INTELLIGENT POWER SYSTEM PLATFORM FOR SUPERVISION AND CONTROL OF DISTRIBUTED GENERATION AND CUSTOMER DEMANDS - SUPERMEN

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ABSTRACT

Rapidly increasing share of distributed generation (DG) in distribution networks introduced the need for active distribution networks i.e. SmartGrids. The DG introduced many technical challenges in sense of power quality, network planning, protection schemes, voltage stability, etc. This paper presents the first results of an ongoing Slovenian project "Intelligent power system platform for supervision and control of distributed generation and customer demands", shortly SUPERMEN. The project addresses DG impacts on distribution network by implementing the concept of virtual power plant (VPP), where distributed generation units are equipped with the appropriate information and communications equipment and connected to the control center for the supervision and management. The concept of aggregation allows joint appearance on the ancillary services and energy markets. Within the project, a modular point-of-common-coupling interface (PCCI) and virtual power plant control centre (VPP CC) middleware were developed.

INTRODUCTION

The rapid deployment of distributed generation (DG) in recent years and the present uncertainties concerning adequate grid integration methodologies are closely linked to technical feasibility and new information and communication solutions. The Slovenian 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) [1, 2, 3]. The main goal of the project SUPERMEN is the practical realization 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.

Within the project, a modular point-of-common-coupling interface (PCCI) and virtual power plant middleware software were developed. 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 low voltage (LV) and middle voltage (MV) distribution networks, e.g. photovoltaic (PV) systems, combined heating/cooling and power (CHP/CCHP), small hydropower (SHP) stations, etc.

SUPERMEN CONCEPT

Project SUPERMEN addresses DG impacts on distribution network by implementing the concept of virtual power plant (VPP), where DG units are equipped with the appropriate monitoring, metering, information and communications equipment and connected to control center for the supervision, control and management. The main goal of the project SUPERMEN is the practical realization of the demonstration network, based on a virtual power plant solution, where distributed resources are controlled and supervised through the information and communication technologies.

SUPERMEN's system architecture is shown on Fig. 1. The system consists of:

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

The system provides information exchange between different roles on the market, such as DG operators, VPP operators, distribution system operators (DSO), market operator, etc.

The SUPERMEN concept of aggregation allows not only

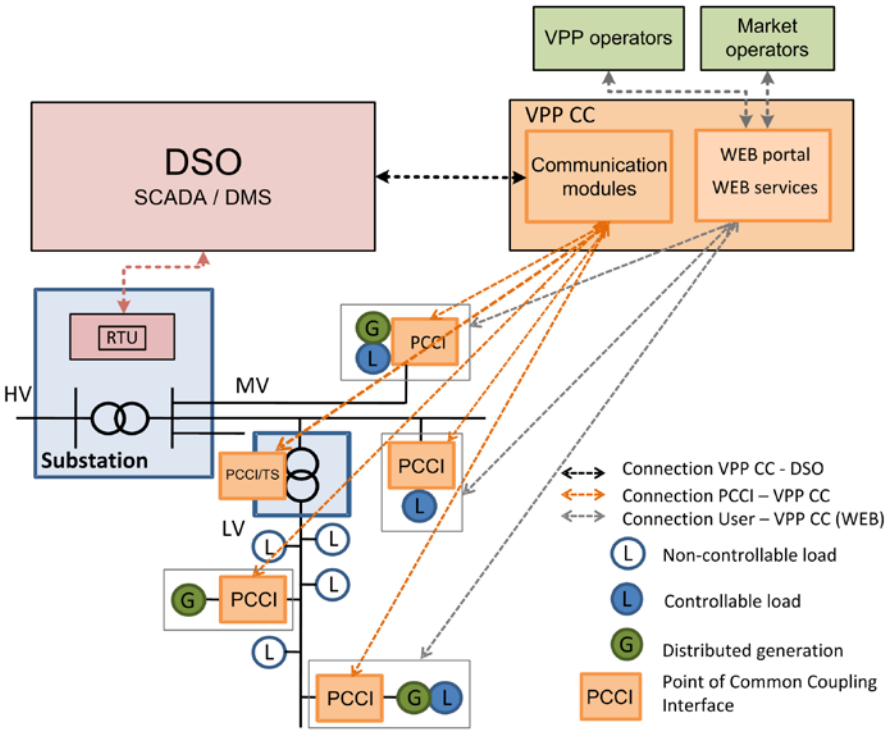

Figure 1: SUPERMEN system architecture.

joint appearance on the ancillary services market, but also joint appearance on the energy market. Ancillary services are essential for safe and reliable operation of power systems. Following ancillary, services can be provided by virtual power plant:

- active power control,
- Volt / VAR control,
- congestion management,
- power losses reduction,
- islanded operation.

It is important to realize that all distributed resources are not suitable for all ancillary services and that ancillary services are mostly tied to a specific location (e.q. network segment, feeder, etc.). The larger the number of distributed resources aggregated in the virtual power plant, the more relevant is the formation of portfolios of them that are appropriate for ancillary services at a given location.

Aggregation of distributed resources in a VPP, incorporate them to the wholesale energy markets (day-ahead market), which for a single small resource would not be possible. The same applies to ancillary service market for services that are not tied to a specific location, such as the provision of a tertiary reserve. The portfolio of DG units is taken to the market as a single bid arose by aggregating bids from DG units. Also important are the information services offered to users by the virtual power plant, such as access to a Web portal with information on the energy produced, ancillary services participation, price information, bids, revenues, etc.

PCC Interface

A Point-of-Common-Coupling Interface (PCCI) is used for a simple, standardized connection of micro and small generation of electricity from distributed resources to the distribution network. It provides remote monitoring and control of energy generation or consumption and ensures safe disconnection from the network. All types of distributed resources from photovoltaic, wind power systems, CHP/CCHP, small hydropower stations can be connected, as well energy storage systems and controllable loads. Some functionalities of PCCI include:

- remote monitoring and control,
- communication with the control center,
- power quality monitoring according to EN 50160,
- possibility of controlling compensation devices,
- various protection functions (voltage, frequency, island operation, etc.).

Virtual Power Plant Control Centre

Features of Virtual Power Plant Control Center (VPP CC) are realized by VPP CC software. Software is able to operate in two modes:

- software as a virtual power plant control center,
- software that is part of the other solutions (embedded).

The main functions are as follows:

- two-way communications with PCC interfaces

(data acquisition, controls, alarms),
- two-way communications with DSO systems (SCADA, DMS),
- system configuration and user management,
- applications and user interfaces (WEB applications, WEB services) for:
    - DG operators,
    - VPP operators,
    - market operators,
    - data archiving and recording of event logs.

The software is modular and allows building new functionalities and applications using same structure and communications methods.

Information and communication technology

SUPERMEN network concept requires communication between different devices and participants. Distributed generation and other participants can be geographically dispersed therefore, to connect them into a virtual power plant, it is necessary to provide a wide range of communication networks. Main role could have the networks of the mobile operators. Communication links are limited to those networks that enable protocols based on IP. The following communication channels are necessary:

- communication between the PCCI and VPP CC,
- communication between VPP CC and DSO (SCADA),
- communication between VPP CC and users.

Communication is done via standard protocols such as:

- IEC 61850 for communication between the PCCI and VPP CC,
- IEC 60870-5-104/101 or ICCP/TASE2 for communication between VPP CC and DSO (SCADA),
- HTTP / HTTPS for communication between VPP CC and users.

RESULTS - CURRENT STATUS

The main technical accomplishments of the project SUPERMEN can be summarized as follows:

- PCCI was developed using protocol IEC 61850, including two-way DG unit control (on-off, parameterization, generation control, quality control) and data acquisition/metering,
- Virtual Power Plant middleware software was developed using service oriented architecture, suitable for versatile users (virtual power plant operators, control centres, DG unit owners, etc.),
- IEC 61850 protocols was used for maximum compatibility and reliability.

The PCCI device and the first versions of the VPP CC software were tested through the first demonstration of the SUPERMEN system.

The demonstration system included installation and configuration of PCCIs and installation and configuration of VPP CC software. Five PCCIs were installed at: small photovoltaic power plant (PV Radovljica), two small hydropower plants (SHP Sorica and SHP Savica) and at two transformer station (TS Planina and TS Štore).

PCCIs were connected to the net using local available

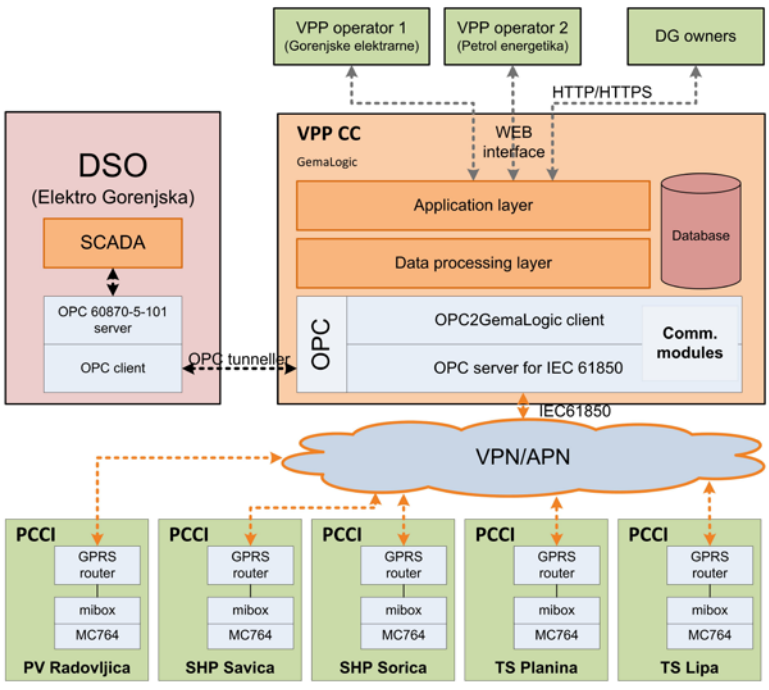

Figure 2: SUPERMEN demo system configuration.

Figure 3: VPP CC prototype.

network or GPRS network. Protocol IEC 61850 was used for communication with VPP CC. Communications were secured by using VPN.

Integration with the SCADA system was done by using an OPC tunneller and OPC server for the IEC 60870-5-101 protocol, which was required by the DSO. The system configuration is shown in Fig. 2.

Within the demonstration a demo VPP CC graphical WEB interface and a demo database, operating in real time were presented. The prototype of the graphical interface is presented in Fig. 3 where selected measurements from the PCCI locations are presented. Two VPP operators were configured and access to data of their power plants/stations was granted. We have demonstrated: process data acquisition (measurements, energy metering, power quality measurements) from five different geographically dispersed locations, one small photovoltaic power plant (PV Radovljica), two SHPs (Sorica and Savica) and two transformer station (Planina and Štore), preservation of data and aggregation of certain types of data. A subset of data was also integrated into the SCADA system of the DSO Elektro Gorenjska.

CONCLUSIONS

Demonstration projects are crucial for further development in the area of integration of the distributed generation into the distribution networks. The transformation of the existing passive networks towards active distribution networks 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. The Slovenian project SUPERMEN is a step towards practical introduction of the active distribution network. The main technical accomplishments of the project can be summarized as follows:

- PCCI was developed using protocol IEC 61850, including two-way DG unit control,
- VPP CC middleware was designed using service oriented architecture, suitable for versatile functions and users.

The first results of the demonstration project were presented in this paper. The operability of PCCIs from five different geographically dispersed locations and VPP CC middleware was successfully tested and demonstrated. VPP CC integration with the DSO's SCADA was also successful, as well the usage of WEB interfaces for VPP operators and DG owners.

The future work on the project will include development of advanced functionalities for VPP operators based on market requirements and integration of Demand Side Management / Demand Response functionalities into the middleware. The project will, at the end, provide standardized PCCI modules with ability of integration into existing distribution network communication system, new ICT infrastructure in distribution system and demonstration prototype of an intelligent platform for supervision and control of DG units and costumer demands with hardware and software solutions. Developed platform will be optimized from the technical and economical point of view.

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