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RESEARCH ON POWER QUALITY IN DISTRIBUTION NETWORKS WITH DISTRIBUTED GENERATION IN JOINT UKRAINE-POLAND SCIENTIFIC PROJECT

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Abstract: The paper presents objectives and results of the implementation of Joint Ukraine-Poland R&D Project on power quality in distribution networks. The project uses the unique theoretical experience of the Electrical Engineering department of Pryazovskyi State Technical University in the field of power quality and electromagnetic compatibility, and theoretical and practical experience of the Institute of Electrical Power Engineering of Lodz University of Technology on the integration of energy sources into the power networks, the network operating modes and the reliability of supply. Research and investigations that were carried out under the project are described and main results are indicated.

1. INTRODUCTION

The growing of the installed capacity of distributed energy sources (photovoltaic and wind power stations, fuel cell power stations, combined heat and power plants etc.), besides positive effects caused by decreasing of exhaust emission, reducing of electrical energy losses due to maximum bringing of such sources nearer to the customers, increasing of the redundancy level of power supply, and so on, results in some problems with power quality (PQ) degradation in the distribution networks. For example, the connection of photovoltaic and wind power stations to the "weak" network causes the voltage quality worsening due to significant voltage fluctuations (flicker) aroused from the variable nature of the active power generation. In such circumstances, the periodic oscillations of the mechanical torque causing considerable distortions in the point of common coupling can also appear. In addition, a widespread proliferation of modern frequency converters in the distributed generation sources (including double-fed induction generators) causes higher content of harmonics, subharmonics, interharmonics and kHz-range voltage components in the network voltage waveform. High level of the network voltage distortion has a negative impact on the electrical equipment insulation, increases the risk of resonance issues causing the electrical equipment

failures (especially capacitors for reactive power compensation), aggravates operation of the communication systems, measurement hardware, digital electricity meters, microprocessor-based protective relaying modules with programmable logic controllers, etc.

The requirements for power quality and stable network operation may be the barriers for the new installations and unlimited use of distributed energy sources in the networks. Effective solving of the aforesaid PQ problems is not possible without using new mathematical methods and approaches to the modeling of electromagnetic processes occurring in the networks, applying modern measurement hardware, using experimental facilities and uniting efforts of the research teams internationally. All these issues are included in the Ukrainian-Polish research and development project "Power quality in the distribution networks with distributed generation" realized by the Institute of Electrical Power Engineering of Lodz University of Technology (LUT) and the Electrical Engineering Department of Pryazovskyi State Technical University (PSTU). The purpose of the project is:

1. Development of models, algorithms and systems for the distribution networks with distributed generation with special attention paid to the aspects of electrical power quality.
2. The enhancement of scientific cooperation effectiveness between partners from Poland (LUT) and Ukraine (PSTU).

Joint using of the unique LUT Laboratory of Distributed Generation (LDG), which is a real, operating microgrid with DG, with advanced knowledge and experience of the Ukrainian and Polish researchers makes this project really innovative, mutually beneficial and commercially attractive. Results received during the joint project implementation have been integrated into the teaching process of the Polish and Ukrainian institutions of higher education through bachelor and master study programs, PhD and DSc dissertations, study tours.

2. RESEARCH OF POWER QUALITY WITHIN THE COOPERATION OF LUT AND PSTU

During implementation of the Ukrainian-Polish research and development project "Power quality in the distribution networks with distributed generation" the research of the following is carried out:

- electromagnetic compatibility indices describing voltage fluctuations, distortion and unbalance which occur in the distribution networks with the photovoltaic and wind power stations, fuel cell power stations, combined heat and electric power plants;
- negative technological and economical effects caused by degradation of these indices for electrically coupled power equipment, protective relaying and automation devices, communication systems, measurement equipment and for whole electric supply system;
- positive effects aroused from using of the electrical energy storages to suppress the fluctuations of the mechanical torque, active power and voltage in the distribution networks with DG;
- positive effects caused by applying the means and techniques for enhancement of the power quality indices;
- means for the enhancement of hosting capacity of the networks;
- control strategies for the operation of the networks with DES in grid-connected and islanded regimes;
- problems with standardization in the field of electromagnetic compatibility for electrical networks with DES.

Project implementation resulted in developing universal mathematical models for renewables (photovoltaic and wind power stations, fuel cell power stations), and simulation models for:

- prosumer installation with photovoltaics,
- low voltage microgrid with controllable and renewable energy sources.

These models offer possibility to conduct investigations of operating modes, power quality and energy efficiency parameters for power networks with DES and storage systems.

The investigations are carried out in the LDG laboratory in LUT. The laboratory is the operating microgrid with energy sources, storages and loads integrated by SCADA-system into all-in-one and contains the following equipment:

- cogeneration plant based on Capstone C30 gas microturbine manufactured by US company Capstone Turbine Corporation which can be operated continuously both in the connection with the supplying network (Grid Connected mode) and autonomously (Stand Alone mode); it is possible to change remotely a work schedule of plant (daily, weekly, on-line) via Remote Capstone Monitoring System;
- mini-wind power station which consists of two separated wind installations from company Fortis Wind Energy (Netherlands) based on induction generators with permanent magnets (nominal power of a single generator equals 5.8 kW);
- mini-photovoltaic power station which consists of static and tracking photovoltaic panels (static part involves 37 cells with total power of 6 kW while tracking part consists of 3 panels by 15 modules each with total power of 9 kW); each panel in the tracking system is constructed within the mast equipped with hydraulic actuators allowing for the panels rotation in both horizontal and vertical directions to receive the optimal angle towards the sun rays; both systems are fully automatic and inverter-based grid connected (inverters operate as current sources);
- fuel cell power station based on two NexaGen type fuel cells with proton exchange membranes from company Ballard (Canada); nominal power of installation in Grid Connected mode is up to 2 kW;
- energy storage systems including: flywheel energy storage from US company Vycon (maximum power is 350 kW, speed is 36,000 rpm, efficiency is 99.4%), supercapacitor energy storage of 300.kW and 10 kW lead-acid battery energy storage with three-phase pulse-width modulated inverter from company SMA (UK);
- real-time digital simulator (RTDS) from company RTDS Technologies Inc. (Canada) that running together with multi-functioning programmable three-phase DC/AC 60-kVA power source NetWave from company EM TEST (Switzerland) having embedded arbitrary waveform generator so that to restore electric supply after voltage sags in the networks.

The experimental part of project included the implementation of measurements, data acquisition and their subsequent processing by means of such equipment:

- power quality recorder Fluke 1760 (USA);
- power quality analyzer LEM TOPAS 1000 (Switzerland);
- power quality analyzer LEM MEMOBOX 800 (Switzerland);
- two-channel and four-channel digital recording oscilloscopes LeCroy (USA) and Rigol (Taiwan) with 100 MHz-bandwidth and high sampling rate in the on-line mode;
- power source/AC power analyzer Agilent/HP 6813B (USA);
- hardware Power DNA Cubes from company United Electronic Industries (USA) operated as part of SCADA-system BTC PRINS (Poland) of the laboratory with the operating distributed generation sources.

To approve the received theoretical and simulation results, it was perform measurements in the Polish running electrical installations and electrical networks with the distributed generation sources.

3. CONCLUSION

As a result of the project execution, universal mathematical models of renewable energy sources and microgrids with distributed generation were developed. These models allows for the analysis of PQ aspects in the integration of energy sources with power networks and testing different control strategies for the operation of microgrids in both gridconnected and islanded modes. Results obtained under the project allows to develop recommendations for optimizing the operation of renewable energy sources as well as electrical networks with DG. These recommendations will be aimed at reducing the damage from reduced power quality, reduction of active power losses, increase the lifetime of electrical equipment and reliability of electrical supply.

One of the results of the project may be the preparation of proposals for updating standards regarding power quality and electromagnetic compatibility in electrical power networks with DG in accordance with European requirements.

As part of the project the dissertation researches of two post-graduate students of the department of Electric Power Complexes and Systems of PSTU are completed and 11 scientific papers were published by the executives of the project [1-11]. Moreover, three PhD dissertations at LUT are under development.

The project results may contribute to the increase of electricity generation by renewable energy sources in the networks, which is one of the priorities in the electricity sectors of both countries in short-term and long-term perspectives.

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