Monitoring of the synchronous generators working in parallel operation with focus on their dynamic behavior

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Abstract

This paper is focused on a dynamic behavior of gensets with internal combustion engines connected to the distribution grid. Measurement of the dynamic behavior is carried out using developed analogue wattmeter. Proposed measurement method uses two gensets and compares the power output of the genset synchronized to the electrical grid with the power output of genset being already synchronized. Resulting dynamic responses of both outputs were evaluated showing a visible dependency of both gensets dynamic behavior. Obtained results will be used to evaluate frequency characteristic of the distribution grid and to identify potential frequency vulnerabilities of the distribution grid.

Keywords: analogue wattmeter; genset; output power; dynamic; internal combustion engine

1. Introduction

In the last couple of years, we noted, that renewable sources have been widely deployed. This development is related to many factors e.g. nuclear power reducing, so called green policies etc.

Utilizing renewable sources itself brings many challenges. With growing ratio of renewable sources there arise the “Smart Grid” technologies. A “Smart Grid” is a concept of transforming an electric power grid by using advanced communications and information technology with an automated control. It integrates new innovative tools and technologies from generation, transmission, and distribution all the way to consumer appliances and equipment. [1][2][3]

A Huge deployment of renewable sources (RES) has led to significant generation shares of variable RES in power systems worldwide. RES units, notably interconnected wind turbines and photovoltaics (PV) units that do not provide rotational inertia, are effectively displacing conventional generators and their rotating machinery. This has implications for frequency dynamics and power system operation. Since frequency dynamics are faster in power systems with low rotational inertia, this can lead to large transient frequency and power oscillations in multi-area power systems. [4]

Above mentioned disadvantages lead to the wide discussion about power system stability. In recent studies, we can recognize two areas of interest. The first area is focused on modelling of power system leading to better understanding and control of the power system. [5][6]

The second area is connected with the electromechanical behavior of the power system. Those studies are based on the particular studies which are analyzing the influence of rotational inertia on the power system fluctuations e.g. frequency, voltage etc. [7]

The problem of instability of power system is widely dependent on the increasing ratio of RES. Those RES do not provide rotational inertia, so it can be a possible source of any fluctuations. The rotational inertia of power systems becomes thus markedly time-variant and is reduced, often non-uniformly within the grid topology.

An important example of such a research is [8], where grid analysis related to placing so-called virtual inertia into the power system to enhance a stability of the power system introduced. This formulation gives rise to a large-scale and non-convex optimization program.

2. Methodology

As is mentioned above there are many challenges to achieve stable and reliable power system. If we are unable to maintain stable and reliable power system, then we are offering the space for possible blackouts.

In this paper, the functionality of analogue wattmeter is presented. Analogue wattmeter is used to monitor the behavior of the synchronous generators operated in parallel.

The aim of this method is to generate a power impulse to the power system and observe the response of the system. The response of the power system could be then used to estimate the frequency characteristic of the power system and the find the suspected vulnerabilities, e.g. machines with dangerous frequencies, which can in some certain power system condition lead to the breakdown of the system and potential blackout.

Power impulse emitted into the power system was generated by phasing of the synchronous generator with a certain phase shift with respect to the phase angle of operated distribution grid.

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3. Measurement description

We did several measurements and utilize developed wattmeter to observe dynamic behavior of the power system.

3.1. Power station description

The experiment was taken in the backup power supply station of The Prague Public Transit Co. Inc. situated near Radlicka subway station. The backup station includes 5 three-phase gensets each with a nominal power of 1.3MW.

Tab. 1. *Genset properties*

Make	ČKD
Engine type	Turbocharged, diesel
Displacement	61 litre
Number of cylinders	12
Nominal genset power	1.3 MW
Speed controller	Woodward UG 8 (mechanical-hydraulic)

Fig. 1. *Tested genset G4*

3.2. Measurement setup

Two gensets were selected, where the output power of one genset was logged using measurement device. Fig. 2 shows the measurement setup.

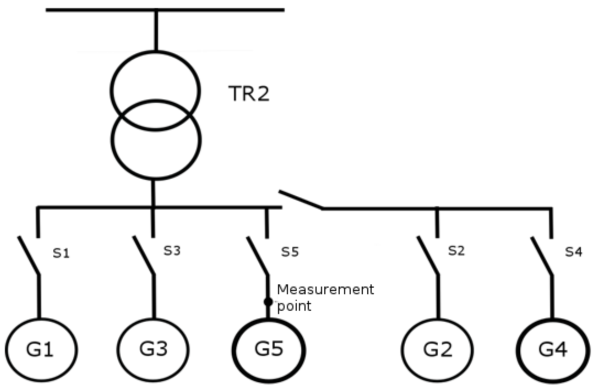

Fig. 2. *Experimental setup connection*

Current and voltage outputs of selected genset were connected to developed analogue wattmeter. Wattmeter output was connected to Labjack U3HV measurement device.

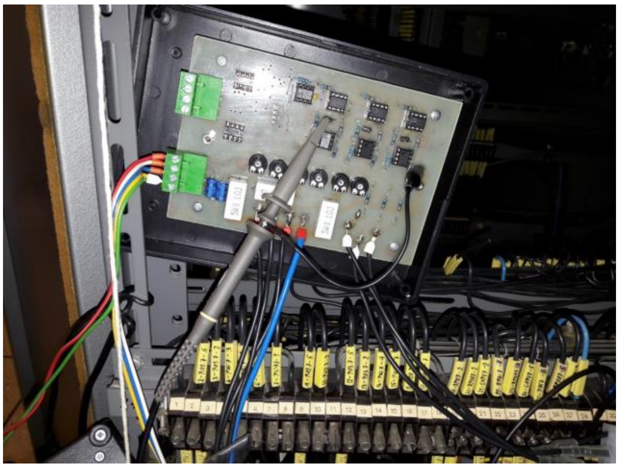

Fig. 3. *Connection of analogue wattmeter to genset output and to data logger*

3.3. Measurement method

With the lack of 2nd analogue wattmeter, measurement was taken in 2 steps. Both measurements were taken from genset G5 (according to Fig. 2). Where in first case output power of G5 was measured when G5 itself was phased to the distribution network and in second case output power of G5 running under the load of 100kW was measured when G4 was phased to the distribution network.

In both cases, genset was synchronized with a slight phase shift between genset and the electrical grid in the time of connection. This led to a higher disturbance in the network and therefore to better identification of the event in the measurement results.

4. Results

Connecting other genset G4 to electrical grid caused glimmer on the distribution network. This led to a visible response on already phased genset G5. Even the results are not measured at the same time, both measurements were synchronized in time and plotted using the same time axis, where the synchronization is given with the start of the synchronization event of G4. The results are visible in following figures.

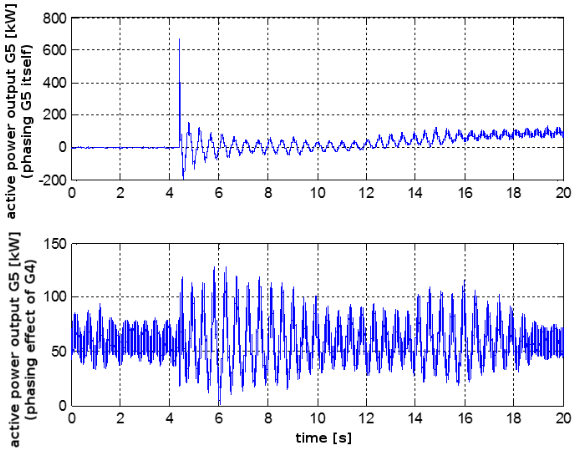

Fig. 4. *Set of measurement of active power of G5 genset – plot with 2s resolution (upper –synchronizing genset to electrical grid, bottom – response of synchronized genset to synchronization event of 2nd genset*

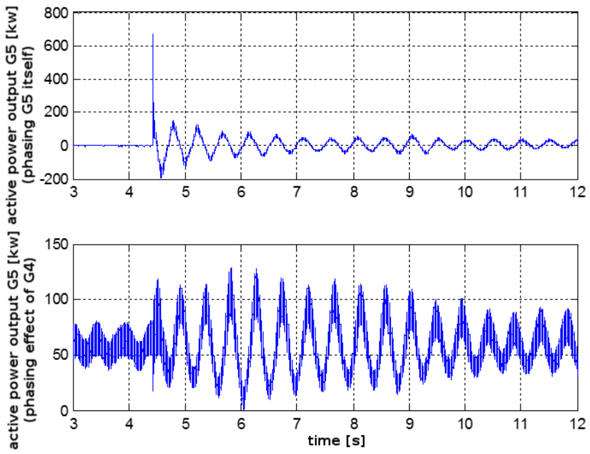

Fig. 5. *Set of measurement of active power of G5 genset – plot with 1s resolution (upper –synchronizing genset to electrical grid, bottom – response of synchronized genset to synchronization event of 2nd genset*

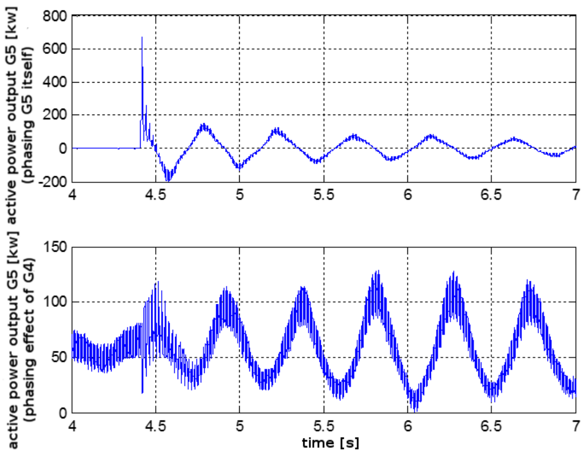

Fig. 6. *Set of measurement of active power of G5 genset – plot with 0.5s resolution (upper –synchronizing genset to electrical grid, bottom – response of synchronized genset to synchronization event of 2nd genset*

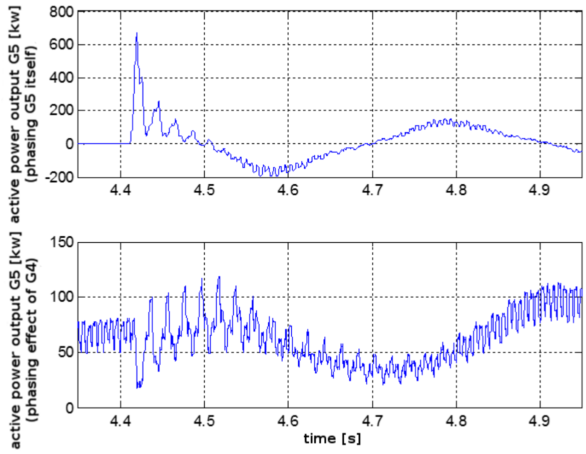

Fig. 7. *Set of measurement of active power of G5 genset – plot with 0.1s resolution (upper –synchronizing genset to electrical grid, bottom – response of synchronized genset to synchronization event of 2nd genset*

5. Conclusion and future steps

Developed analogue wattmeter was used to measure genset instantaneous active power output over all 3 phases. Active power output response of genset G5 during synchronization to distribution network was measured with initial peak power and following stabilization period. This measurement was compared to the active power response of genset G5 under 100kW load when genset G4 was synchronized to the distribution network. Resulting response on G5 follows the previously measured trend of G5 synchronized to network, with the same period of oscillations and stabilization trend.

Measurement method will be improved by deployment of the second analogue wattmeter. The second wattmeter will be measured in parallel to the first one, giving comparable responses of both gensets measured at the same time.

Improved method can be used in development and calibration of mechanical parameters of electrical grid (definition of "toughness" of electrical grid), where dynamical parameters of electrical machines can play an important role.

Improvements in the identification of electrical grid components can lead to deeper understanding of grid behavior and therefore to improvements in electrical grid control avoiding emergency states leading to possible blackouts.

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