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Integration of Solar and Wind Energy System for Hybrid Power Generation

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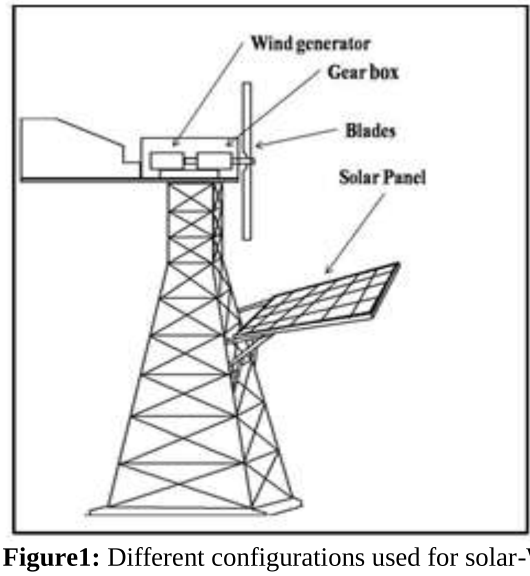
Abstract: *With the increased global warming concern it is becoming important to find an alternative to conventional energy sources causing less pollution and leading to sustainable use of available resources. This has encouraged renewable energy generation to become a leader in energy sector but the main obstacle in its path is its cost effectiveness. This has motivated for combining two or more renewable energy resources i.e. hybrid power generation. The paper deals with the study and design of hybrid system of solar and wind energy for rural area's electrification*

Keywords - *Flexible solar panels, hybrid power system, PWM charge controller, rural electrification, sine wave inverter, and vertical axis wind turbine.*

I. Introduction

Solar and wind hybrid generation is most popular power generation method as these are available readily everywhere. This paper focuses on design aspects and fabrication of hybrid power generation model. Hybrid energy generation is turning out to be a more popular method of distributing electricity in rural areas and in urban areas as well where the land constraint play a major role. Hybrid model proposed here combines solar panels and vertical axis wind turbine and provides continuous supply with increased reliability [5] [6]. This Hybrid renewable Generation system can become the best solution for feeding the mini-grids and isolated loads in remote areas. The system can also provide an answer for the individual energy concern. Higher total energy efficiency, improved operational performance, dispatch and operational control can be obtained through the proper technology selection and generation unit sizing. Researchers and engineers are developing different configurations to utilize the system component effectively. The figures below show such two kinds of arrangements used for the hybrid generation system.



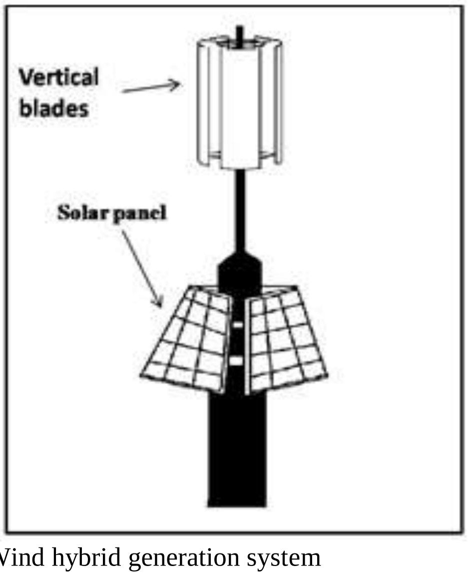


Figure1: Different configurations used for solar-Wind hybrid generation system

Horizontal axis wind turbine system, which is most of the time used in wind farm, produces energy generally in MW; but its installation and maintenance cost are high whereas the vertical axis machines are cost and size effective, hence useful for small scale applications [1][7]. Many countries are also providing fund and assistance for building it in order to satisfy the need of electricity. In India, central as well as state governments are spreading awareness and guiding people for its expansion. Maharashtra State Energy Development Agency (MEDA) is one of government institution, who promotes renewable energy systems. Following list shows year wise achievement of wind and solar hybrid systems and its progress in the state of Maharashtra, India.

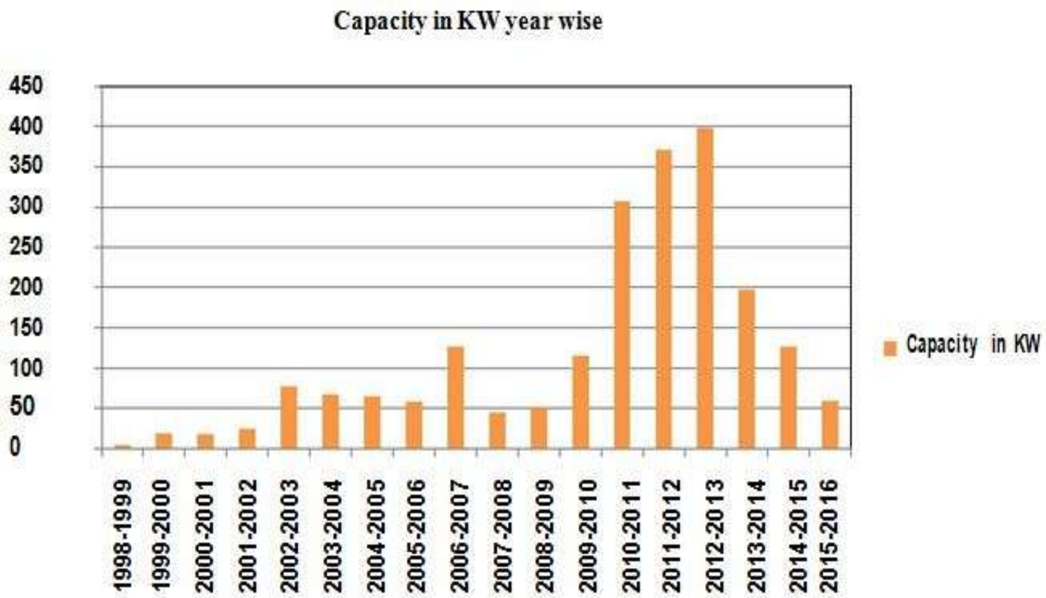


Figure 2: Progress of solar-wind hybrid system in Maharashtra state

II. Design Prerequisite and Criteria

The data collection and analysis included energy requirements, mean annual hourly wind speed in m/s, location of installation and installation structure, energy storage system, annual mean daily duration of sunshine hours and daily horizontal solar radiation in Kwh/m2/day. The calculations of electricity generation estimation from the wind turbine, system installation capacity and battery sizing are done based on data analysis and load requirement. The charge controller and inverter are designed and fabricated for the proposed model.

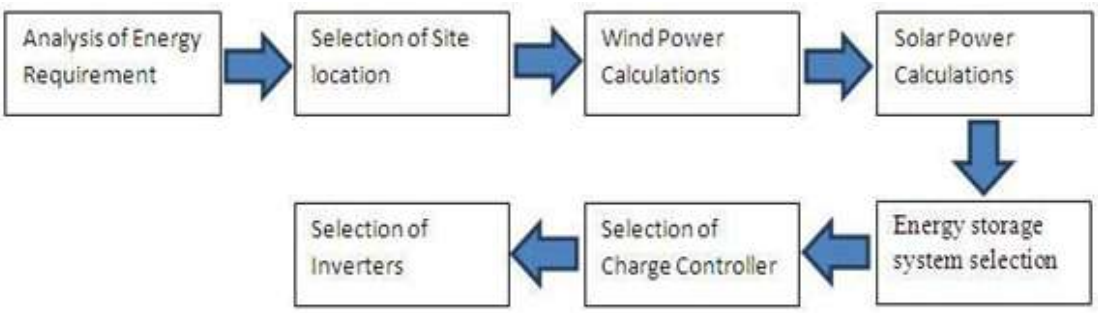


Figure3: Block diagram of the process flow for data reacquisition

1. Analysis of Energy Requirement:
   This is the foremost step which needs to be carried out, where the load which the hybrid plant will be supplying is selected. Load flow studies may also be performed while analyzing the load which will be powered by the hybrid plant.
2. Wind Power Calculations:
   The size of the wind blades and the wind speed (in m/s) values are substituted in the formula below, which yields the wind power which will be available for energy generation

The power generated by wind energy is given by,
Power = (density of air * swept area*velocity cubed)/2

$$PW = ½* ñ* (AW)* (V)^3$$

Where,
P is power in watts (W).
ñ is the air density in kilograms per cubic meter (kg/m³).
AW is the area swept by air in square meters (m²).
V is the wind speed in meters per second (m/s).

3. Solar Power Calculation:
To determine the size of PV modules, the required energy consumption must be estimated. Therefore, the power is calculated as
Solar Power = Ir * A*Eff (PV)
Where,
2
Ir is the Irradiance (W/ m) at the plant location.
2A is the Area of single PV panel (m).
Eff (PV) is the overall efficiency of the PV panels and dc/dc converters.
4. Energy Storage System:
The Energy storage system is chosen according to the load and as per the requirements. A number of studies also need to be conducted in order to select the Storage system which best fits the particular load constraints.

III. System Description and Working

In the proposed model, a charge controller is used to regulate the power generated by both solar panels and the wind turbine [3]. It also simultaneously charges battery and gives power to the load. The controller has over-charge protection and short-circuits protection. A specifically chosen battery is used to store the generated power.

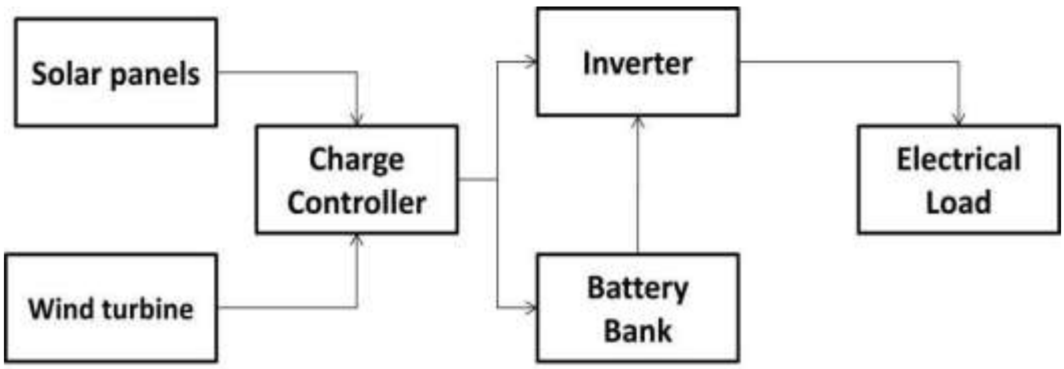


Figure 4: Block Diagram of proposed system

IV. Pwm Charge Controller Design and Invertors

Charge controller:
A Charge controller, considered as a heart of solar generation system, is used to regulate the voltages and current coming from the solar panels and wind generator. It regulates the charge to the batteries preventing any overcharging.
Types of charge controller are:
1. ON OFF2. PWM 3. MPPT

ON OFF type is the simplest type with just monitoring the battery voltages and currents and opening, stopping, closing the circuit according the battery voltage rise to predefined level. MPPT is the one with high efficiency and cost, whereas PWM is simpler and cost-effective [2].

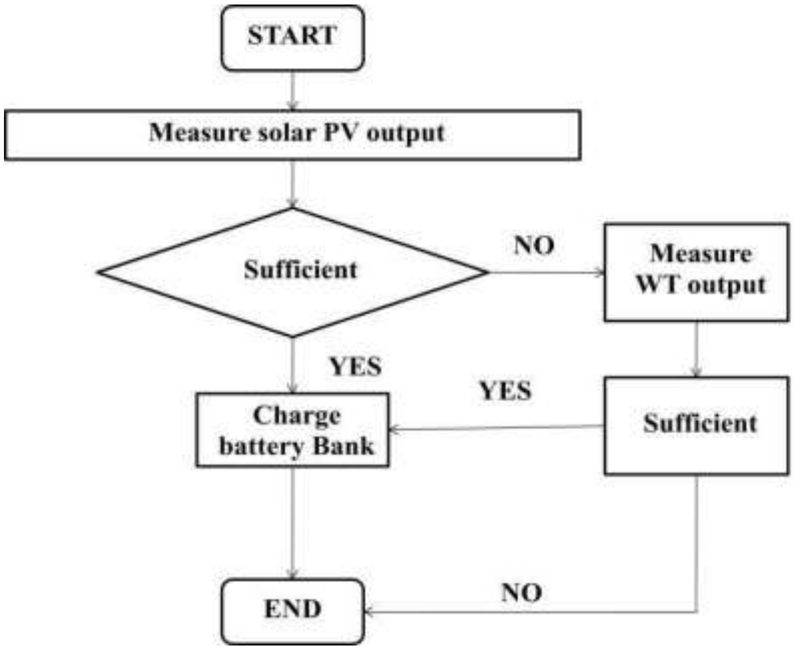


Figure 5: Flow diagram of working of charge controller

A Charge controller has higher charging efficiency, reduces battery overheating, and minimizes stress on battery, which ensures longer battery life. This charge controller is made using Arduino nano board. According to the difference in solar generator voltage, wind generator voltage and battery voltage, Arduino decides the extent and duration of charging. The difference between the battery voltage and set point voltages, determines the charging current. Fixed frequency of PWM signal to the solar panel side of P-MOSFET is 490.20 Hz. The duty cycle is varied from 0-100%, as the error signal changes. According to standard practices, the sizing of solar charge controller is to take short circuit current of the PV array, and multiply it by 1.3. So if PV module have I_{sc} rating as 7.5 A and there are 4 panels then solar charge controller rating will be greater than (4*7.5) 39 A, hence a 40 A current rated inverter will be fine.

Inverter:

Inverter ratings depend upon the load of the system. There are three basics types of inverter, they are:-

1. Square wave
2. Modified sine wave
3. Pure sine wave

Out of these three types the pure sine wave inverter is the most suitable type for all appliances. For standalone system the inverter must be large enough to handle the total amount of watts using at a time. The inverter must have same nominal voltage as battery. The inverter size should be 20-30% more than the total watts of appliances. So for a load of 153 W, inverter will be of 190 W. For grid tie systems or grid connected systems, the rating of the inverter should be same as PV array rating to allow for safe and efficient operation.

V. Results and Discussion

This paper provides a summary of available approaches and those currently under research for optimal design of hybrid renewable energy systems. The Current statuses, research, vision for the future of RE power generation technologies have been discussed. The review has also discussed the efficiency calculations and procedure required in development of hybrid RE systems. The resulting energy system serves local stationary and LV-based mobile consumers, and it is a good citizen within the main grid as it reduces emissions by local usage of wind and solar energy. The solar and wind generator power outputs can be maximized using MPPT control systems and algorithms. It was also observed that wind and solar are complementary since sunny days are usually calm and strong winds are often accompanied by cloud and may occur at night. The charging of the battery by the wind turbine greatly depends on the rotational speed of the blade which in turn depends on the wind speed. As the machine size is small, cost of machine is comparatively lower than the available power generator and can easily be installed where the power requirement is small like on the terrace of building, gardens, commercial buildings, small industries etc. The only advantage at which this system lacks is that the initial and installation cost of machine is higher compare to available energy generating systems, but it can be recovered within few years as it has very less maintenance cost. Energy generated after breakeven point is very cheaper compare to available energy.

Overall it is a reliable and affordable solution for electricity generation.

VI. Conclusion

A hybrid power generation system is better solution for power generation than conventional energy resources especially in rural areas where electricity is not stable or absent. The power generated can be utilized in situ thereby reducing transmission losses and cost. The designed hybrid system is very compact, easy to install and ensures no power failure by solar during the day and wind during the night. As the idea is in its initial stage, so productive changes may be implemented in later stages. It is highly safe for the environment having long life span and only need initial investment thus overall it is good, reliable and affordable solution for electricity generation.

VII. Future Scope

The proposed hybrid system model can also be erected in the path of rail road where high pressure of wind is developed by motion of the train. When manufactured on a large scale, power generation cost of this system will reduce. Excitonic solar cells can be used which has Tatiana nanotube arrays that shows considerable promise to harness a larger fraction of the solar spectrum. This will ultimately make this system more reliable and efficient. India recently proposed to augment cooking, lighting, and motive power with renewable in 600,000 villages by 2032, starting with 10,000 remote UN-electrified villages by 2012. India's new feed-in tariff was capped at 50 MW through 2009, although a second policy phase may increase the program cap to 1,000 MW. The tariff provides up to 12 Rupees per kWh for Solar PV projects promising a 10-year commitment with a cap of 50 MW. The proposed system can provide power to remote places where government is unable to reach. This will reduce the transmission losses and cost. By interconnecting these systems load sharing can be done. The power to the loads can be equally shared. Thus the power can be regularized.

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