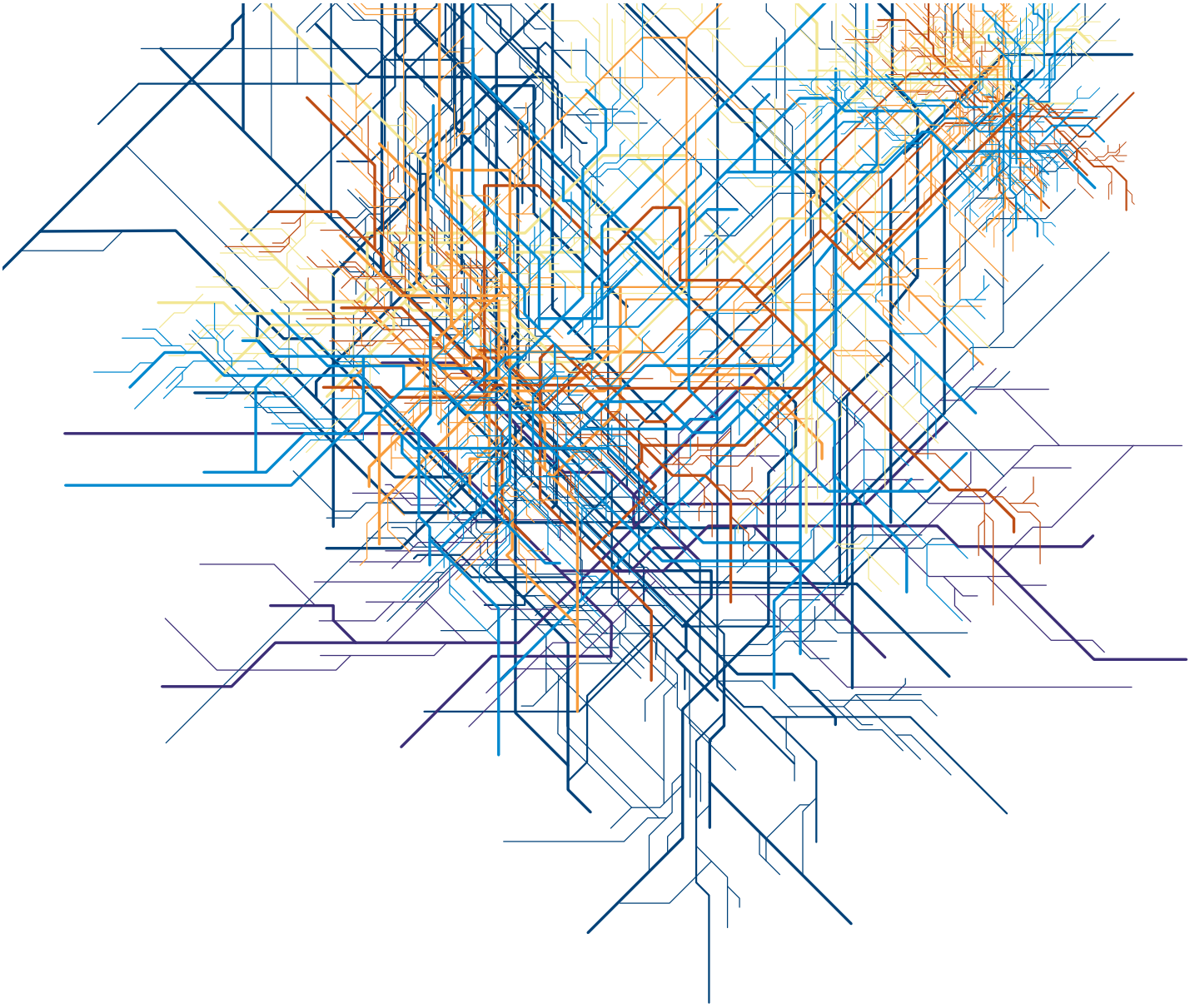


# Smart teamwork

## Collaborations with recognized research institutes are helping ABB meet the challenges of the future electric grid

CHERRY YUEN, ALEXANDER OUDALOV, ANDREW D. PAICE, KLAUS VON SENGBUSCH – The battle against climate change combined with the search for energy and process efficiency has been slowly but surely pushing the topic of smart grids up the agendas of many companies. In fact, since European and US governments identified them as key to meeting their environmental goals and achieving energy security, it has found its way into the popular media. While it may seem like a new concept to many, ABB has actually been active in this area for several years, developing the technologies and standards that will be needed in the future. In fact many are already being used to enable modern grid operation and provide greater efficiency, reliability and intelligence. Research efforts on smart power transmission and distribution have focused on implementing smart functionalities into both ABB products and customer installations. Some of the current efforts, carried out in collaboration with external partners and partly funded by public bodies such as the European Commission, are described in this article.

The traditional power grid is based on large centralized power stations that supply end-users via transmission and distribution systems where power flows from the top down. However, today's conflicting demands for more reliable, higher-volume power supplies from cleaner and more renewable energy sources mean this very same infrastructure must operate in ways for which it was not originally intended. The solution lies in gradually transforming the old system into a more intelligent, more effective and environmentally sensitive network that can receive power of all qualities from all sources – both centralized and distributed – and deliver reliable supplies, on demand, to consumers of all kinds. In other words, what is needed is a smart grid.

The term smart grid can mean many different things to different people. However, in ABB's view a smart grid is an infrastructure that puts the emphasis firmly on active rather than passive control. ABB's vision for the smart grid is of a self monitoring system based on industry-wide standards that crosses international borders and participates in wholesale energy trading, and provides a stable, secure, efficient and environmentally sustainable network.

There has been a great deal of discussion in the media about smart grids. In October 2009, President Barack Obama promised $3.4 billion to fund "a broad range of technologies that will spur the nation's transition to a smarter, stronger, more efficient and reliable electric system" [1]. In Europe the European Commission has been financing projects to develop the technologies that "play a key role in transforming the conventional electricity transmission and distribution grid into a unified and interactive energy service network using common European planning and operation methods and systems" [2].

While true smart grids are still a vision of the future, the technologies and standards that will be needed have been under development at ABB for some years and many are already in use. In particular, projects have been ongoing to develop an alternative approach to the transport of energy based on centralized power generation. In other words, instead of relying solely on large power plants, small generators could be used to serve villages or towns or even factories. Known as active distribution grids, they would ensure uninterrupted power to the critical communications infrastructure and control systems that drive today's economy. In addition, because the energy is created close to where it would be used the energy lost in electric transmission and distribution would be reduced significantly. ABB has been working in this area in close collaboration with external partners and their efforts have led to the execution of several demonstration projects, four of which (More Microgrids, AuRA NMS, ADDRESS and MEREGIO) are briefly discussed in this article → 1.

## Microgrids

Microgrids comprise medium- and/or low-voltage distribution systems with distributed energy sources, storage devices and controllable loads. They can operate when connected to the main power network or when isolated – or islanded – in a controlled and coordinated way. The microgrid concept is a logical evolution of simple distribution networks and can accommodate a high density of various distributed generation sources such as microturbines, fuel cells, solar photovoltaic systems, and small diesel, wind, hydro and energy storage devices such as batteries. Microgrids can offer supply reliability, power quality improvement, and a greener and (possibly) cheaper energy supply to energy consumers. Network operators and utilities benefit because microgrids are better able to integrate distributed generation as well as reduce losses.

Nevertheless, the technical challenges associated with the integration and operation of microgrids are immense. One such challenge is to ensure stable operation during faults and various network disturbances. Switching from an interconnected to an islanding mode of operation is likely to cause large mismatches between the generation sources and loads, which in turn could lead to severe frequency and voltage control problems. Maintaining stability and power quality in islanding mode requires the development of sophisticated control strategies that include all aspects of both the generation and demand sides as well as energy storage.

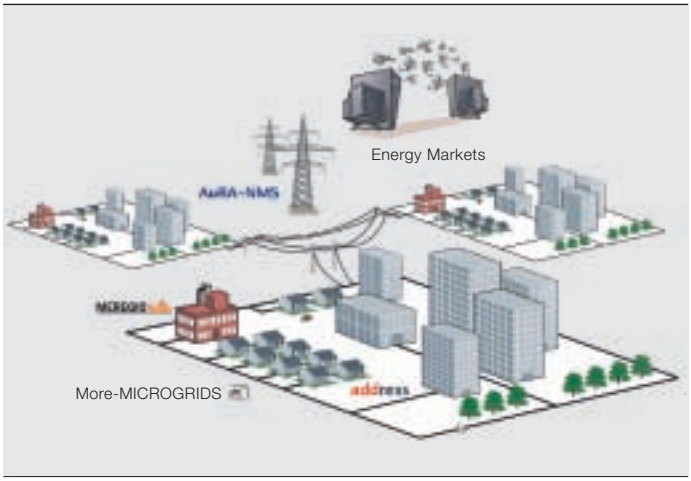
Protection is another key challenge. When a fault occurs on the grid, the microgrid should be isolated from the main utility as quickly as possible to protect the microgrid loads. If the fault lies within the microgrid, protection functions should be able to detect the normally low short-circuit currents provided by the power-electronic based micro generators in order to isolate only the most necessary part of the microgrid. The unique nature of microgrid design and operation requires an investigation of the various aspects of low-voltage network protection, such as new concepts of relaying.

In ABB's view a smart grid is an infrastructure that puts the emphasis firmly on active rather than passive control.

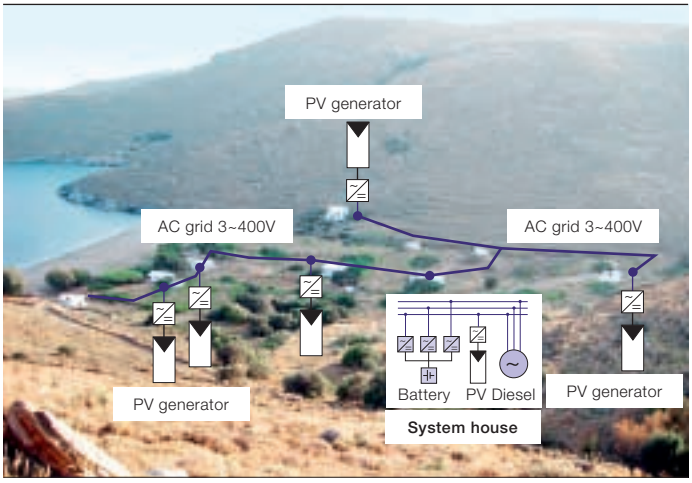
## More Microgrids

To meet these challenges, a European Commission project known as Advanced Architectures and Control Concepts for More Microgrids – More Microgrids aims at providing solutions to support the

1 Projects financed by the European Commission focus on integrating distributed generation and improving energy efficiency.




2 A low-voltage Gaidouromantra microgrid deployed in Kythnos Island, Greece.




widespread deployment of microgrids. In particular, the project investigates:

- Centralized and decentralized control strategies to determine which provides more efficient voltage and frequency control and less mismatch between various micro sources and loads in cases when islanding is required.
- Novel protection paradigms suitable for microgrid operation.
- The technical and commercial aspects of integrating multiple low-voltage microgrids with a large number of active participants, such as small scale generators, energy storage devices and flexible loads, via a medium-voltage distribution grid.
- The operational and environmental benefits and the impact of microgrids on the future replacement and investment strategies of transmission and distribution infrastructures at regional, national and European levels.

Currently eight pilot microgrids are available to enable the experimental validation of various microgrid architectures, control strategies and protection algorithms → 2.

The More Microgrids project started at the beginning of 2006 and will end in January 2010. The consortium involved in the project comprises 22 manufacturers including ABB, Siemens, ZIV and SMA Solar Technology; power distribution utilities such as Liander, MVV and EdP; and research teams from 12 European countries.[1] It is co-funded by European Commission's sixth framework program (FP6) for research and technological development with a budget of 4.7 million euros ($6.4 million). ABB is a member of the steering committee and sits on the manufacturer's board. It is coordinating the work package that develops microgrid protection schemes and functions as well as novel concepts, such as DC microgrids. In addition, ABB is heavily involved in analyzing the idea of using microgrids as a provider of ancillary services.

Finding ways of better managing real-time operations of electricity distribution systems is key to improving the quality of the supply offered to customers. However, the almost certain need to connect small-scale renewable energy sources to a vast and complicated infrastructure that is considered passive and too expensive to replace prematurely is a technical barrier that must be overcome. In the grid of the future, overall central control will not be realistic and therefore suitable ways of delegating control need to be found.

This search is currently underway and is being carried out by a team consisting of three power industry giants (ABB, EDF Energy and Scottish Power) and eight universities, including Imperial College London who is acting as the principal investigator. The project, known as Autonomous Regional Active Network Management System (AuRA-NMS), is sponsored by the Engineering and Physical Science Research Council (EPSRC) in the United Kingdom and has a total budget of 5.46 million pounds[2] ($9.13 million).

## AuRA-NMS

Existing network control centers are typically semi-automated and semi-manual in which network operations and analyses, such as load flow studies, reconfiguration, short-circuit analysis and outage management are performed by the network operator. The AuRA-NMS project explores ways of gradually devolving control authority from these centers and replacing them with peer-to-peer networks with distributed intelligence (ie, automatic controllers/decision makers) at each substation. The controllers could open and close remotely controlled switches to reallocate loads to different parts of the network and take different voltage correction actions. In addition, they could control the charging status of energy storage systems as well as the

> While true smart grids are still a vision of the future, the technologies and standards that will be needed have been under development at ABB for some years.

**Footnotes**

1 Research teams include those from the Universities of Athens, Porto, Manchester, ISET, Labein and CESI.

2 This figure includes the allocated contribution of the collaborating industrial partners.

outputs of distributed generation. An effective communication system would be required to obtain feedback information and to allow controllers with only a partial view of the system to cooperate in determining an optimal set of actions in the event of a fault, a voltage excursion or a generator whose output is being limited by network constraints. The controllers located in primary substations would coordinate with each other to facilitate secure network operation during normal and abnormal operating conditions. The control functions in these substation controllers need to be able to handle the challenges faced by the two distribution network operators arising from changing regulations and the increase in the number of distributed generation sources in their networks.

ABB's role as project manager in the AuRA-NMS project is to provide expertise on substation automation and distribution state estimation. In addition, the substation controllers, COM615, as well as the SVC Light® with Energy Storage system are supplied by ABB.

The project started at the end of 2006 and will finish in early 2010. Pilot installations are currently installed in some of the EDF Energy substations in England.

In the not too distant future, it is envisaged that renewable energy resources, such as wind and solar power, will be exploited to satisfy a large part of our energy needs. However, unpredictable weather conditions can potentially wreak havoc with the power supply. This need not be a problem if an appropriate response to a sudden change in the power supply is built into the distribution system. While storage elements in the grid will help compensate for any variance, household energy consumption could be optimized by an "energy box," which would react by briefly shedding unimportant appliances or equipment to ensure uninterrupted power to critical ones during power shortages. If done properly, this approach, called active demand, can increase the flexibility of the energy system, which in turn will enable a greater utilization of renewable energy sources. Providing the ideas necessary to enable active demand is the aim of another European Commission project called "Active distribution networks with full integration of demand and distributed energy resources," otherwise known as ADDRESS.

## ADDRESS

The primary goal of ADDRESS is to enable active demand. Active demand refers to the possibility of domestic and small commercial customers to influence grid operation by modulating their power demand. The key concept investigated is that of the Aggregator, a business which would represent a large group of small consumers in the electricity market. An Aggregator would sell modifications of their consumption profiles as a service to other power system participants, such as retailers, provide distributed system operators (DSO) and balance responsible parties (BRP). In order to achieve this, the project will develop a technical and commercial architecture to implement the concept, as well as investigate measures to motivate consumers to participate in the power system. The technical architecture consists of a network control and communication architecture and an interface (ie, the energy box) to the consumer. Algorithms are being developed for the optimization of medium- and low-voltage network operation and of energy use on the consumer premises, and to allow consumers to select services that enable them to reduce consumption in the short term or shift it to hours during which prices are lower. The commercial architecture includes a description of the services an aggregator may offer on the electricity market.

ADDRESS started in June 2008 and will continue for four years. The proposed architecture will be demonstrated at three test sites in France, Spain and Italy. Five energy companies, EDF, Iberdrola (Spain), ENEL (Italy), ABB and KEMA (Germany), together with the Universities of Manchester and Cassino constitute the main partners in the project and are supported by a further 18 partners from around Europe. The project is co-funded to the tune of 9 million euros ($13.5 million) by the European Commission's seventh framework program (FP7/2007-2013) for research and development. ABB is a member of both the management and technical boards and leads the work package responsible for the development of the communications architecture. In addition, the company contributes significantly to the development of new algorithms for network operation.

The mitigation of climate change is a long-term issue that calls for significant changes in the way industry and society at large produce and use energy and electricity. For its part, ABB has been committed to helping its customers use energy more efficiently and reduce their environmental impact through a broad array of products, systems and services [3]. It continues this commitment through its involvement in yet another European consortium project, whose objective is to create an optimized and sustainable power network that reduces $CO_2$ emissions to as close to zero as is technically feasible to produce a so-called minimum emissions region or MEREGIO as the project is commonly known.

By actively pursuing collaborations with external partners, ABB will be able to provide customized smart solutions.

## MEREGIO

MERIGIO is a collaborative project between ABB, IBM, SAP, EnBW (one of Germany's largest utilities), Systemplan Engineering and the University of Karlsruhe. It was one of the six winning proposals submitted to the "E-Energy: ICT-based Energy System of the Future" competition sponsored by the German Federal Ministry of Economics and Technology.

Taking the Karlsruhe/Stuggart [3] area of Germany as the "model" region, the project makes use of information and communication technology (ICT) in its bid to eliminate the $CO_2$ emissions caused by heating and electric power consumption. A thousand smart meters with bidirectional broadband communication interfaces will be installed as part of the pilot

**Footnote**

3 The Karlsruhe-Stuttgart region of southern Germany is one of the most densely populated areas of the country and widely considered Europe's biggest manufacturing and high-tech hub.

project: 800 will be shared among household and industrial consumers, 150 for generation units and 50 for energy storage systems. A certificate showing regional energy efficiency will be used to inform industrial and household consumers of the size of their $CO_2$ footprint.

Technically, the efficient use of an electric grid is achieved by optimally integrating the many sources of distributed generation and the active management of electrical demand. To achieve the latter, the grid operator needs to be provided with real-time information about the entire power network in terms of supply and consumer demand. The communication infrastructure employed in the pilot will give the operator the information needed to control the network by predicting power flow and responding rapidly to changing situations. In addition, the operator can transmit time-variant tariffs – or price signals – to consumers, allowing them to respond by adapting consumption according to energy price and availability. [4]

ABB's role in the project is to provide the expertise in network control and distribution automation. In particular, this includes the detection of bottle necks and the optimization of network operation by, for example, minimizing switching operations during maintenance, and the provision of forecasting nodal generation and demand. All these can be achieved by applying the various sophisticated algorithms. The accuracy of a forecast will depend on the quality of the input data the algorithm receives. In other words some algorithms receive (real-time) data such as voltage and current values from network devices as well as information from the smart meters. Moreover, ABB's network management system will also interface with market and trading systems[5] to ensure that market-based measures, such as market splitting, can be applied both to avoid bottlenecks and analyze data on future energy trades in order to predict load flow in the distribution network.

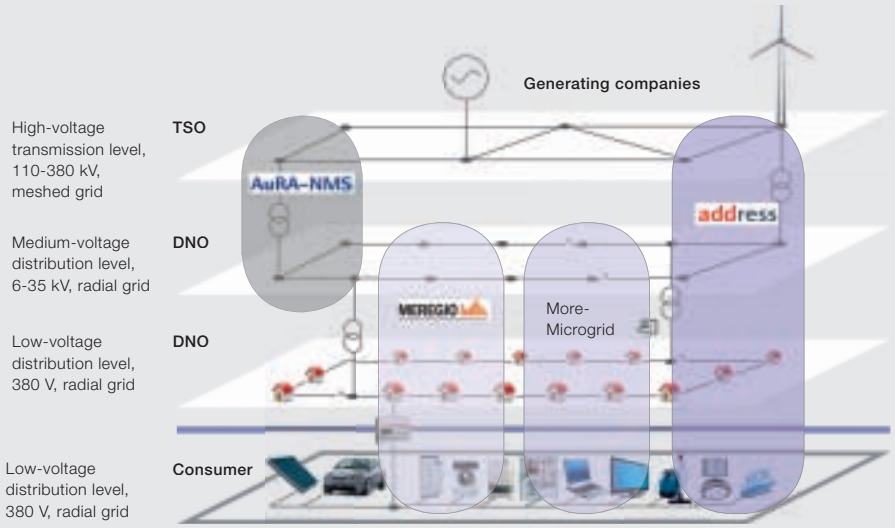
The four-year MEREGIO project started at end of 2008 and the one-year field test of the complete system with customers is planned to start in 2011.

## Four projects, one vision

For ABB, these projects not only provide up-to-date and firsthand information on the technical and regulatory needs of utilities and network operators, but they also enable fruitful collaborations with other well-known institutes working on state-of-the-art smart grid technologies → 3. The results from each of these projects complement each other and can be applied to a wide variety of ABB products and solutions to satisfy different customer needs.

Although the grid of the future is being called the smart grid all over the world, it is clear that there will be significant differences in the challenges faced in introducing these technologies in different places. This means the smart grid will probably be different in each location. By actively pursuing collaborations and cooperation with utilities, universities and other participants in the energy sector, ABB will be in a position to provide solutions that are appropriate to each individual customer situation. A truly smart strategy.

**3 The grid of the future? Collaborations are working to transform the old "traditional" system into an intelligent, more effective and environmentally sensitive network.**

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**Footnotes**

4 This is in effect a verification of a concept that comes into effect in Germany after 2010 whereby utilities should offer tariffs to consumers according to current network operation conditions.

5 These systems are also an integral part of the MEREGIO project.

**References**

[1] The White House (2009, October 27). President Obama announces $3.4 billion investment to spur transition to smart energy grid. Retrieved November 11, 2009, from www.whitehouse.gov/the-press-office.

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[3] Nordstrom, A. H. Challenges and opportunities aplenty: How to meet the challenge of climate change. *ABB Review* 3/2009, 6–10.