CIGRE Sessions 2012

Paris, France – August 26 to 31, 2012

The following report is an outline of key topics and papers covered at CIGRE Sessions 2012 that are related to the Queensland electricity distribution sector. Specifically, an overview of the developments of workgroup C6 – Distribution Systems and Dispersed Generation – is covered, focusing on the impact of dispersed generation, electric vehicles, energy storage, and demand side management, on the distribution network. A complete list of presented papers is included in Appendix 1 and these papers can also be made available upon request.

Donald McPhail
E.S. Cornwall Memorial Industry Scholar 2011 - 2013

13/09/2012
CIGRE Sessions 2012

Paris, France – August 26 to 31, 2012

Overview of CIGRE

Founded in 1921, CIGRE, the Council on Large Electric Systems, is an international non-profit Association for promoting collaboration on a national and international level. With more than 11000 equivalent members composed of researchers, academics, engineers, technicians, CEOs and other decision makers, CIGRE allows experts from around 90 different countries, to share and join forces in order to improve existing systems and build the electrical power systems of the future. The 44th edition of the CIGRE Session assembled more than 3000 senior executives, experts and specialists, from the worldwide Power Industry, to enhance their knowledge, to discuss new developments and innovations, and to network.

A complete list of technical papers presented at CIGRE Sessions 2012 can be found in Appendix 1. The paper numbering used throughout this report aligns with the paper numbering used in the appendix.

Learning From C6 – Distribution System and Dispersed Generation

The scope of C6 is to “assess the technical impacts and requirements which a more widespread adoption of distributed/dispersed generation could impose on the structure and operation of transmission and distribution systems”. Rural electrification, demand side management methodologies, including management of the Distributed Generation (DG) and application of Energy Storage Systems (ESS) are within the scope of C6\(^1\). Specifically for discussion at the 2012 CIGRE C6 session, three preferential topics were selected which included:

- PS1. Planning and operation of active distribution networks including DG, ESS and Demand Side Integration (DSI)
- PS2. Integration of Electric Vehicles (EV) in power systems
- PS3. Electricity supply of rural and remote areas including islands

The following is an overview of developments presented and discussed in the C6 technical session and poster session regarding the key topics of Smart Meters (SM) and Information and Communication Technology (ICT) architecture, DG, EV, Demand Response (DR), ESS, and supply of island and rural networks. Additional supporting papers from study groups C1 (System Development and Economics), and C5 (Electricity Markets and Regulation) are also discussed in this section.

Smart Meters and Information and Communication Technology Architecture

The topic of integration of SM and the supporting ICT architecture into the distribution network to develop a smart grid was discussed in various forms in C6 PS1, specifically in papers C6.111, C6.112 and C6.114. The following is an overview of the main developments presented in these papers:

\(^1\) Joos, G., Peca Lopes, J. A., Maire, J., “Study Committee C6 Special Report”, CIGRE 2012, August 2012
• An analysis of the ability to control electricity networks with SM data is presented in paper C6.114. The findings suggest that in addition to the communication technology, SM hardware constraints, such as sampling rate, sampling resolution, processor, memory and architecture, will be a limiting factor to the functionality of the SM system available to network operators. It is suggested that the main flaws of the present SMs being installed in the UK are that they are unable to store sufficient data, are not able to allow for remote firmware upgrades, and are not capable of near real time data transmission which is required for voltage control and improved power system state estimation.

• The paper C6.112 presented a demonstration which included an advanced distribution automation system, a digital substation automation system, an advanced transmission system and active tele-metering, and many software functionalities which will enhance the operation of the smart grid. Some highlights of the system they presented include fault waveform data capture, grid self-healing, grid optimization and load balancing, and dynamic line rating. Results from the demonstration showed a 7.2% reduction in distribution losses and the improvement of load balancing rate.

• An Advanced Distribution Automation system (ADAM) is discussed in the paper C6.112. Components and functions of ADAM (shown in Figure 1) include a Volt/VAr/Watt optimizer (shown in Figure 2), protection coordination, voltage regulation coordination (including fast and slow methods), and auto healing and fault clearing/isolating. The paper also investigates four test cases using Matlab to determine the performance of different Volt/VAr control strategies of DG and its coordination with transformer tap changers and switched capacitors. The preliminary results show the coordinated dynamic voltage regulation method used in ADAM is effective in achieving better voltage performance and reduced power losses compared with other methods of voltage regulation such as constant power factor control or constant voltage control.

Figure 1 - Coordination of advanced distribution automation functions in the ADAM system

During the course of the CIGRE sessions, a number of projects were presented and discussed which related to the installation and application of SM and the corresponding ICT architecture within the distribution grid. In the second half of this report, a few of these projects are introduced including Web2Energy, Grid4EU, E-Energy projects, and The Green Button.

**Distributed Generation**

DG within the main distribution networks was presented and discussed within C6 PS1, with papers C6.103 and C6.113 specifically covering the network challenges faced with integration of DG. Both papers address the need to manage LV network voltage as a result of high penetration of PV on current grids, with different methods discussed:

- The paper C6.103 analyses four strategies of voltage management whereby reactive power control of the PV inverter is allowed, with the strategies consisting of the IEEE 1547 requirements (P control), reactive power injection (Q control), power factor control and voltage regulation. In addition, the paper proposes four indices to gauge the performance of the strategies, which consists of Maximum Voltage Deviation Index (MVDI), Average Feeder Loading Index (AFLI), Substation Reserve Capacity Index (SRCI), and Feeder Loss to Load Ratio (FLLR). The presented analysis shows that penetration of solar PV up to a certain percentage may be beneficial for supporting distribution systems; however above this level network performance degrades in terms of feeder voltage deviation, feeder and substation loading and loss due to reverse power flow. It is also shown that the power factor control strategy is the most effective to reduce reactive power flow in the network and therefore help to reduce feeder loading and power losses in the network. The voltage regulation strategy was shown to perform better in MVDI however it resulted in greater loading due to reactive power flow.

- The paper C6.113 presents experimental verification of an advanced voltage control approach which combines a centralized voltage control by tap change transformers (LRT: load ratio control transformer, SVR: step voltage regulator) and a coordinated voltage control by reactive power compensators (STATCOM: static synchronous compensator). The voltage control method is verified through modelling as well as using an analogue type 200V
experiment system named ANSWER (Active Network Simulator With Energy Resources) which is designed to simulate the Japanese 6.6kV network. Results from the simulation show that the centralized and coordinated voltage control allows higher penetration of PV on the residential feeders, while significantly reducing voltage fluctuations and adhering to the voltage constraints. For the modelled two feeder system, up to 100% penetration is achievable with LRT, SVR and STATCOM (10% feeder capacity), up to 90% penetration with LRT and SVR, while penetration is limited to 50% with conventional LRT and SVR control. In addition, the tests show that the operation of the STATCOM significantly reduces the number of tap changing operations of the LRT and SVR (from 34 to 20 on a cloudy day).

Throughout the CIGRE sessions, a number of projects were presented or discussed which investigated aspects of the connection of DG and Distributed Energy Resources (DER) on to the distribution network. Several of these projects are introduced in the second half of this report, including Web2Energy, Grid4EU, and the E-Energy projects.

**Electric Vehicles**

The integration of EVs into the distribution grid was covered in a dedicated session, C6 PS3, and as such, a number of papers were presented on identified network issues and projects addressing the challenges. The following is a summary of the identified network and market issues and limitations which were presented in papers C6.105, C6.201, C6.202, C6.203, C6.204, C6.205, C6.206, and C3.204.

- **Network Impact from Unconstrained Charging** – The presented analysis shows that on typical European urban LV networks, unconstrained charging will lead to overloading of transformers and/or of the initial segment of the feeder, whereas on rural networks it will also lead to under-voltage and phase unbalance issues (C6.105, C6.201, C6.203). Both types of networks though could experience voltage phase unbalance outside statutory limits at as little as 10% penetration if there is uncoordinated connection and charging (C6.203). An example study completed on a UK network model showed at 20% penetration, uncontrolled charging lead to a 38.4% increase in peak demand, with dual ToU (Time of Use) tariff managed charging leading to a 22% increase in peak demand, whereas smart charging (i.e. controlled by ICT architecture) will not cause an increase in peak demand (C6.206). It is important to note that this increase in network demand will also result in an increase in network losses (C6.201). With respect to network harmonics, the research in the paper C6.205 shows that modern PWM charges will cause no additional power quality issues.

- **Network Impacts from Fast Charging** – Due to the power demand intensive nature of EV Fast Charging (FC) stations (both AC and DC), the work presented at CIGRE showed that most distribution transformers could handle one FC station (43kW), however it would need to be electrically close to the transformer as there is a high risk of causing conductor overload. As such, a network study would need to be completed for each FC connection and ESS could be utilised to help with load flattening; however the station is likely to be located at supermarkets, parking lots or restaurants in order to be economical. (C6.201, C6.204, C4.207)

- **Market models for Smarter EV integration** – Given the electricity distribution network issues associated with unconstrained EV charging, ToU tariffs have been proposed as an efficient transition charging control method, however even at moderate penetration levels
they are shown to cause a new peak demand (C6.201). While the impact of EV charging on the electricity network is very much dependent on the customer behaviour, it is suggested that the only viable long term solution is to deploy smart charging in order to avoid overloading and voltage issues; however this will require the roll out of advanced network control and SM infrastructure (C6.201). Utilities will have to be smart about how they manage this though, as the control of charging could result in reduced range available to the driver, and reduce the overall vehicle battery life. With respect to the EV charging infrastructure required, paper C6.202 mentions that while long term battery technology will reduce the need for Public Charging (PC), PC will be critical initially to encourage adoption, however the infrastructure will need to be government subsidised and managed by DSOs (or a new similar body) to avoid incorporating the capital costs onto the user, as this will result in non-usage of the infrastructure.

Further to the papers presented at CIGRE, a number of international projects were also discussed which look at the integration of EV charging on the electricity grid. Several of these projects are introduced in the second half of this report, including Grid4EU and MERGE. While not a CIGRE paper, it was also discussed during a session presentation about the commencement earlier this year of an Estonian government and ABB project to create a nationwide EV fast charging network by installing 200 DC fast chargers[^3]. The Estonian government aims to provide fast charging in all urbanized areas with more than 5,000 inhabitants, and on main roads every 50km, creating the highest concentration of DC chargers in Europe. ABB Terra 51[^4] DC fast charge stations will be used with systems to be running by the end of 2012. As part of the five-year contract, ABB will also deliver network operating support services for the chargers in the field and the backbone IT architecture.


Demand Response

Demand response has been used in various forms in the past, particularly at transmission level, for managing short and long term changes in load and generation. Given the increasing level of DER being integrated into the distribution network, DR has begun being utilised to manage power flows, as well as voltage levels within MV and LV grids. The following is a summary of the developments presented in papers C6.115, C5.301 and C5.302.

- Based on a model single family house dwelling (Switzerland) in terms of heat flow and energy use, paper C6.115 presents an optimisation study to compare DR versus ESS and minimize energy costs, taking into account variations in energy prices, ESS and DR parameters, and available renewable energy sources. Taking into consideration customer behaviour across summer and winter cycles, preliminary results indicate DR is quite useful but generally ESS is not worth the cost at a single house dwelling level compared to DR. Following on from this work, the study is being repeated for a model Spanish household, which experiences a summer peak.

- The several key initial findings of the European ADDRESS project (Active Demand of Distributed Renewable Energy Sources on distribution System) are presented in paper C5.301. From work at five demo sites (within Italy, France, and Spain), the paper investigates the role of DR in the paradigm shift from “production follows load” to “load follows production” as a result of RES. The paper points out that DR acts as storage and not as a simple change in consumption, due to the “payback effect” – loads are postponed to a later time rather than prevented. Initial findings indicate that a minimum of 15 minutes notification period is required for DR to allow for activation and delivery.

- A three stage local market roadmap for DR is also briefly discussed in paper C5.301 according to the level of the degree of flexible resources, with stages coexisting at the same time in different local levels. A summary of these stages is presented in Table 1 below.
Stage | Level of DR and Flexible Resources | Operation of Local Market
--- | --- | ---
First Stage | Very Little | The aggregator would act on the existing day-ahead and intra-day markets and would propose its conditional re-profiling products to other actors (especially the DSO) on a bilateral contract basis.
Second Stage | Moderate | The DSO will have to open calls for tenders for its network needs and the aggregators that are active locally will have to send their offers, while still considering also the benefits they could get from keeping their resources available for the other markets they are involved in.
Third Stage | Fully Integrated | There will be a local market obtained from splitting the market at a very small scale and allowing all the actors interested in purchasing local flexibility to act on that market.

Table 1 – DR Local Market Roadmap

- A DR roadmap with respect to technology readiness is discussed in paper C5.302, highlighting types of products utilised in wholesale markets that are significant and sensitive to retail DR. The demand-side technology readiness roadmap in Figure 4, extracted from the paper, depicts an evolution of DR capabilities in the short, medium, and long-term, with each stage of technology readiness supporting new applications and capabilities. Figure 5 also indicates which technology requirements have a role in which retail contract or program types, as well as technology requirements for each program type. The paper concludes that by enabling widespread integration of DR under “Bids to Buy” schemes, elastic demand can be introduced into markets for reliability, potentially reducing total procurement and associated costs well below the status quo. In order to do so, it is suggested technology requirements must be met in a cost-justified fashion (e.g., by leveraging advanced metering or other infrastructure deployments to also provide the necessary communication and/or controls for DR coordination in system operations).

<table>
<thead>
<tr>
<th>Stage</th>
<th>Horizon</th>
<th>Applications</th>
<th>Key Enablers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability DR Program</td>
<td>Now</td>
<td>Emergencies (e.g., hottest summer days)</td>
<td>Equipment retrofits, Customer adoption and program participation</td>
</tr>
<tr>
<td>Energy Market Integration</td>
<td>Short</td>
<td>Wholesale energy prices (e.g., day-ahead or day-of)</td>
<td>Tariffs for dynamic energy pricing, Smart end-use devices with one-way communication</td>
</tr>
<tr>
<td>Distribution System Mgmt</td>
<td>Medium</td>
<td>Reduce facility loading (e.g., transformer overloads)</td>
<td>Localized event triggers, Smart end-use devices with two-way communication, Tariffs for demand-based rates/pricing, Configurable demand limit (e.g., PEV charging)</td>
</tr>
<tr>
<td>Ancillary Service Market Integration</td>
<td>Medium</td>
<td>Supply operating reserves (e.g., Participating load or self-supply)</td>
<td>Smart end-use devices with integrated communications and controls (e.g., DR Ready), Cost justified or relaxed telemetry requirements, Cost allocation method (e.g., avoided cost from self-supply of reserves)</td>
</tr>
<tr>
<td>Renewable Integration</td>
<td>Long</td>
<td>Balance intermittent supply (e.g., regulation, other fast response services)</td>
<td>Deep situational awareness, Smart end-use devices with integrated communications and rapid automated control</td>
</tr>
</tbody>
</table>

Figure 4 - Technology Readiness Roadmap for Demand Response

---

Further to the papers presented and discussed at the CIGRE sessions, several industry projects were discussed which include DR in some form as a key part of either research or application projects. A few of these projects are introduced in the second half of this report including Grid4EU and a number of the E-Energy projects.

**Energy Storage**

The integration of ESS into the distribution grids was covered in the use of allowing for greater integration of other DER such as DG and EV, as well as supporting remote and island networks with RES and diesel generators. The following is a summary of several key points presented from papers C6.115, C6.207, C6.307, and C5.111.

- As mentioned in the DR section, paper C6.115 suggests that when comparing DR versus ESS, ESS is not worth the cost at a typical urban single dwelling and only becomes cheaper (per Wh) and potentially beneficial as size increases (i.e. at LV feeder level).
- In the case of islanded networks however, it is presented in paper C6.307 that for two Spanish test case island networks, the savings of using ESS as primary reserve (when compared to pumped storage) are approximately linear functions of the ESS rating. Furthermore, when the rating of the EES is approximately 20% of the peak demand, the savings become approximately 4% and 6% of the total generation costs respectively for the trialled cases.
- Focusing on the transmission and sub-transmission level, paper C5.111 discusses an economic assessment of the benefit of using ESS in integrating RES into the grid, specifically with two case studies: (1) using a Compressed Air Energy Storage (CAES); and (2) using Concentrated Solar Power (CSP) with storage. Using a market simulation model for western USA, the studies showed that ESS could help to mitigate base load cycling, minimize renewable curtailment, increase economic benefits from renewable integration, and improve market efficiency in a deregulated power market.
- With the anticipated use of Ultrafast (<10min) Charging Stations (UFCS) for EVs, in order to provide high power output with minimal influence on the electricity grid, ESS will be
required to act as a buffer. The paper C6.207 uses a stochastic approach to analyse the impacts UFCS will have on the electricity grid, and the role ESS will play. It is shown that UFCS will cause peaks on distribution systems, and that ESS can be used for two main buffering strategies: load levelling or shifting, with buffering being more effective at low utilisation. With present technology and cost constraints, the analysis shows that CAES would be the most optimal, provided there is sufficient space. Furthermore, load-side management would decrease power levels by avoiding overlaps, but require drivers to queue up and experience longer charge times. Most importantly though, the paper suggests that provided the UFCS was close to the substation, a buffered station could be connected to the LV network with a utilisation rate of up to 200EV/day.

Related projects and resources discussed at CIGRE that covered the application of ESS in distribution grids are the Grid4EU project and the Electricity Storage Association, both introduced later in the second half of this report.

**Supply of Island and Rural Networks**

Within preferential topic three, there were a number of papers presented that discussed case studies of utilities addressing quality of supply for islanded or remote networks. The following is a summary of several of these case study papers.

**Remote Area Power System (RAPS) on King Island, Australia (Paper C6.301)** – This paper covers the recent work by Hydro Tasmanian to reduce diesel fuel consumption by drastically increasing the share of energy produced by Wind Turbine generators (WT). The island’s load varies between 1.2MW and 3.5MW with an annual consumption of 16GWh. The 2.45MW of WT produce about 10GWh per year but due to inflexibility of the diesel generator, power from WT only represents 33% of the total production, with about 4.5GWh being spilled. To increase this share up to 40%, a Resistive Frequency Control (RFC) has been designed to cope with the changes of 600 to 800kW per second that may be observed with the WT that does not match with diesel generator regulation capability. This RFC consists of a large resistive load (1.5MW) fed by a thyristor Phase Angle Controller. The paper goes further to determine what is the limit for high RE penetration and what major factors define this limit, indicating that it is technically and economically feasible to achieve very high wind penetration levels (above 50%) in a RAPS. It is demonstrated that a Diesel Uninterruptible Power Supply (DUPS) with very large inertia coupled to a RFC can, wind conditions permitting, allow a RAPS system to operate without diesel generation. The DUPS also improves the reliability of the system in response to credible contingency events. The studies presented have not found any adverse interactions between the proposed DUPS and the existing WT. However, simulations indicate that when operating with the DUPS a reduction in diesel governor control gain may improve damping.

**Hybrid Energy System on Island of Eigg, United Kingdom (Paper C6.302)** – This paper presents the field experience of the hybrid energy system deployed in 2008 to replace the approximately 100 inhabitants’ reliance on their own diesel generation. The MV hybrid system includes 10kWp of PV, 3 hydro plants (100kW, 2 x 6kW), 4 WT (4 x 6kW) and 2 diesel generators (2 x 64kVA). With approval of the residents; domestic and small business supplies have been limited to 5kW, and larger business supplies to 10kW representing a total consumption of 316MWh/year. The control of the total system is assured by inverters feeding a 48V - 4400Ah (C10) battery without any communication lines. The control is exclusively done through the grid
frequency monitoring. The battery can provide to approximately 12 hours of power for the whole island. An automatic load management system is deployed which involves the master battery inverter starting and stopping the generators depending on the available production, the State Of Charge of the battery, and the demand. Thanks to this system, 80% of the demand is covered by the hydro generator, about 10% from the WT and 2% from the PV arrays. The paper reveals that the electricity costs for an average household is about 25-40% of what they were previously for the fuel to run their own generator, and at €2M the system is estimated to cost approximately a third of that to connect the island via submarine cable to the mainland.

**Stand Alone Power System (SAPS) on North Island, New Zealand** (*Paper C6.305*) – This paper describes the SAPS that have been developed and tested as an alternative to the renewing of remote rural distribution lines in New Zealand by Powerco. The aim of the SAPS is to continue to supply existing customer at a lower overall (or whole life) cost than grid supply renewal. For the Powerco case it is found that lines in excess of 2 km length serving a sole customer with transformer capacity of less than 15kVA are worth considering for SAPS. This modular “plug and play” concept includes energy storage modules, load management (inverter) modules, scalable photovoltaic cells, scalable micro-hydro generation, fossil fuel generators, the use of bottled LPG for stoves and water heating, and energy efficient products for lighting and motive power. Satellite or mobile communications are used to monitor performance and indicate system failures. Installation and maintenance of the modular systems is carried out by Powerco however the customer is required to pay their normal line charge and is responsible for supplying and filling the fuel for the diesel generator. The first system was put in place in 2008 at a sheep shearing facility and was representing one third of the cost of the line replacement. Powerco presently has installed, and is installing, SAPS at four sites, with a further five sites being planned for 2012 at locations ranging from wool sheds, single households, and island networks.

**Optimal Sizing of Stand Alone Power System** (*Paper C6.306*) – This paper describes the development of an optimal unit sizing methodology for remote autonomous microgrid with multiple energy sources. The methodology takes into account the economical and environmental values of RES. Generally, the microgrid load is supplied by a diesel generator (which serves as a balancing plant) and RES (typically WT and solar PV). An ESS is used in the microgrid to smooth the output fluctuation of RES and to provide peak load shaving. A dump load is used to absorb the redundant power of the microgrid system when ESS is fully charged or at its maximum charging power. The goal of energy dispatching strategy is to maximize the total RES energy contribution to the system and improve the overall efficiency of diesel generation (or maximize the fuel saving). Diesel generation production has to adapt to the RES production available, to the demand and to the State Of Charge of the ESS. An optimal unit sizing model is proposed utilising the Particle Swarm Organisation algorithm, with the objective of minimising total cost and maximising environmental benefit under the constraint of system reliability. The paper gives results with an example (75kW diesel generator, 80kW WT, 30kWp PV and 8kW/15kWh ESS) comparing two scenarios; the first scenario ignores the environmental benefits of WT and PV and the second scenario takes them into account. Results show that considering the environmental benefit of RES increases the capacity of WT by 16% and PV by 10% and decreases diesel unit production by 10% in the optimisation result. A sensitivity analysis is presented showing either the effect of diesel fuel price or average wind speed variation on optimal sizing: the increase of diesel fuel price and average wind speed leads to a decrease of proportion of diesel generator in microgrid and an increase of contribution of WT and PV generation.
Island Micro-grid, Japan (Paper C1.116) – This paper describes demonstration tests of microgrid systems developed to control RES generation on small remote Japanese islands. For demonstration tests, the following three system control methodologies are evaluated and presented in the paper:

1) Compensation for PV output fluctuation – Through compensation of short-cycle PV output fluctuations using ESS, output fluctuations at a grid-connected point can be smoothed.
2) PV output levelling – Through using ESS to compensate for all PV output fluctuations, output at a grid-connected point can be maintained at a fixed level.
3) Output shift of PV surplus power – By storing surplus power generated by PV and WT in ESS, stored power can be output at times of peak demand through output-shift. This can contribute to increased utilization of RES as well as reduced fuel consumption and CO2 emissions by avoiding operation of diesel generators.

Relevant CIGRE Technical Brochures
CIGRE Technical Brochures (TB) are the result of the work completed by the study committees. There are several relevant TBs that are scheduled to be released in the next 18 months that are the result of current workgroups. Some of which are:

- TB C6.20 – Integration of Electric Vehicles in Power Systems (start of 2014)
- TB C6.21 – Smart Meters – State of the Art, Regulations, Standards and Future Requirements (end of 2013)
- TB C6.22 – Microgrids Evolution Roadmap (end of 2013)
- TB C6.24 – Capacity of Distribution Feeders for hosting Distributed Energy Resources (mid 2013)

Notable Projects and Resources
The following is an overview of several related notable projects and resources that were shared by presenters during the CIGRE 2012 sessions which the learning and achievements from would be of benefit to the Australian distribution system operators. Much of the work from Europe is supported by the European Commission (EC) Joint Research Centre (JRC) Institute for Energy and Transport (IET) (ses.jrc.ec.europa.eu/). A map that provides an overview of all of the supported projects can be found in Figure 6.
Web2Energy ([www.web2energy.com](http://www.web2energy.com))

Web2Energy is a European Commission supported project made up of a consortium of utilities and technology specialists from Germany, Netherlands and Austria, running from 2010 to 2012. The project objective is to implement the three pillars of “Smart Distribution” – Smart Metering, Smart Energy Management and Smart Distribution Automation. Notable attributes and outcomes of the project thus far include:

- Installation of a few hundred SMs into customer premises and integration into a deployed IEC 61850 communication system via the specification of the especially developed remote terminal unit and the control centre.
- 100kWh Redox flow batteries installed in substations
- The creation and optimization of Virtual Power Plants (VPPs) utilizing storage and DG (Cogeneration Heat and Power (CHP), Wind, PV, and Hydro)

---

6 [ses.jrc.ec.europa.eu/project-maps](http://ses.jrc.ec.europa.eu/project-maps)
- The development and implementation of a new SCADA system and purpose built Human Machine Interface allowing for overview of feeders, VPPs and customer load profiles.
- Implementation of day ahead tariff pricing for domestic customers, resulting in peak load shifting of 8% and total energy saving of 2-3%.

Figure 7 - Components within the Web2Energy Project

**Grid4eu** ([www.grid4eu.eu](http://www.grid4eu.eu))

Grid4eu is a European Commission supported project made up of a consortium of six DSOs and several technology specialist partners collectively from twelve EU member states, running from November 2011 to 2015. The project objective is to conduct six demonstration sites which will address the following:

1. Smart grid pilot testing and validating massive integration of DER and ESS.
2. Demonstration that European MV networks can use the concept of autonomous, self-organising nodes to serve the needs of both the DSOs and the served client.
3. Validation that the control of LV distribution networks using automatic meter reading events allows for more DG while improving customer power quality.
4. Demonstration that existing networks which have SM and CHP units can be upgraded to allow automatic islanding while ensuring enough power supply.
5. Increase the MV network's hosting capacity for DER, introducing Active Control and DR of MV generators, controllable loads and storage.

---

MERGE (www.ev-merge.eu)

MERGE is a European project supported within the Seventh Framework Program for Research and Technological Development and made of a consortium of multi-disciplinary partners from eight European countries with a final report outlining all findings expected by end of 2012. The project mission is the evaluation of the impacts that Electric Vehicles (EV) will have on the EU electric power systems regarding planning, operation and market functioning. The focus will be placed on EV and Smart Grid/Microgrid simultaneous deployment, together with renewable energy increase, leading to CO2 emission reduction through the identification of enabling technologies and advanced control approaches. The main scientific and technical (S&T) objectives of this project are:

1. To develop a management and control concept and to identify potential smart control to be adopted by system operators to allow the deployment of EV without major changes in the existing network and power system infrastructures;
2. To provide insights into the dynamic behaviour of power systems having a large penetration of EV together with intermittent RES;
3. To address the impacts on generation and grid infrastructures planning, evaluating at the same time the required/deferred investments due to the simultaneous presence of intermittent RES and EV in the grid;
4. To identify the most appropriate ways to include EV into electricity markets, including an evaluation of how SM should take the presence of EV into account;
5. To propose a regulatory framework capable of: a) treating EV users in a fair and non-discriminatory way and b) defining a way to deal with the additional investments in control and management structures that network utilities will have to make, in order to reliably accommodate a large number of EV;
6. To provide quantitative results on the impact of integrating EV into the grid of EU national power systems.

\[8\] www.grid4eu.info/overview.php
7. To provide an evaluation computational suite able to identify and quantify the benefits that a progressive deployment of the MERGE concept will bring to the EU national power systems, taking into account several possible smart control approaches.

(residential area)

Results:
- Branches’ loading for the peak hour:

  ![No EV](image1)
  ![Dumb Charging](image2)
  ![Dual Tariff Policy](image3)
  ![Smart Charging](image4)

- Voltage profiles for the peak hour:

  ![Voltage Profile](image5)

- Weekly losses:

  ![Weekly Losses](image6)

Figure 9 – Example of EV impact on LV grid during demand peak from MERGE (loading, voltage and losses)

**E-Energy Projects ([www.e-energy.de/en](http://www.e-energy.de/en))**

E-Energy is a funding program of the German Federal Ministry of Economics and Technology and Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The purpose of the E-Energy model projects is to develop an "Internet of Energy" which monitors, controls and regulates the electricity system intelligently. There are six model regions that make up the E-Energy projects, which consist of (Figure 10 shows the priorities of each project):

- **eTelligence ([www.etelligence.de/presse.php](http://www.etelligence.de/presse.php) - German)** - Producers and consumers in and around Cuxhaven will be able to take part in a new marketplace to buy and sell electricity, as well as offer system services and idle power, and help reduce the load on the power grid. The marketplace takes advantage of the many refrigerated warehouses and the spa in the town. The water in the pool is heated when electricity from the CHP power plants is needed. The refrigerated warehouse is cooled more than usual when electricity is cheap, with controls developed within the framework of E-Energy ensuring that the goods contained within the refrigerator do not spoil in the process.

- **E-DeMa ([www.e-dema.de/en](http://www.e-dema.de/en))** – Based in the region of Rhein-Ruhr, the E-DeMa project builds on the existing distribution of SMs to drive energy efficiency in integrated homes,

---

using the ICT gateway. The focus of the project includes the development of an intelligent power consumption control system and the real-time collection and provision of consumption data. The project also aims to optimize network operation management in decentralized distribution networks.

- **MeRegio (www.meregio.de/en/) -** The E-Energy MeRegio project takes place in the region of Baden-Württemberg, where several model test customers will be recruited. These test customers will include:
  - **The Storing Producer** - The house will be equipped to combine generation (PV or CHP) with an ESS with the ability to control when to import or export power from the network, playing an active role in market activities.
  - **The Energy Traffic Light Consumer** – Utilises SM to respond to dynamic price signals to adjust household demand.
  - **The Smart Appliances Consumer** – Smart appliances are connected to SM gateway and respond to MeRegio signals. The customer also has a mobile to display to remain in control.
  - **The Decentralised Producer** – The customer exports all energy that is generated directly into the grid.
  - **The Producer in Control of Production** – The customer has a generator (CHP) and is able to choose when to produce energy and export to the grid, playing an active role in market activities.
  - **The Storing Consumer** – An ESS is installed at the customer’s premise and the customer is able to shift load through the use of dynamic price signals.

- **Moma (www.modellstadt-mannheim.de/moma/web/en/home/index.html) -** The Model city of Mannheim project (Moma) trial aims to improve energy efficiency, grid quality, and the integration of renewable and decentralized sources of energy into the urban distribution network. The focus is on developing a cross-sector approach (involving electricity, heating, gas and water) to interconnect the consumption components with a broadband power line infrastructure. Proactive users in the energy market (“prosumers”) can gear their power consumption and their power generation towards variable pricing structures. Furthermore, real-time information and energy management components also aim to help the customer contribute to even greater energy efficiency.

- **RegModHarz (www.regmodharz.de/ - German) –** The project aim is develop a control room at the renewable energy combined-cycle power plant in the Harz region and receive real-time information on the energy situation in the region. A complete overview of power generation, storage and consumption will be gained, and it will be possible to make forecasts, and optimize the use of renewable energy sources. The Harz model region has extensive sources of renewable energy, ranging from wind farms and solar power systems to hydroelectric power stations.

- **Smart Watts (www.smartwatts.de - German) -** Smart Watts aims to define the Internet of Energy on three levels:
  - At the system level - a number of power generators, consumers and control systems communicate with one another.
  - At the business level - the stakeholders plan, control, monitor and optimize the efficient use of plants and contract conditions depending on their particular market role.
At the information level - the centrepiece of E-Energy, linking the other two levels and allowing the stakeholders and systems in the "energy web" to safely communicate with one another in real time. Based on this architecture, the consortium partners aim to develop systems to optimize business decisions, settlement of trade transactions, measured energy value, and message exchange and device control.

**Figure 10 – Priorities of E-Energy Projects**

**The Green Button** ([www.greenbuttondata.org/](http://www.greenbuttondata.org/))

Green Button is an industry-led effort that responds to a US Government call-to-action to provide electricity customers with easy access to their energy usage data in a consumer-friendly and computer-friendly format via a “Green Button” on electric utilities’ website. Green Button is based on a common technical standard developed in collaboration with a public-private partnership supported by the US Commerce Department’s National Institute of Standards and Technology. Voluntary adoption of a consensus standard by utilities across the US allows software developers to leverage a sufficiently large market to support the creation of innovative applications that can help consumers make the most of their energy usage information. The data from the Green Button can be used for insight into consumer use of electricity to provide personalised tips, customising heating and cooling activities, education, retrofits of houses and appliances, verification of investment into energy efficiency, and optimising the size and use of rooftop solar power.

---

Electricity Storage Association (www.electricitystorage.org)

The Electricity Storage Association is an international trade association established to promote the development and commercialization of competitive and reliable energy systems. Through membership and their website they provide information regarding the technical capabilities and application of various storage technology types and their suitability for various grid applications.
APPENDIX 1 – LIST OF CIGRE 2012 TECHNICAL PAPERS

(See attachments or refer to CIGRE Sessions 2012 website:
http://www.cigre.org/content/download/16641/676989/version/1/file/DETAILED+TECHNICAL
+PROGRAM.pdf, accessed 11 September 2012)