Optimum Sizing and Economic Assessment of Hybrid Microgrid for Domestic Load Under Various Scenario

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Abstract: Electricity price, various duties related to electricity bill and environmental concerns are increasing. Due to technological advancement and mass production, the cost of solar modules and energy storage system is going down. The number of consumers is growing by having the Solar Home System (SHS) transform from consumer to prosumer. The present assessment aims to analyze the techno-economic feasibility of residential households in Karnal, India, under three scenarios: a grid-connected net-metering system without feed-in tariff, feed-in-tariff and an off-grid system. It would help the consumer to choose the best configuration as per their geographical location. The study's outcome shows that a grid-connected system will require less investment, and it will be more economical with a feed-in tariff policy. Government support will motivate the peoples towards SHS to reduce carbon emission along with financial and social benefits.

Keywords Hybrid systems, microgrid, HOMER, solar home system, renewable energy sources, techno-economic analysis.

1. Introduction

Worldwide, primary energy consumption is increasing at a rate of 1.5% annually, whereas Carbon emission rises at 2%. India stands third in production as well as consumption of electricity, followed by China and the US. Despite this, the per capita energy consumption is low as compare to other countries. The Indian power sector is transforming into a restructured power system at a slow rate with deregulation of generation, transmission and distribution system. Renewable energy resources are integrating with the grid, and their penetration rate is increasing day by day. Renewable plants, including large hydro plants, constitute 35.86% of the total installed capacity [1]. The Government of India provides secure, affordable and sustainable energy while meeting the target of new renewable energy plants' setup to reduce local air pollution. The total installed capacity as of 30.11.2020 is 374199 MW, having a thermal contribution of 61.8%, renewable 24.2%, hydro 12.2% and nuclear power 1.8%, as shown in Fig.1 [1]. The various initiative taken by the Indian government makes 100% electrification throughout the nation and decreases the power shortage as well as load curtailment issues.

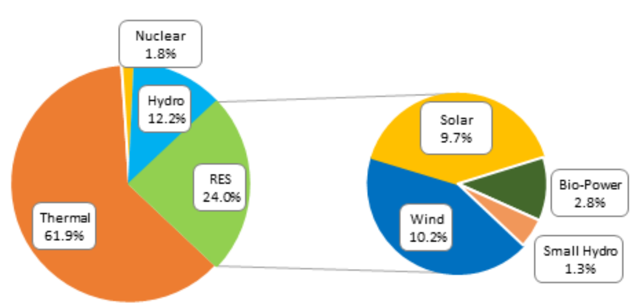

Fig. 1. All over India, installed capacity

Transformation of centralized controlled traditional power grid into competent, reliable and self-healing grid is taking place. These new smart/microgrids can efficiently operation of generation, transmission and usage of electricity to minimize environmental issues [2], [3]. Environment concerns, depleting fossil fuels, growing energy demands etc., leads towards the use of Renewable Energy Resources (RERs). Electricity consumer is now transforming into prosumer due to its dual role of generation and electricity consumption. Microgrid having regional renewable energy sources, energy storage devices, and consumer load can work either in isolated or grid-connected mode. Fossil fuels are depleting with time and create environmental issues too. The Renewable Energy Resources (RERs) are plentiful, yet their discontinuous nature is a significant snag toward their feasible turn of events [4]. The hybrid and grid integrated mode can overcome this issue. HRES can fulfil the developing energy need and gives a doable and practical arrangement.

A domestic single home system is analyzed for the economic and technical parameters of autonomous solar/wind/battery system in Urumqi, China [5]. The author in [6] investigated that the unit cost of electricity produced by a stand-alone solar system for household electrification is lower than conventional electricity supply in Faisalabad, Pakistan. Campana et al. [7] emphases the need for optimum sizing of SHS for the satisfaction of the users and improving the standard of living in developing countries. An investigation conducted on grid-connected solar PV system for various residential consumption and feed-in tariffs along with the time of day system for a net metering infrastructure at New Delhi, India [8]. The study concluded that the decentralized grid integrated solar PV system without BESS is a techno-economic viable solution. Different combination of nano/mini-grids having the combination of Solar/Wind/Diesel was studied by [9], [10] at various location at Nigeria for 5/12 neighboring houses and analyzed that the hybrid combination of renewable sources is costly in starting but reliable and economically viable in the long term and capable of meeting the load demand too. Singh et al. [11] present a solar/hydrogen fuel cell-based grid integrated system for academic research building. The excess energy produced is sold back to the grid for making the system sustainable and economically viable. An investigation performed in [12] shows that the forecast-based strategies can improve battery life and reduce the curtailment period for DC-coupled PV-battery system for a home to minimize the COE 12%. A study has been conducted at an offshore location in Turkey on seasonal and regular occupancy homes. The results show that COE 0f hybrid grid comprising photovoltaic/wind/ with battery/hydrogen storage system for an off-grid system is somewhat costly then utility grid but will be a viable solution with time due to reduction in the cost of components [13]. Li et al. [14] use the smart meter and economic analysis for SHS to decide on the battery storage system's optimum sizing. A study conducted by [15] at households in Japan found that a photovoltaic system in combination of electrical vehicle (EV) in 2030 will reduce the annual energy cost by 68% and decarbonize the household energy by 92%, makes the system more economical and strengthen the installation at household premises. A smart meter will help the utility company identify the household prosumers, their energy profile, and increase in numbers to maintain voltage regulation and protection of the circuit [16]–[18]. Khan I [19] evaluates the social and economic impacts of adopting solar photovoltaic technologies. Diallo and Moussa [20] analyses the SHS benefits from income, education and health perspective.

From various literature, it seems that SHS has significant impacts on remote, rural, and urban locations. The various researchers have performed hybrid optimization studies using multiple software tools like HOMER, MATLAB, LabView, and iHoga. The investigation on single household domestic load under different scenario is missing. In this paper, a study has been performed for a domestic household load under three different energy scenarios, i.e. grid integrated net-metering without feed-in tariff, grid integrated net metering with feed-in tariff and off-grid system. The optimal sizing of hybrid microgrid has been performed based upon technical and economic parameters under all scenarios for the same geographical site. As per the result's outcome, the user can decide which method will be feasible and choose the appropriate plan.

The paper is arranged as section 2 described system Modeling; section 3 gives a brief overview of software tool considered in this study; section 4 elaborates the results and discussion. Section 5 concludes the paper with a future research perspective.

2. Modelling of System Components

Modelling of an optimum and feasible system depends upon component which aid in electricity production and economics. The components to be considered are (1) components, which can produce electricity, (2) Economic components, which affects the sustainability and reliability of the proposed model.

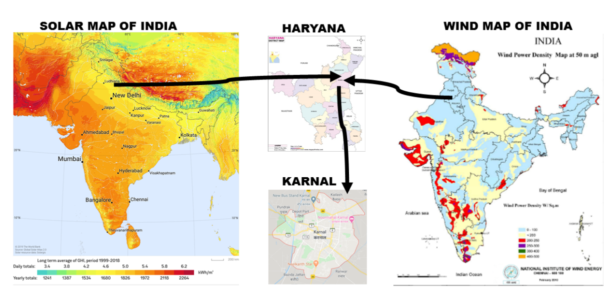

Fig. 2. The geographical location of the study site

Karnal, located at 29.68°N 76.98°E, is an agricultural-industrial district of Haryana and believed to be founded by Raja Karna, one of the central figures in the epic Mahabharata as shown in Fig. 2. India's government selected Karnal, under the smart cities mission, intending to improve the quality of life and economic growth through information and communication technologies, and the city has to meet its 10% of energy requirement through solar power.

2.1 Load Profile

Most of the load demand is lightning, TV, fan, domestic water supply and some other small appliances used for daily life. The daily load demand is an estimation by analyzing the appliances requirement and duration of usage. The electric load estimation is a very crucial factor. It depends upon the social-economic of the consumer, their behaviour and preferences [21]. Peak load demand is assumed in July due to hot weather, and most of the fans and cooling devices operate during this time duration. The domestic load's load demand is considered 14.0 kW/day with a peak demand of 2.97 kW.

2.2 Solar Photovoltaic System

The output power of the PV module, P_{PV} in kW, is calculated as [22]:

$$P_{PV} = Y_{PV} f_{PV} \frac{G(\beta,\alpha)}{G_{STC}}[1+\gamma(T_C - T_{STC}] \quad (1)$$

Where Y_{PV} defines the rated capacity in kW, f_{PV} is PV derating factor, $G(\beta, \alpha)$ is net PV irradiance in kW/m^2, G_{STC} is incident PV irradiance in W/m^2, γ represent temperature coefficient, T_C and T_{STC} is cell temperature in ˚C. The initial capital is taken as 630$/kW with a replacement cost of 600 $/kW. All other cost and performance parameters are considered as per paper [23]. The solar module's output power depends upon the intensity of solar irradiation, clearness index, and temperature [24]–[27]. The variation of various parameters at the geographical location is shown in Fig. 3.

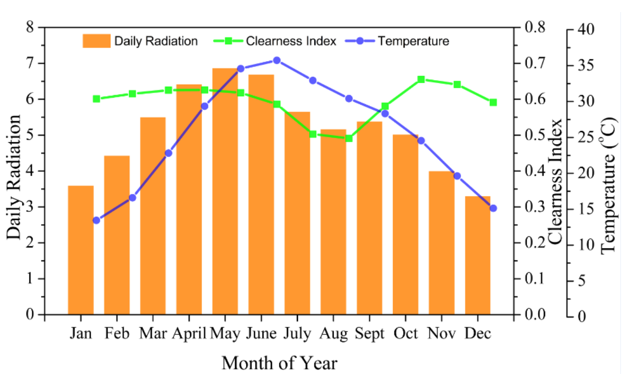

Fig. 3. Irradiation, clearness index and temperature at the site.

2.3 Wind Energy System

With the advancement in aero and structural dynamics of wind turbines (WTs), their energy output increases with a reduction in turbine weight and noise production. The kinetic energy of the wind rotates the turbine's blade, which is connected with the generator. The mechanical power of the wind turbine, P_{WT} in kW, is calculated as [28]:

$$P_{WT} = \frac{1}{2}\rho\pi R^2 C_p(\lambda,\beta)V^3 \quad (2)$$

Where ρ, R, C_p, λ, β and V denotes the air density (kg/m^3), turbine blade radius (m), power coefficient, the ratio of tip speed, blade pitch angle (degree) and wind speed (m/sec) respectively.

The initial capital and replacement cost are considered 1350 $/kW and 1000 $/kW, respectively [29]. The month-wise variation of average wind speed is depicted in Fig. 4.

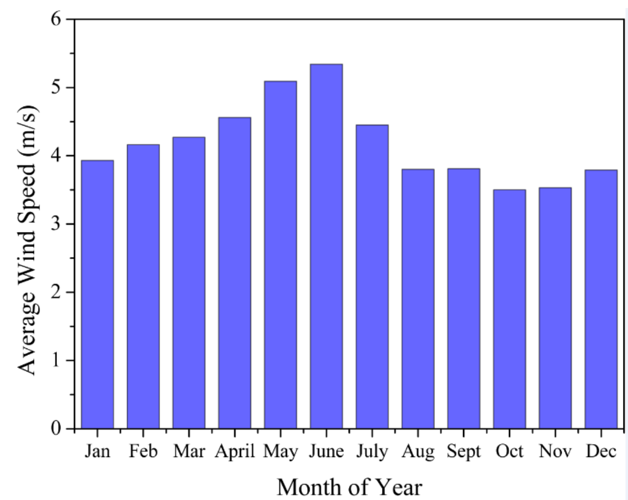

Fig. 4. Monthly profile of average wind speed at the site

2.4 Diesel Generator

The generic diesel generator (DG) model has been considered for this study. Fuel cost for DG operation can be calculated as [30]:

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \quad (3)$$

$F_i(P_i)$, P_i, a_i, b_i, and c_i represent the fuel cost, output power, and cost functions related to i^{th} DG. The capital and replacement cost are considered as 220$/kW and 200 $/kW, respectively. The operation and maintenance (O&M) cost is taken as 0.03$/operating hours for a lifetime of 15000 hours [23]. The fuel cost is considered as 1$/Liter as of January 2021, diesel price of India.

2.5 Battery Energy Storage System

The environmentally friendly power sources are irregular; accordingly, the dependability of power can be improved with energy storage devices. It is like the virtual inertia of the generating device, which absorbs the temporary transients. It supplies the power to the load after absorbing extra power generated from sources. The optimum capacity of the storage system should be considered. The limitation involves with energy storage system are higher cost and low research in management and control strategies. The technical constraints of state of charge *(SOC)* can be expressed as [31]:

$$SOC(t+1) = SOC(t) + \eta_{BESS}(P^{i}_{BESS}(t)/V_{Bus})\Delta t \quad (4)$$

$$SOC_{\min} = (1-DOD)SOC_{\max} \quad (5)$$

Where $SOC(t), \eta_{BESS}$ and P^{i}_{BESS} represents the energy stored in the last day, efficiency and power stored on the same day in battery energy storage device. The discharging of BESS is calculated by equation (5), where $DOD, SOC_{\min}$ and $SOC_{\max}$ represents the depth of discharge, lower and upper limit for charging BESS, respectively.

The battery life relies on its utilization in allowable cutoff points, so power drawn from the battery should be appropriately observed. The breaking point, just as the speed of charging/releasing, ought to be inside a passable reach. The limit and rate of charging/discharging ought to be inside a permissible range. The various cost and performance parameters are considered as per reference [32].

2.6 Power Converter

Power converter performs linkage between AC and DC buses with other micro-grid components by working as rectifier or inverter. The converter size depends upon peak demand (P_L^m). The inverter power rating P_{inv} can be found by the given expression [33]

$$P_{inv} = \frac{P_L^m}{\eta_{inv}} \quad (6)$$

Where, η_{inv} is the inverter efficiency The various cost and performance parameters are considered as per reference [32].

2.7 Economic Parameter Modelling

To find out the feasibility of the proposed hybrid system, various economic parameters are to be calculated, which are as follow:

Net Present Cost (NPC) is calculated by summarizing different costs like capital, replacement, O&M, fuel, various penalties, salvage cost, power purchase cost and revenue from power sell back to the grid over the entire lifetime of the project [32].

$$NPC = \frac{\text{Net Annual Cost}}{CRF(i,N)} \quad (7)$$

Where i describe the yearly real interest rate in %, N represents project duration.

Capital Recovery Factor (CRF) converts the present cost in parts of equivalent year-wise cash flow over a project life and represented as:

$$CRF(i,N) = \frac{i(1+i)^N}{i(1+i)^N + 1} \quad (8)$$

Levelized Cost of Energy (LCOE) gives the per-unit cost of electricity produced in $/kWh.

$$LCOE = \frac{\text{Net Annual Cost}}{\text{Useful Electric Energy Produced}} \quad (9)$$

3. Software Tool and Methodology

The assessment of the optimum design of hybrid microgrid has been performed by using HOMER Pro (version 3.13.6). The software can analyze hourly energy balance and a feasibility study by imposing several constraints on the islanded and utility-grid connected systems for remote, autonomous, and distributed generation. The optimum system configuration is found out by minimizing an objective function, like NPC with system constraints like a balance of power, demand management and penetration of renewable sources. There are four dispatch strategies (DS) such as Load following (LF), Cycle Charging (CC), Combine Dispatch (CD) and Predictive dispatch (PS). A pre-HOMER analysis is required before performing the optimization. In the first step, annual electricity load demand has been estimated based on similar work types by other researchers and personal judgment. After that, resource data is being collected from various references. Based on HRES components, the microgrid system model has been prepared in the software and cost data with technical specifications. The pre-HOMER assessments are given to the software for techno-economic analysis.

4. Result and Discussion

The analysis has been performed using HOMER software on domestic load under three different scenarios, i.e. Grid-connected hybrid microgrid without feed-in tariff, grid-connected hybrid system with feed-in tariff and islanded system. The schematic diagram of the integrated grid system is shown in Fig. 5, while the islanded configuration is shown in Fig. 6. For grid connected system, flat rate tariff of $ 0.06/kWh is considered. In case of feed-in tariff facility, selling price to the grid has been considered as $ 0.05/kWh [32].

The feasible and optimal solution under three scenarios is tabulated in Tables 1-3. For Scenario-I, the best optimum solution, which meets the load demand, consists solar module of 3 kW, a Battery energy storage system of 2 unit and a converter system of 3 kW. The NPC comes out to be 4652 $

with COE as 0.0460 $/kWh. For Scenario-II, the optimum solution has a 5kW solar module, 2 unit of BESS and a 4 kW

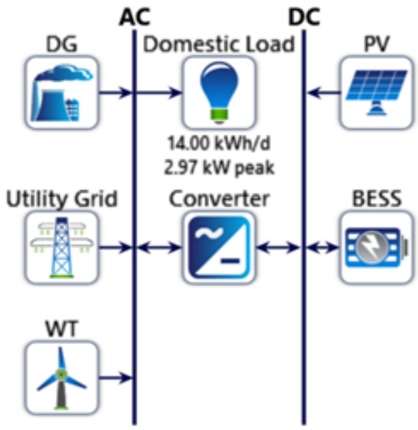

Fig. 5. Schematic diagram of the grid-connected system

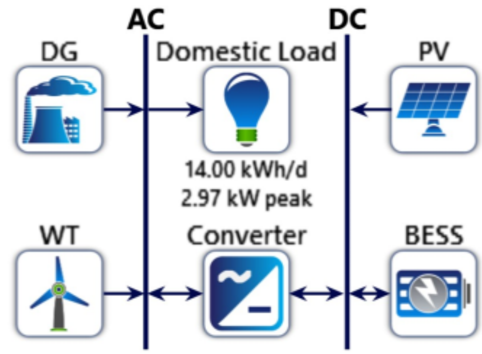

Fig. 6. Schematic diagram of Islanded system

Table 1. Optimized result under scenario-I

S. No.	Solar (kW)	Wind (kW)	DG (kW)	BESS (Unit)	Converter (kW)	DS	NPC ($)	COE ($/kWh)	Operating Cost ($)	Initial Cost ($)	RF (%)
1	3	-	-	2	3	LF	4652	0.0460	114.92	3090	62.2
2	3	-	3	1	3	LF	4924	0.0484	108.45	3450	61.8
3	3	-	3	-	3	CC	5667	0.0552	185.17	3150	59.6
4	3	1	-	2	3	LF	6105	0.0591	122.54	4440	64.8
5	-	-	-	2	3	CC	6182	0.0891	366.54	1200	0
6	-	-	3	-	-	CC	6317	0.091	416.25	660	0
7	3	1	3	1	3	LF	6365	0.0611	115.14	4800	64.4

Table 2. Optimized result under scenario-II

S. No.	Solar (kW)	Wind (kW)	DG (kW)	BESS (Unit)	Converter (kW)	DS	NPC ($)	COE ($/kWh)	Operating Cost ($)	Initial Cost ($)	RF (%)
1	5	-	-	2	4	LF	4330	0.0310	-16.21	4550	74.5
2	5	-	3	1	4	LF	4577	0.0326	-24.52	4910	74.1
3	5	-	3	-	4	CC	5258	0.0372	47.71	4610	72.5
4	5	1	-	2	4	LF	5825	0.0409	-5.50	5900	76.1
5	5	1	3	1	4	LF	6060	0.0424	-14.7	6260	75.7
6	-	-	-	2	3	CC	6182	0.0891	366.54	1200	-
7	-	-	3	-	-	CC	6317	0.0910	416.25	660	-

Table 3. Optimized result under scenario-III

S. No.	Solar (kW)	Wind (kW)	DG (kW)	BESS (Unit)	Converter (kW)	DS	NPC ($)	COE ($/kWh)	Operating Cost ($)	Initial Cost ($)	RF (%)
1	5	-	3	9	3	LF	14772	0.213	563.75	7110	96.1
2	5	1	3	9	3	LF	15919	0.229	548.84	8460	97.0
3	6	-	3	-	3	CD	38957	0.561	2495	5040	11.2
4	5	1	3	-	3	CD	39955	0.575	2516	5760	11.4
5	-	-	3	3	3	CC	40148	0.578	2795	2160	-
6	-	1	3	4	3	CC	40179	0.579	2676	3810	-
7	-	-	3	-	-	CC	54712	0.788	3977	660	-

converter. Due to the feed-in tariff facility, the COE is 0.0310 $/kWh with 4330$ as NPC. As the same load is also investigated without grid as Islanded system under

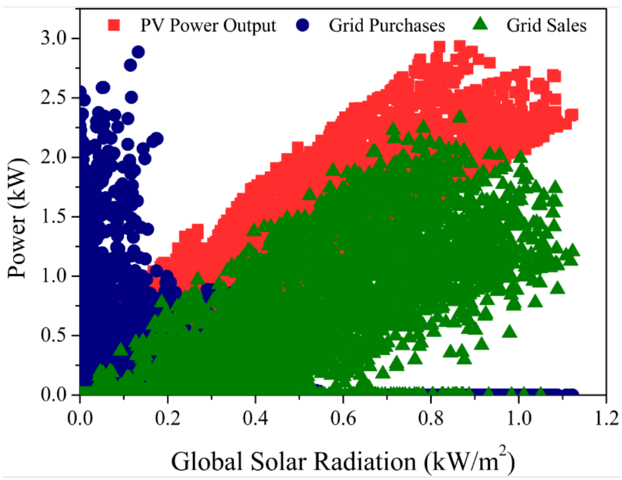

Fig. 7. Scatter plot under Scenario-I

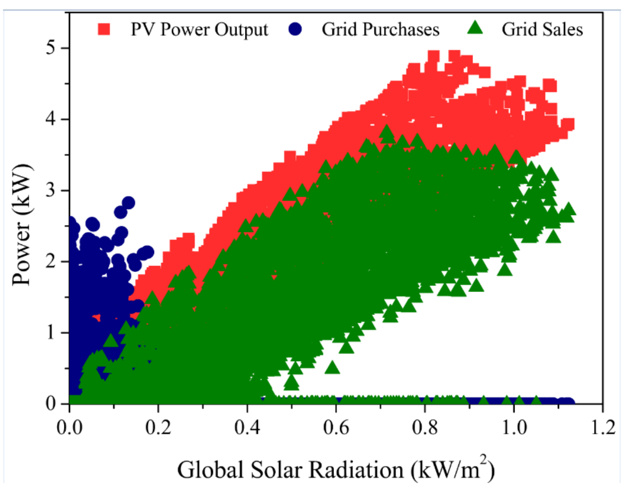

Fig. 8. Scatter plot under Scenario-II

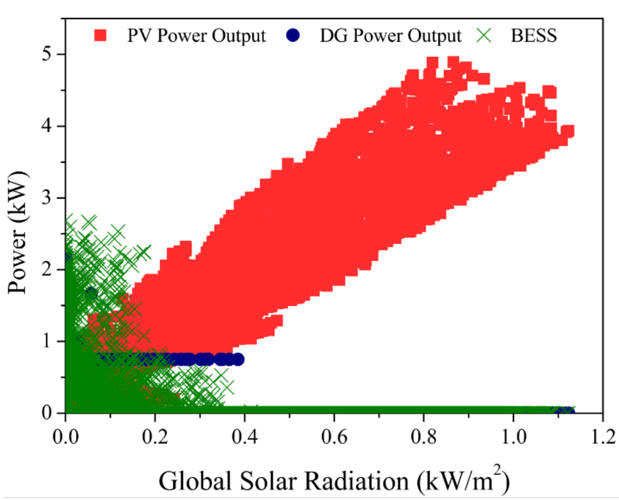

Fig. 9. Scatter plot under Scenario-III

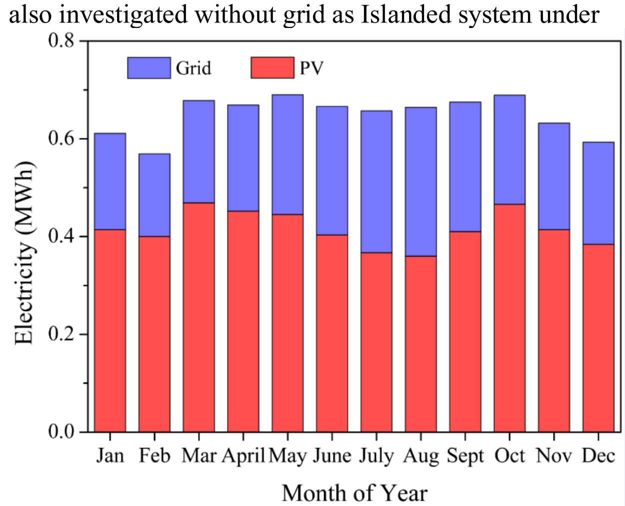

Fig. 10. Electricity production under Scenario-I

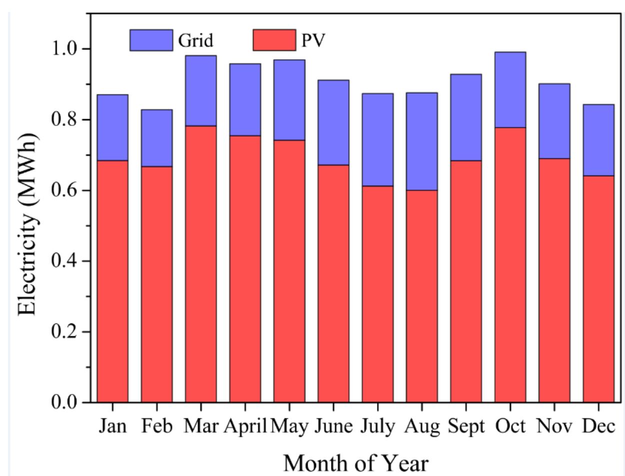

Fig. 11. Electricity production under Scenario-II

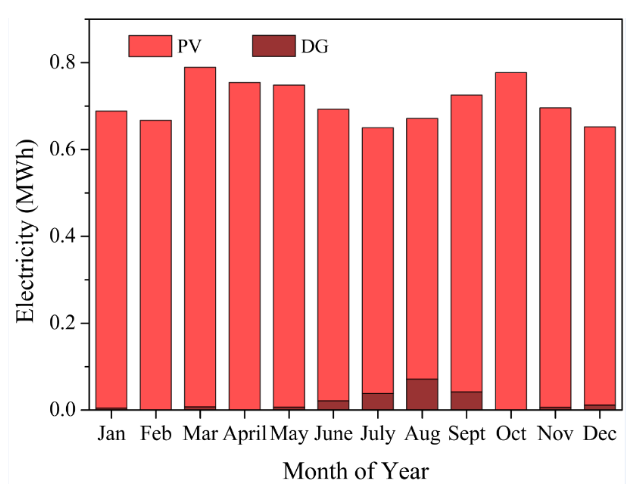

Fig. 12. Electricity production under Scenario-III

Scenario-III. In this system, the COE is 0.213 $/kWh with NPC of 14772 $ for solar module of 5kW, DG of 3kW, BESS of 9 units and system converter of 3 kW capacity. The other configurations are also tabulated in Table 1-3 for all scenarios. The dispatch strategies for the best seven configurations in scenario-I, II, and III are load following, cycle charging, and combine dispatch. The feed-in tariff policy decreases the per-unit cost, further reducing the net present cost despite higher initial costs due to more solar modules.

Variation of PV power output, grid purchase, grid sale, DG operation and BESS output as per configuration for scenario I-III are shown in Figs. 7-9, respectively. As depicted from the figures, during the low value of solar radiation, the electricity produced from the solar PV system is lacking or negligible to meet the load demand, so grid supply or BESS or DG requires various scenarios. With the rise in solar irradiation, PV output is sufficient to meet the load demand and can be feed-in into the grid as per availability and policy. The monthlies electricity production to meet the load demand for a year are shown in Figs. 10 and 11for grid connected mode. In summer, the grid supply contribution increases to meet the load demand compared to the winter season. As shown in Fig. 12, DG will run to meet load shortage for a concise period throughout the year except in summer.

A graphical presentation of PV production, load demand, electricity purchased, and electricity sold back to the electricity grid is shown in Figs 13-15. The load demand is higher in summer as compared to the winter season. In the winter season, under scenario-I and II, electricity demand is less than electricity produced from the solar system, so electricity sold back to the grid is higher than the purchase of electricity, which is also depicted in Figs 13 and 14. In summer, load demand increases, PV output declines due to very high temperatures. Other environmental factors like storms, monsoon, and lesser sun hours affect the PV output in July and August. Therefore, grid purchases increase in these months of the year. Due to the grid's absence, the load demand is fulfilled by PV, DG, and BESS in islanded mode. The extra electricity produced from the solar system charges the energy storage system, which supplies the load demand during the non-availability of solar energy. If still, there is need of electricity, diesel system starts operation. The operating hours of DG are more in summer, with the highest in July, August, and September.

The solar module has a higher initial investment, whereas the DG system will have more fuel cost. Initial cost, replacement cost, O&M cost, fuel cost and salvage cost of the various component has been given in Table 4-6 of all three scenarios for best optimal configuration. In scenario-I, due to the absence of a feed-in tariff policy, there is an O&M cost of 393.89. For scenario-II, there is revenue due to selling back of extra electricity, having an income of 1733.37 $. Despite higher initial capital, the NPC of scenario-II is 4329.74 $ than scenario-I, having 4651.91 $. Scenario-III, an off-grid system and a DG/PV/BESS system, has a higher initial cost, replacement cost, O&M cost, and fuel cost. The NPC of the system is highest as compared to the grid-connected system.

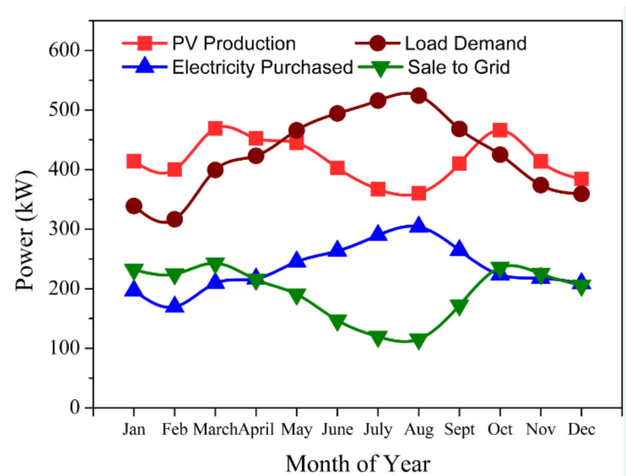

Fig. 13. Monthly profile under Scenario-I

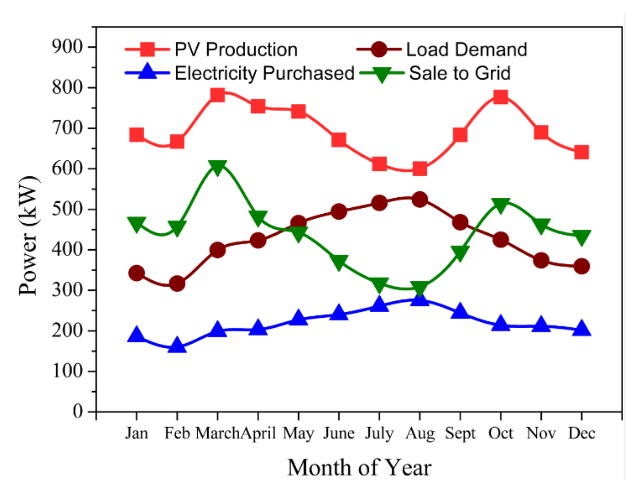

Fig. 14. Monthly profile under Scenario-II

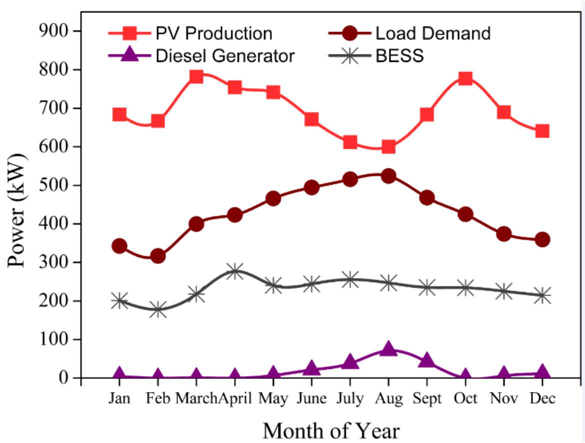

Fig. 15. Monthly profile under Scenario-III

Table 4. Cost summary under scenario-I

System component	Initial capital ($)	Replacement cost ($)	O&M cost ($)	Fuel ($)	Salvage ($)	Total ($)
Grid	0.00	0	393.89	0	0.00	393.89
Solar PV	1890	0	407.74	0	0.00	2297.74
BESS	600	472.24	135.91	0	-67.78	1140.48
Converter	600	273.94	0	0	-54.14	819.80
System	3090	746.18	937.54	0	-121.82	4651.91

Table 5. Cost summary under scenario-II

System component	Initial capital ($)	Replacement cost ($)	O&M cost ($)	Fuel ($)	Salvage ($)	Total ($)
Grid	0.00	0.00	-1733.37	0.00	0.00	-1733.37
Solar PV	3150	0.00	679.57	0.00	0.00	3829.57
BESS	600	472.24	135.91	0.00	-67.68	1140.48
Converter	800	365.25	0.00	0.00	-72.19	1093.06
System	4550	837.50	-917.89	0.00	-139.87	4329.74

Table 6. Cost summary under scenario-III

System component	Initial capital ($)	Replacement cost ($)	O&M cost ($)	Fuel ($)	Salvage ($)	Total ($)
DG	660	0.00	314.37	1092.64	-92.85	1974.15
Solar PV	3150	0.00	679.57	0.00	0.00	3829.57
BESS	2700	4861.94	611.61	0.00	-25.01	8148.54
Converter	600	273.94	0.00	0.00	-54.14	819.80
System	7110	5135.88	1605.54	1092.64	-172.00	14772.05

The graphical representation of cash flow under all three scenarios is depicted in Fig. 16-18. During the project lifetime, all the cost parameters like capital cost, replacement cost as per lifetime of the component, annual operating, annual fuel cost and a salvage value of elements at the end of the project are presented in the diagram.

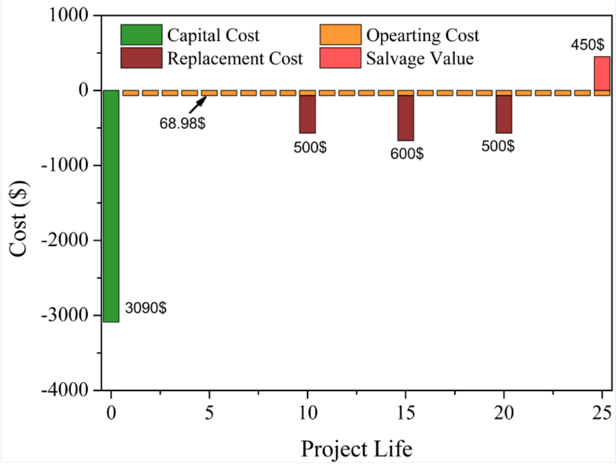

Fig. 16. Cash flow under Scenario-I

The payback period under all scenario is 6.88, 7.94 and 1.74, respectively. A detailed comparison sheet of various components is presented in Table 7. The solar PV module operates for 4373 hours and generates 4982, 8304 and 8304 units/year in scenario-I-III with a rated 3, 5 and 5 kW capacity. The off-grid system uses BESS for the highest

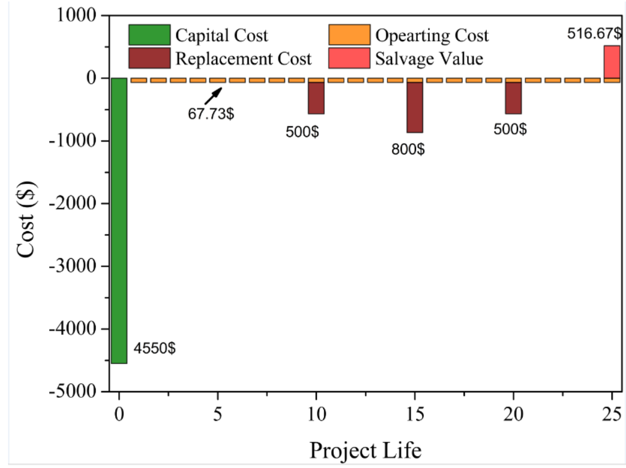

Fig. 17. Cash flow under Scenario-II

Table 7. The output of the various components under all three scenario

	Scenario:1	**Scenario:2**	**Scenario:3**
Solar PV Module			
Rated capacity (kW)	3.00	5.00	5.00
Mean Output (kW)	0.569	0.948	0.948
Mean output (kWh/day)	13.7	22.8	22.8
Capacity factor (%)	19.0	19.0	19.0
Total Production (kWh/year)	4982	8304	8304
Maximum output (kW)	2.94	4.89	4.89
PV penetration (%)	97.5	163	163
Hours of operation (hours/year)	4373	4373	4373
Levelized cost ($/kWh)	0.0339	0.0339	0.0399
BESS			
No. of BESS	2	2	9
Nominal capacity (kWh)	6.25	6.25	28.1
Usable nominal capacity (kWh)	4.37	4.37	19.7
Autonomy (hours)	7.49	7.49	33.7
Lifetime throughput (kWh)	1184	1109	15344
Losses (kWh/year)	26.5	24.9	679
Annual Throughput (kWh/year)	118	111	3044
System Converter			
Capacity (kW)	3.00	4.00	3.00
Mean output (kW)	0.528	0.874	0.565, 0.0043
Maximum output (kW)	2.78	4.00	2.70, 0.641
Capacity factor (%)	17.6	21.9	18.8, 0.144
Hours of operation (hours/year)	4519	4519	8579, 149
Losses (kWh/year)	243	403	260, 1.99

Diesel Generator (DG)			
Rated capacity (kW)	--	--	3.00
Hours of operation (hours/year)	--	--	257
Operation life (year)	--	--	58.4
Number of starts/year	--	--	106
Capacity factor (%)	--	--	0.766
Fixed generation cost ($/hour)	--	--	0.299
Electrical production (kWh/year)	--	--	201
Fuel consumption (Liter)	--	--	80.4
Fuel energy input (kWh/year)	--	--	791
Mean electrical efficiency (%)	--	--	25.4

time due to the supply load demand in the absence of solar power. A diesel generator is used in the off-grid system and runs for 257 hours throughout the year. CO_2 emission of solar PV hybrid system is significantly less than the DG system or grid only system. Therefore, Grid integration of renewable energy sources and storage devices improves system reliability and makes it an economical and sustainable approach.

5. Conclusion

The rise in energy demand, exhausting fossil fuels resources and environmental concerns motivate the power community to search for power production methods. Renewable energy sources seem to be a promising alternative for fossil fuels and sustainable development. In this paper, an investigation has been performed for a domestic load under three different scenarios using the HOMER software tool.

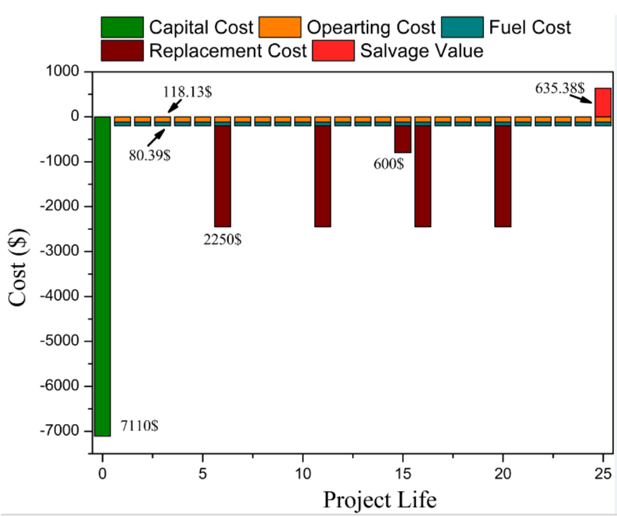

Fig. 18. Cash flow under Scenario-III

The results reveal that an integrated grid system is economical than an off-grid system, and it would be more economical with a feed-in tariff structure. Feed-in tariff reduces the payback period and further motivates the consumers to install a hybrid system. The investigation has been performed at the study site using various cost components for the same load demand. The proposed efficient system may not be feasible for all areas. Therefore, a comprehensive study required, and this paper suggested an approach that can be applicable for studying for any site or geographical region. A 40% share of renewable energy in overall power production can be met by motivating consumers to behave as a prosumer. It will improve the carbon emission goal and economic position of the consumer and the power industry.

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