within the following operating envelope

![Fault envelope for England & Wales](image)

Figure 8. Fault envelope for England & Wales

In order to simulate the fault and the wind turbine drive train, the model will be complex and prone to errors. By running the control system on a reference hardware model, the system can be tested and tuned to look at all voltage notches. NaREC will use their VPS hardware to control the voltage to represent the faults, and their DFIG hardware to explore the fault ride through issues, putting both systems within the same circuit. This represents a major advance in the research facilities available for examining these problems.

### SMALL SCALE GENERATORS

When purchasing a micro generator (or any renewable powered generator), one of the main issues is establishing how much power will be generated in your application. For large scale developments, great efforts are made to try and establish the size of the resource prior to installation. For small scale generators, however the market will be quite segmented, with for some the kudos of generating their own power from renewable sources being enough, through to those who are bulk purchasing on a mainly economic criteria and where minor changes in performance specification could have profound implications on the investment decision.

Quoting the expected output of a micro-generation unit, such as a micro CHP unit or a wind turbine is not particularly helpful in establishing the annual output that the unit will generate. The output from small scale generators which rely on the elements for their power, such as wind turbines or photovoltaic cells, clearly need to take into account the prevailing weather conditions at the location where the turbine is to be mounted.

The output from small scale combined heat and power generators is influenced by the external weather conditions around the building, the buildings heat load which is in turn influenced by the insulation, desired temperature and other uses of the heating system, for example drying clothes. It is important to understand the heat demand of a range of houses to be able to establish which generator will perform the best in the situation. CHP and standard boiler efficiency is affected by run time and thermal input requirements.

At NaREC we are working to establish the thermal and electrical profiles of the UK housing stock in order to determine realistic thermal and electrical profiles that will test the CHP units efficiency and determine is the buildings electricity is being imported or exported. The import or export of electricity is important in determining the value of the investment since export is worth only a fraction of the import price.

Once the loads have been established, again NaREC expect to use their variable power technology to provide loads and extreme condition testing for micro generation units.

### REFERENCE


