SIMULATION OF WIND DIESEL SYSTEM WITH ENERGY STORAGE SYSTEM

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ABSTRACT

This paper presents the modeling and simulation of isolated Wind diesel hybrid system (WDHS) with energy storage. It comprising a wind turbine generator (WTG) along with a diesel generator (DG), and a dump load (DL) provides the supply to consumer load. WTG and BESS are used in the system to minimize fuel consumption of DG and make this system more eco-friendly. In this article different types of battery (lead Acid, lithium-ion, nickel cadmium and Nickel-Metal-Hydride) are discussed for simulation and simulation result is shown by using Ni-Cd battery.

Keywords: Active Power Regulator(APR); Battery Energy Storage System(BESS); Circuit Breakers (C.B); Consumer Load; Dump Load (DL); Wind Diesel.

I. INTRODUCTION

In years lately on a earthly scale, the climatic repercussion have become more probable, natural fuel like coal, petroleum, gas fossil fuel reserves have become scant, and prices of energy reached a high level. Renewable energy sources have attracted attention among all classes rural or urban. With the renewable energy sources the dependence on the coal, petroleum automatically came down, the emission of greenhouse gases also saw a drastic decrement. Sustainable sources of energy are the natural energy resources that are never ending for example, energy from wind, energy from sun and biomass. The kinetic energy of the wind can be converted into usable form. The generators can be used to convert wind power into electricity. Most share of renewable energy that is used for generation is of wind power about 13GW nearly 70%. Hydro electric power is near about 16%. The rest of the generation by renewable energy is distributed among biogases (8%) and biomass-based power from agro residues (5%). In year 2015, the power generated from wind subject to near about 8.5% of India's total installed power generation capacity. One of the major Challenge for wind energy is the lack of financial inducement to change the older WTGs. With the decontrolled environmental conditions, power aspect and dependability have become an important factor for the growth of latest technologies. DG technologies such as photovoltaic systems, wind turbine, fuel cell, diesel engines are used in various places.

A WDHS is an isolated system comprising WTG along with a DG, Ni-Cd battery based energy storage source and a dump load provides the supply to consumer load. There are three modes of operation in the WDHS: Wind diesel mode, Wind only and Diesel only mode. In Wind only mode the WTG and BESS supplies the active power and reactive power is supplied by the capacitor bank and BESS. In Diesel only mode active and reactive power are supplied by DG and BESS. In the Wind Diesel mode both WTG and DG connected. The other modes of operation are done by the use of clutch.

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There are so many papers which have been published on the subject of WDHS. This is the vast area of renewable energy. In [1] the modeling and simulation of isolated WDHS with BESS is described and the performance of the WDHS is tested through dynamic simulation. The simulation of high penetration WDHS with a Ni-Cd battery energy source is simulated in [2], it also described the use of clutch system and control scheme of active power. WDHS is simulated against several perturbations without having any storage device in [3]. Comparative study of flywheel systems in an isolated wind plant is presented in [4].

II. PROPOSED SYSTEM BLOCK DIAGRAM

The WDHS comprises of one WTG, one DG, Consumer load and dump load along with BESS connected through current controlled inverter (CCI) and transformer is used to isolate the BESS to the whole system. The layout of the system is shown in the Figure 1. Wind diesel system is designed [6] is such that WTG and DG are connected to grid with BESS.

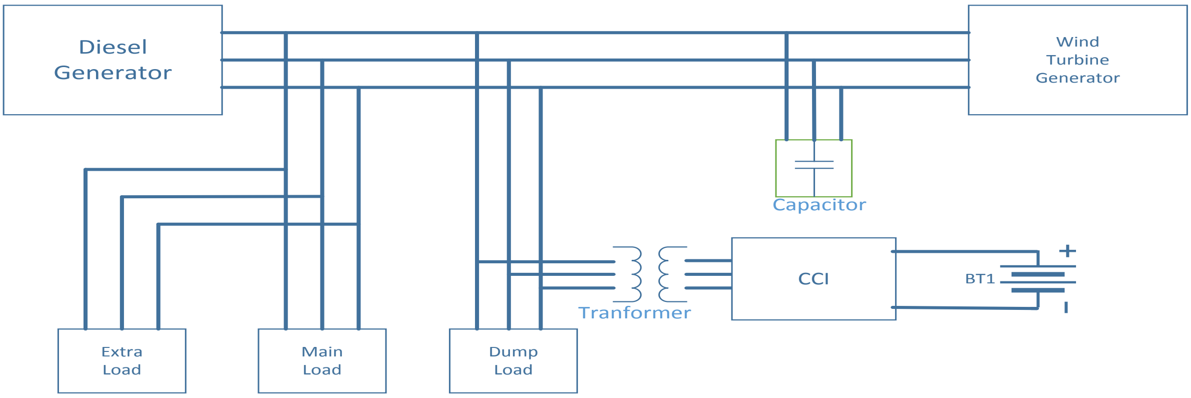

Fig. 1. Layout of WDHS

III. DESIGN OF SYNCHRONOUS MACHINE BASED WIND SYSTEM CONNECTED TO GRID FEEDING RESIDENTIAL LOAD COUPLED WITH DL AND BESS.

The Layout of WDHS for a remote location with the consumer load varying from main load of 125KW and additional load of 100KW is reduced with the help of circuit breaker at t=3sec There is also a DL connected with a capacity of 0- 357KW.

1. Selection of Rating of Synchronous Machine,wind turbine and diesel generator

- The rating of SM is selected as 300 KVA, 480V Frequency 50Hz, Salient Pole Rotor Type.
- The Wind turbine driving a 480V, 275KVA induction generator. The Wind speed is 10m/s.

2. Specification of Battery

- Nickel–Cadmium battery type with 240V nominal voltage and 390.625Ah Rated Capacity.

3. Dump Load

- The dump load consists of series of semiconductor switches and resistive loads. It is of range 357kW. DL consumed power varies discretely in multiples of 1.4 kW.

4. Consumer Load

- Main load, P=175KW
- Extra load, P= -100KW
- Extra load is connected with three-phase circuit breaker.

IV. BATTERY

A BESS[7] is connected to the grid with the help of a LC filter, an IGBT three-phase bidirectional Current Controlled Inverter (CCI) of rated power PS-NOM = 150kW and a 150 kVA elevating transformer. The type of BESS is Ni-Cd of 240V and its model consists of a DC voltage source function of the state of charge (SOC), based on the discharge characteristic of the battery, and an internal resistance of constant value. The energy stored in the battery is 93.75 kWh, which corresponds to a capacity of 390.625Ah (93.75 kWh/240V=390.625Ah). A LC filter is connected to the BESS to determine the charging and discharging time constant. The elevating transformer isolates the three phase power inverter and the battery bank from the autonomous grid. Its rated line to line voltage in the grid/inverter sides are 480/120V AC (transformation ratio=4). The CCI receives its active power reference PS-REF from the power sharing block. PS-REF is used for inverter mode operation or rectifier mode operation. The CCI can control the reactive power it produces/consumes its reference reactive power is set to 0. BESS can be used as the dump load at the time of charging and it can be used as source at the time of discharging, it can be used as either active power source or reactive power. Specification of different types of battery is given in Table1[8].

Types of battery

- Lead-Acid
- Lithium-Ion
- Nickel-Cadmium
- Nickel-Metal-Hydride

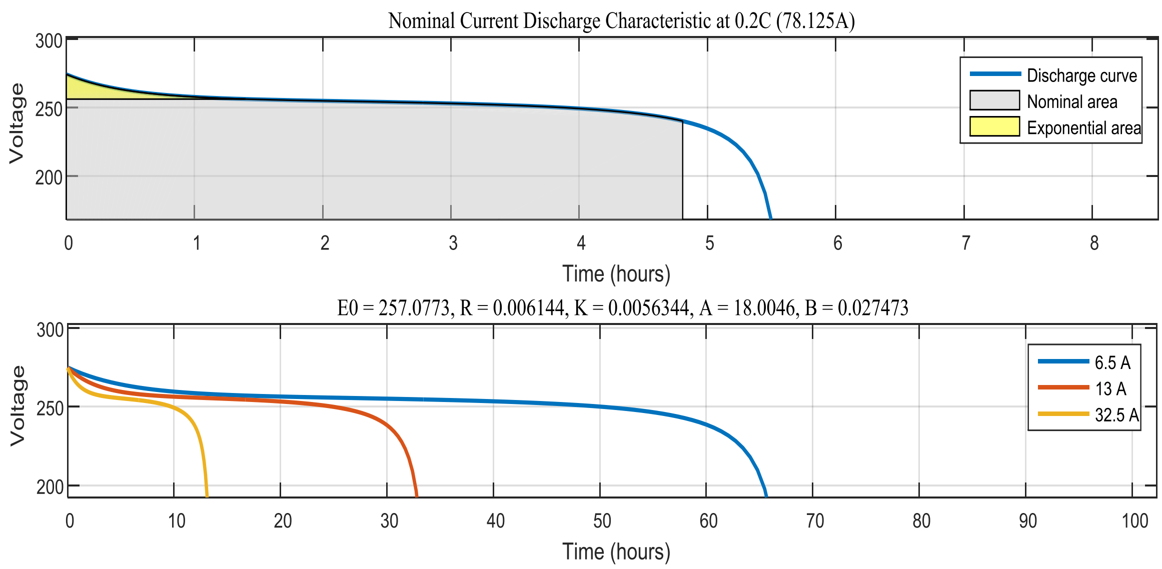

Fig. 2. Battery Characteristics

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4.1. Lead-Acid(Pb-Acid)

Pb-acid [7] batteries are low energy-to-weight ratio, robust, fully proven. When the Pb-acid batteries are used in WHDS increases its internal temperature and may lead to a decrease in the capacity. Pb-lead is a low energy-to-volume ratio; its ability to supply high surge currents means that the cells have a relatively large power-to-weight ratio. Its lower cost makes it attractive for use in WDHS. Pb-lead can also used in all season because it has good performance in bad weather also.

4.2. Lithium-Ion(Li-Ion)

Li-ion batteries [7] provide heavy power and energy densities. Its voltage rating is 3.6V so require lesser no. of series batteries. The discharge rate is very high, life cycle is very long. Li-on batteries have impedance greater than that of the Ni-Cd batteries. Lithium is a very reactive element and provisions are necessary to keep the safety operation limits. As Li-ion batteries become commonplace in high power systems by reducing the initial costs, they will eventually be used for WDHS. The newer lithium–sulfur batteries have the highest performance-to-weight ratio. It contains a flammable electrolyte and is kept pressurized Li-ion batteries so it can be dangerous under some conditions and can pose a safety hazard. It is costlier than other batteries.

4.3. Nickel-Cadmium(Ni-Cd)

Ni-Cd[7] batteries have good energy density and can tolerate the AC ripples. High discharge rates are possible because of low internal resistance. It can tolerate high range of temperature. Ni-Cd battery has a terminal voltage of around 1.2 volts. It is available in wide range of sizes and capacities. Compared with other types of batteries they offer good cycle life and performed at low temperatures with a good capacity but their advantage is the ability to deliver practically their full rated capacity at high discharge rates. Cadmium is also a heavy metal requiring special provisions for disposal. However, the materials are more costly than that of the lead acid battery, and the cells have high self-discharge rates. It is costlier than Pb-acid batteries but cheaper than the Ni-MH or Li-Ion batteries.

4.4. Nickel-Metal-Hydride(Ni-MH)

The energy density and power capacity is higher than Ni-Cd batteries. Its terminal voltage is 1.2 V that makes higher no. of series cells to achieve the operation voltage. The self-discharge rate of the Ni-MH[7] batteries can be ten times higher than that of the Ni-Cd and Pb-acid batteries. Ni-MH batteries, just like Ni-Cd batteries, tolerate AC ripple and allow high discharge rates with a wide range of operation temperature. Ni-MH batteries have a shorter lifespan, that’s why it will costlier than the other one. Ni-MH batteries can be used in WDHS where is difficult to comply with the disposal requirements.

Table1. Specification of Different Types of Battery

	Pb-acid	Ni-cd	Ni-MH	Li-ion
Commercial	1881	1951	1990	1991
Cell voltage	2.0	1.2	1.2	3.6
Specific power (W/kg)	180	150	250	760
Specific power (Wh/kg)	30-40	40-60	30-80	90-150
Energy density (Wh/l)	60-75	50-150	150-300	200-250
Max discharge rare (C)	10	30	20	40
Cycle number	500-800	2000	1500	1200
Self-discharge (%monthly)	3-4	20	30	5-10
Temperature range (degC)	-15 to 60	-40 to 60	-20 to 60	5 to 50
Cost($/kwh)	150	400-800	250	300

V. MATLAB BASED MODELLIND AND RESULT

The Matlab-Simulink model of the WDHS of Fig. 1 is shown in Fig. . SM and its voltage regulator, IG with Wind turbine the consumer load, the 3-phase CB and Battery etc. blocks are available in the Sim Power Systems library for Simulink.

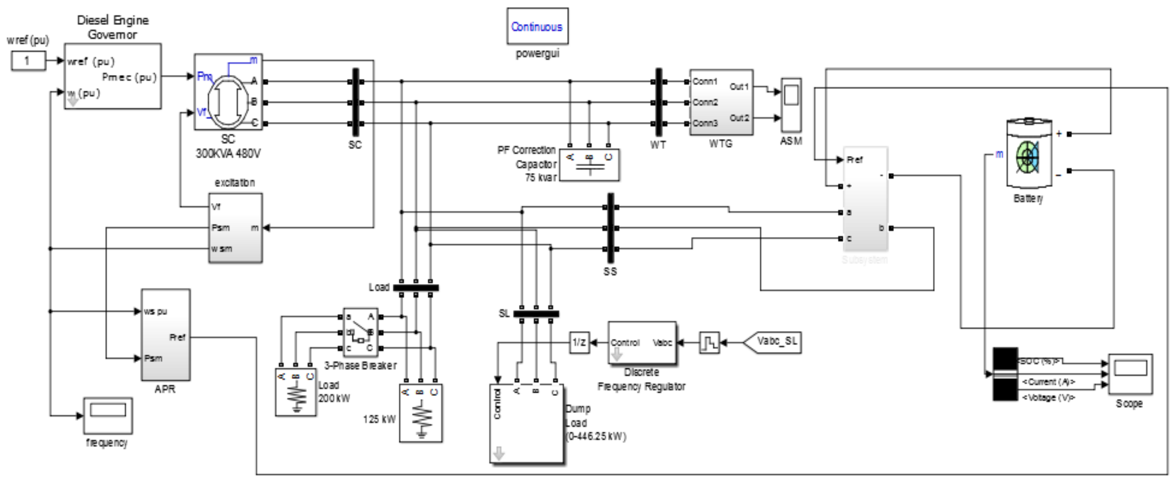

Fig.3. Matlab Simulink model of WDHS

In the presented paper the WDHS system responds to a change in consumer load of -100kW at 3sec. Generally this sudden drastic change will not happen in real system. In the real system the changes in wind speed and laod is slightly smoother and more progressive. So here the presented case be taken as the worst cases in order to test the validity of the isolated system. In the section below various graphs for different terms are shown: Voltage and current in per unit (pu) at the DL bus bar. The frequency drop at t= 3sec. in pu, the active powers for the WTG, DG, consumer load is observed in figure.

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Fig.4 shows the voltage per unit. It shows that there is constant 1 per unit voltage in the system. In fig.5 frequency per unit shown, in this figure frequency is stablized in period 0 to 3 sec. and at 3 sec there is reduction of load of 100kw due to that freq increases at that instance and after 4 sec it becomes stable. In the fig.6 all the power is shown these are: consumer load, diesel generated power, wind generated power, and BESS power. Initially the consumer load is 275kW and and 3 sec consumer power is decreased by 100kw. according to the consumer power diesel generated power, wind generated power, and BESS power changes.

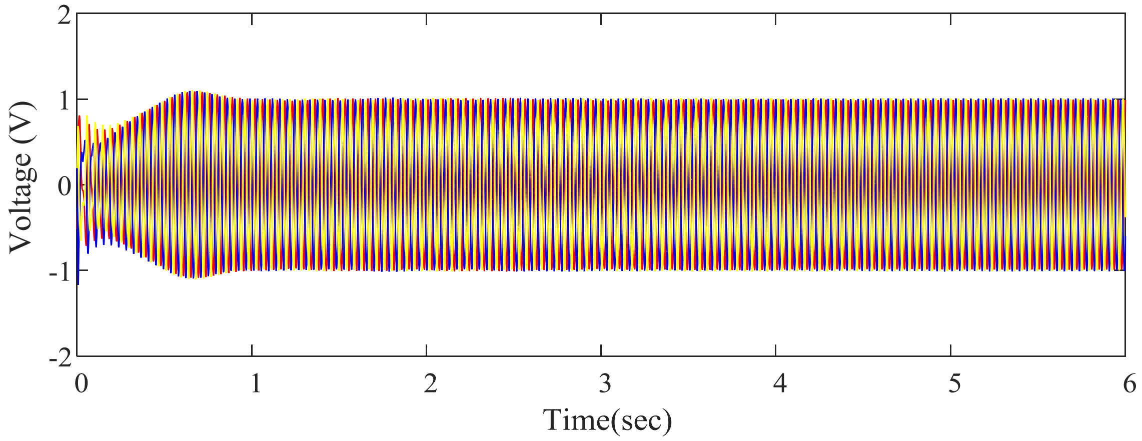

Fig.4. Voltage (Pu)

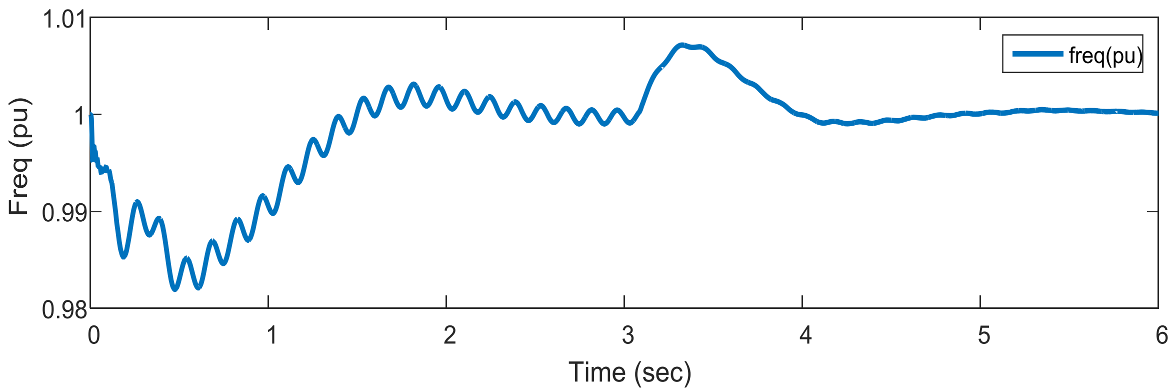

Fig.5. Frequency (Pu)

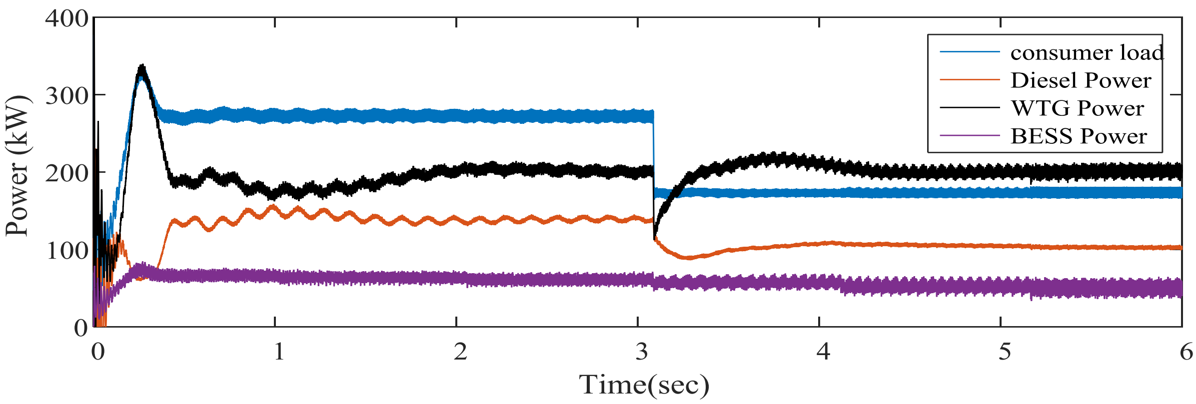

Fig. 6. Active Power

VI. CONCLUSION

The Wind Diesel energy system is coupled to the AC grid and the residential load, in between components modeling have been presented focusing on the APR, DL, SM. Circuit breakers closing is done to check the instant reaction of frequency regulator according to active power demand. DL charge controller is not only capable of disconnecting the wind turbine from feeding excess generation to loads and it is also capable of switching the wind turbines connection to the diversion load.The WDHS system has been simulated using Matlab-simulink and is gives satisfactory results. After varying the load on the system the system becomes stable after some time as shown in results. The above result shows we can use WDHS system for power generating and use Ni-Cd battery for the system more economic. The WDHS components modeling have been presented focusing on wind diesel mode of operation.

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