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Power Reliability of Hybrid Non-Conventional Off-Grid Generation Systems using Multilevel Inverter

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Abstract; The country is progressing forward towards generating surplus energy from household properties and renewable sources to fulfill the nation requirement for power that can be replaced or renewed without causing extreme ecological. Using hybrid renewable energy (solar – wind combination) is one of the potential alternatives to supply the electrical energy to rural/ remote areas. This paper proposes an integration of energy systems to ensure power to the consumers with utmost exploration of non-conventional energy sources, Multi Level Inverters (MLI) and battery as a storage device. Here, Solar and Wind Energy systems are considered with ratings of 2 kW and 3 kW respectively. After integration it is expected to a load of 5 kW. The main feature of this work is the use meet nearly of a single Boost Converter with 3 phase Inverter to connect to the load. Using the MATALB Simulation, the performance of standalone energy systems and the hybrid model is obtained and validated.

Key word: Renewable source, energysystems, PV panel, wind turbine, battery, MLI.

I. INTRODUCTION

Hybrid energy systems comprises of fusion linking non-conventional power sources used with storage systems as batteries, which causes the lowering of generation costs from non-renewable sources and motivating the approval of renewable energy systems ensuring sustainability and reliability of the changing non-fossil sources[3,1].The work taken up serves a solution where the distribution system aims at maintaining the sustainability of the system [2, 3, 5]. At a broad spectrum the changes in the behavioral pattern of wind and solar is variable, also each individual working is less reliable. Therefore at many occasions these resources are made to combine for power generation which gives a sustainable and reliable service as they contradict to each other. The integration of these contradict systems provide a challenge to many constraints such as component sizing , operational control strategies of the energy systems depending upon the climatic conditions, therefore renewable energy resources and storage components must be sized to match the given load profile and the estimated ease of use of solar radiation and wind.

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The heat on today's scenario focuses on use of renewables due to their major benefits like cost, availability, economic aspect, feasibility, power quality and sustainability. These renewable technologies are cost effective and are promising towards the development of the country providing clean power. The main hurdle lies in the integration of these two systems with a target of achievement of improved performance and lower THD values so as to reduce the switching power losses. In this paper the focus is thrown on the selection of MLIs, converters for precisely forecasting the outputs and thereby causing the reliable integration between the resources. All the energy sources are modeled using MATLAB software tool to analyze the system performance. In this the batteries are used with adequate capacity to store surfeit energy and supply power when there is reduced generation from renewable sources.Feasibility of hybridPV/ wind energy system strongly depends on solar radiation andwind energy potential available at the site. Various feasibilityand performance studies are reported to evaluate option ofhybrid PV/wind energy systems [2,3,4,5]. PVarrays area,number of wind machines, and battery storage capacity play animportant role in operation of hybrid PV/ wind-systemto continue supplying the load.

II. PROPOSED SYSTEM AND ITS BACKGROUND

As per the literature survey there are multiple combinations of PV, Wind and Battery to supply power to the load (remote or low power applications).In this paper few such combinations are considered for comparative analysis. The capacity allocation problem is achieved with fewer amounts of power deficiency and low rate[10]. Here better ability can be found by confined optimal solution by ―disturbance operation‖, trimming down the non-linearity problems.PV systems acts as a main source where power fluctuation of hybrid system is less compared to that of the standalonesystem [11].The power swing is suppressed using a battery which is a subject to future scope. The size of battery increases the overall cost.Moreover the assurance of load stress is not guaranteed [12].

Therefore, according to the comparative analysis it can be inferred that if the wind turbine is directly connected to the load and PV connected to the load via battery, then the size of the batterycan be reduced comparatively and load may notalways be dependent on battery. The wind turbine will act as the main source and supply the load in combination with solar.

When the energy from solar is insufficient,the load demand is met via wind and battery. In addition to this if the power generated is surplus from the PV and solar,the excess power can be used for somenon-prioritizedload like water pumping stations. The proposed scheme is shown in Fig.1

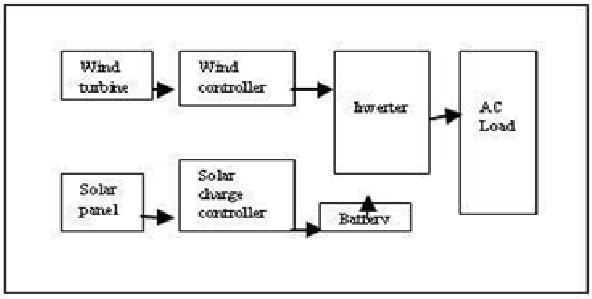

Fig1: Standalone hybrid model involving Solar and Wind.

The work presented in this paper is aiming at design and implementation of a solar-wind hybrid energy system. This work is expected to help to understand the basics of solar-wind hybrid power generation. A hybrid system where the solar power is stored in a battery and the combination of battery output and wind power output is fed to the load. This is with the assumption that the wind available throughout the day &night and availability of solar power only duringdaytime that to for a limited period.

The objectives of this paper include:

 Development and simulation of Standalone hybrid

C_p is the power coefficient of the wind

turbine V^3 is wind speed in m/s model

usingMATLAB/simulink. It is time in secs.

- To supply continuous power for Low Power Applications using storage batteries.
- To design solar for 2KW output power and wind for 3KW output power.

III. METHODOLOGY

An amalgam of nonconventional sources for the generation of electric power comprise of wind turbines, PV panels and storage batteries.In this system variable speed pitch controlled wind turbine using synchronous generator is used.The wind turbine is designed for 3 kW power output.The wind turbine consists of 2 turbines each generating 1.5 kW output power.The output of wind turbine generator is AC which is fed to a controlled rectifier to get DC voltage.In the similar manner solar panel is designed for 2 kW power output which gives DC voltage.Theintegration of these two sources after matching the voltage profiles of both the sources, are connected in parallel and further connected to a boost converter via battery. The output of the boost converter is given to a three phase inverter which supplies power to a balanced three phase load.

IV. ASSESSMENT OF RESOURCES

A. Wind Power

Wind is created due to uneven heating of atmosphere by the energy received from the sun. Seasonal variations affect the speed and direction of the wind.The wind turbine captures the kinetic energy associated with the wind and set itself in motion thereby driving the coupled alternator to generate power.

The equation for the wind generator power is given by equation(1)[9,10].

$$Pm=0.5\rho ACp\ v^3 \qquad (1)$$

Where ρ is density of air in
3 2

Theoretically maximum value of power coefficient C_p obtained is 0.59. It depends upon two variables, Tip Speed Ratio(TSR) and pitch angle. The angle where the turbine blades are allied wrt its longitudinal axis is called pitch angle and linear speed of rotor to wind speed is TSR.

$$TSR=\lambda=\omega R/v \qquad (2)$$

Where ω is the speed of rotor turbine in rad/sec
R represents radius of the turbine blade V
is wind speed in m/sec
The utmost achievable speed for high speed turbines of wind ranges from 0.4 to 0.5m/s and 0.2 to 0.4m/s for turbines of slower speed. From equation(2) optimum speed of rotor is estimated as follows:

$$\omega_{opt}=TSR_{opt}v/R \qquad (3)$$

Torque is given by the equation

$$T=\frac{1\rho A\ v3\ Cp}{} \qquad (4)$$

Substituting eqn (2) and (4), the torque equation is

For below rated wind speed:

$$T=k_{opt}\omega^2 \qquad (5)$$

$$\text{Where } k_{opt} = \frac{1\rho ACp}{}(R/\lambda)^3 \qquad (6)$$

For above rated wind speed:
T=Prated/ω for P≥Prated.

B. Photovoltaic (PV) System

A PV module consists of a number of solar cells connected in series and parallel to obtain the desired voltage and current output levels[10].Each Solar cell is similar to a diode with a p-n junction formed by semiconductor material. When the junction absorbs light, it can produce current by the photovoltaic effect. The power output of a solar cell is given by

$$Ppv=V*I \qquad (7)$$

Where: I - solar cell output current (A)
V - Operating voltage of solar cell (volt)
Ppv - Output power of solar cell (W)

C. Battery

Batteries are the storage devices converting electrical energy into chemical energy. Lead acid, nickel Cadmium, sodium sulphur, lithium ion etc are some of the major energy storage technologies. With the inclusion of battery in the hybrid model the application of Battery State of Charge estimates becomes more vital issue as it displays the battery conditions before recharging preventing it from being over or under charged to get enhanced lifetime.

D. Loads:

When it comes to the domestic load, majority of the loads are 12V, 24V, 36V, 48V etc. here the load consumption is given in the intervals of hours/minutes, week length, month/year. There are optional loads that have to be attended at specific periods or otherwise considered as dumped loads. There are deferrable loads which need to be covered within certain time period. Some loads like fluorescent lamps, laptops, ceiling fans etc are considered as the highest priority loads which need to be run at the given time period only[11].

Table 1: Load Estimation

Sl. no.	Appliance	Qty	Power Rating W	hrly use hrs	Total power w	Energy w-hr
1	Flourescent Lamp	30	9	5	270	1350
2	Fans	3	60	6	180	1080
3	Laptops	5	250	2	1250	2500
4	Television	22	150	3	3300	9900
5	Spare				250	250
					5250	15080

Total power is 5250watts.

Total power in KVA will be 5250/0.8=6.562KVA =6.5KVA

This matches with the size of the inverter.

Energy in watthour is 15080Wh

Energy in kilowatt/hour is ≈ 15KWh

V. DESIGN OF COMPONENTS

1. Solar Model Design

- Total Load supplied by Solar =2kW
- Efficiency =0.85
- Voltage =12V.
- Period of operation or duration =6 hrs (when the sunlight is at peak)
- Load in Wh/day in solar =2000 X 6=12000Wh/day

Total PV panels to generate energy needed(considering loss factor and panel generation factor)

=12000X1.3/2.93 = 5324.23 Wh/day

- No. of PV panels needed (considering 200 Wp)=5324.23/200 =26.62≈27 (9X 3).

Total Area=2000/1000X0.18 =11.11m^2 ≈ 12 m^2

= 2m X 6m

- 1 panel area =2.25 m^2

2. Inverter Rating:

- Total Watt Inverter rating =6000.
- Capacityof Inverter 30% greater than actual requirement=6500 Watts.
- Inverter capacity =6500W

3. Battery rating:

- Total Energy =48000 Wh.
- Νομιναλ Βαττερψ ςολταγε =12 ς.
- Δαψσ οφ Αυτονομψ =3 Δαψσ.
- Βαττερψ Χαπαχιτψ =(48000∗3)/(0.85∗0.7∗12)

= 20168.06 Ah.

- ✓ 0.85 is the Battery Efficiency.
- ✓ 0.7 is the Depth of Discharge.
  - 1 Battery =1500Ah.
  - Total No.of batteries

=20168.06/1500=13.44≈14

4. Wind system Design:

- Rated Power =3kW.
- Rated Speed =10m/sec.
- No. of blades =3.
- Hub Height =30.48037m
- Rotor diameter=2.8m
- No. of turbines=2

Power = 0.5 x ρ x Ax v^3 x Cp x η.

Where,

- ρ - Air Density in Kg/m^3 = 1.27.
- A- Sweep Areain m^2 = 8.5.
- V-Wind Speed in m/sec = 10.
- H-Efficiency of AC/DC Converter = 0.85.
- Cp-power Coefficient = 0.59
- Therefore P =2.706kW.

VI. MATLAB SIMULATION MODEL

As the two systems PV and wind are used in the same model, it becomes essential to reflect their interdependency to work as hybrid system.So simulation helps to pre determine the terminal behavior of the system under wide range of parameter(s) variation. Simulation of the hybrid wind and PV system is shown in Figure 2 which was done in MATLAB/SIMULINK environment. In Hybrid Wind-PV System, the load is shared by both the generating systems such that the wind system will be supplying the load without any modulation i.e. directly. However, the solar energy is stored in the battery and depending upon the load, it will supply deficit power. If the power generated is surplus,the excess power can be used for water pumping stations and any non-prioritized loads.

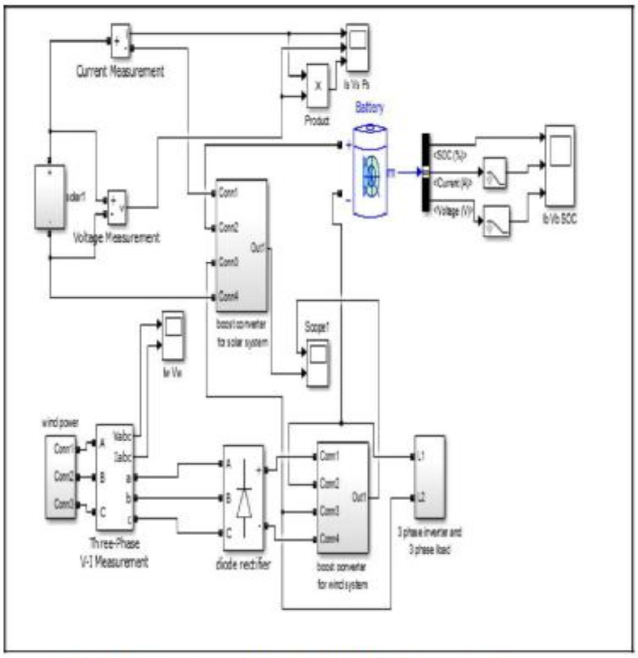

Fig.2 Combined simulation model of hybrid system

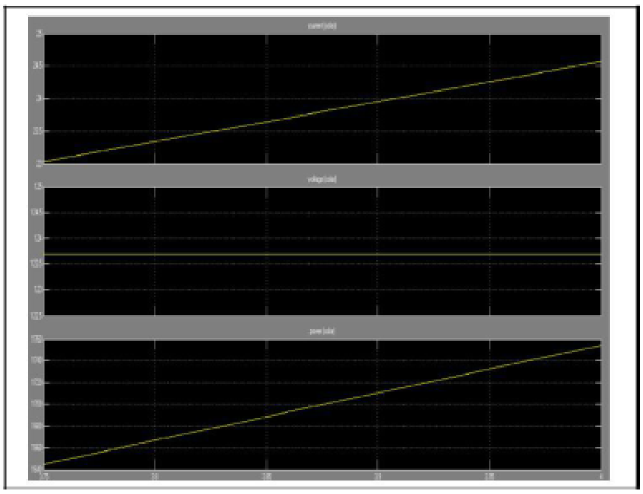

Fig.3 Current and Voltage vs time of solar system

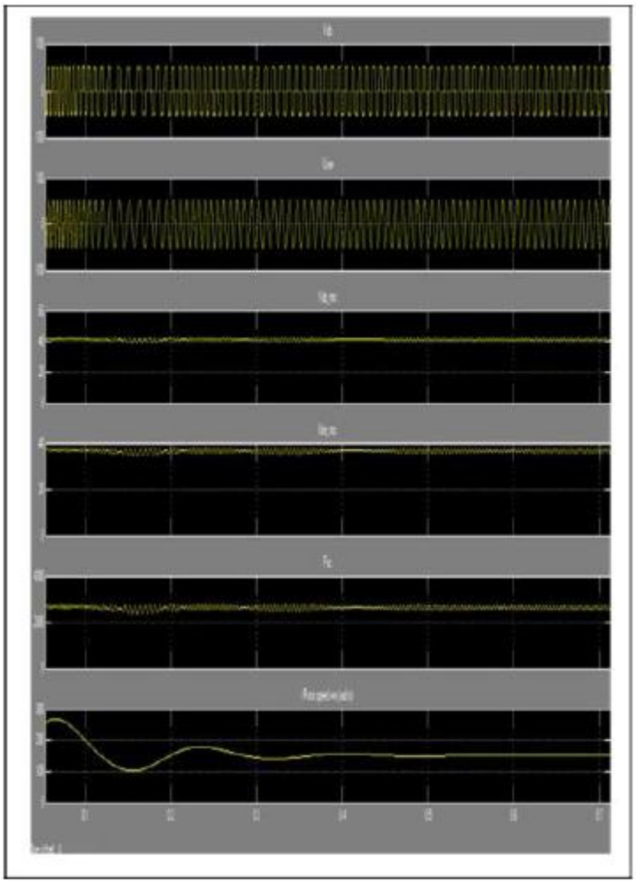

Fig.4 Output waveforms for wind system

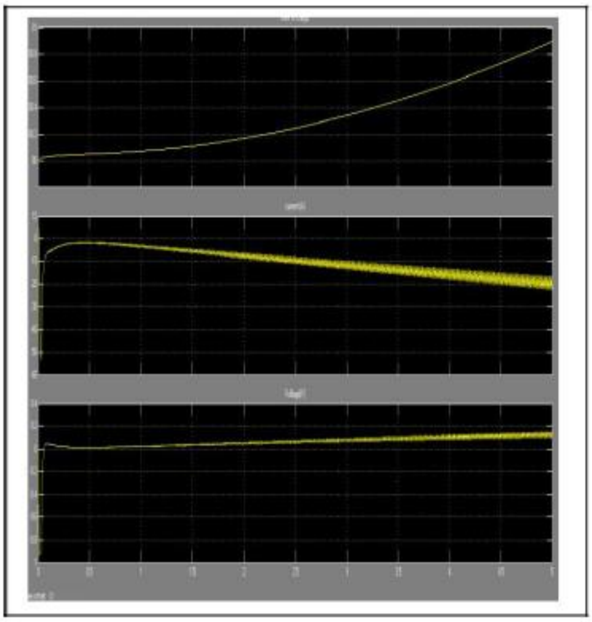

Fig.5 Battery characteristics state of charge showing charging and discharging currents

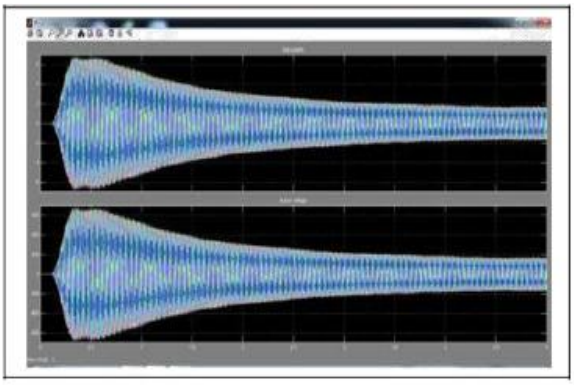

Fig. 6Hybrid Inverteroutput V-Icharacteristicsfor 10cycles

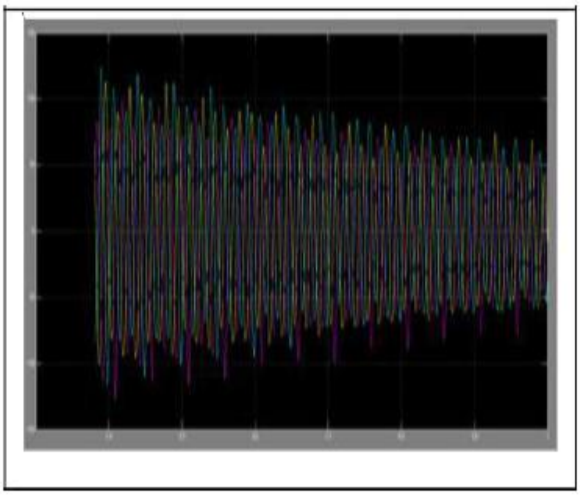

Fig. 7 HybridInverter output

Table 2.Simulated results for wind and solar power under varying wind speed and constant irradiance

Wind speed m/s	Wind power watt	Solar power watt	Total power watt
	P_W kW	P_S kW	P_T kW
6	2.529	2.190	3.425
7	2.742	2.190	3.562
8	2.474	2.190	3.544
10	2.531	2.190	3.444
11	2.651	2.190	3.456
13	2.635	2.190	3.245
15	2.578	2.190	3.456

From the Table 2 it is clear that for a variable wind speed range of 6 to 15 m/s, the total power almost remains constant for the assumed designed parameters of the Hybrid renewable model. Here the irradiance and number of cells are considered and the solar module is designed accordingly. The obtained solar output is fed to the Boost Converter circuit to get boosted values of voltage and then it is given to the battery and thereby fed to the Inverter to get output which is in DC. Here the focus is also targeted on the selection of inverter, with the use of conventional inverter the THD obtained is approximately 30% and with the use of 7 level MLI the obtained THD is 19.25% which is within the IEEE standards as in Fig.9 and Fig.11. By using MLI the switching losses will be reduced and output waveform obtained will be in the staircase form .Also the frequency obtained using MLI can be used for both fundamental and very high frequency.

Considering the state of charge as 85%, the battery is charging accordingly withdecrease in the value of the charging current. The wind turbine is designed considering a wind speed of 10m/sec and solar system with an irradiance of 1000. As the two sources are to be combined the voltage level must be equated before hybridization .By simulation both

output voltages are 100V considering resistiveload.After getting the same voltage profile the hybrid system is connected to boost converter to get constant dc and finally connected to inverter to get 3 phase ac.

The wind output is continuously varying and therefore to get a sinusoidal output waveformwith constant frequency it is rectified using a diode and then it is inverted using switches like MOSFET’s, IGBT’s etc. Lastly, it is supplied tothe AC load.Due to large variationin climatic conditions and the pressure and density of air, the wind output is always havingsevere levels of distortions.

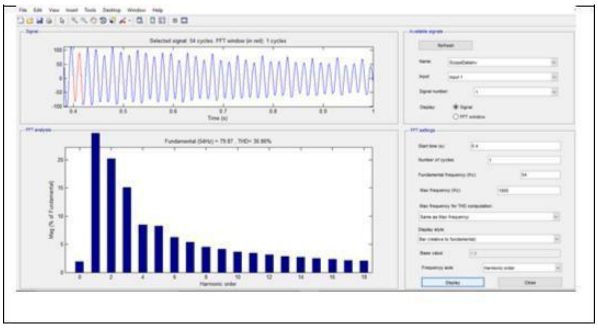

Fig.9 THD of conventional Inverter

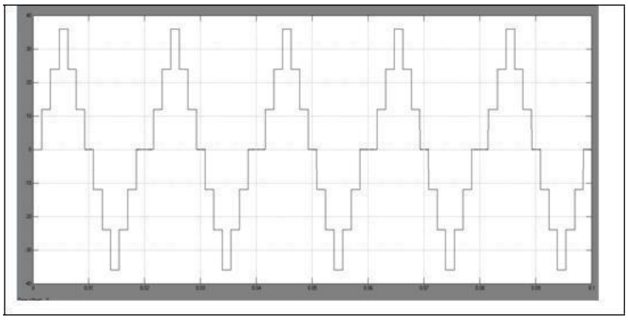

Fig.10 Hybrid MLI output(7 level)

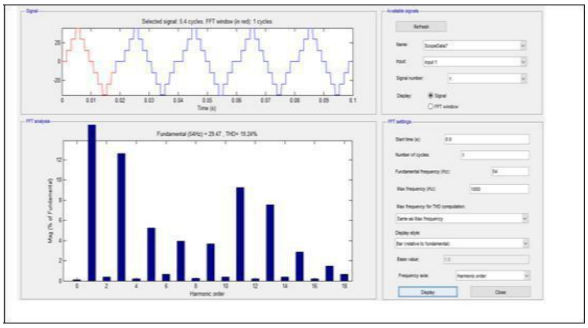

Fig.11THD of 7level MLI

VII. RESULTS AND DISCUSSIONS

Fig 3 & 4 shows the simulation results of solar & wind energy system respectively in terms of V & I. After simulation the solar power output is 87.7% of the design values, which is acceptable and similarly the wind power output is 90 % of the design vales which is also satisfactory.Considering performance analysis of the hybrid model for a time period from 0 to 1.2 seconds, the simulated r.m.sphase voltages and currents and taking 0.9 lagging power factors as per the modeling design parameters, the power output of the hybrid system is 4.320 kW.Finally, here the attempt was to design 2kWSolar and 3kW wind and simulate the system. The simulation results showed the solar power as1.754kW and wind power as 2.699kW.

VIII. CONCLUSION

The Hybrid System is designed for 5kW, modeled and Simulated using MATLAB/Simulink. The simulationresults reveal that the output power of hybrid model is as per the design with an efficiency86.4 %as expected. Further, the frequency at varied load condition is 50 Hz. The Hybrid PV and Wind Energy system is designed not only to meet the electricity requirements but can also be used for water pumping stations.The proposal ascertains the optimum system involving few essential components only. The panel size,turbine size and battery size calculations serve as guidelines for the people willing to set up such systems. The complexity is reduced due to the use of a Single Boost Converter with 3 phaseMLImaking the system more economically viable and reliable to reach the distant places. This hybrid system is a suitable alternative to providepower to rural/remote areas when it is not possible to supply power from central grid due to lack of infrastructure.

REFERENCES

1. M. AtiqurRahman Ali T. Al Awami A.H.M.A. Rahim ―Hydro-PV-Wind- Battery Diesel Based Stand-Alone Hybrid Power System‖ IEEEpp 1 - 6, April 2014.
2. M.A. Elhadidy and S.M. Shaahid, Promoting applications of hybrid (wind+photovoltaic+diesel+battery) power systems in hot regions, Renew Energy 29 (4) (2004), pp. 517–528.
3. Giraud F, Salameh ZM. Steady-state performance of a gridconnectedrooftop hybrid wind–photovoltaic power system with battery storage. IEEE Trans Energy Convers2001;16(1):1–7.
4. Bhave AG. Hybrid solar–wind domestic power generating system—a case study.RenewEnergy 1999;17(3):355–8.
5. D.B. Chia, B.L. Yong, R.K. Rajkumar, V.K. Ramachandaramurthy, Design of a PV/Wind Hybrid System for Telecommunication Load in Borneo Region, 9.International conference on environment and electrical engineering, 2010 Prague, Czech Republic, pp. 73-76, ISBN978-1-4244-5374-0
6. B. Tudu, K. K. Mandal, N. Chakraborty I. Mukherjee―Stand-alone Hybrid Renewable Energy System-An Alternative to Increased Energy Demand'' IEEE. Control, Instrumentation, Energy and Communication (CIEC), 2014 International Conference pp 335 – 339, Jan 31.
7. A. Gupta, R.P. Saini and M.P. Sharma ―Design of an Optimal Hybrid Energy System Model for Remote Rural Area PowerGeneration‖IEEE.Electrical Engineering,2007. ICEE.International Conference, pp 1-6, April 2007.
8. R. Belfkira, G. Barakat, T. Nicolas, C. Nichita―Design study and optimization of a grid independent wind/PV/Diesel system‖ IEEE. pp 1-10 , September 2009 .
9. BinayakBhandari , Kyung-Tae Lee , Caroline Sunyong Lee ,Chul-Ki Song , Ramesh K. Maskey , Sung-HoonAhn, ―A novel off-grid hybrid power system comprised of solar photovoltaic,wind, and hydro energy source‖ Elsevier Vol. 133, pp 236–242 November 2014.
10. Rajesh Kumar a,n, R.A.Gupta a, Ajay Kumar Bansal,―Economic analysis and power management of a stand-alone wind/ photovoltaic hybrid energy system using biogeography based optimization algorithm‖ Elsevier. Vol. 8, pp 33–43 February 2013,
11. HaoQian, Jianhui Zhang and Jih-Sheng Lai, ―a grid-tie battery energy storage system,‖ IEEE Conference, June 2010
12. S. Jain, and V. Agarwal, ―An Integrated Hybrid PowernSupplynfor Distributed Generation Applications Fed by Nonconventional Energy Sources,‖ IEEE Transactions onEnergy Conversion, vol. 23, June 2008.