Hybrid Solar and Wind Turbine System: A Review

Sudhanshu Shekhar[1]Dr. Uzma Qureshi[2]

[1.]*Research Scholar Mechanical Engineering Department, SSSCE, RKDF University Bhopal*

[2.]*Professor and HOD of Mechanical Engineering Department,SSSCE,RKDF University Bhopal*

Abstract - Energy is one of the most important things which direct the world toprogress and opulence through various means of growth, like education, technology, transportation, trade, health and various other important aspects. In the beginning we had adequate amount of natural resources and fossil fuel storage by which we used to accomplish our energy needs, but in view of the fact that 3 decades enormous development in all kinds of technological over and above in socio- economical areas took place. Our former source of energy is electricity, and the demand of electricity is increasing day by day on escalating rate as the population of the world is increasing.

This disaster escorts researchers and scholars to move towards the alternate and sustainable source of energy i.e. renewable source of energy. Renewable energy may be obtained or extracted through sun, wind, tides, ocean, geothermal, hydel power plant etc. These all are received from the nature directly and are never ending.

This creates lots of new possibilities for future energy generations for mass. The aim of this work is to investigate the results and efficiency of electricity generated from integrated solar-wind hybrid system to a remote locations t rich in receiving peak sunshine and winds being a

plain land throughout the year. This review presents the several papers in which as a hybrid system solar and wind turbine are taken. But In some cases, authors or researcher concentrates only either on the solar based system or wind based systems and analyzed the power generation and oits comparison. Inthis aspect the system is very useful for the researchers.

Keywords: Hybrid system, Wind and solar system, Energy generation, Solar Panels,efficiency

I. INTRODUCTION

For the economic growth and development of the whole nation and even the whole world energy became a very important criterion. And the demands of energy increasing day by day at an accelerated rate for more better living standards. Almost all countries of the globe are involved inthe improvements in energy infrastructure and economic growth. For the purpose researchers are very much involved towards the development and generation of newest sources of energy. Energy services meet the basic human requirements, contemporary energy services focus on step up of environment, by reducing the pollution caused by underperforming equipment and processes and negligence of energy resources.

Current energy consumption rate, proved that coal reserves should end within 100 years, oil & gas for approximately 50 years and natural gas for roughly 55 years. With the disagreement between rapid development and retreating fossil fuel resource, as well as to circumvent pollutant emissions or other ecological troubles, and not to involve the consequential health hazard, we should consider the manner in which we produce and consume energy for sustainable development. Energy generated from solar, wind, biomass, geo-thermal, hydropower and ocean resources, could increase multiplicity of energy supplies and offer us clean energy beyond all doubt. Photovoltaic (PV) cells are based on photovoltaic effects of semiconductor and harness solar energy from sunlight to produce electricity. PV modules commercially possess maximum efficiency in the order of 35%.

On the other hand, Wind Energy may be generated through the specially designed vertical or horizontal axis speed in the wind is prerequisite for the generation of electricity as a wind with high velocity about 12m/s may contribute in the generation of electricity through aerodynamically designed wind turbine blades this speedy wind strikes the blade of wind turbine and made it ready to rotate at a faster rate which in turn generate the electricity which can be stored in the battery bank. The shaft connected to generator through optimized & specially designed gear trains producing electricity all weather, this energy is then stored in series of batteries, hence becoming the best ever growing renewable energy technology all over the world.

Photovoltaic panels and wind turbines are now extensively used globally in such locations where it might be difficult or costly to use conventional grid supplies. People who are selecting the non-conventional energy resources prefer to connect their energy system to the grid as a huge battery for some convenient grid-tied situation. On the contrary, especially in rural areas electricity grids are frequently non- existing and all forms of energy are generally very pricey in several developing countries. Here PV modules and wind turbines may be highly cutthroat with other forms of energy supply. However, the fact that natural energy resources are irregular and storage batteries are costly, this has led to the utilization of supposed hybrid renewable energy systems. Any power system that

incorporates two or more of the following is referred to as a hybrid power system: PV panels, wind turbines, or diesel, propane, gasoline generators. For small loads, the most common combinations are PV-wind hybrid system. PV and wind are a good match, because inland wind speeds are poorer in summer, which may be compensated by peak sunshine, and in winters, when sunlight falls to very low levels, the wind speeds are usually sufficient.

II. BASIC THEORY ABOUT WIND ENERGY

Those areas around equator need aid warmed that's only the tip of the iceberg Toward those sun over whatever remains of the globe. The warm colors, red, orange and yellow show the high temp regions in the infra-red picture from claiming ocean surface temperatures (taken from an nasa satellite, NOAA-7 to July 1984). Mossy cup oak renewable vitality Eventually goes from the sun Furthermore 1-2 % of the sun’s vitality arriving at the earth is changed over under wind [Danish wind, 2008]. Contrasts in pneumatic force created Eventually Tom's perusing the uneven warming of the earth's surface Eventually Tom's perusing the sun powers air circulation; and air streams starting with territories of high point should regions from claiming low weight.

Concerning illustration an aftereffect of temperature What's more weight differences, and also the Coriolis Effect, there would different worldwide wind examples toward diverse latitudes. Exchange winds, prevailing westerlies, what’s more polar easterlies are some of the sorts that could make said in this respect. The coriolis power may be the clear redirection about air starting with its way Likewise it moves starting with helter skelter will low weight ranges due to those revolution of the world. Other wind assets for example, Geostrophic Winds, surface Winds, neighborhood Winds (as for ocean Breezes), mountain winds, and so forth throughout this way, observing and stock arrangement of all instrumentation may be enhancing. Ought further to bolster Additionally make noted [Danish wind, 2008].

III. BASIC THEORY RELATED WITH THE SOLAR ENERGY

General information about solar power is found in the following references [Duffie and Beckman, 1991] [Markvart, 2000]. The sun radiates energy radially, from an effective surface temperature of about 5760 K, as electromagnetic radiation known as `solar energy' or sunshine. The earth is situated at about 150 million km from the sun with a total surface area of about 510 million km2, of which only about 21% is land. A substantial portion of the solar radiation, on its way to reaching the earth’s surface, is attenuated due to atmospheric interventions. Additionally, because of the sun-earth angle concept, the solar radiation received at the earth's surface varies on hourly, daily, or monthly basis. Hourly variation is due to the motion of the sun from east to west, and also due to the presence of clouds, whereas daily variation and monthly (seasonal) variation is due to the position of the sun. Longitude and latitude give the location of a place on the earth's surface. The Sun comes overhead twice a year in the tropical belt. Ethiopia is in the equatorial region which is probably the most favorable region for solar energy. According to the findings of this work, disregarding the rainy season, July and August, the average daily duration of sunshine is approximately 8-10 hours [Bekele and Palm, 2009a]. It is well known that most developing countries do not have properly recorded radiation data. What usually available is sunshine duration data. Solar radiation data is the best source of information for estimating the 26-solar energy potential of a certain location, which is necessary for the proper design of a solar energy conversion system. Ethiopia is one of the developing countries without properly recorded solar radiation data and, like many other countries, what is available is sunshine duration data. However, given a knowledge of the number of sunshine hours and local atmospheric conditions, sunshine duration data can be used to estimate monthly average solar radiation, with the help of empirical equation 2-1 [Duffie and Beckman, 1991].

In this thesis, a PV-wind hybrid system is presented that is installed on the roof of Sri Satya Sai college of Engineering, Gandhinagar Bhopal of 1kW wind turbine and 600 watts PV panels which may be able to produce 1.6kW power to supply power to the department of Mechanical Engineering. The aim of this study is to introduce the local PV-wind hybrid system working principle by reviewing one case where the system is connected to the grid.

IV. HYBRID SYSTEM MODEL

The hybrid system consists of 3 Solar panels of 200 watts each and a wind turbine of 1 kW to generate 1.6 Kw power. This system has been designed and installed on the rooftop of SSSCE RKDF University Bhopal. The hybrid system model is purely Renewable energy system model which receive both the energy Wind as well as solar energy and convert it into useful form of electrical energy. It’s our attempt to use both the energy simultaneously to recover the losses. This project will be helpful to install the system in the remote area to produce electricity for the rural people without interruption. Because wind is available twenty-four hours while the solar energy is available for 8-10 hours so that the energy supply from the hybrid system is uninterrupted, although the energy receive from the system is stored in the suitable form for

the intermittent supply.

V. REVIEW OF PREVIOUS LITERATURE

Literature survey has been carried out to formulate the problem for the current research work. An exhaustive review of available literature mainly published in IEEE transactions has been carried out. This review of available literature consists of several papers which are already published in the IEEE conferences and the journals.

E. Muljadi, C.P. Butterfied [1] worked on the wind turbine with variable speed with pitch control. They also explained about the loads and minimum acceptable speed of the generator to control the wind speed at very high speed. They added that how the wind turbine controls the power production.

They have been suggested two methods to control the power:

(1) Through controlling the Pitch line velocity

(2) Through controlling the generator load.

Meei-Song [2] worked on power system and applied a fuzzy logic to wind generation capacity to calculate the demand of various consumers in different times. He proposed a method and profiling chart of the demand and usage of different consumer.

It can control the cost of energy production from the available energy wind energy effectively by assessing the load summary of particular consumer. It is observed that the wind power generation can substitute economically and efficiently with the diesel power plant and provide partial power supply capability for the net peak load demand.

T.Tanabert, T.Sato [3] discussed on system controls which can be used to fulfill the requirement. Each control system was verified to be practically feasible by simulation result based on an actual network and usage data. Using these data, we can determine adequate capacity of battery which can be enough sufficient for loads. He also discussed about the scheduling of power generation by wind and other plants by controlling direction and speed of wind mill blade and how much energy we can receive from that system. A control system was developed to meet the technical requirements prescribed by the electric power company. These requirements will extend the acceptance limit of connecting wind power generation into the utility grid.

If the demand is fulfilled through the wind generation then it can be practiced in large scale in the form of wind farms.

Through the meteorological data in which regression analysis is to be carried out then the comparison of power production from the available amount of wind energy in a given specific area can be evaluated.

Takaaki Kai and Akio Tanka [4], worked on the performance of conventional power fluctuation to make it smooth running system. They applied two generators to control the power factor and variable speed of wind energy, integrated with (EDLC-electric-double-layer-capacitor system). The circuit of the system consisting from mainly two inverters- (I_a) and (I_b) with a capacitor (C_a) placed between them.

I_a = Inverter a

I_b = Inverter B

C_a = Capacitor

S_1 = active power of the stator and

R_2 = active power of the rotor

W P_g = Sum of wind power generation

The sum of the power fluctuation system output and wind power generation output power (Pg) is defined as the composite output power.

Composite output power= fluctuation system power output + wind power generation output

In this new wind power generation method, the EDLC system is connected to a DC circuit between inverters through a bi-directional DC to DC converter, and the power fluctuation smoothening system is added in the control system of inverter (A). The rated voltage is 1500V of DC circuit between Inverters, and the capacitor of 5 farads is connected to the circuit. The EDLC system is formed by cell module 600S1 (2 in series and 85 in parallels). with rated voltage 150-volt, capacitance 4.7 farads and internal resistance 0.55 Ω.

(Electric double-layer capacitors (EDLC) are electrochemical capacitors which stores energy, and the energy density is determined by specific capacitance (farad/gram or farad/cm^3) and the operating voltage of the battery.

Hiroyuki Mori and Akira Await [5] worked on the effect of several parameters which affects the wind energy either directly or indirectly. This method can be applied to detect the real-time data. The variable parameters may be depending upon the winter and summer condition and it is also depending upon the sea level pressure and direction of air. Sea level pressure affects the speed of wind.

Noriyuki Kimur a, Tomoynki Hamada [6] has been given an idea about Suppression of current peak of PFC converter to induction generator for wind power generation excited by voltage source converter. This work is about the combination of induction generator with electronic equipments. The induction generator cannot generate electricity at lower rotor wind speed. To overcome this problem, expensive synchronous generators with permanent magnets are used. The diode rectifier used to convert the real power from the induction generator to dc voltage. If we use induction generator with VSC, the cost of the wind power generation system may be reduced.

As a substitute of using expensive synchronous generator a low cost cage induction motor is used with Capacitors to compensate the reactive power.

Lu Yuegang, Xi Peiyu [7] discussed about the layers of wind turbine in their work and presented apaper on wind turbine with two control layers

(1) Supervisory Layer & (2) Control layer. The one layer i.e. supervisory layer is designed by Lab VIEW which gives the graphical user interface to control and monitor, whereas the control layer is used to replicate the working of wind power generation system and it is based on MATLAB. In this preparation a mathematical model of wind turbine is designed with the help of these programming software and analysed the result obtained. Control strategy of Double-fed induction generator, variable speed constant frequency (VSCF) wind power generation training system is presented in the work. Major operations taken into consideration like control, MPPT (maximum power point tracking) at lower wind speeds and variable pitch and power control on rated wind speed. By making comparison among these curves correctness and feasibility of these systems are offered.

Ming-Shun Lu et.al. [8] presented a paper on integrated system of the wind power generation with energy storage equipments. With the advancement and rapid growth of wind turbine technologies, the cost of power production from wind energy becoming competitive with other fuel-based resources. Due to the globally increasing demand of energy and accelerating rate of the fossil fuel and no doubt the alarm of the global warming, wind power generation has rapidly developed since the last two decades.

Since it is easier said than done to predict forecast and control the output of the wind generation and its potential impacts on the electric grid are unlike from the conventional energy sources. A system may be generated to compensate short-fall of power output at times when abrupt change of wind takes place at high penetration level and respond fast to use the reserve capacity. To facilitate a proper supervision of the ambiguity, this study presents an approach to make wind power become more reliable source on both energy and capacity by using energy storage devices. Combination of these generation system with energy storage will reduce fluctuations of overall power output. Even though high assets investments for these storage systems are required, so it is important to estimate reasonable storage capacities for desired applications. In addition to that energy storage application for reducing output variation during the flurry wind is also studied.

Bongani Malinga et.al [9] studied the dynamics and control of distributed resources (DRs) in non-regulated power industry'. Since arrival of wind energy is not just limited to selective geographical areas it has now deep penetrated the possibilities of its arrival and feasibility globally and as a result of this deep penetration researchers favors to look at large wind farms as future possibilities of power plants, To achieve most favorable incorporation of high output of wind energy in the generation system ecology, the wind power plant must be able to replace other usual plants, i.e. able to participate in the control and stabilization of the power system. This research covered a way to a different approach to wind turbine modeling and control design methodology. All the outcome be in close agreement with outcome from other studies. The main approach of the controller is to regulate the rotor angular speed and the power demand to equivalent the required profiles. Further continued research illustrates that the most efficient wind turbine has not been build yet and rest of the work lies on how it is controlled.

Wijarn Wangdee, et.al [10] presented that the acceptance to use clean wind energy has increased in last decade as due to being unlike from any more renewable resource. The power generation from wind energy depends upon the location and graphical condition in hilly areas the speed of wind is more so we may generate the large amount of energy. The transmission of power which is generated by wind energy can be considered on the load demand. MECORE software may be used, using a DC-based power flow algorithm. it is a composite generation and transmission system reliability analysis tool. As previously noted, the voltage stability is prevailing to limit the transfer capabilities of the system.

A usual AC-based power flow program was primarily used to explore the transfer limits under system normal (N- 0) and contingency (N-1) situations. After the transfer limits based on voltage stability study. The voltage stability limit can be measured by MECORE using DC based optimal power flow solution. The load duration curve during winter period in which 1,000,000 samples were taken in all MECORE studies in order to achieve the coefficient of

variation with tolerance error less than 1.

Mohammad Zakir Hossain and A.K.M. Sadrul Islam [23] presented a paper on PV-wind hybrid system modeling which is appropriate for operations in rural and remote areas. A PV-wind hybrid setup was developed to simulate a stand-alone power system with battery storage. This model was applied to a typical consumer peak load of one kW at a remote community in Bangladesh. Using the model, various parameters are evaluated for one-year at full operation of the system. Furthermore, an economic analysis has also been carried out to evaluate the feasibility of such a system at considered locations.

Mel George [12] focused on the worldwide handling of renewable energy in utility scale applications continues to increase, it is important to assess the impact on the grid and conventional generation. This report unites the analysis of load and generation characteristics, generation capability and base and peak load variations to gain insights into the future role of wind generation. A simulation of Tamil Nadu state in India which possesses a high penetration of wind power (27% by installed capacity) is also presented here. The savings achieved in traditional generation due to installation of wind power are computed as the capacity credit, using a power system reliability based approach.

Rickgonzalel, Rana Muke Ji [13] observed on the rapidly growing number of renewable power generation locations in the USA. Over the times of yore few years this number has increased significantly. Wind-powered projects plays and important and dominant part of the future NYISO programme. It will support the users to generate and utilize independently.

Florin Lov et.al [14] have been discussed about the very general and detailed description of the wind turbine models through their studies and work they have presented in this paper. During their studies they have developed a toolbox “Simulation Platform to model, optimize and design wind turbines”. This report mainly focuses on the descriptions of important mathematical models that encountered during design and development in the toolbox.

Jiang Chang and Shu-Yun Jia [15] discussed the modeling and application of wind-solar energy hybrid power generation system based on multi-agent technology. Multi-agent system is society made up of several agents, with collaboration of multi-agent, it can optimize control system and enhance its intelligence and reliability. Wind and solar energy hybrid power generation is a novel and promising power system. Complex as well as unpredictability of the climate makes wind and solar hybrid power generation system a complicated system. In this paper, they first introduced advanced agent technology into wind and solar energy hybrid power generation system, establish the wind and solar energy hybrid power generation multi-agent system (WSHGMAS) and analyze multi agents’ collaboration relationship.

V.J.Yeshwenth et.al. [16] reported that a purpose of a DC connection for capacitor Energy storage in Wind Power generation system. For meeting the requirement firstly, they have analysed the performance of two wind power generation system with the energy storage at the dc side.

Energy storage is advantageous to be installed to keep constant output from the wind power generation system. The DC connection of two wind power generation system helps to exchange power between the two systems and may suppress the disturbances of the output power to the utility systems longer than the stand-alone system. the performance of two wind power generation system with the energy storage at the dc side through simulation. And the system is modeled and simulated through Simulink/MATLAB and the effectiveness of the system is evaluated.

This effect is easily achieved and implemented without any additional control. The controller measures only the common dc side capacitor voltage of the local system. MATLAB/Simulink simulation verifies the better performance in a certain situation.

Lan Li and Guang-yu Xiong [17] described about the main problem for variable speed constant frequency in wind power generation system is and the improvement of dynamic response and its stability. In this work, mathematical model of wind power generator and active power separate control strategy with reactive power, PI controller and fuzzy controller were entertained separately in the control link of active power. And active power fuzzy controller was designed. In MATLAB/Simulink, doubly-fed wind power generation systems controlled by two kinds of controller were simulated and their properties were compared, it is shown that wind power generation system based on fuzzy controller has capacity to better dynamic respond and disturb resistance.

H. Belmili, N. Matidji and fellows [18] presented a paper about the size of a (photovoltaic/wind) Hybrid System. Integrating Solar Photovoltaic systems with batteries can be an assurance of high supply reliability, but in hazy weather (weak irradiation) this approach requires large storage capacity and is costly. It is cheaper to supply peaks of demand and the demand during this period, with either an additional wind generator. Under this objective different type of (photovoltaic/wind) hybrid systems for

supplying electricity have been demonstrated in a large number of pilot and demonstrated projects. In their framework, the design of hybrid systems is a significant issue. An ideal system has to supply, at any given time in the year, an instantaneous energy that equals the consumed energy by all system loads. A sub-sized system of course not satisfying the demand on electric power and on the other side jumbo or oversized system may be completely unaffordable due to both the reasons one is economical and another one is financial.

This work suggested the various methods of sizing a small PV-Wind hybrid system and the choice of the method that gives the optimal technical-economic configuration.

John A. Castle et.al. [19] analyzed the merits of Hybrid Wind/Photovoltaic Concept for Stand-Alone Systems. Methods for evaluation of the merits of hybrid wind/photovoltaic systems for use in stand-alone applications were discussed and developed. The best possible blend of wind and photovoltaic power with an electrochemical storage system, with or without fossil fuel generator backup, depends upon the individual subsystem economics.

They developed a computer code to calculate the most favorable subsystem-sizes that minimize the energy cost. The actual merits of a hybrid system over a pure photovoltaic or wind system depend upon many factors:

load profile; wind regime; insulation; cost and availability of backup power; the relative costs of wind rotor area, array area, and storage; and subsystem efficiency factors. Examples of optimized hybrid systems for a range of photovoltaic costs and estimated wind and storage costs are shown for an Ely, Nevada application where backup power is allowed to supply 5% of the total annual load.

CADDET Centre for Renewable Energy suggested a project [20] on A PV- Wind Hybrid System on Bullerö Island, Sweden. For the purpose they have presented a report which gives an idea about The PV-wind power installation meets almost all the island's energy demand less than half the cost of installing grid connection. Thus, this method is a cost-effective to be used in a remote region.

C.A. Nwosu, et.al. [21] explained about the power and energy balance in Wind-Solar Hybrid Power System. In this paper, power and energy balance in a wind-solar hybrid power system possess battery and integrated heat and power (CHP) sub-units as backups, is presented. A case study for winter and summer seasons are conducted in an urban city in the Netherlands. Load profiles for the periods of winter and summer over a period of 24 hours were developed from a load pattern program developed through load research sampling (LRS). It is observed that within the period under investigation, there exists an instant when the produced energy from the combined wind and solar system was below the certain demand and needs. Because the battery unit supplies the less amount of energy to manage steady power from the plant every time.

Xu Zhenchao, et.al. [22] have been worked on a remote monitoring system of wind-photovoltaic hybrid plant using mobile phone and an internet. In the work they have been proposed, a remote monitoring system of wind-photovoltaic hybrid generation system using mobile phone and internet. several kinds of data can be acquired, analyzed and saved automatically by this system. The hybrid system is composed of 1kW PV with DC/DC converter, battery banks and 5kW wind power system with power inductor and AC/DC converter. In adding together, wind monitoring sensors, voltage and current meters, current transformers and potential transformers are used as accessory instruments. All of these signals are fed into DAQ (Data Acquisition) board after converting the data which have been processed by many types of converters, dividing circuits and signal conditioning circuits. These data can not only be displayed on a computer, transmitted using the server program to remote computer and saved on a computer as a file according to the day but also be sent as a CDMA message. The monitored-data can be downloaded, analyzed and saved from server program in real-time via mobile phone or internet at a remote place. All of the programs were designed with Lab VIEW software.

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