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Development of Renewable Energy based Hybrid System for Electricity Generation-A Case Study

Robinson P[1], Ashwin C Gowda[2], Syed Sameer[3], Shahnawaz Patil[4]

[1,3,4] *Assistant Professor, School of Mechanical Engineering, REVA University, Bengaluru, India*
[2] *Assistant Professor, VTU PG Center, Muddenahalli, Bengaluru, Karnataka India*

Abstract: **- Energy demand always lags energy supply in developing countries, which results in energy crisis. The conventional energy sources are finite and exhaustible. The solution to problem of energy crisis is utilization of renewable energy. Renewable energy sources are usually found in small scale, decentralized with regard to different geographical distribution, transition to renewable energy sources is viable option as the price of oil and gas continues to fluctuate. As an alternative to custom, onsite construction of centralized power plants, renewable systems based on PV arrays, windmills, Biofuel energy based systems or small hydropower, can be mass-produced "energy appliances" capable of being manufactured at low cost and tailored to meet specific energy loads and service conditions. , to make optimum utilization of renewable energy there exists a need to integrate the different renewable energy systems. The present work involves development of Renewable Energy based hybrid system for electricity generation that can supply desired power continuously throughout the year irrespective of fluctuation of energy available from standalone systems. The energy assessment has been done using Homer simulation tool for developing small solar-wind hybrid system, performance evaluation has been done.**

Key Words: **Standalone systems, Hybrid Systems.**

I. INTRODUCTION

The potential of renewable energy sources is enormous as they can in principle meet many times the world's energy demand. Renewable energy sources such as Solar PV, wind, hydropower, geothermal can provide sustainable energy services, based on the use of routinely available, indigenous resources. A small scale system and located near the consumer is called the Micro-Grid (MG) system. The world's energy situation, whether in developing or industrialized countries, is an issue frequently discussed under economic, technical and political aspects. While it has meanwhile become common knowledge that today's main resources of energy such as coal, crude oil, natural gas will become scare within the next generation the renewable sources such as hydro,wind,solar and bio-energy are gaining importance in terms of research and development as well as implemented systems. A common feature of renewable energy system is that they are mainly available through a decentralized, sometimes even individual approach. This generates a chance of having energy at its one's disposal but creates a problem of management and network when large energy quantities are required. This paper in organized as follows: Section II and II describes objectives and methodology of the project undertaken, section IV provides a brief description of load assessment as well as energy assessment from standalone systems and solar-wind hybrid system using Homer simulation tool at National Institute of Engineering-Centre for Renewable Energy and Sustainable Technologies (NIE-CREST), Mysuru, India. Lastly, the conclusions are drawn in Section V.

II. OBJECTIVES

The main objective of the project is to design and develop as well as to analyse the behaviour of the solar-wind hybrid system at NIE-CREST. In order to develop hybrid system required load assessment, performance study of the standalone systems has been carried out later the performance of the hybrid system has been done.

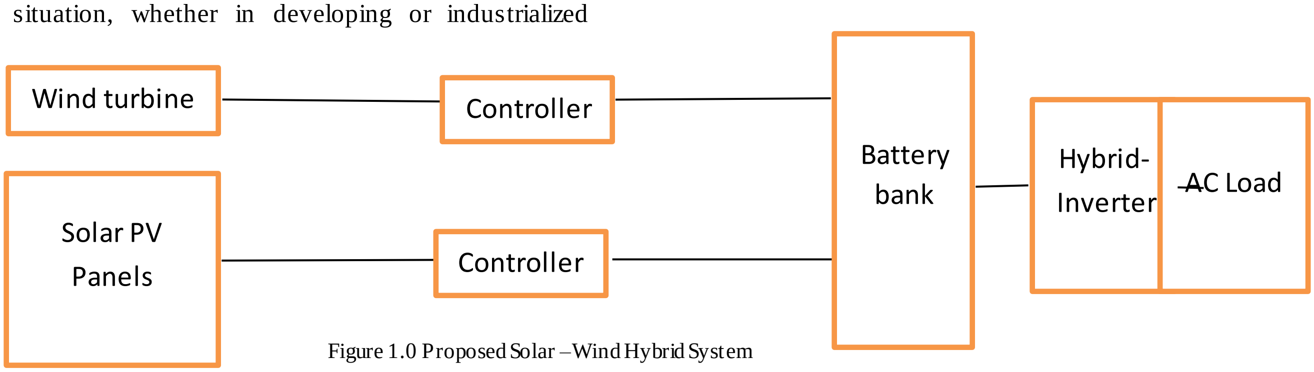

Figure 1.0 Proposed Solar –Wind Hybrid System

III. METHODOLOGY

- Conducting Load assessment at NIE-CREST.
- Evaluation of Energy from Solar photovoltaic system.
- Evaluation of Energy available from wind turbine.
- Performance Study of Bio fuel based Energy system.
- Exploring the feasibility to integrate these standalone systems
- Developing the hybrid system and evaluating its performance

IV. LOAD ASSESSMENT AND PERFORMANCE EVALUATION OF STANDALONE SYSTEMS.

4.1 Load Assessment

Detail load assessment as shown in table 1 at NIE-CREST was carried out in order to connect to the solar-wind hybrid system and it was calculated that 2508 W-hrs of energy is required per day for the CFLs, Tube lights and Street lights. It has been observed that peak load was found to be 596Watts during 6pm to 9pm. The total successive energy consumed per day is the cumulative energy that accounts to about 2508 Watt-hours. The term day of autonomy as 2 days, with depth of discharge as 70% at 24V, ampere hours required is (2508*2)/24*0.7) Ah i.e. 146.3 Ah, considering battery specifications as 100Ah at 24 V no of batteries needed is 146.3/100=1.463,hence minimum 2 batteries needs to be considered.

4.2 Energy Assessment From Solar Photovoltaic System

The total panel capacity required for fulfilling 2508 Watt-hrs of energy per day can be determined by using solar irradiation data available from the homer software is shown in figure 3. To determine the minimum amount of energy that would be usable throughout the year the month with the least solar radiation i.e. July (4.36 kW-hr/m^2/day) is considered. The total panel capacity required for fulfilling 2508 Watt-hrs of energy per day can be determined by using solar irradiation data available from the homer software. To determine the minimum amount of energy that would be usable throughout the year the month with the least solar radiation i.e. July (4.36 kW-hr/m^2/day) is considered.

- Daily watt-hrs = daily solar radiation on the panels (kW-hr/m^2)*1000/1000(W/m^2)

  =4.36*1000/1000 =4.36 hr

- Total energy required =2508W-hrs/day
- Total wattage of panel required =total energy required/daily in watt hrs

  =2508/4.36 = 575.22W

- Taking DSP sinewave inverter efficiency as 90%,the wattage of the panel

  =575.22/0.9 =639.14

Table 1 Load pattern planned for hybrid system.

Sl no	particulars	quantity	load(W)	Total load(W)	hours used(h)	total energy(Wh)
1	Tube lights	6	40	240	3	720
2	CFL Lights	12	23	276	3	828
3	Street Lights	2	22	44	12	528
4	LED Street Lights	1	36	36	12	432
	Total			596		2508

Table 2 Energy assessment table

Month	Energy available in Watt-hrs/day		
	Solar PV system	Wind Turbine	Solar-Wind hybrid system
January	4485.29	169.61	4654.9
February	5198.84	108.99	5307.83
March	5588.12	106.08	5694.20
April	5409.33	130.52	5539.85
May	4782.73	217.67	5000.41
June	3730.29	764.88	4495.17
July	3543.37	667.48	4210.85
August	3624.64	574.59	4199.23
September	4107.38	204.10	4311.49
October	3987.91	75.06	4062.98
November	3968.41	127.15	4095.57
December	4169.15	257.75	4426.90
Annual average	4383.22	283.66	4666.89

Therefore, number of 43W panels required is 639.14/43 =14.86. Hence 15 panels of 43 watts is sufficient to light 3 street lights, 12 CFLs and tube lights. But since 21 panels were made available and taking into the account of intending to connect more load in near future and also by considering the capacity of hybrid inverter installed at NIE-CREST is of 1.5kVA capacity it was decided to connect all 21 panels available in parallel to get maximum energy available.

Daily watt hrs =daily solar radiation on the panels (kW-hr/m^2)*1000/1000 = 4.36*1000/1000 =4.36hrs

Energy available at the panel output=43*21*4.36 =3937Watt-hrs/day. Considering efficiency of the DSP sinewave inverter as 90%, the amount of energy available is 3543.3 Watt-hrs/day in the month of July, similarly amount of energy available in other months are tabulated and is shown in the table.

4.3 ENERGY ASSESSMENT FROM WIND TURBINE.

The wind speed at NIE-CREST vicinity was recorded using an Anemometer, it was observed that the wind speed is very low at turbine vicinity. For the turbine to give the rated output

(400W), the wind speed must be 12.5m/s, since the wind speed observed at crest top is less than the cut-in wind speed of the turbine. However, wind turbine is expected to produce some amount of electricity during windy season hence energy produced by wind was tabulated theoretically using wind speed data available from Homer Software is shown in figure 2. We can approximately estimate the energy from the wind speed data that is available from the Homer software.

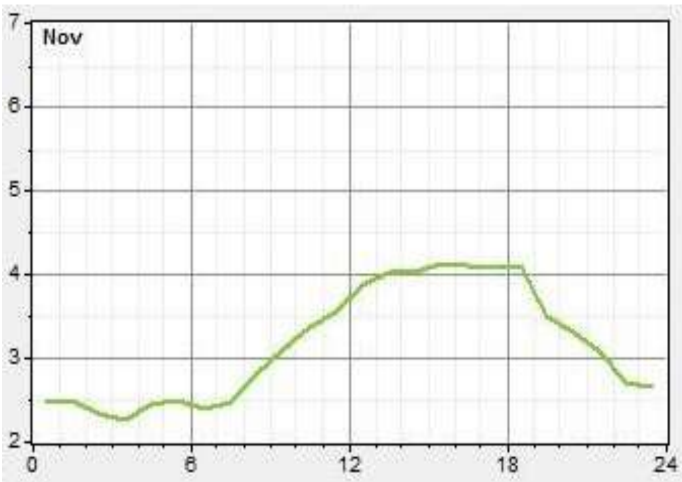

Figure 2.0 24 hours Wind resources input in the month of November in m/s at NIE-CREST Mysore

Wind power density,

$P_{rmc} = 0.5 * \rho * V_{rmc}^3$ Watt/m²………… (a)

Root mean cube velocity Vrmc= $[(1/n)*(\sum_i V_i{}^3)]$ ^⅓ m/sec….(b)

The cut in wind speed of the turbine is 3 m/sec and hence we consider only those wind velocities greater or equal to 3 m/sec to calculate Vrmc for a da Power in the wind, P = 0.5 * ρ * A * Vrmc ³ Watts ….(c)

Wind power(in Watt-hrs/day)=0.5* ρ * A * Vrmc ³ *T….(d)

Power at the turbine o/p (in Watt-hrs/day) = (d)* η……….(e)

Inverter efficiency = 90 %……….. (f)

Power available for use = (e) * (f) …..Where,

ρ = Air density (kg/m³), V_{rmc} = Root mean cube velocity of the wind (m/sec),V_I = Wind speed (m/sec) at the i^{th} observation, n = number of observations in the averaging period. A = Rotor swept area (m²) which is given by: π/4* D², D = Diameter of the rotor (m), T = number of hrs in a day for which velocity is greater or equal to 3 m/sec,η = Efficiency of the turbine, ρ = Air density (kg/m³),V_{rmc} = Root mean cube velocity of the wind (m/sec).V_I = Wind speed (m/sec) at the ith observation. n = number of observations in the averaging period

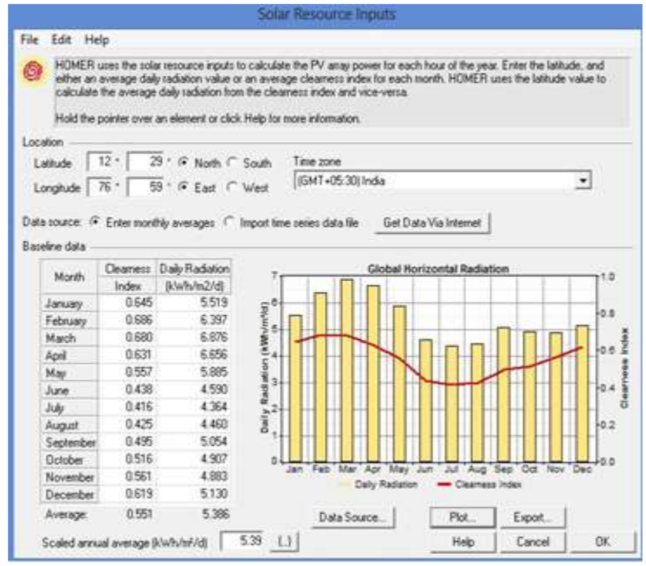

Figure 3 Wind Resource inputs at NIE-CREST Mysore

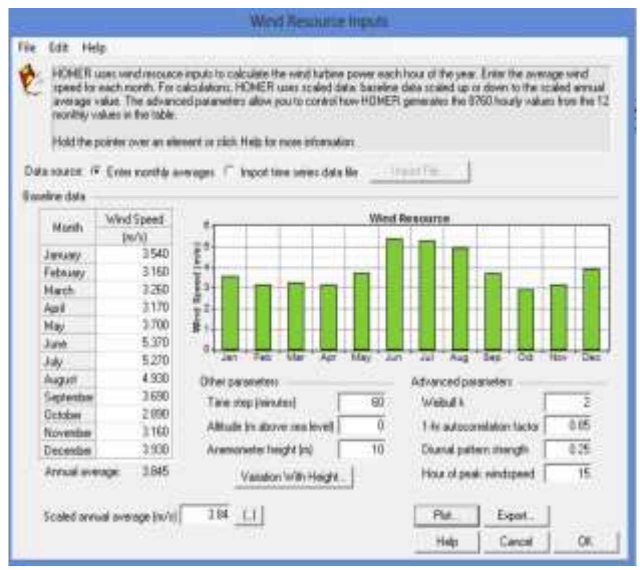

Figure 4 Wind Resource inputs at NIE-CREST Mysore

- The turbine is rated to produce 400 Watts at a speed of 12.5 m/sec as specified by the manufacturer and hence this data could be used to calculate the efficiency of the wind turbine as follows:
- Power in the wind, P = 0.5 * ρ * A * V³ Watts = 0.5 * 1.225 * π/4* 1.17 * 1.17 * 12.5³ =1286.2 Watts
- Power at the turbine output, P_{actual} = 400 Watts
- Efficiency, η = P_{actual} / P * 10 = 31.1%

Tabulating the energy from the wind turbine; for the month of November the average hourly wind speed data was collected from the graph shown below from the homer software.

- Root mean cube velocity, V_{rmc}= $[(1/n)*(\sum_i V_i\ ^3)]$ ^⅓ m/sec In November, only for 13 hours we get the wind speed more than 3 m/s. Hence n=13. Figure 3 shows the wind velocity values are taken using the data available from the graph stimulate by Homer software.
- $V_{rmc}=[(3^3+3.2^3+3.5^3+3.7^3+4^3+4.1^3+4.1^3+4.2^3+4.1^3+4.1^3+3.7^3+3.4^3+3.2^3) / 13]$ ^⅓ m/sec = 3.75 m/s
- Power in the wind, P = 0.5 * ρ * A * V³ Watts =0.5 * 1.225 * π/4* 1.17 * 1.17 * 3.75³ = 34.73 Watts.
- Wind power (in Watt-hrs/day) = 0.5 * ρ * A * Vrmc³ * T=34.73*13 = 454.3 W-hr/day
- Power at the turbine output = 454.3 * efficiency of turbine = 454.3 * 0.311 = 141.28-hr/day
- Energy available for use = 141.28* efficiency of the inverter = 141.28 * 0.90 = 127.75 W-hr/day

Similarly the energy available throughout the year can be tabulated by using the data available in the figure 4, table 2 shows the consolidated data of energy available from solar PV system and Wind turbine.

4.4 PERFORMANCE EVALUATION OF BIO-FUEL BASED ENERGY SYSTEM

. The performance the individual system has been carried out, the performance of conventional 4-stroke diesel engine was carried out using diesel, bio-diesel as, well as blend of bio-diesel and bio-gas.

1. Specific fuel consumption

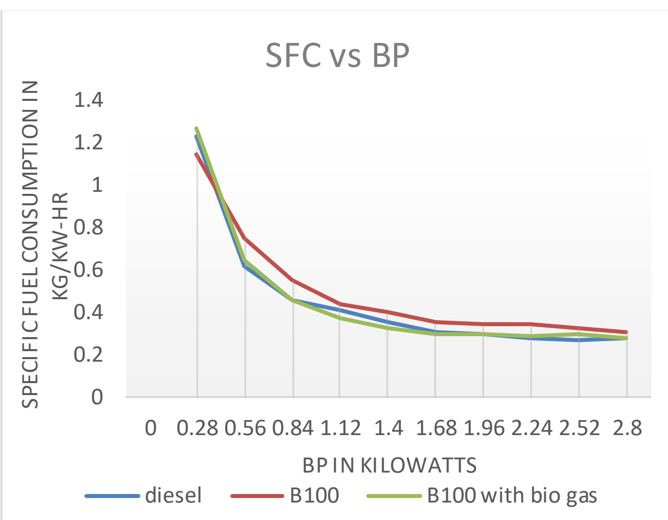

Figure 5 Variation of Specific Fuel Consumption with Load

Minor variations in specific fuel consumption of the diesel and B100 with biogas mixture were observed during the experiment, from the figure 1 it is evident that SFC of B100 is slightly more than that of diesel. After repeating the experiment by blending B-100 with biogas SFC observed at the beginning of the experiment was slightly more compared to Diesel and B100 but as the load gradually increases the SFC of the B100 blended with biogas will stabilise and is comparable to that of the diesel.

2. Mechanical efficiency

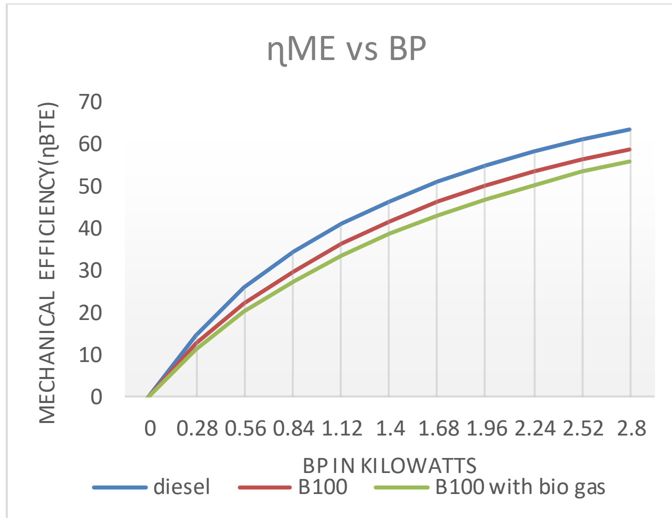

Figure 6 Variation of Mechanical efficiency with Load

The mechanical efficiency of the B-100 and B100 with biogas dropped substantially as compared to the diesel through-out the experiment. Drop in mechanical efficiency was observed for the biodiesel when it was blended with the biogas. The reason for this is because of the lower calorific value of biodiesel which is comparatively lesser than that of diesel.

3. Indicated Thermal Efficiency.

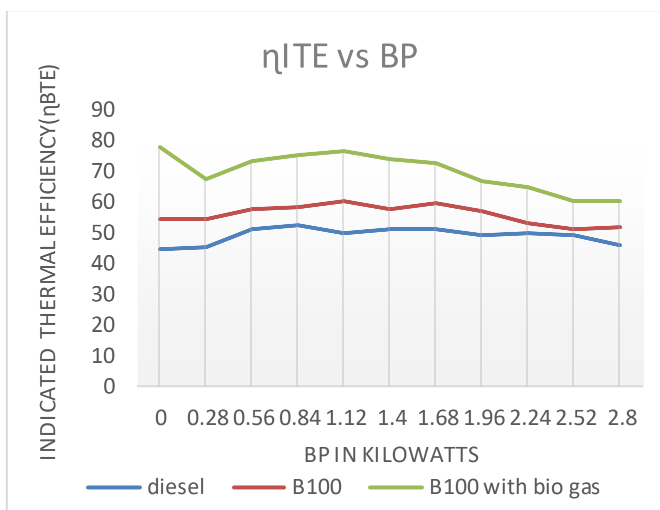

Figure 7 Variation of Indicated Thermal Efficiency with Load

Compared to diesel the indicated thermal efficiencies of the b100 and b100 blended with bio gas has the higher indicated thermal efficiency throughout the experiment. Highest

Indicated thermal efficiency was observed during the initial loading condition and it slowly decreases with increase in load.

4. Brake Thermal Efficiency

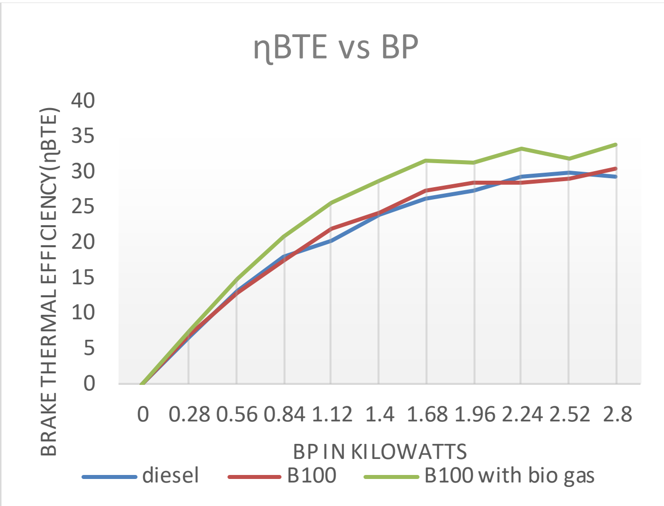

Figure 8 Variation of Brake Thermal Efficiency with Load

Compared to diesel and B-100 the brake thermal efficiency of b100 blended with bio gas has the higher brake thermal efficiency throughout the experiment. Brake thermal continuously increased with increase in load.

V. IMPLEMENTATION OF SOLAR-WIND HYBRID SYSTEM

The 21 solar panels 43 watts capacity were connected in parallel. The hybrid inverter of 1.5KVA developed was successfully installed to the solar panels of 903watts and 400 watts wind turbine. The technical details of the various components of hybrid system is shown in table 3 and table 4,it basically consisted of the following components

Solar photovoltaic panels: The panels convert sunlight directly to electricity (DC). They work any time the sun is shining, but more electricity is produced when the sunlight is more intense and strikes the PV modules directly (as when the rays of sunlight are perpendicular to the PV modules).

Table 3 Technical Specifications of the Solar Photovoltaic Panels installed at NIE-CREST

Rated power of the PV Panel	Number of Panels	Maximum Power(P_{max})	Open circuit voltage(V_{oc})	Short-circuit current(I_{sc})	Voltage at P_{max}	Current at P_{max}	Make
43 Watts	21	43 Watts	101V	0.78A	71V	0.616A	BP Solar

Table 4 Technical specifications of Wind Turbine and Hybrid Inverter installed at NIE-CREST

Wind Turbine		**Hybrid inverter**	
Rated power	400 watts @12.5m/sec	Capacity of the inverter	1500kW
Start-up wind speed	3m/sec	Battery Voltage	24V
weight	6kg	Solar charging capacity	40Amps
Rotor diameter	1.17m	Make	DREDO
Make	Southwest Wind Power		

The purpose of a bridge rectifier in electronic circuit is to convert the ac voltage (wave) into Dc voltage. Here it is connected to the wind turbine which is supplying AC power.

Maximum Power Point Tracker an MPPT controller, in addition to performing the function of a basic controller, also includes a DC voltage converter, converting the voltage of the panels to that required by the batteries, with practically no loss of power. In other words, they attempt to keep the panel voltage at their Maximum Power Point, while supplying the varying voltage requirements of the battery.

Hybrid Inverter: Many electrical appliance work on AC and hence the inverter is used for this purpose. Although the maximum load connected to the output of the hybrid system is of 596 Watts but taking into the overview of enhancing the load near future and taking into consideration that unlike battery and solar panels which can be scaled up/down as per requirement inverter capacity cannot be changed once installed, after discussion with the CREST Director we decided to put 1.5kW DSP pure Sine wave hybrid inverter. The hybrid inverter has power factor of 0.8 hence the load that needs to be connected from the output of this hybrid inverter should not exceed (1500*0.8) i.e 1200watts.

Battery: Although it was suggested to put 146.3A-hr battery at 24 Volts. But the energy consumed in a day less than that of the maximum cumulative energy of 2508Watthrs since we may not use the tube lights and CFLs for 3 hrs exactly, as some days the office may get closed earlier and taking into the consideration the cost involved in installing battery of this capacity with our available budget we had installed two 100-A-h battery of 12 Volts connected in series. Capacity of the battery – 24V, 100 A-hr.

5.1 PERFORMANCE EVALUATION OF HYBRID SYSTEM

The Solar Wind hybrid system was fully charged during the day time and the performance was conducted from 6.30pm by connecting to 596W load through the 1500kVA inverter. The loading arrangement was connected to the energy meter to note down the exact energy consumed over the time period. The time duration for which the load was run was also noted.

Table 5 Energy meter readings of solar wind hybrid system

Trial No	Time at the beginning of experiment	Initial energy meter reading in kWh	Time at the end of experiment	Final energy meter reading in kWh	Total energy consumed in kWh
1	6.35pm	199.8	9.45pm	201.1	1.3
2	6.30pm	204.8	9.39pm	206.1	1.3
3	6.30pm	208.3	9.42pm	209.6	1.3

The test was started repeatedly conducted from around 6.30 PM and the discharge from the battery was complete at 9.45 PM. Hence the solar-wind hybrid system was able to supply energy for 3 hrs and 10 minutes. The test was started at 6.35 PM and the discharge from the battery was complete by around 9.40 PM. Hence the solar-wind hybrid system was able to supply energy for 3 hrs and 10 minutes. The details of the experiments were shown in table 5.

Capacity of the battery =24 Volts ×100 A-hrs = 2400 Watt-hrs.
Actual capacity of the battery = 1300 Watt-hrs
Depth of discharge of battery = (1300/2400) ×100 = 54.16%

Presently the battery is delivering about only 1300 Watt-hrs a day at 54.16% depth of discharge when it is fully charged from the hybrid system. As per the load assessment 2.5kWh of energy is required per day hence the present battery capacity has to be upgraded twice the present capacity so that it would deliver backup of 2600 Watt-hrs/day (1300×2). If the battery capacity is enhanced then 2508 Watt-hrs of energy needed per day will be fulfilled and this avoids utilizing energy from conventional sources. Also as estimated from table 5.3 that irrespective of any conditions minimum of 4 units of electricity will be available in every month out of which only 1.3 units electricity is being utilized hence for optimum utilization of the energy available from the system load has to be enhanced and prior to this battery capacity has to be increased.

VI. CONCLUSION

The project is indeed a unique system for optimum utilization of energy from different RE based systems. The project aims at the integration of renewable energy system at NIE-CREST. It has been achieved by integrating the solar-PV system and wind energy system at NIE-CREST. A Hybrid inverter has been installed to take inputs from the solar-wind hybrid energy system. The performance study of all the individual systems including, bio-fuel, solar and wind energy systems has been done. As per the data obtained by the anemometer at the CREST top wind speed observed is less than that of the cut-in wind speed of 3m/s specified by the manufacturer of the wind turbine hence this needs to be further analysed during May to August when average wind speed will be around 5 m/s. Hence it is clear that at present maximum electricity to the hybrid inverter is being contributed by 21 solar panels of 43Watts connected in parallel. The output from the individual systems vary in terms of electrical parameters like voltage and current, hence these outputs cannot be directly connected to the load, the outputs from these individual standalone systems need synchronization prior to their connection to the load. The PV-wind hybrid inverter that has been developed and installed at NIE-CREST functions as a synchronizer and provides a constant desirable output ($220V_{AC}$) for common electrical applications. Presently the battery is delivering about 1300 Watt-hrs a day at 54.16% depth of discharge when it is fully charged from the hybrid system. As per the load assessment 2.5kWh of energy is required per day hence the present battery capacity has to be upgraded twice the present capacity so that it would deliver backup of 2600 Watt-hrs/day (1300×2). If the battery capacity is enhanced, then 2508 Watt-hrs of energy needed per day will be fulfilled. Also as estimated from table 5.3 that irrespective of any conditions minimum of 4 units of electricity will be available every month out of which only 1.3 units electricity is being utilized; hence for optimum utilization of the energy available from, the system load has to be enhanced and prior to this, battery capacity has to be increased. Although the bio-fuel based energy system was not integrated due to complexity involved in reducing 140 Volts DC to 220Volts AC and also due to limited budget. Further the present system can be integrated if the load needs to be enhanced near future solar wind hybrid system installed presently would not be sufficient hence Biofuel Based Energy system sets can act as a supply source to the hybrid inverter since the biogas digesters is being setup at the vicinity of NIE-CREST. Integration of the RE based hybrid energy system has huge scope because it serves as alternative source for electricity generation. The present project is a small prototype/ model of how Renewable Energy can be utilized for common electrical applications. Hence efforts are to be made for large scale implementation of these types of systems.

REFERENCES

[1]. **Tae-young Lee, Kwang-ho Ha, Hyun-jeaYoo, Jong-wan Seo and Myong-chul Shin**, "Research for Data acquisition equipment with micro-Grid system", 5th International Conference on Electrical and Computer Engineering, IEEE, Bangladesh, 2008, pp. 712-715.
[2]. **Xiaoming Yuan and Yingqi Zhang,** "Status and Opportunities of Photovoltaic Inverters in Grid-Tied and Micro-Grid Systems", IEEE Power Electronics and Motion Control Conference, vol.1, Shanghai, 2006, pp. 1- 4

[3]. **T.K. Panigrahi, A.K. Saha, S.Chowdhury, S.P.Chowdhury, N.Chakraborty, Y.H.Song, S.Byabortta,** "A simulink based micro grid modeling & operational analysis using distributed generators", Proceedings of the 41st International Universities Power Engineering Conference, vol. 1 ,Newcastle, 2006, pp. 222-226.

[4]. **Swati Negi1 and Lini Mathew2**, Hybrid Renewable Energy System: A Review, International Journal of Electronic and Electrical Engineering. ISSN 0974-2174, Volume 7, Number 5 (2014), pp. 535-542.

[5]. **Hashimoto, S., Yachi, T., and Tani, T.**, "A New Stand-Alone Hybrid Power System with Wind Turbine Generator and Photovoltaic Module for a Small-Scale Radio Base Station," IEEJ Transactions on Power Energy, Vol. 125, No. 11, pp. 1041-1046, 2005.

[6]. **Tina G, Gagliano S, Raiti S**. Hybrid solar/wind power system Probabilistic modeling for long-term performance assessment Energy 2006; 80: 578.

[7]. **Nayar CV, Phillips SJ, James WL, Pryor TL, Remmer D.** Standalone Wind/diesel/battery hybrid energy systems. Sol Energy 1997; 21: 13-19.

[8]. **Arribas L, Cano L, Cruz I, Mata M, Llobet E.** PV–wind hybrid system performance: A new approach and a case study. Renew Energy 2010; 35: 128-37

[9]. S P Sukhatme. Solar energy

[10]. AIR-X wind turbine manual.