# HYBRID RENEWABLE PLANT WITH VOLTAGE SAG COMPENSATION

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**Abstract:** This paper presents a hybrid plant consists of wind and hydro pump storage plant which is used mostly used in the remote areas for agriculture process and also used for the voltage sag compensation for the wind plant. The wind farm has the capacity of 9MW which uses the doubly fed induction generator (DFIG) and a critical remote load. The hydro plant is simulated in the MALAB with is connected to the main grid where the wind farm is also connected. The hydro storage pump plant is operated when the voltage sag is occurred. It prevents the wind farm from tripping during the under voltage condition. Due to this cost and the maintenance is reduced. The fault used in this paper is LLLG fault.

**Keywords:** Wind farm, Voltage sag, DGIF, Hydro pump storage plant.

## I. INTRODUCTION

Renewable energy sources are the type of energy sources which are plenty in quantity and are derived from earth. Wind energy, solar energy, geo thermal and bio mass are different types of renewable energy sources. These resources are inexhaustible in nature. The known advantages of renewable energy sources are its clean nature, abundant in quantity and most importantly it is ecofriendly unlike non renewable energy sources. Among different types of renewable sources of energy, wind energy is the most cleanest and the efficient source of energy. The major advantages of wind energy are wind-generated electricity doesn't pollute the water, air or soil.

The kinetic energy in the wind can be used to run wind turbines, some capable of producing 5 MW of power. The power output is a function of the cube of the wind speed, so such turbines generally requires a wind in the range 5.5 m/s (20 km/h) and in practice relatively few land areas have significant prevailing winds. Luckily, offshore or at high altitudes, the winds are much more constant. There are now many thousands of wind turbines operating in various parts of the world. This has been the most rapidly growing means of electricity generation at the turn of the 21st century and provides a complement to large-scale power stations. Globally, the long-term technical potential of wind energy is believed to be 5 times current global energy consumption or 40 times current electricity demand. This would require covering 12.7% of all land area with wind turbines. This land would have to be covered with 6 large wind turbines per square kilometer. Offshore resources experience mean wind speeds of ~90% greater than that of land, so offshore resources could contribute substantially more energy. Wind strengths vary and thus cannot guarantee continuous power. Some estimates suggest that 1,000 MW of wind generation capacity can be relied on for just 333 MW of continuous power. It is best used in the context of a system that has significant reserve capacity such as hydro, or reserve load, such as a desalination plant, to mitigate the economic effects of resource variability. It is particularly useful for India having such a long coast line and high altitude areas.

Hybrid energy systems consisting of two or more energy resources can be used in the remote places and independently operated purposes by consuming less power from public grid. In some researches the hydro and wind power generation combination indicate the power quality improvement and the less cost. Kaldellis et al. proposed a micro hydroelectric power plant from a wind farm and a pump station to store the energy during periods of low demand in the farm of water potential energy in the islands isolated networks. Castronuovoed proposed the daily operation of a hybrid plant consisting of wind farm and small hydro unit.

## II. MODELLING AND CONTROL

The hydro and wind plant is located 20km away from the main grid which is used to supply power to the near remote or critical load. The hydro pump storage is used to compensate the under voltage caused by the wind farm to prevent the voltage sag conditions. The main purpose of hydro system is used for the agriculture water management in the remote places, so this can be used to compensate the voltage sags in the system. The hydro plant has the rating of 2MW capacity with is sufficient to overcome the voltage sag. This is simulated in MATLAB Simulink.

The main source of the supply to the nearby load is the windfarm and hydro pump in the normal operation. The lower reservoir water is used for the agricultural and irrigation purposes. The protection is required for different abnormal conditions due to the internal faults of the windfarm and grid. There should be continuous monitoring of voltage, current, frequencies turbine speeds which are should in the limits. If these are not in limits than the plant will trip.

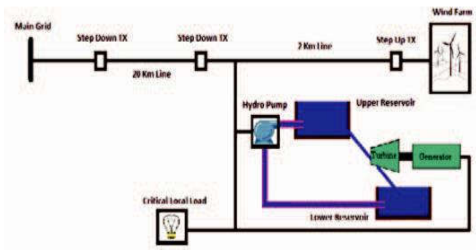


**Figure 1** Overall Renewable Plant Block Diagram

The hydro plant acts has the hydro generator and hydro pump which will operate in opposite actions i.e., when the fault occurs then the breaker trips the pump and starts the to operate as the hydro generator to prevent tripping of the wind farm due to voltage sag of the system. The figure 1 shows the overall block diagram of renewable plant.

The rotor current and voltages are used to control to the stator output active and reactive powers. The generator torque and terminal voltage are controlled by q component of rotor current.

## III. DFIG AND HYDRO GENERATOR

The most commonly used wind generator is DFIG (Doubly fed induction generator). The generator stator is connected to the grid whereas rotor is connected through the converters with a common DC link in between the converters. The Machine side converter (MSC) is used to control the power and voltage and the Grid side converter is used to keep the constant DC bus voltage. The slip value may be positive or negative depends on the rotor speed. Figure 2 shows the block diagram of DFIG wind generator.

The hydro has the asynchronous machine motor which acts as pump and synchronous machine which acts as a generator.

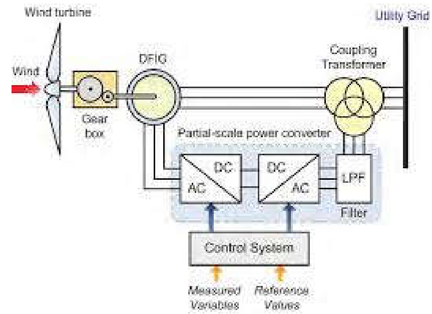


**Figure 2** DFIG Wind Generators

## IV. SIMULATION AND OPERATION

The simulation are done based on the phasor model for MATLAB blocks which helps to solve the simpler algebraic equations and complex numbers of voltages and currents. In this paper windfarm has the six 1.5MW wind generators which makes the total of 9MW generation of power. On the other hand the hydro pump storage plant has a rating of 2MW for the compensation of voltage sag. The windfarm is connected to the 575V which is 2KM away from the hydro pump storage plant. The voltage is stepped up to 25KV by using step up transformer.

The plant is regulated at a load voltage of one per unit across the motor and the main line at the normal running operation. The hydro plant has the two breakers which are operation in opposite to each other when the breaker 1 is closed then the pump will operate and at this time breaker 2 is opened and vice versa when the synchronous generation is in operation. The breaker operations are depends on the utilization of hydro plant for the protection purpose. The breakers are triggered by the system output. They are two cases for the operation.

### Case 1: During the Normal Operation

In the normal operation there is no voltage sag in the system grid and the wind turbine is operated at the speed of wind 8m/s. So there no need of any pitch control and there is no windfarm nor the motor has tripped. Due to the no fault condition there no switching operation and DFIG protection actions are not required. This also makes the system less harmonic distortions when compare to the fault condition because of the absence of switching actions. In this case the hydro plant is used to run as a motor and so the breaker 1 is in closed position and breaker 2 is in open position. The motor is used to pump the water from lower reservoir to upper reservoir.

### Case 2: During the Fault Condition

In the fault operation there will be a voltage sag in the system due to any condition some of them are due to the decrease in the wind speed or any other fault condition. In this paper LLLG fault is simulated by using the fault block. Due to the fault there will be some voltage sag it depends on the type of fault used or by applying the sag by changing the amplitude to the required sag from the main network voltage sag, if the fault continuous than the windfarm will trip and will lose the synchronism with the grid. The windfarm controllers try to compensate by injecting more reactive power but if the windfarm trips then there will not inject any reactive power to the grid. However the windfarm trips there will lose of power to the nearby remote load. In order to prevent the windfarm to trip the hydro plant starts to compensate the voltage required by stopping the pumping action and starting the power generation by closing the breaker 2 and opening the breaker 1 when it takes the tripping signal from the under voltage relay. By the operation of hydro generator the compensated voltage is supplied to the grid and compensates the voltage sag of the system. This makes the switching operation of the converters in the DFIG and so produces the more harmonics than the normal operation. The figure 3 shows the overall block of the hybrid renewable plant and figure 4 shows the hydro plant used to compensate the voltage sag.

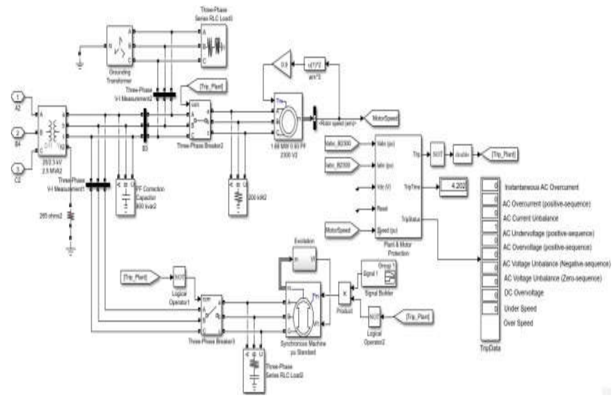

**Figure 3** Overall Block Diagram of Hybrid Renewable plant

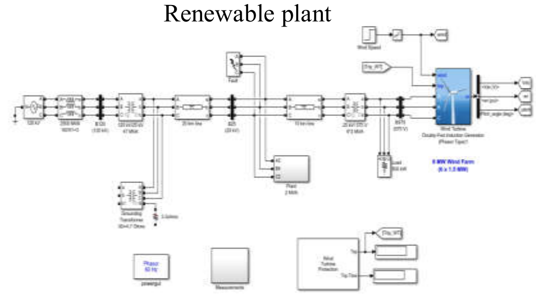

**Figure 4** Hydro Pump Storage Plant

## IV. RESULTS AND CONCLUSION

The results are simulated in the MATLAB Simulink by using the available models in the library. The figure 3 shows the overall block diagram of the hybrid renewable plant with is constructed in the Simulink. The figure 4 shows the block diagram of the Hydro pump storage plant which is used for the voltage compensation when sag occurred and agriculture purposes. The outputs of the system is show in figures with the operation of some monitored parameters of the main and the wind plant such as voltage at different buses and in the wind farm, current at the different buses, speed, DC voltage, active power and reactive power of the grid and wind farm in three different cases.Figure 5 shows the outputs when the overall plant is in normal operation i.e., no fault is occurred. Figure 6 shows the outputs when the fault is occurred and so the voltage sag is appeared when the hydro plant is not supported. Figure 7 shows the outputs when the voltage sag is there and hydro pump storage plant is supported for the voltage sag compensation.

This paper includes the renewable hybrid plant with wind farm and hydro power storage plant which is used in a remote area

**Figure 5a** Bus Voltages at 120KV, 25KV, 575V, Active and Reactive Powers, Plant Voltage and Current, Motor Speed of grid at normal operation.

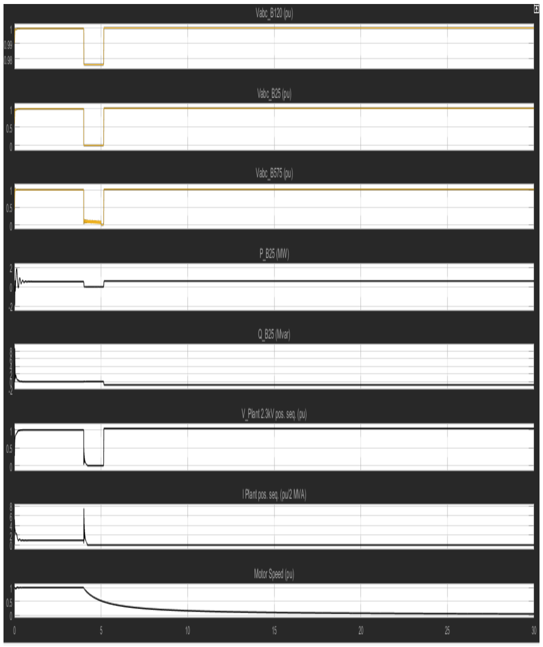

**Figure 6a** Bus Voltages at 120KV, 25KV, 575V, Active and Reactive Powers, Plant Voltage and Current, Motor Speed of grid with sag and without hydro plant.

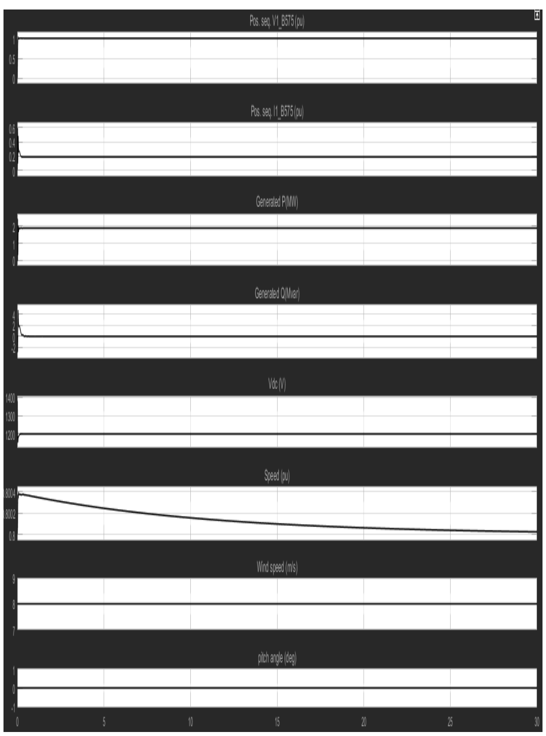

**Figure 5b** Positive sequence Voltage and Current, DC voltage, generated active and reactive powers, Speed, Wind Speed, Pitch angle of wind at normal operation.

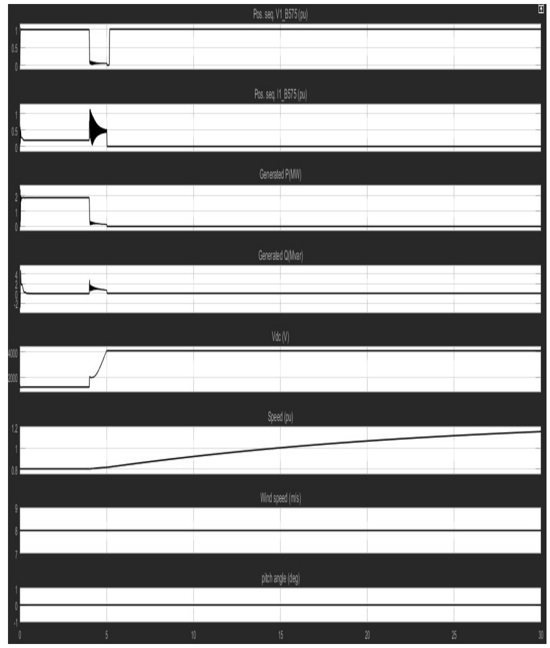

**Figure 5b** Positive sequence Voltage and Current, DC voltage, generated active and reactive powers, Speed, Wind Speed, Pitch angle of wind at normal operation.

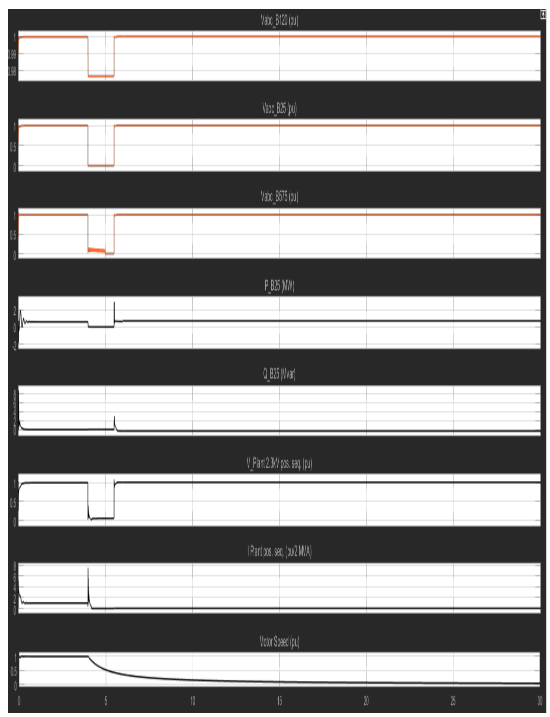

**Figure 7a** Bus Voltages at 120KV, 25KV, 575V, Active and Reactive Powers, Plant Voltage and Current, Motor Speed of grid with sag and without hydro plant.

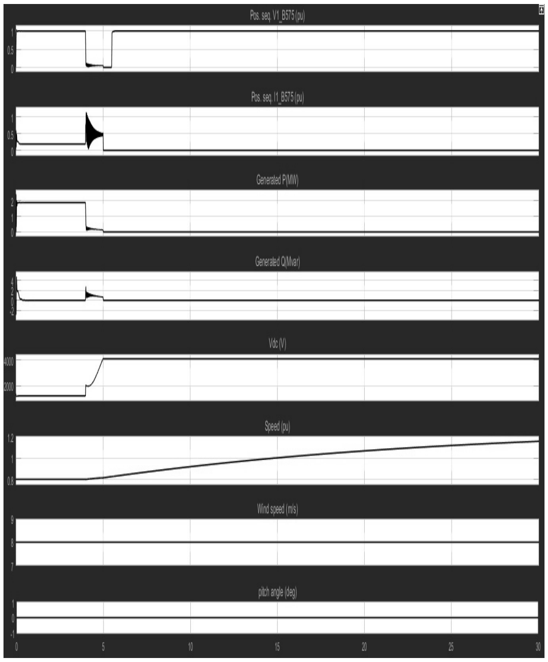


**Figure 7b** Positive sequence Voltage and Current, DC voltage, Generated active and reactive powers, Speed, Wind Speed, Pitch angle of wind at normal operation.

with critical load. The voltage sag is applied by using the fault block by this different faults can be generated and this paper LLLG fault output is shown with a partial output. Voltage sag can also be applied by using voltage source connected to the grid by changing the voltage amplitude. Detailed simulation and analysis are done which prevents the wind farm from tripping due to the fault condition or under voltage condition.

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