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Green Energy Home

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Abstract
Renewable Energy technologies like solar, biomass, hydro, etc are deployed both in rural and urban areas to curb the growing gap between the demand and supply of power, which is due to increase in the per capita energy consumption and importantly, the much hyped climate change concerns. The paper aims in the design of wind- solar hybrid system for three different scales of houses which are low, medium and high scale houses, sited at Amrita Vishwa Vidyapeetham in Ettimadai. First the energy audit is conducted in these houses with normal appliances. Then after replacing with energy efficient appliances, the energy consumed by these three different types of houses are obtained. Depending on the energy consumption of each type, different capacities of solar and wind electric generators with battery rating are suggested for different cases. This work also includes the design of the controller unit. Simulation of controller is done which controls the whole hybrid system, the main purpose of which is to ensure continuous availability of electricity.
Keywords: Wind electric generator, Solar panel, Low scale house, Medium scale house, High scale house, PIC controller, Battery

1.INTRODUCTION

Accelerated growth is expected in all renewable energy sectors with favorable conditions in terms of potential, technical support facilities, policy framework and regulatory environment, robust manufacturing base, and investors confidence in the country. Hybrid systems include both solar and wind power and they allow the power user to benefit from the advantages of both forms of energy. These two generation methods offer a more comprehensive alternative to grid-powered electricity. However, there is still the matter of what to do when both solar and wind energy are not available. This can be done by tying the system to the grid or by using a battery bank or a backup generator. Adding a second and a third power supply to a system adds both cost and complexity to a somewhat already complex system, but special electric controllers are designed to integrate all the three powers. The power controller will integrate the wind, solar and backup system providing power to the user and send additional power to a battery bank or the grid, giving the user a reliable and stable source of energy.

2.ENERGY AUDIT

Energy Audit involves a systematic study undertaken on major energy consuming sections and equipments with a view to identify the flow of energy and utilization efficiency of energy. Home energy audit is done by taking down the readings from electronic meters that are fixed these days in most of the houses. A home energy audit is often used to identify cost effective ways to improve the comfort and efficiency of buildings. Energy conservation involves reducing or eliminating unnecessary energy use or loss. In this paper, three different types of houses at Amrita Vishwa Vidyapeetham campus have been considered for energy audit. The number of appliances and their hours of usage were recorded in all three types and energy auditing was done using the details.

2.1 ENERGY AUDITING BEFORE REPLACING WITH ENERGY EFFICIENT APPLIANCES

2.1.1 LOW SCALE HOUSE

In this house there are fans, tube lights, bulbs and one 21 inch television. The energy consumed per day for these appliances are calculated by multiplying the number of the specific appliance by the number of hours used. Similar procedure is followed for all the other appliances and then the total energy consumed by the low scale house per month is calculated. The recordings have been tabulated and given in Table 1.

Table 1-Monthly energy consumption in Low scale house

Load	Rating (Watts)	No of hours used per day	Quantity	Energy consumed per month(kWh)
Fan	80	7	2	33.6
Tube light	40	3	4	14.4
Bulb	60	2	2	7.2
TV	70 (21'')	3	1	6.3

Total energy consumption: 61.5 units per month

2.1.2MEDIUM SCALE HOUSE

In this house there are fans, tube lights, television (25''), washing machine, fridge, iron box mixer grinder, pump motor and water heater. The mixer grinder and iron box are not used every day so we take the average which is 10 min for iron box and 15 min for mixer and grinder.

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Table 2 Monthly energy consumption in Medium scale house

Load	Rating (Watts)	No of hours used per day	Quantity	Energy consumed per month(kWh)
Fan	80	5	3	36
Tube light	40	4	4	19.2
Bulb	60	2	2	7.2
TV	80(25′′)	4	1	9.6
Washing machine	500	2	1	30
Fridge	102	12	1	36.72
Iron box	1000	10 min	1	5
Mixer & Grinder	200	15 min	1	1.5
Pump motor	740	1	1	22.2
Water heater	1500	1	1	45

Total energy consumption: 212.42 units per month

The energy consumed per month for these appliances are calculated and the recordings are tabulated in Table 2.

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2.1.3 HIGH SCALE HOUSE

In this house there are fans, tube lights, two televisions (29′′& 21′′), washing machine, AC ,vacuum cleaner , fridge, iron box, oven, exhaust fan, mixer grinder, computer , laptop, pump motor and water heater. The vacuum cleaner is not used daily and so an average of 17 minutes is taken per day. The energy consumed per month for these appliances are calculated and the recordings are tabulated in Table 3.

Table 3 Monthly energy consumption in High scale house

Load	Rating (Watts)	No of hours used per day	Quantity	Energy consumed per month(kWh)
Tube light	40	6	7	50.4
Bulb	60	2	4	14.4
Fan	80	7	5	84
Water heater	1500	1	1	45
Washing machine	500	2	1	30
AC	2363	5	1	354.45
Vaccum cleaner	1000	17 min	1	8.5
TV	140(29′)	4	1	16.8
	68(21′)	2	1	4.08
Computer (pc)	125	1	1	3.75
Oven	800	0.5	1	12
Iron box	1000	10 min	1	5
Mixer & Grinder	200	15 min	1	1.5
Fridge	102	12	1	36.72
Laptop	25	2	1	1.5
Exhaust fan	150	1	1	4.5
Water pump	740	2	1	44.4

Total energy consumption: 717 units per month

2.2 ENERGY AUDITING AFTER REPLACING WITH ENERGY EFFICIENT APPLIANCES

Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy policy. In many countries energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted.

2.2.1 LOW SCALE HOUSE

If energy efficient appliances are used then energy consumed is reduced. Here tube light and bulbs are replaced by an energy efficient appliances of 20 watts. The television is also replaced which is of 45 watts. This causes reduction of energy consumed. Total energy consumed per day for the low scale house is 47.25 units per month as shown in Table 4.

Table 4 Monthly energy consumption in low scale house

Load	Rating (watts)	No of hours used per day	Quantity	Energy consumed per month(kWh)
Fan	80	7	2	33.6
Tube light	20	3	4	7.2
Bulb	20	2	2	2.4
TV	45(21′′)	3	1	4.05

Total energy consumption: 47.25 units per month

2.2.2 MEDIUM SCALE HOUSE

In the medium house, tube light which is replaced is an energy efficient one which is of 20 watts. The replaced bulb is of 20 watts, the replaced fridge is 93 watts and the television is also replaced which is of 53 watts. This causes reduction of energy consumed. Energy consumed per month is calculated in the above mentioned way and hence the total energy consumed per month for the medium scale house is 191.54 units per day as shown in Table 5.

2.2.3 HIGH SCALE HOUSE

Table 5 Energy consumption in Medium scale house

Load	Rating (watts)	No of hours used per day	Quantity	Energy consumed per month(kWh)
Fan	80	5	3	36
Tube light	20	4	4	9.6
Bulb	20	2	2	2.4
TV	53(25'')	4	1	6.36
Washing machine	500	2	1	30
Fridge	93	12	1	33.48
Iron box	1000	10 min	1	5
Mixer & Grinder	200	15 min	1	1.5
Pump motor	740	1	1	22.2
Water heater	1500	1	1	45
				191.54

In this house the replaced appliances are tube light, bulb, television, fridge and AC. The replaced AC is of 1677 watts. This causes reduction of energy consumed. Energy consumed per month is calculated in the above mentioned way and hence the total energy consumed per month for the high scale house is 566.45 units per month as shown in Table 6.

Table 6 Energy consumption in High scale house

Load	Rating (watts)	No of hours used per day	Quantity	Energy consumed per month(kWh)
Tube light	20	6	7	25.2
Bulb	20	2	4	4.8
Fan	80	7	5	84
Water heater	1500	1	1	45
Washing machine	500	2	1	30
AC	1677	5	1	251.55
Vaccum cleaner	1000	17 min	1	8.5
TV	61(29')	4	1	7.32
	45(21')	2	1	2.7
Computer (pc)	125	1	1	3.75
Oven	800	0.5	1	12
Iron box	1000	10 min	1	5
Mixer & Grinder	200	15 min	1	1.5
Fridge	93	12	1	33.48
Laptop	25	2	1	1.5
Exhaust fan	150	1	1	4.5
Water pump	740	2	1	44.4

Total consumption: 566.45 units per month

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3. WIND SPEED DATA OF AMRITA CAMPUS

Wind speed is the most important parameter to be considered in the design and operations of WEGs[4].

Energy produced by wind generator (Whr)

$=[\sum P(v)*f(v)]*T$ --------------------- (1)

f(v) = probability density function of Weibull distribution (fraction of time for which the wind is at a given velocity v

where, $f(v) = k/c(v/c)^{k-1}e^{-(v/c)^k}$

where, k= weibull shape factor $=(\sigma/v_m)^{-1.09}$

c= scale factor $=2v_m/\sqrt{\pi}$

P(v) = Power generated from WEG at a given velocity v and

T = time period

From wind speed data that is obtained from the Amrita campus, Coimbatore, for two months (Jan and Feb) from which the worst case(Feb) is taken and the value of k and c are determined and hence energy produced by the WEG is obtained. The probability density function is calculated for different values of the wind speed and the corresponding values are tabulated in Table 7.

Table 7 Probability density function for different values of wind speed

v(m/s)	f(v)
2	0.1721

4	0.0642
6	0.0184
8	$4.4*10^{-3}$
10	$9.4*10^{-4}$
12	$1.8*10^{-4}$
14	$3.1*10^{-5}$
16	$5.1*10^{-6}$
18	$7.7*10^{-7}$
20	$1.1*10^{-7}$

Table 8 gives the rating, rated wind speed and the working wind speed of the different wind electric generators considered for the study. From the power curves of the different ratings of the generator, the power output of the WEG can be obtained at various velocities of the wind [2]. Amount of power generated by the wind electric generator at different wind speed for different ratings of the wind turbine are tabulated as shown in Table 9.

The amount of the energy generated for 225 hours of operation (i.e) the time in which the WEG can produce energy in one month is calculated using Equation (1) . And it is calculated for per day and the values are tabulated in Table 10.

4.PHOTO VOLTAIC SOLAR PANEL

A photovoltaic system typically includes an array of solar panels, an inverter, and sometimes a battery and/or solar tracker and interconnection wiring[1].

Energy produced by the solar panels E_{spv} = 60% of solar irradiance * no of sun light hrs * area of solar panel *η --------------(2)

In order to calculate the energy generated by solar panel, peak solar irradiance value for Amrita university=1000 Wh/m^2 .

No of sun light hrs=12 and Efficiency η=0.1

V-I characteristics of solar panel during Morning, afternoon and evening at Amrita University are obtained from the values tabulated in Table 11. Table 12 gives the maximum power output at the different temperature at different time.

Table 8 : Ratings and the details of wind electric generators

Rating(kW)	Rated wind speed(m/s)	Working range of wind speed(m/s)
1	10	3-22
1.5	10	3-25
2	9	3-20
5	10	3-25

Table 9: Power output of different wind electric generators

Wind velocity (m/s)	WEG output (kW)			
	1 kW	1.5 kW	2 kW	5kW
2	0	0	0	0
4	60	100	200	420
6	250	300	800	1360
8	600	800	1600	3100
10	1100	1600	2300	5030
12	1400	2000	2850	6500
14	1300	1980	3200	7380
16	1250	1800	3000	7100
18	1100	1600	2400	6050
20	900	1400	2000	5000
22	570	1150	0	0

Table 10 Energy generation for different WEGs

Rating of WEG	Energy generated per day(Wh)
1 kW	672
1.5 kW	1918.8
2 kW	4476.6
5 kW	8328.8

Table 11 : Voltage- current values taken from the solar panel at Amrita University

Morning		Afternoon		Evening	
Voltage (V)	Current (A)	Voltage (V)	Current (A)	Voltage (V)	Current (A)
0.15	3	0.1	2.25	0	3.5
0.16	2.95	0.16	2.22	0.6	3.5
6.19	2.95	1.59	2.22	1.2	3.5
13.23	2.4	7.18	2.2	5	3.4
15.85	1.8	9.55	2.15	7.18	3.2
17.15	1.2	15.26	1.8	16.02	2.1

17.42	1	16.97	1.2	16.29	1.85
17.68	0.8	17.68	0.8	17.63	1.2
17.81	0.6	17.89	0.7	17.7	0.75
17.9	0.5	17.99	0.65	17.89	0.6
18.09	0.45	18.06	0.6	17.98	0.55
18.6	0	18.6	0.1	18.36	0

Table 12 Maximum power output at different times

Time	Pm (watts)
9:00am	25
12:00pm	18.84
4:00pm	21

5.DESIGN OF HYBRID SYSTEM

The hybrid system is a combination of solar and wind energy conversion system and a bank of batteries are included for backup purposes. Power conditioning units, such as converters, are also a part of the system. The hybrid system is designed for all the three scales of houses. The demand values for low scale, medium scale and high scale houses are obtained from energy auditing . These values are denoted as E. With the help of different ratings of the WEG , the energy extracted from the WEG is calculated using the power curve and the formulae. Then using the formula $E_{spv} = E - E_{weg}$, where E_{spv} is the energy obtained from solar panels and E_{weg} is the energy from WEG. After getting the E_{spv} , the energy which should be generated from the solar, the area required for the solar panel installation is calculated using the Equation (2).Table 13 shows the generated amount of energy by both the wind and solar systems.

Table 13 Design of hybrid system for low, medium and high scale houses

Case	WIND		SOLAR	
	Rating of WEG (kW)	Energy extracted (Whr)	$E_{spv}=E-E_{weg}$ (Whr)	Area of the solar panel(m^2)
LOW	1	672	903	1.8
MEDIUM	1.5	1918.8	4521.2	9.4
HIGH	5	8328.3	10571.2	21.3

6.SELECTION OF BATTERY RATING

Battery serves very important role in hybrid systems. They are used as back-up resources in grid-connected systems. Lead acid battery is most preferred battery for hybrid system compared to all other batteries[1][5].

Formula used for calculating the battery capacity and inverter rating are given below:

Capacity of battery (Ah) =Daily energy demand / (nominal V * %discharge * η) ---------------------------------- (3)

Inverter rating(VA) = Power consumed per day/ pf * η -------------------------------------(4)

Daily load demand of low range houses has to be calculated to estimate the battery capacity. Ratings of batteries and inverters for all three different types of houses have been tabulated in Table 14.

Table 14 Rating of battery and inverter

Case	Inverter rating(VA)	Battery rating(Ah)
Low	510	280
Medium	8000	850
High	13500	3300

7.CONTROLLER FOR HYBRID SYSTEM

The Wind Solar Hybrid system is composed of Solar cell, wind electric generator, intelligence controller, storage batteries, and inverter, etc[3]. When the generated power is just sufficient to meet the load requirement, the controller gives the battery charging signal. Now when generation from wind generator and solar increases, and rises above the demand value, the controller sense the excess power and stores in the battery which is used to charge the battery fully. If the generation is greater than the battery capacity, controller makes use of this excess power generated to run the pump load to fill water tank at home which has a fixed capacity. Now if the water tank gets filled during this state of operation, then the excess power remained is exported to the grid. Now if the generated power decreases, exporting to grid is withdrawn. And after withdrawn, still the generation is less than the demand, energy stored in the battery is used. Then the controller gives signal indicating battery discharging.

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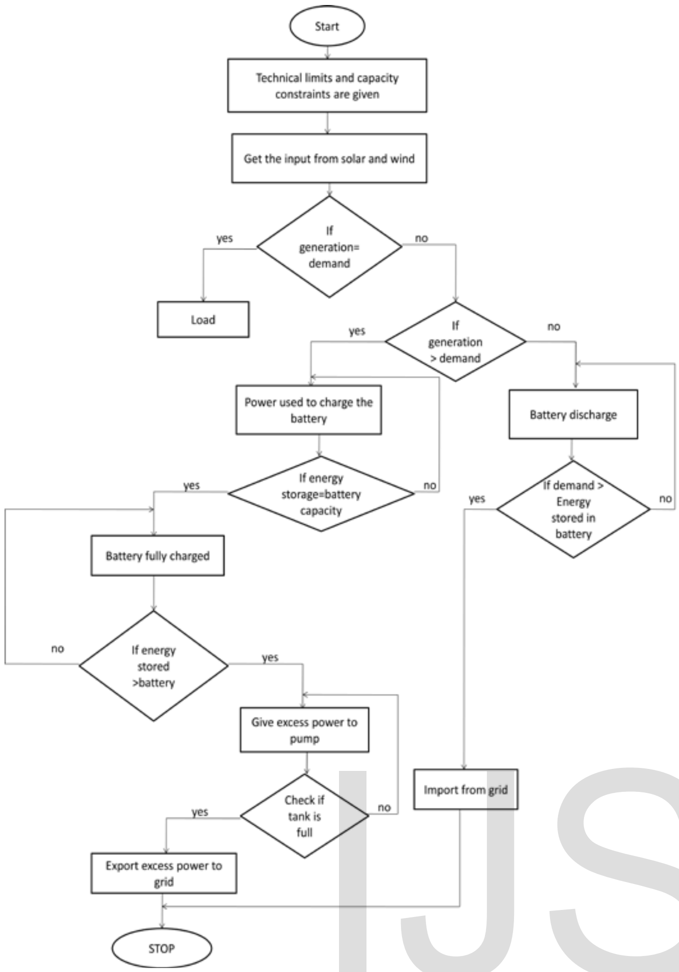

Fig. 2 Flow chart for control algorithm of the hybrid system

If the demand is greater than the power generated and stored energy, then the controller gives the signal indicating import from grid. If the total generation increases, again battery is charged and excess power is exported to grid and load balancing is achieved. The results of simulation prove the feasibility of the design scheme and the validity of the design parameters.Figure 2 shows the flowchart for the control algorithm for the hybrid system. Program for the controller part is done in the software named MIKRO C and the simulation for the controller circuit is done in the PROTEUS software. The simulation circuit is shown in Figure 3.

7.1 SIMULATION RESULTS

One day (24 hrs) is split into four different timings. That is from 6 to 12 pm, 12 to 4 pm ,4 to 6 pm, 6 pm to 6 am. Then average load variation is calculated for four different timings. Battery capacity is assumed as 6500 Ah and pump capacity as 745 W. All the above technical constraints are given to the controller. It will sense the generation for different timings of the day and compare with the respective average load variation. Controller will check all the conditions as mentioned in the algorithm and indicate the corresponding status. The different cases were taken and the results are tabulated.

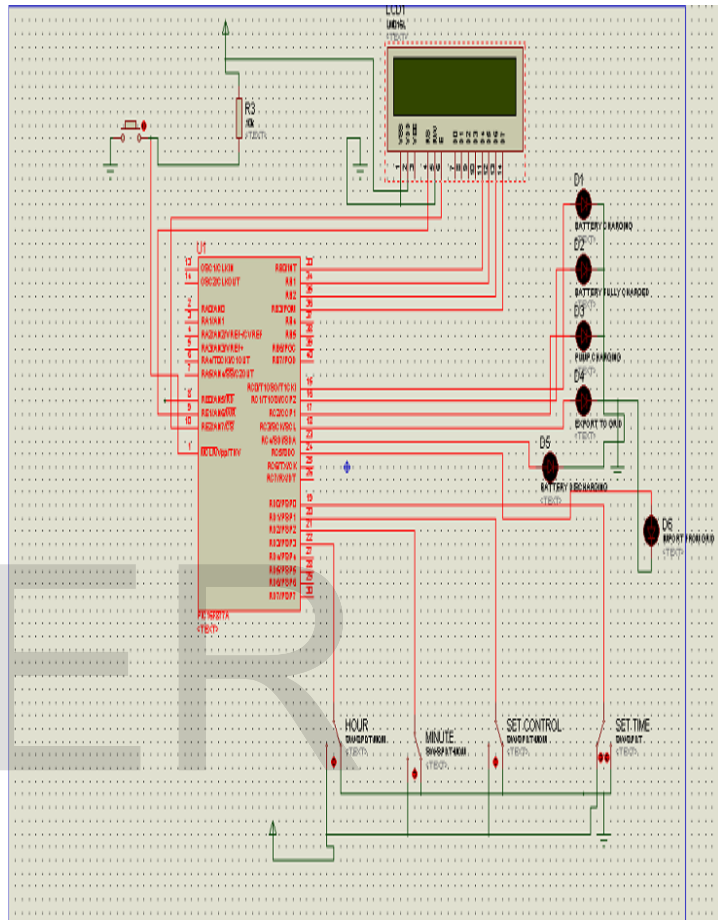

Fig. 3 Simulation setup of the hybrid system controller

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7.1.1 CASE I

Table 15 Simulation result Case 1

Timings	Generation(W)	Load(W)	Battery(Ah)	Status
6 am to 12 pm	6700	1662	5038	Battery charging
12 to 4 pm	100	699	4439	Battery discharging
4 to 6 pm	3000	413	6500	Battery fully charged & pump
6 pm to 6 am	3000	7455	2049	Battery discharge

7.1.2 CASE II

Table 16 Simulation result Case II

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Timings	Generation (W)	Load(W)	Battery(Ah)	Status
6 am to 12 pm	1000	1662	-	Import from grid
12 to 4 pm	7900	699	7301	Battery fully charged & pump
4 to 6 pm	3000	413	2587	Export to grid
6 pm to 6 am	1000	7455	Full	Battery discharging

7.1.3 CASE III

Table 17 Simulation result Case III

Timings	Generation(W)	Load(W)	Battery(Ah)	Status
6 am to 12 pm	6100	1662	4438	Battery charging
12 to 4 pm	2761	699	2062	Battery charging
4 to 6 pm	1155	413	Full	Pump
6 pm to 6 am	100	7455	Full	Export to grid

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8.COST ESTIMATION :

Taking into account the electrical cost, installation and labour cost, Carbon Credit & other financial assistance for all three classes of houses, the payback period for the hybrid system is calculated and tabulated in Table 18.

Table 18 Payaback Period for the hybrid system

Class of House	Payback period (years)
LOW	68.23
MEDIUM	49.11
HIGH	49.43

9.CONCLUSION

In this paper, the design of Hybrid system for three scales of houses at Amrita Vishwa Vidhyapeetham in Ettimadai has been done. Energy auditing is done in three different types of houses and the energy efficient methods are suggested to reduce the power consumption. Hybrid system is designed for all types of houses and installation cost and payback period is calculated. Simulation of controller is done ,which controls the whole system.It effectively implements the load balancing.The main objective of the control system is to ensure continuous generation of electricity. The proposed system can further be enhanced by the usage of latest technologies available. By implementing such a system at every home, the power crisis in the nearby areas can be clearly reduced.

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