

Dynamic Performance of a Microturbine Connected to a Low Voltage Network

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Abstract. Nowadays there is a great interest for the use of microturbines as sources of distributed generation, particularly in areas where demand is both electricity and heat. In these areas microturbines reach very high efficiency rates.

Microturbines can operate both stand-alone and grid connected. The second one of the mentioned possibilities is which deserves a much deeper study, to analyse the interaction of the microturbine with the distribution network it is connected to.

In this paper a dynamic model of a microturbine is developed with Matlab/Simulink/Simpowersystems. The model has been included within a low voltage network model and several dynamic simulations have been performed to study the response to step changes in the power control references. Also, the performance of the microturbine to faults in the network has been analysed.

Key words

Distributed generation, Microturbine, Dynamic model, Simulation.

1. Introduction

In recent years, the search for generation systems more efficient and less harmful to the environment have helped to introduce distributed generation within the electric networks, as opposed to the traditional large generation plants.

Traditional power plants involve high investment and maintenance costs and the energy produced must be delivered across long transmission lines with losses of about 2% of the energy transmitted. In addition, nowadays there is also a strong social rejection to the extension of traditional generation.

In contrast, distributed generators are small power plants, with lower costs than traditional units. This type of

generation is mainly connected to the distribution network, which implies smaller network losses. It is also frequently based on renewable resources so they have a lower environmental impact than traditional generation.

Combined heat and power or cogeneration is, at present, the most significant type of distributed generation. The simultaneous production of electrical power and useful heat at the location where they are to be consumed increases the overall efficiency in the use of fuel. There are different technologies for combined heat and power. One of them is based on the use of microturbines, which allows to reach overall thermal efficiencies of around 90%.

Microturbines can operate both stand-alone and grid connected. The second one deserves a much deeper study, to analyse the interaction between the microturbine and the distribution network it is connected to. The connection of microturbines to the current medium and low voltage distribution networks modifies the electrical parameters in the network operation, as distribution networks were designed for radial operation and supply from a power transformer located at the sending end.

In addition to the modifications in the voltage profile and the influence on power losses, the modification both in fault levels and in the distribution of fault currents must be considered. This is an aspect that needs to be studied because the network protection scheme may be affected, being influenced both the individual operation of each existing protection device and their coordination.

2. Gas Microturbines

Microturbines are small combustion turbines, with installed capacity from 25 to 300 kW and very high rotation speeds (between 50.000 and 120.000 rpm). They can be used as a support device to satisfy demand peaks, or as distributed generator in microgrids.

Microturbines can work according to a simple or a regenerative cycle. In the first one, of lower cost, compressed air is mixed with fuel and the combustion is carried out under constant pressure. Hot gases expand inside the turbine producing work. The regenerative cycle requires an interchanger to recover exit turbine heat and transfer it to the air entrance. The preheated air is used lately in the combustion process, saving between 30% and 40% of fuel [3-4]. The combination of microturbines with energy recover equipments allows duplicating the electric efficiency with respect to simple cycle microturbines.

Different fuels can be used: natural gas, LPG (commercial butane and propane), diesel, kerosene, biogas, hydrogen, etc. Besides, related to air emissions, they are very low when operating at full load or even above 60-70% of full load.

3. Microturbine Dynamic Model

This section describes the dynamic model of the microturbine, which is based on the Capstone C30HP microturbine. The model incorporates the AC/AC VSC converter and the primary motor as well as the controls associated with both components. Figure 2 shows a simplified model of the microturbine structure.

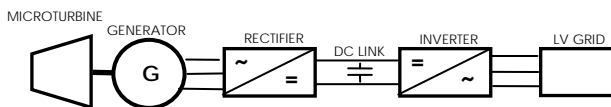


Figure 2. Microturbine model

A. Microturbine

In this research a simplified single shaft gas turbine has been implemented to represent its dynamics. [1-2].

B. Electric Generator

The PMSG model used in this study consists of a non-salient rotor with two poles. Its power is 30kW, reaching speeds up to 96,000 rpm. On this way the generator provides a three-phase variable frequency signal up to 1600 Hz and a voltage level between 400 and 480 V. For the model of PMSG their mechanical and electrical equations have been used, obtaining a second-order state-space model [3].

C. Power Conditioner System

The system consists of a three-phase diode rectifier, and a voltage source inverter, interconnected by a DC-link. In order to control the grid connected microturbine a PQ control strategy has been used, where the inverter must control active and reactive power using two independent control loops. The active power control loop, regulates the DC bus voltage and the reactive power control loop, regulates the i_q current [4-5].

The microturbine operates connected to a low-voltage distribution grid (400 V, 50 Hz).

4. Simulation and results

Simulation has been performed in order to study the response of the grid connected microturbine to a variation in the power set-point, as well as the microturbine response with a three phase fault produced at the output terminals. Simulations have been run in discrete time with a fixed-step size of 0.5 μ seg.

5. Conclusions

A microturbine simplified model has been developed by using Matlab/Simulink/Simpowersystems software. The model has been simulated working in grid connected mode and different operation conditions have been analysed (Step change, fault,...). The simulation results have showed that the microturbine works properly connected to a low voltage distribution grid. Next developments in this field will be the improvement and optimization of the microturbine model as well as the analysis of multiple operation conditions, mainly related to different fault situations and the definition of the settings of protection relays.

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References

- [1] W.I.Rowen, "Simplified mathematical representations of a heavy duty gas turbines", ASME Trans. Journal of Engineering for Power, Vol. 105, no. 4, pp.865-869, Oct. 1983.
- [2] S.Banetta, M.Ippolito, D.Poli, A.Possenti, "A Model of Cogeneration Plants Based on Small-Size Gas Turbine", CIRED.16th International Conference and Exhibition, Amsterdam, 2001, Vol.1, pp. 266.
- [3] D.N.Gaonkar, R.N.Patel, "Dynamic Model of Microturbine Generation System for Grid Connected/Islanding Operation", Industrial Technology, 2006. ICIT 2006. IEEE International Conference, Mumbai, India, Dec. 2006, pp. 305-310.
- [4] A.Bertani, C.Bossi, F.Fornari, S.Massuco, S.spelta, F.Tivegna, "A Microturbine Generation System for Grid Connected and Islanding Operation", Power Systems Conference and Exposition, 2004. IEEE PES, Oct. 2004, Vol. 1, pp. 360 – 365.
- [5] H. Nikkhajoei, R. Iravani, "Electromagnetic transients of a micro-turbine based distributed generation system", Electric Power Systems Research, Vol. 77, pp. 1475-1482, 2007.