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TWO GENERATORS MICRO-GRID BASED ON RES

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Abstract – **This paper deals with a hybrid power system based on renewable energy sources (RES), working as a stand-alone system. It consists in a micro-hydro power plant with synchronous generator (SG) and a wind turbine with permanent magnet synchronous generator (PMSG), forming a single-phase micro-grid. The wind generator is connected to the micro-grid via a single-phase inverter. A maximum power point tracker (MPPT) technique is used to control the wind turbine. The SG performs the voltage regulation, while an inverter commanded by a proper regulator controls the frequency. Simulations are accomplished in order to investigate the system reliability.**

Keywords*:micro-grid, permanent magnet synchronous generator, frequency controller, stand-alone system.*

1. INTRODUCTION

The requirement for clean and Renewable Energy Sources (RES) has resulted in the introduction of rather small power sources, supplying autonomous electrical systems.

Two types of electric generators are of interest to equip small wind turbines: the Permanent Magnet Synchronous Generator (PMSG) and the Induction Generator (IG). On the other hand, for constant power turbines, such as hydraulic ones, the SG is the most suitable as it delivers the required voltage and frequency at a suitable Power Factor (PF), [11].

Variable speed wind energy systems integrated with power electronic interfaces are becoming popular because they can extract optimum power, smoothly the electrical power output and supply reactive power on demand. The PMSG are now being used instead of synchronous generators, because of improved efficiency, modularity and absence of excitation current. For maximum energy extraction, the speed of the turbine should be varied with wind speed so that the optimum tip-speed ratio is maintained, [2], [5].

Frequency regulation is achieved by maintaining a power balance in the network. The main disturbance factors from this point of view are the wind speed, which is reflected in a wide variation of the electrical power generation of the wind generator, and the loads, which are not constant by nature, [9], [10], [11].

The idea of interconnecting on an isolated micro-grid both a SG and PMSG relies on the need to combine the advantages they offer. This study focuses on obtaining a control structure for such systems, in order to ensure proper energy quality.

2. SYSTEM CONFIGURATION

The proposed electrical system contains a 5 kVA SG, a 3 kW PMSG, a diode rectifier bridge, a buck-boost converter, a transformer, an inverter, AC loads, and a battery bank (to store a surplus of wind energy and to supply power during a wind power shortage. A basic diagram of the studied system is presented in Fig. 1.

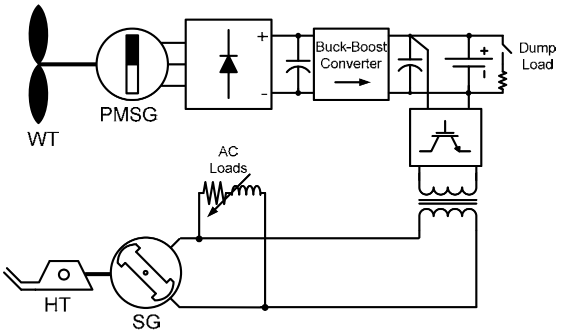

Figure.1: The basic system configuration

The prime movers are a Banki (Cross-flow) hydraulic turbine for the SG and a common wind turbine WG (without pitch angle) for the PMSG. The hydraulic power is considered being constant, without any mechanical turbine governor, and the WG supplies electrical power according to the wind speed.

In island grids that contain at least a SG, the problems concerning the voltage and frequency regulation can be solved easier, but the overall cost is higher. By controlling the excitation current, the real and reactive power of the system can be properly regulated.

To obtain maximum power from a stall controlled wind energy converter systems (WECS), it has to operate in the variable speed mode. With the PMSG connected to the grid via a converter with intermediate voltage circuit, the generator speed and hence the speed of the wind turbine can be controlled by the generator-side inverter. A MPPT is used to maximize the turbine output power and to adjust generator speed. The PMSG is controlled by a maximum-efficiency control and a maximum-torque control in order to maximize electric power output [1], [3].

In this paper, the MPPT control is implemented via the buck-boost converter shown Fig.1.Depending on wind speed, the regulator adjusts the power transferred through the buck-boost converter, bringing the turbine operating point on the "maximum power curve" like in Fig.2.

During simulations, it is considered that the system can absorb the entire energy supplied by the PMSG.

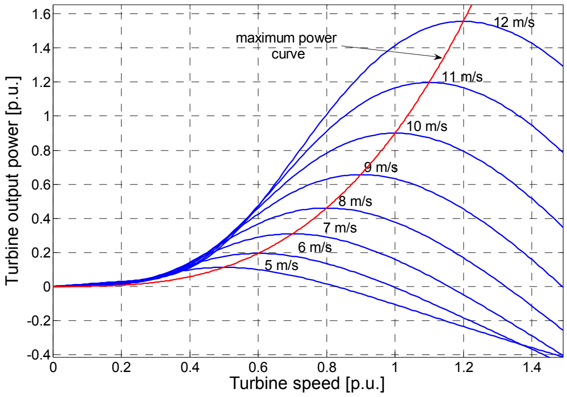

Figure.2: Wind turbine power characteristics

The SG - through its field current and a proper tuned regulator- performs the voltage regulation.

In order to maintain the frequency in an acceptable range, a load controller is used. It behaves as a load tracker, permanently maintaining the power balance in the system. The presented frequency controller is effective when the generated power is bigger or smaller than the loads demand.

The DC voltage resulted from the rectified voltage of the PMSG is delivered to the micro-grid through a single-phase inverter and a transformer. The battery and the inverter, driven by a regulator, form the frequency controller for the entire micro-grid. The control technique focuses on enabling only active power circulation through the inverter. This is similar with the synchronous machines operation, at unity power factor. By keeping the magnitude of the inverter voltage and its phase equal to the micro-grid voltage, the reactive power that flows through the inverter is zero. The active power circulation, which can be in both directions, is controlled by the phase displacement between the two voltages. The difference gives the amount of power and its sign gives the power direction.

When the battery is fully charged, an additional circuit is used, to maintain the power balance. It consists in a dump load placed at the battery leads, which has the role to dissipate the additional power given by both generators. Its control technique maintains the battery voltage constant. For the system optimum efficiency, the dissipated power on the dumping resistance can be used in useful purposes such as a water heating process.

In order to verify the reliability of such configuration, the presented system has been modeled using the Matlab/Simulink environment and simulations were accomplished.

3. SIMULATION RESULTS

Fig.2 shows the block diagram of the considered system. The configuration includes the PMSG, a three-phase rectifier bridge, a buck-boost converter, a 120V batteries bank, the voltage regulator, the synchronous generator, the hydraulic turbine and a block that models the wind turbine. Measurement blocks are also included. The main library used for system modeling was SimPowerSystem.

The PMSG has a sinusoidal flux distribution and 4 pairs of poles. It is a 2300-RPM and 14.2 Nm machine, while the synchronous generator is a S = 5kVA 230V/50Hz machine.

The battery bank is obtained by linking in series five 24V batteries. Its capacity is influenced by the topology of the site and by loads characteristics.

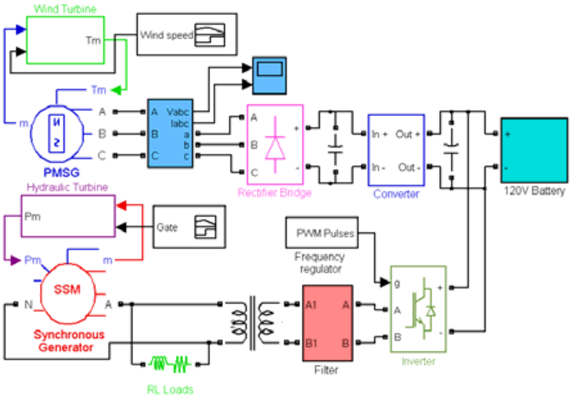

Figure.3: Simulink block diagram

The buck-boost converter and its regulator will work as a maximum power point tracker for the wind turbine. The input voltage varies with the wind speed, while the output voltage is kept constant according to the battery charging state. In addition, the buck-boost converter controls the battery state; therefore, no additional charging converter is required.

Initially, the micro-grid supplies a P=3kW load.

At t=1s, an additional load (P=2kW and Q=1kvar) is suddenly connected and disconnected at t=2.5s. This transitory regime leads to frequency variations, as can be seen in Fig.4. When the additional load is connected, the frequency value decreases to 49.8 Hz, being rapidly brought to the rated value by the frequency controller. When the load is disconnected, the frequency rises to 50.2 Hz, and then returns to the rated value. Therefore, the frequency regulator acts fast, providing optimum frequency regulation.

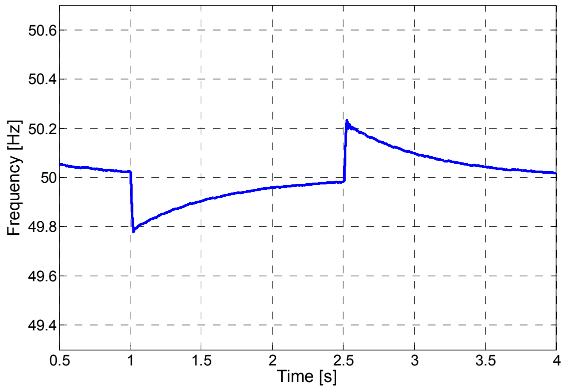

Figure.4: The frequency variation

In steady-state regime, the battery from the PMSG side is charged with an average current of 21A. When the consumed power increases, the average battery current shall decrease from 21 to 7A. When the transitory regime is over, the charging state returns to its initial value, as can be seen in Fig.5.

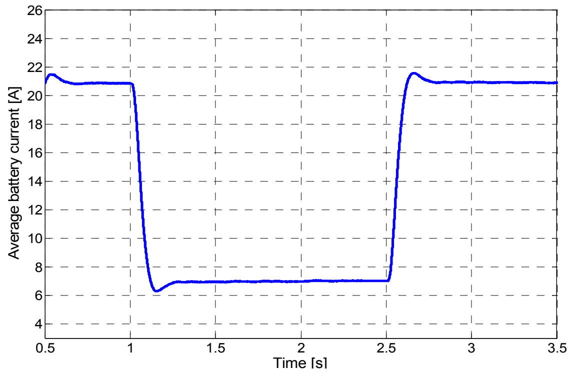

Figure.5: The average battery current

As for the power circulation in the system, the process occurs as follows. Let us assume that in steady-state regime, both generators give the maximum power. In this case, the inverter, which acts as a rectifier, shall charge the battery. In Fig. 6, the active power circulation is depicted in blue. The 1kW difference between the power produced by the SG (4kW) and the one demanded by the loads (3kW) flows through the inverter to the battery. Its initial value is negative due to the considered way of power circulation, from the battery to the grid. When the active power demand increases with 2kW, the circulating sense shall change. The battery will feed via the inverter the micro-grid. As for the reactive power circulation, it is quite insignificant, because the SG provides the demanded quantity.

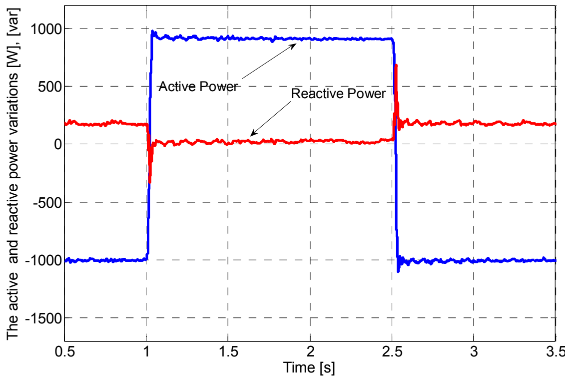

Figure.6: The active power and reactive power variation at the inverter's leads

The line voltage is not significantly affected by the transitory regime and inverter operation, as can be seen in Fig. 7.

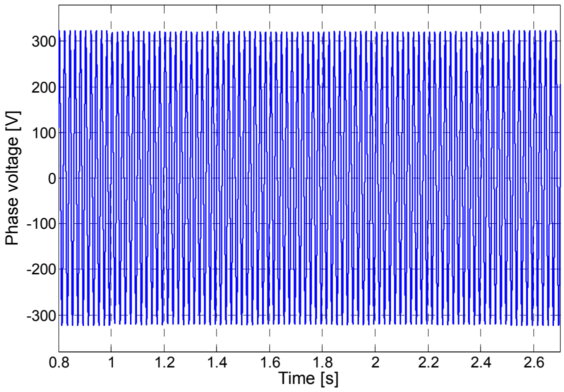

Figure.7: The AC link voltage

Fig.8 shows the PMSG's line voltage and current, under steady-state conditions. The current is highly affected by the rectifier bridge – capacitor block operation. The diodes commutations produce the overlap effect, which influence the voltage shape.

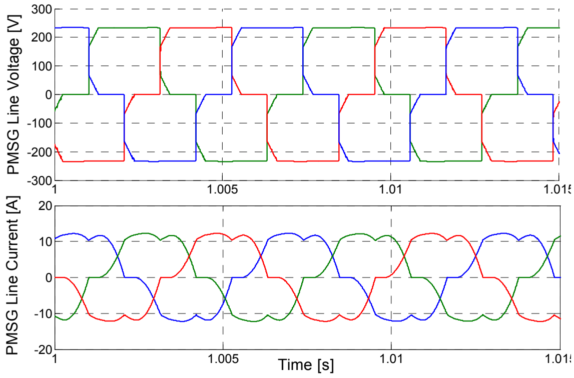

Figure.8: The PMSG line current and voltage

4. CONCLUSIONS

For small power autonomous micro-grids, the single-phase configuration appears the most suitable.

By paralleling a SG and a PMSG on such an isolated grid, good performances are obtained.

The SG performs the voltage regulation, while the frequency is kept constant by a load controller – the battery and the inverter, driven by a regulator-.

Simulations show that the system behaves satisfactory during transient periods, so the system's stability is ensured.

In conclusion, the proposed system is effective for low power hybrid systems requiring good energy quality.

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