Technische Universität Berlin
Innovationszentrum Energie

Smart Grid: The Central Nervous System for Power Supply

- New Paradigms, New Challenges, New Services -

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Schriftenreihe **Nr. 2**
Innovationszentrum Energie

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ISSN 1869-5906
ISBN 978-2-7983-2216-5

Vertrieb/ Publisher:
Universitätsverlag der TU Berlin
Universitätsbibliothek
Fasanenstr. 88 (im VOLKSWAGEN-Haus), D-10623 Berlin
Tel.: (030)314-76131; Fax: (030)314-76133
E-Mail: publikationen@ub.tu-berlin.de
http://www.univerlag.tu-berlin.de

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Contents

ABSTRACT

In future power systems, a smart grid is expected to manage supply and demand of electricity efficiently. This article explores (1) the trends and challenges of today's power system that trigger the development of smart grids, (2) the elements that may eventually constitute the smart grid and (3) the role a telecommunication provider may adopt in the emerging smart grid market.

The trend towards an increasing share of renewable and distributed energy sources bears two major challenges: A lack of predictability and a lack of controllability of power generation. This article introduces four elements of a smart grid which address these challenges: virtual power plants, demand side management, control of power flow and storage and buffering.

Finally, it is pointed out that in order to enhance the smart grid's actual value, the elements have to be systemically integrated. It is argued that telecommunication providers are well positioned to address the integration challenges as they have crucial experiences and capabilities: profound understanding of large IP networks, experiences in cloud computing, extensive service platform know-how and cooperation experience.

Keywords: Smart Grid, Virtual Power Plant, Demand Side Management, Energy Storage, Telecommunication

ZUSAMMENFASSUNG

Im Energiesystem der Zukunft wird ein intelligentes Netz (Smart Grid) Angebot und Nachfrage effizient steuern. Dieser Artikel beschreibt (1) die Trends und Herausforderungen heutiger Energiesysteme, die die Entwicklung eines Smart Grid auslösen, identifiziert (2) Elemente eines Smart Grid und stellt (3) die mögliche Rolle eines Telekommunkationsunternehmens im entstehenden Smart Grid Markt dar.

Der Trend zu einem steigenden Anteil erneuerbarer und dezentraler Energieerzeugungsanlagen bringt zwei große Herausforderungen mit sich: Eine mangelnde Vorhersagbarkeit und eine mangelnde Regelbarkeit der Erzeugungsleistung. In diesem Artikel werden vier Elemente eines Smart Grid vorgestellt, die diese Herausforderungen adressieren: Virtuelle Kraftwerke, Demand Side Management, Lastflussregelung und Energiespeicherung.

Abschließend wird herausgestellt, dass die Elemente systemisch integriert werden müssen um den eigentlichen Wert des Smart Grid zu heben. Es wird erörtert, dass sich Telekommunikationsanbieter in einer guten Ausgangsposition befinden um die Herausforderungen dieser Integration zu adressieren, da sie über wesentliche Erfahrungen und Fähigkeiten verfügen: Umfassendes Verständnis großer IP-Netzwerke, Erfahrungen mit Cloud Computing, umfangreiches Wissen zu Service-Plattformen und Kooperationserfahrung.

Keywords: Intelligente Netze, Virtuelle Kraftwerke, Demand Side Management, Energiespeicherung, Telekommunikation

1 INTRODUCTION

The need to meet growing electricity demand reliably and to integrate an increasing share of distributed generation and renewable energies are the challenges the world's aging electricity networks are facing today. Experts agree that the next generation of electricity networks will be intelligent, bringing the worlds of IT, communications and energy systems closer together than ever before. A smart grid is expected to manage supply and demand of electricity efficiently. Understanding the major opportunities in the emerging smart grid market, companies worldwide from major enterprises to small start-ups are launching activities in this field.

This article gives an introduction to smart grids. It aims at answering three questions:

1. What are the trends and challenges of today's power system that trigger the developments of smart grids?
2. What are the elements that may eventually constitute the smart grid?
3. Which role may a Telecommunication Provider adopt in the emerging smart grid market?

Figure 1 outlines the structure of this document.

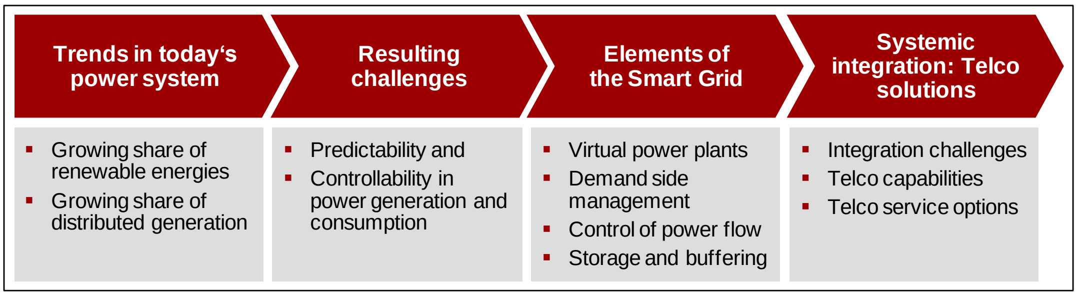

Figure 1: Structure of the document (Own figure)

2 TRENDS AND CHALLENGES IN TODAY'S POWER SYSTEM

2.1 THE ADVENT OF RENEWABLE ENERGIES AND DISTRIBUTED GENERATION

The European energy sector has faced a number of significant structural changes within the past 10 to 15 years. Until the end of the 1990s, the power market was characterized by regional stateowned monopolies. In 1996, the liberalization of the European energy sector began with the adoption of the European Union directive 96/92/EC (Franz et al. 2006). The new energy legislation broke up the regulated monopoly and introduced competition in the generation and trading business.

Parallel to the liberalization process, a shift in European energypolicy towards a more sustainable power system could be noticed. An increasing awareness of global warming and its ecological, social and economic consequences triggered regulative activities to mitigate CO_2 emissions. On December 17th 2008, the European Parliament adopted the European climate and energy package which will help Europe to transform into a low-carbon economy and increase energy security. With the adoption, the European Commission and the Parliament have agreed to meet legally binding targets by 2020 in order to cut greenhouse gas emissions by 20 %, to establish a share of 20 % in renewable energies, and to improve energy efficiency by 20 %. In Germany, the biggest power producer in Europe, for instance, the electricity generated from renewable energy sources almost quadrupled between 1996 and 2008, increasing its share in the total power supply from 4.2 to 14.8 % (BMWi 2010).

From the entire power system's point of view, these developments are accompanied by major structural shifts. In the past, the European need for electricity was mainly covered by large central coal, lignite and nuclear power plants. Incentivized by the regulator, a growing trend towards greater use of distributed and renewable generation was initiated. The emphasis of government policies on a reliable and sustainable power supply that encourages the use of distributed combined heat and power (CHP) and renewable energies accelerated this development (IEA 2008b). These shifts have considerable implications for a functioning and efficient power supply system, which will be discussed in the following.

2.2 New Challenge: Predictability and Controllability

In an electricity system, power supply and demand have to match at any given moment. As consumers have the flexibility to switch on and off their electrical devices as they please, the supply side of the system must be able to react to these load changes. In a central-station-dominated system with controllable thermal power stations these load alternations can be dealt with easily. In a system with a high share of renewable generation, another source of uncertainty in terms of predictability and lack of controllability is introduced into the system, especially when it relies on wind and solar power as is predominantly the case. According to the European Wind Energy Association, integrating wind or solar power into the grid at scale – at levels higher than 20 % – will require advanced energy management techniques and approaches at the grid operator level (DOE 2009).

Although controllable in principle, the introduction of distributed CHP facilities can challenge the grid operator. While in a central station dominated system optimization can be performed by a central entity, distributed generation is operated to the benefit of its owner, often disregarding overall system efficiency and reliability. In addition, most distributed CHP facilities are run heat-led which means that the operator’s need for heat defines the operating mode and thus its power output. In conclusion, changes in the distributed CHP facilities’ operating mode may occur spontaneously and irregularly (IEA 2008a).

3 ADRESSING THE CHALLENGES: ELEMENTS OF THE SMART GRID

It has been shown that today's power system is faced with major challenges. It is clear that these challenges will even grow in the future as the underlying trends towards more renewable energies and distributed generation are further enforced by social preferences, political will and economic evidence.

A plausible approach to deal with the challenges is the introduction of modern information and communication technologies (ICT) into the power system, thus making the whole power system intelligent. A so-called "smart grid" would be able to manage power supply and demand efficiently.

But what is a smart grid and how can it help to match power supply and demand at any time even though generation and consumption seem to be increasingly unpredictable and uncontrollable? Being a relatively new paradigm, the smart grid is associated with a large variety of different concepts. In our view, these concepts can be understood as elements of the smart grid that will eventually have to be systemically integrated. Figure 2 shows the elements of the smart grid that will be introduced and discussed in the following.

Elements of the Smart Grid		
Supply side	▪ **Virtual power plants:** Enhancing controllability by diversification	**Storage and buffering:** New degrees of freedom
Demand side	▪ **Demand side management:** Making Consumption Adaptive	
Electricity network	▪ **Control of power flow:** Linking supply and demand effectively	

Figure 2: Elements of the smart grid (Own figure)

3.1 Virtual Power Plants: Enhancing Controllability by Diversification

A Virtual Power Plant (VPP) addresses the supply side of the problem at hand. The basic idea of it is to connect several hundred or thousand distributed and renewable power generating facilities via modern ICT. A central control entity continuously monitors the generation data and has the possibility to switch individual generators in and out of the system at any time. Thus, the facilities' operation can be scheduled and optimized.

The objective of connecting multiple distributed generators is to reach almost the same controllability as with conventional plants. Two effects in VPPs contribute to the achievement of this objective:

1. **A well-chosen mix of volatile generators can offset their inherent unreliability to some extent:** Following basic stochastic principles the connection of different volatile systems with different fluctuation patterns may lead to a decreased overall volatility. It is clear that this logic is applicable to power generation from renewable energy sources: On the one hand, in many places strong winds and bright sunshine do not typically appear simultaneously (Figure 3). A solar power station and a wind farm hence complement one another well. On the other hand, larger geographic dimensions of a VPP may include regions with different weather conditions that help to offset volatility.
2. **The inclusion of selected controllable generators in a centrally controlled system can compensate the remaining unreliability:** As described above, power generation from distributed CHPs is uncontrollable from the overall system's point of view because only the owners decide upon their insertion. It is a slightly different story if several distributed CHPs systems are integrated into one system. In this case the control entity of a VPP is able and legitimated to shut down certain facilities in case of oversupply. In addition to distributed CHPs the integration of fully controllable renewable sources like pumped hydro facilities or biogas plants may compensate the remaining unreliability in the system.

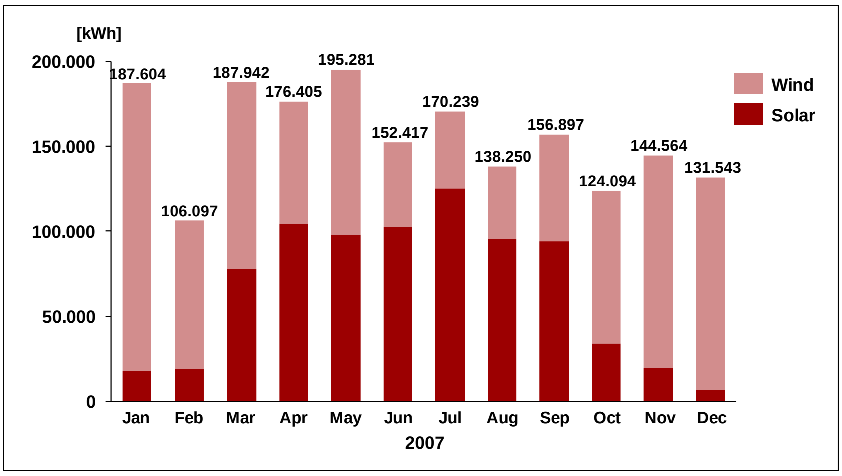

Figure 3: Power generation from solar and wind energy in a virtual power plant (E.ON Hanse 2010)

The business logic behind the concept is simple: In the power market controllability has substantial value. The more a power generation facility is controllable, the more efficiently and economically it can be run, the more it can contribute to the system's stability and provide valuable regulating energy. The benefits of a VPP at first lie with its operator. Depending on the business model the operator may share his benefits with the owners of the integrated power-generating facilities as a compensation for transferring control over them to the VPP operator.

3.2 Demand Side Management: Making Consumption Adaptive

The basic idea of Demand Side Management (DSM) is to actively influence power consumption and thus reach a certain degree of controllability on the demand side of the energy system. The underlying assumption is that consumers in principle have some flexibility in how and when they use electricity. Given both the ability to manage power consumption and incentives to actually do so, a consumer may be willing to change his habits.

The main objectives of DSM are:

- Reduction of demand peaks when power consumption comes close to its limits of availability and blackouts may occur
- Load shifting from times of high consumption to times of low consumption for an efficient usage of existing power stations

- Load shifting from times of low to times of high generation from volatile sources like wind and solar power

In principle, DSM may be differentiated into indirect and direct load control.

1. **Indirect load control:** Indirect load control means that consumers are given incentives to shift their electricity demand according to the system's requirements. However, consumers keep full control over their efficiency patterns. The most efficient way to influence consumers' behaviour is to use price signals. That way, supply and demand may be balanced, driven by economic market forces: In times of oversupply, for example, when the wind blows heavily and the sun shines brightly, consumer prices would drop, hence giving the incentive to shift flexible loads. Load shifting using price signals may also be automated to a certain extent. Some devices may be able to process price signals automatically and react to them according to their owner's preferences.
2. **Direct load control:** Direct load control means that the consumer abandons control over some devices and transfers it to his utility or grid operator. In this case consumers sign up for a demand-side management program to allow the utility to switch off or limit power consumption of some devices like pool pumps, air conditioning, water heaters and electric heating. Obviously, direct load control is a more effective way for utilities to influence demand and may thus create a stronger willingness to pay for it. Consumers on the other side may be willing to accept a defined loss of control for compensation like cheaper power prices or bonuses.

As an example for indirect load control a washing machine could be programmed to be ready in 48 hours at the latest. The washing machine, capable of receiving and processing price signals, would then "decide" autonomously when to start the wash cycle considering actual power prices. In a further step the washing machine could also be capable of communicating with other devices in the household or even in the whole neighbourhood in order to coordinate consumption. That way, a group of consumers could control their aggregated demand to a certain extent. In its quest for predictable load patterns, a utility may be willing to pay a bonus to this group for not excessing or undercutting an agreed load.

A strong case for direct load control may be the integration of industrial refrigerated warehouses into a load control program as they display several well-suited characteristics: (1) Refrigerated warehouses are energy-intensive facilities, (2) the number of processes conducted in these facilities is limited and the processes are well understood and (3) most refrigerated warehouses are not sensitive to short-term (2 - 4 hours) lower power operation and thus DSM activities are not disruptive to facility operations. Recent case studies with refrigerated warehouses conducted and published by the Ernest Orlando Lawrence Berkely National Laboratories suggest a load reduction potential of up to 30 % by introducing DSM activities (Lekov et al. 2009).

3.3 Control of Power Flow: Linking Supply and Demand Effectively

Generally, within the alternating current (AC) grid the power flows on the lines from generation surplus areas to load surplus areas. In generation surplus areas there is an excess of power supply, while in load surplus areas there is an excess of demand for power. Especially in meshed grids, there are multiple paths between areas. For the sake of an example, this is indicated by two parallel lines with reactance X linking both areas in Figure 4. Here the two lines are shown with the same reactance X. As the reactance values are equal, the power P flowing between both areas splits up equally, too. Since the reactance is a function of the length of a line, the reactance values typically differ for different lines.

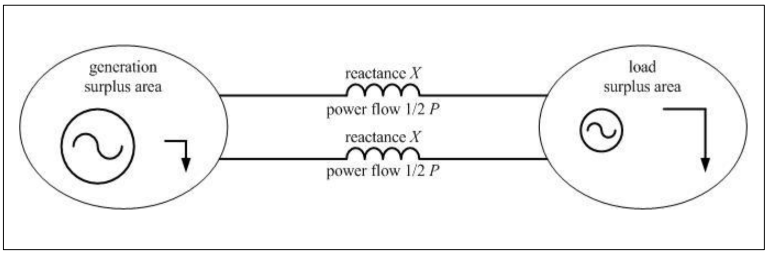

Figure 4: AC power flow according to fixed reactance (Own figure)

The way how electric power distributes over the network for a given pattern of generation and load heavily depends on the reactance values of the paths. This also implies that power flowing from off-shore wind farms in the north of Germany to load excess areas in the south does not entirely take the direct path, but in part can also flow through neighboring countries to the west and east before arriving in the south. Such parallel flow is undesirable. Network control devices (NCDs) such as phase-shifting transformers and flexible AC transmission system devices (FACTS) can be operated to reduce parallel flow.

In Figure 5, it is illustrated how different reactance values impact the flow of power. The power flow is inversely proportional to the reactance values. Some FACTS devices operate in that they modify the composite reactance of a path. As an example, the variable capacitor shown in the lower path of Figure 5 reduces the composite reactance contributed by both line and capacitor. Since the reactance of the path can be changed, it is possible to change the power flow patterns. In this sense, NCDs can become important elements of the smart grid as they assist in linking supply and demand effectively.

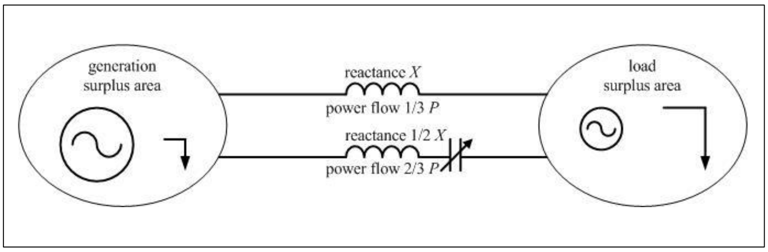

Figure 5: AC power flow controlled by variable reactance (Own figure)

3.4 Storage and Buffering: New Degrees of Freedom

As stated above, one of the major challenges of a power system is that supply and demand have to match at every given moment. The possibility to store energy eases this constraint: In periods of oversupply, storage devices artificially create additional demand, while during periods of high demand they act as extra suppliers. Thus, in the logic of this paper, energy storage and buffering addresses the supply side as well as the demand side of the discussed challenges.

Energy storage can be differentiated according to its storing and discharging time and the capacity of storage into high-power and high-energy technologies (IEA 2008a).

- **High-power storage devices** aim at supplying the electricity system with high electrical power for a short time at short notice. These devices are used to re-act to abrupt demand peaks or power drops in order to ensure grid stability and uninterrupted power supply. Examples for high-power devices are high-power super capacitators (supercaps), high-power flywheels and supercon-ducting magnetic energy storage (SMES).
- **High-energy storage devices** are designed to store and discharge electricity over longer time periods, though sacrificing response time and power output. High-energy storage is typically applied for balancing power supply and de-mand in daily cycles. Various technologies exist in this category, the most prominent ones being pumped hydro and compressed air energy storage, fuel cells and batteries.

Figure 6 shows an overview of different storage technologies regarding the system's power rating and the discharge time.

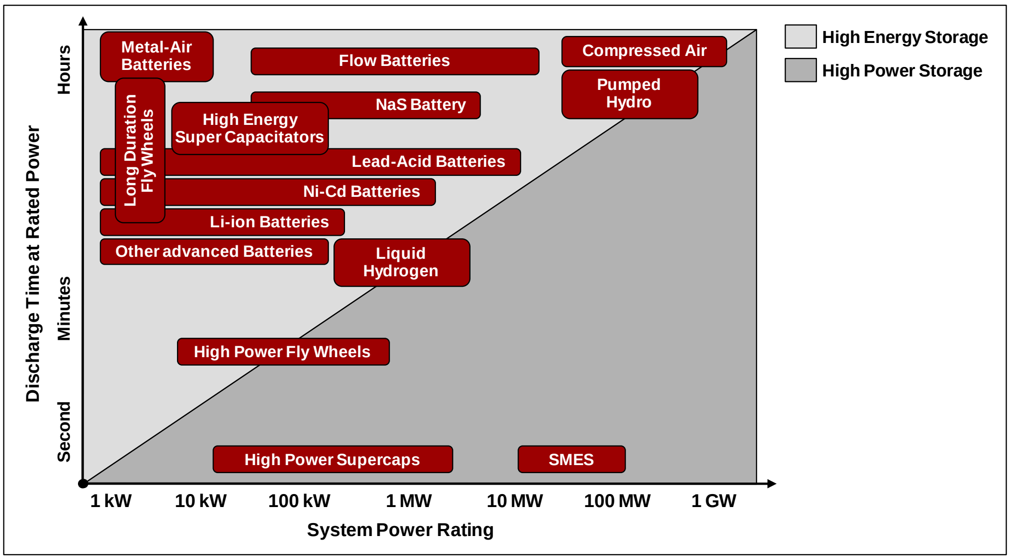

Figure 6: High-power and high-electricity storage technologies (IEA 2008a; ESA 2009)

The option of storing energy offers new degrees of freedom to the whole power system: Once electricity is generated it can either be used directly or – when demand drops or excess generating capacity is available – be stored and made available later. These options are particularly useful in a future power system with a high share of renewable energies: Storage systems could be attached to wind farms and store energy captured whenever the wind blows. That energy could then be dispatched into the grid during periods of peak consumer demand. Equipped with a storage system, solar systems could be used both day and night.

In addition to improving the integration of renewable energies into the power grid, energy storage also yields considerable business potential for its owner. The owner of a wind farm with storage device, for instance, may intentionally store electricity when wholesale prices are low and then dispatch it into the higherpriced midday market. Even without combining the ownership of generation and storage facilities, arbitrage may result in a viable business case: Energy storage allows purchasing inexpensive electricity when its demand and cost are low and then reselling it when prices rise. Acting as a buffer between power supply and demand, energy storage finally helps to reduce the need for expensive reserve energy and to run available generation facilities more efficient.

The drawback of using storage in the power system is that electricity as such cannot be stored. In fact, it has to be converted into other forms of energy (e.g. chemical, mechanical, thermal) which usually goes with high losses. In order to make energy storage an economically viable component of the future power grid, its information and communication technological integration into the system is crucial (DOE 2009).

4 INTEGRATING THE SMART GRID: NEW OPPORTUNITIES FOR TELCOS

In the foregoing paragraph, the constituents of an envisaged smart grid have been discussed. The technological push behind these elements is – apart from political motivation – the principal driving force behind the forming of a smart grid. It has to be pointed out, though, that the actual value of the smart grid lies in its systemic integration. To take up the title of this paper: a number of muscles and bones are only put to sensible use if a central nervous systems organizes them in a concerted fashion. Figure 7 sketches our understanding of the integration challenge: The elements discussed so far address the discussed challenges of today's power system from clearly defined perspectives: Power generation and consumption are mitigated by the new degree of freedom which is associated with dynamic buffering of energy. In order to unleash the full potential of the smart grid, however, the whole system will need to be integrated in the new ICT network domain.

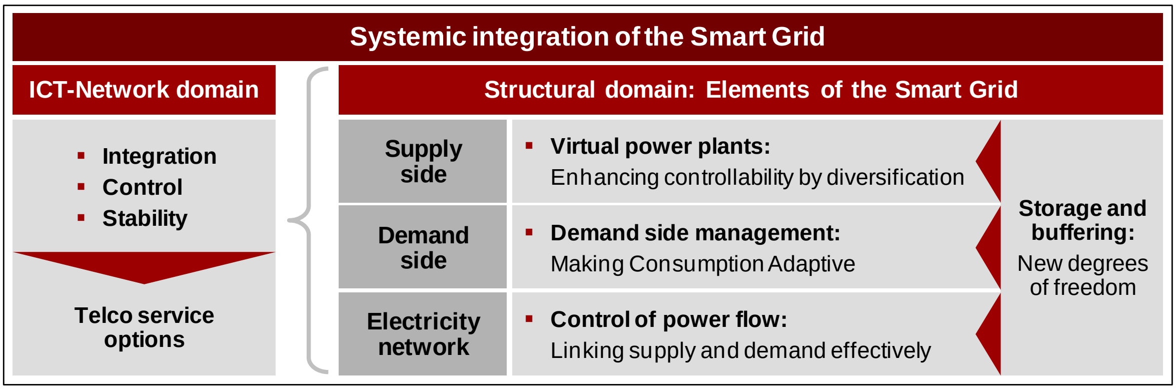

Figure 7: Integration architecture of the smart grid (Own figure)

In the following section, the integration challenges are considered. Afterwards, potential contributions of a large ICT provider – such as, e.g., the Deutsche Telekom AG – are discussed.

4.1 INTEGRATION CHALLENGES

Managing volatility instead of static over-provisioning:

It has been argued that generation from renewable energies and distributed CHP facilities depends on external factors, for instance, weather conditions or heat requirements of the CHP facilities' owners. In a grid analysis, the correlations of these external factors with the demand side can be understood, hence enhancing predictability. The kind of statements that are sought after, read, for instance, like "weather conditions leading to generation pattern X lead, in a statistically significant way, also to consumption pattern Y". A rather trivial example would be the correlation between decreased average daily sunshine hours and decreased average temperatures during northern-hemisphere winters. A more profound and spatio-temporally resolved statistical analysis of this kind enables the smart grid to relate the effects of volatile energy generation to demand-side consumption patterns. In the smart grid, this kind of analysis needs to be coupled with adaptable balancing and generation control algorithms in order to unleash the grid's full smartness.

Towards adaptable balancing:

Theoretically, generation and consumption could be balanced out within one place: A solar facility plus a privately run windmill and storage in a small number of car batteries more or less equals the aggregate consumption of the household in question. In practice, point balances will not work, or, if they do, they will not result in a systemically optimal balancing. The optimal balance might be struck at some meso-scale level, where transport losses are still considerably low, but coordination effects lead to performance levels which are economically viable. Finding this optimal balancing group is a hard optimization challenge within the ICT network domain. Furthermore, the balancing will not just involve plusses (generation) and minuses (consumption), but also buffers which may go either way, i.e. take in energy or release it. A "smart" load management of these buffers – containing a generation-demand correlation analysis similar to the one discussed above – will certainly be a key ingredient of the smart grids balancing control in its developed stages.

Stabilizing the smart grid:

The move towards regenerative energies and distributed CHP facilities bear new stability challenges. With area cover rates of volatile regenerative facilities little by little approaching unity, the stability increases by a simple statistical argument: With a low cover rate, statistical cloud coverage of 30 % may yet lead to zero energy production if the location of the solar device is unfortunate. With increasing cover rate, however, the integrated cloud coverage rate reproduces in the generation picture – in a wording taken from the financial sector – a "hedging" of the nonproduction risk is effected by spanning up a portfolio of spatially distributed generation. With respect to the ICT network domain it can be stated that a sound understanding of the characteristics of the different area sources are a mandatory prerequisite for ensuring the smart grid's stability and realizing its efficiency potential.

The above discussion reveals an enormous complexity of the integration challenges within the smart grid's network domain. This discussion is easily still further complicated by taking into account the effects of the fragmented value chain or regulative actions. The point we intended to make is that the crucial services, i.e. the ones that go farthest in realizing the smart grids efficiency potential reside in the network domain and have to be addressed by service propositions within this domain. The following section discusses what kind of contributions a telco could make in this context.

4.2 TELCO CAPABILITIES

Above, it has been suggested that the network domain of the smart grid will be the place where a number of crucial services will need to reside. Companies that obviously have arrived at this conclusion are, e.g. Vodafone, Intel and Philips Electronics who have founded a "New Energy Finance" consortium together with renowned British research institutions. In the charter, it says: "There will be game-changing opportunities for hardware and software developers, telecoms providers, utilities and others in what is not only an unexplored landscape, but largely an unimagined one". Telecommunication providers, more specifically a national carrier including an ICT service provisioning branch, may build a position from:

- **Profound understanding of large IP networks:** The operation of a provisioning network with roughly 40 million end points with hierarchical technology and organization, security issues, a broad manifold of configurations, quality of service demands and the imminent shift to all-IP production directly answers the requirements catalogue of the smart grid. Analytics of consumer behaviour and the resulting implications for the management of the network may also be scanned for transferable insights.
- **Experiences in cloud computing:** A virtual power plant is, from the organizational point of view, very similar to a virtual data centre: Reconnaissance of available distributed resources, the economics of their dynamical aggregation and the general management issues are identical requirements. Deutsche Telekom Laboratories' spin-off Zimory is an example of a telco-bred company entering this kind of collaborative economics. The know-how transfer to what might be called the "cloud computing of energy-generation facilities" is evident.
- **Extensive service platform know-how:** The ICT infrastructure of the smart grid is only the informational hardware – the actual steering transactions, the software so to speak, will need to reside on backend platforms where high demands are put to processing times, stability, security and flexibility. T-Systems as the ICT service provider branch of Deutsche Telekom AG has extensive know-how in the design and operation of such platforms.
- **Cooperation experiences:** The deregulation history of the telecommunication industry in Europe is somewhat older than that of the energy providers. Enforced cooperation situations, shared use of facilities and symbiotic value creation models have generated a knowledge base potentially useful to players in the power provisioning ecosystem.

While these points may make it plausible for a large carrier to enter a foreign industry, the most decisive argument is another one: The smart grid will be as alien to today's energy providers as the emerging automotive industry became to carriagemanufacturers one-hundred-odd years ago. In the following, two starting points for telco service propositions are discussed.

4.3 Telco Service Options

For the first opportunity we have to return briefly to the home domain discussed before. With the all-IP trend in telecommunication, the demarcation point of the telco's network at the customer's premises will act, in the future, as a bridge to IP-enabled sensors and devices. Today, this bridge just reaches the television set and connects it to the IP network. In the future, however, fridges, washing machines, heating systems and utility meters will be addressed as well. A whole value chain may be targeted for service offerings: from the reading of IP-based meters over data handling and backend-based processing to domain-specific value-add services. To be specific, consider a use case of the socalled "Ambient Assisted Living": electrical devices have certain consumption characteristics – electric cookers will in recognizable intervals heat and stall, TV sets will display characteristic peaks when turned etc. With a remote pattern recognition running on the electricity consumption signal, a situation analysis of the considered household is possible. Evaluation of these situations may point to dangerous situations – a cooker running for three or more hours should set a trigger for an immediate inspection by a housing support company.

The second opportunity concerns the service propositions in the network domain itself. Particularly, the spatio-temporal usage data of telecommunication networks shall be considered for useful information that can be derived for the management of the smart grid. In order to highlight this point, the successful foray of a telecom company into a foreign industry shall be briefly summarized: The most advanced product of the car navigation solution provider TomTom calculates the current traffic situation from the navigation devices' built-in SIM card data. The propagation of an entire ensemble of vehicle-related SIM cards is then compared with the typical patterns of traffic flow. Thus, deviations like congestions may be identified and used as input data for a real-time route calculation. This successful product may be understood as a proof of concept for mapping the telecom network data – in a suitably aggregate form – with a 3rd-party domain (here the road network) in order to achieve a new quality. This is precisely what may be done in the power provisioning context as will be argued here:

- Trajectories of mobile phone data lead to fine-grained pictures of the load shift in space and time
- Especially, singular events like, e.g. football games or rock concerts may be detected
- Space- and time-dependent IP data traffic points to offices being occupied or not, further correlations with respect to consumption patterns can be made
- A running IPTV will point to a certain expectation value for the room temperature, etc.

The sheer mass of telco usage data here counteracts statistically uncertain correlations so that a high-definition picture of the spatio-temporal load pattern can be generated. If this is merged with additional information such as weather forecasts, stock-exchange data or the operational data of energy providers, a comprehensive description model of generation and load can easily be envisaged. If, further, propagation and evolution mechanisms are fed into this model, a powerful prognosis system arises. Starting from this, a number of prognosis services to different players in the value creation grid are possible. A telco is, by using its unique wealth of data, well positioned to develop and offer such services.

5 CONCLUSIONS

Today's power system is dramatically changing. The awareness of global warming and the environmental impact of burning fossil fuels are increasing, oil and gas prices are soaring and security of supply is becoming a major global concern. In this environment, energy policy is shifting towards a more sustainable power system. Incentivized by the regulator, a growing trend towards greater use of cleaner and more efficient distributed CHP facilities as well as renewable generation can be perceived.

As the share of power generation from distributed and renewable energy sources constantly grows, new challenges occur: (1) Power generation from solar and wind energy is only predictable to a certain extend, and (2) power generation from renewables as well as distributed, heat led CHP facilities are less controllable from a central control entity, e.g. a utility or network operator.

In order to meet the challenges it is suggested to introduce modern ICT into the power grid, thus making it intelligent. In this article promising elements of such a smart grid have been introduced:

- In a **virtual power plant** several renewable and distributed facilities are connected via modern ICT and centrally operated in concerted fashion.The idea is to mix different volatile and controllable generators so that the overall system's characteristics resemble those of traditional power plants.
- The idea of **demand side management** is to actively influence consumer behaviour and thus electricity demand. An ICT connection between the utility and the consumer could be used to transfer information on varying power prices to incentivize changes in behavior or enable remote control of electric devices.
- In traditional electricity networks, current flows in one direction from major central power stations to distributed consumers. In today's power system, current flow patterns become more complex. In order to manage supply and demand effectively, **power flow control devices** may be introduced to the grid.

- **Energy storage** devices work as buffers between power supply and demand. In periods of oversupply, electricity is converted into other forms of energy such as mechanical or thermal and dispatched again when needed. Integrated into an intelligent electricity network, the value of storage is expected to increase fundamentally.

It has been pointed out that the introduced elements only address distinct parts of the challenges at hand. In order to enhance the actual value of the smart grid, though, the elements have to be systemically integrated. It has been argued that telecommunication providers are well positioned to offer the network-based services that will, eventually, address the “smartness” of the emerging energy grid. The central capabilities of a telecommunication provider are:

- Profound understanding of large IP networks
- Experiences in cloud computing
- Extensive service platform know-how
- Cooperation experiences

By using these existing competencies in analyzing and managing large networks, in communication infrastructures and data handling and processing, telecommunication providers are natural constituents of the smart grid’s value creation.

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