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Designing of Solar PV/Wind/Grid-Tied Hybrid System for A Domestic Load

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ABSTRACT- In ancient times mostly house chore are done by using muscle powers. With the advent of electrical energy there is a tremendous shift in the working pattern of such chores, which resulted in availability of ample time with the home maker to engage in other productive works. In achieving this the Indian national grid plays a pivotal role. However there are such places which faces difficulties in performing such chores due to frequent outage of electricity, which creates discomfort and economic loss. As the technology is developing at a rapid rate, the world is witnessing new renewable energy sources with improved efficiency. These sources not only solve the energy shortage problem, rather it is able to fight the environmental menace too. The ever fluctuating global crude oil price also creates a challenge for India to maintain its energy security. The time when the Union government is promoting the renewable source for its various advantages, this study assesses one such model. The study operates the solar PV and wind mill in unison and then the hybrid combination is integrated with the national grid. The study aims to provide continuous power supply with cost effective price. The model is simulating using the HOMER software and its various impacts are assessed critically.

KEYWORDS- Solar PV, Wind energy, Hybrid energy, HOMER, Grid

I. INTRODUCTION

Energy is essential to our society to ensure our quality of life and to accomplish all other elements of our economy. Renewable energy technologies offer the promise of clean, abundant energy gathered from self-renewing resources such as the sun, wind, and ocean. These resources can be used to produce electricity for all economic sectors, fuels for transportation, and heat for buildings and industrial processes[1]. Renewable energy resources can satisfy the demand [2]. Renewable energy power production is intermittent. Proper capacity of backup can be used to overcome this intermittency nature. Backup or storage devices can pollute the environment. So in this study the grid is integrated instead of any storage device. Hybrid optimization model for electric renewable[3], HOMER software developed by the National renewable energy laboratory NREL USA is used for simulation. [4]. The simulation was focus on the supply reliability, assessment of performance of major components of the scheme and the cost of energy.

II. LITERATURE REVIEW

Díaz et.al (2011) studies power framework made up of (PV) in non urban Areas. The examination is established on region working of 12 aggregate PV establishments providing the electrical energy to off grid towns put inside the territory of Jujuy, Argentina. 5 of them have PV generators as explicit power supply while different other 7 are diesel based generators. Performance of such combination, power productivity and fuel usage were investigated [5].

P K Chaurasiya et.al (2019) shows that India is enriched with tremendous renewable power and wind power especially. Assessing the possibility of wind power is crucial for progression of wind generator in India. As of 2018 as much as 34605MW capacity wind energy plants are already in operation. In the wind energy transformation/use, India is in fourth spot of the globe. This paper offers the condition and advancement of wind power in India [6].

V. Kumar et.al (2016) presents study on grid integration and power quality issues related with renewable energy. In this paper, plan of execution of electronic devices for the joining of wind and photovoltaic (PV) power generators are presented. Conversations concerning typical and future plan in renewable energy systems considering dependability and improvement are given. Execution of a grouping of systems as applied to direct the many Power Quality issues is introduced for account [7].

III. MODELING

The scheme employed solar PV and wind mill as the renewable energy sources which will act as the primary energy producer. As the system does not have the provision of battery, the system's supply reliability is a challenge. To mitigate the challenge the national grid is integrated, which too provides an opportunity to generate some financial gain by exporting excess energy from the system. The system is designed for a domestic load consisting of five members, based in Leh of Ladakh Union territory.

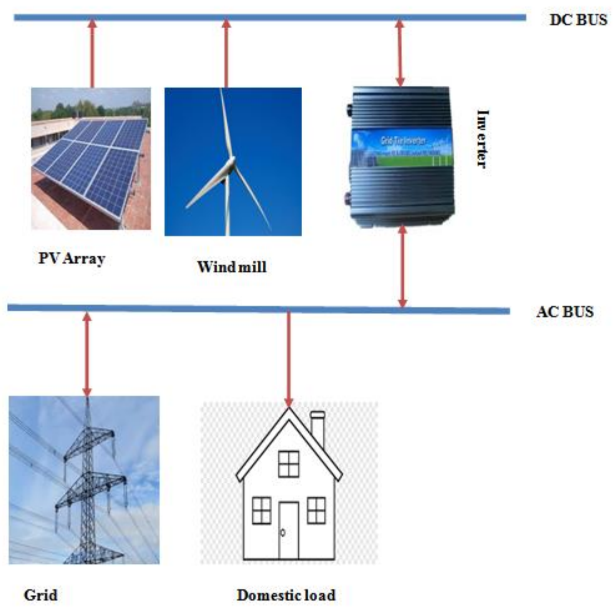

Figure 1: Schematic diagram of the PV/wind/grid integrated model

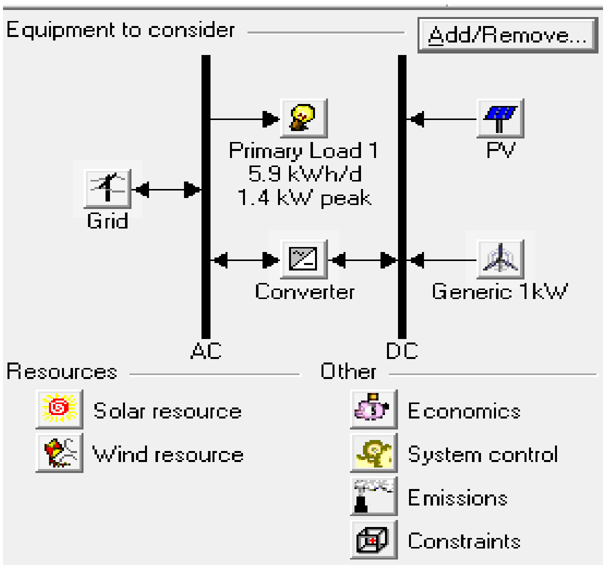

Figure 2: HOMER model of the PV/wind/grid integrated system

The system have both the renewable source of energy and the national grid and operated in integrated mode. The objective is to provide continuous and cost effective power supply. The grid act as secondary source and also maintain the equilibrium by providing shortfall of energy and absorbing excess energy produced from the hybrid combination of solar PV and Wind mill. The exchange of energy with the grid is taken place with a pre-fixed price. The system employed an converter of 3 kW to convert the DC power produced by the wind mill and PV array to usable AC form.

A. Load profile

The scheme is designed for a domestic load having 5 members. The load of the system includes all the electrical equipments generally used in a middle income group house. The system calculate the peak load to be 1.4 kW and the energy consumption of the load is 5.9 kWh per day. The load is synthesized in HOMER to develop a more realistic load profile. The load is assumed on the basis of national average energy consumption. For simplicity in the calculation the load on the system for the entire year is taken as constant.

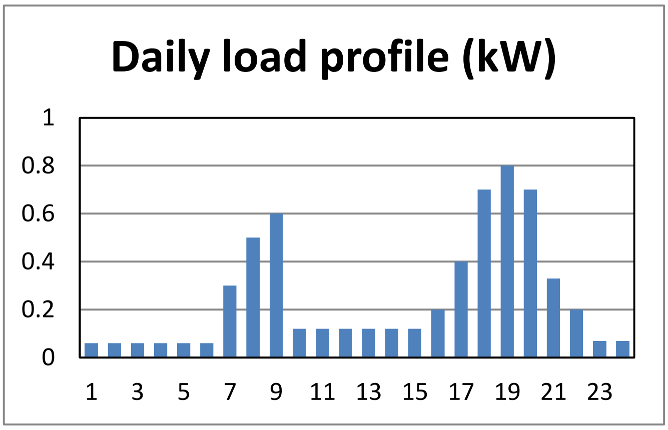

Figure 3: Estimated daily load profile of the scheme

IV. COMPONENTS USED

Table 1: Optimized major components

Component used	Size/Rating
Solar PV	4 kWP
Windmill	1 kW
National Grid	50 Hz, 1000 kW
Converter	1 Kw

V. MATHEMATICAL FORMULATION

A. PV power generation

The power output from a PV array is:

$$P=VI= N_p I_{ph} V - N_p I_0 V\left(e^{\frac{1}{V_t}\left(\frac{V}{N_s}+\frac{I_{RS}}{N_p}\right)} - 1\right) - \frac{N_p}{R_p} V\left(\frac{V}{N_s} + \frac{I_{RS}}{N_p}\right)$$

where Iph is the photo current (A); I0 is the diode saturation current (A); Rs is the series resistance (Ω); Rp is the shunt/parallel resistance (Ω);NP Ns is the number of PV cells in parallel, Vt = nKT/q is the diode thermal voltage; n is the diode ideality factor; Ns is the number of PV cells in series [8-9] .

B. Wind Power Generation

$$Power = \frac{1}{2}\rho A v^3$$

where

ρ is the air density (kg/m^3)

P =power A =area
V = velocity of wind

C. Energy Balance Equation

The equations governing the energy balance of the different configurations of systems, can be written in the following way, where Ein is the Energy IN the System and Euse is the Energy Used:

$$E_{in} = E_A + E_{BU} + E_{FUN} + E_{FSN} \quad (3.1)$$

$$E_{use} = E_L + E_{TUN} + E_{TSN} \quad (3.2)$$

where E_{FUN} and E_{TUN} are, respectively, the Net Energy FROM and To the Utility, and E_{FSN} and E_{TSN} are, respectively, the Net Energy FROM and To the Storage Unit, as defined in the IEC-61724 Standard. E_A, E_{BU}, the net energy from Array generation and battery respectively and E_L is the load in the system [10].

VI. SIMULATION METHODOLOGY

Hybrid optimization model for electric renewable (HOMER) software [11], developed by the NREL of USA. The software used to simulate renewable and non renewable energy sources, optimise the system for making the system cost effective. This is widely used for research and studies. The economic analysis of the software is designed to provide a basic estimation for the scheme.

VII. RESULT AND DISCUSSION

A. Monthly power output from PV array

The power output of the solar PV in monthly fashion is estimated by the HOMER. The clear sky of october results in harnessing the maximum power output from the PV array. The amount of solar enenrgy production varies as per the prevailing waether condition. The PV power output is estimates as 7,188 kWh annually.

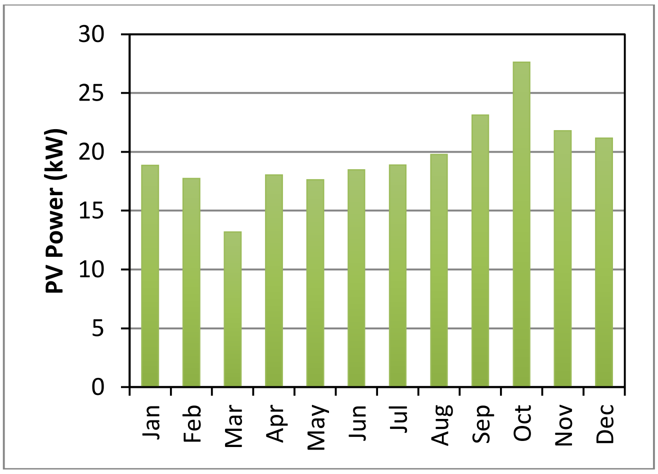

Figure 4: Power generation of SPV array

B. Wind mill power generation

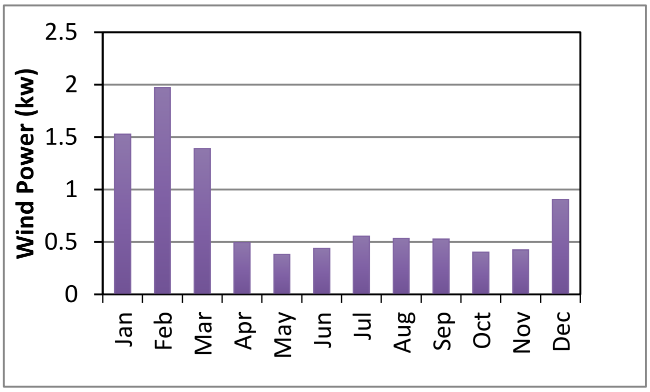

Figure 5: Wind mill power output

The study reveals that the power output from the wind mill at the installed location is limited. However if adequate capacity of wind mill is installed it can be proven as a complementary power source to the PV array. It is observed that, the month where the PV power generation is declines due to cloud cover and other associated causes, the power generation by the wind mill is quite inspiring. The power supply by the wind mill to the load is 289 kWh/ year.

C. Grid supply

Grid is integrated with the system with the view to enhance the reliability of the supply. The grid not only does this work with utmost efficacy but it helps to make the project more cost competitive too by optimizing the component size of the scheme. However in the view to curtail the pollution level the grid power purchase is restricted. To support the scheme financial viable and to optimize the power production the scheme is facilitate with the provision selling the extra power to the grid. The blue bar represents the energy purchased from the grid, as this involves expenditure it is shown in negative side of the graph. The orange bar represents the energy sold to the grid, which creates an option of income. And the grey line shows the net energy sold to the grid.

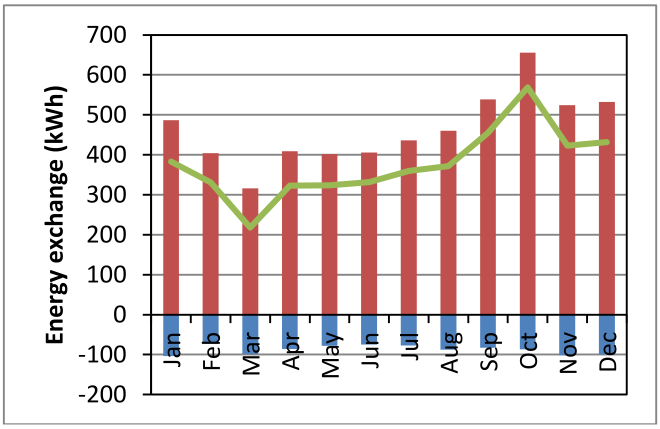

Figure 6: Grid energy exchange

D. Operation of scheme as a standalone system

To analyze the impact of grid two conditioned were depicted. In one condition the energy sources and load are matched without the grid connection. In the second testing condition the grid is integrated and the results were examined by comparing both the situations.

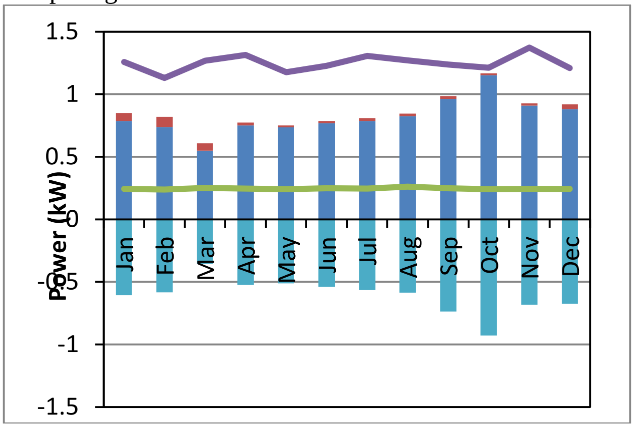

Figure 7: System operation without grid

E. *Inverter Performance*

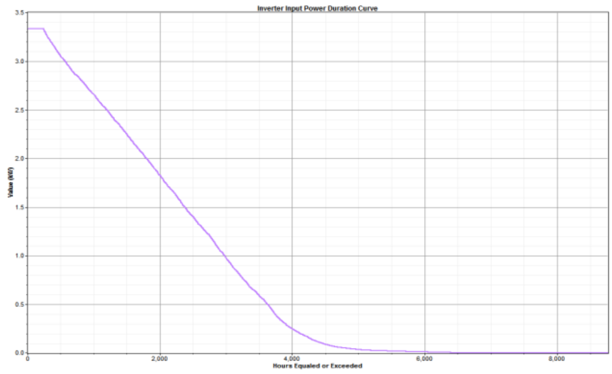

Figure 8: Inverter Duration curve

Inverter is an integral part of the proposed scheme. It is used to serve the load by converting the DC power produced by solar PV and wind mill to AC power. The inverter performance mainly affected by the DC side. The duration curve of inverter shows the operation hour of inverter along with its rated operating capacity. The inverter operates for 6,567 hours annually with maximum capacity of 3 kW. The capacity factor of the inverter is estimated as 25.4%.

F. *Environmenta impact assessment*

To make the system economical viable the scheme incorporates the grid. With the grid integration the penetration level declines and also the system releases little pollution to the atmosphere. However the system saves around 2857 kg of CO2 , 12.4 kg of SO2 and 6.06 kg of NOX annually. All these gases are green house gases and have potential to disturb the ecology of the location.

Table 2: Emission from the system

Pollutants	Emissions with grid (kg/yr)	Emission without grid
Carbon dioxide	-2,857	3246.59
Carbon monoxide	0	0
Unburned hydrocarbons	0	0
Particulate matter	0	0
Sulfur dioxide	-12.4	14.09
Nitrogen oxides	-6.06	6.88

G. *Duration Curve*

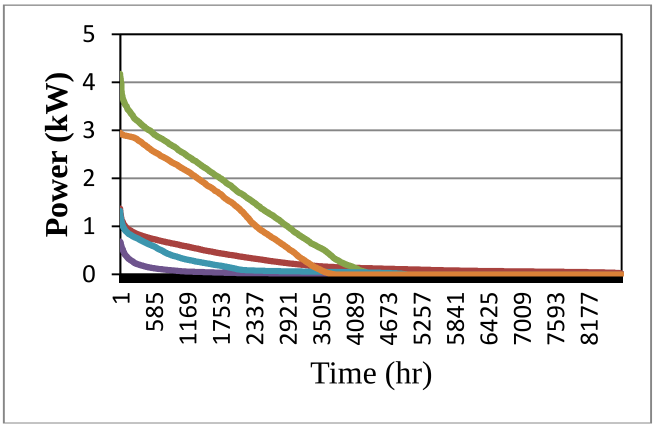

Figure 9: Spider Graph

Duration curve shows operating hours of individual components along with its operating capacity. The power requirement of the system for the simulated year stands at 8760 hours shown in orange line. Solar PV operates for 4385 hours annually shown in grey line, where as wind mill operates for around 5000 hours shown in yellow line, however the wind power production is very less as it operates with less capacity. Power purchased from the grid is 5308 hours represented in blue line and sold to the grid is 3750 hours shown in green lines.

H. *Hourly energy balance of the proposed system*

An illustration of the hourly reenactment result during one ordinary days is outlined in the below figure to investigate the energy equilibrium of the proposed framework. Clearly the accessible power yield is first used to cover the nearby power requirement. The grid comes into picture to coordinate the power production and requirement. If there would arise an occurrence of deficiency of energy that energy is taken from the grid at the cost fixed before and in the event of excess of energy subsequent to fulfilling the peak need the subsequent part of energy is offered to the grid. Average load displayed in red line, PV power in grey bar, yellow bar portrays the windmill yield. Grid sale and purchase are shown by green and blue bar individually.

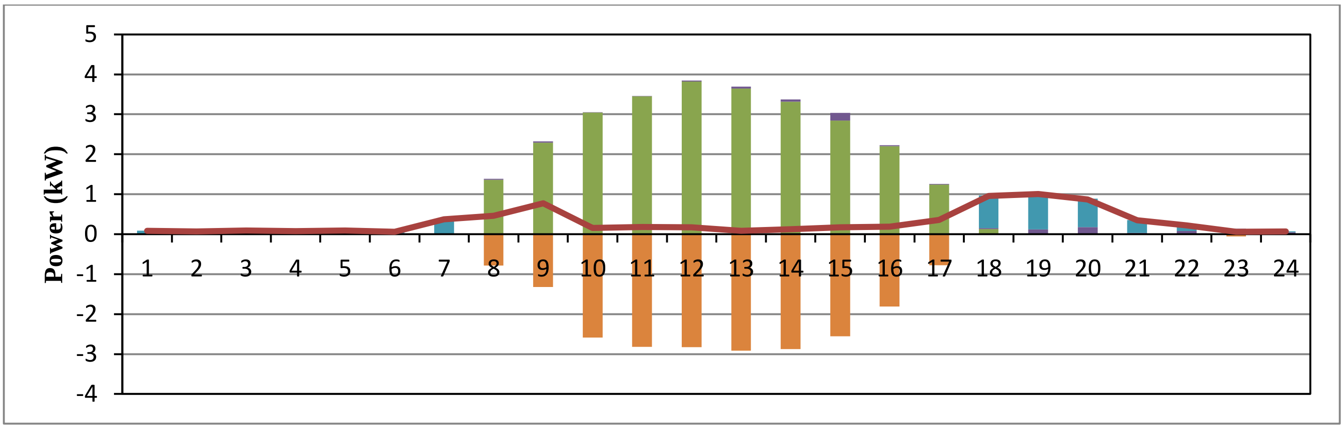

Figure 10: Hourly energy balance

I. *Spider Graph*

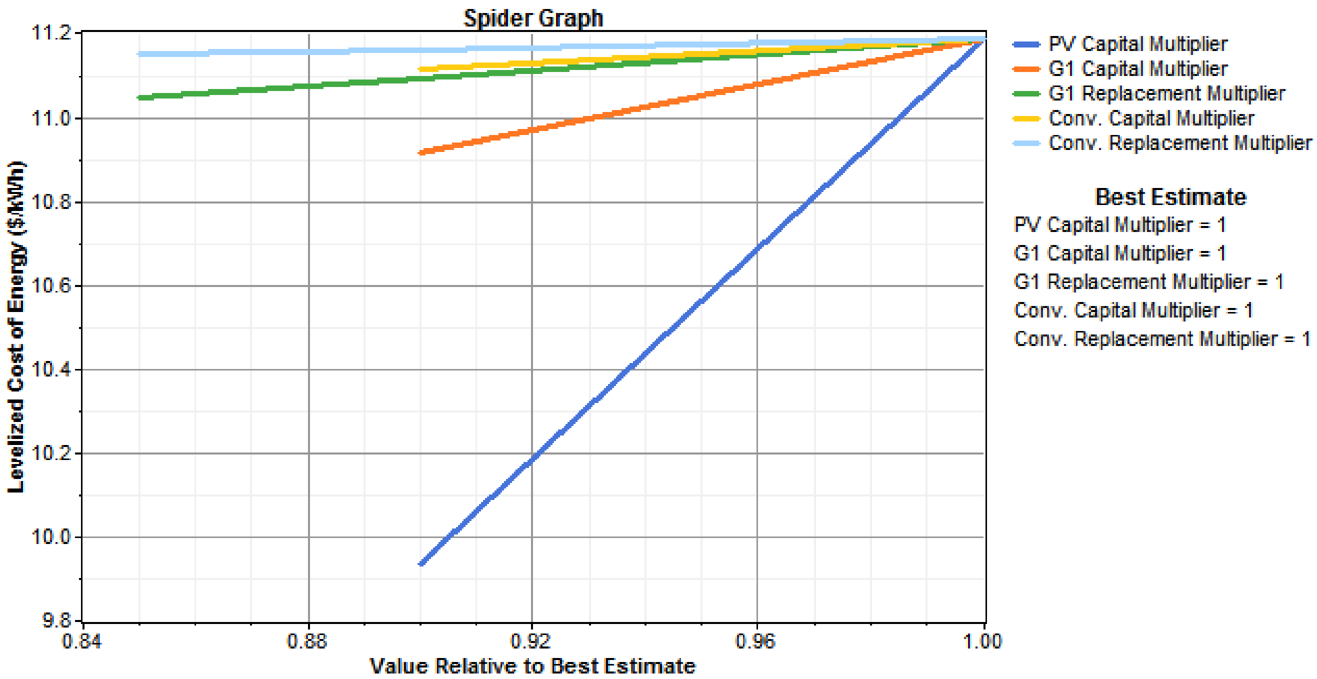

Figure 11: Spider Graph

Spider plot is used to show the sensitivity results. It explain the relationship between the levilised cost of energy and capital of solar PV, wind mill and converter and replacement cost of converter and wind mill. The decline in PV reduces the cost of energy to 9.9 INR per unit. Other costs also affect the reduction in energy price but their effect is very less.

10.Economic analysis

The first fig. shows the general advancement which is created in the HOMER programming. Each column in the table addresses a feasible framework design. The initial 4 segment shows symbol , next four segment demonstrate number or size of every part, the following five section shows key creation results, like capital expense of the system, working capital arrangement is the one having least NPC which includes 1000kW of grid, 4 kWP PV,1 kW of Generic made windmill , 3 kW converter. The COE is found to be11.185/kWh and 88% renewable penetration level. There is an opportunity of income generation of INR 10,239 yearly.

PV (kW)	G1	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage
4	1	3	1000	$ 438,800	-10,239	$ 307,908	11.185	0.88	0.00
4	1	4	1000	$ 445,400	-9,955	$ 318,147	11.557	0.88	0.00
5	1	4	1000	$ 531,400	-16,450	$ 321,111	11.664	0.90	0.00
4	1	5	1000	$ 452,000	-9,449	$ 331,207	12.031	0.88	0.00
5	1	3	1000	$ 524,800	-15,088	$ 331,925	12.057	0.90	0.00
5	1	5	1000	$ 538,000	-16,042	$ 332,931	12.094	0.90	0.00
4	1	2	1000	$ 432,200	-7,334	$ 338,443	12.294	0.88	0.00
3	2	2	1000	$ 421,200	-2,024	$ 395,327	14.360	0.85	0.00
5	1	2	1000	$ 518,200	-9,527	$ 396,410	14.400	0.90	0.00
3	2	3	1000	$ 427,800	-2,316	$ 398,196	14.465	0.85	0.00
4	2	3	1000	$ 513,800	-8,641	$ 403,334	14.651	0.89	0.00
3	2	4	1000	$ 434,400	-1,819	$ 411,153	14.935	0.85	0.00
4	2	4	1000	$ 520,400	-8,456	$ 412,310	14.977	0.89	0.00

Figure 12: Optimization result of PV/wind/grid integrated System

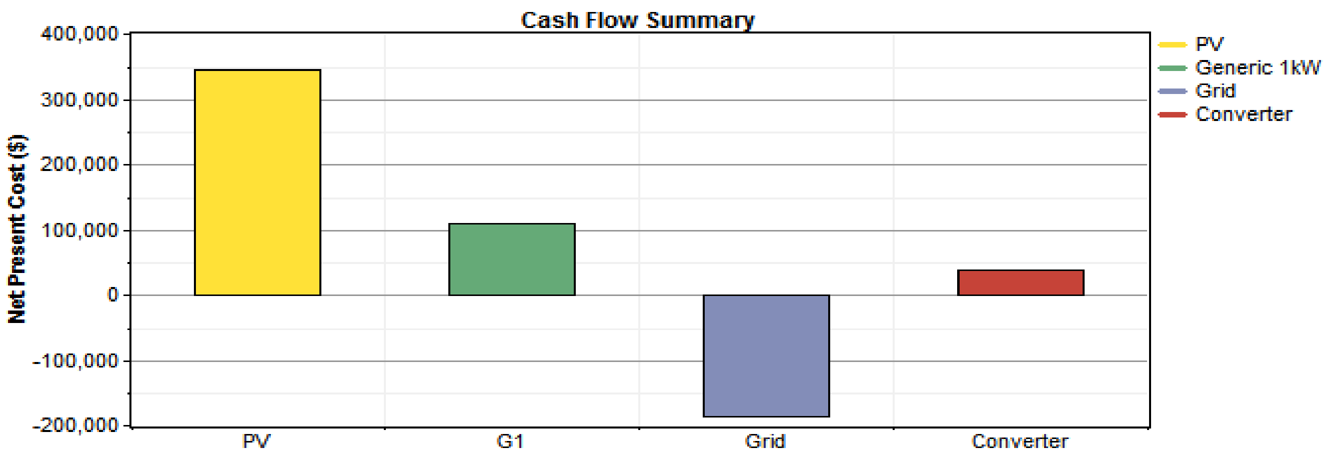

Figure 13: Cash flow outline of the project

The above figure represents the cost of the system with different heads. The PV cost is shown in yellow bar, as the capacity of PV is more the cost too is more. The wind mill is the second major instrument and the cost of this wind mill too second in the scheme. The converter cost is least in the scheme. The grid cost is shown in light blue bar is in negative because it provides an opportunity to generate economic gain where as other show the expenditure of the scheme.

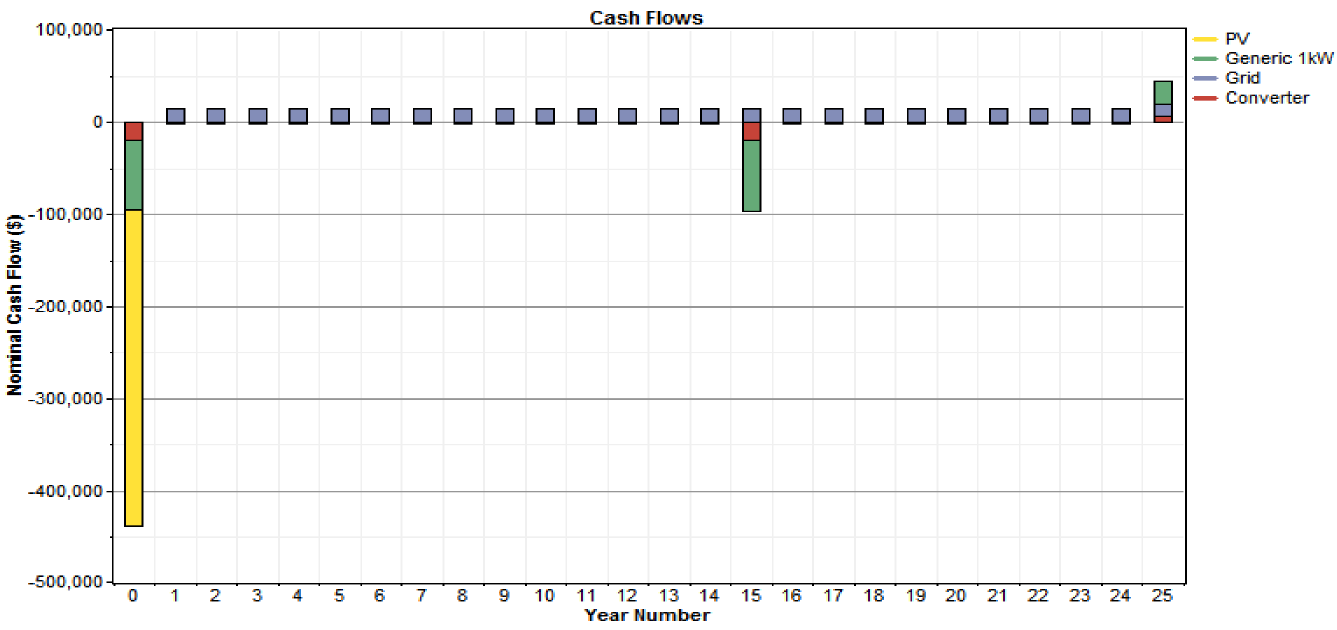

Figure 14: Cash flow information of the scheme

The yearly cash flow throughout the systems life span is depicted in the below fig. Each bar in the graph represents either a total inflow or total outflow of cash for a single year. The first bar, for year zero, shows the capital cost of the system. A negative value represents an outflow (expenditure) due to equipment replacement, or O&M. Possible replacement of converter and wind mill in the 15th year. A positive value represents inflow, which may be income from the salvage value of the equipment's at the end of the project life time.

VIII. CONCLUSION

In this study Solar PV/Wind/grid integrated scheme is analyzed for a domestic load located in Leh. The results are promising. It concludes that with the integration of such system, the supply reliability will be enhanced, the levilised cost of energy is 11.185 INR/kWh, the system provides an opportunity of economic generation of INR 10,239 annually. The scheme concluded to be technically feasible and on the ground of environmental concern it is highly recommended.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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