SYNERGETIC EFFECTS FOR DSOs AND CUSTOMERS CAUSED BY THE INTEGRATION OF RENEWABLES INTO THE DISTRIBUTION NETWORK – INFLUENCES ON BUSINESS AND NATIONAL ECONOMICS

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ABSTRACT

The required increased use of renewable energies and the intensified involvement of centralised and (small) decentralised renewable power sources into existing networks requires the reinforcement and development of electrical power systems. The reorganisation of existing networks to smart grids, especially in medium and low voltage networks, provides not only technical but also from an economic point of view significant changes in comparison to the current structure. Besides higher costs caused by an increased use of renewables a cost shift between the affected stakeholders (DSOs and customers) occur. This means that higher investments on customer side (e.g. in storage and smart technologies) can lead to reduced costs for reinforcement and development in the network infrastructure.
Existing relationships between functionalities, technologies and benefits are represented in dependency matrices to clarify the question of “which factors and interactions between energy services and functionalities are necessary?”. Consequently, this is the basis for the determination of investment costs and benefits of the various stakeholders in the smart grid.

INTRODUCTION

Distribution networks – current situation

So far medium and low voltage networks have to provide a stable load flow only in one direction – from centralized generators situated in the high voltage level via transformers and power lines down to the customers in the low voltage system. Control tasks were performed only on the network side by the grid operators with a special focus on power quality as a product feature.
If we focus on the interests of consumers (benefits) and reflect them onto the energy flow, the functional chain of energy service can be described in the following form:

1. Functionalities
2. Technologies and
3. Benefits

It must be mentioned that the consumer´s role at the end of the load flow chain was - concerning the classical network - only a passive one.
To efficiently integrate a notable number of decentralized generators in the low and medium voltage network, the classical electrical network structure has to be transformed to a smart grid structure causing considerable investment costs in the entire electricity system.

Distribution networks – future aspects of generation, distribution and consumption

Recent changes, particularly through increased integration of distributed generation systems into power distribution systems, are accompanied by significant changes in customer behavior regarding consumption, energy saving efforts and home production of energy. The interaction between consumers and producers at the network connection point in the smart grid can lead to an active participation of customers in the energy market as well as in the network operation. This active participation will transform former “mere” consumers to both: to electricity consumers and to electricity producers so called ”prosumers”. The prosumer should be able to react quickly, individually or externally controlled, to signals (price signals, network requirements, ...).
In addition to the structure and components of a classical network (radial or semi-meshed network with an unidirectional load flow to the consumer) in a smart grid electrical (smart) appliances and devices as well as decentralized storages and in particular ICT (e.g. smart meters for energy measurement and load control through advanced process control, controller and smart home appliances, ...) are gaining in importance.

ECONGRID – METHODICAL APPROACH

The technical and economic analyses are based on three scenarios [1]:

- **Current policy,**
- **Renewable^{+}** and
- ***Flex*demand**

which include the expected energy generation and demand by the year 2020 as well as by 2030 and adoptions and developments at the DSO and customer side. The current policy scenario covers the legal Austrian and EU requirements regarding the integration of renewable sources, the renewable+ scenario includes the ambitious use of renewables, and the *flex*demand scenario, besides the use of a high amount of renewables, additionally includes a high potential of demand side management measures and a high penetration of electromobility (E-Mobility) [1].

The desired targets (favored development of renewables, E-Mobility, smart metering, storage etc.) of the defined scenarios should be reached by different migration paths:

- **Conventional** (classical),
- **Smart** (moderate use of smart technologies) and
- So called **smart plus** (extensive use of smart technologies).

The conventional migration path considers classical and proven methods in network maintenance, retrofitting and expansion (transformers, power lines, …) as well as only a low penetration of smart technologies (smart home applications, storage …). The smart and the smart plus migration paths include a higher number of smart grid and smart building components as well as smart home applications.

DEPENDENCY MATRICES

Considering international references [5] and [6], the relationships between functionalities, technologies, benefits and finally the costs are integrated in dependency matrices. Figure 1 shows the interaction of the functionalities, technologies, benefits and the resulting investment costs. A direct interaction exists between functionalities, technologies, benefits and investment costs [7].

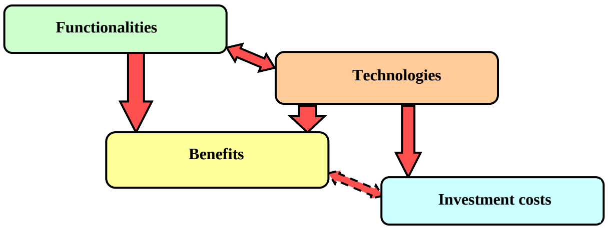

Figure 1: Interconnection between functionalities, technologies, benefits and investment costs [7]

Dependency matrix : functionalities – technologies

The desired energy services, especially functionalities and necessary supply tasks as well as specified technical requirements - are assigned to the three main stakeholders: DSO (with focus on the network), market participant and customer.

The main functionalities can be allocated to the stakeholders as follows [7]:

DSO (with focus on the network):

- Integration of active customers ("prosumers") into the network
- Increased efficiency in daily network operation, reduction of response time and improved network fault management
- New network protection concepts, network monitoring
- Improved network planning and network optimization, investments in networks, maintaining the level of reliability

Market participant:

- Improved markets and customer services through real time measurements of energy

Customer:

- Improved information, better awareness, active participation in the market, e.g. control of consumption

Dependency matrix: functionalities – benefits

Based on the functionalities that represent the real interests of DSOs and customers, functionalities that are required just to achieve these benefits have to be identified [1], [7].

Operational safety and reliability:

- Providing reliability of network operation (e.g. comprehensive information on voltage quality, reliability of supply)
- Contribution to reliability of supply (minimization of supply outages)

Ecology (aspects regarding the environment):

- Emissions

Security of supply:

- Availability of energy and energy services
- Using local resources (e.g. reduction of energy imports)

Economy:

- Improved facility management
- Transmission and distribution of electrical energy: capital savings
- Transmission and distribution of electrical energy: more efficient operation and maintenance costs
- Energy efficiency and power consumption savings

It should be noted that the benefits will often be positive for more than one beneficiary. In particular, the resulting benefits in terms of the positive impact on the environment (e.g. use of locally available resources, reduction of greenhouse gas emissions) and security of supply (e.g. reduced supply outages) generates, among other things, positive impacts on economic and ecological aspects for DSOs, customers and society.

TECHNOLOGIES

Necessary technologies to reach the defined target values in the scenarios and migration paths of the project "EONGRID" [1] can be allocated to the following categories:

- Distribution Network
- E-Mobility
- Distributed Generation
- Battery Storage
- Smart Technologies

The category "Distribution Network" includes the development of transformer substations (HV/MV), the installation of additional switchgears in medium voltage networks, line reinforcement and development in medium as well as low voltage networks, control and communication systems for distribution networks, voltage regulation transformers and transformer stations for E-Mobility and network protection.

Boost charging stations in the low voltage networks for E-Mobility are allocated to the category "E-Mobility".

The category "Distributed Generation" contains renewable generation units like PV and CHP plants on building level.

Battery storage incl. charge controllers are allocated to the category "Battery Storage". The category "Smart Technologies" includes besides the installation of smart meter, also load management at the consumer executed by the network operator (replacement of ripple control), load, demand side and generation management at the customer and smart home technologies.

INVESTMENT AND OPERATIONAL COSTS

Fig. 2 – fig. 4 show cumulative <u>investment</u> as well as <u>operational costs</u> for the stakeholders <u>DSO, customer</u> and <u>market participant</u> for <u>one metering point (mp) in Austria</u> for the period 2014 to 2030. The conventional technical progress of technologies and reinvestments have been considered in the following figures.

The investment costs are assigned to the above-mentioned categories "Distribution Network", "E-Mobility", "Decentralised Generation", "Battery Storage" and "Smart Technologies" [1].

In general, the investment and operational costs of the category "Distribution Network" are born by DSOs and are compensated indirectly by the customers through tariffs claimed by the DSOs. The operational costs are caused by annual line reinforcement and other development in the medium and in the low voltage networks. Service and maintenance of control and communication systems as well as of network protection are also allocated to operational costs.

The investment costs of the category "Smart Technologies" are separated in costs for DSOs and in costs for customers. The smart meter installation is primarily financed by DSOs and will be refunded by higher tariffs conceded to the DSO by the regulator. Investment costs for smart home technologies are paid by customers directly, the same applies for decentralised generation units. The small percentage of operational costs (fig. 2 – fig. 4) for the customer is given through annual costs exemplarily for CHP plants. The investment costs for E-Mobility considering public charging stations and access to the network etc. are allocated to the market participants.

The differences between the costs in the scenarios current policy, renewable^{+} and *flex*demand are caused by defined target values depending upon the scenarios [1]. The various costs in the migration paths conventional, smart and smart plus depend on the usage of technologies and consider predetermined exogenous parameters. For example the number of decentralised generation units, smart meters and necessary technologies to integrate the assumed number of E-Mobility into the network by 2030 differs between scenarios but not between migration paths [1]. However, in contrast, the number of smart home technologies or battery storage is different. This means, that a higher percentage of smart technologies is either used in the smart than in the conventional migration paths.

Comparing the costs for one metering point in the scenarios it is conspicuous, that the investment costs directly attributable to the customers are higher than the investment costs for DSOs in the conventional and in the smart migration paths – see fig. 2 – fig. 4.

In the current policy scenario (maximum costs € 2,981, fig. 2) the investment costs in the conventional migration path for the customer amount to 44 % (€ 1,320) of the maximum costs per metering point (main cost driver: decentralised generation units). In contrast the investment costs for DSOs amount to 26 % (€ 778) of the maximum costs per metering point (cost driver: smart meter installation). Regarding the operating costs, contrary conditions appear: The operating costs for DSOs amount to 30 % (€ 882) in relation to the maximum costs (cost driver: reinforcement and development in network infrastructure) and are higher than for the customers (< 1 %). In the smart migration path, an analogous relationship appears: The investment costs for the customers amount to 49 % (€ 1,450) of the maximum costs per metering point (cost drivers: decentralised generation units, storage, smart home technologies) and for the DSOs 25 % (€ 757) in relation to the maximum costs (cost driver: smart meter installation). The operational costs for the DSOs amount to 18 % (€ 541) in relation to the maximum costs (cost driver: reinforcement and development in network infrastructure) and are in this case also higher than for the customers (< 1 %). Due to the predetermined targets, the occurring costs for market participants do not differ from each other in the conventional and in the smart migration path (< 1 %). The above- mentioned cost drivers are also valid for the renewable+ and *flex*demand scenario.

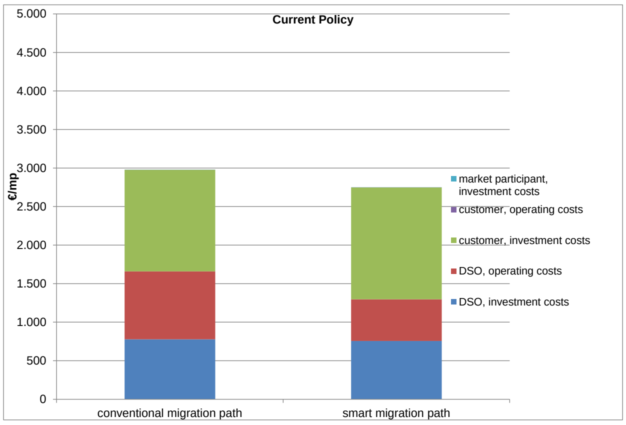

Figure 2: Current policy scenario - cumulative investment and operating costs for stakeholders (DSO, customer, market participant) for 2014 to 2030

Figure 3 shows cumulative investment and operational costs for the stakeholders DSO, customer and market participant for one metering point (mp) in Austria for the period 2014 to 2030 for the renewable+ scenario.

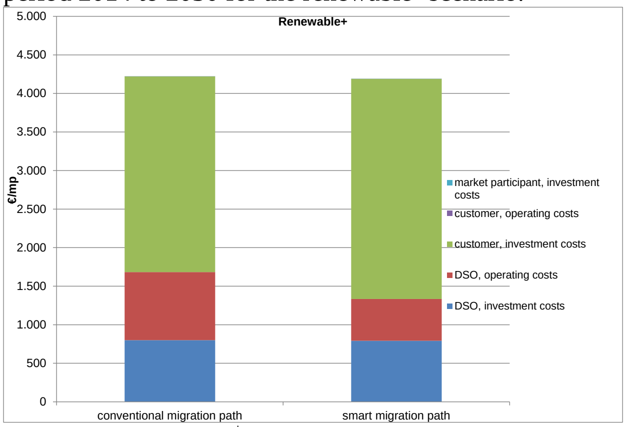

Figure 3: Renewable+ scenario - cumulative investment and operating costs for stakeholders (DSO, customer, market participant) for 2014 to 2030

In relation to the max. costs per metering point in the renewable+ scenario (€ 4,222, fig. 3), the investment costs in the conventional migration path for the customer amount to 60 % (€ 2,538) and in contrast the investment costs for DSOs amount to 19 % (€ 800). Regarding the operating costs, contrary conditions appear: The operating costs for DSOs amount to 21 % (€ 882) in relation to the max. costs and are much higher than for the customer (< 1 %). In the smart migration path an analogous relationship appears: The investment costs for the customers amount to 68 % (€ 2,856) and for the DSOs 19 % (€ 793) of the maximum costs per metering point. The operational costs for the DSOs amount to 13 % (€ 541) and are in this case also higher than for the customers (< 1 %). Due to the predetermined targets, the occurring costs for market participants do not differ from each other in the conventional and in the smart migration path (< 1 %).

Figure 4 shows cumulative investment and operational costs for the stakeholders DSO, customer and market participant for one metering point (mp) in Austria for the period 2014 to 2030 for the *flex*demand scenario.

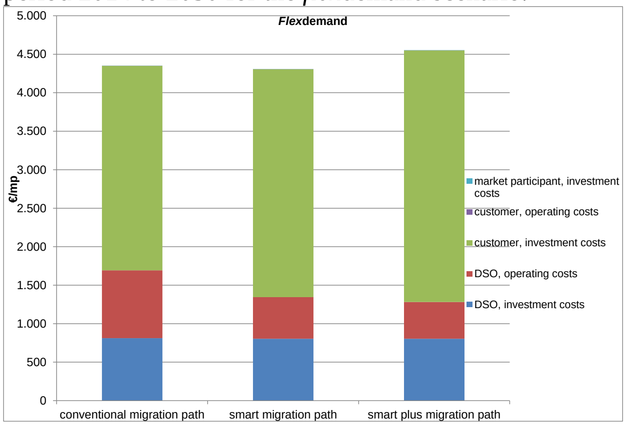

Figure 4: *Flex*demand scenario - cumulative investment and operating costs for stakeholders (DSO, customer, market participant) for 2014 to 2030

In relation to the max. costs per metering point in the *flex*demand scenario (€ 4,553, fig. 4), the investment costs in the conventional migration path for the customer amount to 58 % (€ 2,656) and in contrast the investment costs for DSOs amount to 18 % (€ 811). Regarding the operating costs, contrary conditions appear: The operating costs for DSOs amount to 19 % (€ 882) of the max. costs per metering point and are higher than for the customer (< 1 %).

In the smart and smart plus migration paths an analogous relationship appears: The investment costs for the customers in the smart migration path amount to 65 % (€ 2,961) and for the DSOs 18 % (€ 804) of the max. costs per metering point. The operational costs for the DSOs amount to 12 % (€ 541) and are in this case also higher than for the customers (< 1 %). The investment costs for the customers in the smart plus migration path amount to 72 % (€ 3,267) and for the DSOs to 18 % (€ 804) of the maximum costs per metering point The operational costs for the DSOs amount to 11 % (€ 479) and are in this case also higher than for the customers (< 1 %).

Due to the predetermined targets, the occurring costs for market participants do not differ from each other in the conventional and in the smart migration paths (< 1 %).

NATIONAL ECONOMICS

While comparing the migration paths smart and conventional analyses show positive overall economic effects by focussing on the smart strategy, irrespectively of the considered scenario. In the scenario current policy choosing the smart migration path instead of a conventional investment strategy leads to a net present value (NPV) of € 226 per metering point. In scenario renewable^{+} NPV amounts to € 248 per metering point, in scenario *flex*demand choosing the smart migration paths results in a NPV of € 328 per metering point.
The highest NPV results by choosing the migration path smart plus in scenario *flex*demand. This migration path includes the integration of an ambitious number of smart technologies: in this case the NPV amounts to € 378 for one metering point in Austria [1], [8].

RESIDENTIAL BUILDING – COST, BENEFITS, PAY OFF PERIOD

The previous presentations have shown that with the introduction of smart technologies, high investment costs for customers and network operators are incurred. In particular, the direct investments represent a high burden of financial liquidity for the customer. Looking for positive synergy effects e.g. as a part of the thermal renovation of several detached houses, smart electrical heating systems (direct electric heating, electric storage heating and heat pump systems) have been compared to the improvement of the thermal insulation of the building [9]. It has been shown that significant overall cost savings (annuities, investments) on the side of the customer can be achieved. Even more savings or cost shift on the DSO side are possible, if the positive effects of load control by help of heat pumps and the thermal inertia of the heating system are utilized. Typical consumer investment costs for direct electric heaters, electric storage heaters and heat pumps of € 10,000 / € 20,000 / € 30,000) can be compared with investment costs of € 30,000 for a thermal refurbishment of the building with comparable overall costs over 20 years.

CONCLUSIONS

The integration of renewable energies recommends adoptions of customer installations and situational, local reinforcement and expansion in the distribution networks. Customers, who previously appeared as pure consumers can now, supported by ICT, produce and trade energy through distributed electricity and heat generation systems. It follows from the investigations described in this paper, that the customer must invest a lot of money for decentralized generation units, storage, smart devices, heating systems, better thermal insulation etc. to generate an economical or ecological advantage. If the investments are made, significant business (investments) and economic (operational savings) successes can be achieved. On the side of network operators investment delays and operational cost savings can occur.

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