REPLACING DIESEL-DRIVEN GENERATORS WITH BATTERIES TO POWER ISLANDED GRIDS: MODELING AND PERFORMANCE COMPARISON

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Motivation

The increasing penetration of energy production from renewable sources has, on the one side, decreased the CO_2 emissions coming from the electricity industry in most parts of the world. Still, on the other hand, it has also brought some challenges to grid operation. High penetration rates of inverter-based resources have raised questions regarding the amount of available short-circuit power and inertia inside an interconnected system and in isolated grids. The resultant system behavior in the presence of other conventional generators is also unknown.

During scheduled maintenance, grid operators could use low to medium-sized generators like diesel engines to continue providing electricity to a low-voltage network for the whole duration of the interruption. By this, an intentional and temporal islanded grid is formed. Usually, the generator is operated so that the power injection from installed decentralized generators (DG), such as rooftop PVs, is not allowed. However, it has been proven that it is possible to reach a stable islanded grid operation using a mix of conventional generators together with DGs [1]. The carbon footprint of such individual events can be further reduced by replacing these combustion engines with a battery-generating unit. The battery can be charged with the surplus electricity generated from decentralized generators available in the low-voltage network and discharged when the demand increases. As described in [2], a small diesel-driven generator is included in this concept and designed for times when the battery needs to be recharged so that its state of charge does not fall below the minimum defined by the manufacturer, compromising the stable islanded operation. In this paper, the modeling and validation of both aggregates is explained. In addition, their frequency performance under a worst-case scenario is compared.

Methodology

The model of the diesel-driven generator is shown in Figure 1a) and has been validated using measurement data as described in [3].

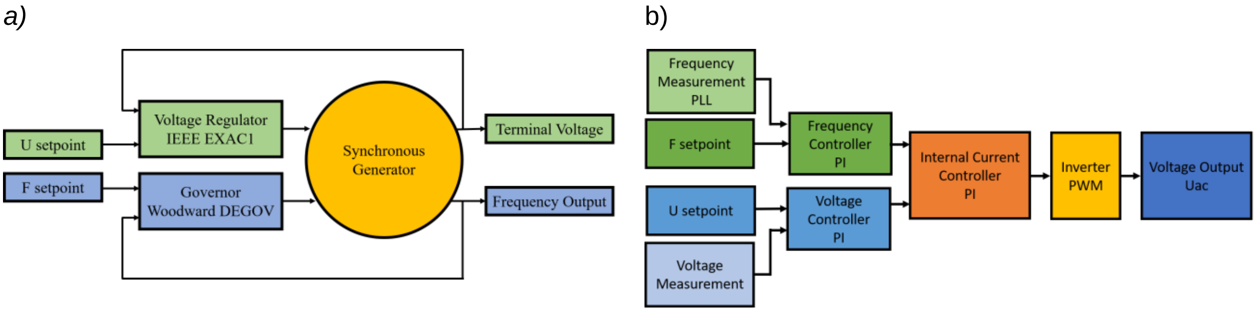

Figure 1: Comparison between the model of the a) diesel-electric generator and b) battery-generating unit

The battery-generating unit is interfaced to the grid through an inverter, a filter, and a transformer, parametrized according to the manufacturer datasheet. The inverter model composes an external

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frequency and voltage controller and an internal current controller, modeled as two separate proportional-integral (PI) controllers, as shown in Figure 1b). The controller parameters were validated using measurement data from a test setup composed of a resistive load bank connected to the output of the battery-generating unit. Different base loads and load steps were performed. Although the parameters were identified for the case of a 50 kW base load and 200 kW load step, they are also valid for measurement sets with different base loads and load steps.

Measurement and simulated data are contrasted for a critical case for the performance comparison. This paper analyzes the change between idle to 50 kW. Measurement data also show that power jumps on low-voltage grids typically range from 10 to 50 kW and up to 100 kW during changeable weather. Therefore, the analysis presented here represents a worst-case scenario.

Results

A performance comparison of the frequency output between the battery-generating unit and the diesel-electric generator for a power jump from idle to 100 kW is shown in Figure 2. Both measurement data and simulation data are illustrated.

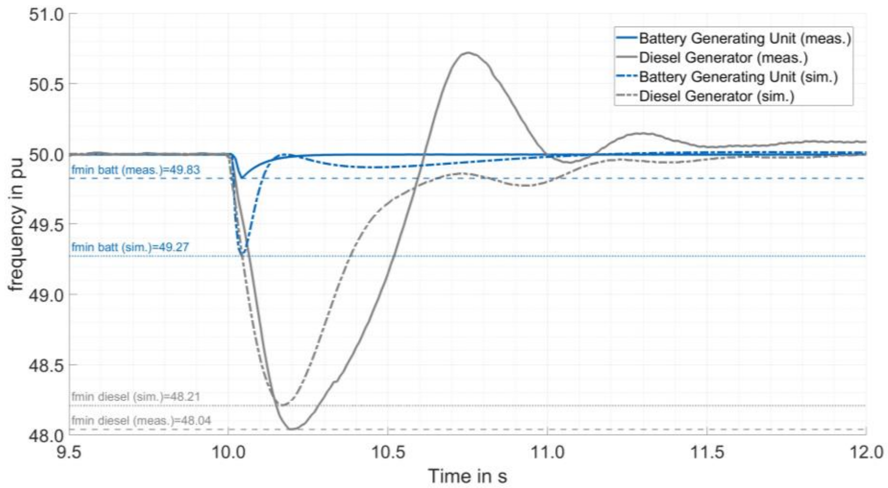

Figure 2: Performance comparison between the battery-generating unit and the diesel-electric generator

It can be noticed that the difference in the measured minimum frequency between both devices lies around 0.033 pu, which corresponds to 1,65 Hz. It can also be observed that the reaction time of the battery unit takes around 200 ms; meanwhile, the diesel generator returns to the setpoint after a few seconds. Therefore, in terms of frequency response, it can be stated that the performance of the battery aggregate is better compared to the diesel-driven counterpart. However, the frequency behavior is only one aspect to be considered when moving from thermoelectrical engines to battery-based aggregates to power islanded grids. The usage of inverter-based generation for emergency power supply is an emerging area with many additional aspects to be further explored.

References

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