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Investigations on Control and Operation Schemes of Hybrid Source Based Microgrid

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Abstract- This paper presents the design of a dc grid-based wind and solar power generation system in a poultry farm. The proposed system allows flexible operation of multiple parallel-connected wind generators output with grid. The power control, of a wind and solar hybrid generation system for interconnection operation with distribution system is achieved. Power control strategy is to extract the maximum energy available from varying condition of wind speed while maintaining power quality at a satisfactory level. A model predictive control [MPC] algorithm that offers better transient response with respect to the changes in the operating conditions is proposed for the control of the inverters. The simulation results show the improved control performance and dynamic behavior of the wind/PV system.

Index Terms—*Wind Power Generation, Dc Grid, Energy Management, Model Predictive Control.*

I. INTRODUCTION

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 photovoltaics and fuel cells. Many research works on dc micro grids have been conducted to facilitate the integration of various DERs and energy storage systems. In [1,2], a dc micro grid based wind farm architecture in which each wind energy conversion unit consisting of a matrix converter, a high frequency transformer and a single-phase ac/dc converter is proposed. In [3], a dc micro grid based wind farm architecture in which the Wind Turbine[WTs] are clustered into groups of four with each group connected to a converter is proposed. However, with the existing architecture, the failure of one converter will result in all four WTs of the same group to be out of service. The research works conducted in [4]–[7] are focused on the development of different distributed control strategies to coordinate.

The operation of various DERs and energy storage systems in dc micro grids. These research works aim to overcome the challenge of achieving a decentralized control operation using only local variables. However, the DERs in dc micro grids are strongly coupled to each other and there must be a minimum level of coordination between the DERs and the controllers. In [11], [12], a hybrid ac/dc grid architecture that consists of both ac and dc networks connected together by a bidirectional converter is proposed. Hierarchical control algorithms are incorporated to ensure smooth power transfer between the ac micro grid and the dc micro grid under various operating conditions. However, failure of the bidirectional converter will result in the isolation of the dc micro grid from the ac micro grid.

Advances in wind turbine and photovoltaic generation technologies have brought opportunities for utilizing wind and solar resources for electric power generation [4]. They have unpredictable random behaviors. However, some of them, like solar radiation and wind speed, have complementary profiles.

The Wind/solar complementary power supply system is a reasonable power supply which makes good use of wind and solar energy. This system shall not only provide a bargain of low cost and high dependability for some region where power transmission is not convenient such as frontier defenses and sentry, relay stations of communication, farming or pasturing area and so on, but also inaugurate new areas which resolve the crisis of energy sources and environment pollution.

It is very difficult to make use of the solar and wind energy all weather just through solar system or wind system individually, for the restriction of time and region. So a system that is based on renewable resources but at the same time reliable is necessary and wind/solar hybrid system with battery storage can meet this requirement.

II. HYBRID SYSTEM CONFIGURATION

A typical hybrid energy generation system is shown in Fig. 1

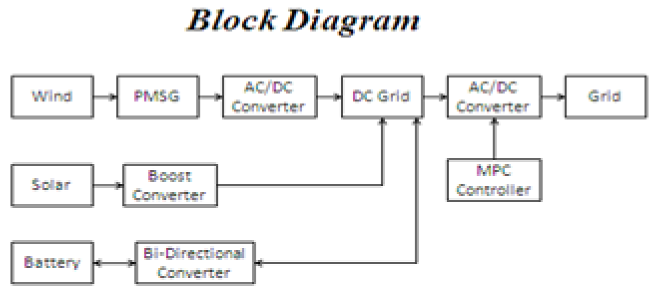

Figure 1: The studied hybrid system configuration [10]

At present, most research on photovoltaic and energy-storage hybrid system focuses on predictive techniques, and control methods for modular converters and voltage regulators [6–9]. Control strategies of different time scales are also taken into consideration [10]. Some researchers have studied storage charge and discharge control strategies based on hybrid energy storage. Tummuru proposed a fast acting DC-link voltage-based energy management schemes for a hybrid energy storage system (HES) fed by solar photovoltaic (PV) energy.

III. CONVENTIONAL METHOD DESCRIPTION

A dc grid based distribution network where the ac outputs of the Wind Generators (WGs) in a poultry farm are rectified to a common voltage at the dc grid is proposed in this paper. The most significant advantage of the proposed 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.

Many research works on designing the controllers for the control of inverters in a micro grid during grid-connected and islanded operations [6]. A commonly adopted control scheme [7] contains an inner voltage and current loop and an external power loop to regulate the output voltage and the power flow of the inverters. In [8], a control scheme which uses separate controllers for the inverters during grid-connected and islanded operations is proposed. Although there are lots of research works being conducted on the development of primary control strategies for DG units, there are many areas that require further improvements and research attention. These areas include improving the robustness of the controllers to topological and parametric uncertainties, and improving the transient response of the controllers.

Grid reinforcement increases the capacity of the grid by increasing the cross section of the cables. This is usually done by erecting a new line parallel to the existing line for some part of the distance [7]. Because of the increased cross section the impedance of the line is reduced and therefore the voltage variations as a result of power variations are reduced. Grid reinforcement increases both the amount of wind energy that can be connected to the feeder and the maximum consumer load of the feeder. Since the line impedance is reduced the losses of the feeder are also reduced. Grid reinforcement can be very costly and sometimes impossible due to planning restrictions. Since grid reinforcement can be very costly or impossible other options are interesting [7]. The simplest alternative is to stop some of the wind turbines when the voltage level is in danger of being exceeded. This can be done by the wind turbine controller monitoring the voltage level at Point of Common Coupling (PCC).

At a certain level the wind turbine is cut off and it is then cut in again when the voltage level is below a certain limit. The limits can be pre calculated and depends on transformer settings, line impedance and other loads of the feeder. This is a simple and crude way of ensuring that the voltage limits will not be exceeded.

It can be implemented at practically no cost but not all the potentially available wind energy is utilized. A method that is slightly more advanced is to continuously control the power output of the wind turbine in such a way that the voltage limit is not exceeded. This can be done on a wind farm level with the voltage measured at the point of common connection [6]. The way of controlling the power output requires that the wind turbine is capable of controlling the output (pitch or variable speed controlled) and a bit more sophisticated measuring and control equipment, but the amount of wind energy that is dumped is reduced compared to the option of switching off complete wind turbines.

Table 1: Block Parameters

NO	PARAMETERS	VALUES
1.	Turbine output power	**8500w**
2.	Base power of electrical generator	**9444VA**
3.	Base wind speed	**12m/s**
4.	Base rotational speed	**1**
5.	Capacitance filter	**0.002 farad**
6.	Battery nominal voltage	**180V**
7.	Battery Rated capacity	**150Ah**

IV. PROPOSED HYBRID SYSTEM CONFIGURATION

The PV system produces dc voltage whereas wind system generates ac voltage. For grid-connection of these two sources, the different power electronic interfaces are required. The AC-shunted grid connected hybrid PV/wind power system is shown in fig 2 is used for interfacing the system to the grid.

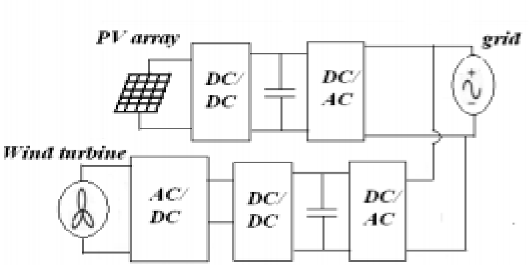

Figure 2: Block diagram of AC-shunted grid-connected hybrid PV/wind energy system [9]

In AC-shunted grid-connected hybrid PV/wind power system, the output of PV array is connected DC/DC boost converter and controlled to regulate the DC link voltage. Then a Voltage Source Inverter (VSI) with PQ controller is used to integrate the system to grid. AC output voltage of wind power system is first rectified using uncontrolled rectifier and then DC/DC boost converter is used to control DC link voltage. The VSI with MPC controller is used to connect the system to the grid.

A. The DC/DC boost converter

The DC/DC converter regulates unregulated DC voltage obtained by PV arrays and wind system. The circuit of boost converter [8] is shown in fig 3. The design of DC-DC boost converter is based on the equations 1-4.

$$D = 1 - \frac{V_{in}}{V_{out}} \text{------------ (1)}$$

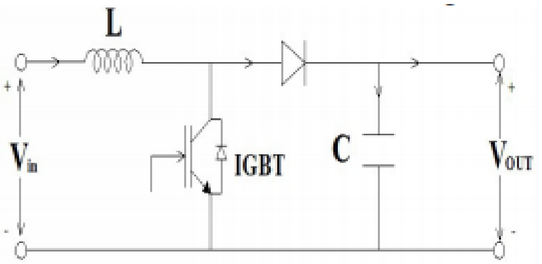

Figure 3: Circuit diagram of DC/DC boost converter [8]

$$\boldsymbol{R = \frac{V_{out}^2}{P_{in}}} \quad \text{----------- (2)}$$

$$L = \frac{DR(1-D)^2}{2 * f_s} \quad \text{----------- (3)}$$

$$C \geq = \frac{V_{out} * D}{R * f_s * \Delta V_{OUT}} \quad \text{---------- (4)}$$

Where, D is the duty cycle, V_{in} is the input voltage, V_{out} is the output voltage, R is the load resistance and f_s is the switching frequency. PI controller is used to get regulated output voltage from the boost converter [9, 10].

B. System description

Many research works on designing the controllers for the control of inverters in a micro grid during grid-connected and islanded operations is conducted [11]. A commonly adopted control scheme which is detailed in [11], [12] contains an inner voltage and current loop and an external power loop to regulate the output voltage and the power flow of the inverters. In [12], a control scheme which uses separate controllers for the inverters during grid-connected and islanded operations is proposed. Although lot of research works being conducted on the development of primary control strategies for DG units, there are many areas that require further improvement and research attention.

These areas include improving the robustness of the controllers to topological and parametric uncertainties, and improving the transient response of the controllers. In this work, the inverters are controlled to track periodic current and voltage references, control signals have a limited operating range. Under such operating condition, the MPC algorithm is operating close to its operating limits where the constraints will be triggered repetitively. In conventional practices, the control signals are clipped to stay within the constraints, thus the system will operate at the sub-optimal point. This results in inferior performance and increases the steady-state loss. MPC, on the contrary, tends to make the closed-loop system operate near its limits and hence produces far better performance.

MPC has also been receiving increased research attention for its applications in energy management of micro grids because it is a multi-input, multi-output control method and allows for the implementation of control actions that predict future events such as variations in power generation by intermittent DERs, energy prices and load demands [13]. In these research works, the management of energy is formulated into different multi-objective optimization problems and different MPC strategies are proposed to solve these optimization problems.

The scope of this work is however focused on the application of MPC for the control of inverters.

When the micro grid is connected to the distribution grid, the WTs in the micro grid are responsible for providing local power support to the loads, thus reducing the burden of power delivered from the grid. The SB can be controlled to achieve different demand side management functions such as peak shaving and valley filling depending on the time-of-use of electricity and State of Charge (SOC) of the Storage Battery (SB). During islanded operation where the Circuit Breaker (CBs) disconnect the micro grid from the distribution grid, the WTs and the SB are only available sources to supply the load demand. The SB can supply for the deficit in real power to maintain the power balance of the micro grid as follows:

$$\boldsymbol{P_{wt} + P_{sb} = P_{loss} + P_l} \quad \text{-----------} \ (5)$$

Where P_{wt} is the real power generated by the WTs, P_{sb} is the real power supplied by SB which is subjected to the constraint of the SB maximum power P_{sb}, max that can be delivered during discharging and is given by

$$P_{sb} \leq P_{sb,max} \qquad \text{-------------} \ (6)$$

P_{loss} is the system loss, and P_l is the real power that is supplied to the loads.

V.SIMULATION RESULT

Simulations using MATLAB done to verify the theoretical studies. The overall block of the system used in simulations is provided in Fig. 4. The parameters are selected as close to practical applications as Possible.

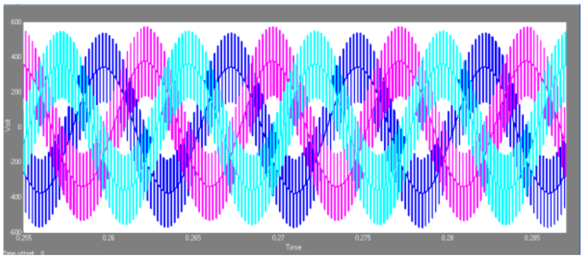

Figure 5: Wind output voltage (volt vs time)

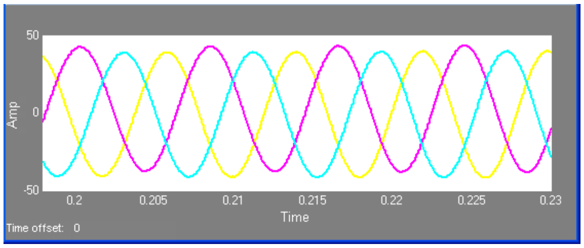

Figure 6: Wind Output Current (current vs time)

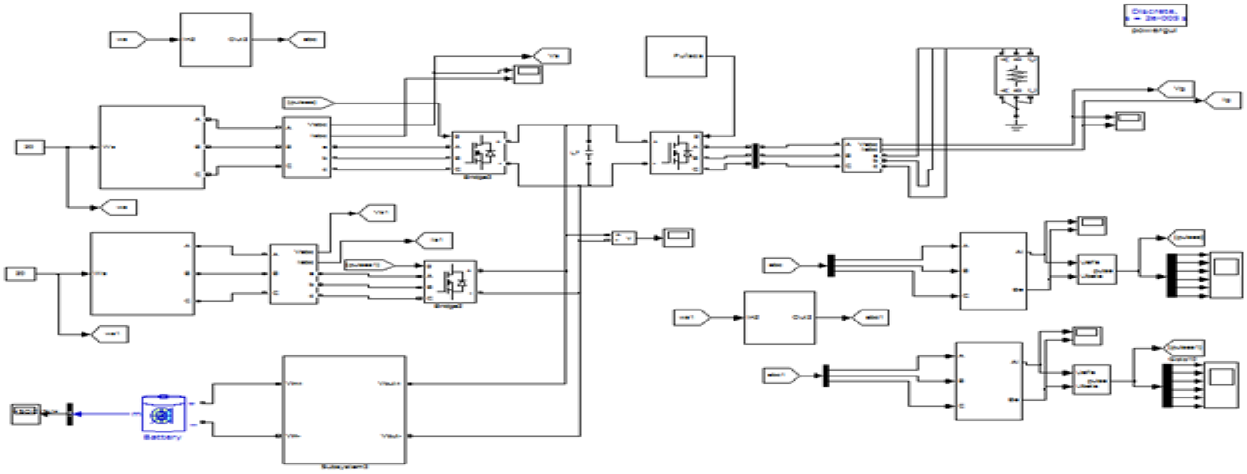

Figure 4: wind power grid system

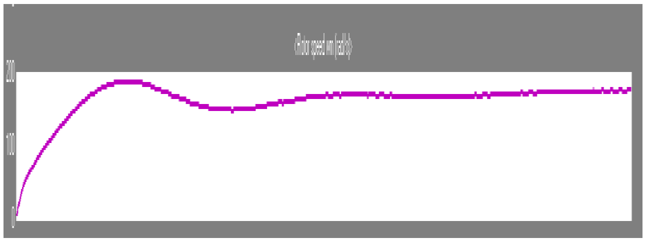

Figure 7: Rotor Speed (speed vs time)

When the wind is rotating at a certain speed, the output voltage of wind power generation is 230 V and the Output current is 42 A respectively is shown in the fig: 5and 6.

The output voltage of wind power Generation is connected to the Converter and the output from converter is connected to Dc grid. The resultant voltage is shown in fig: 8

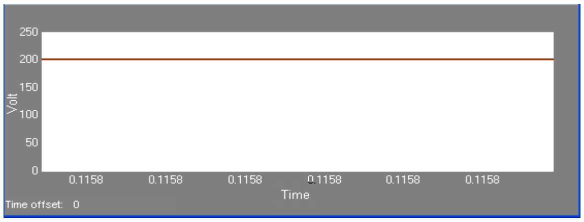

Figure 8: DC Grid voltage (volt vs time)

The AC Grid voltage (120 V) and AC Grid current (0.5A) is shown in fig 9 and 10 respectively

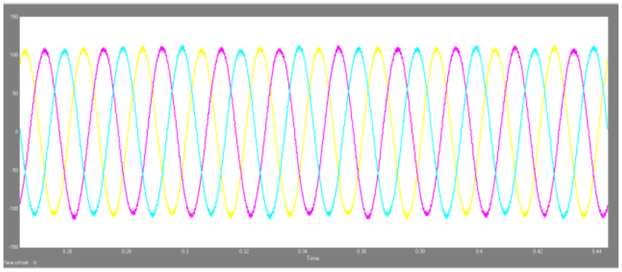

Figure 9: AC Grid voltage (volt vs time)

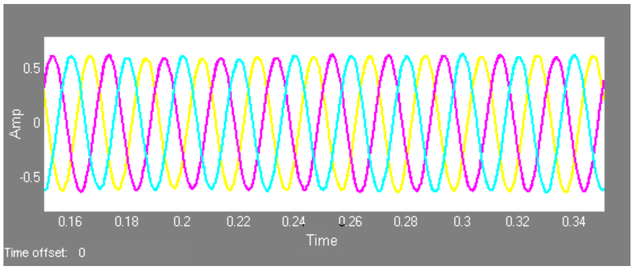

Figure 10: AC Grid Current (Amps vs time)

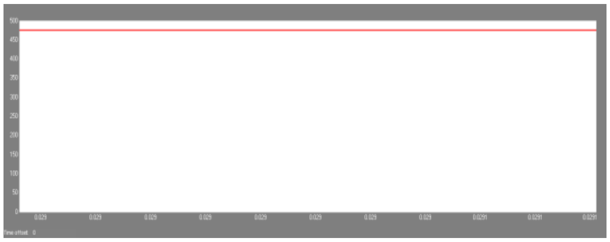

Figure 12: DC Grid voltage (using boost converter) (volt vs time)

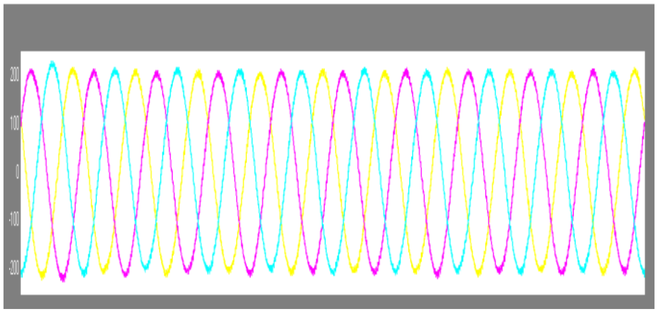

Figure 13: AC Grid voltage (using boost converter)

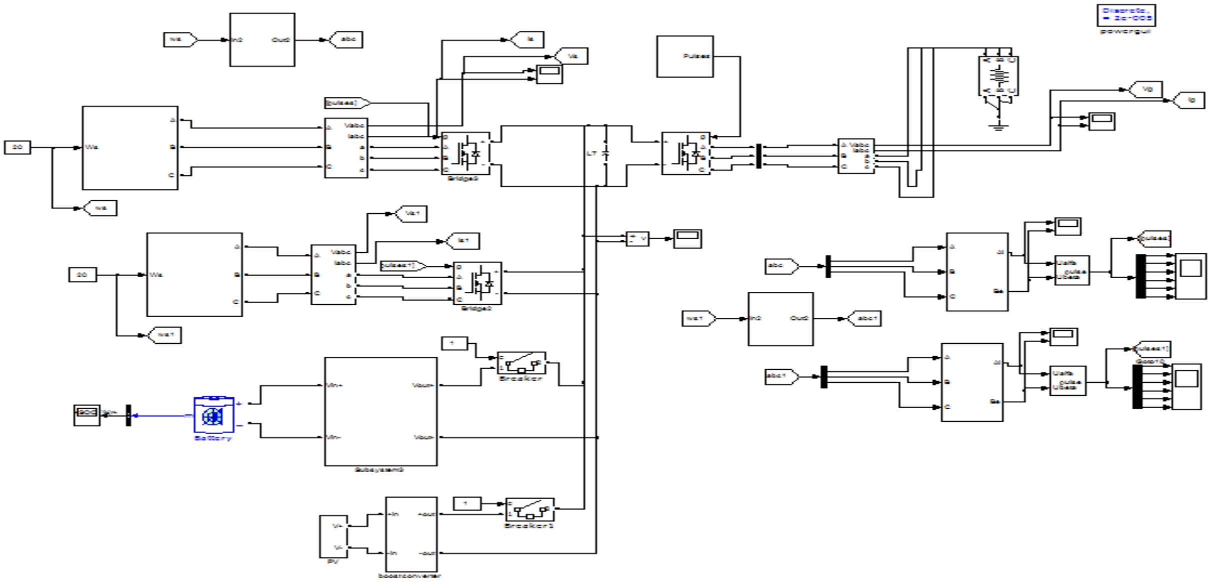

Figure 11: Hybrid Energy System With Boost Converter (Volt Vs Time)

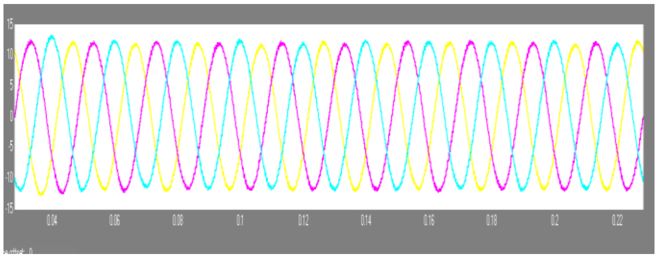

Figure 14: AC Grid Current (using boost converter) (Amps vs time)

Compared to Wind power generation system, the hybrid power generations with boost converter produce high voltage and current. This is shown in Fig 12, 13, 14 respectively. From the above simulation result we are obtaining continuous energy management in the grid system.

Improvement of control parameters with and without Boost converter

No	**PARAMETERS**	**Without boost converter**	**With boost converter**
1.	DC grid voltage	200 V	450 V
2.	AC grid voltage	120 V	215 V
3.	AC grid current	0.5 A	13 A

CONCLUSION

In this work, the design of a DC & AC micro grid based hybrid power generation system in a micro grid that enables parallel operation of several WGs has been presented. The hybrid model system consisting of wind turbine coupled with Permanent Magnet Synchronous Generator (PMSG) and photovoltaic energy system connected to the grid is developed using MATLAB. The AC-shunted grid-connection is used as interface with MPC control strategy for the VSI. The dynamic performance of wind and photovoltaic power systems are studied for different system disturbances like load variation and wind speed variation. The simulation results shows that, using a VSI and MPC control strategies, it gives a good response of grid-connected hybrid energy system.

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