The Smart Micro Grid: IT Challenges for Energy Distribution Grid Operators

The E-Energy moma project addresses the challenges of an open standards-based smart cell service platform for micro grid and smart home/business/building applications

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Modern society is facing the global dilemma of an increased demand for energy, while traditional energy generation resources are diminishing. Therefore, global policy makers have begun crafting roadmaps to increase energy efficiency and sustainable, "green" energy generation.

From an energy grid operator's point of view, this megatrend translates into an urgent need for modernization of the energy distribution grid infrastructure. The main issues are:

- Small and medium clients (traditional energy customers) increasingly becoming "energy aware" and engaging pro-actively in the energy market by becoming "smart clients" who consume as well as produce energy—so-called "prosumers";
- Energy distribution grids coping with an increasing amount of de-central "green" energy generation, which is fed back into the energy grid and often volatile (e.g., solar and wind power);
- Integration of de-central energy storage technology, such as electro-mobility storage capacities;
- Reduction of overall CO_2 emissions by increasing the amount of "green" energy generation;
- Increase in overall efficiency of energy generation and distribution.

To address these challenges, new business models are emerging that redefine the traditional energy and utility value chain. A new class of devices and deployment of associated communication infrastructures are required throughout the distribution grid to support these new business models, including, for example:

- Smart meters and other sensory devices (networked);
- Smart networked actuators, i.e., devices with (remote) control functions;
- Smart de-central energy generators (the smart grid is not only for distribution of energy anymore; it also must cope with many small new energy generators that feed energy back into the grid).

Another key aspect is the expected decentralization of energy distribution grid services. Balancing of energy generation, storage, and consumption can be realized most efficiently as near to the physical location of generation/storage/consumption as possible. This reduces the need for centralized communications and enables autonomous operations of increasingly smaller sections of the distribution grid.

The efficiency and viability of innovative energy management applications, or the "core of the smart grid," depends on the ability to capture fine-grained, real-time, energy-related sensor data, such as power consumption/power generation meter values, and control commands (e.g., direct load-control commands for devices which support control functions). Depending on the use case—customer information services or grid management applications, for example—different "real-time" data is required from the sensors and actuators, therefore these must be installed throughout the energy distribution grid.

But the availability of this kind of fine-grained real-time data (e.g., power consumption measured every second, or the status and activation schedule of smart home household devices such as freezers) introduces a high risk of privacy violation because this data is related to individual people. This in turn introduces a new risk of data abuse, which is a prime concern in today's society.

The "Model City Mannheim" (moma) project focuses on researching the implications of innovative IT for the energy grid. The project is part of the E-Energy project framework initiated and partly funded by the German federal ministries for economics and environment. The framework runs from October 2008 to October 2012.

The E-Energy moma project concentrates on smart grid device integration via broadband power-line communications and real-time communications. The main focus of the project is the de-central aspects of new smart grid applications for the following domains:

- Smart home/smart business energy services
- Smart micro grid energy services
- Energy market services

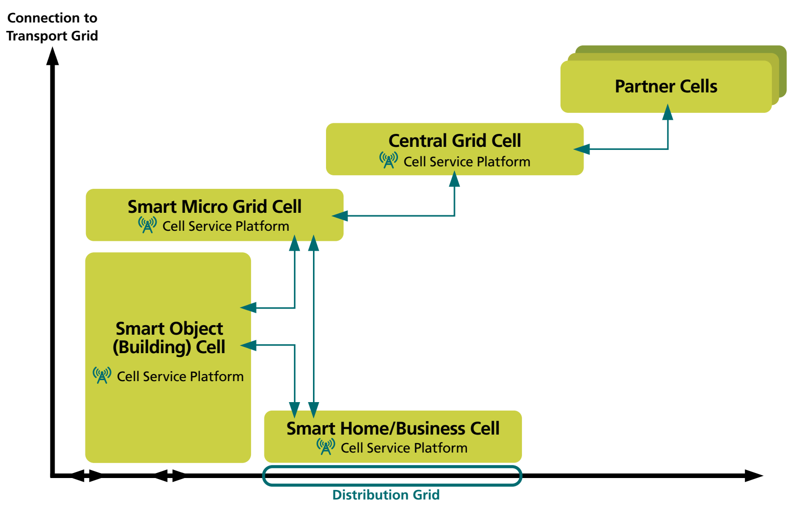
The Cellular Smart Grid

Smart Home/Business/Building Cells and Micro Grid Cells are the parts of the infrastructure that are expected to undergo massive changes and require IT investments due to the introduction of new sensors, new actuators and new service application capabilities within the energy distribution grid.

Autonomous so-called energy grid cells, as a place for applications in all three aforementioned domains, are an integral part of the moma project. The IT system model partitions Mannheim's energy grid in a number of autonomous smart micro grid cells that aggregate a number of smart home/smart business/smart building cells.

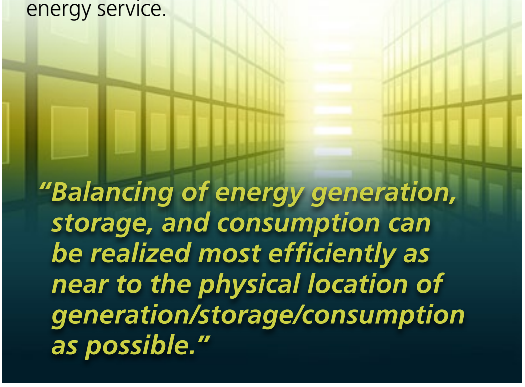
The moma project pilots the cellular approach in two pilot stages. In the 2010 Mannheim field trial, the cellular architecture approach will be piloted with about two hundred pilot users organized in ten micro grid cells with basic smart grid use cases. In 2011, the pilot will be scaled up with an additional approximately thirteen hundred pilot users in Mannheim and Dresden.

The E-Energy moma project's answer to these smart grid challenges is the introduction of a "cellular systems topology" as depicted in the following figure:



This "cellular concept" was introduced in the E-Energy moma project for the following reasons:

- Primarily, to provide support for privacy data protection of individual-related personal data. Data (sensor readings or energy grid device control functions) should only travel as far as required by the respective smart grid use cases. The smart grid use case should be deployed on the cell most appropriate for the service. Meter data and control commands are "cell concept aware" and are not exchanged over cell borders if not required or allowed by the energy service.



- Secondarily, to define autonomous cells within the energy distribution grid (micro grid cells) that do not require constant connectivity to the Central Grid Cell. Energy management, grid management, or other smart grid applications that are executed within the micro grid cells allow for de-centralized load balancing of the energy grid. This results in improved efficiency because the balancing functions can be executed faster, compared to a central systems approach. Additionally, grid failures (e.g., due to overload) can be encapsulated in the affected cells and, therefore, complete grid down time can be reduced.
- Lastly, to enable and integrate a tariff-independent, standards-based, and cost-efficient smart metering infrastructure. Integrating the basic functions of smart meters (reading, switching) at the micro grid level allows for a cost-efficient integration of meter data into micro grid cells and backend business processes. Smart metering functions can be covered by the standard data and service model already used within energy grids, eliminating the need for costly installation of meter-dependent Advanced Meter Management (AMM) systems in the central data center.

The IT Challenges of Smart Micro Grid Cells

In the E-Energy moma project, the various discussed business models imply the availability of a plethora of Smart Micro Grid Services. Consequently, the E-Energy moma Smart Micro Grid cells service platform is expected to host a number of services, including smart metering, energy management, production/ consumption forecasting, market and grid agents, data security, and privacy services.

This high-level description of the E-Energy moma smart micro grid services can be mapped to a number of (new) market roles, each with their individual services, across the traditional energy value chain. The management of these services from different market roles demands a common and open service delivery model that is implemented by the smart micro grid cell service platform.

From the IT perspective, there are a number of challenges that an open standards-based smart cell service platform for micro grid and smart home/ business/building applications must address.

Challenge 1: Heterogeneous Device, Device Connectivity And Protocol Landscape

When looking at smart metering and smart grid device and communications technology today, a very heterogeneous vendor environment can be seen, with standardization still in the early phases. Each vendor's technology brings in specific functions, often resulting in a vendor "lock-in" for the use of these functions, either because of proprietary protocols or software tightly coupled with a specific device. In this heterogeneous device, connectivity, and protocol landscape, it is necessary to adopt an abstract, standards-based view of the new smart grid system as early as possible. In an ideal smart grid world, all smart grid device functions, device connectivity, and device protocols would be standardized in order to avoid multiplied maintenance effort and vendor lock-in for proprietary components.

IT and business standards are extremely important for reducing the complexity of the infrastructure and integration effort. For example, in the complex partner ecosystem of the E-Energy moma project, with its different development partners, three cell layers and different energy value chain roles, using standards is paramount in order to reduce the complexity of the moma smart grid and the complexity of implementation.

As one of its central business standards, the moma project relies on the IEC61968/61970 standard for the common information model (CIM) integrating the cell layers. Moma is focused on acquiring experience in using CIM and collecting recommendations on how to extend the CIM model based on project experience. From a technological standards point of view, OSGi1 is the core standard for de-central (Smart Home, Smart Micro Grid) application software and services used in the moma project.

Challenge 2: Different Evolution Speeds of Business And Technology

Business and technology have different speeds of evolution with technological evolution being the faster of the two. Therefore, it is essential to decouple business functions from technology. Business functions (use cases) must be independent of technology in order to save investments, retain flexibility in adapting new smart grid business models, and for selecting the underlying technology (e.g., new smart grid hardware, new smart metering, or energy management device technology).

Challenge 3: Diversity of IT Infrastructure in Different Energy Grid Cells

Often it is not known upfront whether a given business function should be deployed centrally in the data center, or de-centrally in a smart micro grid, smart building, or smart home cell. For example, the final number of potential users or data flows is not known during development, but early pilots are required, and the piloted infrastructure should almost be the final one. Therefore, it is important to smart grid operators that this deployment location decision be very sensitive to any relevant business function, regardless of the actual deployment model.

This constitutes a major paradigm shift in defining smart grid systems. In today's smart grid systems, business functions are often tightly coupled to a unique implementation for a specific device. Several incompatible smart metering technologies have already been rolled out in different segments of the energy distribution grid. An example of this tight coupling is a specific tariff model that is "hard-coded" in a specific smart meter device. This makes it very expensive to deploy new, probably more complex tariff models for the smart meter after roll-out. Implementations of business use cases are currently different for each energy grid cell in which they are deployed.

Challenge 4: Lack of Common Operational Support Infrastructure

Another relevant challenge involves operating various service platforms deployed into the energy distribution grid. As outlined in the previous sections, the cellular concept of moma establishes four smart grid cells. As a cell core, each of these cells requires a physical device, or gateway, which allows for the execution of energy services applications. A common operational support concept is required in order to minimize the operational effort as much as possible.

The paradigm of the moma project is that the energy market of the future is not device-centric (smart meters, smart home), but services-centric. This is why smart grid hardware deployments (devices, sensors, actuators) will be potentially beneficial for various roles within the energy value chain. Smart grid applications running on those smart grid devices are becoming increasingly important as "business assets." The moma project foresees a number of innovative, new energy service applications from different independent software vendors (ISVs) being deployed in smart grid cells, supporting and implementing different roles of the energy value chain.

However, these energy service applications cannot exist without an underlying IT infrastructure that manages them. In order to leverage the benefits of hardware independence and avoid the build up of separate, incompatible smart grid IT infrastructures, a synchronized approach for the definition of this infrastructure is required. As with every new IT infrastructure, there must be an operator of this infrastructure in order to address important aspects such as infrastructure management, security, and privacy policy enforcement. The operator of the cellular smart grid takes control of two very important control points—the smart home and the smart micro grid cell—and integrates both into the complex grid infrastructure.

Challenge 5: The Current Backend-Centric Infrastructure Requires High Investments in High Availability and Security

Many enterprises have started integrating their applications, IT systems, and business processes to achieve higher flexibility and productivity by using a services-oriented approach. For the cellular smart grid, distributed and remote (edge) cell service platforms, such as the smart home and smart micro grid platforms, must be integrated into the central system's processes and IT infrastructure. The benefit of this cellular energy grid approach is that business functions and some aspects of IT infrastructure such as availability and security can be decentralized and evenly distributed over all de-central components. In contrast, a centralized system that has to integrate tens of thousands of smart grid devices directly has significantly higher requirements for availability and security.

In the cellular smart grid approach, the remote locations must therefore be able to independently integrate local processes and IT infrastructure, such as smart meters, in a flexible and efficient fashion. Connection problems to the central system location must not stop the remote endpoint infrastructure (e.g., a substation or a consumer home) from working and hence affecting the business. Data communication between the remote smart grid service platform locations and the central system must be reliable, manageable, and secure.

Even when business and IT standards are employed to enable easy integration of the energy service applications, two very important operational aspects

must be considered for the operation of such a complex infrastructure. These must be considered as early as possible during the conceptual phase of the definition and creation of service platforms for an actual cellular smart grid deployment:

- The platform operator needs to set up standards for the developers/ISVs of the energy service applications from the various energy value chain roles. Open standards such as CIM and open technologies such as OSGi are key.
- The platform operator needs to support service levels for the stable execution of the energy service applications from the various developers/ISVs.

Guaranteeing these service levels and enabling stable platform operations are the platform operator's prime concerns for keeping the operational costs of such a platform as low as possible.

In addition to basing the smart cell service platforms on open standards and open software frameworks, the platform operator must establish component and deployment guidelines to address these operational topics and achieve operational efficiency. This also includes implementation guidelines for energy service application developers/ISVs.

Challenge 6: Legal, Security, and Data Privacy Regulations May Differ for Each Cell, Depending on Cell Location or Cell Contracts

As mentioned above, deregulation of local markets fosters the creation of cellular smart grid infrastructures. Furthermore, it introduces new business models and roles. This results in changes to the traditional energy value chain. Market power shifts from central to de-central participants. New energy value chain players are emerging and are occupying the new roles, such as "smart grid data highway" operators, energy management software providers, or energy information brokers.

On the other hand, the new diversity and number of players and roles requires new regulations to ensure interoperability. Furthermore, the operator of a cellular smart grid infrastructure faces the challenge of adopting the legal, security, and data privacy regulations within the new smart grid infrastructure. For example:

- Different legal requirements depending on the type of clients (e.g., clients of a different nationality or energy value chain in the same micro grid cell);
- Different data privacy and therefore security requirements, depending on the type of client and/or the energy grid services the client provides or subscribes to.

The cellular system's service platforms have to be highly flexible to support diverse business rules for each potential smart grid service participant.

Benefits of the IBM Solution Approach

The deployment of open standards based smart micro grid or smart home cell service platforms establishes business control points for innovative smart grid applications across the whole energy value chain, from prosumer-centric services to smart grid operational support services.

- Sensor reading and device control functions can be adapted to industry data and service models.
- Sensor reading and device control functions can be normalized, enabling easier integration with business processes with interface mapping and reducing integration efforts.
- Sensor reading and device control functions can be normalized much earlier in the development cycle and at lower cost than in the old pure central system approach.
- Smart micro grid and smart home cell service platforms add an additional scalability layer to the smart grid.

- Business process integration and business control can be flexibly deployed on the common smart grid layer. This is highly efficient from a service function and operational point of view.

For the operator of such an open standards-based smart cell service delivery platform, the model-based approach introduced by the IBM alphaCELL platform brings the following benefits:

- It increases "speed-to-market" for new business use cases, i.e., new energy service applications.
- It reduces interface adaptation efforts on a large scale due to a single data model within the whole system distributed over all "intelligent" parts of system cells.
- It addresses all important operational aspects of the platform from the start, including scalability, autonomy, and security.

The model-driven approach also allows for flexible smart grid business function implementation and deployment on either the central cell/central system or the de-central smart micro grid cells, depending on given business, security/data privacy, scalability, or autonomy requirements and technology availability. Since deployment scenarios may change as technology or business changes, business functions can be initially modeled independently from the final selected deployment scenario. This results in more agile business and significantly reduces effort compared to regular, non-model-driven development.

To view references and sources please visit www.generatinginsights.com

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