Analysis of Wind Power Generation System in Micro-grid Using D-STATCOM

Puja Shinde[1] Dr. Pawan Tapre[2] Prof. Amit Solanki[3]
[1,2,3]Department of Electrical Engineering
[1,2,3]S.N.D. College of Engineering & Research Center -Yeola, India

Abstract— This paper work presents an improved control strategy for a DC Grid based multiple parallel wind power system by eliminating the necessity for voltage and frequency synchronization. The Permanent Magnet Synchronous Generator 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. Separate controllers are proposed for the inverter when grid is in grid-connected and islanded modes of operation. Model predictive control algorithm is employed for the higher transient performance with reference to the change within the operating condition for the inverter operation. A separate controller has been developed for the turbine to take care of the constant power and to mitigate the variation error. Performance of the proposed micro grid in grid connected operation for inverter failure, connection of AC/DC Grid and also islanded mode of operation is evaluated.

Keywords: Micro-grid, D-STATCOM, Model Predictive Control

I. INTRODUCTION

In general now a day's renewable energy sources are most popular and vast increasing trend for production of power. Production of power from wind energy is one of the concept and vital role in our state. Wind power using wind turbines (WTs) to reduce the demand on the grid. Usually in wind farms the wind speed is variable one. The most significant advantage of the existing system is that only the voltage at the dc grid has to be controlled for parallel operation of several WGs without the need to synchronize the voltage, frequency and phase, thus allowing the WGs to be turned ON or OFF anytime without causing any disruptions. A commonly adopted control scheme contains an inner voltage and current loop and an external power loop to regulate the output voltage and the power flow of the inverters. A control scheme uses separate controllers for the inverters during grid-connected and islanded operations is used. The system under study is a Cooling Fan in farming. The main objective of this project is to1) the voltage at the DC grid has to be controlled for parallel operation of several WGs without need to synchronization voltage, frequency and phase. 2) Elimination of voltage swells, sags generated during switching, by implementation of DSTATCOM topology

II. LITERATURE SURVEY:

A micro grid is a small-scale power grid that can operate independently or collaboratively with other small power grids. The practice of using micro grids is known as distributed, dispersed, decentralized, district or embedded energy production. Implementing a Cooling fan of Farming System unit into a minor Micro-grid connected to grid to work in islanded and non-islanded mode as required. The literature below has enabled to understand the concept and helped in designing this Micro-grid through the implementation of PMSG generator interfaced through inverter circuit.

PMSG Based Wind Turbine System Connected to DC Micro-grid with MPPT Control is discussed in this reference [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. During grid faults, a Low voltage ride through (LVRT) strategy for generator-side converter, main GSC and auxiliary GSC is presented, which provides reactive support to the power grid and maintains the energy balance of the system to achieve an LVRT requirement that complies with grid codes. The LVRT strategy exploits the converters capacity and coordinates the converters control depending on the depth of the voltage dip, thus minimizing the heat dissipation burden on the DC chopper.

Operation and Control of a Direct-Driven PMSG-Based Wind Turbine System with an Auxiliary Parallel Grid-Side Converter is discussed in this reference [2]. The battery bank is connected to the DC link voltage through a bidirectional DC-DC buck-boost converter. In addition to, charge/discharge current to/from the batteries bank according to the generated power from the wind and the demanded load power, the DC-link voltage can be maintained constant as a reference value. This can be attained by controlling the bidirectional DC-DC buck-boost converter. The paper 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 DClink 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.

Low Power Stand-Alone Micro-Grid with Wind Turbine is discussed in this reference [3]. 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 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.

Control of PMSG Wind Turbine Based on PI/ANN Controllers under Unbalanced Grid Voltage and Nonlinear Load Conditions is discussed in this reference [4]. In meet

fluctuating loads‟ active and reactive power demands, the units generally adopt primary P-f and Q-U droop control methods. However, at different state of charge (SOC) values, the capability of Lead Acid Battery Bank (LABB) based units to take loads varies in a large range; active power should not be shared according to the units P capacities in a constant ratio. Besides, influenced by the output and line impedance between units, reactive power is not able to be shared in proportion to the reactive units capacities. The active power/frequency control demands that the active power deviation around actual output should stay in accordance with a voltage/frequency diagram stated in grid codes. A power/frequency characteristic, or droop characteristic controls the slope of active power production. This control shall be adjusted according to transmission demands.

III. SYSTEM DEVELOPMENT

The architecture consists of cooling fans 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. Besides cooling the farms, the wind energy produced by the cooling fans can be harnessed using wind turbines (WTs) to reduce the farms‟ demand on the grid. The variability of wind speed in wind farms directly depends on the environmental and weather conditions while the wind speed in Cooling Fan in farming is generally stable as it is generated by constant-speed ventilation fans. In recent years, the research attention on DC grids has been resurging due to technological advancements in power electronics and energy storage devices, and increase in the variety of dc loads and the penetration of dc distributed energy resources (DERs) such as solar photovoltaic and fuel cells.

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 with grid, load and battery to operate the system in both grid independent and grid connected to keep the interruption time at minimum level.

Fig.1 shows the power circuit consisting of a PMSG which is connected to an ac/dc voltage source converter. The PMSG is modeled as a balanced three-phase ac voltage source esa, esb, esc with series resistance Rs and inductance Ls. The state equations for the PMSG currents isa,isb,isc and the dc output voltage Vdc of the converter can be expressed as follows-

$$L_S \frac{di_S}{dt} = -R_s i_s + e_s - KSV_{dc}$$
$$C \frac{dV_{dc}}{dt} = i_s^T S - I_{dc} \quad \text{.....(1)}$$

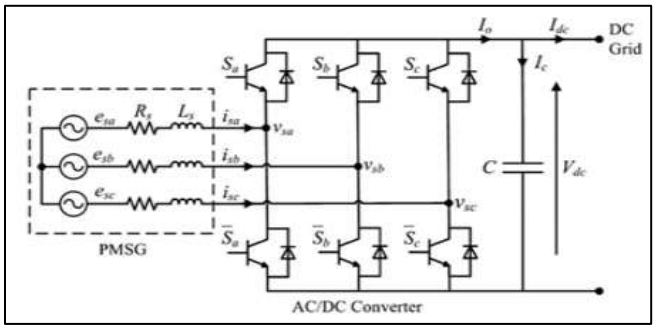

Fig. 1: Power circuit of a PMSG connected to an ac/dc voltage source converter

Fig.2 shows the configuration of the proposed controller for every ac/dc voltage source converter which is used to take care of the dc output voltage Vdc of every converter and catch up on any variation in Vdcdue to any power imbalance in the dc grid. The power imbalance will induce a voltage error at the dc grid, which is then fed into a proportional integral controller to generate a current reference i*d for id to track. To eliminate the presence of high frequency switching ripples at the dc grid, Vdc is first passed through a first order LPF. The current iq is controlled to be zero in order that the PMSG only delivers real power. the current errors Δid and Δiq are then converted into the abc frame and fed into a proportional resonant (PR) controller to generate the The effectiveness of the proposed design concept is evaluated under different operating conditions when the micro grid is working within the grid-connected or islanded mode of operation. The system parameters. The impedances of the distribution line are obtained.

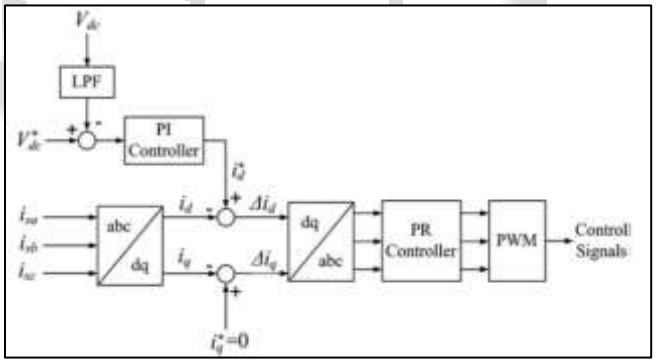

Fig. 2: Configuration of the proposed controller for the ac/dc converter.

In practical implementations, the values of the converter and inverter loss resistance aren't precisely known. Therefore, these values have been coarsely estimated. When the micro grid is operating in the grid-connected mode of operation, the proposed wind power generation system will supply power to meet part of the load demand. Under normal operating condition, the entire power generated by the PMSGs at the dc grid is converted by inverters 1 and a couple of which can share the entire power supplied to the loads. When one of the inverters fails to operate and needs to be disconnected from the dc grid, the other inverter is required to handle all the power generated by the PMSGs. In this test case, an analysis on the Micro grid operation when one of the inverters is disconnected from operation is conducted. MATLAB simulation model for rectifier with PMSG wind

turbine is given below required control signals using pulse-width modulation

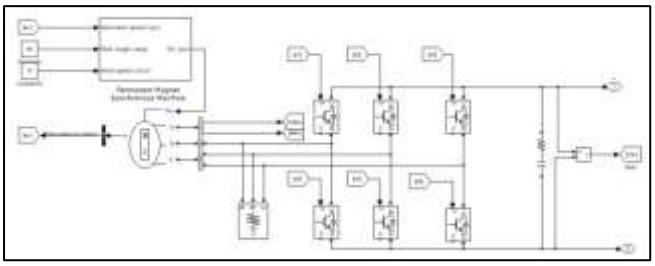

Fig. 3: MATLAB simulation model for rectifier with PMSG wind turbine

A. DC/AC Inerter Control Design & Modeling

An inverter is basically a device that converts electrical energy of DC form into that of AC. The purpose of DC-AC inverter is to take DC power from a battery source and converts it to AC. Recently, the inverters are also playing an important role in various renewable energy applications as these are used for grid connection of Wind Energy System or Photovoltaic System. In addition to this, the control strategies used in the inverters are also similar to those in DC-DC converters.

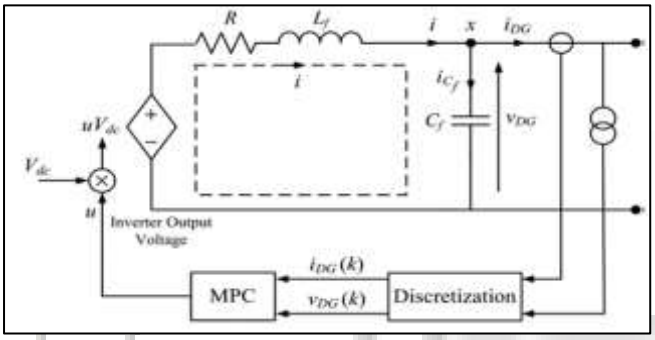

Fig 4- Single-phase representation of the three-phase dc/ac inverter

B. Model Predictive Control for Inverters-

Approach for implementing MPC for power converters and drives is to require advantage of the inherent discrete nature of power converters. Since power converters have a finite number of switching states, the MPC optimization problem are often simplified and reduced to the prediction of the system behavior just for those possible switching states. Then, each prediction is employed to guage a price function (also referred to as quality or decision function), and consequently, the state with minimum cost is chosen and generated. This approach is known as a Finite Control Set MPC (FCS-MPC), since the possible control actions (switching states) are finite.
To derive the control algorithm for the inverters, the state-space equations are transformed into augmented state-space equations by defining the incremental variables within the following format:

$$\Delta\xi(k) = \xi(k) - \xi(k-1) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where ξ represents each variable in the inverter model, such as vDG , iDG ,i and u as shown in Fig.4.

C. D-STATCOM Implementation for three phase fault Condition to maintain Voltage Stability.

The basic limitations in power grid transmission like distance, stability, effective power-flow and cable loading limits led to the investigation of power electronic devices into power systems and their impact on reactive power compensation. Thus Flexible AC Transmission System (FACTS) devices were introduced as a solution for ameliorating the power system performance. Development of this technology was supported an equivalent principle as in traditional power grid controllers. Growing capabilities of power electronic components resulted in creation of controllers with much faster response times, thanks to their lack of mechanical switch inertias. Lower transient over-voltages are accomplished when using semiconductor devices; also a smooth, gradual change in VAR output is formed, compared to the massive discrete steps that arise from mechanically switching in capacitor and/or reactor banks.

FACTS controllers using semiconductor devices are the fastest option for obtaining maximum system benefits. Recently the expansion within the use of sensitive loads altogether industries has caused many disturbances like voltage sags, swells, transient and unbalance. These sorts of disturbances which caused malfunction or pack up and have a tendency to revenue losses. Several methods are available to prevent equipment mal operation due to voltage swells and sags. One of commonly used methods is the use of D-STATCOM in order to mitigate voltage swells and voltage sags. The shunt controller, also known under the name. Distribution static compensator or D-STATCOM.

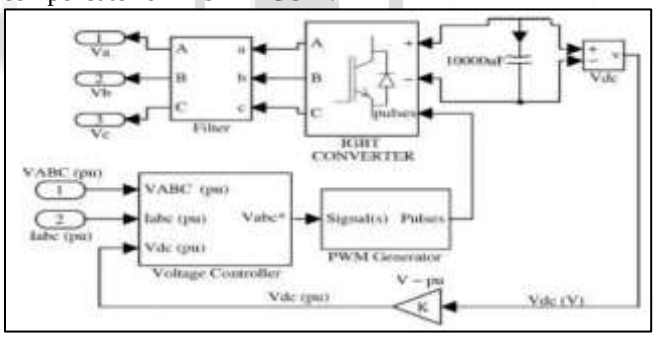

Fig. 5: DSTATCOM Control Circuit

IV. SIMULATION MODELING & RESULT ANALYSIS

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.

The simulation model of the dc grid based wind power generation system with use of DSTATCOM which is used for the correction in bus voltages. Fig.6 is implemented in MATLAB/Simulink for operation of DC Grid as shown in Fig.4 with use of DSTATCOM. The simulation model comprising of PMSG block consist of Subsystem of PMSG turbine plus AC to DC converter (Rectifier) which connected to DC Grid which is connected to DC to AC converter (Inverter). DC buck boost converter with Battery Storage System is also connected to DC grid.

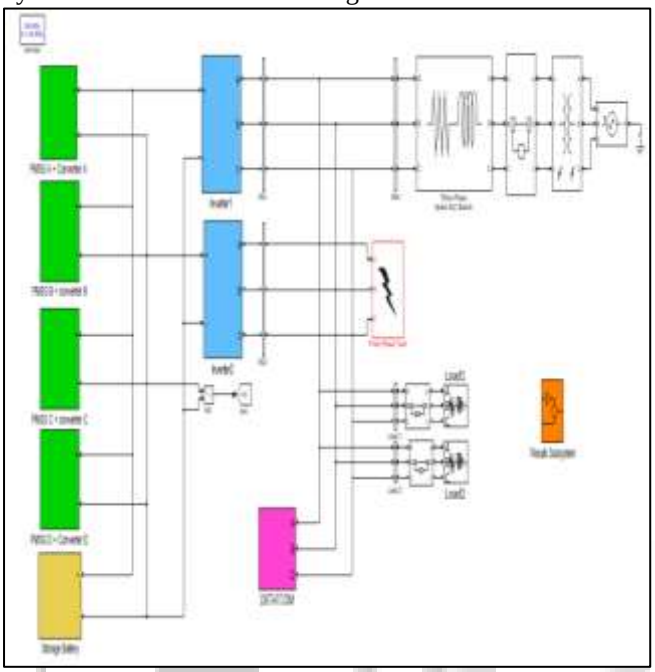

Fig. 6: Simulation model of DC Grid Based wind power generation system with use of DSTATCOM

The effectiveness of the proposed design concept is evaluated under different operating conditions when the micro-grid is operating in the grid-connected or islanded mode of operation.

1) Case I: Simulation Details of Connection Ac/Dc Converter during Grid Connected Operation –

The most significant advantage of the proposed dc grid based wind power generation system is that it facilitates the connection of any PMSGs to the micro-grid without the need to synchronize their voltage and frequency. This capability is demonstrated in this case study. The micro-grid operates connected to the grid and PMSG A is disconnected from the dc grid for 0 ≤t0.2 s as shown in Fig.7 The real power generated from each of the remaining three PMSGs is maintained at 5.5 kW and their aggregated real power of 16.5 kW at the dc grid is converted by inverters 1 and 2 into 14 kW of real power and 8 kVAr of reactive power.

As shown in Figs. 8 and Fig.9 each inverter delivers real and reactive power of 7 kW and 4 kVAr to the loads respectively.

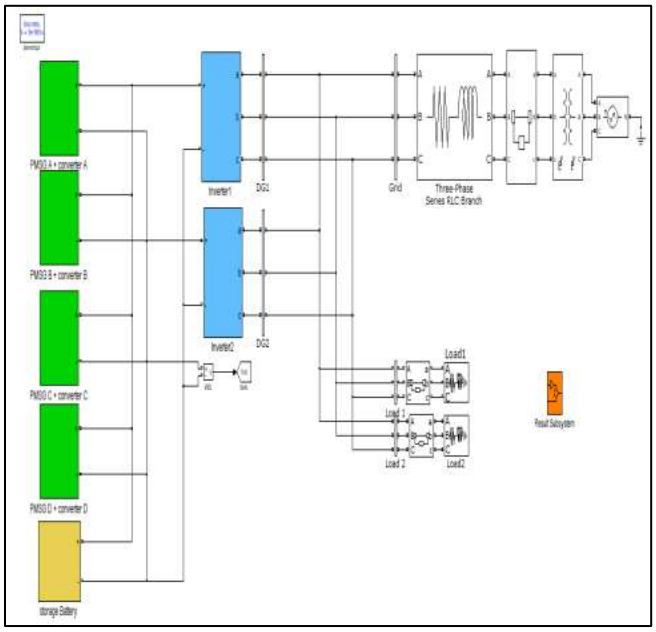

Fig. 7: Simulation model for DC grid based wind power generation system in grid connected Operation

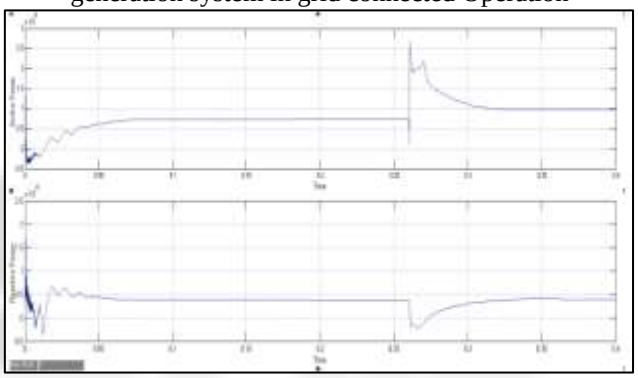

Fig. 8: Real & Reactive Power Delivered by inverter1

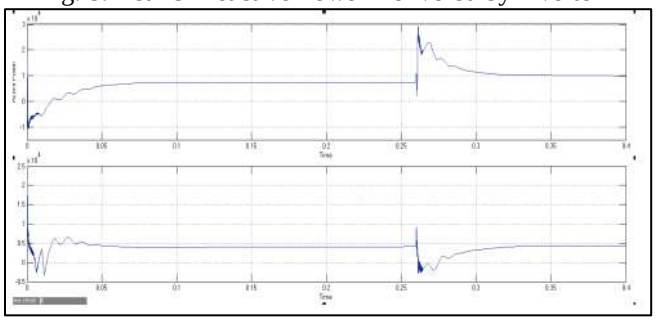

Fig. 9: Real & Reactive Power Delivered by inverter 2

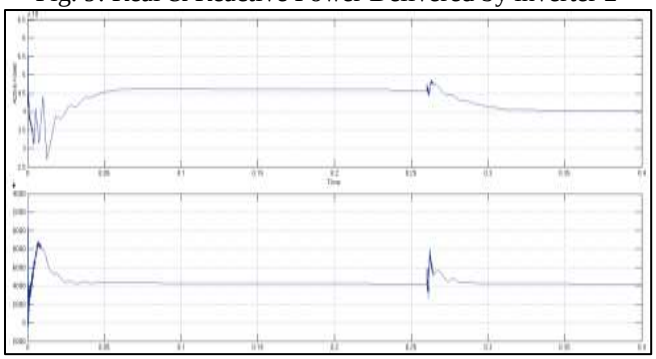

Fig. 10: Real & Reactive Power delivered by the grid

At t = 0.2 s, PMSG A which generates real power of 5.5 kW is connected to the dc grid. This causes a sudden power surge at the dc grid and results in a voltage rise at t = 0.2 s as shown in the voltage waveform of Fig. 13. At t = 0.26 s, the EMS increases the real delivered by each inverter to 10 kW while the reactive power supplied by each inverter remains unchanged at 4 kVAr as shown in Fig.5.3.2 and Fig.5.3.3. This causes a momentarily dip in the dc grid voltage at t = 0.26 s as observed in Fig.5.3.5 which is then restored back to its nominal voltage of 500 V for 0.26≤t<4.The grid also simultaneously decreases itssupply to 40 kW of real power for 0.26 ≤t<4.while its reactive power remains constant at 4 kVAr.

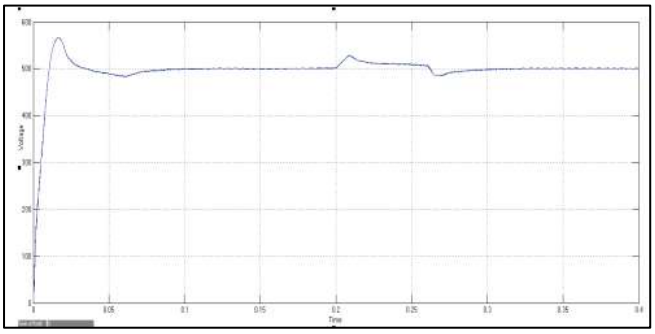

Fig. 11: DC Grid Voltage

V. CONCLUSION:

In this Paper, the operation of a dc grid-based wind power generation system that allows flexible operation of multiple parallel - connected wind generators by eliminating the need for voltage and frequency synchronization is discussed in detail. The design of a dc grid based wind power generation system in a micro-grid enables parallel operation of several WGs worked upon this work. Compared to the conventional wind power generation systems, the proposed micro-grid architecture eliminates the need for voltage and frequency synchronization, thus allowing the WGs to be switched on or off with minimal disturbances to the micro-grid operation. In addition, MPC relies on the accuracy of model establishment; hence further research on improving the controller robustness to modelling inaccuracy is required. The simulation results obtained and the analysis performed in this work serve as a basis for the design of a dc grid based wind power generation system in a micro-grid. Comparative results showed that the grid voltage profile improved after DSTATCOM Implementation. The voltage swells reduced with the DTATCOM implementation by reactive power balance. Implementation of DSTATCOM topology resulted in elimination of voltage swells, sags generated during switching and hence, it proved to be an efficient method for control strategy of inverters in micro grid.

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