# Design of a Grid Simulator for the Dynamic Frequency Stability Studies


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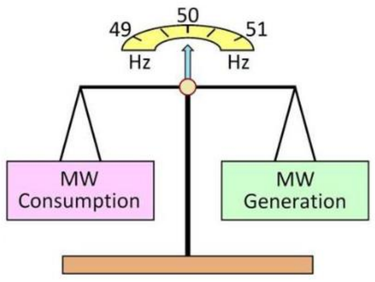
## Frequency in Power Systems

- Frequency in power systems depends on the balance between generation and consumption.
- Increasing renewable energy systems causes higher flactuations in the frequency.



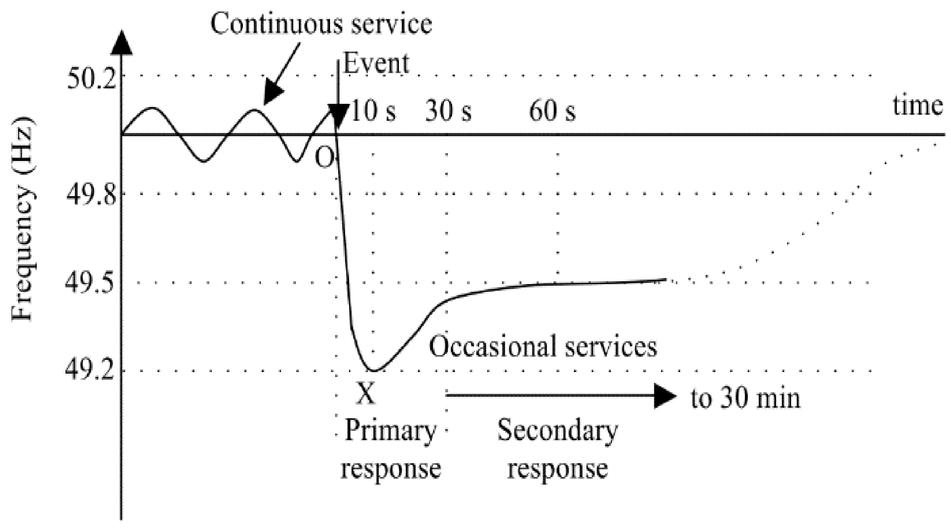




**Figure 1.** Frequency control in England and Wales [1]

- Therefore, frequency stability studies require higher attention. However, absence of dynamical grid simulators makes these studies more challanging in laboratory conditions.

## Commercial Grid Simulator vs AC Synchronous Generator

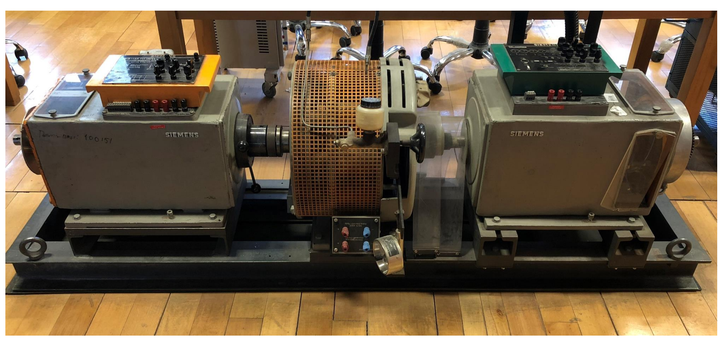



**Figure 2. Commercial Grid Simulator (left) and AC Synchronous Generator (right)**

- There is **no rotational part**!
- Frequency is **commanded**!
- System is composed of **rotational** elements.
- Frequency is determined according to power balance.

## Proposal

**Figure 3.** Laboratory Setup ( AC Generator, DC motor and External Flywheel

- A realistic grid simulator can be designed in the laboratory by controlling the **system speed** and **output voltage**.
- DC motor and AC motor will be controlled by controlling their **field currents** in order to deal with **low power** equipments.

## System Description

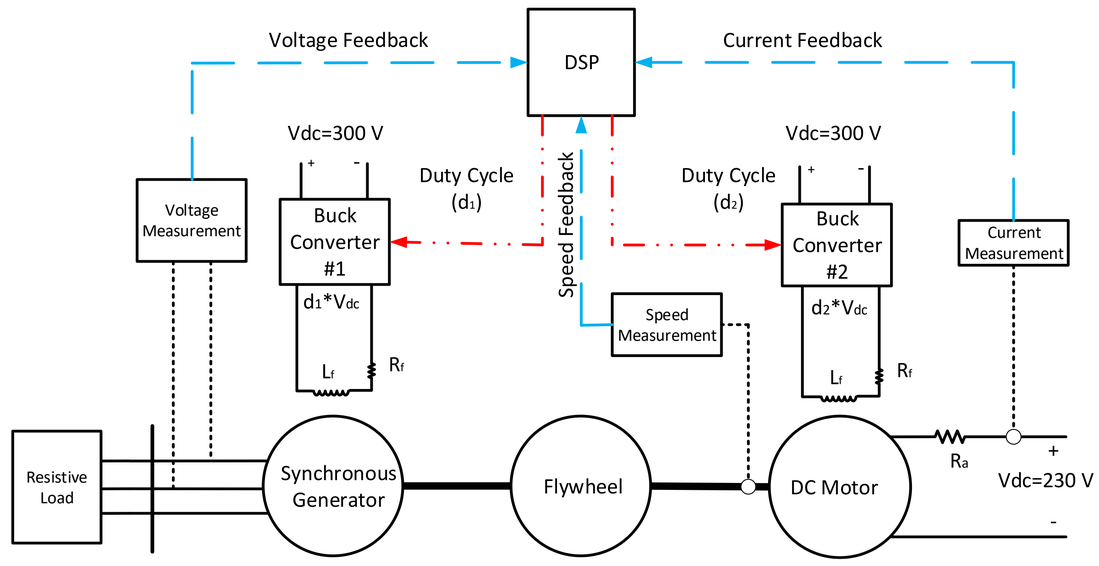
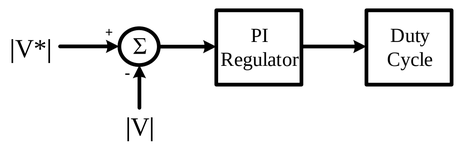



**Figure 4.** Proposed System Description

| Exciter | Governor |
|---|---|
| It adjust the **output voltage**. | It adjust the input **mechanical power**. |




AC Generator:

$I_f \alpha V_t$

**Figure 5.** Exciter Control Diagram

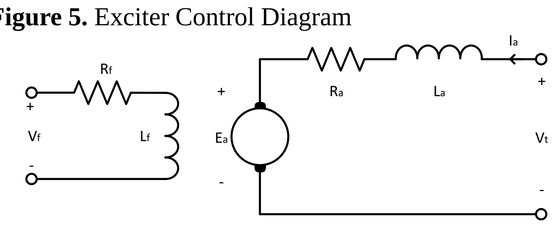



**Figure 6.** Separately excited DC motor equivalent circuit [2]

DC Motor:

$\omega \alpha E_a$

$I_f \alpha E_a$

$I_f \alpha \frac{1}{I_a}$

$I_a \alpha T_e$

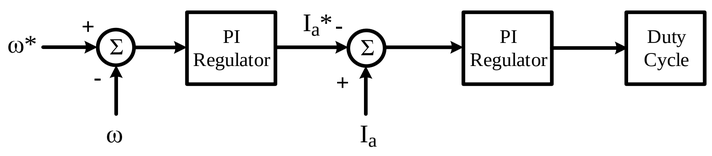



**Figure 7.** Governor Control Diagram for mode 1

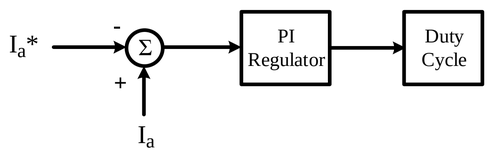



**Figure 8.** Governor Control Diagram for mode 2

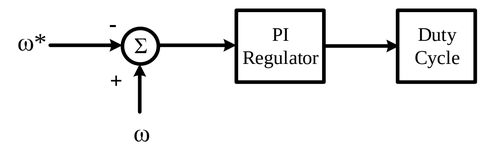
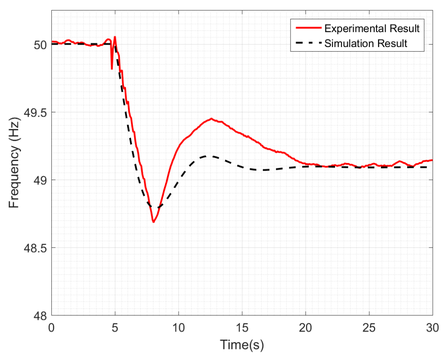
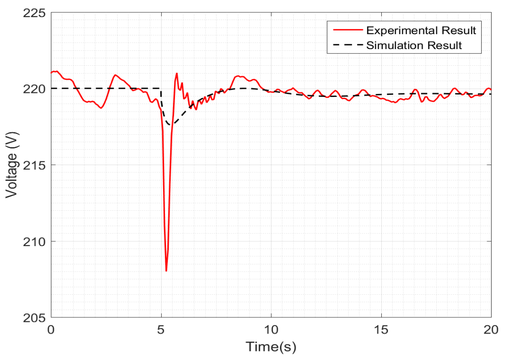



**Figure 9.** Governor Control Diagram for mode 3

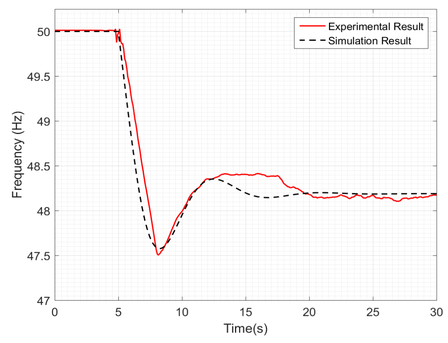
## Results



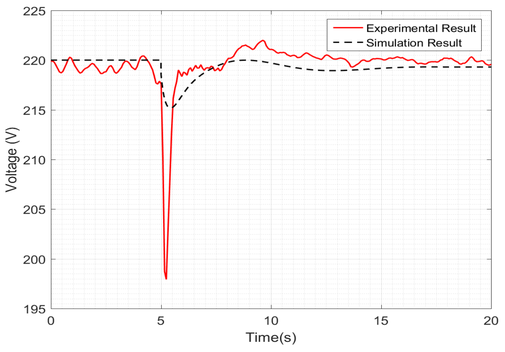

a. Frequency response for the 12.5% additional load connection




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 10.** Comparison of computer simulations and hardware results

# Bibliography


[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.

[2] S. D. Umans, Fitzgeral & Kingsley's Electric Machinery. 2014.