Experimental Study of 1.1 KW, 230V Single Phase Hybrid Wind-Solar System

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Abstract- **Nowadays the provision of Electricity is the basic need of any nation in the world. There are many renewable resources like solar, tidal, wind as well as geothermal are present in the nature. To avoid extra expenses on separate power generation system there is new technology designed as a Hybrid Solar-Wind power system, which can provide reliable supply during any situation. Weibull distribution is done to obtain the average power from the hybrid the results showed that development of hybrid wind –solar system for off grid communities will go a long way to improve socio-economy lives of people. The energy balance model for reliable power has been developed and is presented in three steps. The system incorporates a wind turbine, solar photovoltaic panels, a controller interface for paralleling and controlling power from the sources, supplying the power to charge a battery and an inverter to supply power to ac loads. The more important renewable sources, wind and solar power, are mainly related to the weather in a local geographic area. However, the weather is a chaotic system with limited predictability.**

Index Terms- **Hybrid Solar-Wind Technology, PV Panels, Wind Turbines, Load Profile, On & Off Grid System.**

I. INTRODUCTION

One of the primary needs for socio-economic development in any nation in the world is the provision of reliable electricity supply system. In this paper, hybrid system technology was used with Hybrid Solar-Wind Power System that harnesses the renewable energies in sun and wind to generate the electricity. Here electric DC energies produced from photovoltaic and wind turbine system are transported to the load Centre. Complete hourly data of output from solar system and wind generator is collected for 91 days during Oct.2013 to Dec.2013. The analysis of this data using Weibull distribution is done to obtain the average power from the hybrid the results showed that development of hybrid wind –solar system for off grid communities will go a long way to improve socio- economy lives of people. One of the driving forces for social and economic development and a basic demand of nations is energy. Most of the energy production methods are one-way, which requires change of form for the energy.

The study discusses the development of a simple iterative technique for the design of an integrated solar-wind generating system, which is based on energy balance. The algorithm is then used for the design of a generating system for a small household. The site matching of equipment, sizing system components, specific strategy for energy flow are presented for an integrated PV–Wind system as an example for a small house. The energy balance model for reliable power has been developed and is presented in three steps. Necessary site- specific atmospheric data is processed in first step. Site matching of equipment and power delivered by renewable energy source, which depend on the atmospheric data, is calculated in second step. Calculated power is combined with system load in the final step to obtain appropriate unit sizing of system components for adequacy and energy indices. Annual average hourly load profile for the site has been used [5]. Based on the available hourly average data on wind speed, insolation, and the power demand, the generation capacity is determined to best match the power demand by minimizing the difference between generation and load over a period of day. Capacity of the storage needed to make the system operate independently as a stand-alone system is determined from the hourly information obtained from ΔP. Input data such as wind speed and solar insolation have been obtained from the India Meteorological Department (IMD) of

Pune region stationed at Ahmednagar and is processed using the model described.

II.OBJECTIVES

The design of a hybrid system will depend on the requirements of the user (isolated or not isolated location, rural or urban, DC or AC. power supply), and on the power supply system proper. Off-grid hybrid power systems can also incorporate energy storage in batteries to increase duration of energy autonomy. If some of the loads connected to a hybrid PV-wind system require permanent electric power supply, a backup diesel generator can be connected to the system to provide electric energy for peak loads which cannot be covered by the hybrid wind-solar combination.

Researches for renewable energies have been initiated first for wind power and then for solar power. Efficiency of solar power conversion systems is 18%, whilst that of wind power is 55%. These efficiencies could be increased by 50% with beam tracking, beam focusing and wind direction adaptive motion methods.

III.NECESSITY

In today's world there is a huge shortage of energy, especially electric energy. In developing countries like India, the problem is acute and severe. A major cause of concern in generation of electricity is the use of fossil fuels and greenhouse gases emitted by it. Also rural electrification and perennial shortage of electricity supply is a major issue. Here comes the role of generation of electricity by renewable resources. Hence electrification by standalone hybrid solar and wind generation can go a long extent to solve above problem.

IV. METHODOLOGY

In this paper a model of hybrid solar and wind power generation system is developed with design modifications for improved efficiency. This system may be designed as a micro and mini generation system for applications in rural areas as a source of standalone generation system.

The system incorporates a wind turbine, solar photovoltaic panels, a controller interface for paralleling and controlling power from the sources, supplying the power to charge a battery and an inverter to supply power to ac loads as shown in figure 1.

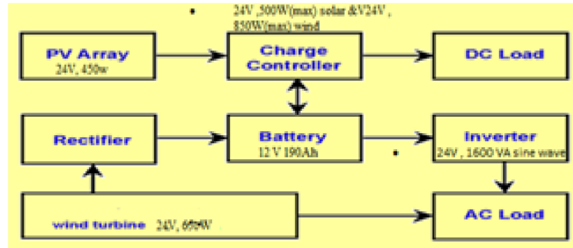

Figure 1. Block diagram of Hybrid Wind-Solar System.

For solar power systems (known as PV power due to semiconductor technology) power output of PV module P(s) is a product of module output voltage and current.

The equivalent PV model is represented in Figure 2, The power output from which is given by

$$P(s) = V(s) * I(s) \qquad (1)$$

The module equivalent current I can be expressed as function of voltage V as

$$I(v)=I_{sc}-I_{sc}C_1\left[\exp\left(\frac{V+\Delta V}{C_2 V_{oc}}\right)\right]-1 \qquad (2)$$

Where

$$C_1 = \left[1-\left(\frac{I_{mp}}{I_{sc}}\right)\right]\left\{\exp\left[1-\frac{V_{mp}}{C_2 V_{oc}}\right]\right\},$$

$$C_2 = \left[\left(\frac{V_{mp}}{V_{oc}}\right)-1\right]\left[\ln\left(1-\frac{I_{mp}}{I_{sc}}\right)\right]^{-1},$$

$$\Delta I = \alpha\left(\frac{S}{S_{ref}}\right)\Delta T + \left(\frac{S}{S_{ref}}-1\right) I_{sc}$$

$$\Delta V = -\beta\Delta T - R_s\Delta I,$$

R_s = Series resistance

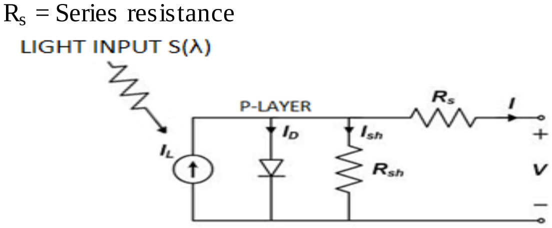

Figure 2. Equivalent circuit of module.

Various parameters for particular modules can be taken from manufacturers specifications of PV modules.

Average power output from a PV model is the power produced at each radiation level, which is a random function to account for this a suitable probability density function is worked out which gives the probability of radiation experienced and integrated over all possible radiation spectrums,

$$P_{PV\ average} = \int P(s)f(s)ds \qquad (3)$$

The incremental values of V and I are given by

f(s) = probability density function (pdf)
Average power produced varies largely based on the module parameters used, to determine the current I. Hence, before making selection of PV modules, it is required to know the capacity factor (CF) defined as the ratio between average power output to the rated power of the module.

$$CF = \frac{1}{P_r}\int P(s)f(s)ds \quad (4)$$

The module with better CF is selected. [6][7][9].
Wind turbines are used to convert the wind power into electric power. Electric generator inside the turbine converts the mechanical power into the electric power. Wind turbine systems are available ranging from 50W to 3 MW. The energy production by wind turbines depends on the wind velocity acting on the turbine. Wind power is used to feed both energy production and consumption demand, and transmission lines in the rural areas.
Turbines can be classified with respect to the physical features (dimensions, axes, number of blade), generated power and so on. For example, wind turbines with respect to axis structure: horizontal rotor plane located turbines, turbines with vertical or horizontal spinning directions with respect to the wind.
Electricity produced by a wind turbine at a specific site depends upon many factors. These factors include mean wind speed of the site and wind mill characteristics – Hub Height Cut-in (V_c), Rated (V_r) and furling (V_f) wind speeds. Wind generation is possible at any time of the day depending on the availability of the wind. As wind speed is a random function, hence a proper probability density function need to be worked out for appropriate choice to be made from long term wind speed data at the site under consideration. [15] [16] [17].

Mean Wind Speed
Mean wind speed is calculated as

$$V_i = \left(\frac{\sum_{j=1}^{N_j} V_j^3}{N_j}\right)^{\frac{1}{3}} \quad (5)$$

where V_j is the observed wind speed, N_j the number of wind speed observations and V_i the mean wind speed.
A cubic mean form of equation 5 is used to find out mean wind speed for the wind data of the site. CF are computed using mathematical formulation as given by equation 11 and are compared with actual and analytically computed capacity factors for wind speed data of the site using different means (such as arithmetic mean, cubic root mean etc.). These computations show that the estimates of CF obtained from Weibull model using cubic root means are closed to the actual CF. Further it can be seen that the CF in case of cubic means are higher than the CF obtained from other means. This leads to a notation and conclusion that in the process of site matching, cubic means of the actual wind speed data give closer estimates of Capacity Factor.
The mean speeds are then upgraded to the hub height. Wind speeds increases with height; hence to obtain mean wind speeds, Vi has to be projected to the hub height. This is achieved by using the power law equation as

$$v_H = v_i = \left[\frac{H}{H_i}\right]^x \quad (6)$$

Where V_H is the mean wind speed at projected height H, Vi the mean wind speed at reference height Hi (10 meters usually), H the projected hub height and x the power exponent (normally, 1/7).

Wind Speed Density Function
Speed density function is required at the hub height as wind speed is a random function. Normally Weibull and Rayleigh pdf are used. The Weibull pdf is given by

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} exp\left[-\left(\frac{v}{c}\right)^k\right] - \quad (7)$$

Where c is the scale factor, k is the shape factor and v is the wind speed.
Wind speed and Wind Power can be related by

$$P = \frac{1}{2}\left(\eta_v C_p \rho A v^3\right), - \quad (8)$$

Where η_v is the efficiency of wind turbine, C_p is the wind turbine coefficient of performance, ρ the air density factor and v the mean wind speed.
From equation (8) average power produced from wind turbine at each wind speed is given by the power at each wind speed multiplied by pdf.

$$P_{w\ average} = \int P\ f(v)\, dv \quad (9)$$

Substituting for P the power output between Vc and Vf is

$$P_{w\,average} = \frac{1}{2}\eta C_p \rho A \int_{v_c}^{v_r} v^3 f(v) dv + \int_{v_r}^{v_f} f(v) dv \quad (10)$$

Capacity factor defined as ratio of average power to rated power.

$$CF = \frac{P_{w\ average}}{P_{rated}}$$

$$CF = \frac{1}{v^3}\int_{v_c}^{v_r} v^3 f(v)\,dv + \int_{v_r}^{v_f} f(v)\,dv \qquad (11)$$

Wind turbine with highest CF for the site can be selected. [6] [10] [3] [11] [9].

Load Estimate of a Typical Residential System

The study input includes investigation of few households of similar nature. For the purpose of establishing a commitment comparison point, a typical home was defined. Most of the analysis and comparison s are based on the power requirements of this house. This typical home requires 1.1kWh/day. It includes lighting of fluorescent type and other typical load such as television; radio and water pump etc. though 1.1kWh/day is very small, it is a realistic initial requirement for many of small household, buildings, as well as small communities. Further it is of a scale that can be increased in modular fashion for the higher energy requirements of larger communities or as smaller communities expands. In the present work certain load profile has been assumed and the same is presented in the figure 3.

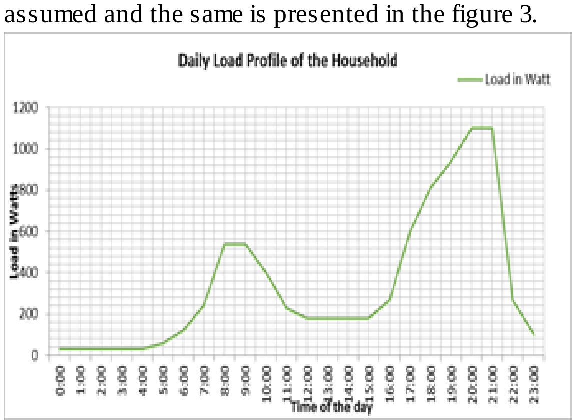

Figure 3. Assumed load profile of household

System Development

Energy Flow

The following operating strategy is employed [11] [12]

- Use of electric power generator by the PV array and wind turbine generators has priority in satisfying electricity demand over that provided by batteries.
- If the total electric power generated by PV array and wind turbine generators is higher than the demand, the additional electric power will be charged into the batteries.
- After charging the battery the electric power that remains is disposed of.
- If total electric power generated by PV arrays and wind turbine generators is less than the demand, electric power will be discharged from the batteries.
- If the batteries cannot supply the demand, then a certain amount of electric load has to be shut down from the electric system.

Energy Balance Algorithm

Having decided on the operating strategy, the next step is to establish a proper power and energy balance for a proposed design. Accordingly, in a hybrid system the total power is given by

$$P_T = K_W P_W + K_S P_S \pm K_B P_B - P_L = 0 \qquad (12)$$

From the above discussion, it is evident that the fraction of total power generated and demand is ΔP, where

$$\Delta P = P_{gen} - P_{dem} \qquad (13)$$

The loss of power supply probability is constrained to minimize the magnitude of difference between generated power and demand power over a given period of time. The total average generated and demand energy, over a period of day can be written in terms of generated wind and solar power and the power demand as

$$W_{gen} = \sum_{n=1}^{24}[(\Delta T)(N_W P(t)_W + N_S P(t)_S] \qquad -(14)$$

$$W_{dem} = \sum_{n=1}^{24}[(\Delta T)(P(n)_{dem})], \qquad (15)$$

where Pw and Ps are the power generated by a specified wind turbine and a single PV panel, respectively, as in Equations (14) and (15). Nw and Ns represent the number of wind turbines and PV panels used, t is the sampling time (hour of day/day of month), and DT is the time between the samples (in this case 1 h). In order for generation and load to balance over a given period of time, the value of DP must have an average of zero over the same time period. Positive values of Dp indicate the availability of generation when the energy will be utilized in charging the batteries and negative Dp indicates generation deficiency when the energy from the batteries will be used to supply the load. An equation of energy vs. time ΔW can be obtained by integrating ΔP.

$$\Delta W = W_{gen} - W_{dem} = \int \Delta P dt \qquad (16)$$

Energy curve of Eq. (16) can be used to find the required storage capacity for wind/PV system. On an average day, battery is required to cycle between the positive and negative peaks of the energy curve. Therefore, battery should at least have a capacity equal to the difference between the positive and negative peaks of the energy. Thus number of batteries can be fixed using the equations given below:

$$Required\ storage\ capacity = MaxW_{gen} - MinW_{gen} \quad (17)$$

$$Number\ of\ batteries = \frac{Required\ storage\ capacity}{(0.8)(Rated\ capacity\ of\ each\ battery)} \quad (18)$$

The iterative procedure adopted for selecting wind turbine size and number of PV panels needed to satisfy the energy flow strategy for a stand-alone system to meet a specific load is as follows:

1. Select commercially available unit sizes for wind turbine, PV panel, as per site matching strategy and storage battery.
2. Since the rating for wind turbine far exceeds that of a single PV panel, keep the number of turbines N_w constant and increase number of PV panels Ns until the system is balanced.
3. Repeat step 2 for different number of wind turbines, i.e. K = 0, 1, 2, 3 … as needed.
4. Calculate the total system LPSP for each combination of Nw and Ns, that satisfies the requirements in step 2.
5. Choose the combination with the lowest LPSP

Capacity Factor Assessment for Wind Turbine Generator

For the site under consideration 11 years' long-term wind speed data have been used. After processing the data annual mean wind speed (Kmph) and standard deviations for specified day are determined. Fig. 4 shows the hourly average wind speed profile from the data recorded for the site on annual basis.

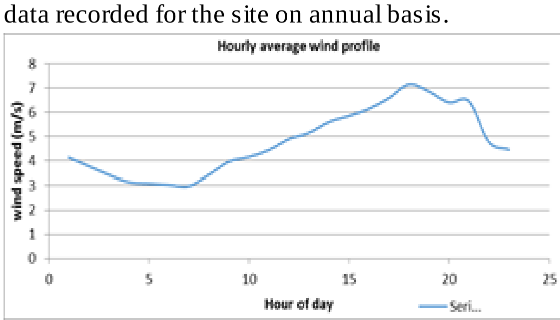

Figure 4. Annual hourly wind speed profile

Mean wind speed and standard deviation values are used in evaluating the pdf for the site and the functions are represented in Fig.5 Probability density function values are useful for determining average power of different wind turbines as per Eq. (9).

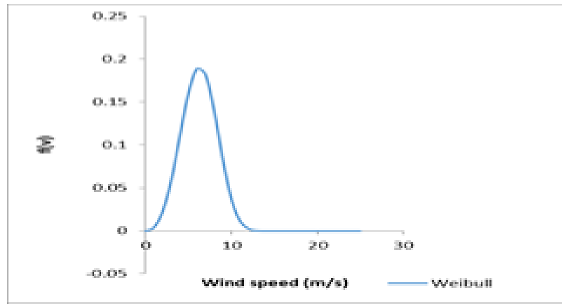

Figure 5. Probability density function and wind speed

Capacity factor as defined in Eq. (11) is determined for different wind turbines and are represented in Table 1 along with the parameters. From Table 1, it is evident that the wind turbine with 1000 W output with the associated parameters shows highest CF for the given wind speed data at the site and hence the same is being selected.

TABLE I. CF FOR SELECTED WTG

Pr(W)	Vc	Vr	Vf	CF
1000	4.0	12.3	15.2	0.273
1600	3.2	9.4	16.2	0.1745
2000	3.4	13.6	18.3	0.1365

V. PERFORMANCE ANALYSIS

A. Load Profile of Wind System

Electricity generation using single system that is only PV system is very expensive as large surface area is required, effect of weather condition also does not permit use of only PV system. It is noticed that for 1.1 kW residential bungalow hybrid PV-wind system gives economical solutions.

The load profile analysis is done by considering the systems separately that is wind power, solar power, and Hybrid power. One by one analysis of systems is presented here. At first the power output from wind system is taken on the hourly basis and instantaneous values are noted down for a complete week, then for a month and similarly for three months' durations. The procedure was repeated for solar system. On the basis of average power output by Hybrid wind-solar system operating simultaneously are analyzed for the three months viz. October 2013 to December 2013.

It was observed that the system is fulfilling the total demand of the house without any interruption and a good quality power is obtained from the installed system.

B. Load Profile of Wind System for A Week

The content of Table II gives the load profile of wind system for a week. The system gives more output up to 456 watts' maximum. It has happened in winter season. This is because in winter season the winds are flowing with higher speeds, temperature is relatively low and hence the air density is having a somewhat higher value thus producing more energy.

Analysis of data is done using different tools and it is noticed that maximum power output of 456 watts is obtained using wind mill.

Here is a comparative study of the load profile of the wind generation systems. It will help us to understand the output of the wind turbine coupled generator in supplying load. Following is the load profile of a wind turbine supplying load of 1.1kW for one week from 1st October 2013 to 7th October 2013.

Time	Tue	Wed	Thu	Fri	Sat	Sun	Mon
6:00 AM	37	40	42	38	39	40	43
7:00 AM	45	50	52	130	144	67	56
8:00 AM	62	64	60	157	100	78	70
9:00 AM	90	88	97	104	91	97	87
10:00 AM	78	90	88	89	79	110	102
11:00 AM	100	120	98	130	97	134	147
12:00 PM	214	127	212	228	219	159	212
1:00 PM	275	198	270	289	283	270	286
2:00 PM	242	237	245	345	246	245	300
3:00 PM	340	358	327	294	334	340	327
4:00 PM	410	448	430	378	425	405	430
5:00 PM	434	456	442	439	450	380	442

Table II. load profile data of wind mill for a week

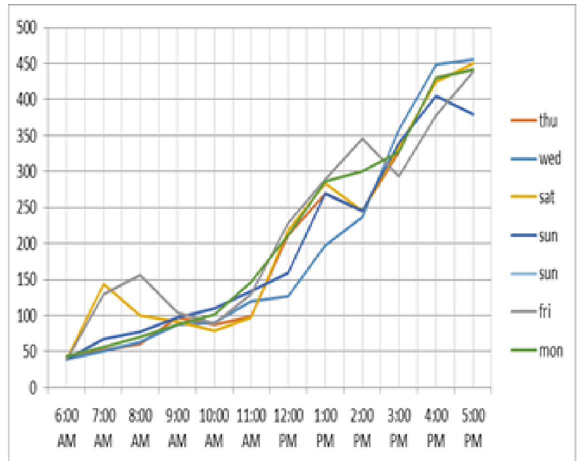

Figure 6. Load profile of wind system

C. Load Profile of PV system for Week

Following table shows power output details of PV panel for one week.

TABLE III. POWER OUTPUT OF 450 WATT SOLAR PANEL MEASURED IN A WEEK

TIME	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Mon.
6	10	10	15	20	20	15	15
7	30	25	35	40	35	30	35
8	45	35	50	60	45	50	45
9	125	85	110	115	100	105	110
10	225	165	230	225	185	200	235
11	250	245	260	260	240	250	270
12	300	310	290	305	315	300	305
13	315	300	320	335	325	315	290
14	285	265	270	300	275	225	145
15	245	210	195	205	190	145	55
16	150	140	115	165	85	75	30
17	45	50	35	85	35	40	15

Observations:

1. It is noticed that power output is between 10 to 20 Watts at 6:00 am and 15 to 85 Watts at 5:00 pm
2. Maximum power obtained is 335 Watts at 1:00 pm.

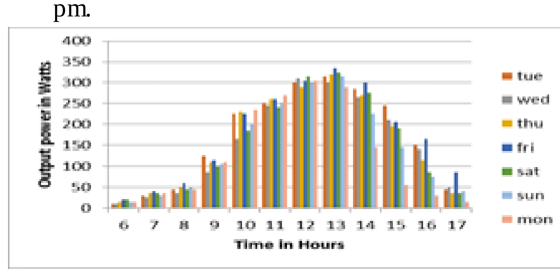

Figure 7. Effect of Solar Radiation on Electrical output during Oct 2013

Figure 7 gives the relation between time of the day and the power output obtained using solar PV panel.

D. Analysis of Hybrid System Data

Table IV. difference between electrical power output and power demand

Hr. of Day	Power Demand	ΔP PV)	ΔP(Wind)	ΔP(Hybrid)
0	30	-30.00	266.37	266.37
1	30	-30.00	197.89	197.89
2	30	-30.00	286.46	286.46
3	30	-30.00	168.24	168.24
4	30	-30.00	124.97	124.97
5	60	-60.00	44.24	44.24
6	120	-106.77	-60.52	-47.29
7	240	-207.42	-165.15	-132.57
8	430	-370.97	-337.10	-278.07
9	390	-278.87	-279.47	-168.34
10	320	-124.68	-225.90	-30.58
11	230	19.03	-112.71	136.32
12	180	113.71	15.45	309.16
13	180	206.47	93.65	480.12
14	180	144.98	112.16	437.14
15	180	119.32	156.68	456.00
16	270	-83.06	130.32	317.26
17	600	-489.42	-183.71	-73.13
18	810	-751.66	-346.35	-288.01
19	940	-940.00	-612.45	-612.45
20	1030	-1030.00	-743.47	-743.47
21	1030	-1030.00	-851.77	-851.77
22	270	-270.00	-43.43	-43.43
23	100	-100.00	212.44	212.44

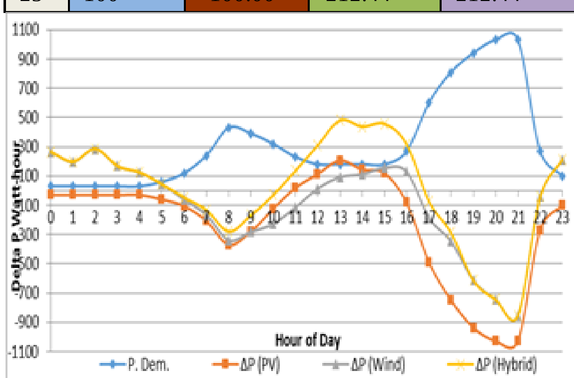

Figure 8. Average Daily Data W

Observations:

1. The minimum power output of 72.71 W of Hybrid system is noticed at 6:00 am
2. The maximum power output of 660.12 W of hybrid system is noticed at 1:00 pm
3. There is a large variation in output power of combined PV-Wind system during a time of a day
4. The difference between demanded power and Generated power by the use of above method.
5. Above observations clearly indicate the necessity of battery (storage system) for residential load.

IV. DISCUSSIONS AND CONCLUSIONS

A. Discussions

A hybrid (solar PV and wind) system was designed and installed for a residential bungalow. Interesting observations are noted down and data obtained continuously for the months October 2013 to December 2013. Renewable energy technologies offer clean, abundant energy gathered from self-renewing resources such as the sun, wind etc. As the power demand increases, power failure also increases. So, renewable energy sources can be used to provide constant loads. A new converter topology for hybrid wind/photovoltaic energy system is proposed. Hybridizing solar and wind power sources provide a realistic form of power generation. Renewable energy sources also called non-conventional type of energy are continuously replenished by natural processes. Hybrid systems are the right solution for a clean energy production. Hybridizing solar and wind power sources provide a realistic form of power generation.

The more important renewable sources, wind and solar power, are mainly related to the weather in a local geographic area. However, the weather is a chaotic system with limited predictability. Many countries follow two trends in the development and planning of their public electric systems; the first is the increase in the generation power from RES and the second one is the transition to open electricity markets. These two trends have a common impact on the public grids, because they both increase the number of agents in the system and the level of uncertainty in the balance between generation and load. The use of RES reduces the economic costs due to lesser fuel consumption, and also reduces the greenhouse gas emission. However, the access of more and bigger RES electricity producers can increase the risk of fail and decrease the service quality. That risk can be reduced by increasing the power reserve based on high response gradient systems. These, e.g. diesel or hydraulic, have a high speed of change in their generated power, that is suitable to balance the frequent sudden and unpredictable changes of RES-based electricity production. Therefore, the positive impact of the use of RES on the cost of fuel consumption would have a negative impact on the global cost of electricity systems. The control and planning of public electric systems covers a widespread set of levels, ranging from the hundred millisecond domain associated to the frequency and voltage control, to the yearly planning domain. Precise regulations for these levels are the concern of the national Electricity Authorities of each country as well as to supranational agencies. In each national system, the transmission System Operator (TSO) deals with the management of the electric system in the different control and planning levels.

With the increasing penetration of RES systems, the TSO becomes concerned with the impact on system stability. The Electric Authorities of countries had included the power forecasting in its Regulatory Norms which goal is to preserve the quality of the electricity supply. The planning of an Electric System requires several levels related with different time scales as well as the weather forecasting. Regulation of power quality also requires several time scales. At very short time scale it is mainly related to voltage and frequency regulation, but at large time scale is mainly related to the power balance among the energy producers and the consumer loads. Different approaches related to power quality can be focused on different time scales as well as in different device details. The case 2 corresponding to this paper where we are interested in short term energy storage covering from few minutes to many weeks and in low device details.

Details about the hybrid power system designed, installed and analyzed in this paper are given as below: -

- The hybrid power plant selected for the study has been installed in September 2013 at Ahmednagar, Maharashtra, India.
- The installation cost of this hybrid power plant estimated to approximately Rs.1.30 lacs.
- The installed power generation capacity of the plant is 1.10 kW and the capacity ratio of wind to solar power units is 60:40.
- This plant is designed to develop 3.0 kWh/day which meant that wind power plant should generate 1.8 kWh/day and solar power plant should generate 1.2 kWh/day. Thus, the annual generation should be up to 1095.0 kWh.

B. CONCLUSIONS

In this paper hybrid system implementation for a residential bungalow is presented. Following are some conclusions

1. Analysis of data obtained for PV system, wind mill and hybrid system for duration from October 2013 to December 2013 is done.
2. Effect of weather condition on PV system and wind mill is studied.
3. The possibility to combine two renewable energy sources based on the natural local potential of users is presented.

The solar and wind hybrid system is definitely targeted for application as a stand-alone system is concluded.

C. FUTURE SCOPE

1. Islanded system (remote areas)

Hybrid generation system can be used for remote generation systems where the hybrid system delivers power to the concern place only.

2. Hybrid vehicle (fuel less)

Vehicles need fuel for their mobility. At present there is a shortage of conventional fossil fuels such as petroleum and diesel. Trends are emerging for using hybrid sources of energy for automobiles. Batteries may charge from a solar source and used as a source of energy for automobiles.

3. Industrial power source

Major heavy industries need a large amount of power. They may take this power either from utility grid or have their own captive power generation. Plants presently use fossil fuels as a source of fuel for their captive generation. But now they have option to use solar and wind hybrid for their captive power generation.

4. Distributed power generation

This system is can be utilised as a standalone, off-grid power generation System. This system will generate electricity at the area where power is needed and supplied to the load. Thus it is not grid dependent

5. Solar Hot Water Heaters:

The sun's light is an excellent source of hot water for home or commercial use, such as swimming pools, car washes and Laundromats.

6. Cooking:

Simple solar ovens and cookers are used around the world in both commercial kitchens and in people's homes. ¾ Solar cookers can be made with everyday materials such as cardboard and tinfoil.

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