

Microgrids are becoming important constituents of electric power distribution networks. Microgrids are typically comprised of both inverter interfaced and non-inverter interfaced renewable energy generators (REGs), hence their dynamic characteristics are significantly different from the conventional grids comprised of centralised synchronous generators. Different inherent characteristics of REGs, power dispatch levels, relative REG capacities, and external grid characteristics are some of the important features of significant interest in relation to microgrid dynamic behaviour.

## INTRODUCTION

A range of aspects such as different inherent characteristics of REG, different power dispatch levels, generator capacities, and external grid characteristics will play prominent roles in successful operation of microgrids in the future. This paper presents a case study carried out focusing on those aspects. The importance of understanding the dynamic behaviour of microgrids is highlighted through a comparative analysis undertaken on a hybrid microgrid containing solar-PV system, double-fed induction generator (DFIG), and synchronous generator such as mini-hydro power plant (MHPP) developed in DIgSILENT PowerFactory.

## MICROGRID TEST MODEL AND RENEWABLE GENERATOR MODELS

Simulations were carried out using a microgrid model developed in the DIgSILENT PowerFactory. The REGs were modelled using the DIgSILENT simulation language (DSL).

### A. Microgrid model

Necessary modifications were made in the IEEE-13 node test feeder to obtain a balanced microgrid. The total active and reactive power demand of the microgrid are 3.8 MW and 2.4 MVar respectively. Two switched shunt capacitor banks were installed at buses 611 and 675 to provide the reactive power support to the microgrid. The microgrid voltage was maintained between 0.95-1.05 pu, and it was connected to the external grid through a 115/4.16 kV, 10 MVA transformer. Three types of REGs namely; Mini-hydro power plant (MHPP), DFIG and PV system are considered in the study.

### B. Mini-hydro power plant

The plant model of the synchronous generator represents a MHPP. The hydro turbine governor model and IEEE type AC1A excitation system in have been used to implement the MHPP model.

### C. DFIG model

The DFIG was modelled as a three-mass model (i.e. turbine, drive train and generator inertia) and operates at unity power factor mode.

### D. Solar-PV model

The solar-PV system operates at power factor mode while the irradiance level and temperature were assumed to be constant during dynamic studies.

## MICROGRID DYNAMICS DURING UNPLANNED ISLANDING

During the grid connected mode microgrid generates 4 MW of active power while the external grid supplies 1.38 MVar reactive power support to the microgrid. The following scenarios have been analysed in the study;

### A. Different machine ratings

**Scenario 1:** A MHPP (SG) and a DFIG were connected to buses 646 and 680 respectively to supply the active power demand of the microgrid.

**Scenario 2:** DFIG was replaced with a PV system having same power rating.

### B. Different dispatch levels

5 MVA MHPP (SG) and 4.5 MVA DFIG have been connected to bus 646 and bus 680 respectively. Different to previous scenarios, only active power dispatch levels of SG and DFIG were changed while maintaining machine capacity constant.

### C. Faults during grid connected and islanded mode

A three-phase short-circuit fault was applied to bus 634 at  $t=120$  s and cleared after 150 ms during both grid connected and islanded modes.

### D. Effects of external grid short-circuit capacity

The impact of external grid short-circuit capacity (SCC) on microgrid dynamic characteristics during faults are analysed by applying a three-phase short-circuit fault at bus 634 at  $t=1$  s for 150 ms.

### E. Effect of external grid inertia

A fault was applied in the microgrid and maximum ROCOF was observed for different external grid inertia.

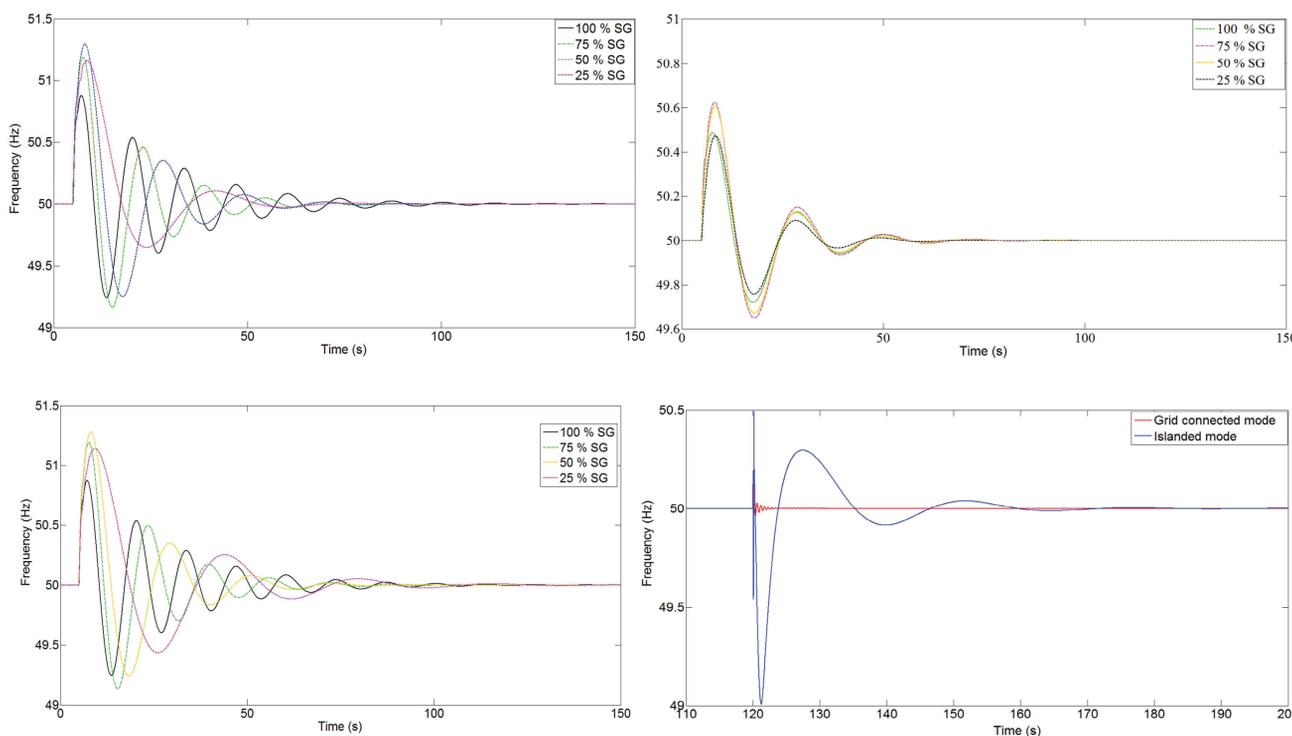


Fig. 2 . Microgrid frequency variations for different machine ratings during unplanned islanding: (Top) DFIG and MHPP; (Bottom) PV and MHPP

Fig. 3 . Microgrid frequency variations for (Top) different active power dispatch levels of SG and DFIG during unplanned islanding; (Bottom) due to a three-phase short-circuit fault

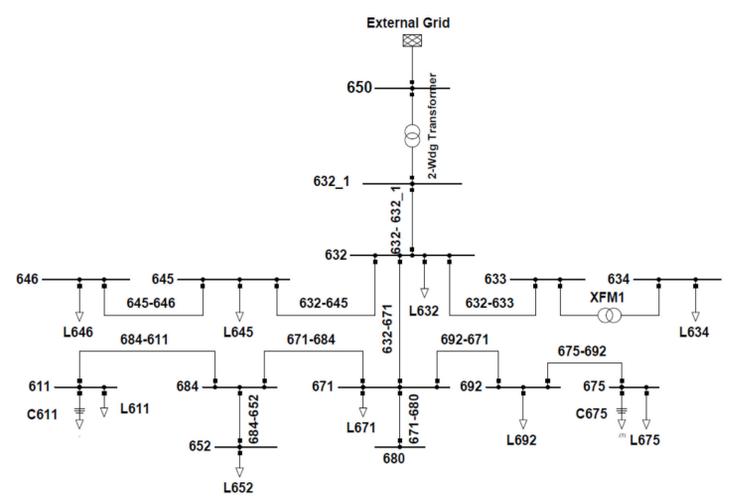


Fig. 1 Microgrid study system

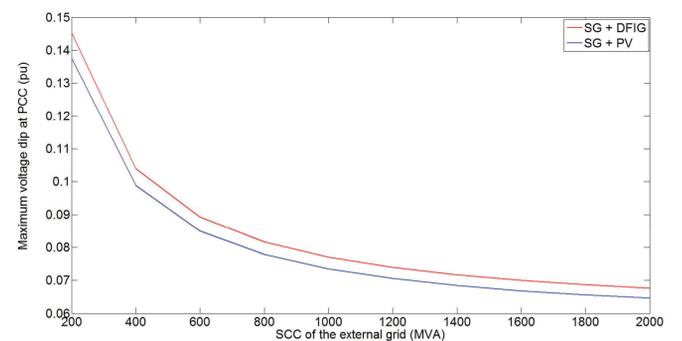


Fig. 4 . Variations of maximum voltage dip at PCC with external grid SCC

Table 1. Maximum ROCOF of the microgrid with DFIG and SG for case A

Installed capacity	Maximum ROCOF (Hz/s)	
	DFIG and SG	PV and SG
25% SG	0.2577	0.2525
50% SG	0.1743	0.1542
75% SG	0.0990	0.0737
100% SG	0.0289	0.0281

## CONCLUSIONS

The study has shown that the dynamic characteristics of the microgrid are significantly influenced by the individual characteristics of renewable energy generators. Penetration of inverter based REGs has a significant effect on improving the oscillatory behaviour of the microgrid due to the emulated damping provided by the fast current controller. Further, studies have shown that different power dispatch levels, generator MVA capacity, and external grid characteristics also influence the dynamic behaviour of the microgrid, thus these factors should be considered when planning microgrids, and in particular designing protection systems for the microgrid.