SPECIAL REPORT FOR GROUP C6
(Distribution Systems and Dispersed Generation)

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Special Reporter

Introduction

The scope of SC C6 is *to assess the technical impacts and requirements which a more widespread adoption of DG and which a larger proportion of presently not dispatched power generation could impose on the structure and operation of transmission and distribution systems"*. Rural electrification, demand side management methodologies, including management of the DG and application of storage are within the scope of this SC.

The debate about the expected benefits of the development of the DG concept and some drawbacks raised by their integration in the power electric system, especially in areas where the penetration achieved significantly high levels, is still receiving great interest. Limited dispatching capability and fluctuation of DG output (as in the case of wind generators) create some concern in system operators and calls for suitable integration rules; the development of new energy management and control systems are also reported. Such systems may also consider the management and control of demand as a suitable option to face local electricity requirements.

The SC decided to propose for discussion in the CIGRE 2006 General Session three preferential subjects dealing with:

- Operating systems with dispersed/renewable energy resources (DER/RES),
- Demand management (DM) and demand response (DR),
- Innovative distribution systems facilitating widespread deployment of DER.

25 reports were selected for discussion in the General Session. The main issues raised in the reports are summarised hereunder, together with some questions to solicit a lively and profitable discussion.

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1. Preferential Subject 1 - Operating systems with Dispersed Energy Resources (DER) or Renewable Energy Resources (RES)

Preferential Subject 1 received 12 papers addressing various aspects of the operation of power systems with renewable energy resources connected either to transmission or distribution networks. Authors were drawn from 10 countries reflecting the international interest in the topic.

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1.1 Operating systems with DER

Paper C6-101 reports early results from the EU DEEP project supported under the FP6 programme of the European Commission. The paper is in the three parts, studies of small systems with 100% penetration of Dispersed Energy Resources, investigation of increasing penetration levels in traditional systems with an emphasis on distribution networks and consideration of high levels of Dispersed Energy Resources on major power systems. The last topic will be studied further by the project in 2006. Although the results are presently still preliminary the early indications are that, although the various integration issues require careful study, it is unlikely that they will pose material restriction to the connection of Dispersed Energy Resources in many power systems.

The development of Dispersed Energy Resources in Italy is described in paper C6-110. This contribution pays particular attention to the regulatory environment and how that influences the development of Dispersed Energy Resources. To date the focus of the Italian Regulator has been on continuity and quality of supply with only limited attention paid to operation and management of distributed generation. This regulatory uncertainty poses difficulties when active distribution networks are considered. The paper also provides an interesting insight into how ICT might be used for control of distributed generation and reports on-going research work being undertaken at CESI.

Question 1.1: How material are the technical barriers to operating power systems with Dispersed Generation? At what level of penetration does the cost of integrating Dispersed Generation become significant?

Question 1.2: Is the regulatory framework for the integration of Dispersed Generation being developed at the appropriate speed and are adequate incentives for system operators in place? If not, what can be done to stimulate this process?

1.2 Ancillary services provision from Distributed/Renewable Energy Resources.

The subject of ancillary services and how Distributed/Renewable Energy Resources should move beyond merely supplying energy and contribute to the operation of the power system was the subject of a number of papers. It is clear that as penetrations of Renewables (particularly wind power) increase, this topic will become increasingly important. The question of how to ensure delivery of ancillary services and the role of Grid Codes was raised in several papers

Paper C6-103 specifically addresses the contribution of wind farms to ancillary services. It considers a range of wind turbine architectures including conventional fixed speed induction generations, doubly fed induction generators and those using fully rated power electronic converters. Voltage/reactive power control can be provided by wind turbines incorporating power converters while additional STATCOMs or SVCs may be used with fixed speed induction machines. Simulations are used to show how frequency control is possible using either fully or partially loaded wind turbines.

A rather similar approach is proposed to provide primary control response of the Nordic power grid in Paper C6-113. This suggests using increased inertial response from variable speed wind turbines and a short boost of mechanical input from both fixed speed and variable speed wind turbines for frequency response. Simulations of the Nordic power grid are used to demonstrate the techniques.

Spanish experience of integrating and operating large wind farms is discussed in paper C6-106. This is a joint paper by the TSO and a large wind farm operator. It discusses how the output of a large fraction of the high wind power penetration in Spain (now 10 GW) is reported to the TSO within 10 seconds and this data is used for network control. It also discusses recent developments in market mechanisms to encourage wind farm operators to contribute to local reactive power/voltage control and also fault ride through capability.

Question 1.3: ***What ancillary service functions should be required or requested from Renewable Energy Resources? How should these services be obtained, through mandatory requirements specified in the Grid Codes or through market mechanisms?***

Question 1.4: What progress is being made towards ensuring consistency among the various national Grid Codes for functions to provide ancillary services? Is consistency an important objective and, if so, how should this be encouraged?

1.3 Power System Communications for Dispersed Generation

The key aspect of power system communications in systems with high penetrations of DER is addressed in paper C6-104. This reports findings from the German research project “Network for energy and communications” and begins with a discussion of how the provision of network services is likely to migrate from large central generators with increasing use of DER. The papers shows how the data models and services of standard IEC 68150 can be mapped on to various physical layers and an example is given of its application on a typical medium/low voltage network.

Question 1.5: What are the communication needs of DER and how should these be developed given the uncertain development of small scale generation?

1.4 Wind Forecasting

Wind power forecasting is recognised as offering important benefits to power system operators who have significant wind generation in their area. Paper C6-105 describes experience in the development and use of forecasting tools from Germany. Meteorological data from the German weather service is used and the output power of the distributed wind farms is estimated using artificial neural networks

In addition to the estimates the system provides tolerance bands to indicate the uncertainty of the forecasts.

Question 1.6: What are the prime objectives of wind power forecasting in large power systems and how do these vary for different types/sizes of power system (e.g. Ireland, GB, German, and Spain)? Do the functions required vary with different market arrangements?

Question 1.7: If the applications of wind forecasting vary (as suggested in Question 1.6) then how should the effectiveness of the different forecasting tools be measured and compared? Should a set of standard performance measures be developed and agreed?

1.5 National Experience

Paper C6-102 from Brazil, reports the state of progress of the development of wind power in that country and the evolution of the National Grid Code to include significant wind generation. Brazil has a very extensive transmission network with a peak load of about 82 GW. There is presently only 28 MW of wind generation although there are plans to increase this to 1.4GW. The National Grid Code will be revised in 2006 to include consideration of fault-ride-through and wind forecasting, both key issues of increased integration of large wind farms in power systems.

Paper C6-108 describes the development of dispersed generation in Iran and places this in the context of global trends. A renewable energy organisation (SUNA) has been established and tariffs are in place to support generation from renewable sources. However, to date only limited capacity has been installed and the paper discusses what steps might be taken to accelerate deployment of DER and DES.

Paper C6-111 discussed the technical issues of the connection of DER and the development of connection guidelines in Malaysia. To date there has been only limited connection of DER and Renewable energy in Malaysia and the paper reports on a research project initiated by the utility to address barriers to connection. A “Technical guidebook for the connection of generation to the distribution system” has been developed and the main aspects of this are described.

Question 1.8: Are there similarities in the policy objectives of national programmes for integrating Distributed Energy Resources and Renewable energy? Does CIGRE have a role in supporting a consistent approach to the integration of DES/DER?

1.6 Hydrogen Energy Storage

Paper C6-112 describes a generic sizing methodology for a remote wind-hydrogen power system. The techniques uses an Excel spread sheet and its internal solver to calculate Net Present Values and optimise a cost function including the capacity and operating costs of the proposed system. A number of uses are proposed for the Hydrogen including as a vehicle fuel. The analysis is carried out on a weekly basis and results are presented to one of the control strategies investigated.

Question 1.9: What is the most cost-effective use of Hydrogen manufactured from renewable energy? Is Hydrogen as a storage medium for electrical energy likely to be cost-effective?

1.7 Impact of Distributed Generation on reliability worth

Monte Carlo sequential simulation is used in paper C6-107 to evaluate the impact of dispersed generation on the reliability worth of power systems. Customer interruption costs are those gathered from a customer survey undertaken in Greece and an example based on a low voltage network with significant Distributed Generation is given.

Question 1.10: What tools are needed to calculate the performance of the power system with high penetrations of renewable generation? Are special developments needed for the analysis of Distributed Energy Resources connected at low voltage?

2. Preferential Subject 2 - Demand Management (DM) and Demand Response (DR)

Preferential subject 2 had a total of 4 papers submitted with particular regard to DM and DR. Some contributions for preferential subjects 1 and 3 also covered issues associated with aspects of this preferential subject 2. Those papers are treated under the respective preferential subjects.

One of the issues of this preferential subject is the terminology itself. While the preferential subject referred to the terms "Demand Management (DM)" and "Demand Response DR", other terms that are used interchangeably are "Demand Side Management" (DSM) and "Demand Side Response".

Papers C6-204 and C6-205 used the term DSM to describe activities in this field, while Paper C6-203 grouped the terms DSM and DSR interchangeably and referred to them collectively as Demand Side Initiatives (DSI). Although not specifically referred to in any of the submitted papers, some refer to DSR activities as being a subset of DSM while others, such as the CIGRE SC C6 have adopted the view that DSR more reflects the market based approach to application and utilisation of DER.

Question 2.1: Are the terms DM, DR, DSM, DSR or DSI truly equivalent or should they in some way be differentiated? In lieu of the increasing acceptance that initiatives in this field are market based, is it appropriate that the term DSR be adopted in lieu of all the other terms?

2.1 DM and DR as capacity and energy source

Paper C6-201 describes the CSIRO's research in technologies in Australia for the management and control of distributed energy (DE) devices. This work is designed to provide real-time, two-way communications and decision making between DE resources-, loads- and generators- in electricity distribution networks. The focus is to apply decentralised control of DE devices through the use of "agents" where an agent gathers data, makes decisions, and takes actions on behalf of a certain entity. The concept is for agents to be deployed at each DE device, such as an air-conditioner, hot water heater and pool pump. The agent concept is stated by the authors of C6-201 as a shift from the control architectures employed by distributors that tend to seek to rely on traditional SCADA techniques.

Paper C6-203 was jointly authored from Germany and Australia and describes implementation examples from both countries. The example from Germany describes the implementation of an Energy Management System (EMS) that performs management of demand side, on-site generation, management of local storage devices and management of supply contracts EMS can be used both online for actual management of balance groups, and offline for day ahead planning as well as for scenario studies. The example from Australia refers to paper trials conducted by the Energy Users Association of Australia aimed at increasing the opportunities for DSR in the National Electricity Market in Australia. The trial involved the collection, aggregation and dispatch of DSR through a central processing facility using software developed for the trial. The trial showed that customers were interested in providing DSR so long as it was not too disruptive and provided with a clear commercial return on the effort. A commercial company has been established that provides a dedicated DSR facility and supplies its services to the various actors that have an interest in DSR capacity.

In paper C6-205 by the Chairman of the IEA DSM Programme it notes the reserve margin, the difference between peak demand and capacity, in several member countries is shrinking. Balancing via the demand has positive impacts on reliability and security of systems, but also on price volatility, environment and climate, system cost and industrial development. The IEA calculated in their World Energy Outlook 2004 savings in investments for power generation, transmission and distribution during 2003-2030, was found to be 10% a total investment of 10 trillion USD. While liberalisation has changed the landscape for DSM-advocacy and implementation, the need for DSM remains and even greater now due to climate and environmental issues. The same long-standing issue is the need to change the load shape (peaks and valleys) and to change the load level (conservation and growth).

The paper C6-204 provides a Case Study utilising a variety of scenarios to study the impact of DSM on the loading of the network. The four most significant scenarios included:

a) Use of cooling storage in conjunction with summer air-conditioning in the tertiary sector
b) Use of high efficiency lighting in household and service sectors
c) Power factor regulation at end-user premises
d) Switch-off of split household air-conditioner during peak hours upon Distributor’s signals

The various scenarios referred to in paper C6-204 address issues of both demand initiatives that may actually result in higher energy costs (such as cooling storage), DSI that either reduce the demand or shift the time of maximum demand (power factor control or switch-off of household air-conditioners) and energy / demand reduction through use of lower energy consuming appliances (CFL).

Question 2.2: What are the drivers associated with demand side response initiatives? What forms of demand side response initiatives are being utilised and to what extent are these initiatives found acceptable by the end-user?

Question 2.3: To what extent should Demand Side Response initiatives be automated and not require intervention by the end-user? In this regard, what is the potential for end-use appliances to be controlled by controllers?

Question 2.4: To what extent is demand for electricity elastic and the extent to which price signals have an impact on demand?

2.2 Distributed Generation as an option of DM and DR

Papers C6-201, C6-203 and C6-205 all, either directly or indirectly, referred to the use of distributed generation as one of the elements associated with the providing contributions towards DSM and DSR. Although distributed generation was mentioned as a form of provision of DSR, none of the papers that have been submitted have dealt with any of the issues related to the application of DG to provide an effective form of DSR.

Question 2.5: What is the role of distributed generation in the provision of demand side response initiatives?

Question 2.6: To what extent do the economics of operating DG affect the application of DG for DSR? To what extent do renewable energy resources alter the economics of the use of DG compared to energy sources such as diesel engines or gas engines?

2.3 Role, willingness and approach of Distribution Network Operators in implementing DSM and DSR projects

Paper C6-204 presents a methodology based on DSM approaches for an optimal planning of MV-LV expansion in highly congested urban areas. The project focused on three aspects:

a) A set of techniques to evaluate the evolution of the load in highly crowded contexts
b) Review of the cost/benefit effectiveness of typical DSM actions of "load shedding/levelling'
c) A method for evaluating each time the most suitable mix of investments on grid expansion and of DSM measures to face an unforeseen increase of the demand.

The paper presents a case study of a network serving an area of approx 10 km^2 and serviced by 3 HV/MV substations. The first phase of the study describes the use of DECAPLAN software on a model generated grid to evaluate Grid Relief costs. That is, the costs to be faced from the beginning of the planning period to take the actual MV and LV grid from overloaded to normally loaded conditions. The second phase of the study involves the evaluation on the real grid through the use of the SPREAD software, considering some of the selected DSM measures in the first phase. This software allows for evaluation of the costs and benefits involved in focused measures when non-uniform load evolution on the considered load area occurs.

This analysis in Paper C6-204 led to the following general remarks:

a) The LV portion of the grid requires generally the greatest part of expansion costs. DSM measures on this part of the grid are in principle convenient and do not require any special attention.
b) Effectiveness of DSM measures on the MV portion of the grid may be nullified when they are scattered indiscriminately over the territory and not targeted on critical subsets of users.
c) DSM policies allow grid expansion costs to be avoided or put off.
d) Limitations of modelling approaches do not give evidence as to whether and how DSM programmes could help in postponing or avoiding theses costs. Further research is required
e) Relaxing technical constraints on the maximum allowable line overload in emergency conditions, it is possible to achieve economic benefits as those obtained with targeted DSM actions.

None of the papers submitted addressed the issue of the role and responsibilities that networks owners and operators should have in ensuring the effective implementation of DSR initiatives.

Paper C6-205 notes that the transmission and distribution companies may have a more profound interest in the using DSM-measures actively as they could save and postpone investments . This is shown in the IEA World Energy Outlook. In addition, new business activities are foreseen in the range of DSR. Balancing services need to be developed. Energy Service Companies (ESCOs) should develop service concepts and tailor them to customer needs and understanding of the service concept.

Question 2.7: To what extent are Distribution Network Operators willing to implement DSM and DSR projects? In that regard what actions have been taken by Distribution Network Operators in taking on board the possible implementation of DSR?

Question 2.8: To what extent have Distribution Network Operators adjusted planning techniques to take into account the impact of DSR initiatives?

2.4 Role of regulators

The paper C6-205 notes that the process of "commodisation" and tradifying of energy efficiency is creative and has seen the:

a) development of ESCOs with many different modes of application
b) development of "White Certificates" and "Energy Efficiency Commitments" to engage the energy industry
c) development of incentives and metering to enable Demand Response activities.

The paper notes that the process has only just begun. This paper states that to any on both the supply side and demand side of the business, the entire thinking is a "paradigm-shift" which will require support from governments. It states that policies should be more explicit both as regards the carrot and the sticks for load-shape and load-level actions.

With respect to load shape, countries should develop a regulatory regime that allocates responsibility for adequate electric system capacity and makes demand side balancing service the prioritised option.

With respect to load level, Paper C6-205 states that countries should have a system of assessment of least-cost delivery of energy services, including both demand and supply side, and allowing divergence from possible sustainable loads. The impacts of adopting such a policy include:

a) Development of markets for energy service companies and performance contracting
b) Allocation of commitments and obligations mobilising large scale energy efficiency actors
c) Organisation and targeting of support programmes
d) Improved allocation of obligations for reduction of GHG-emissions
e) Improved use of market communication mechanisms
f) Input on how further research and support mechanisms should be distributed amongst actors.

In paper C6-203 the creation of a commercial company to supply demand side response resources has been in a market based environment but in which various levels of regulatory support have been provided at both National and State government levels in Australia. At the national level, a Mandatory Renewable Energy Trading Scheme has been established that requires all retailers to purchase an additional two percent of their total energy purchases from Renewable Energy Services.

At the State government level, various initiatives have been put in place in Australia. In NSW, a Greenhouse Gas Abatement certificate system is in place. This arguably is one of the first mandatory greenhouse gas emission trading schemes in the world.

Question 2.9 To what extent are regulatory support and economic drivers required for networks to undertake implementation of demand side response initiatives? To what extent is the restriction of the structure of the deregulated market affecting the distribution network service provider from taking action to implement demand side response initiatives, including the application of distributed generation?

3. Preferential Subject 3 - Innovative distribution systems facilitating widespread deployment of DER

Preferential Subject 3 received 9 papers dealing mainly with various aspects of coordinated control of DER by innovative structures, like Microgrids and Virtual Power Plants, including practical experiences.

3.1 Innovative Distribution System Structures

Paper C6-301 deals with Virtual Power Plants (VPP), a distributed system control architecture comprising an aggregation of small DER in a virtual production unit. This concept is being studied within the European project FENIX. The paper presents three aspects of the development of VPPs:

a) The problem of optimal control of DER including intermittent sources

   It is shown that wind farm owners can increase their incomes by participating in VPP, especially including CHPs with thermal storage and provided that a good risk management strategy is used.

b) The risk management techniques which could be used for VPP management

   Risk management and dispatch strategies (bidding and short-term forecast through real-time electronic market process, coordinated resource control for economic dispatch, close monitoring of deviations and imbalance penalties) are essential tools for asset companies and DER, managed as VPP.

c) The problem of voltage regulation in a distribution network using a coordinated control of DER

   It is shown that Coordinated Voltage Control used at the distribution network level enables aggregated DER to manage efficiently reactive power and support secondary voltage control similar to the one dealing with central generation connected at the transmission grid.

Question 3.1: What are the advantages of the integration of small DER into wholesale markets aggregated as a Virtual Power Plant of a significant size? Given the current tariff based mechanism for DER is it feasible to move to market based mechanisms? How can you align DER subsidies with

market based revenue streams? What are the necessary adaptations of the Energy Dispatch process, especially regarding risk management?

Paper C6-307 presents a new vision of the Future Energy Networks project in Switzerland, based on the use of multiple energy carriers (not only electricity) and distributed energy resources for energy conversion and storage. The concept is based on two key elements: a) the integration of converters and storage devices in so-called energy hubs and b) the combined transmission of different energy carriers (electricity and gaseous) in one device, the energy interconnector. The paper focuses on modeling and analysis issues of hybrid energy systems including power flows, reliability, optimization and economic evaluation of investments. Results from investigations have shown potential for reduction of energy costs and system emissions.

Question 3.2: How can current energy systems be transformed to the future Greenfield structure envisaged and what are the associated costs for this transformation? Can they be justified by the assumed benefits? How is this transformation feasible in the current decentralized planning philosophies?

Paper C6-309 outlines selected research findings from the recently completed EU funded Microgrids project. Results include the development of Microsource controllers to support frequency and voltage based on droops concepts, the development of the Microgrid Central Controller scheduling functions, the analysis of communication requirements of the proposed Microgrids control architecture, methods for the quantification of reliability and loss reduction and initial measurements from an actual LV installation in Portugal. In the latter, the integration of a Microturbine in LV grid has shown reductions in the number of voltage interruptions by 66%, in interruption times by 61% and in Expected Energy Not Served (EENS) by 80%.

Question 3.3: The benefits provided by Microgrids to power system operation (reliability, losses, congestions, environmental effects) and planning (deferral of investments for reinforcement and replacement) need to be quantified and incorporated into an appropriate commercial and regulatory framework so that a level playing field for all energy technologies can be established. What are current efforts for this benefits quantification at regional, national or international level?

3.2 Microgrids – Control Issues

Paper C6-303 describes the economic scheduling functions of a Microgrid Central Controller (MGCC) responsible for the optimization of the Microgrid operation. This is achieved by maximizing its value, i.e. optimizing production of the local DGs and power exchanges with the main distribution. Two novel techniques are developed: one in Italy employing Neural Networks and one in Greece applying Dynamic Programming with Merit Order. Using actual prices from the Italian power exchange and typical load and production profiles of a realistic MV industrial Microgrid, it is shown that by aggregating the power bids from generators, the MGCC can effectively participate in the energy market maximizing the revenues for the DG owners and for the microgrid itself. The adoption of demand side actions further increases the benefits from market participation.

Question 3.4: The participation of Microgrids in Electricity Markets, especially coupled to Demand Side Management provides clear economic benefits. How realistic is this coordinated participation, given the different ownership of the various DER units and loads with possible conflicting goals and requirements? What are the market mechanisms foreseen and what is the role of Aggregators or other Energy Service Providers?

Paper C6-304 describes a central dispatcher system designed and implemented in a prototype test facility at CESI representing a Microgrid LV network interconnecting several distributed generators of different technologies, storage devices and loads. The project was supported by a National Research Project in Italy. The dispatcher is advised to exploit the capabilities of DER in order to increase the reliability of supply by islanded operation of some parts of the LV network at the occurrence of faults. The system is equipped with functions typical of central EMS systems like State Estimation, Forecasting (both load and RES productions), both short-term in 15-min intervals and longer term for 24 hour ahead, economic dispatch and intra-day scheduling.

Question 3.5: What are the differences, simplifications and complexities of classical EMS functions vs. the essential Microgrid control functions? Can we simply transfer centralized system operation concepts to LV Microgrids? Given the relatively small size, the available modest computing facilities and the support of a strong upstream network in interconnected mode of operation, what is the need for longer term horizon functions, like 24 hour scheduling?

Question 3.6: Are forecasting functions relevant for interconnected Microgrids? Today forecasting technology is expensive and forecasting tools are not plug & play ones. Developing and implementing forecasting functions involves costs for research & studies, instrumentation for data collection, operational costs for numerical weather predictions etc. Moreover, the aggregation or smoothing effect is reduced and uncertainty increases, as the size of the Microgrid gets smaller and time resolution is increased. Are there cost effective approaches for forecasting? Are there any comparisons of costs versus the expected benefits for Microgrids? Are there any tools to estimate and quantify the underlying uncertainty?

Question 3.7: In order to operate a Microgrid in a coordinated manner, there are several decision making approaches varying from a centralized to a fully decentralized approach. In the first case, the main responsibility for optimized operation lies with the Microgrid Central Controller that runs optimization functions and communicates setpoints to DER and controllable loads. In the second case, the main responsibility is given to the controllers of the microgenerators that, based on distributed multi-agent technology, compete to maximize their production to satisfy demand and possibly maximize exports to the grid. What are the advantages and disadvantages of the two approaches regarding optimality of operation, costs, communication needs, acceptability, openness of the system, etc?

Question 3.8: Customer participation? Is it possible to provide security functions enabling islanded operation without wide customer participation? Is it possible to assume that DER owned by individual owners will allow their remote control?

3.3 Pilot Installations

Paper C6-302 provides an overview of pilot installations in Europe which were identified in annual surveys in the context of the European Coordination Cluster IRED. It presents the lessons learned from the “connect and forget” philosophy of individual generators towards the “integration” approach. It focuses on 4 sites, in Germany, Greece and Spain. Pilot installations have shown that a high share of DER can be integrated in LV grids contributing to improvements in power quality and providing benefits to overall system performance, if they are managed efficiently by a central control or decentralized control units. Several pilots have also proven the cost reduction potential for the energy supplier if energy managements systems are used.

Question 3.9 : Pilot installations are very important to prove innovative distribution structures. Are there more real pilot installations? What is the distinct difference between “connect and forget” and “integrate” practices? What is the cost of upgrading individual DERs to coordinated DER control, i.e. cost of telecommunication and control infrastructures? Is there ant study quantifying the benefits vs. these costs?

Paper C6-305 provides results from the Regional Power Grid with RES project in Hachinoe, Japan that aims to demonstrate an integrated energy management system designed to reduce the impact of PV and WT generation systems on commercial grids and allow the interconnection of more DER. The energy management system ensures that the demands of electricity and heat within the system are optimally provided by controlling the output of gas engine generators and boilers the use of battery storage. Operating costs and environmental effects are minimized while maintaining the power flow at the coupling point constant. Four stages of control are assumed, i.e. weekly operation planning (30 min intervals, one week head), economic dispatch control (3 min, two hours ahead), tie-control schedule (every second), frequency control in islanding operation (control of batteries every 10 msec). The Microgrid system consisting of 80 kW of PVs, 20 kW of WTs, three gas engines of 510 kW total using digester gas from a sewage plant and 100 KW lead-acid batteries, has been put in operation since October 2005. Preliminary studies show poorer cost effectiveness, due mainly to the employment of full-time operators, back-up contracts with the local utility and lower efficiencies of the gas engines.

Question 3.10: Frequency Control in isolated operation is a challenging task given the low inertia of DER. The response of many DER like Fuel Cells, and the frequency maintaining functions in gas engines are generally inadequate or slow. How is local control realized? How are imbalances treated in case of instantaneous disconnections resulting large deviations in frequency and voltage?

Question 3.11: How Microgrids cost-effectiveness can be improved? Is it feasible to assume that full-time operators will be needed for Microgrid types of networks? Should back-up contracts be needed when technology matures and confidence on DER technologies is built up? How is cost-effectiveness affected when Microgrids participate in the market selling energy or ancillary services rather than keeping interconnection flows constant?

Paper C6-306 presents laboratory experiments aiming to prove that a single Microgrid or a cluster of Microgrids with an adequate Energy Management System can be used in the stabilization of frequency when a frequency drop is detected in an isolated grid operation. The 1 GW isolated power grid is represented by a scaled prototype built in the DeMoTeC laboratory in Germany. The experiments prove that by effective load disconnection provoked at frequency drop steps within the Microgrid, frequency of the main grid can be stabilized, when small disturbances are presented.

Question 3.12: What is the current status of laboratories regarding DER facilities? What is the value of laboratory work regarding standardization and testing? What is the necessary infrastructure to transfer laboratory experiments to real life experiences? Can real time set-ups represent real cases?

3.4 Coordinated FACTS Control to increase the Transfer of Wind Power on Transmission Networks

Paper C6-308 provides optimization algorithms for a) coordinated control of power flow and voltage at wind farm level to maximize penetration of wind power in transmission networks and b) coordinated control of power flow and voltage at transmission network level using FACTS to maximize the transfer capability of wind power on existing transmission networks. In addition, a method to determine the optimal location of FACTS controllers to improve the transfer capability of transmission networks is proposed. Case studies demonstrate the effectiveness of the proposed coordinated FACTS control techniques to manage power flows. The alternative of transmission network reinforcement is also examined.

Question 3.13 : What are the proven FACTS solutions to increase transfer capability of wind power on existing transmission systems? Are there reports from practical applications? How can we compare costs of installing FACTS versus network reinforcements considering also advantages of increased controllability? Have they been quantified?