Effect of Renewable Energy Sources to the Stability of the Low Voltage Distribution Networks

Z. Szabo[1,3], **F. Zezulka**[2,3], **Z. Roubal**[1,3], **P. Marcon**[1,3], **O. Sajdl**[2,3], **and I. Vesely**[2,3]

[1]FEEC, Department of Theoretical and Experimental Electrical Engineering
Brno University of Technology, Technicka 12, Brno, Czech Republic
[2]FEEC, Department of Control and Instrumentation
Brno University of Technology, Technicka 12, Brno, Czech Republic
[3]FEEC, Centre for Research and Utilization of Renewable Energy
Brno University of Technology, Technicka 12, Brno, Czech Republic

Abstract— The paper describes the recent development in the area of renewable energy sources (RES). Shows the situations in countries supporting a great growth of RES, particularly in photovoltaic energy what leads to the big problems. The modelling of situation shows that in a very near future there will be a big overflow of electrical energy production in the low voltage networks (LVN). It would evoke necessity to transfer energy into higher voltage networks. However it's not possible, because of the protection systems of high voltage networks (HVN) are developed for the opposite flow of energy. The traditional power engineering industry assumes centralized energy sources (power plants), and delivers electrical energy into consumers via very high voltage networks (transition networks VHN), high voltage networks (HVN) into LVN. In the low voltage networks the energy is totally consumed. Because of the existing protection systems in the HVN, and the recent energy distributors and producers correspond with this traditional conception, is necessary to consume all energy from RES in the low voltage networks where it was produced. Our contribution deals with this phenomenon and offers some part solution of the problem.

1. INTRODUCTION

Recent development in the area of RES shows, that situation in countries supporting a great growth of RES, particularly photovoltaic leads to big problems. Modelling studies shows that, in a very near future there will be a big overflow of electrical energy production in the networks of NN (low voltage networks). It would evoke necessity to transfer energy into higher voltage networks. However it will not be possible while protection systems of high voltage networks are developed for the opposite flow of energy. The traditional power engineering industry assumes that centralized energy sources (power plants) deliver electrical energy into consumers via very high voltage networks (transition networks VVN), high voltage networks (transition networks VN) into low voltage networks (NN). In low voltage networks is the energy totally consumed. Because the existing protection systems, the recent short-time task for energy distributors and producers, corresponding this traditional conception, is to consume all energy from RES in low voltage networks where it was produced.

2. STATE OF THE ART

On the Fig. 1 is shown a typical star topology of an energy network. The energy, produced in power plants is transformed from 6 to 30 kV typically to 115 kV or 230 kV (VVN). Let us assume an energy network, i.e., from smaller power plants. The energy from turbines will be transformed to the high voltage 115 kV phase AC transmission network. In the Fig. 1 there are shown several lines of the VVN (very high voltage network). Each of the lines goes into a transform station (DTS GROUP) and is transformed and distributed into several (e.g., ten) high voltage lines (22 kV AC). These lines (i.e., outsides VN distribution lines) go to single localities and there are transformed to 400 V AC of the low voltage distribution lines NN. These NN distribution lines goes to single consumers (households, schools, institutions, SMEs), i.e., to OMs.

In the recent time situation in the single OMs as well as in the whole NN network can be more complicated in the past. The task for electrical energy distribution in the past was to deliver enough energy in a high quality (voltage and frequency) to consumers. Next tasks in a near future will be specified as how and where to spend surplus energy which will be produced in NN networks by non-stable distributed photovoltaic (FV) [7], wind power plants and etc. [10]. Simulation which goes from information of installed and contract promised power from RES shows, that power and

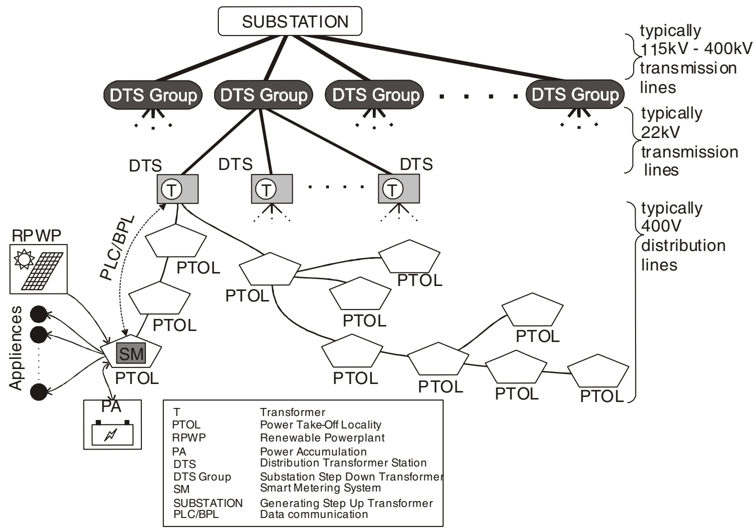

Figure 1: Topology of electrical networks.

energy volume from RES will be greater then consumed power and energy in the existing NN framework [9].

Therefore distributors and producers of electrical energy have to solve the problem where and how to spend so much energy in the framework of the NN network where it was produced or in the all NN networks behind one transformer 22 kV/400 V AC. In emergency case would be still acceptable to spend an surplus of the energy volume in the framework of more then one NN network. The contribution deals with possibilities how to influence energy consumption in NN networks by a smart control combining operator control as well as individual control from OMs. At present only an operator control from a central operator level is realized in so called two tariff system. Authors assumed that individual control of energy consumption in the NN network's framework, combined with still existing two tariff system could be an important mean for stability of electrical grids with RES.

Solution of the problem has several aspects. The first one is a data acquisition and prediction of the possible development of energy loss or energy surplus in the NN network framework behind one DTS 22 kV/400 V. It will depend much on a weather forecast in the area concerned. Second aspect consists in an equipment of any OM, i.e., monitoring and measurement instrumentation to measure OM's own energy consumption [5]. The last aspect consists in creation a motivation mechanism to motivate OMs to cooperate with central operator station to stabilize the NN grid. Authors assume the dynamic tariff of energy will be the most motivation mechanism.

3. SUBJECT OF THE PROBLEM

Contribution deals mostly with technical aspects of the problem of the stability NN grids with important quotient of energy from renewable energy sources. As it was already said, central operator stations as well as OMs have to be equipped by instrumentation for energy monitoring, individual as well as centralized appliances control (switch on-switch off) and by prediction of time development of energy prices.

Such prerequisites to stabilize NN networks is named "smart metering system" and its possible solution named smart-energo system is specified in next chapters.

3.1. Smart Metering and Control System [1, 2]

In the Fig. 2 is shown the complete project conception of the system for monitoring, planning and energy saving with stabilization of a grid with important ratio of renewable energy sources [3, 8]. The concept of the system goes out from the fact that households are equipped mostly by one or three phase electrical installation with one central distributor. There are current protectors and energy meters. Next the electrical installation is split into more light and socket's networks, which are protected by one or three phase protectors. From the electricity meter the electrical installation is user available. The system smart-energo uses two types of energy monitors [6].

The first one is the SM1 (Smart Meter 1) [4] and it makes monitoring of the whole energy consumption of the flat or house (households) or the whole energy consumption of a small energy consumer (SMS, institutions, offices, etc.). The SM1 is situated at the distributor behind the energy meter and monitors the whole energy consumption in one or three phases. The second element [4] of the system smart-energo is the SM2. It is an element for energy consumption monitoring of an electrical appliance that is connected in one socket. The SM2 can by realized as a special wall socket (with additional measuring sensors, processing electronic and communication interfaces). A communication of SM2 is done by WLS or via power line. In this epoch when households are not totally equipped by internet we decided to realize SM2 in these two options. The SM2 can be realized on demand as a pass-through module or as a special wall socket with embedded SM2 functionality additionally to the standard power functions of the socket.

One new option of the system smart-energo for internet based monitoring (PDA, netbook, notebook, PC, tablet) is its total distribution. That means, data of energy consumption are written in local memories of each SM2s and because of the fact, that SM2s are developed by WIFI interface, data can be observed directly in PDAs, netbooks, notebooks, tablets, PCs in WLS intranet of the households or enterprises, institutions etc. System would enable a distance monitoring by users via internet in a near future. As shown in the Fig. 2, SM1s are equipped by internet interface (Ethernet, GPRS and other interfaces). The world first internet based system which is equipped by such a service is Google energy monitoring system. Users have access to individual user's database with historical data of their individual energy consumption from anywhere.

The recommended PWL (Power Line) option for SM2 (recommended by energy distribution firms for this temporary time period) enables direct translation data from SM2s to the SM1 without WLS (Wireless) interfaces in SM2s via power lines connecting any wall socket for energy purposes. The price for such a solution is not cheaper in general and authors believe on a final solution in the WLS option. The block diagram of the SM2 is described in the Fig. 4.

3.2. SM1 Module for Monitoring of the Whole Energy Consumption of a User

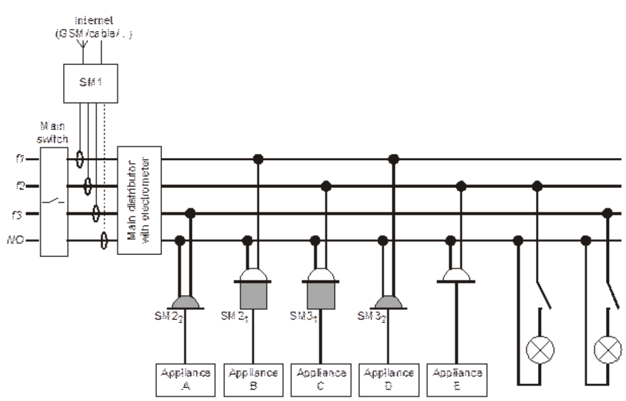

Figure 2: Complete project conception.

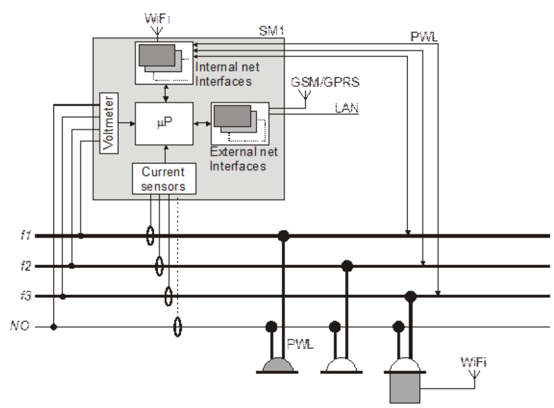

Figure 3: Block diagram of SM1.

This module (Fig. 3) is intended to be situated and installed in energy distributors of households or in central energy distributors of smaller energy consumers. The SM1 is only one device for a consumer. The SM1 will monitor the total energy consumption continuously over the all day, week, and years. Module is supplied directly from a power line. Module SM1 is connected to a power lines directly in the main distributor via current measuring transformer and enables to measure the total current and power of individual smaller energy consumer. The installation of SM1 is as simple as possible to motivate consumers to accept it. System is equipped by a simple display for visual monitoring and indication of the function.

As mentioned above the SM1 will collect data from SM2s and send them to the user or to the database of a provider via internet.

3.3. SM3 Module for Monitoring And Distance Control

The principal block diagram of the module SM3 [4] is in the Fig. 5. This diagram is very similar to the SM2's diagram, but its function is smarter. By means of energy breaker (just in the power socket) the electric current into the socket is switched on and switched off. These actions are controlled by en embedded microcontroller. The SM3 is controlled by individual user (from the central SM1 and/or intranet/internet) and/or central control station of the smart grid system. Communication of the SM3 in the household framework is via WLS and/or PWL and no direct

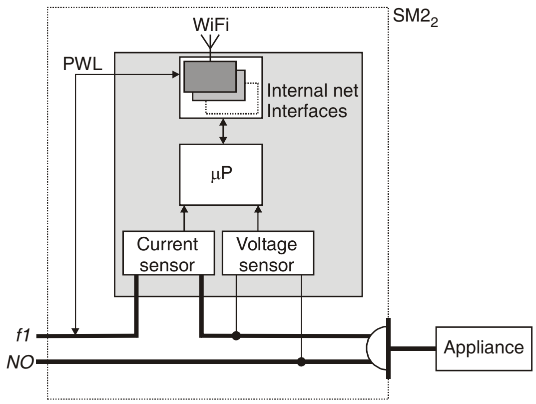

Figure 4: Block diagram of SM2.

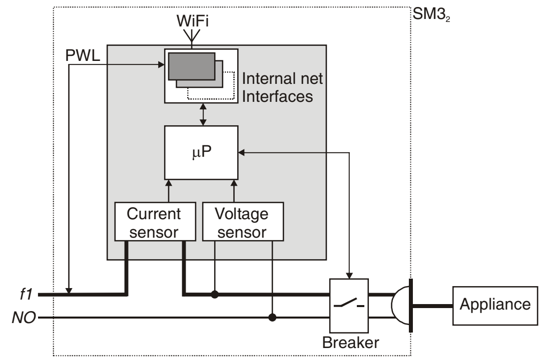

Figure 5: Block diagram of SM3.

connection of SM3 towards central control station of the smart grid and towards direct internet based access of user is planned. The basic higher level communication of the smart-energo system via internet is possible from the SM1 module only.

Thanks to the module SM3 the smart-energo system realizes an important step from a pure smart metering system towards smart-grid functionality. Its future enhancements, an individual user could influence an individual energy consumption according the lower or higher tariff for energy and in the same moment to contribute to the stabilization of the grid with important share (ratio) of renewable energy sources. A new generation of the SM3 should take into account also appliances equipped by an embedded individual control systems which don't enable switching by simple connection/disconnection of the power line in the socket.

4. SW FOR DATA PROCESSING AND CONTROL

The measured data from the SM1 and individual SM2s will be stored in individual data storages of SMs with defined size. Historical data will be stored in the central database of the smart grid/smart metering system for marketing and management as well as for research purposes.

Another important function of the SW will be information about the dynamical tariff of costs for energy. The tariff is proposed to correspond with excess or lack of energy in the smart grids. And the excess or lack of energy should dynamically depend on the weather situation in area of PV and wind farms. The smart-energo system expects to utilize precise weather forecasts from internet sources (Nordic servers and others).

Next generation of the system will be equipped by more sophisticate SW with advisory functions to help users to economize their energy consumption according adaptive and learning algorithms.

5. CONCLUSION

Contribution deals with the idea of NN network stability by a combination of an operator and a lot of individual smart control systems in OMs. The system is intended for NN distribution networks with important deal of RESs. Presented system smart-energo contributes to NN grids stability by means of individual control based on economical behaviour of many small energy consumers. System is modular and enables not only monitoring but will more and more enable an individual control of bigger electrical appliances in households and by smaller energy consumers in order to save money for electrical energy. By proposed dynamical tariff for energy, smart-energo will contribute to a better stabilization of grids with great ratio of renewable energy sources by following mechanism: price for energy unit will dynamically correspond to excess or lack of energy from renewable sources (PV and wind farms).

There are described block diagrams of smart-energo hardware elements SM1, SM2 and SM3 and their functions specification in the contribution, as well as the basic specification of an user's SW. The smart-energo system is conceived to utilize internet weather forecast services to predict an excess or a lack of energy from renewable energy sources to plan strategy for energy consumption by households and by smaller energy consumers.

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