

ACTIVE DISTRIBUTION NETWORKS – SLOVENIAN APPROACH

Igor Papič

University of Ljubljana, Faculty of Electrical Engineering
Email: igor.papic@fe.uni-lj.si

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Abstract

New concepts of active electricity networks represent a (r) evolution in the production and efficient use of electricity. On the one hand, the developed system-oriented solutions will allow high penetration of distributed energy resources and, on the other, consumer-oriented solutions an efficient use of energy by end-user operation, the concept and implementation of active networks from the Slovenian perspective is presented. An overview of some national projects and the state of play is given.

Keywords: Distributed Energy Resources – DER, active distribution networks, Smart Grids, demonstration projects

1. Introduction

The distributed generation is mostly based on renewable energy resources (solar energy, wind energy, biomass, hydro energy ...) and is marked by production of electrical energy in a large number of relatively small units connected to transmission and distribution networks. The traditional network does not assure a reliable and efficient operation in case of a large share of distributed production. Today power system operation is based on continuous balancing of production and consumption, as storage of electrical energy is not viable. Distributed sources with their stochastic energy production introduce new challenges in the operation of power systems. The use of distributed sources is certainly welcome in terms of increasing energy needs, environmental protection and reduction of CO₂ emissions. However, a high share of distributed sources may jeopardize the operation of a classical power system and endanger stable, safe and economic supply of electrical energy.

Because of these reasons a new concept of power networks is needed, namely active networks (or Smart Grids). The concept of active networks is still based on the classical network structure with centralized energy production, central network control and relatively passive customers. The concept does make extensive use of new technologies, e.g. ICT, distributed sources, compensation devices, energy storage, etc. and enables an evolution of the power system. Active networks in the first place make it possible to control a large number of sources and loads, thus increasing the role of customers in power system operation. Customers will be able to adapt their consumption to network and market conditions and will be able to participate with their distributed sources in the energy market. The concept of active networks requires substantial changes in the fields of network control, design and operation.

users. In the paper, the European Strategic Energy Technology Plan is presented. Main drivers for changing the existing power networks are discussed. The question arises why changes are necessary and what are the characteristics of today's (yesterday's) networks compared to the networks of tomorrow? Further, the impact of Distributed Energy Resources on network Active network concepts actually represent a (r)-evolution in the field of energy production and efficient energy use. Such concepts provide systemic solutions (ancillary services, electrical vehicle infrastructure ...), enable efficient integration of distributed production and at the same time provide customer-side solutions (demand side management, virtual power plant ...). This results in increased energy efficiency in the entire network, from production to end users, with economically feasible costs.

2. EU Energy Policy

Energy production and consumption will change the European energy landscape forever. They will also promote better living standards, stimulate economic growth, create jobs and enhance the competitive position of European industry on world markets.

Energy consumption in the European Union continues to rise, and we are becoming increasingly dependent on imported fossil fuels, which adversely affect the security of energy supply in Europe. This increase in the use of fossil fuels also has a negative environmental impact.

In future, energy supply and demand in Europe will have to utilise more renewable energy sources and focus more on energy-efficient methods.

Today, we can be proud of the fact that Europe is already a leading developer of technologies in efficient heating and cooling, combined heat and power generation and industrial processes, as well as in renewable energy fields, such as wind and photovoltaic energy. Solar thermal technologies, bio fuels, energy efficient building applications and renewable powered or high-efficiency district heating applications are all penetrating new markets.

Experience in European regions and cities, however, has proven that encouraging wider uptake of such systems is not simply a question of major research and demonstration efforts, but of raising awareness. In other words, our task is now to persuade both, consumers and key decision-makers, of the benefits of intelligent sustainable energy production and use.

EU Energy Policy Targets are:

- to reduce greenhouse gas emissions by at least 20% (compared with 1990 levels) by 2020,
- to improve energy efficiency by 20% by 2020,

- to increase the share of renewable energy to 20% by 2020 (share in 2008, target by 2020),
- to have at least a 10% share of renewable energy in transport by 2020.

2.1. European Strategic Energy Technology (SET) Plan

We are faced worldwide with “climate change”, a situation which calls for an effective low-carbon policy and efficient energy technologies.

The European Union (EU) is tackling the challenge through a policy whose target is nothing less than the transformation of the entire energy system, with far-reaching implications on how we source and produce our energy, how we transport and trade it, and how we use it.

In short, we must make low-carbon technologies affordable and competitive – a market choice. This is the core idea behind the European Strategic Energy Technology Plan (SET-Plan) [1].

The EU’s approach focuses on the European Industrial Initiatives (EII). Industry-led, the EIIs aim to strengthen industrial participation in energy research and demonstration, boost innovation and accelerate deployment of low-carbon energy technologies. EIIs target sectors in which working at EU level adds most value, and technologies for which the barriers, the scale of investment and the risk involved can be better tackled collectively.

The SET-Plan includes:

- the European Industrial Bioenergy Initiative,
- the European CO₂ Capture, Transport and Storage Initiative,
- the European Electricity Grid Initiative,
- the Fuel Cells and Hydrogen (FCH) Joint Technology Initiative,
- the Sustainable Nuclear Initiative,
- Energy Efficiency – the Smart Cities Initiative,
- the Solar Europe Initiative, and
- the European Wind Initiative.

2.2. European Electricity Grid Initiative (EEGI)

The European Industrial Initiative on the electricity grid aims at developing, demonstrating and validating, at scale, the technologies, system integration and processes to [1]:

- enable the transmission and distribution of up to 35% of electricity from distributed and concentrated renewable sources by 2020 and make electricity production completely decarbonised by 2050;
- further integrate national networks into a truly pan-European, market based network;
- optimise investments and operational costs involved in upgrading the European electricity networks to respond to the new challenges;
- guarantee high quality electricity supply to all customers and engage them as active participants in energy efficiency;
- anticipate new developments such as the electrification of transport.

Foreseen activities include:

- an integrated R&D and demonstration programme;
- a network of up to 20 large-scale demonstration projects covering diverse geographical, social and climatic conditions;
- a technical support structure to monitor project progress according to common indicators and to enable successes to be replicated across Europe.

The cost of this initiative is estimated at €2 billion over ten years excluding the costs of generic assets used in the demonstration [2].

3. Power networks – why do we need changes?

The same driving factors for introduction of Smart Grids existed in all EU countries (Fig. 1):

- security and quality of supply,
- the energy market, and
- environmental issues.

Like many other European countries, Slovenia is a net importer of electricity as well as a transit country between East and West. During the subsequent high loading of the national transmission network, the security and quality of supply play a key role. New interconnections with Italy and Hungary and internal transmission lines of 400kV are foreseen. In order to increase operational security during large transfers of energy, a phase-shifter was installed in the Divača substation last year. The complete opening of the energy market is another issue to be considered in future development plans for electricity networks. However, environmental considerations mean that a new approach is required for the planning of future energy facilities: in Slovenia there is a strong opposition to planned wind and hydro generation units in environmentally sensitive areas.

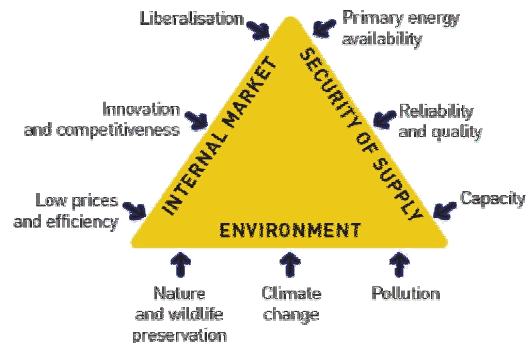


Fig. 1: EU driving factors for introduction of Smart Grids.

In order to convince potential stakeholders from the electricity sector of the need to invest in Slovenia’s electricity networks, we had to answer the question: “What are the characteristics of today’s networks compared with the networks of tomorrow?” Today’s networks with conventional power flows – i.e. from the generation sites through transmission and distribution networks towards consumers – are expected to evolve into networks with bi-directional power flows. The number of small distributed generators will therefore increase, although it is expected that centralised generation will remain dominant.

Distributed generation requires a number of changes at the planning and operational levels – namely control, protection and voltage quality. It should also be noted that in future consumers will play a much more active role when accessing networks. Furthermore, an increase in the number of interconnections between national systems is crucial for the proper functioning of the energy market. From the system operational point of view, it is very important to be aware of the permanent need to balance generation and consumption second by second; huge energy storage facilities are not available. This important issue is often overlooked and not properly addressed. This is a challenge today and will be tomorrow, despite potential energy storage technologies.

As stated in the European Smart Grids vision document, the networks of the future should be [3]:

- flexible – fulfilling the needs of customers;
- accessible – granting connection access to all network users;
- reliable – assuring and improving security and quality of supply; and

- economic – providing best value through innovation, efficient energy management, competition and regulation.

4. Impact of DER on network operation

Impact on network operation depends on DER penetration. A small DER share causes local problems:

- unsuitable voltage profile,
- malfunction of protection operation,
- lower power quality.

A large DER share may also cause system problems:

- adverse effect on network stability,
- uncontrolled reactive power flows,
- impact on power reserves,
- need for active network management.

The question arises, where is the limit?

4.1. Impact on voltage profile

Fig. 2 shows a simple circuit with DER connected to the low-voltage (LV) feeder. The feeder is connected to the medium-voltage (MV) and high-voltage (HV) levels through two transformers. The HV/MV transformer is usually an on-load tap-changing (OLTC) transformer, while the MV/LV transformer has off-circuit taps. The voltage profile of the presented network is also shown in Fig. 2. The MV level is usually regulated to a fixed value. The voltage boost of the MV/LV transformer is also shown. The two lines show the voltage profile with DER connected and disconnected, respectively. Depending on the DER production and loads consumption a voltage rise may also occur in the network [4].

Possible solutions for voltage control in distribution networks with a large DER share are:

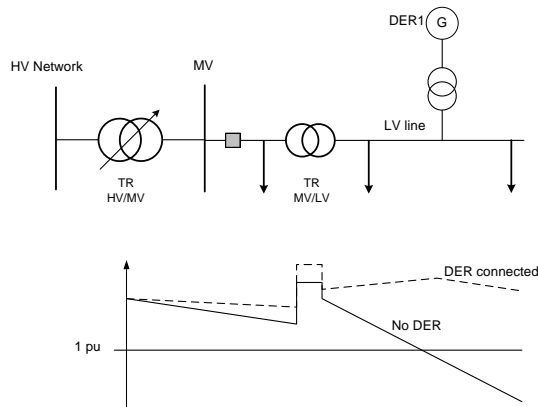


Fig. 2: Voltage profile of a radial distribution line with DER.

- more complex transformer voltage regulation (coordination and additional measurements along the feeders),
- voltage regulation with DER (reactive power),
- active compensators.

4.2. Impact on protection operation

DER contributes to short circuit currents in case of faults (Fig. 3), which may cause malfunction of standard protection schemes. Possible solutions are:

- protection coordination,
- DER connected on a separate feeder,
- new protection equipment (e.g. directional protection).

4.3. Other impacts

Other impacts of DER integration include power quality issues:

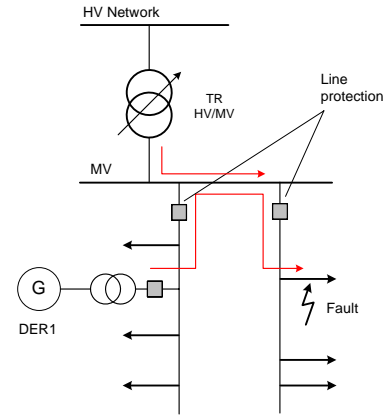


Fig. 3: Impact of DER on protection operation.

- transient voltage variations, e.g. connection or disconnection of DER;
- flicker (especially wind turbines);
- harmonics, e.g. from power converters.

At the same time DER can also improve power quality, where suitable control and operation coordination of sources is required. DER as intermittent sources have an impact on reserve capacity, where power reserves for production/consumption balancing are needed. Integration of DER also requires changes at the level of network planning.

5. Active network concept

As already said, active networks in the first place make it possible to control a large number of sources and loads, and the role of customers in power system operation will increase. Customers will be able to adapt their consumption to network and market conditions and to participate with their distributed sources in the energy market. The concept of active networks requires substantial changes in the fields of network control, design and operation.

The development on the horizontal, physical level of the electrical network and on the level of the information system will enable the implementation of vertical activities – business models, such as:

- Demand Side Management / Demand Response (DSM/DR),
- Virtual Power Plant (VPP),
- ancillary services,
- e-mobility infrastructure, etc.

The mentioned vertical activities demand changes of the electrical system on all horizontal levels. Smart Grids is a concept that represents the evolution of existing EES in systems with a new key feature – possibility of produced energy storage and its efficient consumption.

The essential parts that enable evolution of existing networks into active networks are:

- a communication infrastructure and information technologies that enable communication between the devices in the network,
- a system for measuring production and consumption in real time, with the possibility of two-way data transfer,
- strategies for network control,
- appropriate infrastructure for electrical vehicles
- ...

Basically the concepts of an active network include:

- technology,
- economy,
- regulation, and
- sociology

6. Some national projects

Concepts of active electricity networks that will be based on new technologies should be tested in parts of real power network through demonstration projects. Detailed evaluation of new concepts under real network conditions will enable testing and final specification of developed solutions.

Some Slovenian demonstration projects are presented in the next subchapters:

- Intelligent Power System Platform for Supervision and Control of Distributed Generation and Customer Demands – Supermen,
- International Demand Response Demonstration Centres – KIBERnet,
- Competence Centre Advanced Systems of Efficient use of Electrical Energy.

6.1. Supermen project

The national project Supermen deals with the strategy of converting the currently passive distribution networks to active networks. The conversion from passive to active introduces many challenges considering DG network integration, power quality, concepts and strategies for network planning, control and supervision as well as information and communication technologies (ICT) [5, 6]. The main goal of the project SUPERMEN is the practical implementation of a demonstration network based on a virtual power plant, where distributed resources are controlled and supervised through the information and communication technologies.

The main objectives of the project SUPERMEN are:

- study, development and demonstration of "active network" infrastructure,
- demonstration of basic applications for supervision and control of distributed resources and energy management,
- base for further development of new services and applications supporting new business models.

A modular point-of-common-coupling interface (PCCI) and virtual power plant middleware software were developed in this project. The software is designed to offer solutions for versatile users, e.g. virtual power plant operators, DSO's control centres, DG unit owners, etc. The project focuses mostly on small distributed energy resources in LV and MV distribution networks, e.g. photovoltaic (PV) systems, combined heating and power (CHP), small hydropower (SHP) stations, etc.

SUPERMEN's system architecture is shown in Fig. 4. The system consists of:

- Point-of-Common-Coupling Interfaces (PCCIs), and
- Virtual Power Plant Control Centre (VPP CC).

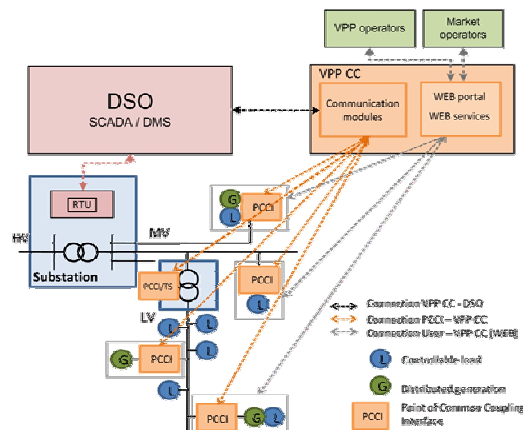


Fig. 4: SUPERMEN system architecture.

6.2. KIBERnet project

KIBERnet system remotely manages electricity consumption and distributed generation across a network of industrial and commercial customer/generator sites to enable a more information-based and responsive electricity transmission and distribution network (Fig. 5). It is a tool for effective management of arising challenges by balancing supply and demand in the electricity system.

The KIBERnet system is a demand response solution which monitors electricity consumption and automatically shed electricity loads to reduce their usage during peak periods. This helps optimize a balance between electric supply and demand and creates significant financial savings.

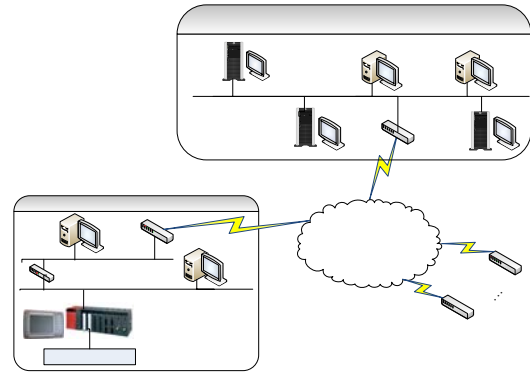


Fig. 5: Schematic overview of the KIBERnet system.

The KIBERnet system is a family of Smart Grids products designed for the following four user groups:

- transmission system operators,
- distribution system operators,
- electricity suppliers,
- industrial and commercial electricity consumers/producers.

6.3. Competence Centre Advanced Systems of Efficient use of Electrical Energy

The main purpose of the competence centre is to build active network concepts based on new technological solutions and to test these solutions in actual power networks. The programme is divided into four complementary R&D projects:

1. Active Power Network Solutions,
2. Power Network Components,
3. Smart, Energy Efficient Domestic Appliances and Systems, and
4. Energy Efficient Electric Drives.

Technological solutions will be developed in the last three projects of the Competence Centre. In the first project, the evaluation of new concepts and solutions in the field will enable industrial partners to test, verify and finally tune the developed components and concepts. A number of demonstration projects in the field of active networks will be carried out. These demonstrations will include systems for increasing power system energy efficiency, implementation of virtual power plant, an upgrade of the distribution remote control centre and automatic demand response of domestic consumers. These solutions will enable a faster growth of the share of distributed generation and ensure power system energy efficiency at the same time. The solutions will therefore take into account electricity generation, distribution and loads connected to the network.

It is even now clear that the strategic EU goals of 20/20/20 aiming at increasing the share of DER and increasing energy efficiency cannot be reached without active network concepts (Smart Grids).

It is also a fact that new network components and solutions can not be fully developed without tests in actual networks. A common problem, for example, is the response of customers to new services, which is not only a technical problem but involves sociology.

The first R&D project – Active Power Network Solutions – is divided into two main parts:

- active network concepts and
- active network solutions.

In the first part the analysis of different active network concepts will be carried out and the specifics of Slovenian power system identified. The goal of this part is to elaborate the Slovenian national programme for the deployment of active network solutions in the Slovenian power system.

In the second part, four demonstration systems will be planned and implemented. The demonstration will use components and solutions developed in other Competence Centre projects and will be integrated into advanced and efficient power systems. Testing of solutions will enable us to finalize technical specifications. The four demonstration systems will broadly cover the field of active networks, including:

- control of energy production, distribution and consumption (power system energy efficiency),
- virtual aggregation of energy production and consumption (virtual power plant),
- ICT which represent the basic infrastructure for network control (upgrade of the distribution Remote Control Centre),
- the development of domestic-consumer loads that enable demand side management (automatic demand response of domestic consumers through SmartHome solutions).

7. Conclusions

By way of conclusion let us examine some facts that illustrate the current state of play:

- electricity networks of tomorrow are becoming a reality,
- customers are dictating current activities,
- network operators are facing new technical challenges,
- equipment manufacturers are responding with new solutions,
- research institutions were/are always willing to participate,
- more research, development and especially demonstration projects are required.

We will not reach 20-20-20 targets without introduction of Smart Grids concepts.

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