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Design of a Power Plant Emulator for the Dynamic Frequency Stability Studies

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Abstract: Increasing renewable energy integration to grid requires inertial support to improve frequency stability of the power system. Inertial support of renewable energy systems requires hardware verification in order to test practical limitations and absence of dynamical grid simulators makes verification studies more challenging. In this study, a test rig which is composed of a DC motor, an AC synchronous generator and an external flywheel, is developed in order to provide a platform in which dynamic properties of an actual power plant can be simulated in the laboratory conditions. A 4 kVA power plant simulator with a field exciter and a speed governor is developed with 1kVA buck converters. The frequency response of the test bench is controlled in parallel with the computer simulations in Digsilent Powerfactory environment. The developed test rig is a low cost and simple solution aimed for experimental studies regarding inertial support of renewable energy systems or power system frequency studies.

Introduction

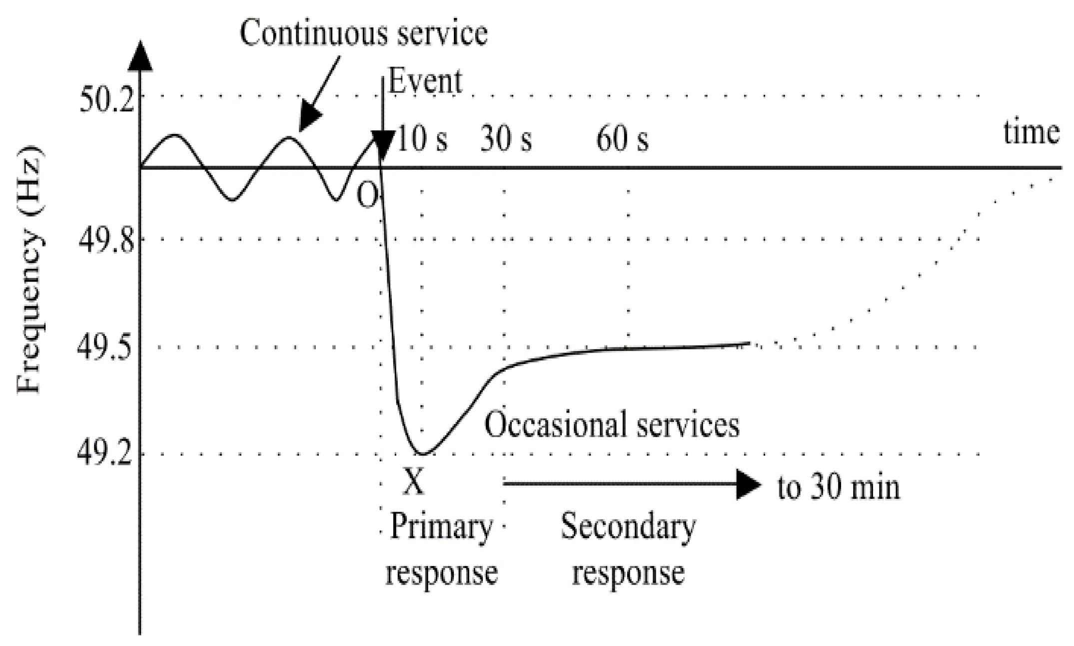


Figure 1. Frequency control in England and Wales [1]

- During the continuous service, system frequnecy is maintained between allowed band by ensuring aggravated mechanical input is equal to aggravated output power.
- System frequency is disturbed with either sudden load connections or generator outages. In Figure 1, from O to X, system frequency is determined by system inertia and the disturbance size.
- Verificaion studies in power system frequency stability are more challanges due to the absence of grid simulators with dynamical frequnecy response.

Figure 2. Commercial Grid Simulator

- Commercial grid simulators are **not** composed of **rotational** elements but **back-to-back converters**.
- Frequency is **not** determined according to **active power balance** but **commanded** to them.
- Therefore, they are **not suitable** for power system **frequency stability studies**. A more **realistic** plant simulator can be achieved with AC Synchronous Generator, DC motor and External Flywheel.

- In order to have a realistic governor model, the system is constructed with **three operating modes**.
  - **Mode 1**: System speed is brought to the nominal speed from standstill.
  - **Mode 2**: Input mechanical power is kept constant for a defined time period. This mode is activated simultaneously with load connection.
  - **Mode 3**: Reduction in the system speed due to mode 2 is compensated. The final speed can be either nominal speed or a lower speed.

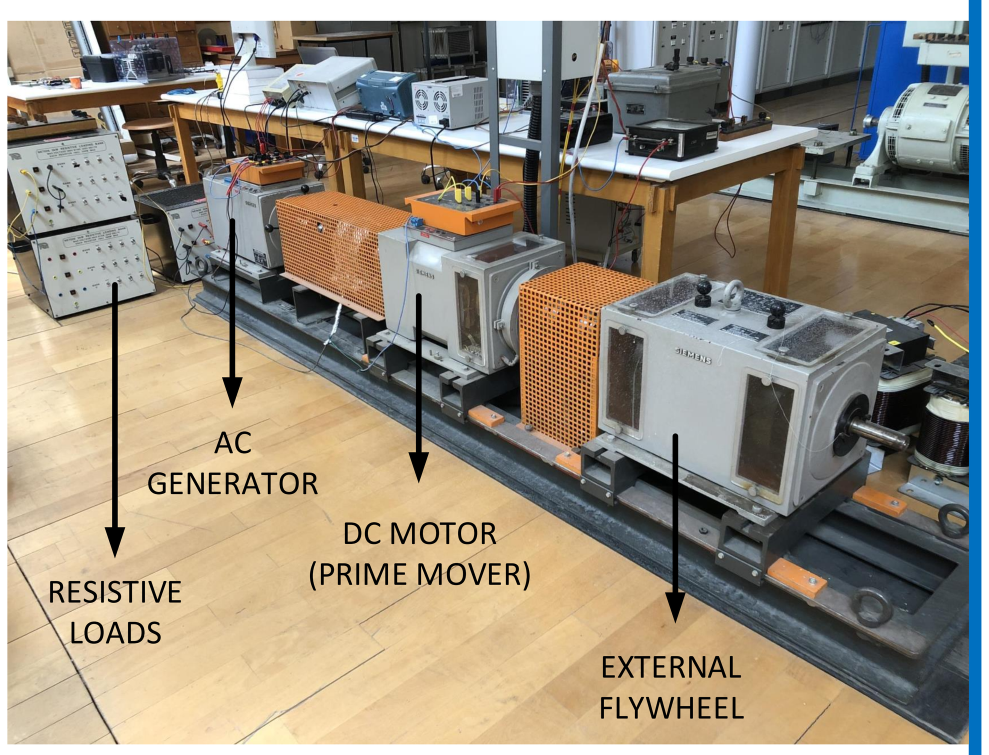


Figure 3. Proposed Plant Simulator

System Description

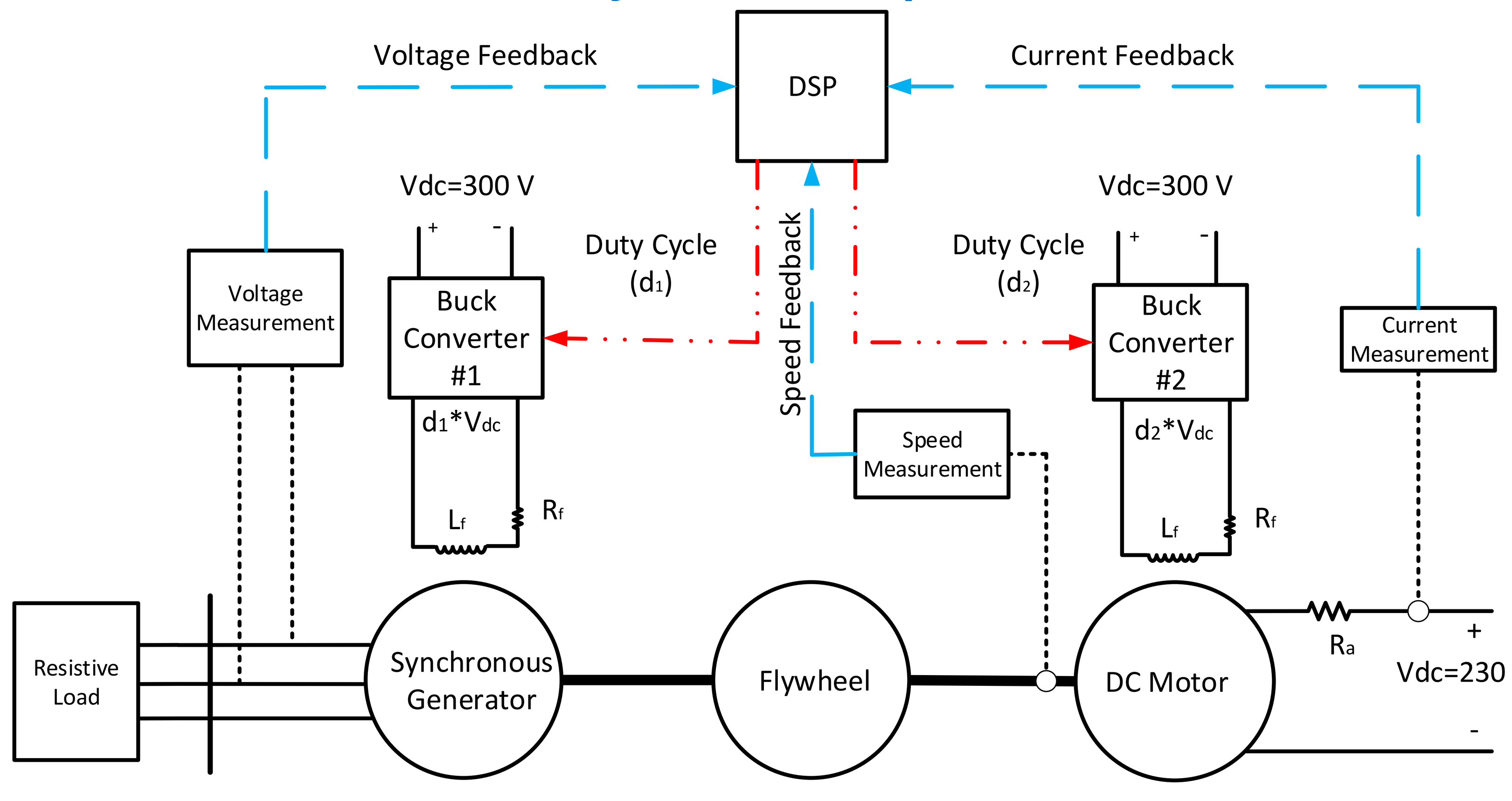


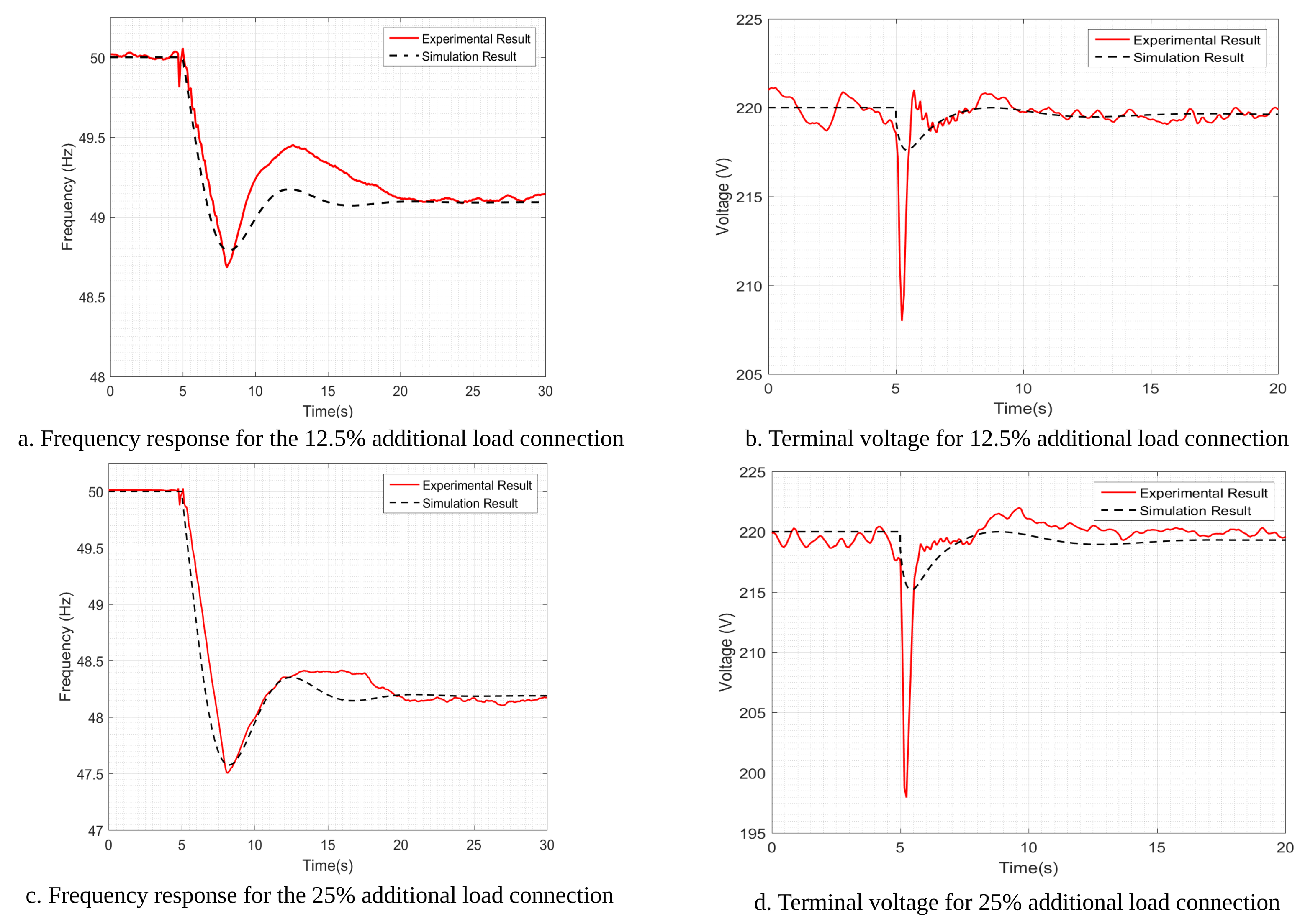
Figure 4. System Description

Generator Rated Power	4 kVA
Nominal Voltage	380 V
Nominal Frequency	50 Hz
Base Load	3 kW
Additional Load	375/750 W
System Inertia Constant	6.16 s

Table 1. Properties of the Emulated Power Plant

- Load power will be increased by either 375W (12.5%) or 750W(25%) in order to create frequency disturbances.
- Frequency response of the system is emulated according to computer simulations of 4kVA generator with IEEET1 Exciter and IEEEG1 governor.

Results



a. Frequency response for the 12.5% additional load connection

b. Terminal voltage for 12.5% additional load connection

c. Frequency response for the 25% additional load connection

d. Terminal voltage for 25% additional load connection

Figure 5. Comparison of computer simulations and hardware results

References & Conclusion -

- The frequency of the system decreased in Mode-2 according to the system inertia and the size of additional load which was the aim of the study. Although initial and final frequencies are commanded externally, system frequency changes in a realistic way following a disturbance.
- The most important advantage is that controlling field current rather than armature current slows down the system response. Therefore, more realistic governor model can be emulated by controlling field current rather than controlling armature current.
- The designed plant simulator can be used to establish a laboratory scale hybrid power generation system in which a wind turbine emulator and a photovoltaic system supply a common load with the plant emulator.

[1] I. A. Erinmez, D. O. Bickers, G. F. Wood, and W. W. Hung, "NGC experience with frequency control in England and Wales-provision of frequency response by generators," IEEE Power Eng. Soc. 1999 Winter Meet. (Cat. No.99CH36233), vol. 1, pp. 590–596 vol.1, 1999.