# MICROGRIDS AND RESILIENCE

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**Summary:** Definitions of Smart Grid (SG) and microgrid open the paper. When resiliency is compared to self-healing, one can see that resiliency contains functions of self-healing as well as additional services. Nanogeneration and integration of electricity and gas systems are considered in the section entitled Miscellaneous. In the conclusion, the author emphasises the need of taking the microgrids with direct current into account in terms of development of their program.

## 1. INTRODUCTION

The history of microgrid is much shorter than of the electric power system, and its development is parallel to the development of Renewable Energy Sources (RES). The accelerated grid development due to multiple blackouts throughout the world, environmental pollution and depleting fossil fuels sources can be considered as a fundamental concept of Smart Grid (SG) development. The outcome of these two important processes implies that microgrids are important parts of the SGs. In order to gain a better understanding necessary for further considerations, I would like to start with two definitions of Smart Grid and microgrid:

*Smart Grids (SG):* provide power quality for the range of needs in a digital economy; accommodate all generation and storage options; enable new products, services and markets; enable active participation by consumers; operate resiliently against physical and cyberattack, and natural disasters (U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability [3].

*Microgrids* comprise LV distribution systems with distributed energy resources (DER) (microturbines, fuel cells, PV, etc.) together with storage devices (flywheels, energy capacitors and batteries) and flexible loads. Such systems can be operated in a non-autonomous way, if interconnected to the grid or in autonomous way, if disconnected from the main grid. The operation of microsources in the network can provide distinct benefits to the overall system performance, if managed and coordinated efficiently." [4]

The bibliography contains a number of references to papers, reports and research projects, and a synthesis of the works, which were published by 2012, is compiled in [4]. The European Electricity Grid Initiative (EEGI) considers microgrids as one of six principal work streams [8]

A growing importance of microgrids has resulted in a number of new research results published after 2012, and the aim of this paper is to present a selection of the most interesting works.

## 2. RESILIENCE

### 2.1. Definitions

For further considerations we need to get familiar with other key aspects of the subject matter. Reviewing presentations published under the Aalborg 2015 Symposium on Microgrids, we can find a presentation [2] with a set of the following definitions of Resilience:

- It is the capacity of a system to continually change and adapt yet remain within critical thresholds (The Stockholm Resilience Centre 2012).
- It is able to bounce back to a single equilibrium.
- It measures robustness or buffering capacity before a disturbance forces a system from one stable equilibrium to another.
- It is able to adapt in reaction to a disturbance.
- It is an underlying capacity of a system to maintain desired services in the face of a fluctuating environment.
- It is able to anticipate risk, limit impact, and bounce back rapidly through survival, adaptability, evolution and growth in the face of turbulent change.

Another definition of resilience is found in [5]: "Resilience means the ability to prepare for adapting to changing conditions and to withstand and recover rapidly from disruption. Grid resiliency depends on many factors, but a fundamental element is being able to forecast what is going to happen in advance". The last definition is a generalization of these presented in [2].

### 2.2. Weather and climate disasters and grid resiliency

One of the earliest U.S.A. definitions applies the following characteristics of the SG: "It is self-healing (from power disturbance events)" [7]. However in the U.S.A. "from 1980 to 2014 a total of 178 weather/climate disasters occurred… with total damages/costs reaching or exceeding US$ 1 billion for each event and US$ 1 trillion for all events. …These weather disaster events represent one of the most significant threats posed by climate change" [7].

Comparing the terms: *self-healing* and *resilient* enables us see that the word *resilience* is more general (including weather/climate, geomagnetic storm and power disaster, and the need for

forecasting) than the term *self-healing*", and for that reason *resilience* dominates in application.

In [7] one can find the following five needs for the resilient distribution grid R&D:

- Design resilience metrics,
- Enhance system design for resiliency,
- Improve preparedness and mitigation measures,
- Improve the system of response and recovery,
- Analyze and manage interdependencies.

### 2.3. Earthquake and tsunami in Japan (2011)

The destructive earthquakes and tsunami in the East of Japan (GEJE) in 2011 "shut down all Japan's nuclear plants by May 2012 and all 48 commercial reactors remain idle at the time article was written…Tsunami damaged 24.000 distribution poles, 42 lattice transmission towers, plus over 7000 pole-mounted distribution transformers and switches, and forced 70 damaged 154/500kV transformers out of service" [1,5]

Restoration of the Japan's Megagrid was not easy, however due to well designed, developed and operated microgrids, that process was easier. The research on microgrids in Japan started around the year 2000, and the deals with five microgrids were performed in the same year????, and in 2005 two new microgrids were realized. The conclusion presented in the end of this paper [5] (see also [4]) states that "The horrific GEJE experience has had understandably profound effect in Japan's national perception of resilience. Fortunately, the country's longrich and distinguished microgrid experience provides guidance toward a more secure energy system."

### 2.4. The European megagrid

Implementation of decarbonization in the EU, needs to deploy RES throughout Europe with a special focus on using specific characteristics of the regional renewable energy sources (e.g. wind in the North and solar in the South). The sound use of the generated power needs to develop transmission grids as the existing lines have not efficient capacity, for example the corridor between Iberia and France currently holds 1 GW while in future it would range from 15 to 30 GW, depending on the level of RES penetration [6]. Development of the transmission capacity must be supported by appropriate communication, information and network technologies, demand-side response (DSR), energy-storage technologies, enhanced flexibility of the distributed and backup generation.

When microgrids are disconnected from the traditional grid, they help to mitigate grid disturbance, serve as a grid resource for faster system response and recovery, and hence strengthen the grid resilience. The proliferation of energy storage, distributed generation, solid state equipment, and greater demand-side participation, are at present not fully integrated for a variety of reasons (such as market, regulatory and policy barriers).

## 3. MISCELLANY ON MICROGRID

### 3.1. Nanogeneration

Very interesting considerations on nanogeneration, including information on the following well-known physical phenomena: piezoelectric effect, triboelectric effect (rubbing glass with fur) and other [3]. The author also states that there are numerous other forms of energy harvesting for generation of electric energy in the nanoscale.

According to [9], nowadays:

a. Sending 100 bits of data consumes about 5 μJ,
b. Measuring acceleration consumes about 50 μJ,
c. Making a complete measurement: measure +
d. Conversion + emission consume 250-500 μJ.
e. Therefore, with 100 μW harvested continuously, it is possible to carry out a complete measurement every 1-10 seconds."

### 3.2. Gas and Electricity Integration System

An interesting task referring to an option of a microturbine supplied with natural gas in microgrid is addressed in [10]. Two improved models for single-shaft (SIMT) and split shaft microturbine (SPMT) were proposed in that paper for the purpose of dynamic modelling of natural gas- and electric network interaction. In the Hybrid natural gas and electricity system (HGES), dynamic behaviour of natural gas is described using differential partial equations whereas the electric network is described using differential algebraic equations. (Transient processes in electric network can be described also with the partial differential equations (Maxwell's equations), and it would be interesting to know why the differential algebraic equations used in the paper describe transients in the electric network.) As a result of HGES study the authors of the paper conclude:

– The (SPMT) based HGES is a weekly coupled system and the energy transfer from the disturbed system to the other is mainly absorbed by the DC link of the SIMT, which implies that SIMT can be seen as decoupled network for small disturbances.
– The SPMT based HGES is a strongly coupled system and the disturbance in one network will easily impact the other network, and as a consequence the dynamic energy transfer

between the two networks after disturbance will reduce the impact of disturbances on the disturbed system.

– The model and numerical method can be used to analyze the interactions between natural gas network and renewable energy sources (RES) as well as to analyze the large-scale integrated model when additional factors are applied in the HGES model.

## 4. CONCLUSION

Based on the short bibliography review, the following conclusions can be formulated:

– Microgrids represent a very important part of the Smart Grid as a tool for its optimization, supporting resilience.
– The following arising opportunities should be taken into account in terms of developing new microgrids:
  - Application of DC in LV and MV distribution networks [2,3]
  - Consider integration of electricity, gas, heat and petrol systems.
– Earthquake and tsunami are not foreseen to take place in Poland, however due to at least two reasons, serious research focused on the program of microgrid development is necessary:
  - Necessity of fulfilling EU regulations in terms of reduction of $CO_2$ emission,
  - Necessity of participating in the European Megagrid, which is linked with the first conclusion.

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## MIKROSIECI I ODPORNOŚĆ

**Słowa kluczowe:** sieć inteligentna, mikrosieć, odporność, nanogeneracja

**Streszczenie.** Na początku artykułu podano definicje sieci inteligentnej i mikrosieci. Z porównania pojęć: samoodnawianie i odporność wynika, że pierwsze z tych określeń zawiera drugie, a ponadto wprowadza dodatkowe funkcje. Jako różne nowości zasygnalizowano nanogenerację i zintegrowane systemy elektryczne i gazowe. W zakończeniu autor uwypukla potrzebę uwzględnienia zastosowania prądu stałego w projektach rozwoju mikrosieci.

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