Hybrid Wind-Diesel Generation System

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Abstract:
This paper presents the simulation of a hybrid Wind-Diesel power plant. Combining two or more generating technologies such as wind and diesel creates a hybrid power system. For remote locations, far from public power grid , the hybrid system forms a self sufficient power supply. This paper presents the modelling and simulation of an isolated Wind/Diesel system. High-penetration, no-storage wind diesel (HPNSWD) system requires a fast-acting dump load controller to maintain the system frequency stability and quality. Individual system components i.e Diesel Set and Wind Set are simulated and discussed in detail. The impact of penetrative variations wiz variations of wind speed, distance between Wind turbine and Diesel generator and fault analysis is effectively demonstrated by simulation results.

Keywords—Wind-Diesel, Hybrid,Dump-Load, System Frequency, Penetrative Variations.

INTRODUCTION

Wind energy development is consumer and environment friendly, it requires shorter construction time compared to thermal, nuclear generation and is cost competitive. It becomes one of the most competitive sources of renewable energy.

However,wind power has some disadvantages. For example, wind power is considered an intermittent power supply because wind does not blow 100% of the time. Today, in many parts of the world, the decisions for new capacity installation become complicated due to the fact that finding new sites for generation and transmission facilities of any kind are difficult. Particularly rural areas in the developing world where most of the population is located, most people lack the essential energy services to satisfy most of their basic needs. The cost of grid connection in these rural areas is very high due to a low density of population; therefore various organizations have turn to explore alternative solutions.[1]

One of the most economical and reliable alternatives is to use diesel power generation, but diesel power generation is very inefficient when the load is a small percentage of the rated power of the engine. The fact that every time, there is a need for power the engine has to operate makes it very inconvenient and reduces the efficiency and lifetime of the power generation system. As a result, wind energy system has been suggested to provide a good solution to supply energy loads in these rural areas. Hence, the role of hybrid power system comes into focus.

Hybrid systems offer different penetration levels, with a large choice of technical solutions. The wind power allows a reduction of the diesel generator rating. Both for reasons of network compatibility and to reduce mechanical loads, many large wind turbines (installed either offshore or onshore) can be operated at variable speed and use doubly fed induction generators.

ANALYSIS OF INDUCTION GENERATOR

For a wind energy conversion system that uses induction generator, a dc link converter is essential for power conversion. The induction generator produces current at variable frequency. This current is rectified onto the dc link using a converter with six active switches. To convert the dc to a fixed frequency of the utility, a second converter with six switches is needed. This results in many switches needed for wind energy conversion system. Hence a new method that uses a six-switch current regulated pulse width modulated inverter and a zero sequence filter is proposed to eliminate some of the switches used and still retaining the original functionality of the system. [2]

Over-voltages are the major cause of excitation capacitor failure. Using a saturable transformer connected to the terminals of the induction generator will improve voltage regulation and also protection against over-voltages. [3]

HYBRID WIND-DIESEL SYSTEM

The hybrid system presented in this paper comprises of a Wind Plant acting as the renewable source of energy and a Diesel generation system serving as the conventional source of energy.

Wind/Diesel system can be classified according to different levels of wind penetration. In low wind penetration, the diesel generator will run at full time with the wind power reducing the net load on the diesel generator. All the wind energy generated will be supplying the primary load.. Due to the simplicity of this configuration, fuel savings is only up to ~20%. [4] Low wind penetration does not require complex technology.

In medium wind penetration, the diesel generator will operate at full time. During high wind power levels, the secondary loads will be dispatched to ensure sufficient diesel loading and alternatively, wind turbines are curtailed during high winds and low loads. To achieve this dispatching of loads, simple control system is required.

In high wind penetration, the diesel generator can be shut down during high wind availability and auxiliary components are required so as to regulate voltage and frequency. When the wind generator output is sufficient to supply the load demand, it is impractical to keep the diesel generator on-line as spinning reserve to cover short-term deficits in wind generator output. Such a wind - diesel hybrid generation system is shown below:

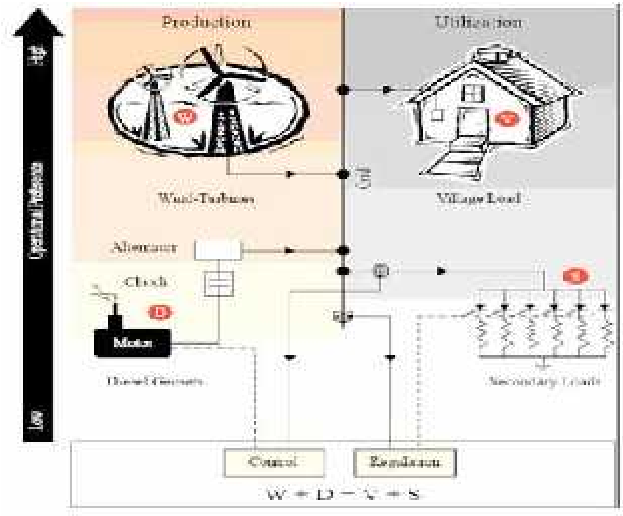


Fig. 1 High penetration no storage wind-diesel system

PROBLEM FORMULATION

Much effort is expended in this research to develop a comprehensive nonlinear and a dynamic model of a HPNSWD system that includes both a detailed mechanical and a detailed electrical system. The objective of this paper is to determine the performance of a wind-diesel hybrid system when various parameters such as wind speed distance between the wind and diesel plant are changed and to carry out the fault analysis. It is important to study the impact of wind speed, variation in distance and the impact of addition of fault on the on the supply of generated power, on the grid voltage and current, on the system frequency and operation of diesel generator as a synchronous condenser and the variation in the reactive power.

SYSTEM & SYSTEM PARAMETERS

The High Penetration No Storage Wind Diesel system presented in this model uses:

- 480 V, 300 kVA synchronous machine,
- Wind turbine driving a 480 V, 275 kVA induction generator,
- 50 kW customer load and a variable secondary load (0 to 446.25 kW)

At low wind speeds both the induction generator and the diesel-driven synchronous generator are required to feed the load.When the wind power exceeds the load demand, it is possible to shut down the diesel generator. In this all-wind mode, the synchronous machine is used as a synchronous condenser and its excitation system controls the grid voltage at its nominal value. A secondary load bank is used to regulate the system frequency by absorbing the wind power exceeding consumer demand.

The model is simulated under three conditions. Firstly, when the model runs at different wind speeds, secondly by changing the length of transmission line between Wind plant and Diesel plant and lastly, when a fault is added on the tie-line. The model and the various results are shown below:

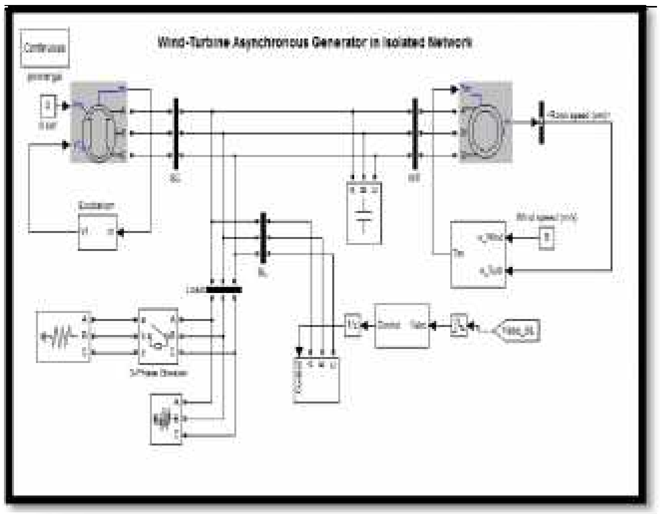


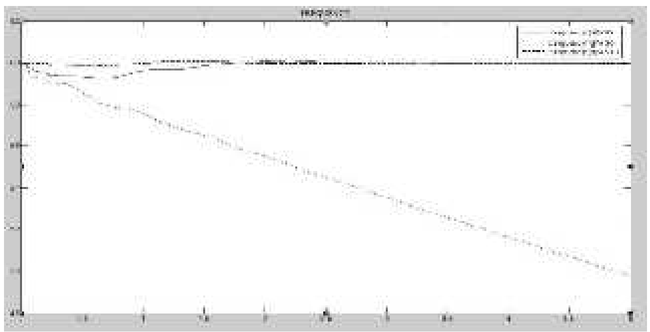
Fig 2. Wind-Turbine Asynchronous Generator in Isolated Network

The various parameters of (HPNSWD) system are :

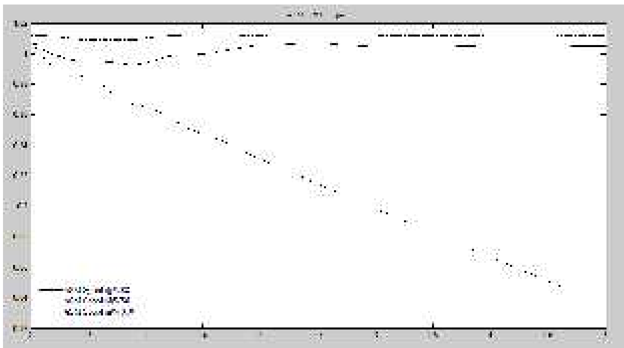
- Wind Speed = 10 m/s
- Output Power = 0.75 pu (206 KW)
- Because of losses turbine produces power = 200 KW
- Main Load = 50 KW
- Secondary load = absorbs 150 KW to maintain frequency of 60 Hz.
- Voltage = 1 pu and no flicker is observed.
- Synchronous Speed = 1.011 pu
- Asynchronous Speed is little more than synchronous speed.

RESULTS

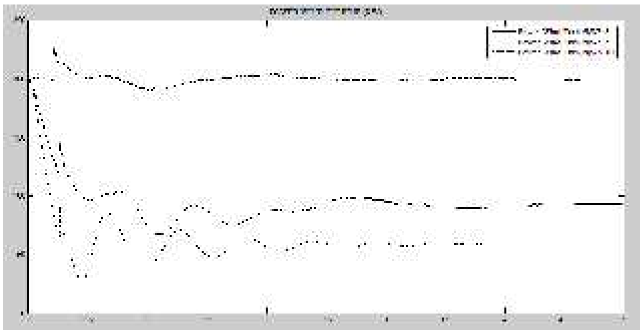
A. Case 1: Change in Wind Speed: The comparative results at different wind speeds are shown below:



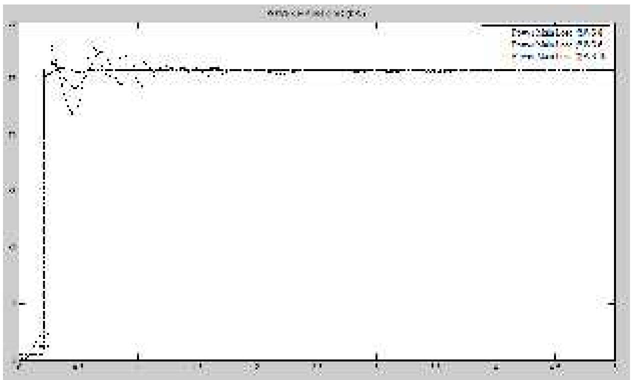
Frequency



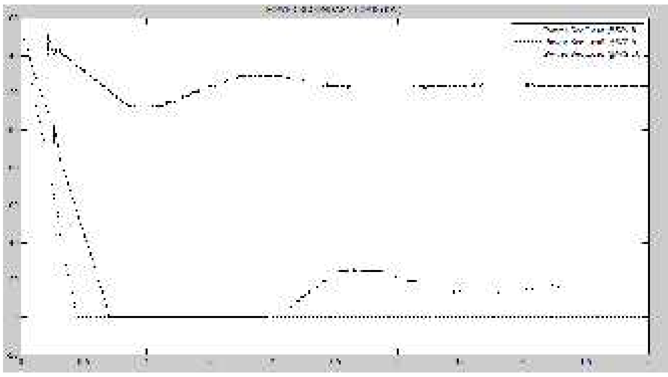
Asynchronous Speed



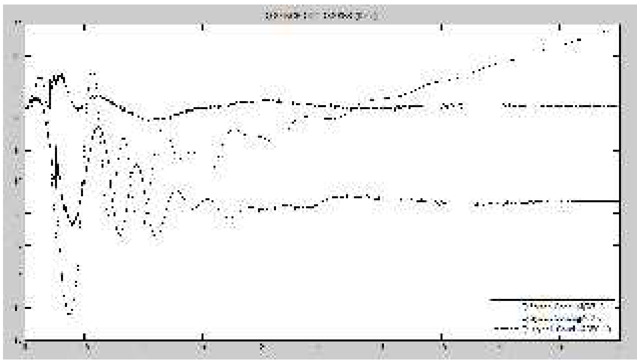
Power of Wind Turbine



Power of Main Load



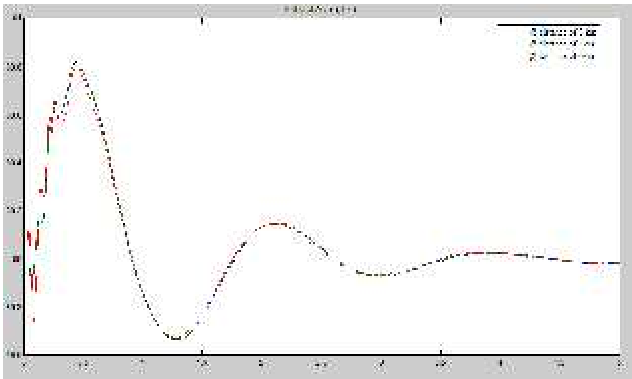
Power of Secondary Load



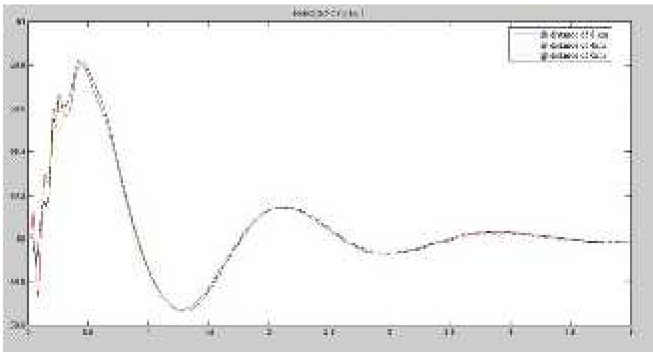
Reactive Power of Synch. Condenser

B. Case 2: Change in Length of Line

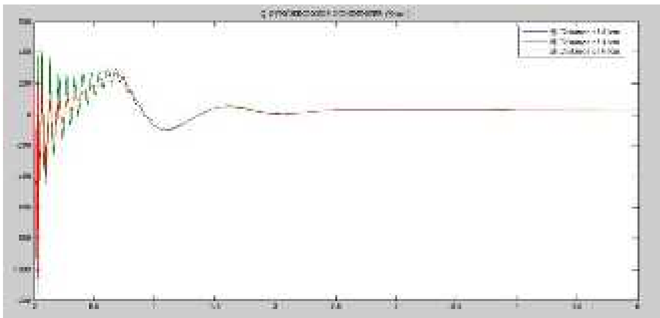
The comparative results with change in length of transmission line are shown below:



Frequency



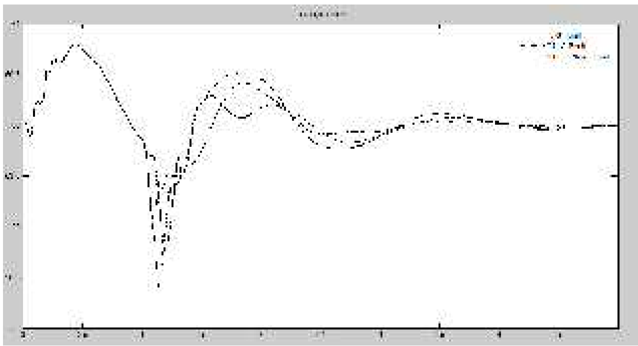
Power of Wind Turbine



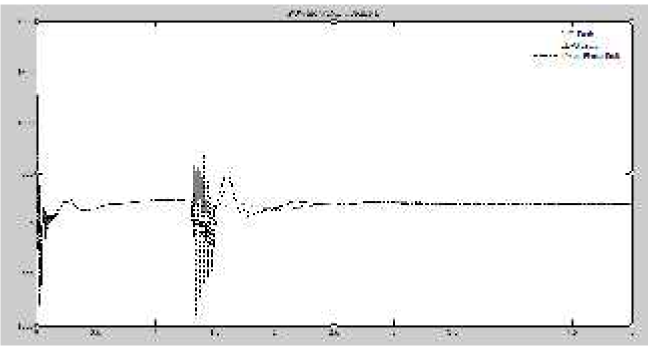
Reactive Power of Synch. Condenser

C. Case 3: Addition of Three-phase fault

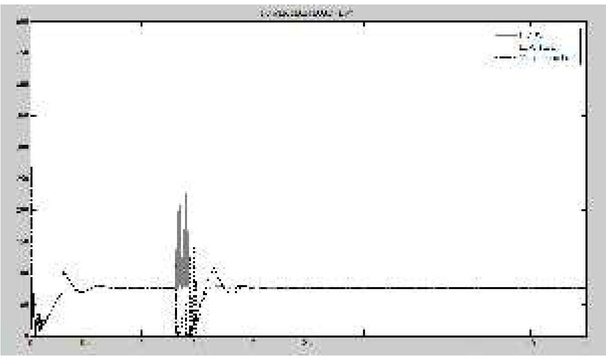
The comparative results after addition of three phase fault in system are shown below:



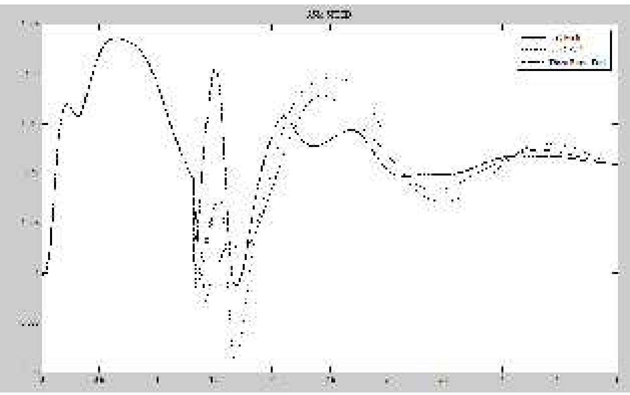
Frequency



Power of Wind Turbine



Power of Main Load



Asynchronous Speed

CONCLUSION

In this work two generating units such as wind set and diesel set were combined to form a hybrid power system. In the remote areas where the grid extension is difficult, hybrid power system can prove to be a boon by being a self sufficient power supply.

The hybrid Wind-Diesel system model was implemented in MATLAB/Simulink. The various system parameters were defined and the Wind generator set and Diesel generator set and their sub-components were simulated and discussed in detail. It was observed that in order to maintain the system frequency and quality a fast-acting dump load controller has to be been used.

It was observed that the effect of change in wind speed was on the overall power flow from the system. It was seen that if the wind speed was more then the diesel generator set could be shut down and the wind plant was sufficient to supply power to the load, but as the wind speed decreases then the diesel generator set comes into action or we can say that the participation of the Diesel Generator set increases with the change in optimal wind flow. At lower wind speeds the system frequency was observed to be unstable.

The variation in the distance between the Diesel Generator set and the Wind Plant resulted in the consumption of more reactive power which further increased the losses in the system and resulted in major fluctuations in the system frequency. Lastly, the addition of a fault on the tie line showed that if the fault is on the wind side power generation or on the Diesel Generator set side then in case of failure of any mode of generation means active participation of the second type but with loss of delivered active power and frequency destabilization would be observed during sub-transient period. It is also observed that if it is a general three phase fault then the there is change in the active and reactive power flow with the reversal of the current quadrant.

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