Microgrid operations: case study at Nilambe mini hydro grid

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Introduction

Embedded generation technologies are proved by researchers as one of the solution to satisfy the increasing electricity demand while optimizing the existing network [1]. In Europe micro grid technology also potentially studied to supply green electricity to most important industries [2, 3]. However, challenges are being made on keeping the micro grid running when the main grid was disconnected due to a fault and smooth reconnection of micro grid when fault is cleared.

The objective of this study is to find out the possibility of synchronizing a microgrid to the main grid at grid connection point, when it is disconnected due to a fault.

In this study, Nilambe 1.6 MW mini hydro generator with its surrounding grid was taken as micro grid. It was studied whether the embedded generator could be kept running while feeding surrounding loads during a Grid failure. The frequency and voltage maintaining capability of this generator was also checked with shedding excess loads when it was islanded. Finally automated synchronizing control of this micro grid was studied once the grid was restored.

Methodology

The micro grid with embedded generator was modeled using EMTDC/PSCAD simulation package. All the loads in the medium voltage network lumped into two loads one representing the non frequency sensitive loads and other representing frequency sensitive loads. Initially steady state stability of the micro grid, connected to the main grid, was studied. Automatic Voltage Regulator (AVR) operation and governor controller operations were checked in islanded operation. Finally resynchronization and automatic grid connection was checked, when grid was resorted. Data of generator, transformer and feeder is annexed.

A simplified model of the system is shown in Figures 2. The transformer and the series impedance of the line are lumped into one series impedance of (0.354+j27.626) Ω. AVR and governor controls together with synchronization control are shown in Figures 3 and 4. The AVR consists of a PI regulator with an output derivative feedback function to represent the practical AVR response. The governor consists of a PI regulator with the permanent droop feedback.

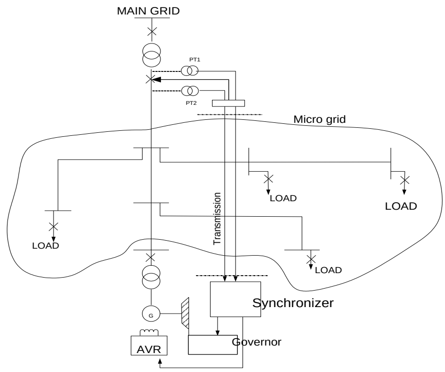

Figure 1: Micro grid at Nilambe

Data collection and modeling

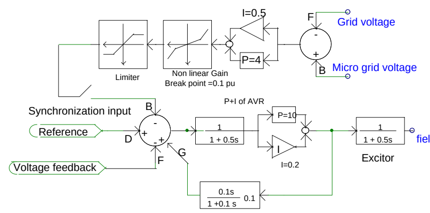

Figure 2: simulation model of the AVR

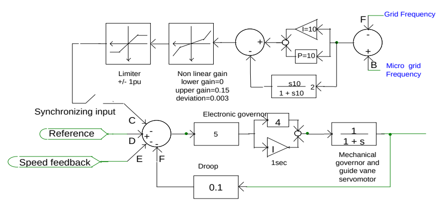

Figure 3: simulation model of the governor

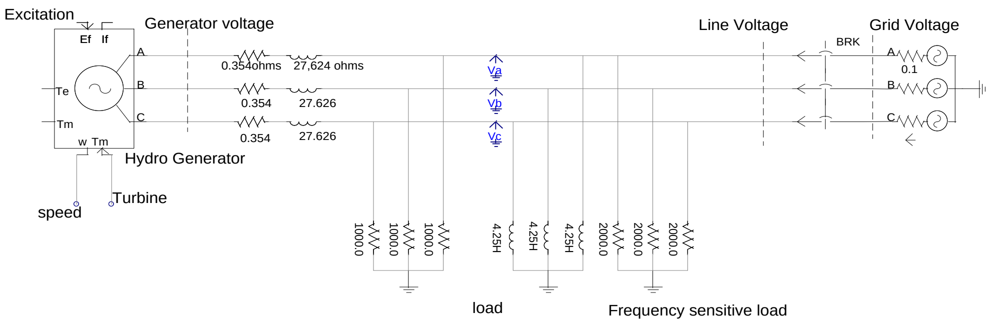

Figure 4: Simulation model of the studied system

In simulation, the stability of the generator in islanded mode, just after tripping of the breaker at the grid connection point, was studied (generator was loaded to ≈75% of its capacity). The results are shown in Figure 5a. Similarly the stability of the generator just after shedding of lumped frequency depended sensitive loads (0.544 MW) was studied and results are shown in Figure 5b. The voltage variations in the generator bus and the micro grid point of connection to grid were tabulated in Table 1.

Here the generator governor setter and the AVR setter were kept at 1.08 pu and 1.01 pu respectively.

The stability of the generator during synchronization to the grid, when grid voltage was initially at 1.06 pu and frequency was 1.1 pu, was tested and results are shown in Figure 6 and the voltage variations are tabulated in Table 2. The synchronizing parameters are selected as (i) maximum frequency deviation is ± 150 mHz and (ii) maximum voltage deviation is ± 10%.

Simulation results:

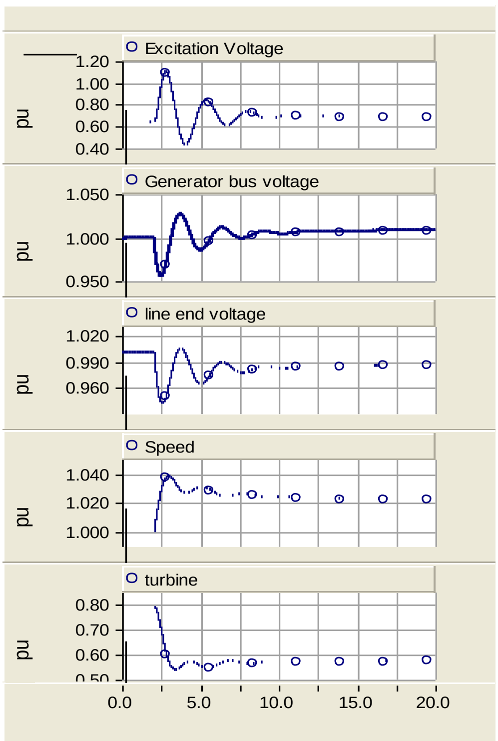

Figure 5a: Results at islanded operation

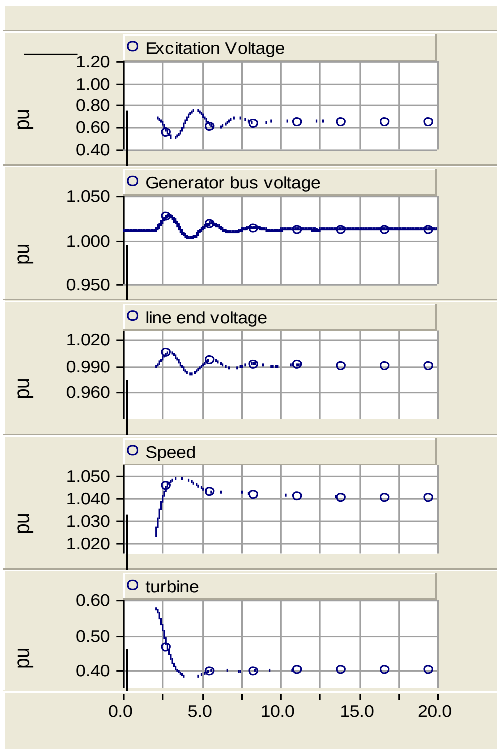

Figure 5b: Results at shedding loads

Table 1: Transient study results at islanded and load shedding operations

	Grid failure		Excessive load shedding	
	Over shoot	Under shoot	Over shoot	Under shoot
Generator bus voltage/pu	1.025	0.983	1.026	1,001
Grid point voltage/pu	1.003	0.966	1.004	0.979
Generator Speed/pu	1.035		1.049	
Guide vane opening /pu		0.556		0.378

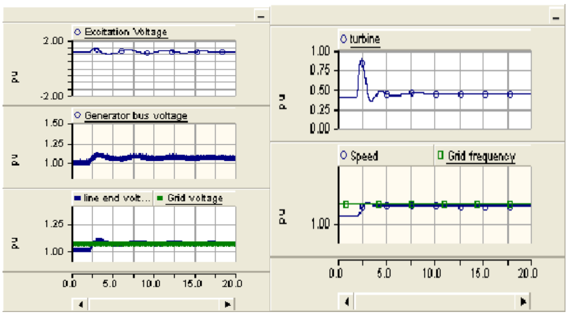

Figure 6: Simulation results at synchronizing process

Table 2: Transient study results at synchronizing process

	Pre synchronization	Over shoot	Under shoot	Steady state
Generator bus voltage/pu	1.01	1.04		1.03
Grid point voltage/pu	0.991	1.021		1.02
Generator Speed/pu	1.03	1.11	1.09	1.098
Guide vane opening /pu	0.41	0.851	0.346	0.438

Discussion

The AVR and governor responses have proven that it can maintain the micro grid stability after a grid failure with excessive load rejection. The maximum generator bus voltage overshoot is 2.6% and maximum grid point overshoot is 0.4% for the grid failure. The maximum frequency overshoot is 4.9%. The maximum bus voltage overshoot during the synchronization is 3%. The speed overshoot is 8%. Even though these overshoots are little higher than the expected values, the system was stabilized within few seconds.

Conclusion

This study confirms that synchronization of the Nilambe generator with the micro grid consisting of local loads after shedding the excessive load is possible. The proposed AVR and governor control together with automatic synchronizer has shown very good performance within allowable responses limits. Therefore this can be taken as a preliminary studied model in for developing micro grid technology to the Sri Lankan power system.

A commercially available synchronizer can be configured and used with transmitters and receivers for this purpose of remote sensing and synchronizing

References

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Appendixes

Generator data: 3MVA, 6.9kV, 0.85 p.f., Xd=1.014 pu, Xd'=0.314 pu, Td0'=6.55 sec, Xd"=0.28 pu, Tdo"=0.039 sec, Xq=0.77 pu, Xq"=0.375 pu, Tqo"=0.071 sec, Inertia 2 sec.

Line data: 33kV tower line of "Links" conductor line length -2km, Positive sequence resistance - 0.177ohms/km, reactance - 0.313 ohms/km, Zero sequence resistance - 0.326 ohms/km, reactance - 1.588 ohms/km

Transformer data: Capacity - 4MVA, Voltage ratio - 6.9kV/33kV, Impedance voltage - 10%