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Hybrid usage of Photo Voltaic and Wind Turbine Systems to attain Self-Sustainability of electric power in Waste water Treatment Plant

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ABSTRACT

The self-sustainability of power for a waste water Treatment plant by using a hybrid combination of power generation using photo voltaic and wind turbine is analyzed in this paper. Attaining self-sustainability of electric power using zero carbon emission renewable energy sources is the primary objective of this project. The study estimated the requirement of electric power by a waste water treatment plant and the individual contribution of photo voltaic and wind turbine under various time intervals and their corresponding electrical power rating. The simulation of the entire concept was performed using MATLAB/SIMULINK simpower system block set and the outputs are validated with practical values.

Keywords: Permanent Magnet Synchronous Generator, Renewable Energy, Photo voltaic, Waste Water Treatment, Wind Turbine

1. INTRODUCTION

Zero carbon emission and reduced maintenance cost of renewable energy sources along with the exponential increase in energy demands with continuous depletion of fossil fuels are resulting in the switchover of energy generation from conventional generation methods to non-conventional renewable energy sources like solar photo voltaic generation and wind energy generation system (S. Rehman, 2007). Difficulties in erecting distribution lines and cables at remote locations lead to the erection of standalone electrical energy generation systems (M.Ball, 2007). The idea of the utilization of renewable energy sources is commonly related with sustainability. A sustainable energy system is defined as a cost-effective, reliable and environment friendly energy system that effectively utilizes local resources and networks (A.Hepbasli, 2008). For providing a sustainable energy supply, renewable energy sources appear to be one of the most efficient and effective solutions (A. Kornelakis, 2010). Apart from small residential applications, industrial establishments like waste water treatment plants are preferring standalone renewable energy sources to achieve their self-sustainability of power and to achieve the relatively high energy demand. Use of renewable energy sources will reduce the operating cost which have increased substantially in the recent past due to increase in the unit cost of energy generated (S. A. Tassou, 1988). The proposed hybrid power system produces zero hydro carbon emissions in to the atmosphere. The system is designed in MATLAB for an average outflow of 5000 m^3/day approximately with total tolerance of 10%.

2. Electrical Loading of Plant: Wastewater treatment plants are often the largest consumer of electric energy when compared to most of the other house hold or industrial loads. Energy requirements in waste-water treatment are mainly for pumping, primary treatment, secondary treatment, space heating, and sludge heating and disposal [S. A. Tassou et.al.1988]. Plant loads according to its design & installation were grouped, and distributed throughout their working hours to form the load profile. The simulation is performed for a plant with a peak load capacity of 200 kW & minimum load of 100 kW. Diversity factor is relatively low compared to residential loads because the aeration system in waste water treatment plant represents a large percentage of total plant power demand with a maximum power deviation of 22% with 175kw average power. Based on this load profile and the results obtained in simulation the power is equally shared by both photovoltaic and wind energy generation system.

3. MODELING OF SYSTEM USING MATLAB

The performance of both wind energy conversion system and solar panels are simulated and verified using MATLAB/SIMULINK software. MATLAB is a high level object oriented programming language with an interactive environment called simulink which can be used to collaborate and analyze energy generation related ideas with its control systems. Matlab R2014a which is the latest version is used for obtaining the performance characteristics of the generating systems by using a scope for obtaining the continuous values and display for obtaining the instantaneous value.

3.1 Renewable energy source modeling: Two renewable energy sources viz. solar and wind are modeled in the program.

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The rating and energy potential of solar & wind generation are determined by the solar radiation and wind speed respectively. The annual average radiation of the site per unit area of horizontal surface is 5kWh/m^2/day. The plant site average wind speed is 5 m/s whereas the optimum wind speed is 6m/s. whereas the rated power of new wind machines has in-creased year by year, the corresponding capital cost per kW has dropped. The current installation costs for an onshore wind farm ranges between Rs.5000/ kW and Rs.7000/kW. Smaller wind farm or residential scale turbines cost less overall, but are more expensive per kilowatt of energy producing capacity. Wind turbines of few kilowatts cost roughly around Rs.15000 to Rs.25000 per kilowatt of capacity. Medium size permanent magnet wind turbine system, as the one modeled would cost typically 120000 Rs./kw. In order to obtain most accurate results during simulation, market prices and standard ratings of turbines are entered as technical specifications in the simulation. The stator phase resistance and inductance are taken as 0.01 ohm and 0.5mH respectively. The three phase permanent magnet synchronous machine is simulate with a sinusoidal back emf in the dq rotor reference frame.

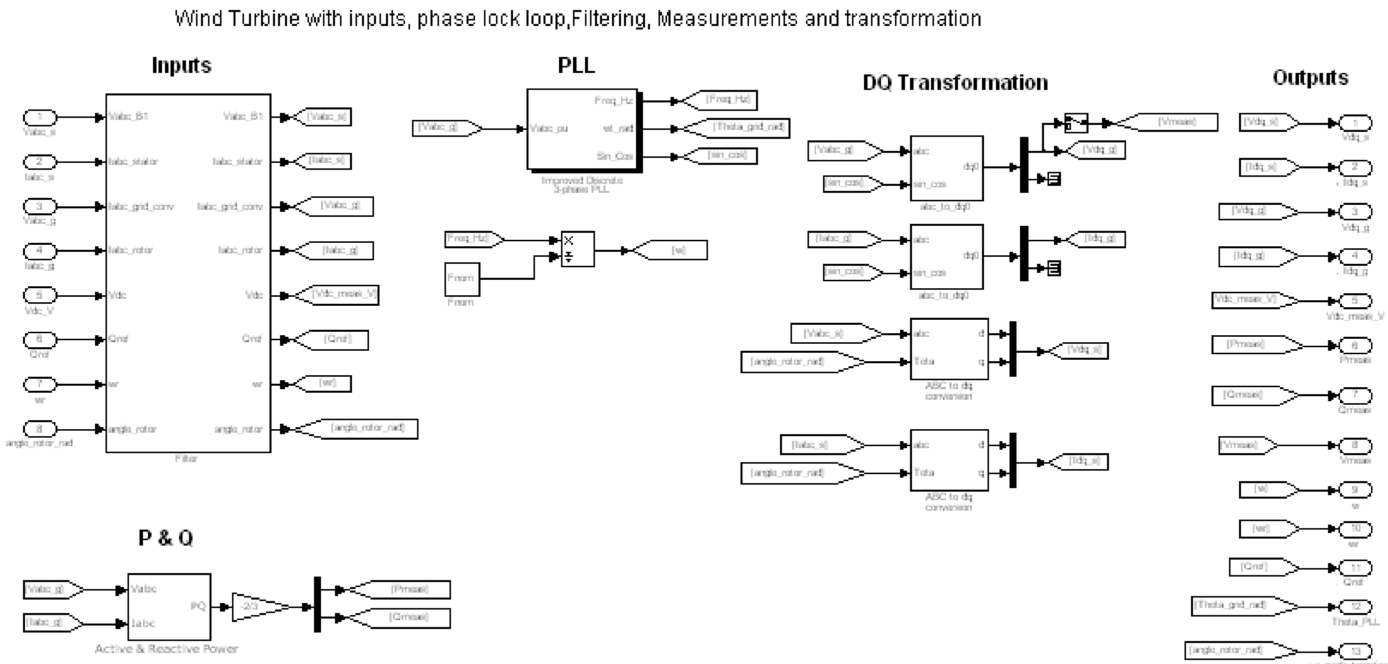

Fig.1 MATLAB simulation of (PMSG) wind turbine with dq-transformation and phase lock loop (PLL)

Table 1: Monthly inference of Solar radiation and Wind speed.

Month	Daily Radiation (KWh/-m^2/day)	Wind Speed (m/s)
January	3.5	4.7
February	4.25	5.15
March	5.3	5.1
April	6.5	4.8
May	7.15	4.8
June	7.75	4.7
July	7.5	4.75
August	6.95	4.8
September	6.2	4.85
October	4.8	4.75
November	3.75	4.5
December	3.2	4.8

3.2. Battery Bank & Other Components Modeling: The output of PV system has to be stored in a battery bank so that it can be retrieved whenever the plant requires electric energy during the absence of energy from the wind turbine. Cost of PV system is based on the market rate during 2014 for medium size photo voltaic systems (100 - 200 kW). Both the technical and commercial datas were collected as done so in the previous referred projects and papers. The converters on the source and load side for both the photo voltaic and the wind turbine were designed and simulated along with the filters and the battery bank. The filters were designed to reduce ripple content in the output. The inverter is priced at 25000 Rs/kW on an average which is typically confirmed to commercial market price. For battery system, commercial cost is according to the type of battery selected in the program. Since the output of PV & wind turbine system are variable, the software would decide which source is to be connected to the plant and the status of the other generating sytem. The optimum system is defined as the system combination which satisfies the user defined constraints at the lowest life cycle cost and the installation cost. The size of the battery bank is largely decided by the rating of the solar photo voltaic panel.

4. RESULTS AND DISCUSSION

The power rating and energy contribution under various time intervals and the performance indices are listed in Table 2. The viewed result in every category is the optimum result of this category; which states the size of each component of the system that grants the lowest lifecycle cost. The energy from solar voltaic is stored in battery bank and then tapped from it whenever there is an energy deficit from the wind generation. When the wind speed is optimum the entire energy is drawn from the wind turbine and the energy from solar photo voltaic is stored in battery. Optimum category in each scenario uses both the components simultaneously. Table 2 showed that the best connection topology is when coupling both PV & WTS systems to the DC bus through an average total generation of 504000 Kwhr/year. PV system is best coupled individually to DC bus in sites with very poor wind and the wind turbine system is coupled individually to DC bus when the solar radiation is very less.

4.1 Wind Turbine System: The wind turbine system has a maximum capacity of 175Kw and a mean output of 85Kw. So the total energy produced per year from wind energy system is 306000KWhr/yr. Results for photovoltaic & wind turbine systems are summarized in **Table 2**. Photo Voltaic system has low capacity factor as it shuts down in the night and poor wind speed in the site caused the same capacity factor. In addition, the weak wind resource caused the effective NPC/kW of turbine very close to the NPC/kW for the PV system. The real and reactive power contribution by the system at various time interval has also been obtained from the simulation.

4.2 PV System: The photovoltaic system has a maximum capacity of 90Kw and its mean output is 55Kw. So the total energy produced per year was 198000 Kwhr/year. Wind turbine system and photo voltaic system contributed power equally and they complimented each other. The output of the solar photo voltaic system was optimized by using maximum power point tracking (MPPT) algorithm. To convert the DC power generated by PV system to AC an inverter circuit was used.

4.3 Battery Storage System: Battery storage system comes in the 2nd order as the highest NPC after the fuel cell. This is because the num-ber of batteries installed is relatively high. This high num-ber was required to match the variable nature of solar & wind energy. The reason for installing this high quantity of batteries (90 strings, 48 volts) as shown in **Figure 2** that the wind speed sometimes stays below the cut-in speed of the turbine resulting zero power output of the WTS system. If this occurrence takes place in the night while PV system is shut down, it falls only to the battery system to cover the electrical demand with the SOFC-MT hybrid system. Battery system can be further mini-mized if turbine cut-in speed is lower.

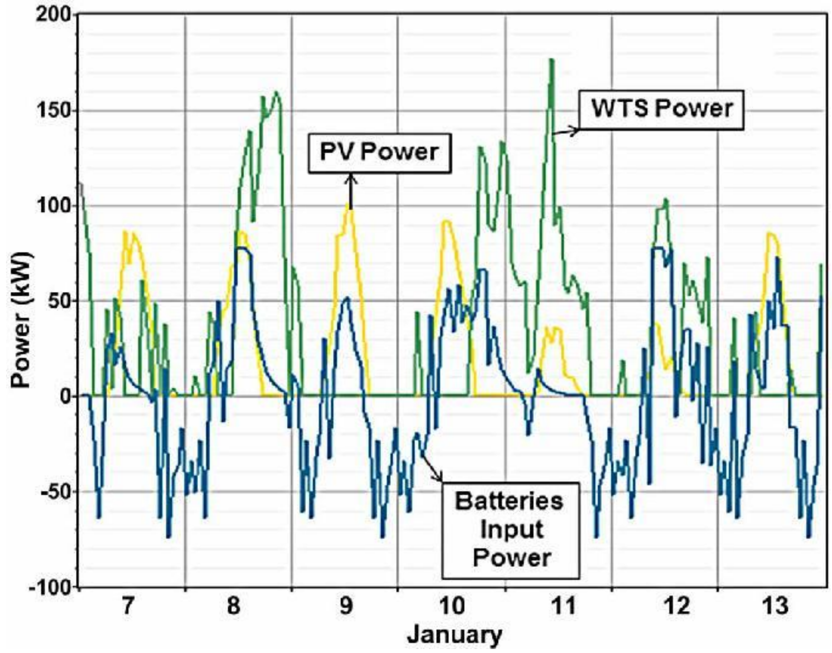

Figure.2.Power contribution by individual sources and battery bank

Table.2.Photo Voltaic and Wind Turbine System output

Parameters	PV	WTS	Units
Rated capacity	100	200	kW
Maximum output	90	175	kW
Mean output	55	85	kW
Energy production/year	198,000	306000	kWh/yr

5. CONCLUSION

This paper evaluated the power rating and duration of operation of solar and wind turbines both independently and together to meet the electric power demand of a Waster water treatment plant. The system serves a wastewater treatment plant using energy sources which are entirely renewable. The Software simulation and optimization results of a 200 kW wind turbine system, 100 kW PV system are obtained. Results show that the best connection topology is obtained by connecting and synchronizing the outputs of both PV & wind turbine systems to the DC bus. Battery storage system to sustain the supply in the absence of power from wind turbine was found expensive.

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