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Model and Simulation of Micro Grid Based on Micro Gas Turbine

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Abstract: Site Microturbine Generation (MTG) is a distributed Generation technology with wide application prospect in micro grid. This paper introduces the single-axis micro-gas turbine power generation system in detail and studies its operation and control in micro-grid. In this paper, PSCAD /EMTDC simulation software is used to simulate the load tracking ability of the micro-turbine power generation system under the island operation mode, and the ability of the micro-turbine power generation system to stabilize the voltage and frequency under the two modes of island and grid connection. The simulation results verify the correctness of the micro gas turbine model and its flexible adjustment control mode according to the needs of micro grid operation, which has good operation characteristics.

1. Introduction

In recent years, micro grid technology has attracted wide attention. Micro grid refers to a small distribution system composed of distributed power supply, energy storage device, energy conversion device, related load and monitoring and protection device [1][2]. It is a system that can accomplish self-control, protection and management. It can be connected to the external power grid and run in isolation.

Micro-gas turbine technology is one of the key technologies in the 21st century energy power system and one of the main characteristics of the second-generation energy system. The micro gas turbine will be plays an important role in the future of our country electric power and power system. It is a very good choice of rational utilization of natural gas resources and it can be installed residents in residential area close to the user which will greatly improve the reliability of power supply to the customer and hence Micro-gas turbine technology will have a great development prospect in our country. It can provide 25~500kW of stable power output and use natural gas and low calorific value of a variety of fuels. Micro gas turbine in recent years has been rapid development and its efficiency has been increased from 17% ~ 20% to 26% ~ 30%, but the micro gas turbine power efficiency of the thermal transfer function of the power supply system is still much smaller than large centralized power stations. The reason was that the considerable available energy in micro gas turbine exhaust, has been discharged into the atmosphere.

Document [3] gives a detailed review of the dynamic model of micro gas turbine. Document [4] conducts simulation research on the micro gas turbine system for grid-connected power generation, and obtains the dynamic operation characteristics of the micro gas turbine power generation system under grid-connected conditions. Document [5] mentioned the following advantages of gas turbines in distributed network: (1) Improve the utilization efficiency of natural gas energy; (2) The combination of natural gas and power grid frame can increase the utilization hours of natural gas channel and

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reduce the burden of power grid; (3) Increase the stability of power network; (4) Install near to users and improve the reliability of power.

2. the Mathematical model of micro gas turbine

2.1. Mathematical model of prime mover of micro gas turbine
Rowen micro gas turbine simulation model is adopted [6]. It is assumed that the micro gas turbine works near the rated speed, and the slow dynamic process of starting and stopping is not considered. The main role of the regenerator is to reduce the fuel demand in the combustion process to improve the efficiency of the system and meet the requirements of cold and hot load. This part has little impact on the power part, so the role of the regenerator is ignored in the model. Figure 1 is the structure diagram of single-shaft micro-gas turbine power generation system.

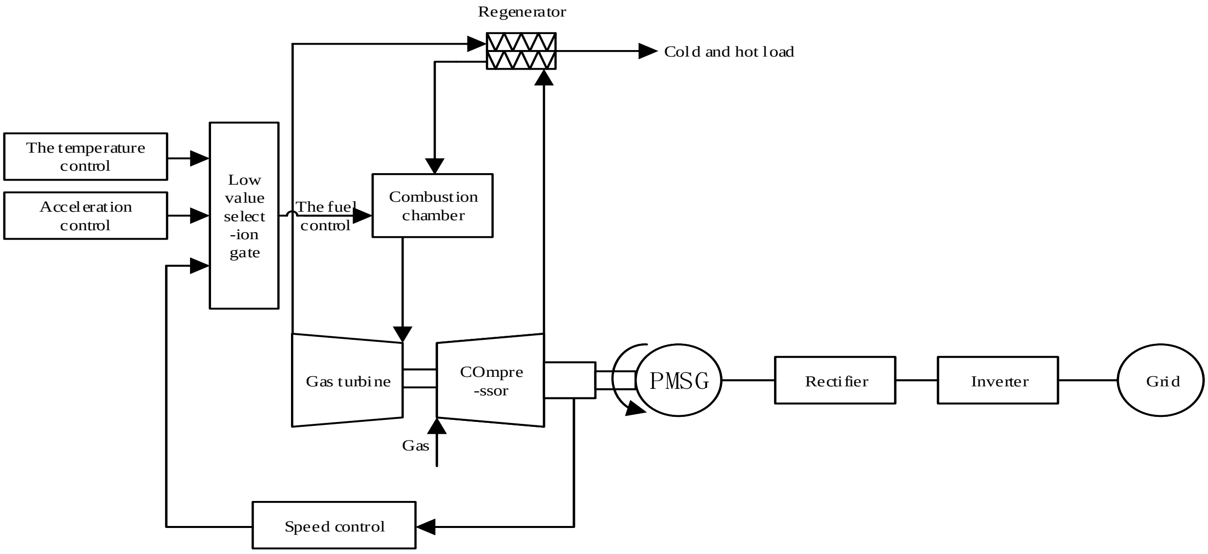


Figure 1. Structure diagram of single-shaft micro-gas turbine power generation system

Micro gas turbine prime mover consists of five parts: speed control, acceleration control, temperature control, fuel control and gas turbine control. Among them, the results of speed control, acceleration control and temperature control are taken as the input of fuel control through the output of low-value gate [7]. The output of fuel control serves as the input of gas turbine control.

2.2. Operation control mode of micro gas turbine
The prime mover of micro gas turbine is used together with the permanent magnet synchronous machine to send out high-frequency alternating current with a frequency of 1000Hz. The high-frequency alternating current sent out by the permanent magnet synchronous motor needs to be rectified and inverted before it can be supplied to the power grid or load. In this paper, a three-phase full bridge circuit composed of IGBT is used to realize rectifier and inverter [8-10], which is shown at figure 2.

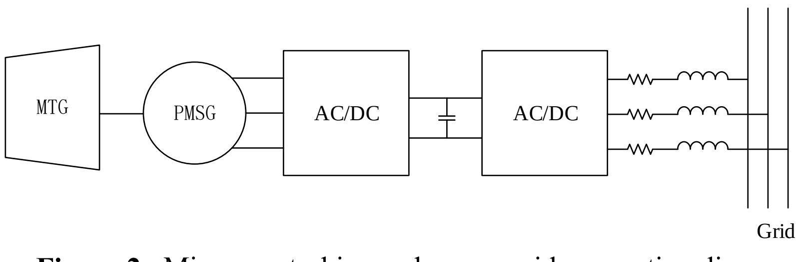


Figure 2. Micro gas turbine and power grid connection diagram

The rectifier adopts direct current control strategy to rectify the high frequency alternating current emitted by permanent magnet synchronous motor. The rectifier is controlled by DQ, and the control objective is to keep the voltage constant at both ends of the dc capacitance. Figure 3 is the diagram of PQ control of the rectifier.

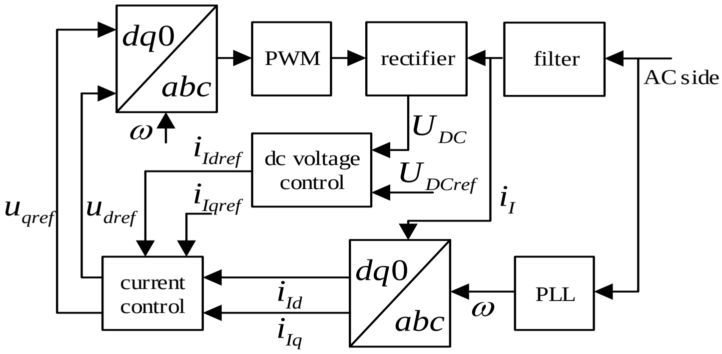


Figure 3. PQ control of the rectifier

The micro gas turbine can be connected to the grid for use or operate as the main power island. PQ control is used when connected to the grid and VF control is used as main power. Figure 4 is the diagram of PQ control and VF control of the inverter.

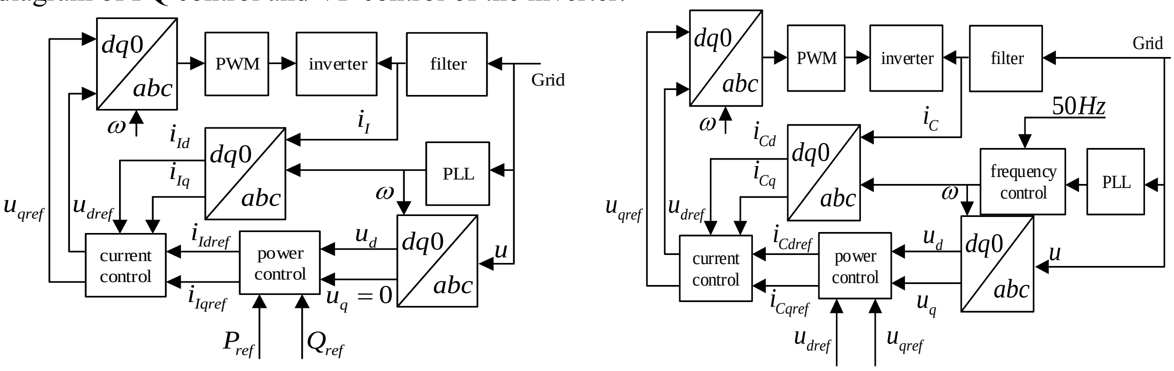
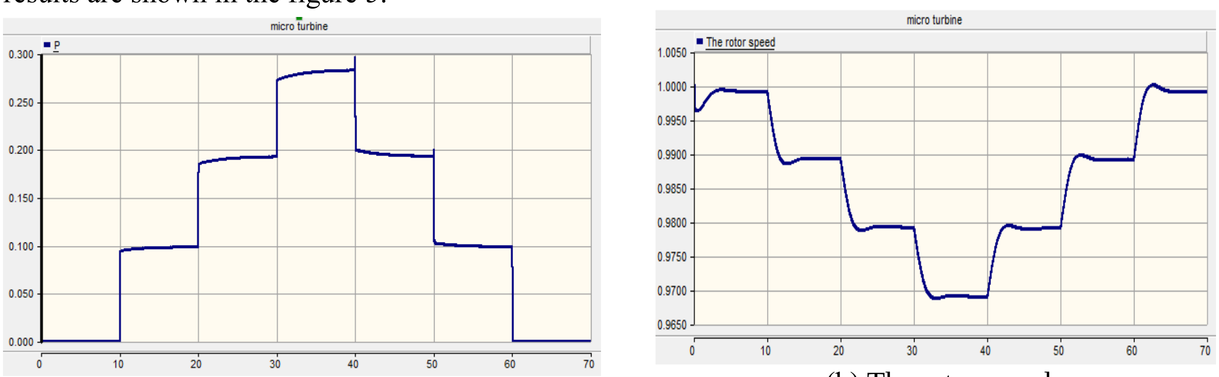


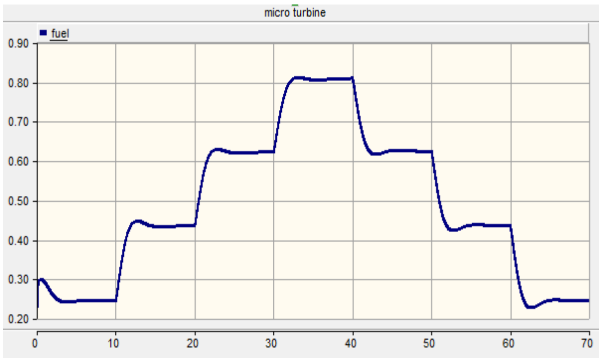
Figure 4. PQ control and VF control of the inverter

3. Simulation analysis of micro gas turbine

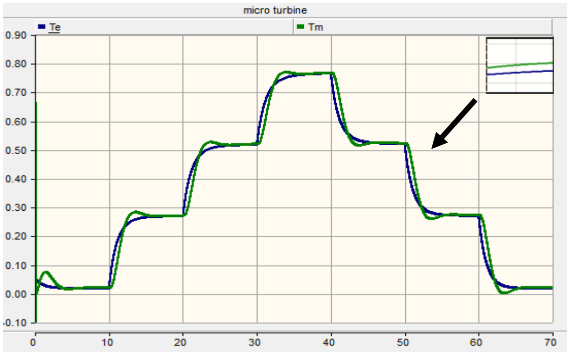
In order to test the performance of the micro gas turbine, this paper first simulated the gas turbine operating in the isolated island mode in PSCAD. The total simulation duration was 70s, and the total capacity of the micro gas turbine was set as 0.4MW. Within 0~40s time, the load was increased by 0.1MW every 10s, and the load was reduced by 0.1MW every 10s during 30~70s.The simulation results are shown in the figure 5.



(a)Active power (b) The rotor speed



(c)Fuel curve



(d)Comparison of Tm and Te

Figure 5. Simulation results of micro gas turbine

Figure 5(a) is the result diagram of the output power of the gas turbine. It can be seen that the gas turbine can basically output force according to the change of load;

Figure 5(b) is the micro gas turbine speed variation diagram, it can be seen that in the process of load change, the gas turbine speed, although there are changes, but the overall speed of the rated speed near;

Figure 5(c) is the fuel change curve of the micro gas turbine. It can be seen that in the time of 0~10s, although the gas turbine has no output at this time, it still needs 24% fuel supply, which is to maintain the rated speed of the gas turbine;

Figure 5(d) is the variation curve of electromagnetic torque and mechanical torque of micro gas turbine. T_e is electromagnetic torque and T_m is mechanical torque. It can be seen that the mechanical torque can quickly follow the change of the electromagnetic torque. When the change of the torque is stable, it can be found that the mechanical torque is higher than the electromagnetic torque. This is because the mechanical torque, in addition to balancing the electromagnetic torque of the load, also provides additional torque to maintain the torque loss of the gas turbine.

4. Micro-grid experimental simulation analysis

This paper studied system network composed of the micro gas turbine, PV systems and wind power. The purpose of this paper is to study the micro-gas turbine's ability to stabilize micro-grid voltage and frequency. In PSCAD, the island mode and grid-connected mode of micro grid are simulated and studied respectively, and the ability of micro gas turbine to stabilize the voltage and frequency when switching between the two modes is studied. Figure 6 is Micro-grid schematic diagram.

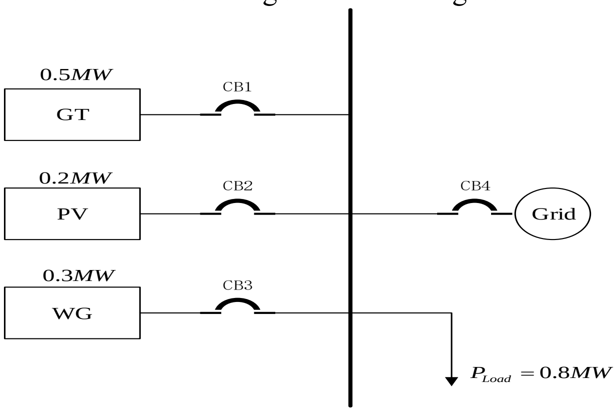


Figure 6. Micro-grid schematic diagram

Set the photovoltaic output as the maximum power, and the output power is 0.2MW; The permanent magnet direct drive fan is output at the maximum power, and the output power is 0.3MW; The rated output power of micro gas turbine is 0.5MW.

The total simulation time is 30s, the distribution network voltage is 690V, and the frequency is 50Hz.

At initial 0, all circuit breakers close:

0~8s, micro grid grid-connected operation;

At 8s, the circuit breaker CB4 is disconnected, 8-20s, and the micro-grid operates on an island;

20~30s, circuit breaker CB4 is closed, and the micro grid is reconnected for operation.

The whole process includes two switching processes: from grid-connected to isolated island, and then from isolated island to grid-connected.

The simulation result is shown at figure 7:

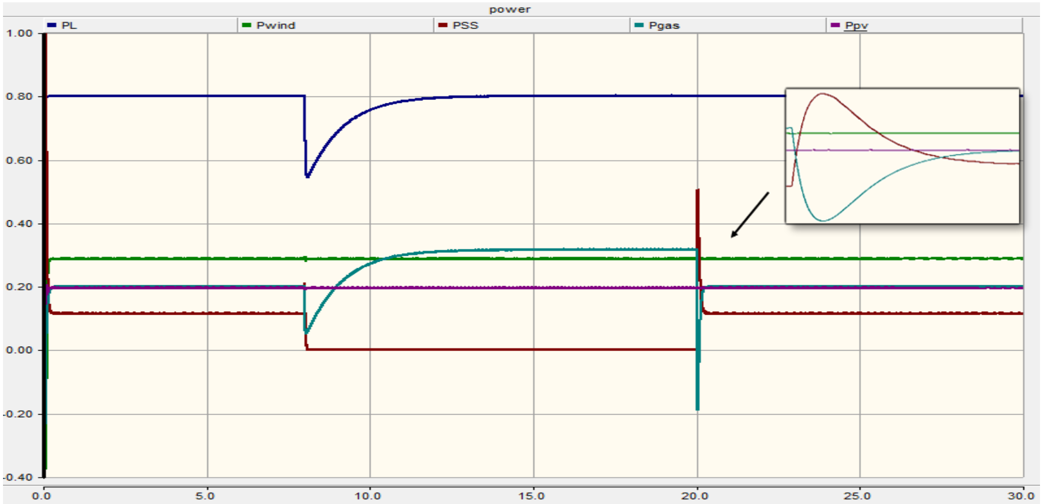


Figure 7. The active power of micro source

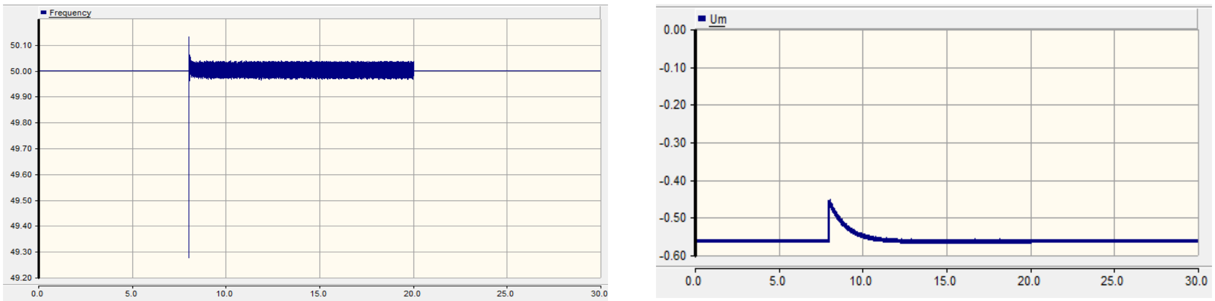
Ignore the start-up process for each unit.

Within 0~8s, the micro-grid is connected to the grid for operation. The output of the fan is 0.3MW, the photovoltaic is 0.2MW, and the micro-gas turbine is 0.3MW. The grid provides 0.1MW power to the micro-grid to meet the load demand of 0.8MW.

At 8s, CB4 is disconnected and the power provided by the power grid drops to 0. The voltage and frequency of the micro grid are maintained by the micro gas turbine. When the micro gas turbine is switched from grid-connected to island operation, it achieves stable operation after 4s.

At 20s, CB4 is connected, and the operation mode of the micro grid was switched from island operation to grid-connected operation, and after 0.25s, the system reaches a stable operation state.

Figure 8 is the changes of voltage and frequency during the whole time.



(a)Frequency curve (b) Voltage curve

Figure 8. Frequency and voltage

During the whole dynamic process, the time when the frequency exceeds the specified frequency range is 0.05s, and the time when the voltage exceeds the rated value by 10% is 0.5s. Both voltage and frequency at PCC of micro grid in dynamic process meet the standard of frequency and voltage specified in IEEE1547TM (2003).

In the whole process, when switching between the two modes of isolated island and grid-connected, the voltage and frequency are always within the standard range, so the micro-gas turbine can be used as the main power source to maintain the voltage and frequency in the micro-grid.

5. Conclusion

In this paper, PSCAD/EMTDC simulation software is used to build a dynamic model of micro-grid based on micro-turbine power generation system, and the grid-connection and island operation characteristics of micro-grid of micro-turbine are studied. This paper firstly simulates the load tracking capability of the micro-turbine power generation system in the isolated island operation mode. The constant power control mode (PQ) is adopted by the inverter in the micro-grid. In addition, this paper also simulates the voltage and frequency stability of the micro-gas turbine power generation system under island operation mode and grid-connected operation mode, and the inverter uses constant voltage and frequency control (VF) and constant power control (PQ). Simulation results show that it has a good load tracking capability under the island operation mode, which verifies the correctness of the miniature gas turbine model. Micro-gas turbine power generation system can flexibly adjust the operation control mode according to the needs of micro-grid operation mode and stabilize the voltage and frequency of micro-grid.

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