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Assessment of Hybrid Energy Sources

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Abstract: This paper comprises exploration of hybrid renewable energy sources (RES) such as solar PV, wind Energy etc. with respect to solar radiation and velocity of wind. Hybrid energy system is a magnificent option for providing power supply to remote locations where grid supply is not reachable. The renewable energy sources (RES) are integrated through DSP with proper programming such that maximum power is fetched through RES. Variations in the output power of solar and wind is analyzed using data obtained through proper integration of RES. The foremost objective of proposed paper is to provide uninterrupted power supply to demand side with scrutiny of hybrid energy sources.

Index Terms: Solar PV, DSP, MPPT, Wind energy

Nomenaclature:

Parameter and Variables:

ρ Density of air (Kg/m^3)

A_s Swept area by wind turbine blades (m^2)

v Velocity of wind (m/s)

C_p Power coefficient

r Length of turbine blade (m)

E Total energy output (kWh)

A_p Total solar PV panel area installed (m^2)

ɳ Solar PV efficiency

H Annual average solar radiation on panel

P_R Performance ratio or coefficient for losses

Abbreviations:

RES Renewable Energy Sources

DSP Digital Signal Processor

MPPT Maximum Power Point Tracking

PV Photovoltaic

VAWT Vertical Axis Wind Turbine

HAWT Horizontal Axis Wind Turbine

I. INTRODUCTION

RES such as solar PV, wind turbines are limitless, free of cost, nature friendly as associated to fossil fuels. Non-renewable energy sources are subjected to depletion and also fossil fuels created generation discharges hazardous gases that have thoughtful influence in increasing the global warming. Therefore, there is necessity of energy supply that conserves the surrounding and save societies [1][9].

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Renewable energy supplies scale back the emission of hazardous gases. The high penetration of renewable energy supply in power sector is taken into account as encouraging generation source to cut back the gap between generation and demand of electricity in current state of affairs. Electrical energy plays a vital role in overall development of community and its economy. The electrical system is an aggregation of various network and multiple power generation suppliers with a multiple operator employing numerous levels of communications [2][4]. To ensure the power reliability, many scientists recommend to not using only one isolated power source such as solar or wind but suggest the integration of both of them working together [1][3]. Grid integration concept will allow power system to operate with large number of RES that can resolve many problems. Renewable energy experts describe that a compact hybrid system that incorporate wind power, solar PV power technologies offer several advantages to various applications. Depending on load requirement, these sources will operate to satisfy load uninterruptedly. The first solar PV structure was established in 1860 in France to generate steam to drive machinery and the first windmill was emerged in 1888 in Cleveland, Ohio for electrical power generation [5][11]. When these systems were evolved they were small and actual development was started in 1990. Nowadays hybrid energy supply about 19.1% of the world's total energy needs [5][9]. Increase in earth's temperature due to global warming made people adapt RES. However, renewable energy sources used independently don't give continuous and trusted power [10]. Thus, the final word resolution is to use them in a much combined manner, forming what's best-known by hybrid energy system [3][8]. This integrated system consists of solar panels as well as wind alternator combined so that maximum power tracking is possible. In collaboration with smart grid, maximum power point tracking concept is used which magnifies power extraction under all conditions [6]. MPPT is a technology mostly used in power system to enhanced power output in less than ideal conditions. In this system there is a hybridization of two energy resources with maximum use of RES with the help of MPPT module [2][7]. The foremost hint of distributed generation is production of electrical energy at the service point of consumers [13]. It may comprise generation from RES like solar PV, wind energy, bio-mass and bio-gas and also from co-generation elements. Diverse methods for distributed generation are active distribution network (ADN), Microgrids, virtual utilities, and virtual power plants (VPPs)[13].

II. WIND AND SOLAR PV POWER

Grouping of solar PV and wind energy become gorgeous solution for remote applications. These two resources combine can provide trustable power supply and cost effective since one source can complement another source's weakness. Hybrid energy system can be distinguished in two types: grid integrated or connected and stand-alone system. Wind alternators covert mechanical energy into electrical energy either AC or DC. It looks very simple by definition but it is very difficult to design wind alternator. Wind turbine is classified into two major types are VAWT and HAWT. Most commercially used turbine is horizontal axis wind turbine which consists of turbine blades, gear box, mechanical transmission system and electrical generator. Usually when wind travels along the axis of wind turbine shaft, the blades of wind turbine starts rotating such that gear box connected to the shaft utilizes the mechanical energy into the electrical power output with help of generator. Generally, three phase induction machines are used in wind turbine to generate electrical power output. Wind energy varies with geographical locations and power output is non-uniform which make individual to go for hybridization. The most dominant factor in wind power output is wind velocity and height of wind turbine. The power output of wind generator is given by,

$$P_{avilable} = 0.5 * \rho * A * v^3 * C_p \quad watt \qquad (1)$$

In general, value of C_p in the equation (1) assigned as 0.59 which is known as Betz Limit or Betz' law states that no wind turbine can convert more than 59% of the kinetic energy into mechanical energy of rotor i.e. only 59% of the incident wind is utilized while 41% is wasted or unutilized and the density of air is standardized as ρ=1.23Kg/m^3. Wind turbine output power is most affected by velocity of wind as it is proportional to third power of velocity. This shows that a small change in wind speed can make large change in the output power of the wind turbine. Swept area of the turbine can be calculated with the help of length of turbine blades as $A=\Pi*r^2$ where r is length of the turbine blade in meters. This is also shown in figure 1.

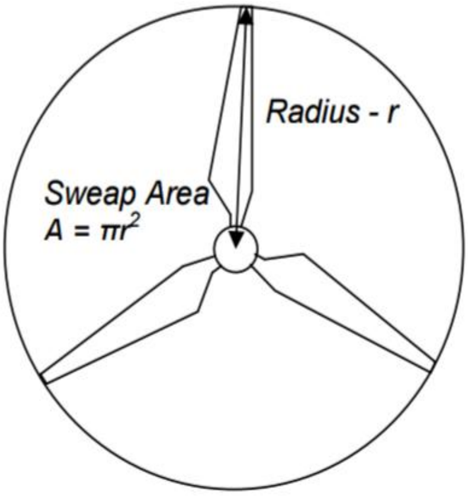

Fig. 1: Swept area by wind turbine blades

This power curve shows variation of wind output power in terms of wind speed. Solar PV power output depends on intensity of radiation as well as environmental season. PV modules produce output proportional to the amount of incident radiation. As the intensity of radiations increases, photovoltaic current increases. The temperature of solar PV is proportional to the intensity of radiation. Hence, if temperature of solar PV increases beyond limit, then efficiency of solar PV decreases. The accessible energy at the surface of the sun is approximately, 60000 kWh/m^2, while total radiation received on the surface of earth is only 1.4 kWh/m^2. Though solar PV efficiency is estimated approximately equal to 23% by laws of physics, but still it is one of the greatest resource over decades. As the cost of solar power generating units has fallen down, number of consumers has grown into millions and still rising. In 2017 solar power provided 1.7% of total worldwide electricity production, growing at 35% per annum.

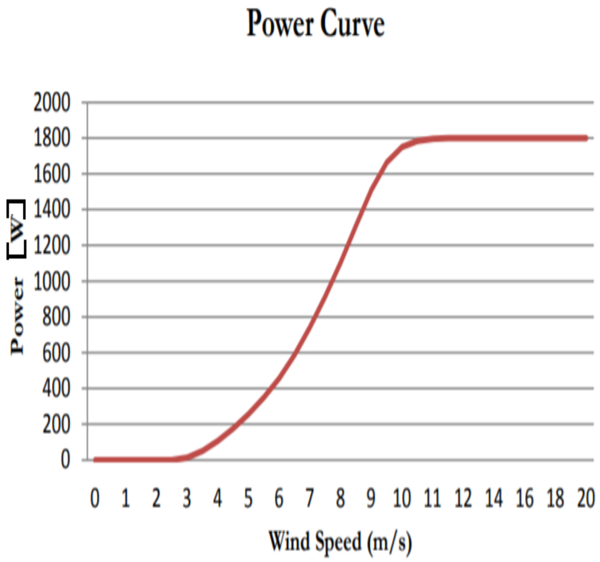

Fig. 2: Variation of wind turbine power v/s wind speed

The combination of wind and solar PV has benefited that these two sources are supplementary to each other. Therefore, the power output of such hybrid system is more stable and consist of less fluctuations when relate to individual sources. The global formula to estimate the electricity generated in output of a photovoltaic system is

$$E=A * \eta * H * P_R \qquad (2)$$

P_R= performance ratio, coefficient for losses (ranges between 0.5 and 0.9, in general value=0.75)

In equation (2), η is the yield of the solar panel given by ratio of electrical power (in kW) of one solar panel to the area of one panel. H is the annual average solar radiation on panels. This value varies with the region as solar radiations are high in deserts. P_R is the most important value to appraise the quality of a photovoltaic installation as it includes all losses.

III. HYBRIDIZATION

This section embraces typical block diagram of combination of RES along with grid. The block diagram explains that solar PV and wind energy is combined with grid power supply and it is fed to the MPPT module with DSP as processor.

This DSP is programmed with proper logic such that there will be maximum use of renewable energy sources to satisfy load demand. If load demand is less than the RES power generation then power is fed back to the grid so that it will reflect in the energy bill. The RES power is fed to the load through three phase inverter operating in 120 degree conduction mode. Hence, the power generated by solar and wind is fed to the load as shown in figure 2. The grid power supply is used as backup to the wind and solar energy such that whenever these two RES are not generating output then load should not be interrupted in any instance.

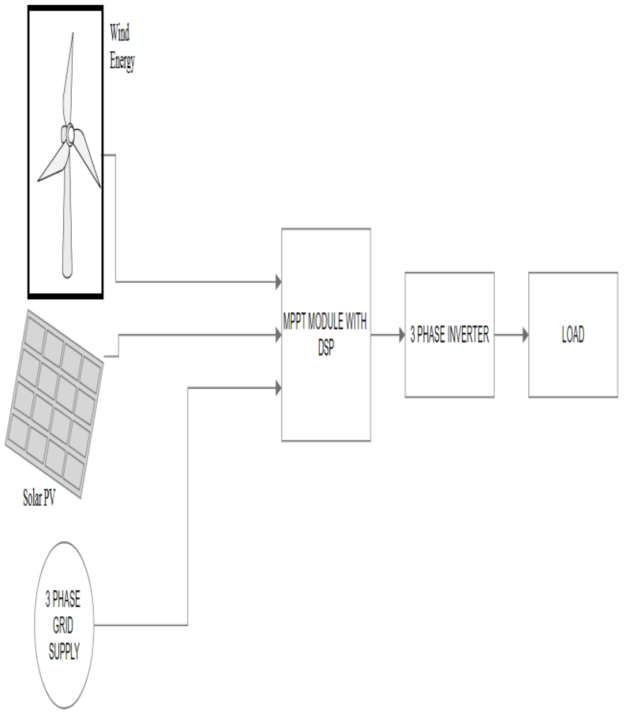

Fig. 3: Block diagram of hybrid energy system

Digital Signal Processor is programmed using C language logic. The algorithm used in DSP is as follows:

Step 1: Initiate solar PV and wind energy source.

Step 2: Check initiated power source is working or not.

Step 3: If both power sources are working in good condition then follow next step otherwise go to step 9

Step 4: Calculate real time power generation.

Step 5: If demand side requirement is fulfilled by total power generation by solar PV only then follow next step else go to step 7.

Step 6: Provide solar power directly to the demand side.

Step 7: If demand side requirement is fulfilled by combination of both solar PV and wind energy then follow next step else go to step 9.

Step 8: Provide power to demand side by both RES.

Step 9: If demand side requirement is more than RES power generation then only provide grid power to load.

Power flow can be explained with help of figure 4.

The power generated through solar PV and wind is feed to the maximum power point tracking module so that maximum power can be traced. This power is then fed to the three phase inverter. Three phase inverter is switched with the programming done in DSP such that output can be fulfilled with RES.

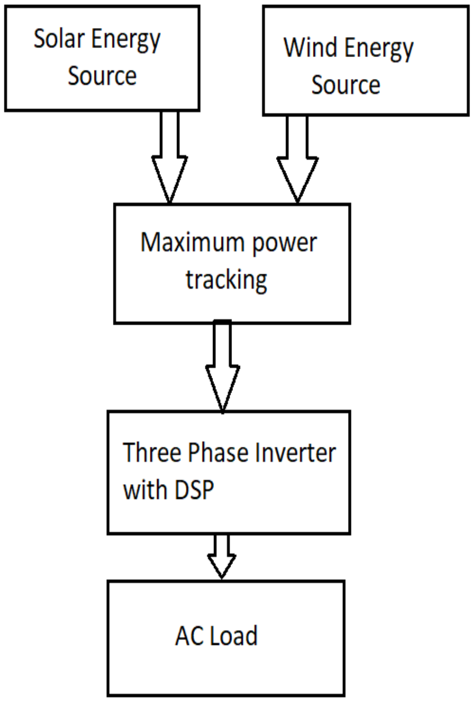

Fig. 4: Power flow diagram

IV. EXPLORATION OF HYBRID SOURCES

In our educational Institute, the real time solar PV and wind alternator are connected through three phase inverter. Two 6 panels of rating 40 volt 80 watt are connected in parallel and wind alternator of 1kW 72 V AC is connected across inverter. Parallel connection of solar panel is done to improve its current rating. This combination is supplied to three phase inverter along with grid power supply. Real time monitoring and data collection system is installed in that inverter. The collection of data can be done through transmission sources such as RS 232 or Ethernet. This real time data sheet shows total power generation of solar PV, wind, power fed to the load, power fed back to the grid, power factor etc. Depending on the 3 days real time data, following observations are made.

A. Load demand

In general, the typical energy output requirement of such educational institute is around 100kW. This total amount of load is not possible to satisfy through the RES. Hence, some part of the load is connected to the 10kW three phase inverter such that real time monitoring and data collection shows that this three phase inverter provides around 4kW power. Hence, total energy consumed is found to be around 15kWh daily.

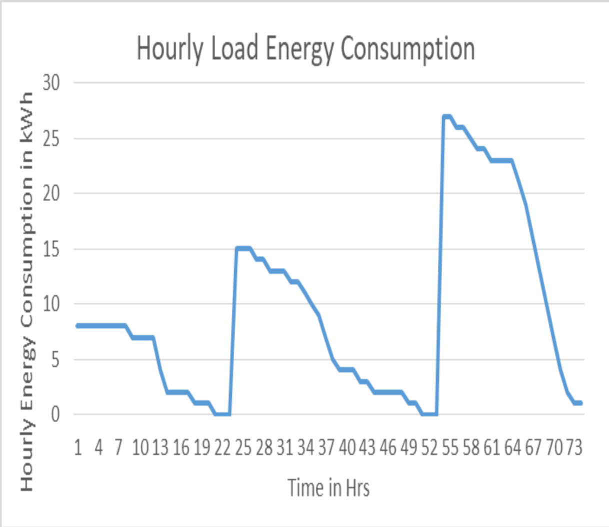

Fig. 5: Hourly energy consumption v/s time

B. Solar PV generation

Using real time data exploration, plot is made which shows the solar PV power w.r.t. time. Plot shows that the radiations are maximum during 12-2PM and load is also at the peak from 9AM to 5PM. The solar output is zero during night period i.e. approximately for 9 hrs. Hence, during this period, plot is showing zero power. Depending on the intensity of radiation, amount of current flows through solar panel and this current can be measured on the real time monitoring system of three phase inverter as shown in Fig. 6.

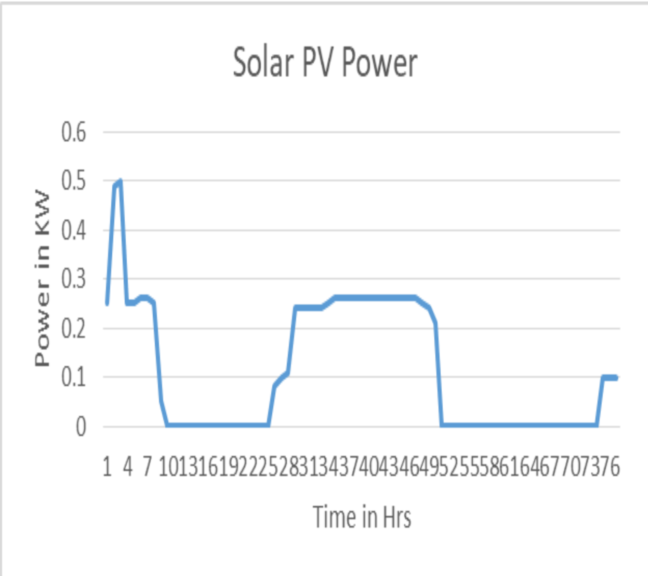

Fig. 6: Solar PV power output

Also, hourly power generation of solar PV panels is shown in Fig.7. Maximum energy generation hourly for solar PV during peak hours is found to be nearly 8-10 kWh. Hence, this shows that load cannot be satisfied only through the solar PV. There is inclusion of the wind alternator which fulfills the remaining amount of load requirement. That means combination of both RES can provide reliable supply. But, during peak hours of load, sometimes these RES cannot satisfy the load requirement. In that case, grid will provide the remaining power to the load.

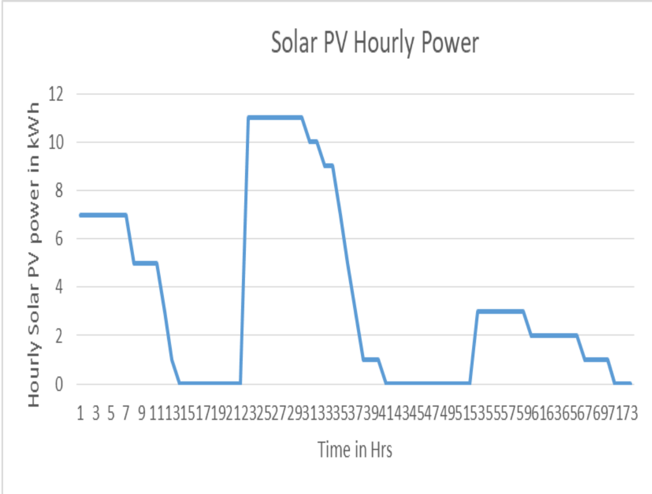

Fig. 7: Solar PV power generation

C. Wind Alternator Generation

Wind power generation shows that during day time there is not constant wind speed while wind generator generates more amount of energy during night period when there is large amount of wind. Peak energy generation of wind turbine is nearly 3kWh in night period while average power generation is approximately 2 kWh. Hence, it can be concluded from above data scrutiny that load can be satisfied with the combination of both RES i.e. Solar PV and wind Energy.

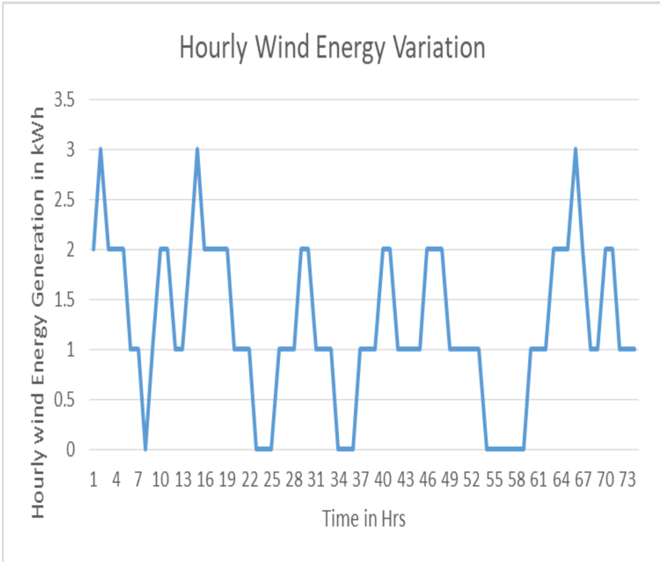

Fig. 8: Wind energy generation

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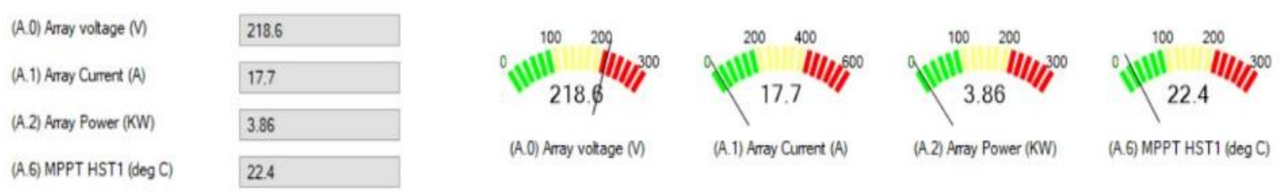

Fig. 9: Real Time Data through VISIO

I. RESULTS AND DISCUSSION

From above data results and plots, it is observed that there should be combination of solar PV and wind so that these two sources work in complement with each other. Large amount of load is usually provided by the solar PV panels and remaining parts is fulfilled by wind such that load is always feed i.e. load is not at all interrupted. If load requirement is still more than the actual generation of RES then that remaining amount should be filled by grid power supply. This can be also explained from following conditions as:

i) If $\mathbf{P_S} > \mathbf{P_L}$ then only solar PV power will be fed to the load.

ii) If $\mathbf{P_S} < \mathbf{P_L}$ but $\mathbf{(P_S+P_W)} > \mathbf{P_L}$ then combination of both solar PV and Wind power will be fed to the load.

iii) If $\mathbf{(P_S+P_W)} < \mathbf{P_L}$ then load is supplied with RES power and remaining part of load is fed to the load. The graphs plotted from real time data collection shows that demand side requirement is mainly from 8AM to 6PM during the day. Solar power generation is also peak during this period. Hence, bulk amount of load is satisfied through solar PV while the remaining amount of demand side requirement is supplied through wind power generation. Fig. 9 data shows that average power generation of solar PV is around 4 kW when solar radiations are maximum and while wind energy provides average energy around 2 - 3 kWh. Hence, combination of these two RES can exactly fulfill the demand side requirement. Whenever there are zero demand side requirements i.e. during night period, the power generated by RES is fed back to the grid supply. Variations in intensity of solar radiations and velocity of wind can cause voltage fluctuations in the output. These fluctuations are symptoms of poor power quality and can cause damage to the load side. Hence, mitigation of these power quality issues is necessary part. Active power filters such as dynamic voltage restorer, static compensator. Reactive power compensation can be done using shunt / series capacitors. In the three phase inverter, there is production of multiple order of power frequencies known as harmonics that can cause poor power quality i.e. output waveform becomes flat topped. Lower order harmonics such as third order, fifth order are more dangerous. Hence, filters can be designed to mitigate these harmonics and it will also improve the power quality.

II. CONCLUSION

From this paper, it is concluded that whenever there is hybridization of two or more RES i.e. solar PV and wind energy then this combination is beneficial for the consumer. The main challenge for hybrid system is that irregular nature of solar PV and wind sources. Integration of hybrid energy sources along with diesel generator set and battery is also challenging task. Although there is large initial investment, but payback period is very short and the amount spent can be covered easily. Only during the rainy season, there is not enough amount of solar radiations which is not compensated through wind power and this should be taken into account while planning to install solar wind hybrid system

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