Development of a Distributed Intelligent Load Controller

The objective of this task was to develop equipment and systems to ensure that networks with high levels of distributed renewable energy generation are operated effectively and economically, and specifically to develop hardware and control strategies for effective load management.

When applied to autonomous power systems, load control can be used to avoid overload by shedding non-essential loads. It can be used with renewable energy/diesel systems to improve the penetration from the renewable source by shedding non-essential loads where necessary to avoid starting the diesel. Load controllers can also be used to fully load the renewable energy generator in times of plentiful supply thus making best use of the energy while it is available and providing good control of system frequency.

When applied to grid-connected power systems, load control can be used to increase penetration of wind energy in medium voltage networks. In many rural areas, which are ideal for wind energy generators, one of the main limiting factors to implementation is the electrical characteristics of the existing network. The most common limiting factor for distributed generation on networks £15kV is steady state voltage change. Controlling customer loads on these weak networks would provide the potential to limit voltage rise and thereby increase the amount of wind generation that can be installed.

For renewable generation schemes embedded in private networks (e.g. factory, community), the electricity generated has a higher value if used internally, especially if it can offset electricity that might otherwise need to be imported in the near future. Load control using deferrable heat loads (e.g. heaters, freezers, washing machines) can enable this.

Results:
- Development of communications capabilities for load control device
- Modelled grid connected applications to demonstrate ability to mitigate voltage rise and reduce power export from a community with embedded generation
- Modelled off grid application to demonstrate ability to control system frequency in wind-only scenario

Test results for stand-alone wind only system, load controllers providing frequency control
TECHNICAL DETAILS

A. Development of controller with communications

Hardware was added to the existing load controller to provide power line carrier communications capabilities. Radiometrix TX2 and RX2 low power radio units operating on 433.92MHz were chosen. The original switching circuit was replaced with a TRIAC to enable faster and more frequent switching.

Associated software was then developed for the communication system, for both uni-directional and bi-directional communications. Testing indicated that both communication methods operated satisfactorily over distance.

New software for the controller itself was also developed. This included algorithms for:
- Frequency and voltage measurement
- Fuzzy logic controller membership
- Random function
- Self-tuning

B. Grid connected power system models with load control

Voltage Rise Mitigation

Simulations to assess the potential of distributed load control to address voltage rise problems caused by distributed generation were carried out which showed that load control was able to maintain the voltage rise below 6% of the nominal value during maximum generation and minimum “normal” load demand. This proved that the load control system could effectively mitigate the voltage rise problems.

Zero Export Management

Simulations to assess the performance of a distributed load control system for ensuring zero power export to the grid were carried out for a 22kW wind turbine. The results of the simulations showed that the load control system was able to ensure close to zero power export to the grid. On some occasions, a small amount of the power output was exported to the grid, however the amount exported was negligible and the period of time during which the power was exported was extremely short.

C. Autonomous power system models with load control

This work first compared the performance of a torque-based model using a distributed governing load controller system, with a more complex detailed electrical model. This work showed that electrical models were suitable for representations of power systems when modelling parameters for electrical machines were available. These electrical simulations, however, were computationally intensive. Hence, they were inconvenient for the simulation of extended periods of time. Simpler torque and power based models were less computationally intensive and therefore allowed for simulations to be carried out over extended periods of time and with the benefit of added complexity in other areas, such as models of communications and self tuning control techniques.

A torque based simulation of the autonomous power system on the Island of Rum (prime power source 30kW hydro) was then used to investigate the potential of distributed governing load controllers for providing frequency regulation on this autonomous power system. This model included a representation of self-tuning behaviour which had improved the frequency control during site testing. The frequency was well controlled in steady state conditions, so a power based model was then created. This model was used to investigate the effect of adding communications to the power system on the Island of Rum. Results suggested that central coordination of intelligent load shedding devices could increase the value of the energy available to users of the power system.