Design and Analysis of Inverter Control Strategy for Operation of DC Micro-grid based on PMSG

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Abstract- *Poultry farming is a cost intensive industry which includes domestication of birds such for the purpose of farming meat or eggs for food. To ensure that the poultries remain productive, the poultry farms are required to be maintained at a comfortable temperature. Electrically, the operation required power supply with very few or less interruption. This requirement can be easily fulfilled by designing the complete electrical network into a microgrid supplied by distributed generators. The variability of wind speed in wind farms directly depends on the environmental and weather conditions while the wind speed in poultry farms is generally stable as it is generated by constant-speed ventilation fans. Thus, the generation intermittency issues that affect the reliability of electricity supply and power balance are not prevalent in poultry farm wind energy systems.*

An important requirement of poultry farming is cooling fans. The power ratings of these loads are approximately 10 kW, which are installed to regulate the temperature in the farms. Along with cooling the area, an alternate output of these cooling fans includes wind energy produced by the fans can be harnessed using small sized wind turbines (WTs) to recover some part of the electricity supplied.

Key Words – *Predictive control algorithm (MPC), intelligent control, maximum power point tracking (MPPT).*

I. INTRODUCTION

In the trend of diversifying the energy market, wind power is the most rapidly growing sector. After the oil crisis from three decades ago, wind power industry started to flourish. Since then wind turbine technology improved rapidly and it soon took the title of champion from all renewable sources of energy. Figure 1 shows the continuously growing trend of wind power installations inside European Union. This reference scenario shows that with installations of up to 300 GW by the year 2030, EU will have a 21% to 28% wind market penetration.

There is a good correlation between wind turbines costs and their sizes. Unlike solar panels, which remain at the same price regardless of array size, wind turbines become cheaper with increased system size.

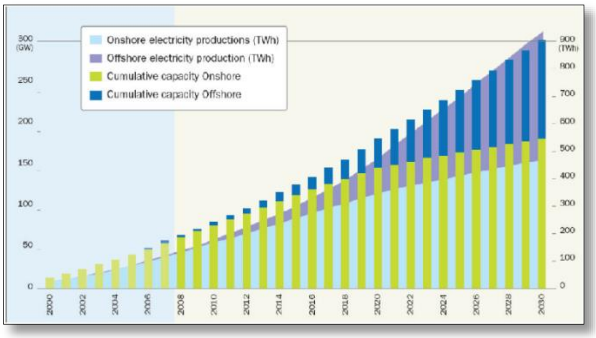

Figure 1: EU Wind Power Forecast for 2030

Figure 2 shows the evolution of wind turbinesize with respect to year of production. It is seen that in the last 20 years the rotor diameter hasincreased by a factor of 10. Today state-of-the-art wind turbines, with 126 m for rotor diameter, produce 5 to 6 MW of power (from RE Power and Enercon manufacturers).

The general design of the proposed dc network based breeze control age framework for the poultry cultivate is appeared in Fig.1.

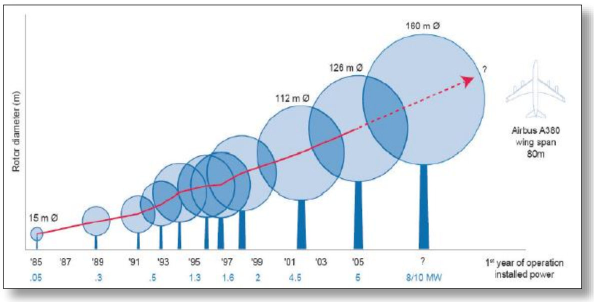

Figure 2: Increase of wind turbine size over the years [3].

The framework can work either associated with or islanded from the conveyance network and comprises of four 10 kW perpetual magnet synchronous generators (PMSGs) which are driven by the variable speed WTs. The PMSG is considered in this paper since it doesn't require a dc excitation framework that will expand the plan many-sided quality of the control equipment. The three-stage yield of each PMSG is associated with a three-stage converter (i.e., converters A, B, C and D), which works as a rectifier to control the dc yield voltage of each PMSG to the coveted level at the dc framework [10]. The total control at the dc matrix is reversed by two inverters (i.e., inverters 1 and 2) with each appraised at 40 kW. Rather than utilizing singular inverter at the yield of each wind generator (WG), the utilization of two inverters between the dc lattice and the air conditioner framework is proposed.

II. LITERATURE SURVEY

The literature below has enabled to understand the concept and helped in designing this microgrid through the implementation of PMSG generator interfaced through inverter circuit.

A simple sensor-less maximum power point extraction scheme for a Permanent Magnet Synchronous Generator (PMSG) connected wind turbine supplying power to a DC micro-grid has been proposed in this paper. The wind extraction topology has a small-scale wind turbine directly coupled with a PMSG. The three phase output voltage of the generator has been rectified using a 3φ uncontrolled rectifier and a DC–DC buck converter whose output voltage is controlled. Simulation of the MPPT controlled small scale wind turbines connected to DC micro grid is performed and the results are obtained. [1]

A direct-driven PMSG WT system, in which an auxiliary grid-side converter is paralleled with the grid-side converter to enhance low voltage ride-through capability and improve power quality. Under normal conditions, the main grid side inverter (GSC) ensures that the WT system is smoothly connected to the grid, whereas the auxiliary GSC operates in active power filter (APF) mode to compensate for the harmonic current and to improve the power quality of the grid. [2]

The paper [3] shows the control strategy used in the boost converter system helped in attaining 380V which is taken as a DC link voltage. The control used in the bidirectional converter which is connected between battery bank and DC-link voltage, is capable of maintaining the DC link voltage at a constant value, further it helps the battery to store surplus of wind energy and supply power to the load when the power generated from the wind turbine is less.

The grid side converter plays a dual role of interfacing the wind energy to grid as well as to supply reactive power as demanded by the non-linear load connected at the PCC. In order to compensate the unbalanced grid voltages, this paper [4] proposed the concept of GSC converter which is controlled by general PI. For this converter the reference signals are generated by positive sequence voltage signals. The speed of generator varies as the speed of the wind varies, which is indicated by a variation in magnitude of PMSG phase voltage and phase current.

The three key issues of technical challenges that must be overcome for effective implementation of microgrid are voltage and frequency control, islanding and protection. Integration of small-scale production in the form of micro-grids, supported by the inclusion of power electronic devices, could possibly contribute largely to the improvements in power quality as seen by end users. With an active management control approach and ability to operate in islanding mode, a cluster of micro generators, electricity storage and electrical loads can be operated within the microgrids framework to provide higher supply reliability to customers.[5]

Based on studies on different aspects of wind technology and its interfacing in a microgrid environment, a few conclusions have been defined. Basically, for the poultry system under study, regeneration of energy is done through PMSG attached in cooling ventilator fans. It is assumed that, majority of the working time, the system will be connected to main grid. As cooling fans do their normal operation using power from grid, the batteries will also get charged simultaneously when ventilation fans rotate due to the wind generated by fan. Now, microgrid can operate in islanded mode whenever the main grid fails, using power from battery. The inverter operation and control needs to be worked out to reduce outage time [6].

III. SYSTEM DESCRIPTION

The architecture consists of cooling fans in a poultry farm which are used to maintain the temperature of the hatcheries. The wind gets out through the ventilation system. The grid failure may result in interruptions in cooling unit. This may affect the output of the hatcheries. The interruptions need to be reduced to get optimal output.

To design a micro-grid power system, that can regenerate power by the application of small size, constant wind speed PMSG generator that saves its power in a battery unit. The system is implemented through an inverter system that will interact will grid, load and battery to operate the system in both grid independent and grid connected to keep the interruption time at minimum level.

A. Permanent Magnet Synchronous Generator

The synchronous electrical generator (also called alternator) belongs to the family of electric rotating machines. The PMSG has many advantages over the more commonly used DFIG system. The PMSG does not require DC excitation as the magnetic field is produced by the permanent magnets rather than by the coil. Hence, the PMSG does not require slip rings and brushes as shown in figure 3 for the structure of PMSG, which reduces the weight, cost, losses, and maintenance. A PMSG, connected to the power electronic converter, can operate at low speeds; hence, a gearbox is not required.

B. Battery Storage Unit

Battery energy storage system architecture consists mainly of the battery and management systems and energy conversion systems.

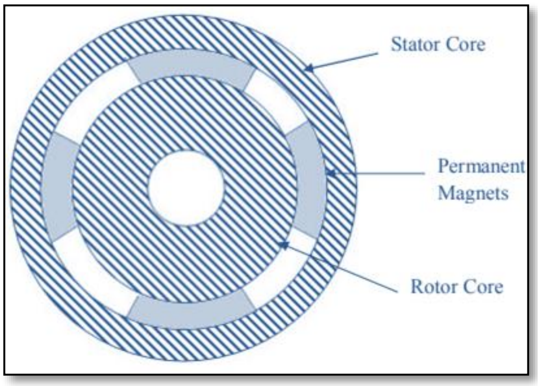

Figure 3: Structure of the permanent magnet synchronous machine

Energy conversion system with battery power by switching energy, according to the actual need to store energy or release energy. Microgrids (MGs) are Low Voltage distribution networks comprising various distributed generators (DG), storage devices and controllable loads that can operate either interconnected or isolated from the main distribution grid as a controlled entity. The extra power generated by renewable energy generators during the low load period can be sold back to the upstream grid. Market prices need to be considered in this mode and the objective function is to maximize the market profit. In recent years, several forms of energy storage are studied intensely. These include electrochemical battery, compressed air energy storage, superconducting magnetic energy storage, super capacitor and flywheel energy storage.

By storage converter control strategy designed to achieve the charge of the battery pack / discharge management, network-side load power smoothing, islanding operation and other functions.

C. Battery Interconnection System

Storage converter control strategies for energy storage converter control method of each part, we study the constant current control, given the DC bus voltage control, droop control three control strategies, and finally selected the droop control strategy. Battery energy storage system consists of DC / DC control and DC / AC controls two parts. The need for both control methods were designed to coordinate both control objectives through the upper controller, so that the two good cooperation in order to implement the entire storage converter control strategy.

Grid converter (three-phase VSR) the main control objectives are twofold: First, to ensure the stability of the intermediate DC voltage, DC link voltage stability is a prerequisite for PWM converter to work properly, which is achieved by controlling the input current of; the second is to ensure good input specific, nearly sinusoidal input current that is small harmonic content to meet the power factor requirements. Network-based control strategy to estimate and side voltage grid voltage detection is based, including voltage-oriented control and Direct Power Control.

IV. IMPLEMENTATION OF PROPOSED SYSTEM

The system can operate either connected to or islanded from the distribution grid and consists of two 10 kW permanent magnet synchronous generators (PMSGs) which are driven by the variable speed WTs. The PMSG is considered because it does not require a dc excitation system that will increase the design complexity of the control hardware. The three-phase output of each PMSG is connected to a three phase converter, which operates as a rectifier to regulate the dc output voltage of each PMSG to the desired level at the dc grid. The aggregated power at the dc grid is inverted by inverter rated at 40 kW. Instead of using individual inverter at the output of each WG, the use of two inverters between the dc grid and the ac grid is proposed. This architecture minimizes the need to synchronize the frequency, voltage and phase, reduces the need for multiple inverters at the generation side, and provides the flexibility for the plug and play connection of WGs to the dc grid. The availability of the dc grid will also enable the supply of power to dc loads more efficiently by reducing another ac/dc conversion.

The coordination of the converters and inverters is achieved through a centralized energy management system (EMS). The EMS controls and monitors the power dispatch by each WG and the load power consumption in the microgrid through a centralized server. To prevent excessive circulating currents between the inverters, the inverter output voltages of inverter is regulated to the same voltage. Through the EMS, the output voltage of inverter is continuously monitored to ensure that the inverters maintain the same output voltages.

The simulation model of the proposed dc grid based wind power generation system shown in figure 4 is implemented in MATLAB/Simulink for islanded operation of DC Grid. When the microgrid operates islanded from the distribution grid, the total generation from the PMSGs will be insufficient to supply for all the load demand. Under this condition, the SB is required to dispatch the necessary power to ensure that the microgrid continues to operate stably. The third case study shows the microgrid operation when it islands from the grid.

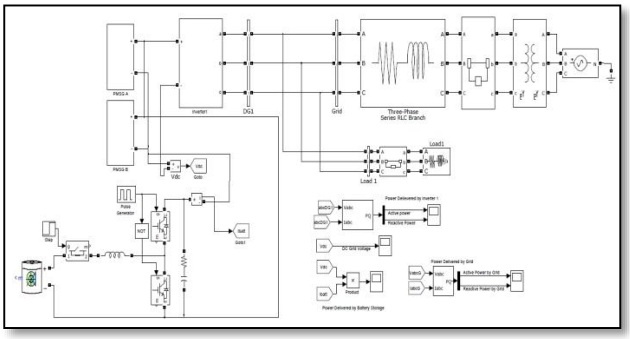

Fig.4: Simulink model for proposed scheme

The microgrid is initially operating in the grid-connected mode. Each inverter is delivering real power of 10 kW and reactive power of 4 kVAr to the loads as shown in figure 5. At t = 0.2 s, the microgrid is disconnected from the distribution grid by the CBs due to a fault occurring in the upstream network of the distribution grid. It can be seen from figure 5 that the CBs fully separate the microgrid from the grid in about half a cycle, resulting in zero real and reactive power supplied by the grid for $0.2 \leq t < 0.4$ s.

With the loss of power supply from the grid, the power imbalance between the generation and load demand is detected by the EMS. To maintain the stability of the microgrid, the SB is tasked by the EMS to supply real power of 40 kW at t = 0.26 s as shown in Fig.6. At the same time, the real and reactive power delivered by each inverter is also increased by the EMS to 30 kW and 6 kVAr as shown in Fig 5.

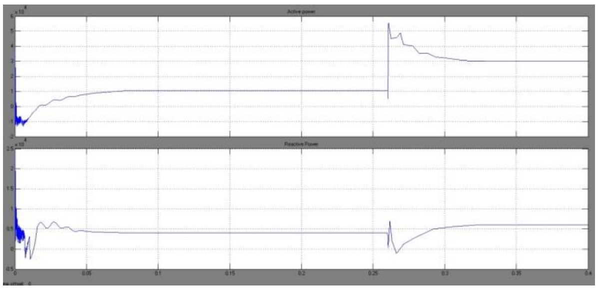

Fig.5: Real (top) and reactive (bottom) power delivered by inverter 1

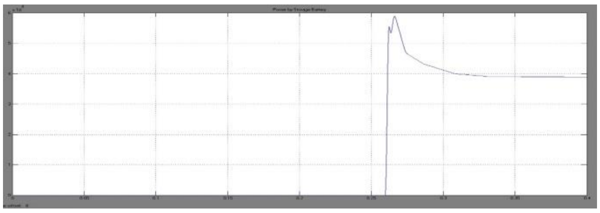

Fig.6: Real power delivered by Storage Battery

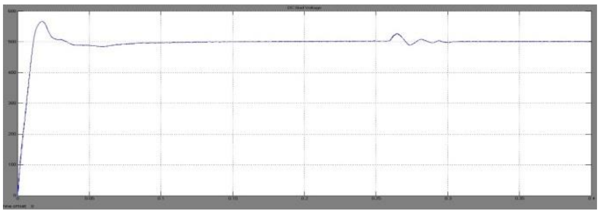

Fig.7: DC grid voltage

Fig. 7 shows the dc grid voltage where slight voltage fluctuations are observed at t = 0.26 s. The initial voltage rise at t = 0.26 s is due to the power supplied by the SB while the subsequent voltage dip is due to the increase in power drawn by the inverters.

CONCLUSION

To design a microgrid power system, that can regenerate power by the application of small size, constant wind speed PMSG generator that saves its power in a battery unit. The system is implemented through an inverter system that will interact will grid, load and battery to operate the system in both grid independent and grid connected to keep the interruption time at minimum level. In the project stage-I, the operation of a dc grid-based wind power generation system in Islanded operation is presented that allows flexible operation of multiple parallel - connected wind generators by eliminating the need for voltage and frequency synchronization. The design of a dc grid based wind power generation system in a micro-grid enables parallel operation of several WGs has been presented in this paper.

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