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Renewable Energy Sources based Hybrid System for Remote and Rural Areas

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Abstract: Irregular production of renewable resources is the main hindrance in front of high penetration of them. A hybrid system of sustainable resources and energy storage is a reasonable solution to compensate for periodic power generation of stand-alone systems. In this paper, on the basis of solar, biomass and battery storage, a hybrid system is proposed to supply power to rural and remote areas. To extract maximum power from solar PV system at different operating and load conditions, MPPT controller has been used in this proposed system. There are some problems in conventional power generation systems like volatility on fuel costs, environmental pollution etc. In this study, using biogas instead of natural gas is proposed to reduce the loss of using fossil fuels. In order to produce electricity from biomass, this proposed framework uses direct combustion technology, in which there is more economic and environmental justification for use especially in rural areas. The proposed strategy has high specialized and financial possibilities to actualize in rural and remote areas.
Keywords: Solar PV; biomass; MPPT; battery; State of charge (SOC).

I. INTRODUCTION

Demand for energy in the day is increasing due to increase in population, urbanization and rapid industrialization. This makes coordinate association between energy usage and quality of life. There are limited reserves in fossil fuel resources like coal, oil and gas, which results in proceeded with fuel value climb which influences the economy of any nation. . Because of oil emergency of 1970s, extensive intrigue has brought about using sustainable power sources [1]. Sustainable power source is gotten from sun, wind, biomass, water, tides, sea waves and geothermal warmth. The consistently expanding demand for electrical energy brought renewed interest in renewable and sustainable power generation technologies such as photovoltaic, wind and fuel cell powered systems. While the thirst for electrical power is expanding because of innovative advancements and increments in population, traditional fossil fuel power sources are declining and there is an increase in environmental concerns such as urban air pollution, global climate change and acid coagulation.

The primary fascination of the PV frameworks is that they produce electrical power without hunting the nature, by releasing the entire source of energy directly, solar power in electricity Additionally, the proceeding with diminish in cost of PV exhibits and the expansion in their effectiveness infer a promising part for PV creating frameworks sooner rather than later [2,3]. Sadly, the innovations related with photovoltaic (PV) control frameworks are not yet completely settled, and in this way, the cost of a energy unit created from a PV framework is a request of extent higher than regular energy provided to city zones, by methods for the grid supply. The effectiveness of energy conversion depends for the most part on the PV boards that produce control .Practical systems have less overall efficiency. This is the consequence of the fell result of a few efficiencies, as the energy is changed over from the sun through the PV exhibit, the controllers, the battery, cabling and through an inverter to supply the air conditioner stack [4,5]. Climate conditions additionally impact the productivity, which depends non-directly on the irradiation level and temperature. . For instance, a cloud disregarding a segment of sun powered cells or a sub-module will lessen the aggregate yield intensity of sun powered PV exhibits. Under certain cloud conditions, the progressions can be sensational and quick.

India gets high level of Direct Normal Irradiance (DNI), 4e7 kWh/m2 every day. Thus, there is a huge possibility of decentralized solar energy applications using Concentrating Solar thermal Power (CSP). Be that as it may, CSP advancements are as of now costly and the take-up in India has been moderate. The Jawaharlal Nehru National Solar Mission was set up in 2010 and delineated help for sun powered energy applications to empower advertise infiltration of grid associated and decentralized off-grid applications, to give energy benefits in India [6,7]. One CSP innovation exceptionally compelling is the Linear Fresnel Reflector (LFR), because of its similarly straightforward and economical plan. The LFR utilizes various lines of low profile mirrors to centre sun powered radiation onto a settled target pipe to create steam specifically. Such Direct Steam Generation (DSG) is a contrasting option to the all the more normally utilized heat transfer fluids (HTFs) synthetic oil and molten salt and can possibly expand CSP plant effectiveness and lessen costs [8]. Be that as it may, warm vitality is hard to store in DSG frameworks [3e5]. Helper fossil/biomass boilers can in this way assume a part in accomplishing temperature and load dependability in LFR control plants. The potential for biomass boilers in India is tremendous with more than 370 million tons of biomass being delivered each year [9]. Biomass is accessible from farming squanders, coordinate gathering and as a side-effect from enterprises, for example, rice plants, sugar factories and saw factories. Nonetheless, because of issues with foundation and the occasional changeability of biomass in India, buyers are attempting to get a steady fuel supply. Besides, while biomass is as yet focused, costs have expanded impressively in ongoing year [10, 11].

Hybridisation of solar thermal with biomass joins two energy sources that supplement each other, both seasonally and daily, to remove their personal flaws. Amid the day the sun's beams can be tackled by solar collector and biomass feedstock can be scorched as a supplementary fuel to accomplish steady base load task. CSP plants advantage from hybridisation or successful energy stockpiling because of the variable idea of sun based energy, especially in India's monsoon season. Steady base load or full load plants are normally executed as plant productivity is expanded and unit cost of vitality is limited. Nonetheless, sun oriented energy could be utilized to build plant yield amid the day. In contrast with a biomass-only framework, sunlight based hybridisation lessens biomass demand, hence enhancing energy security and diminishing area required for cultivating and capacity.

II. MODELLING AND SIMULATION OF HYBRID ENERGY SYSTEM BASED ON RENEWABLE ENERGY SOURCES AND THE BATTERY STORAGE SYSTEM

In order to verify the correct functioning of the designed Hybrid system, a dynamic model of the proposed Hybrid system is necessary. The modelling of renewable energy sources and the energy storage component (the battery) was mainly built by MATLAB simulation, based on equivalent circuits of the components. The detailed description of the model of each subsystem is given below.

A. Modelling of Solar PV system

A photovoltaic array (PV) is the complete power-generating unit. It is consist of any number of PV modules and panels**.** In PV module a number of solar cells are connected in series and parallel to obtain the desired voltage and current output levels. Each solar cell is basically a p-n diode. As sunlight strikes a solar cell, the incident energy is converted directly into electrical energy without any mechanical effort.

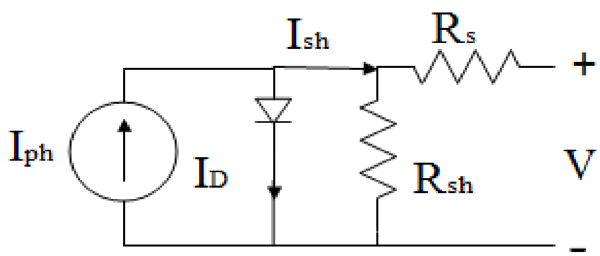

Fig 1 : PV cell equivalent circuit

The equivalent circuit of a PV cell is shown in Fig..The current source Iph repesents the cell photo current. Rsh and Rs are the instrinsic shunt and series resistances of the cell respectively.Usually the value of Rsh is very large and that of Rs is very small ,hence they may be neglected to simplify the analysis.Practically, PV cells are grouped in larger units called PV modules and these modules are connected in series or parallel to create PV arrays which are used to generate electricity in PV generation systems. The equivalent circuit for PV array is shown in Fig1.

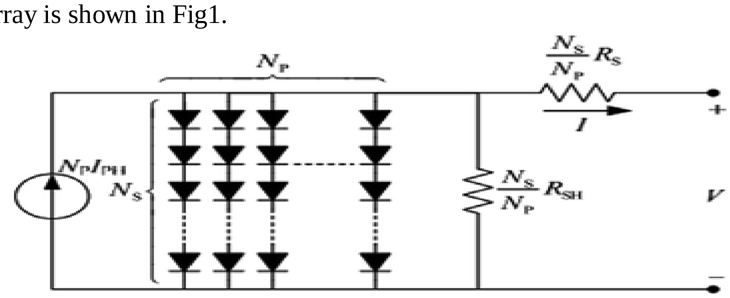

Fig 2: - Equivalent circuit of solar PV array

The mathematical equation for photo current Iph is:

$$Iph=\frac{(Isc+Ki(T-298))*Ir}{1000} \quad \ldots\ldots\ldots\ldots(1)$$

Where, Iph:Photo-current(A); Isc: Short circuit current; Ki: short-circuit current of cell at 25˚C and 1000 W/m^2. T: Operating Temperature(K);

Module Reverse Saturation current,Irs:

$$Irs=\frac{Isc}{[\exp(\frac{q*Voc}{Ns\,K\,n\,T})-1]} \quad \ldots\ldots\ldots\ldots(2)$$

Where,q:electron charge=1.6×10^{-19}C; Voc : Open circuit Voltage(V); Ns:Number of cells connected in series; n:the ideality factor of the diode; k: Boltzmann's constant=1.3805×10^{-23} J/k.

The module saturation current Io varies with the cell temperature and it is given by:

$$Io=Irs(\frac{T}{Tr})^3\exp[\frac{q*Eqo}{n*k}(\frac{1}{T}-\frac{1}{Tr})] \quad \ldots\ldots\ldots\ldots(3)$$

Where Tr: Nominal temperature =298.15K, Eqo: bend gap energy of semi conductor =1.1eV;

The current output of PV module is:

$$I=Np*Iph*10*[\exp(\frac{\frac{V}{Ns}+I*\frac{Rs}{Np}}{n*Vt}-1]-Ish \quad \ldots\ldots\ldots(4)$$

Where, $Vt=K*\frac{T}{q}$

$$Ish=\frac{V*\frac{Ns}{Np}+I*Rs}{Rsh}$$

Where, Np= Number of PV modules connected in parallel

Rs=series resistance, Rsh= shunt resistance

Vt=Diode terminal voltage (v)

To estimate the electricity generated in output of a photovoltaic system the formula is:

E = A * r * H * PR ....(5)

E = Energy (kWh)

A = Total solar panel Area (m2)

r = solar panel yield or efficiency (%) which is given by the ratio of electrical power (in KWatt) of one solar panel to the area of one panel.

H = Annual average solar radiation on tilted panels in Kwh/m^2

PR = Performance ratio is a very important value to evaluate the quality of a photovoltaic installation because it gives the performance of the installation independently of the orientation, inclination of the panel, coefficient for losses (range between 0.5 and 0.9, default value = 0.75) [12].

B. Mathematical Modelling of Biomass fired internal combustion engine (ICE)

The fuel consumption rate (m3/h) of biogas fuelled ICE is expressed as a quadratic function of real power:

$F_{n,t} = a_n + b_n P_{n,t} + c_n P_{2n,t}$ ....(6)

Where, $P_{n,t}$ is the n^{th} generator output in kW at time t, a_n,b_n ,c_n are coefficients that can be calculated from the datasheet provided by the manufacturer .

The total fuel consumption rate Ft is given as follows:

$F_{total} = \sum_n^N (a_n + b_n p_{n,t} + c_n p_{n,t}^2)$ ....(7)

The ICE units are first constrained by their capacities:

$p_n^- u_{n,t} < P_{n,t} < p_n^+ u_{n,t}, \forall_n \in N$

Where, $p_n^{+,-}$, are the generator capacity uper bound and lower bound, $u_{n,t}$ is binary variable indicating the state of nth generator in time t (0 is off and 1 is on), N is the total number of generators.

C. Mathematical Modelling of Energy Storage System

The energy storage system (ESS) consists of a lithium-ion battery and a bidirectional DC-DC buck-boost converter connected at the DC-link of the hybrid system. The role of this converter is to maintain the DC-link voltage constant despite the power changes in the sources and the load.

The state of the battery is the state of charge (SOC) expressed by –

$SOC=100(1+\int I_{bat}\, dt/Q)$ .... (8)

Where, I_{bat} is the battery charging current and Q is the battery capacity.

The battery charge-discharge depends on the available power, the demand and the SOC.

The energy constraints of the battery are determined based on the SOC limits

$SOC_{min} \leq SOC \leq SOC_{max}$

Where, SOC_{min} and SOC_{max} are the minimum and the maximum allowable states for the battery safety.

III. MODEL DESCRIPTION OF PROPOSED HYBRID SYSTEM

In the proposed hybrid system combination of two renewable energy resources like Solar and Biomass is depicted. Power generating systems and storage system are connected to the DC bus through their own DC/DC boost converters, and then they are connected to the AC bus through the same DC/AC converter or inverter. To extract maximum power from solar PV system perturb and observe method based MPPT controller is used and then dc-dc boost converter is used to convert the unregulated dc input into a controlled dc output at a desired voltage level. Since biomass system generates AC power, so rectifier is used which converts the AC power available from biomass system into DC power and then dc-dc boost converter is used to convert the unregulated dc input into a controlled dc output at a desired voltage level. If power available from solar and biomass integrated hybrid system is greater than the demand power in that case excess power will be stored in the battery.

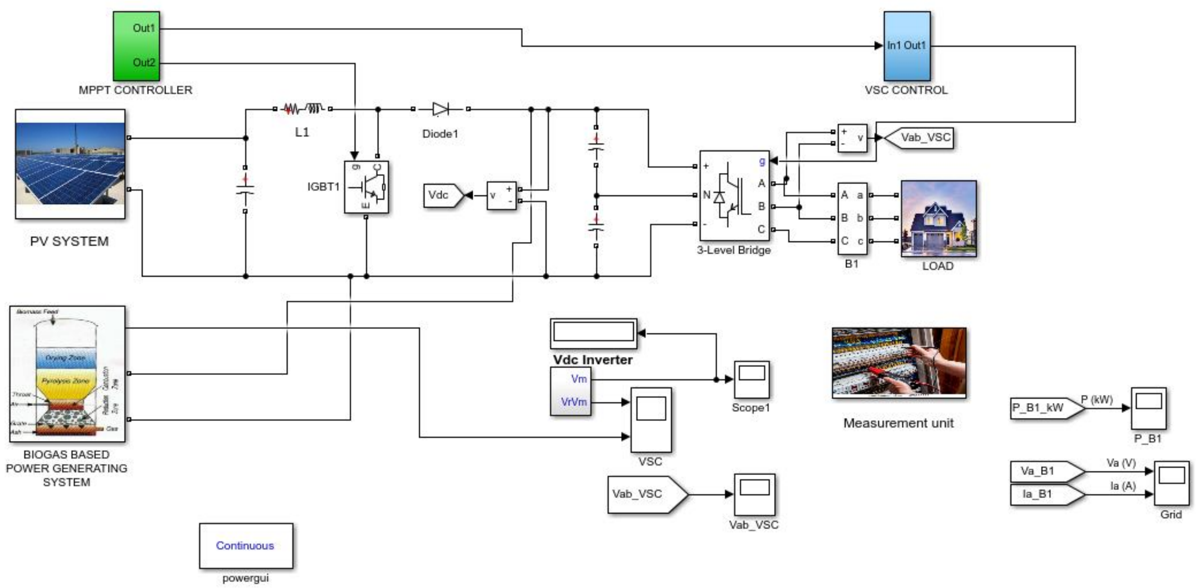

Fig 3:- Simulation model of proposed Hybrid system

By using inverter dc bus voltage converted to AC voltage. This is done by switching the DC input voltage (or current) in a pre-determined sequence so as to generate AC voltage (or current) output.

IV. SIMULATION AND RESULTS

In this project the solar power has been determined for the state Tripura (Agartala) using the hourly solar radiation data for the month of July and using the SAM software hourly solar radiation data has been taken. The simulation model of Solar PV system is shown in figure 4.To produce power from biomass, direct combustion technique is utilized in this proposed framework. In this process, biomass is used for warming the water and for producing stream. After that stream is utilized to rotate turbine which is coupled with one Synchronous generator.

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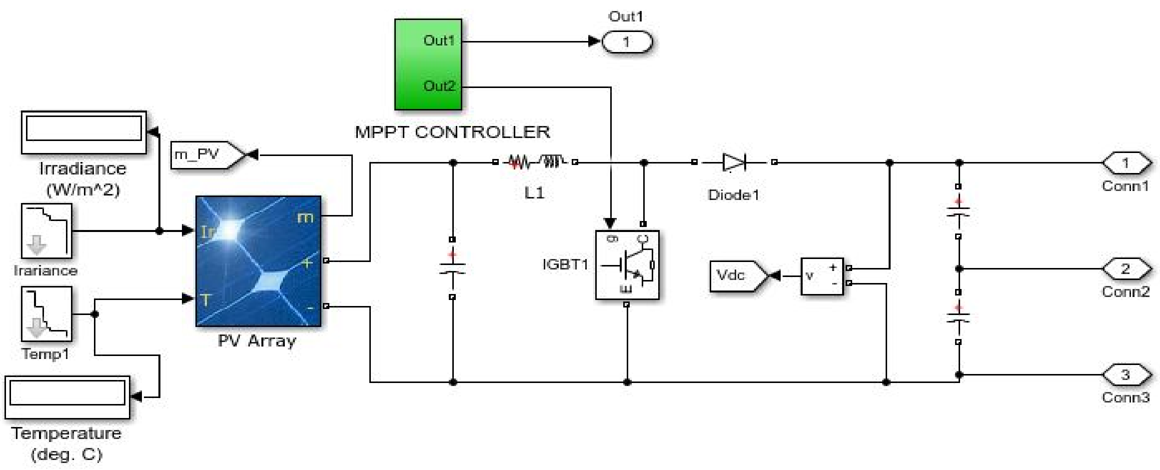

Fig.4:-Simulation model of Solar PV system

The hourly solar radiation data are shown below in both table and figure.

Table:- 1
Hourly solar radiation data for Tripura (Agartala)

TIME	SOLAR RADIATION(WATT/M^2)
1 AM	0
2 AM	0
3 AM	0
4 AM	0
5 AM	0
6 AM	860
7 AM	840
8 AM	720
9 AM	740
10 AM	980
11 AM	860
12 PM	720
13 PM	700
14 PM	620
15 PM	540
16 PM	520
17 PM	0
18 PM	0
19 PM	0
20 PM	0
21 PM	0
22 PM	0
23 PM	0
24 PM	0

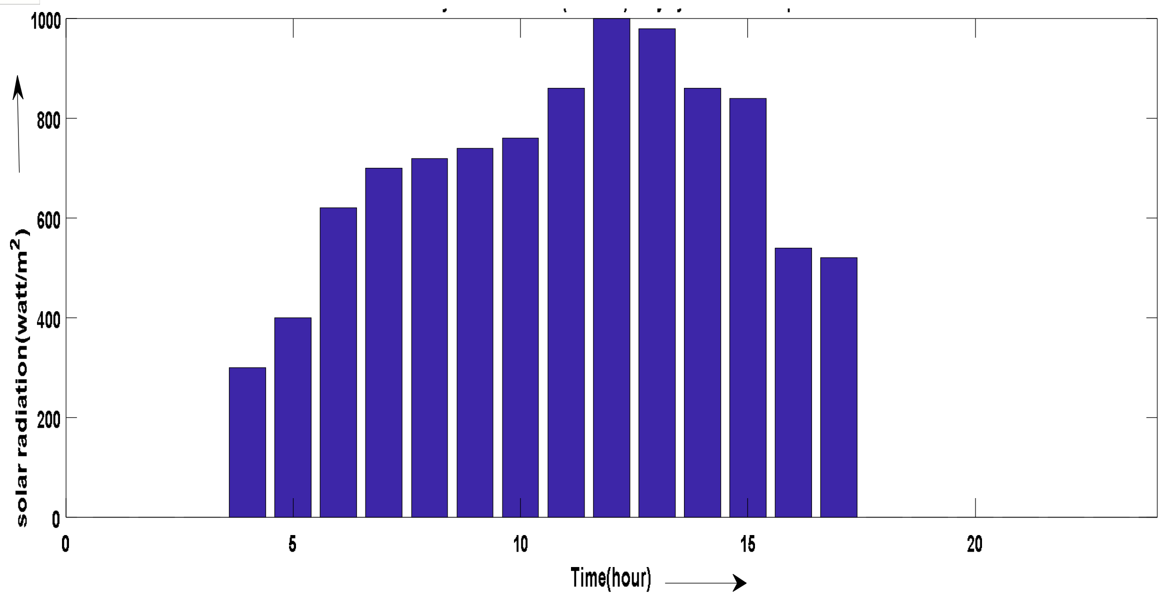

Fig 5:- Hourly solar radiation (watt/m^2) of Tripura for the month of July

24 hour biogas power generation data are shown in table 2 and 24 hour basis solar and biomass power generation is given in figure 5.

Table 2:- 24 hour biomass power generation data

TIME	BIOMASS POWER (KILO WATT)
1 AM	10
2 AM	15
3 AM	11
4 AM	12
5 AM	20
6 AM	20
7 AM	25
8 AM	0
9 AM	0
10 AM	0
11 AM	0
12 PM	0
13 PM	0
14 PM	0
15 PM	0
16 PM	0
17 PM	20
18 PM	25
19 PM	30
20 PM	35
21 PM	20
22 PM	25
23 PM	15
24 PM	10

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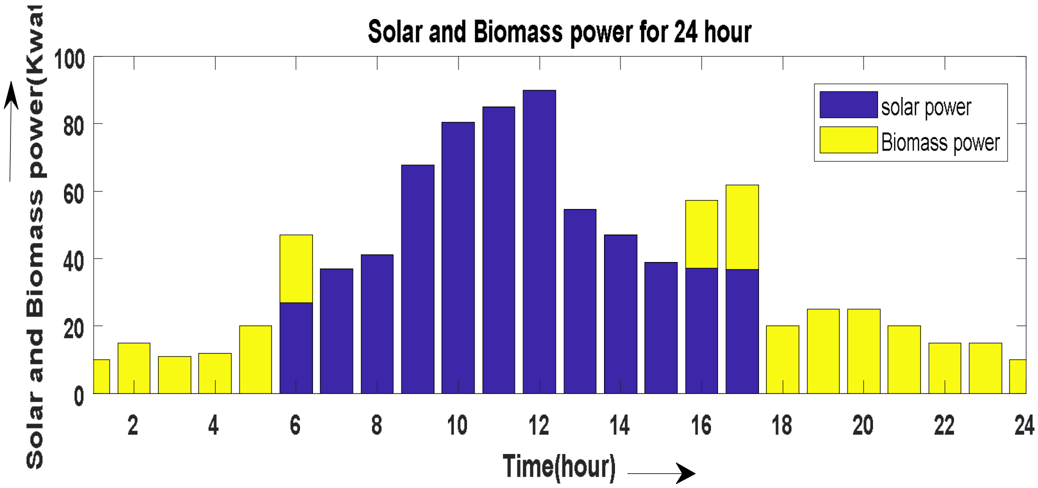


Fig 6 :- Solar and biomass power for 24 hour

The results obtained from the proposed system at three different cases are discussed below and the three different cases are-
Case 1:-Only solar power is available and biomass power is zero.
Case 2:- Both solar and biomass power are available
Case 3:- Solar and biomass both power are zero and only battery power is available.

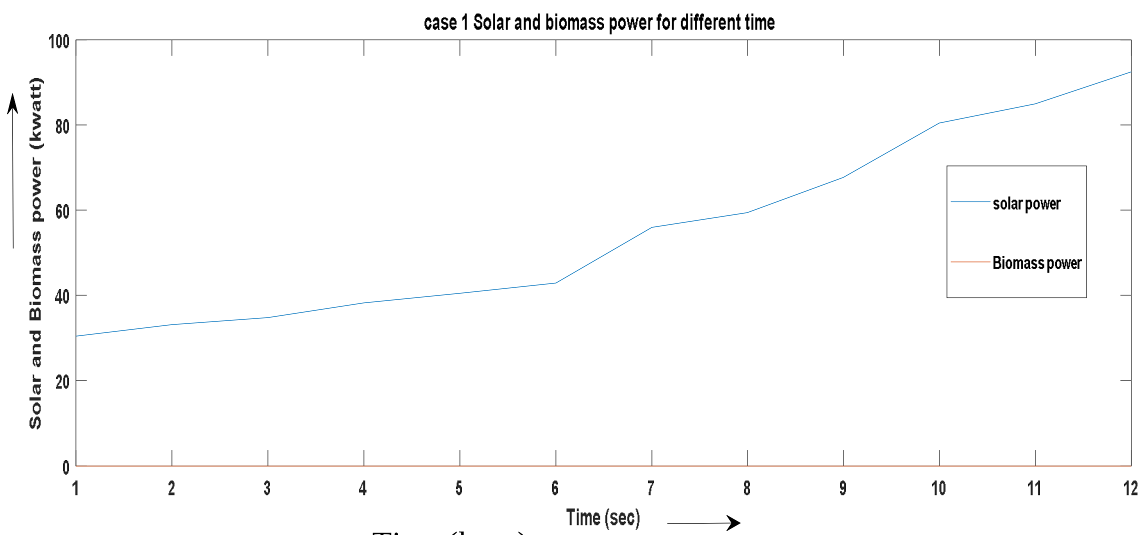
A. Case 1:-Only Solar Power Is Available And Biomass Power Is Zero.

In this case only solar power is available but biomass power is zero. Solar supplied power to the load .When Run the model and observe the following sequence of events on Scopes.

Simulation starts with standard test conditions (40 deg. C, 1000 W/m^2).From t=0 hour to t= 0.05 hour , pulses to Boost and VSC converters are blocked. The three-level bridge operates as a diode rectifier and DC link capacitors are charged above 500 Volt.

At t=0.2 hour, Solar radiation is 1000 W/m^2 (at 40 deg C), Boost and VSC converters are de-blocked. Solar PV system voltage is regulated at Vdc=307.66V. Duty cycle of boost converter is fixed at D=0.5. Inverter voltage is 664.65 volt. Solar system and biomass power are 26969.35 watt and 0 respectively and so on.

Fig 7 shows the graph of solar radiation, solar power, and biomass power for different time when only solar power is available and biomass power is zero.



Time (hour)

FIG 7:- Case1 solar and biomass power for different time

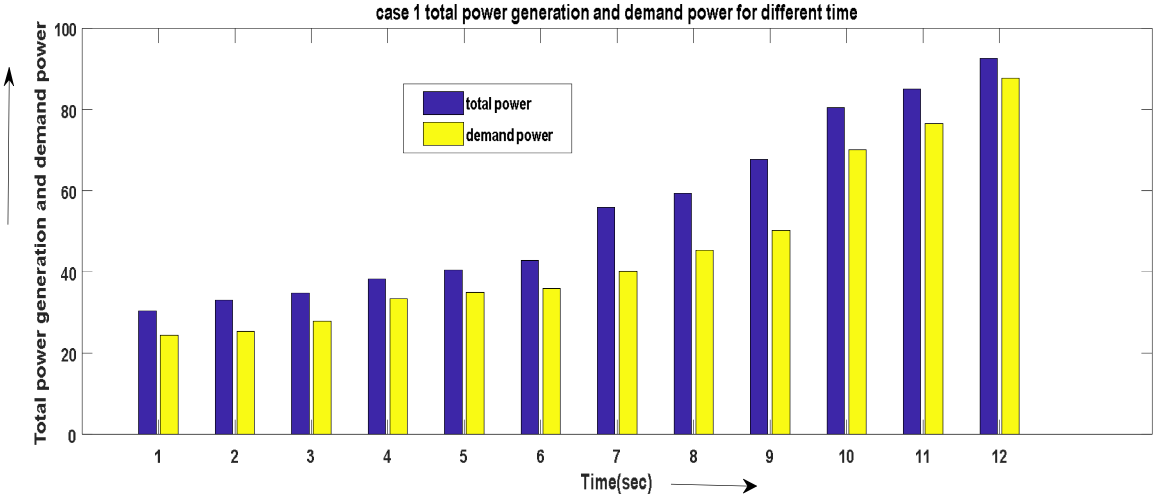


Fig 8:- Case 1 total power generation and demand power for different time

Time

From fig 8 it can observe that the total generation power is greater than the demand power, so unmet electric load demand is zero at that condition.

In this condition battery is charging which can be used for emergency backup for electric load demand.

B. Case 2:- Both Solar And Biomass Power Are Available

In this case both solar and biomass power is available. In that condition solar and biomass supplied power to the load. Battery is charging in this condition.

At t=0.4 hour, Solar radiation is 1000 W/m^2 (at 35 deg C). Solar PV system voltage is regulated at V_{dc}=311.86 V. Inverter voltage is 629.43 volt. Solar system and biomass power are 1788.51 watt and 50000 watt respectively. In that condition solar and biomass supplied power to the load. Battery is charging in this condition.

At t=0.6 hour, Solar radiation is 750 W/m^2 (at 30 deg C). Solar PV system voltage is regulated at V_{dc}=291.91 V. Inverter voltage is 1512.81 volt. Solar system and biomass power are 58124 .02 watt and 100000 watt respectively

The output obtained from solar PV system, biomass system, battery management system for different conditions are given below:-

When Run the model and observe the following sequence of events on Scopes.

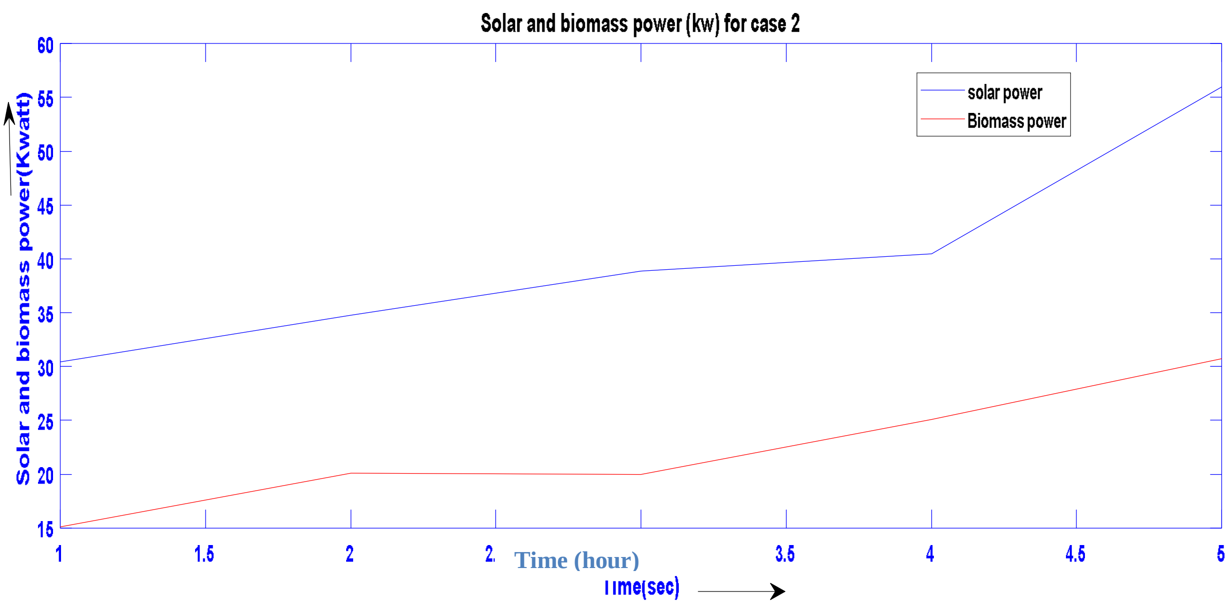


FIG 9:-Case 2 Solar power and Biomass power for different time

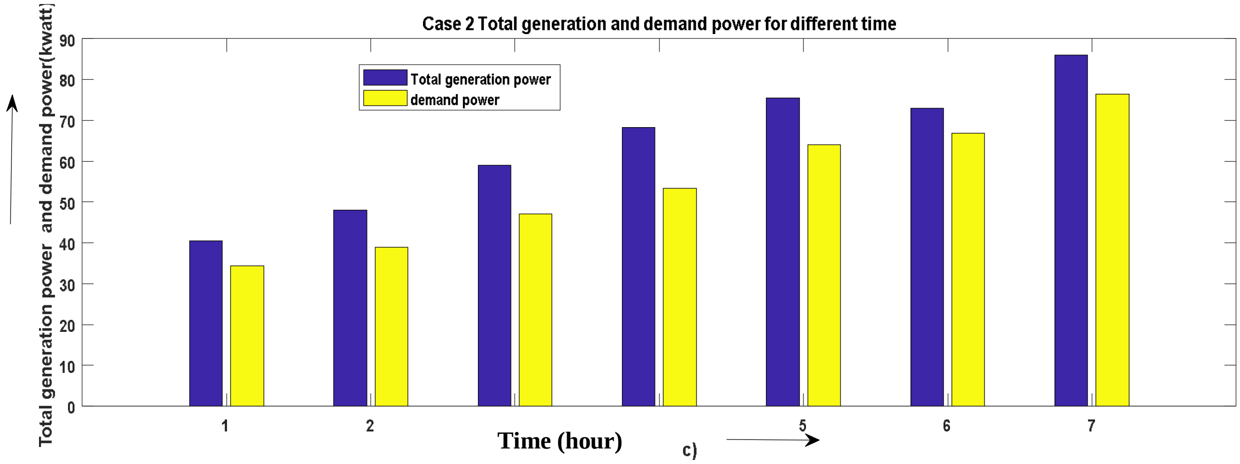


Fig 10:- Case 2 Total generation and demand power for different time

From fig 10, it can observe that the total generation power is greater than the demand power, so unmet electric load demand is zero at that condition and excess power is used to charge the battery.

C. Case 3:- Solar And Biomass Both Power Are Zero And Only Battery Power Is Available

In this case solar and biomass both power are zero and only battery power is available. Battery provides backup power to the load. Fig below shows the Battery SOC, voltage, current in this case.

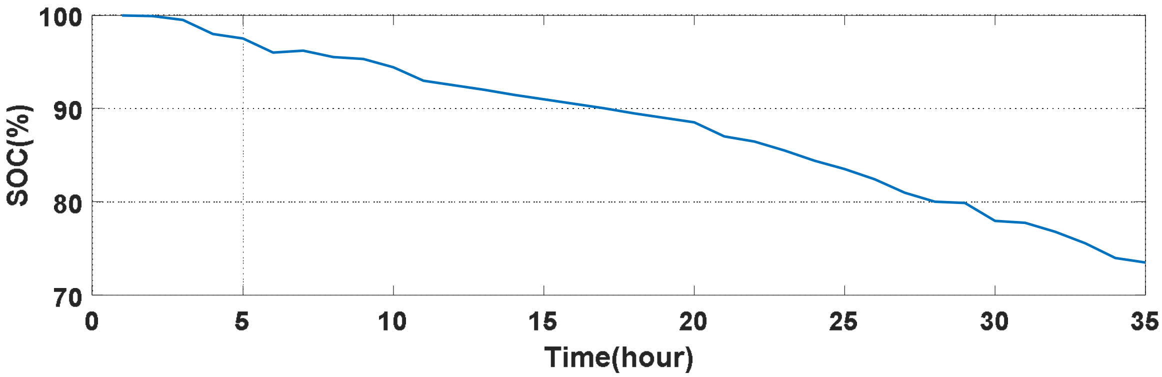


Fig 11:- Case 3 Battery SOC for different Time

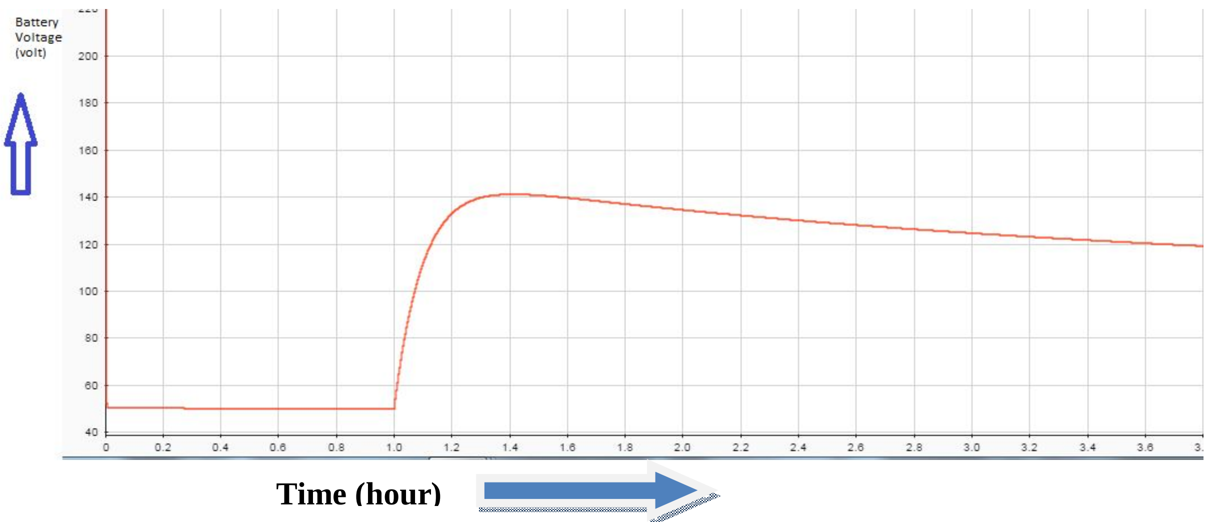


Fig 12:- Case 3 Battery voltages for different time

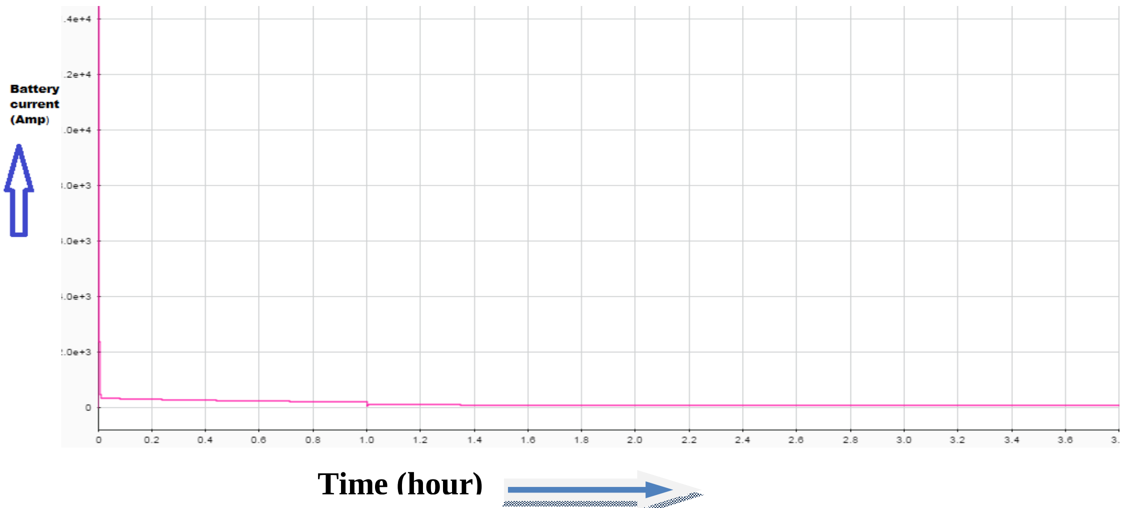


Fig 13:-Case 3 Battery current for different time

In this condition solar and biomass both power is zero and the battery supply power to the load. So battery is continuously discharging which is shown in figure 11.

V. CONCLUSION

In remote and rural areas, there always a crisis for electricity to fulfil the load demands. So renewable energy sources based power generating system is a good option for that areas. Since all the inexhaustible sources are not accessible in the meantime, a blend of different power sources ought to be sent to fulfil the load on the basis of load demand during any particular period. The blend of sustainable power source with energy storing innovation is a proper answer for irregular yield intensity of sustainable power source based power producing framework .In this paper, a hybrid system based on Solar, biomass and battery storage is proposed to supply electrical power in rural and remote areas. MPPT controller has been used in this proposed system to provide maximum output power at different operating and load conditions. The battery has been used to store excess power available from these two generating systems and also to support the nonstop supply in load power if one of these two generating systems fails.

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