ABSTRACT
Significant changes in the distribution system operation are necessary in the context of the following major development trends of “SmartGrids”:
• Smart Distributed Energy Management.
• Smart Metering.
• Smart Distribution Terminal Automation.
All three aspects require information exchange on the distribution level in a quantity and a quality which are not available today.

The provision of the right information within the right time to the right users – this will be a task of new market players. New market roles will be established and consequently, the unbundling process of the electricity market will further continue.

The following considerations are based on the VDE study “Smart Distribution 2020” [1].

1. INTRODUCTION
The prospective integration of millions of dispersed energy resources like PV or CHP, of storage units, of new customers like electric cars or heat pumps as well as the market participation of the consumers by demand response in the result of dynamic tariffs or active participation on the control power market are a great challenge for the distribution systems. The conventional consumer of today becomes more and more a so-called prosumer, because he does not only consume energy, but will also produce energy (PV, CHP) in his house.

The need to ensure the reliable operation in the environment of volatile and reverse power flows, of significant uncertain and intermitting feed-in from renewable sources increases the demand for a more “internet-like” distribution system with information exchange on all levels, with secure data flow from and to whom it may concern.

Central and dispersed generation will exist in parallel and consequently, we will need central and distributed intelligence. New concepts like virtual power plants combining fossil fuel plants, renewable generation, storage, demand side response in the context with dynamic tariffs and smart metering will bring a paradigm change: The grid infrastructure is shifting from a static to an intelligent control system with real-time feedback abilities. In this context, smart distribution is based on three major pillars:

1. Smart distributed energy management to coordinate a large number of aggregated small generators, storage units and demand management facilities into virtual power plants (VPP) with the task to reach optimum prices on the markets for energy, ancillary services and emission certificate trade.

The second pillar can be realized independently of an energy management system like a VPP, but its existence is an integral part of the more advanced VPP system. It motivates the market participation of the consumers.

2. Smart metering which provides digital data collection and communication, dynamic tariffs and a gateway to smart home automation.

3. Smart terminal automation to provide self healing behaviour and to improve reliability of supply.

Currently, data exchange via communication exists only between network control centres and the substations of the transmission and of the 110 kV grids. Different communication protocols are applied on different levels (inside substation, between substation and control centre) and for different equipment (protection relays, meters, switchgear) as shown in Figure 1 (left side).

Figure 1. Current situation and future needs for communication in power systems
This practice needs conversion of data formats on different levels and requires high engineering expenses.

In the future the communication has to penetrate the distribution level down to the low voltage customers and protocols using uniform data models and services should be applied as is shown on the right-hand side of Figure 1.
2. TASKS AND INFORMATION EXCHANGE

Different data are required to perform the tasks of smart distribution. An overview of the information content is presented in Figure 2.

![Figure 2. Required data for smart distribution control and supervision](image)

**2.1. Smart distributed energy management**

In the future, the virtual power plant will act as a trader on the electricity market. In this context it has to provide day-ahead schedules. On this basis it communicates generation profiles (96 quarter hour power targets) to its units. For its on-line coordination function the virtual power plant needs all metered values of the generators, storage units and of the sum load in their balancing area at quarter hour intervals. Based on the metered values, the applicable reserves and the market situation, it communicates corrective power targets and load switch commands or real time price signals to the controllable generators, storage plants and loads or consumers.

The communication of status and fault information to the VPP control centre is useful for efficient disturbance elimination and maintenance.

**2.2. Smart metering**

Smart Metering is taken to mean the measurement of the gas, water, heat or electricity consumption using electronic meters with bidirectional communication for simple transmission of measured data. The data are then no longer only available to the customer and the utility once each year, but as often as they require. The customer can thus be shown his electricity consumption with great transparency. It is also sensible to integrate further media relevant to billing, such as gas, heat or water, as the expenditure for the communication infrastructure is then spread among various media.

The essential advantages of “Smart Metering” cover all the market roles from the final customer through the metering service provider and the network operator to the power supplier:

The metered data can be read out directly and regularly. A tiresome, manual annual survey can therefore be replaced by continuous and automated reading. On changes to tariffs, billing would no longer be based on data estimated by the utility, but on real consumption data valid at the due date.

Transmission of measured data via the communications interface facilitates simple and thoroughly automated change of supplier by the customer.

Energy-efficient behaviour in private households will only come about if the customers are suitably motivated. Graphic illustrations of energy consumption create the transparency needed to reveal a need for action and further reinforce correspondingly energy-efficient behaviour by positive feedback. A study commissioned by the German Federal Ministry of Economics rates the realistic savings potential for electrical energy supply at more than 6.5 % or 9.5 billion kWh in 2010 [3].

Energy suppliers can offer flexible dynamic tariffs. With flexible tariffs, consumers are motivated to avoid expensive peak loads, thus contributing to a smoothing of the load curve, and allowing price-conscious customers to procure energy more equitably and more cheaply. With a load shift on the basis of new, flexible tariffs, expensive and in part inefficient peak loads, such as the use of throttled backup power stations or storage facilities with a low efficiency will be required to a lesser extent. A display which is currently being tested for customer’s information on flexible tariffs is shown in Figure 3.

![Figure 3. Customer’s information on flexible tariffs](image)

In a similar fashion to the cell phone market, new and innovative services will arise on the basis of the modern technologies. For example, extended consulting regarding energy consumption is conceivable in this context.

**2.3. Smart terminal automation**

Currently, the MV/LV terminals in the distribution network are without any remote control and automation. The costs of a communication infrastructure are the main reason for this situation.

However, if a communication infrastructure is to be established for distributed energy management and smart metering, then it is a smaller step to introduce remote control, supervision and automation into the distribution...
terminals. Today, in the case of faults and supply interruption a maintenance team has to drive along the MV feeder to check the terminals. It takes on average more than 1 hour to eliminate the faulty feeder section by switching operations shown in Figure 4.

![Figure 4. Fault elimination on MV networks with open loop configuration - 1- trip by relay, 2.1.2.2 elimination of faulty section detected by fault indicators, 3, 4 closing isolator and circuit breaker for continuation of supply](image)

Communication makes it possible for the short circuit indications to be read remotely in the case of faults. The isolation of the faulty feeder part and the recovery of supply are then executed remotely and automatically. The supply recovery time can be shortened to minutes.

For this “self healing operation”, the communication of the fault indications and the commands for switching the isolators are required.

Furthermore, communication can be used to supervise the switching status of all isolators in the terminals, voltages and load flow along the feeder and to receive diagnostic information on the switchgear or the transformers for efficient asset management.

3. NEW MARKET PLAYERS

3.1. Overview

The information exchange in smart distribution systems requires a telecommunication infrastructure and innovative services. The question is now who will be responsible for all this?

![Figure 5. Logical scheme of users and providers of data](image)

The deregulated market provides the answer: new market players will take over these new tasks in accordance with usual market rules (tenders, offers, competition...).

The logical schematic of data flow between the control levels, the stakeholders, the service providers and the customers and producers of energy is shown in Figure 5.

3.2. Communication provider

The function of the communication provider may be performed by an independent entity or by the distribution network operator (DNO). In each case the existing communication infrastructure should be used for economic reasons.

Depending on the local situation, the most economical situation could be the use of existing telecommunication cables (copper or fibre optics), radio channels or distribution line carriers (DLC).

In accordance with Figure 1 a common language on all communication levels will be required to ensure “plug and play”, interoperability and minimum engineering and operation costs. Therefore, a common communication standard is required.

Today, different communication standards are applied on different levels of the power system and for various kinds of equipment.

However, there is a trend to use common data models and common services of the application layer (7 layer ISO/OSI reference model) coming from IEC 61850 [2]. New data models for distributed generators and storage are standardized accordingly in IEC 6850-7-420.

IEC 61850 was developed as an open communication standard. Its reference model allows flexibility in the design of the 7 layers of a communication protocol. The data model and the services are defined in an abstract communication service model and the layers of the ISO/OSI models can be designed on the basis of common data models and services through specific mappings independently as shown in figure 6.

![Figure 6. 7- Layer model for common data models and services but flexible selection of physical and link layers](image)

In this way the result will be that different physical communication channels can be applied while keeping uniform data models and services. The data conversion required today on each communication level is avoided.
3.3. Metering service provider

On a deregulated market the grid cannot be operated in competition and is therefore subject to governmental supervision and regulation as required by the European regulations. In a traditional grid, the network operator also provides services concerning the operation and performance of electricity metering, which can also be offered in an environment of competition. In a number of European countries, therefore, this metering function has also been opened up to competition. In Germany, the lawmakers are also hoping for the opening up of the market to lead at the same time to an accelerated introduction of Smart Metering with the accompanying benefits of Smart Distribution (e.g., dynamic tariffs dependent on time).

For economical reasons a multiple use of the ICT infrastructure is recommended and consequently also metering of gas, heat or water will be integrated into a Smart Metering approach. The opening up of the market will be exciting, as new market models will become possible: Will metering remain the province of traditional network operators or be offered in future together with electricity or gas supply contracts, will the telecommunication companies take on this function or will there be independent, specialized metering service providers for all media, who can then provide their services cost-effectively for all the market players? For local suppliers such as municipal utilities or the future locally organized VPPs, taking on the market role of metering offers a number of competitive advantages: the increased contact with customers, the opportunity to combine further energy services with the metering, and also the integration of the various media in a multi-utility approach.

If deregulation of the metering system is to succeed, the conditions under which the new market is to develop are important: Minimum standards for interfaces and data formats must be stipulated – at best, on a European market, throughout Europe right from the start; the advantages that Smart Metering has for the various market players must also be made available to them above and beyond the bounds set by deregulation (Who is entitled to receive what information in the spirit of optimizing the entire system?); clear data protection standards will also have to be stipulated to avoid superfluous discussions.

3.4. Information provider

In order to achieve this vision, an information provider would be an efficient solution. The information provider has to perform a new market role which did not exist before smart distribution. Primarily, the information provider has to ensure that each stakeholder will receive the data which are his concern – but only these data. For that the information provider needs to store all incoming data in a server and to pack compressed data files for transmitting to all relevant stakeholders. The data provision will be executed in relation to the order of the stakeholders and in the requested time frame. On the level of meter communication a broad variety of communication standards is applied. It will not be possible to change this practice in medium terms and to use a common standard everywhere. Therefore, a further task of the information provider is the conversion of the data formats coming from the meters into the IEC communication protocols.

4. CONCLUSIONS AND FURTHER NEEDS

The technology to perform “Smart Distribution” is available and mature today. However, significant barriers have to be overcome for a broader implementation of the smart distribution tasks in existing distribution systems.

- The existing practice with fixed feed-in tariffs (over the flexible market prices) for renewable energy motivates the quantity but not the quality of renewable power production. Such a policy prevents the establishment of VPPs. The VDE study [1] presents ways how to overcome this situation by adaptation of the support schemes for renewable energy to the market prices.
- The ICT infrastructure still needs more standardization or the consequent application of existing standards - for communication on the metering level - for mapping IEC 61850-7-420 data models (for distributed energy resources) and services to different physical layers, - for application of common information models (CIM) at the level of data base management.
- The business models of the new information and communication service providers have to be developed and approved in practice.

In Germany 6 projects for different energy regions were funded by the ministries for economy (BMWi) and for environmental protection (BMU) in 2008. The European Commission published in December 2008 the call “Energy.2009.7.3.5 Novel ICT solutions for Smart Electricity Distribution”.

With these activities the chance is given that all open problems will find a proper solution soon and in the consequence “Smart Distribution” will be broadly applied to reach higher energy efficiency, more environmental protection and better reliability of supply.

5. REFERENCES