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Economic and Environmental Assessment of Smart Distributed Power Systems in India for Emission Reductions

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***Abstract:** As the global warming is increasing day by day, distributed generation based on renewable energy will play a major role in the production of electricity. Renewable energy sources are considered as the most viable alternative energy sources to be used in the place of conventional fossil fuels. Microgrids are the fundamental elements in future smart grid distributed generation systems. This paper illustrates various options for supply of electric power from renewable sources along with storage units and main grid to different types of loads. The sizing of the distribution system and the economic analysis were performed using Homer, computer software designed by National Renewable Energy Laboratory (NREL) at Colorado, United States in 1993. This paper will analyze the Cost of Energy (COE) and Net Present Cost (NPC) for various loads and the system configuration with minimal COE and NPC is considered as the optimal solution for each type of load while reducing the emissions.*

***Keywords:** Hybrid power systems, Optimization, Renewable energy sources, Economic analysis.*

I. INTRODUCTION

Electrical energy plays a very important role in all sectors of modern society and it is playing a crucial role in the growth of industrial and economical sectors of both developed and developing countries. The rapid population growth has contributed to an alarming scenario for the production of electricity to meet the growing population needs. At present in global energy production, the fossil fuels account for 87percent but releases high carbon dioxide content into the atmosphere which disturbs the ecological cycle and causes ozone layer depletion [1]. In certain countries, grid parity has been accomplished. Most countries, therefore, are striving to reduce the carbon emissions by integrating and expanding the renewable energy sources into the existing system. The development of Smart Grid (SG) replaces the traditional electrical grid by (a) integrating renewable energy sources (b) using demand response and demand management programs and (c) implementing energy management systems etc [1].

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Indian economy is one of the world's fastest growing economies. In India, there is a rising demand for energy in different sectors. The increasing dependency on foreign fuels could pose a significant threat to the country's long-term energy security.

Power plants must be constructed in a large scale in order to adapt to the increasing demand, in which renewable power projects are to make a significant contribution. Therefore, renewable energy is desperately needed in order to provide customers with clean, reliable and sustainable energy. The integration of renewable energy sources plays a vital role in increasing the Smart Grid's power reserves and thereby enhancing energy quality and efficiency. Electric Vehicles (EVs) and Renewable Energy Sources (RESs) have the potential to reduce the carbon emissions from energy and transportation sectors significantly [2]. The ability of electric vehicles to facilitate the penetration of renewables into the existing grid has the greatest impact on the transition of electrical systems [2]. The new smart grids are gradually developed with the incorporation of Electric vehicles and renewable energy synergies. When EVs are considered as load, optimal charging can be obtained by technical and economic means to arrange charging time so as to achieve peak-load shifting thus improving the efficiency of the system and reducing the influence on the grid security [3].

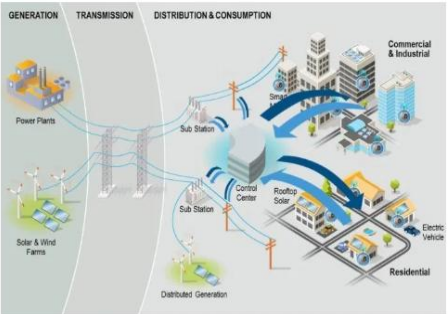


Fig.1. Schematic Smart Grid.

When EVs are considered as distributed energy storage units, they can supply power to grid so that safe reliability of the power system can be improved. Bi-directional communication between EVs and grid can be established by using V2G technology [3]. The smart grid will reduce the impact on the grid made by EVs and RESs by introducing intelligent charging, synergistic distribution and energy management technologies as in Fig.1.

II. MODELING AND METHODOLOGY

The main aim of this paper is optimization and modeling of a Hybrid energy system applicable to different types of loads and to analyze the techno economical values of different configurations.

The optimal ratings of the system components must be identified in order to find the optimum investment costs of the renewable energy system and to lower the energy production costs. The meteorological data of the solar radiation and wind speed for the designed hybrid systems are taken for Tirupati which is located at 13.65°N and 79.42°E in Chittoor district of South Indian State of Andhra Pradesh. Electricity to the city is distributed by Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL), headquartered at Tirupati. The city was the 6th in India among the 200 cities competed during "Swachh Survekshan-2018" organized by the Ministry of Urban Development, Government of India and the Central Pollution Control Board (CPCB) of India. Tirupati has been chosen as one of 100 Indian cities to be adapted by the government of India as a Smart City under the Smart Cities program.

A. Modeling of Photovoltaic energy system (PV)

The PV power generated is dependent on solar radiation, so it's best to keep the PV array facing with the sun all the time. The PV terminal voltage is regulated via a maximum power point tracker to ensure the maximum power available from the PV device. But by using the trackers, the total cost of the system increases. Hence, in this work no tracking was taken. The location chosen in this work is a good resource of solar energy. The output power $P_{PV}(t)$ and energy E_{PV} from a PV array can be obtained as [4]:

$$P_{PV}(t) = N_S \times N_P \times I_S(t) \times V_0(t) \times F_F(t) \qquad (1)$$

$$E_{PV} = G(t) \times A \times P \times \eta_{PV} \qquad (2)$$

where,

N_S is the number of PV modules connected in series,
N_P is the number of PV modules connected in parallel,
$V_0(t)$ and $I_S(t)$ are the hourly short-circuit current and open-circuit voltage respectively,
$F_F(t)$ is the fill factor,
$G(t)$ is the hourly irradiance in kWh/m^2,
A is the surface area of the PV modules in m^2,
P is the PV array penetration level factor and
η_{PV} is the efficiency.

B. Modeling of System Converter

The converter contained both rectifier and inverter. The DC bus connected the battery and photovoltaic generators while the AC bus tied the wind energy and diesel generation systems to the grid.

C. Modeling of Wind energy system (WT)

The Wind Turbine (WT) power output P_{WT} and electrical output $E_{WT}(t)$ of a Wind generator are given as [4]:

$$P_{WT} = \left\{\frac{1}{2}\right\} \rho A v^3 C_P(\lambda, \beta) \times \eta_T \times \eta_G \qquad (3)$$

$$E_{WT}(t) = P_{WT} \times t \qquad (4)$$

where,
ρ is the air density,
A denotes surface area,
ν represents wind speed,
η_T and η_G shows wind turbine and generator efficiency,
C_P is the performance coefficient of the turbine,
λ denotes tip speed ratio,
β denotes blade pitch angle and
t represents time in hour.

At anemometer elevation, the hourly wind speeds were collected. In this work, it was taken as 50m above ground level. The power law equation has changed these speeds to the corresponding wind speed at the hub height of the WT and is given as [4]:

$$v(H) = v(H_g)\left(\frac{H}{H_g}\right)^{\alpha} \qquad (5)$$

where,
$v(H)$ and $v(H_g)$ are speeds of wind measured at hub height (H) and anemometer height (H_g) respectively and
α is the roughness factor which has been taken as 0.14.

D. Modeling of Diesel generator (Dg)

The Diesel generator can be used to power the load when all resources and storage devices do not meet its needs, and is a significant distributed generation resource. With a Dg backup, the system reliability is improved and the size of the other components can be reduced [5]. In the designed model, the diesel generator used diesel as a fuel. The consumption of fuel in the Dg was obtained from the following equation:

$$F_{Dg} = (A \times Q_{Dg}) + (B \times P_{Dg}) \qquad (6)$$

where,
F_{Dg} is the Dg's fuel consumption rate (L/h),
A is the fuel intercept coefficient (L/kWh),
Q_{Dg} is the Dg capacity,
B is the fuel slope (L/kWh) and
P_{DG} is the Dg output.

E. Modeling of Battery

The Storage capacity ($C_{Battery}$) of Lithium-ion battery is defined as [5].

$$C_{Battery} = \left[\frac{V_{off} \times N_{Day}}{\eta_{Converter} \times \eta_{Battery} \times DOD}\right] \qquad (7)$$

where,
V_{off} is offload voltage,
N_{Day} is the number of days without charging,
$\eta_{Converter}$ is yield of convertor,
$\eta_{Battery}$ is yield of battery and
DOD is the depth of discharge.

The State of Charge (SOC) of the battery is determined after a period of time (t) depending on the energy balance between the RES power generated and the load. The battery SOC indicates charging and discharging processes by varying in between lower and upper limits.

III. RENEWABLE ENERGY RESOURCE ASSESSMENT

Solar irradiation, wind speed and temperature data were obtained for the selected location throughout the year from NASA Surface Meteorology and NREL server [6]. In order to synthesize data by Homer, solar, wind and temperature data were inserted as 12 average monthly values. Homer produced a set of 8760 values after entering the values in the table. The graham algorithm (GA) for each parameter generated the synthesized values.

India is an ideal place to use solar energy because the solar radiation ranges from 4 to 6.5 kWh/m^2 all year round as of its location as in Fig.2.

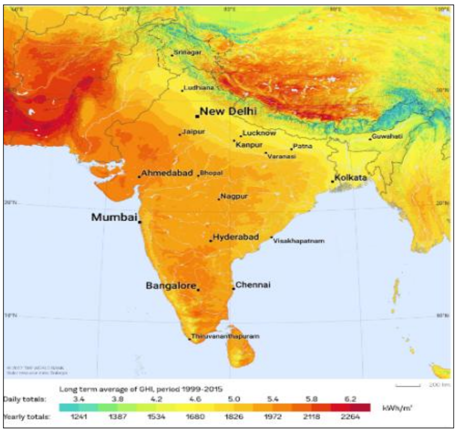


Fig.2. Solar Resource Map in India.

Table- I: Resource assessment

Renewable Energy Resources	Potential
Annual average Solar radiation	5.45kWh/m^2/day
Annual average Wind speed	4.07m/s
Annual average Temperature	27^{0}C

The Table- I represents the average solar, wind and temperature values penetrating at the selected location and it had been shown that a lot of the renewable energy capacity exists and is sufficient enough in this area to meet energy demand.

IV. OPTIMIZATION ANALYSIS

In this work, four different types of loads were considered for optimization. For simulation and optimization purposes, Homer software has been used. This simulates many feasible system configurations for the considered system to identify and scale the best possible configuration based on the least Net Present Cost (NPC) [7]. Each system component and their input parameters like cost, size, lifetime, efficiency etc., are given in Table II.

Table- II: Input Variables

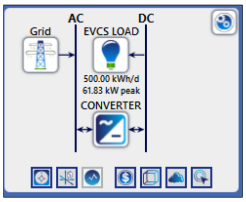
Name of Component	Capacity	Parameter	Value
PV Panel	1kW	Capital Cost (Rs)	1,00,000.00
		Replacement Cost (Rs)	1,00,000.00
		O&M cost (Rs/yr)	400
		Life time	25years
		Derating Factor	80%
		Type	DC
		Ground reflectance	20%
		Slope	30degrees
		Tracking	No
		Azimuth	0
Wind Turbine	3kW	Capital Cost (Rs)	15,00,000.00
		Replacement Cost (Rs)	14,00,000.00
		O&M cost (Rs/yr)	500
		Life time	20years
		Hub Height(m)	25m
		Type	AC
		Turbine Losses	0
		Anemometer height (m)	50m
Battery	1kWh	Capital Cost (Rs)	20,000.00
		Replacement Cost (Rs)	7,000.00
		O&M cost (Rs/yr)	100
		Life time	20years
		Throughput(kWh)	1000kWh
		String Size	20
		Initial SOC	100%
		Minimum SOC	40%
		Minimum Storage Life	10years
		Nominal Voltage (V)	6 V
		Nominal Capacity (Ah)	167Ah
		Roundtrip efficiency (%)	90%
Converter	1kW	Capital Cost (Rs)	10,000.00
		Replacement Cost (Rs)	7,500.00
		O&M cost (Rs/yr)	200
		Lifetime	20years
		Inverter Efficiency	95%
		Capacity relative to Inverter	100%
		Rectifier Efficiency	95%
Diesel generator	1kW	Capital Cost	25,000.00
		Replacement Cost	20,000.00
		O&M cost (Rs/op.hr)	500
		Efficiency	80%
		Fuel Type	Diesel
		Fuel price	60 Rs/L
		Lifetime	15,000hrs
Grid	1	O&M cost (Rs)	160 Rs/yr/km
		Grid Purchase capacity	0-10000kW
		Grid power purchase price	9 Rs/kWh

		Grid sell back price	1Rs/kWh
		Lifetime	25years
Project	-	Annual rate of interest	7%
		Dispatch strategy	Cycle Charging
		Currency	INR
		Discount rate	10.50%

A. Case A-EVCS Load

This paper explores the optimal design for an Electric Vehicle Charging Station (EVCS) with Smart Distributed Generation to reduce costs and emissions. For different cases, both RES integrated EVCS and an EVCS connected to the grid were examined, where energy sources such as PV, Wind and Grid were considered to supply the demand for EVCS as in Fig.3. The model has been developed in terms of physical, functional and economic characteristics based on realistic input data. The location chosen to develop EVCS has incorporated both local and renewable energy sources available at that area. In this paper, DC vehicle charging was chosen as it enables very fast EV charging. The DC charging station having a load of 500kWh/day with a peak of 61.83kW was supplied through renewable energy sources and battery along with main grid. Considering that local resources are arbitrary in nature, EVCS must have the option of connecting to the main grid in order to charge electric vehicles. When it is not only intended to charge electric vehicles, the excess energy will power other users or it can be sold in the network at a rate agreed between the purchaser and the entity with which the grid connectivity is associated [8].

Fig.3a represents the schematic of EVCS load supplying only through grid. Fig.3b represents the case in which EVCS load was isolated from grid and all the demand was supplied through the remaining energy sources. In such a condition, the total renewable percentage will be 100% and the decision variables are the size of the PV, wind turbines, battery bank, and converter. In Fig.3c, both the grid and Renewable sources shown as meeting the demand when the grid maximum capacity was considered to be 500kW and the minimum renewable fraction for supply was 50%. In that, PV supplied more percentage of share than wind and storage due to their high cost of energy compared to PV.



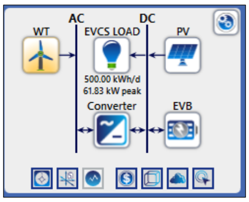


Fig.3a. Case A-1 **Fig.3b. Case A-2**

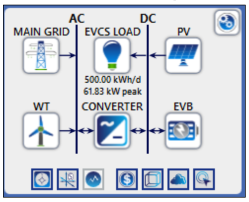


Fig.3c. Case A-3

Fig.3. Case A-EVCS Load Model design.

B. Case B-Town Load

In this case the electric load was calculated for a town area with 6 buildings and 10 shops and categorized as residential and commercial loads respectively as in Fig.4. The electric load consumption of appliances of the study area with their ratings are given in Table III and Table IV.

Table- III: Residential load

Appliance	Qty	Watts	No.of.hrs	Calculated Load (W)
Tube Light	3	40	8	960
CFL Lamp	3	20	3	180
Ceiling Fan	3	60	5	900
Exhaust fan	2	100	2	400
Refrigerator	1	650	20	13,000
Ac 1.5 Ton	1	2,100	3	6,300
Iron Box	1	1,000	0.5	500
Microwave Oven	1	1,200	0.5	600
Induction Cooker	1	1,000	1	1,000
Washing Machine	1	750	1	750
Motor	1	740	1	740
Led TV	1	100	3	300
Laptop	2	100	2	400
Vacuum Cleaner	1	1,000	0.5	500
Mobile Charger	2	5	1	10
Wi-Fi Router	1	10	20	200
Water Geyser	1	2,000	0.3	600
Mixie	1	250	0.3	75
Grinder	1	400	0.1	40
Chimney	1	350	0.3	105
Total Load=27,560 W/day				

No.of.Buildings = 6

Total Load= 27,560x6=1, 65,360=165.36 kWh/day.

Table- IV: Commercial load

Appliance	Qty	Watts	No.of.hrs	Calculated Load (W)
TV	1	100	6	600
Fan	1	60	2	120
Lights	1	40	4	160

Wi-Fi Router	1	10	10	100
Mobile Charger	1	5	4	20
Laptop	1	100	4	400
Xerox Machine	1	300	3	900
Total Load= 2,300W/day				

No.of.Shops = 10
Total Load= 2,300x10=23,000=23 kWh/day

Fig.4a indicates the total residential and commercial loads supplying only through Grid. In Fig.4b model, the loads were isolated from the grid and total load was supplied with renewables. Whereas, Fig.4c represents the case in which, the total load was supplied with both renewables, storage battery and the main grid. In total production of electric power, each component has contributed in predetermined percentage of share. The quantity of power that was produced of the overall load was 40% for the PV panels, 25% for wind turbines and 35% from the main grid.

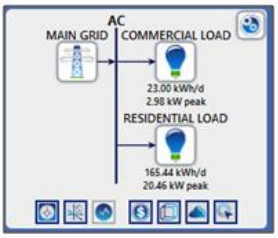


Fig.4a. Case B-1

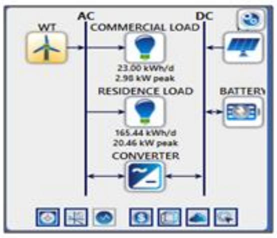


Fig.4b.Case B-2

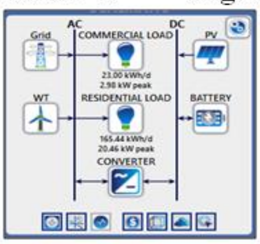


Fig.4c. Case B-3

Fig.4. Case B- Town Load Model design.

The battery bank has been established because renewable energy was available in intermittent mode. During the day, the PV output will meet demand for the electricity and ensure that the battery is chargeable within the average available sun hours. Then an equivalent converter was used to supply the load from the battery bank.

C. Case C- Community Load

In this model, main grid was intended to supply the total load of 2941kWh/day as in Fig.5 and the Diesel generator was used only in emergency conditions as backup as the community load considered was assumed to be a hospital.

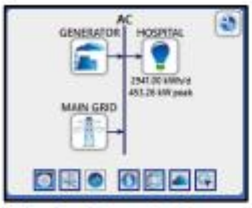


Fig.5a.Case C-1

Fig.5b.Case C-2

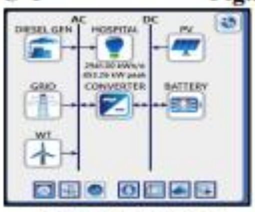


Fig.5c.Case C-3

Fig.5. Case C- Community Load Model design.

The load was supplied with Dg and grid as in Fig.5a. In this work, the fuel emissions were considered when the Diesel generator was in use. Fig.5b represents the model in which renewables along with diesel generator were employed to meet the load. In Fig.5c renewable energy sources along with battery and grid were considered to supply to load. The minimum renewable fraction was taken as 30% in which solar was considered more than wind and battery due to low cost value of PV. The grid purchase price was 9Rs/kWh and sellback Price was 1Rs/kWh and its capacity was limited to 5,000kW. The purchase of PV, wind and battery were taken in subsidy.

V. HOMER SOFTWARE

Hybrid models have been developed using Homer based on renewable energy sources available locally at the study area and various input parameters and constraints [9]. It simulates many feasible system configurations of the modeled systems in order to define and size best possible configuration on the premise of the lowest NPC value [9].

A. NPC

The Net Present Cost (NPC) is defined as the sum of PV cost (C_{PV}), Diesel generator cost (C_{Dg}), Battery cost (C_{Batt}), Converter cost (C_{Conv}), Wind energy cost (C_{Wind}) and Grid cost (C_{Grid}) [10].

$$\{C_{NPC} = C_{PV} + C_{Dg} + C_{BATT} + C_{CONV} + C_{WIND} + C_{GRID}\} \quad (8)$$

The cost for each component including the fuel cost is [10]:

$$C_i = N_i \times \{C_{Cap,i} + (C_{Rep,i} \times K_i) + C_{O\xi M,i} + C_{Fuel,i}\} \quad (9)$$

where,
i is any component of the system such as PV, Wind, Dg, Battery, Converter etc.,
N_i is the number or the size of the system components,
$C_{cap,i}$ is the capital cost,
$C_{Rep,i}$ is the replacement cost,
K_i is the number of replacement,

$C_{O\&M,i}$ is operation and maintenance cost and
$C_{Fuel,i}$ is the fuel cost.

B. COE

The average cost per kWh of the system's useful electrical energy is the levelized cost of energy (COE). COE is given as [11]:

$$COE = \left(\frac{C_{Annual\ Total}}{E_{Served}}\right) \quad (10)$$

where,
E_{Served} is the total electrical load served (kWh/yr) and
$C_{Annual\ Total}$ is the total annualized cost of the system (Rs/yr).

VI. SIMULATION RESULTS

The corresponding ratings of the components were optimized as illustrated in Table V.

A. System Sizing Results

Table- V: Components ratings and quantities

Case Model	PV panel (kW)	Wind Turbine (Qty)	Converter (kW)	Battery	Diesel Generator (kW)	Grid Capacity (kW)
Case –A-1	-	-	100	-	-	100
Case –A-2	300	1	100	1500	-	-
Case –A-3	200	1	100	200	-	100
Case –B-1	1000	-	-	-	-	-
Case –B-2	75	2	25	240	-	-
Case –B-3	75	1	50	80	-	1000
Case –C-1	-	-	-	-	500	500
Case –C-2	600	4	500	10000	500	-
Case –C-3	300	1	200	200	500	5000

B. Electrical Power Results

The electrical production analysis is given as in Table VI. Majority of the power was produced from PV and grid as per the constraints and economic factors considered.

Table- VI: Electricity production

Component	Case-A-1	Case-A-2	Case-A-3	Case-B-1	Case-B-2	Case-B-3	Case-C-1	Case-C-2	Case-C-3
PV Panel (kWh/yr)	-	4,79,178	3,19,452	-	1,18,051	1,18,051	-	9,58,356	4,79,178
Wind Turbine (kWh/yr)	-	1,144	1,144	-	2,288	1,144	-	4,575	1,144
Grid (kWh/yr)	1,92,105	-	95,953	68,781	-	36,138	10,73,465	-	6,82,056
Total (kWh/yr)	1,92,105	4,80,322	4,16,549	68,781	1,20,339	1,55,333	10,73,465	13,73,566	11,62,378
Excess Electricity (kWh/yr)	0	2,88,497	19,423	0	38,850	6,941	0	26,849	17,505
Ren.fraction (%)	0	100	74.9	0	100	74.7	0	61.7	39.2
Unmet electric load (kWh/yr)	0	132	0	0	37	0	0	0	0

Capacity Shortage (kWh/yr)	0	148	0	0	42.4	0	0	0	0
Diesel Generator (kWh/yr)	-	-	-	-	-	-	-	4,10,635	-

C. Environmental Results

The emission analysis is given as Table VII. It can be observed that there are zero emissions if all the required power is generated through renewables. If the system was operated by integrating both grid and renewables, there is a large reduction in emissions when compared to system operating only with grid.

Table- VII: Emission analysis obtained from each study case

Pollutant emission	**Case-A-1**	**Case-A-2**	**Case-A-3**	**Case-B-1**	**Case-B-2**	**Case-B-3**	**Case-C-1**	**Case-C-2**	**Case-C-3**
Carbon Dioxide(kg/yr)	1,21,411	0	60,642	43,470	0	22,839	6,78,430	2,79,091	4,31,059
Carbon Monoxide (kg/yr)	0	0	0	0	0	0	0	689	0
Unburned Hydrocarbons (kg/yr)	0	0	0	0	0	0	0	76.3	0
Particulate matter (kg/yr)	0	0	0	0	0	0	0	51.9	0
Sulfur Dioxide (kg/yr)	586	0	263	188	0	99	2,941	560	1,869
Nitrogen Oxides (kg/yr)	257	0	129	92.2	0	48.4	1,438	6,147	914
Total	1,22,254	0	61,034	43,750.20	0	22,986.40	6,82,809	2,86,615.2	4,33,842

D. Economic Results

The Cost analysis of the designed systems is given in Table VIII to Table X. For each load case, cash flow and costs were calculated for lifetime of 25 years with annual interest rate of 7%. The NPC and COE values were calculated for each case.

Table- VIII: Cost Analysis of Case Study-A

ype of Cost (INR)	**Case A**		
	Case-A-1	**Case-A-2**	**Case-A-3**
Annualized Capital cost	70,077.38	2,087,587.29	1,215,572.99
Annualized Replacement cost	28,089.97	487,019.12	1,32,959.21
Annualized O&M cost	1,753,947.37	290,500.00	789,744.12
Annualized Fuel cost	0	0	0
Annualized Salvage value	-20,131.30	-234,999.94	-95,288.15
Total Replacement cost	625,313.91	10,841,584.55	2,959,819.15
Total O&M cost	39,044,809.34	6,466,851.47	17,580,578.11
Total Salvage value	-448,145.00	-5,231,358.61	-2,121,219.67
Total Capital cost	1,560,000.00	62,500,000.00	27,060,000
Overall Net Present Cost	40.8M	74.6M	45.5M
Overall Cost of Energy (COE)	10.04	18.37	5.35

Table- IX: Cost Analysis of Case Study-B

Type of Cost (INR)	Case B		
	Case-B-1	Case-B-2	Case-B-3
Annualized Capital cost	25,155.98	676,067.02	523,783.49
Annualized Replacement cost	0	362,581.77	87,453.45
Annualized O&M cost	624,029.00	60,000	306,317.87
Annualized Fuel cost	0	0	0
Annualized Salvage value	0	-106,107.67	-62,675.45
Total Replacement cost	0	8,071,471.39	1,946,810.63
Total O&M cost	13,891,576.10	1,335,666.40	6,818,974.65
Total Salvage value	0	-2,362,074.17	-1,395,224.77
Total Capital cost	560,000.00	15,050,000.00	11,660,000
Overall Net Present Cost	14.5M	22.1M	19.0M
Overall Cost of Energy (COE)	9.44	14.44	5.99

Table- X: Cost Analysis of Case study-C

Type of Cost (INR)	Case C		
	Case-C-1	Case-C-2	Case-C-3
Annualized Capital cost	25,155.98	12,667,833.86	1,696,231.94
Annualized Replacement cost	0	3,348,289.48	153,558.52
Annualized O&M cost	9,666,185.00	208,091,400	6,277,214.86
Annualized Fuel cost	0	6359,034.49	0
Annualized Salvage value	0	-1,833,551.78	-110,051.10
Total Replacement cost	0	74,536,629.01	3,418,382.68
Total O&M cost	215,179,974.68	4,632,344,837.57	139,737,749.19
Total Salvage value	0	-40,816,891.52	-2,449,859.34
Total Capital cost	5,60,000	282,000,000	37,760,000
Overall Net Present Cost	216M	5.09B	178M
Overall Cost of Energy (COE)	9.03	212.99	7.15

It was observed that among all the energy sources, PV was considered as major supply of load due to economic and environmental factors. The renewable fraction in all the cases indicated the necessity of transformation from conventional to non conventional sources in electricity production. The grid energy dependence can be further decreased by increasing the capacity of the PV and Wind as this result in increase of capital cost which further reduces the green house gas emissions. The feasible configurations among each of the case study by considering all the economic and environmental parameters are given as Table XI.

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Table- XI: Feasible configuration

Case Study		Overall Cost of Energy (COE) (INR)	Overall Net Present Cost (INR)	Feasible Model	NPC Increment (%)	COE Increment (%)	Emissions Reduction (%)
Case-A	Case-A-1	10.04	40.8M	Case A-3	10.32%	46.71%	50.07%
	Case-A-2	18.37	74.6M				
	Case-A-3	5.35	45.5M				
Case-B	Case-B-1	9.44	14.5M	Case B-3	23.68%	36.54%	47.45%
	Case-B-2	14.44	22.1M				
	Case-B-3	5.99	19.0M				
Case-C	Case-C-1	9.03	216M	Case C-3	17.59%	20.81%	36.46%
	Case-C-2	212.99	5.09B				
	Case-C-3	7.15	178M				

The production of electric power for each month of the feasible configuration is obtained as shown in Fig.6 to Fig.8.

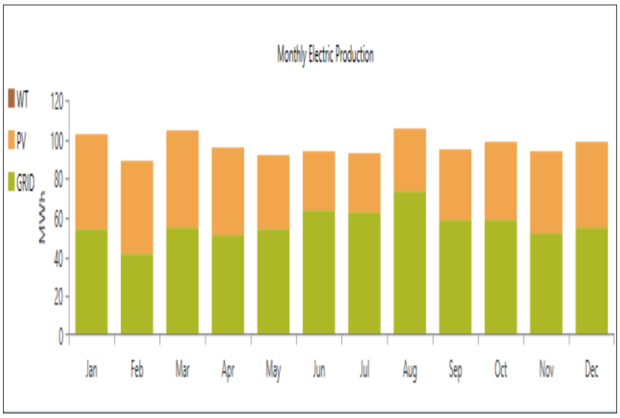

Fig.6. Case A-3.

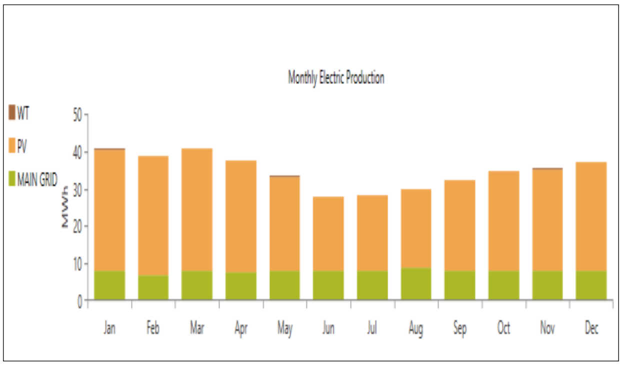

Fig.7. Case B-2.

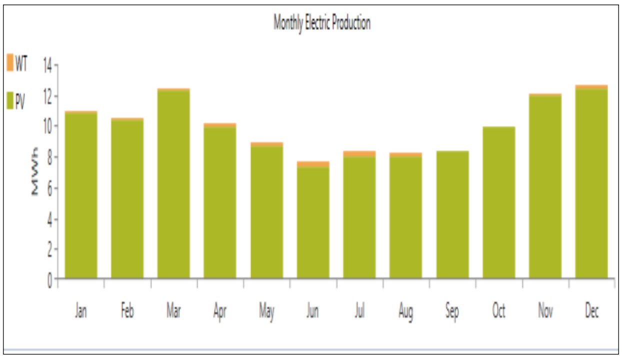

Fig.8. Case C-3.

VII. CONCLUSION

Renewable based hybrid power systems with energy storage facility provide reliable solutions for obtaining sustained power supply. The results of this work show that by optimal sizing of subsystems of hybrid power system using Homer, power can be generated at lower investment cost and at low energy cost. The system proposed would be very effective in achieving the goal of implementation of smart grids in future. From the results, it has been observed that, if the systems were modeled with a possibility of connection to the main grid or national grid along with renewables, the cost of energy would be minimum and beneficiary with low emissions. Thus, the assessment of smart distributed power systems in India can be achieved with reduced emissions in more economic way. Small and medium-sized businesses, local residential and commercial sites, educational bodies and government agencies may use this work to evaluate the costs of smart power systems if they wish to go for implementation of renewables. It helps to reduce carbon emissions and enhance distributed power generation, rendering the customers less and completely independent from the grid.

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