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Study of Solar Wind Hybrid Model at Leh Ladakh

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ABSTRACT- Solar photo-voltaic system, with a reputation being inexhaustible and environmentally benign, has been widely used for power generation. The cost competitiveness of solar PV is likely to get even more obvious, particularly when compared with the continuous rising of conventional fuel prices and the rapid decline of PV module prices. Furthermore, the policies of India are conducive to the development of solar projects. But solar PV suffers from its intermittent characteristics.

Windmill produces power when the speed of wind blows beyond the cut-in speed. The kinetic energy of the wind is captured and by the application of the turbine and generator set, it converts into useful electrical energy. The energy output from this kind of power plants is dependent upon the wind speed.

The proposed scheme integrates Solar PV and Windmills to increase the reliability of the power supply. As both solar PV and wind energy are intermittent, battery banks are placed to realize the reliability of the supply. The system operates on standalone mode. It is evident from various studies that, in the Leh, Ladakh region wind and Solar power production complement each other. During the summer season or sunny days, the Solar PV share a larger portion of generated power whereas in the winter season or cloudy day the large portion of power will be delivered by the Wind mill. The excess power after meeting the load demand will be stored in the battery bank and that stored energy will be utilized when the combined operation of Solar PV And Windmill are not able to meet the load demand. The proposed scheme evaluates the performance of such a scheme and aims to optimize the system.

KEYWORDS- Review of solar PV-wind hybrid system, Methodology used in the study, Modeling of PV-wind hybrid system, Performance of PV- wind hybrid system.

I. INTRODUCTION

World's energy need is growing quickly due to technological advances and population explosion. It's thus vital that you go for dependable, cost effective as well as everlasting renewable power supply for electricity need arising in upcoming [1]. World's energy need increasing considerably due to manufacturing evolution and population growth. The population explosion continued in developing nations. The energy need will definitely increase in the future. Every nation is trying to meet their demand by formulating legislation to ease the process of energy generation. This might the real big challenge for all nations in coming days [2]. 2 Energy need is closely associated with the growth. Although a lot of methods are suggested for boosting electricity generation capability, lots of individuals still unable to access electrify. The growth of demand in future can't be met with the conventional energy source for the obvious reasons [3]. Electricity producing methods presently in using throughout the planet may be classified into 3 major categories: non-renewable, non-conventional and the nuclear powered. Nuclear energy needs sophisticated technology which the poor country can not afford to have, they largely depends upon the firewood, coal and petro chemicals for converting them to useful form of electricity [4]. Electric power may be created (more over converted) coming from different sort of solutions. The energy sources are hydro, diesel and coal, biomass, geothermal, wind, solar, nuclear, tidal etc. There are few power plant, those transform heat into electric energy known as thermal power station[5]. Renewable energy are gaining ground and importance due to various problem associated with those conventional systems [6,7]. Renewable sources are not continuous source of energy production. Demand control [8-10] smart and efficient use [11,12] can do a little, but they may not able to meet the demand without any storing facility. Energy storage is a must to ensure the supply reliability [13] Nevertheless, to create the intermittent solar power to get completely dependable it must be equipped with storage system. The battery integration not only enhances the supply reliability rather it also ensure to maintain the system equilibrium. The fluctuation in the system can be addressed by this [14].

A. Solar PV Energy

PV engineering is benign and elegant, with a selection of striking benefits over traditional techniques of electrical energy generation. Solar is the widely used form of renewable energy. Irrespective of place and facility the solar panel can easily produce power when adequate amount of radiation strikes the solar cell. PV can reduce the CO_2 emission by producing more and more power using this technology [15]. Renewable sources are having lots of advantages over the existing conventional system. They do not harm the ecology, non-depleting, dependable and many more. It is believed that the nest power source is the renewable one which can create large amount of power and effectively address the issues of environment [16-18]. The PV works on solar radiation, so the primary requirement for power generation is the adequate insolation, and the monetary requirement to get this is zero. This is suitable for development of distributed generation scheme, as it can remove the cost of transmission, reduce the loss in the process and incredibly enhance the supply reliability. As the technology is evolving it is evident that the cost of energy produced by PV also declines. Moreover, they are committed to safe guard the environment which provides them huge possibility for their utilization [19]. Solar energy production pattern is little disappointing as it heavily depends upon the weather phenomenon and as there is non-existence of sophisticated weather prediction devices, the energy production from PV also not estimated. By employing ESS, these problems can be overcome which makes the system more reliant. The ESS will maintain the energy flow balance any absorbing the excess energy and by releasing the deficit portion of energy. [20]. The ESS is very much essential to make the system sustainable [21], the report released by European commission suggest the same [22].

B. Wind Energy System

Power is among the essential inputs for socio economic development. The speed at which energy is actually being ingested by a nation usually reflects the degree of prosperity which it might accomplish. Among renewable energy sources of energies, wind energy is a crucial source of environmentally friendly vitality and is now increasingly more crucial in the latest years [23]. The wind energy is an indirect form of solar energy, but it does not depend only on the geographical location rather this considers other related factors, this limits the use of wind energy. The topography dominates the power production from the wind mill [24]. The energy crisis is a real matter of concern for the world, it is exhaustible and controlled by group of countries. This has major impact on the energy market as the price of oil fluctuates the energy prices are bound to do so [25]. The world energy forum has stated that in coming days the fossil fuel will be finished, this will have a major impact on the energy infra as even today these fuels are a significant producer of energy [26]. The condition of energy in developing nation is not good. There are so many villages which are not electrified in the twenty first century. Due to the pollution and other related issue, the use must be restricted, but they don't find any other option for power. In these areas wind can be a game changer by providing electricity for domestic and other usages [27]. The current scenario on power and the environmental concern compels the legislator to legislate policies to favor the non-conventional one [28]. The obvious reasons of environment issue and the limited stock of fossil motivates to use more non-conventional sources [29].

C. PV Wind Hybrid Energy System

Hybrid energy is a combination which makes the renewable sources more reliant and dependable. There exist number of hybrid system depending upon the geographical conditions and energy requirement. In this study the hybrid combination of solar and wind as considered to full fill the energy requirement. India has lot many scopes to produce power in non-conventional way [30]. Many study claims that a significant portion of rural population is don't have access to electricity. There are many reasons under this head, the depleting level of reserve, the geographical constraint and other. Studies also suggest that such villages are having potential to full fill their own need by the application of renewable technologies. One single source may not full fill the requirement because of their characteristics but the combining operation can definitely meet the urgency [31]. The proposed scheme tries to produce a broad design to look for an ideal combined system among many inexhaustible power combinations for a rural cottage industry and residential load. Solar PV, wind and battery backup constituents the model. A unit load is actually taken for Leh region of Ladakh UT, India however no bodily verification is completed. The goal is finding the appropriate component sizes as well as optimum operation program for an integrated energy process.

D. Aim and Scope of the Work

Leh Ladakh has a different geographical feature. It is dominated by hilly terrain and small mountains all around. So the population are not evenly distributed but they are concentrated at some places. Owing to all these features, the electricity reach and the reliability of such supply are challenged. On the other hand the proposed site receives good amount of insolation through out the year. It can be proven that by the installation of SPV system in distributed mode can solve the issue to an higher extent. The proposed site also experience moderate to low wind speed, that might replace the use of battery. In the proposed scheme SPV and wind energy are hybridized and integrated with the battery to mitigate the intermittency nature. Introduction 6 The hybridized energy source will produce energy to meet the local load demand, the excess energy will charge the battery. During deficit o energy to meet the load by the hybridized system, the battery will discharge. Charge controller is employed to command the battery. The proposed scheme aims to electrify such a community by the application of SPV-wind energy system. The scheme also examines the feasibility of such model and the optimal size of component of model, so that cost competitive, continuous and high-quality power can be delivered through out the year. 1.3 Organization of the dissertation Chapter 1 gives introduction about the energy and types of energy and renewable energy. Also aim and scope of the work is given in the introduction chapter. In chapter 2 review of integrated solar PV-wind technology is presented. In chapter 3 methodology used is discussed. Chapter 4 describes integration solar PV-wind and battery system. Chapter 5 shows the performance analysis of the solar PV-wind hybrid system. In chapter 6 summary, discussion of the system as well as conclusion is presented.

II. REVIEW OF SOLAR PV-WIND HYBRID SYSTEM

A. PV Technology

Ali et.al (2010) discussed solar grid tied combined energy source to provide power to domestic requirements. The apparatus of the house will be run on the power produced by the combined system presented in the study. The study suggests a small size solar panel to provide electricity to the house. The study reviews the system details, the different parameters and tried to optimize the system, so that the small sized panel would generate enough energy to full fill the requirements [1].

Ma et.al (2015) investigated the best suitable combination of existing renewable sources to replace the generator which pollutes the environment in which community it is located. Specifically, the load centre is at a remote place. The accessibility to the place is not easy. The study involves software to generate the behaviour of the load. The result covers broad aspects of the model. The model studies the feasibility aspect of the project by integrating several renewable and one generator set [2].

Blum et.al (2013) made a comparison study revolving around the economic factor of renewable source and the mini hydro project already existing in the region. Combination of different sources are also considered. The scheme examines by what amount the pollution can be curtailed by approving the project based on renewable source. The author convinced that the solution is the PV power for the specific site. The micro hydro has the potential to create environmental hazard [3].

Nama et.al (2009) analyses the integrated solar wind with the combined scheme of grid and diesel generator. The study covers various aspects like the concern of grid tied generator, the monetary impact of renewable sources and the popular choice in this matter [4].

Ashok (2007) examines and suggest the major consideration for choosing a scheme looking to provide power for any rural community by the means of either any standalone system or integration of various available sources. The scheme focused on the cost of energy and an attempt was made to optimize the proposed model. The author suggests the model will definitely going to help while choosing the right choice of equipment in right quantity. The study suggests the combination of micro hydro with wind can serve the purpose for the study location [5].

Kindpal et.al (2010) investigates and present a study by comparing the available choices and made an attempt to distinctly present the differences arising thereof. The study involves the cost calculation for solar PV integrated micro grid with the available grid. The study suggest that the solar powered network is more economically viable for small village having considerable low load. The study discussed the difficulties present for the grid system there.

The study find that the sparsely available houses made it more difficult for any grid network to provide supply. The load in the discussion comprises some domestic load, few business establishment and other commonly available community purpose loads [6].

Domenech et.al (2014) generated a model to electrify a town in Alto Peru. The study considers the population and the demand arising thereof. Few more technologies are considered like, wind turbine, SPV, hydro on micro scale etc. the load under consideration are few domestic house load, a center of worship, an institution for providing education, few business establishment . The paper studies the natural location and what can it offer during power production[7].

Akikur et.al (2013) discussed about the method of power producing using PV as standalone and combining PV with other renewable sources. The load proposed in the scheme are mainly domestic in nature and intended to operate a mini grid to cater power to nearby homes. The paper considers various tests and suggested the combination of solar PV and other sources can serve the purpose, while made the decision specific site study has also done. The paper acknowledges few other cases where similar attempts were made to electrify there location [8].

B. Wind energy system

R. Sitharthan et. al (2018) discussed that the issue of climate change and global warming has compelled numerous nations to adopt renewable technologies. The wind energy alone serve around 30% of electricity that is produced using the renewable technologies. Wind has huge scope still few countries are inclined for it and considering this as a game changer. India is among the nations which are striving to tap the possible output from the wind potential. The author suggest that there are numerous activities associated will help to realize this goal [9].

P K Chaurasiya et.al (2019) found that India has tremendous scope for the generation of renewable sources in general, wind being the prominent and significant share holder. The paper suggest that the growing demand can be meet by enhancing the power generation from the wind turbine. The observation found that very year approximately over 1000 MW power is added to the existing power network generated by the windmill. India ranked 4th in the wind power production. The author suggest the method of power production using wind and put light on different stages of its growth in India. The paper narrates the issues related and the solutions of the concerns issue [10].

S. Sharma et.al (2019) reveals the power available in wind was used from ancient time to do various useful work, from irrigation to grinding and many more. The wind also usd to navigate the boats. The present time wind turbine is able to produce electricity which is the most usable form of energy. The paper highlighted the monetary benefit and policies made by Indian government to enhance the use of wind power. Observation has made on the schemes developed by the Government of India and the issues related are too discussed. The paper hailed the effort made by Government of India to enhance the use of wind power and various schemes of Government of India are brought under discussion [11].

Thomas Ackermann et.al (2000) discussed the various stages of development of wind energy. The paper analyses and presents the status of wind power operating globally. There share in standalone and grid integration is presented. The issues related to the development are discussed. Various related factors which affect the power generation from the wind finds elaborate discussion in the paper. The paper acknowledges the issues meet by similar projects in different locations [12].

Atul Sharma et. al (2012) states that India has a huge potential in terms of renewable energy. The power drives the economy and brings growth. The paper focuses in the contribution of India to the renewable sector, and finally praised the ability of wind energy not only to full fill the energy need rather it can also stop the menace of pollution [13].

2.3 Solar PV Wind Hybrid system

Pragya Nema et. al (2009) talked about the benefits and attributes of sun oriented and wind energy. The sun powered PV has more extensive extent of use instead of wind, on the grounds that the breeze tension at each area may not appropriate for wind energy creation. The cross breed model of both sun based and wind are extremely well known and discover wide application as a practical wellspring of energy. The possibility of such plan are demonstrated by its monetary practicality. Especially agricultural countries are to a great extent benefitted by such plan. The join activity totals more than one wellspring of energy alongside other controlling parts. Innovative progression decreases the cost of such advancements. Proceeded with exertion on R&D of sustainable sources will bring greater progression of framework parts and on forecast arrangement of energy creation. The creator concentrates on different arrangements of such frameworks including the capacity innovation to give dependable energy supply. The future extent of such innovation is talked about [14].

Sanjoy Kumar Nandi et. al (2010) inspects practicality of wind-PV-battery incorporated plan for a local area load in Bangladesh. The information utilized in the review were taken from meterological boundaries. Both breeze speed and sun oriented insolation were estimated in Chittagong. The review uncovers the breeze turbine can't work for not many day inferable from low tension of wind. The sun powered breeze cross breed model is inspected. The contamination level is determined and the variety of cost is seen with the variety in framework parts [15].

Ashok (2007) enhances the framework cost of the model created for a country local area and audits the framework design of such mixture conspire. The plan thinks about measuring and part for better execution. The review uncovers wind with small hydro can give the improved answer for electricity towns in Kerala, India [16].

III. METHODOLOGY USED IN THE STUDY

A. PV performance assessment

Documentation of this big power yield of a large photovoltaic (PV) phone system with a sizable time can be beneficial to quantify a capability promise, as being an analysis of this health of the method, for verification of a functionality version to then be put on to an alternative telephone system, or perhaps an assortment of various other uses. Even though the measurement in this overall performance metric might appear to be easy, there are actually a number of subtleties connected with variants inside liquid along with imperfect info collection which complicate the perseverance and details analysis. A overall performance assessment is most useful when it's concluded with a really small anxiety and when the subtleties are systematically dealt with, but presently no common format is present to guide this procedure [1].

B. IEC-61724 standard

This particular guideline suggests methods because of the keeping track of PV method attributes such as for instance in insolation, module power, storage space type in as well as paper & strength moisturizing hair product type in and paper; as well as for the exchange as well as evaluation of monitored details. The objective of the methods is actually assessing the general functionality of PV methods set up as stand-alone or maybe electric grid tied, or may be hybridised with non PV energy resources including car engine generators as well as wind powered generators [2].

C. Energy balance equation [3]

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:

Ein = EA + EBU + EFUN + EFSN	(3.1)
Euse = EL + ETUN + ETSN	(3.2)

where EFUN and ETUN are, respectively, the Net Energy FROM and To the Utility, and EFSN and ETSN are, respectively, the Net Energy FROM and To the Storage Unit, as defined in the IEC61724 Standard. EA, EBU, the net energy from Array generation and battery respectively and EL is the load in the syste

D. Electrical energy quantity [4]

Electric-powered power quantities can certainly be calculated for your telephone system as well as its parts like energy delivered to or maybe starting from a storage space unit or even utility grid connection, or sent as a result of an auxiliary generator. The crucial details appealing, which will signal the contribution of the PV array to the general functioning of this process are online power delivered to as well as from storage space, online energy delivered to & by means of the energy grid, the entire process input power, the total program result electricity, the PV energy too included.

E. System performance indices [4]

Photovoltaic systems in various configurations and at different locations can be helpful instead of evaluating their normalized overall system performance ratios, such as yields, profits, and losses. Yields are energy levels numbers normalized to positioned array power. System advantages are normalized to array region. Losses are the differences involving yields.

F. Wind Energy Assessment

From physics the theoretical relationship between the energy (per unit time) of wind that flows at speed v (m/s) through an intercepting area A (m2) is

$$_2\ PowPower = \frac{1}{2}\rho v^3$$

where ρ is the air density (kg/m3),

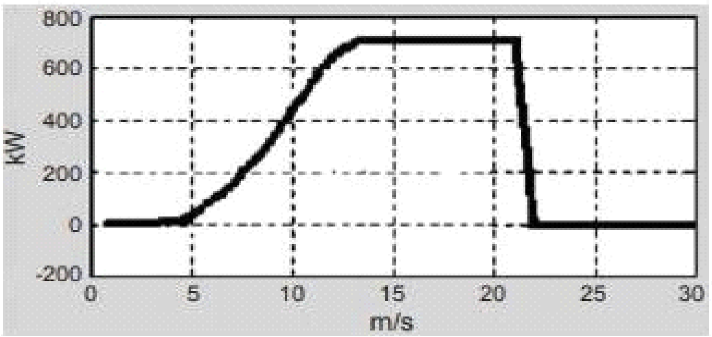

Figure 1: Power Curve

Figure 1 depicts the machine power curve, shows the wind energy output and velocity relations. The cut in and cut out speed can also be observed from the figure. Below the cut in speeds the wind mill siege to operate. The wind mill produces power when the wind velocity lies between the cut in and cut out speed.

G. Simulation methodology

Hybrid optimization model for electric renewable (HOMER) program [5], the renewable based simulation technology developed by the United States (US) national renewable energy laboratory (NREL) is used for the simulation in the study. The software is widely used in many nations for simulating the model to find out the feasibility and viability of the model before going for implementation. The software is capable of simulating various renewable and non-renewable source and the time step can be managed to get the simulation with an desired interval. The software reiterates the given combinations to find out the optimal one, the sensitivity analysis provides safeguard to the project. The software has number of striking advantages. The simulation provides many variation including the financial and other which makes the programming more attracting [6]

H. Modelling of solar geometry [7]

The rotation of earth on its axis is titled with a particular angle. The tiltation is somewhat at 23.5o. More over the solar position changed in the key throughout the year. To harness maximum energy, modelling of such scheme is necessary

Some of the important terms which has effect on the power production from the PV array are as follows

I. Clearness Index

It indicates the clearness of the sky. As the presence of cloud or dust particle deflect the beam radiation and

K. Azimuth

It describes the direction of panel face. The software assumes zero correspond to south, and positive value for west orientation.

L. Solar Declination

The solar declination depends upon the time of the year. It shows the latitude at which sun's ray will be perpendicular. The equation used is

decreases the energy harnessing capacity of the PV array. It has no dimension and values lies between 0 to 1. 1 represents clear and sunny sky, while near to zero represents the reverse value.

J. Maximum power point

At standard test condition, the PV panel efficiency is given by maximum power point. The equation is

$$\eta_{mp,STC} = \frac{Y_{PV}}{A_{PV} G_{T,STC}} \quad (3.4)$$

$$\delta = 23.45 \ \sin\left(\frac{}{365}\right) \quad \circ$$

360∘ 284 + n (3.5)

Maximum power point efficiency

where:

Table 1: n is the day of the year between 1 to 365 as shown in this table.

Where		
	$\eta_{mp,STC}$	Is the PV panel efficiency in STC in %
		is PV module power in STC in kW
	APV	is the area of PV module in m^2
	GT,STC	Is the insolation at STC in kW/m^2

PV de rating Factor

It denotes how the PV output reduces over the time. It also indicates the performance of PV array in the real working condition. The darting factors are deposition of dust on the modules, the losses due to shadow, ageing effect , the losses at junction. The operating temperature ground. Commonly it is known as albedo. The albedo varies with the type of ground. It is highest for the ground covered with the snow, followed by sand and least for the grass cover. The snow has ground reflectance of around 70%, the grass cover has reflectance of 20% and the sand cover produces an intermediate value.

M. Tracking System

As the name suggest it is an method by which the solar module are aligned in such a way that at any point of time, the sun's position will be perpendicular to the module. This can be achieved by the application of GPS with motor mechanism. Two types of such tracking system is available namely single axis and double axis. Different experiments has shown that the power out increases with the application of tracking system.

N. Modeling of PV power generation

The modeling of PV is done to calculate the number and size of PV modules. The number of modules depends upon various factors such as the load to be served, the rated voltage and current. The model employed [8,9] . Shockley diode equation is used to express relation between voltage and current of PV cell, expressed as

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

(3.6)

Iph is the photo current in A; I0 is the saturation current od diode in A; Rs is the series resistance and Rp is the parallel resistance in Ω; Vt= nKT/q is the thermal voltage of diode; n is the diode ideality factor; T is temperature in Kelvin; K is Boltzmann's constant and q is the charge: Np is the module connected in parallel and Ns denotes modules in series

The Power equation of PV array is expressed as

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

P=VI

(3.7)

The important parameters are calculated under STC. The parameters like Iph, I0, Vt, Rs & Rp are specified by the manufacturer. The process discussed in [10] like Iph STC, I0 STC, Vt STC, Rs STC & Rp STC can be calculated as

$$I_{ph} = I_{ph,STC}[1 + \alpha I_{sc}(T - T_{STC})] \frac{G}{G_{STC}}$$

(3.8)

$$I_o = I_{o,STC} \left(\frac{T}{T_{STC}}\right)^3 \exp\left(\frac{E_{g,STC}}{kT_{STC}} - \frac{E_g}{kT}\right)$$

(3.9)

also add as a derating factor as it also decreases the efficiency of panel when the modules are operated other than STC.

Ground Reflectance

It is one type of radiation that strikes the solar panel deflected by the

$$P_{PV} = Y_{PV} f_{PV} \left(\frac{\bar{G}_T}{}\right) \left[1 + \alpha_P \left(T_c - T_{c,STC}\right)\right]$$

$\bar{G}$T,STC (3.10)

$$V_t = V_{t,STC} \frac{T}{T_{STC}}$$

(3.11)

$$R_p = \frac{R_{p,STC}}{G/G_{STC}}$$

(3.12)

Rsh = Rsh,STC + 3 × Rsh,STCe−5.5⁄GSTC

(3.13)

$$T = T_m + \frac{G}{G_{STC}} \Delta T$$

(3.14)

G is the actual radiation incident of PV module; E_g is the band gap in eV; T_m is the temperature of back surface of the module which affects the overall performance of the module; DT denotes the difference in temperature between cell and back surface.

O. Modeling of Wind energy

Complete one year wind velocity average data collected and inserted is for simulation [10]. The HOMER calculates the value for each one hour. The total hourly simulation data are arranged in monthly variation pattern.

P. Tip speed ratio

It is basically the ration of Tip speed of blade to the wind speed. As the air passes through the rotor blade, it gets turbulence in wake. The next blade should arrive when the air turbulent is completely vanished to extract maximum power from the wind. The tip speed ratio adjusted the blades to not pass during turbulent air [11].

$$Tip\ speed\ ratio = \frac{Tip\ speed\ of\ blade}{wind\ speed}$$

(3.15)

Betz limit

This limit denotes the maximum possible efficiency that can be achieved by any wind turbine. It is denoted in percentage and its value is fixed at 59%. This limitation are generally produced for many causes which operate the wind mill.

Height of Tower For ease of calculation, and to make its economical the windmill is installed over the roof top (40 feet). So, the total height is around 30 meters.

Q. Modeling of load consumption

During the system modeling, it is assumed that the load demand is mainly provided by two sources, which are expressed as follows:

PL(t) = PPVL(t) + PT(t) (3.16)

Where PPVL(t)is the power directly delivered from the PV array; PT(t)is the power produced by wind-turbine set. When the net load is negative or zero, no supplementary energy is required and thus PPVL(t) is zero; When the net load exists, the pump-turbine set will be started and the value of PPVL(t)will be positive [14].
3.4 Economic Parameter [10]
Total net present cost
Among the various cost their value denotes the actual cost of the project in present time.
its value throughout the project life decreases.
The system cost can be given by the equation

$$C_{NPC} = \frac{C_{ann,tot}}{CRF_{(i,R_{proj})}}$$

(3.17)
where Cann,totis the total annual cost; iis the annual real interest rate (discount rate); Rproj represents the project lifetime; and CRF () is the capital recovery factor.
Capital recovery factor
The capital recovery factor is a ratio used to calculate the present value of an annuity (a series of equal annual cash flows). The equation for the capital recovery factor is:

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

(1 + i) − 1 (3.18)
Where ‘i’ is the interest charged annually and N shows the years.
O&M cost
This cost shows the value require for maintenance of the component during its operation.
it is generally taken a lump sum value for one year at a time. This cost is of vital importance while deciding the system reliability.

R. Operating cost

This cost is the running cost requires by the project to produce power continuously. This includes the cost of fuel and other consumables. This cost varies with the production of units. For on grid system the power sold and power purchased involves in the calculation of operating cost of the scheme.

S. Project life time

The lifetime represents the year up to which it is expected to perform with utmost efficiency. It gives the time duration to calculate the cost involvement and profit earned. At the end of use full life, the project terminates. Generally, the renewable based projects have project life of 25 years.

T. Salvage value

At the expiry of the project life the system has some potential to incur some finance. It is generally calculated as the cost of scrap or other older machineries when sold at the end of project life.

U. Renewable fraction

The fraction of energy that derived from renewable sources, as compared to the total energy delivered by the system. Its value varies between 0 to 1.1 denotes fully renewable project while approaching towards zero shows the renewable portion of energy share is less.

$$f_{ren} = \frac{E_{ren}}{E_{tot}}$$

(3.19)
Where Eren energy produced by renewable means and Etot denotes the aggregate energy produced by the project in kWh.

V. Levelized cost of energy

Software estimates the cost of energy at which the energy must be sold so that the system can sustain. The calculation involves the total unit of energy produced by the system and the total cost involved. It is expressed as following

$$COE = \frac{C_{ann,tot}}{E_{prim,AC} + E_{def}}$$

(3.20)
Where Cann,tot = total cost of energy in INR/kWh, Eprim,AC AC load in kWh/year and Edef= deferrable load served in kWh/year.

IV. MODELING OF PV-WIND HYBRID SYSTEM

Power drives the development and ensure financial boost. The fossil can be replaced by the green and clean renewable technology. All the energy are derived from sun, wind being the prominent one. Wind needs certain condition to flow, the major one being the difference in heat which generate the conducive condition for such flow. Wind energy no doubt a prominent source of energy, the places experiencing moderate to high wind pressure can generate ample amount of power by using such technologies. Moreover, the wind does not harm the environment neither disturbs the ecology which is the matter of concern. The wind power able to deliver clean energy and have the potential to grow in near future [1].
Probably the most crucial supplier of power for the planet is the sunshine. The whole of life depends upon the sun's energy. It's the kick off point for biological processes as well as the chemical on the planet of ours. At exactly the same time it's by far the most eco-friendly type of all energies, it may be utilized in ways that are many, and it's ideal for those cultural systems [2].
PV engineering is benign and elegant, with a selection of striking benefits over traditional techniques of electrical energy generation. Foremost and first, the share of solar in renewable sector is praised globally.
Solar PV board changes the solar irradiance in electrical energy. It's among the usually used inexhaustible sources of energy globally. It makes pure power, without moving part as well as no noise, which will make the gear strong, long and reliable lasting. Solar PV board energy output is dependent upon the solar intensity as well as the operating heat which the energy supply weather cantered. And so with no storage unit it's not feasible to harness the constant energy from PV array. The windmill is actually

effective at creating electricity from the flow of wind. The turbine generator set changes the energy contained in wind into helpful electric energy. The most frequently used power storage unit is battery. The hybrid system be made up of a PV board as well as wind mill with a suitably rated battery bank. As shown in

The proposed scheme contains major equipment's as source of power (SPV, Wind turbine and battery), a load for which the system is designed and suitable mechanism for control. The model is considered to be operated in stand-alone mode. The study is conceived with small community in Leh of Ladakh UT of India.

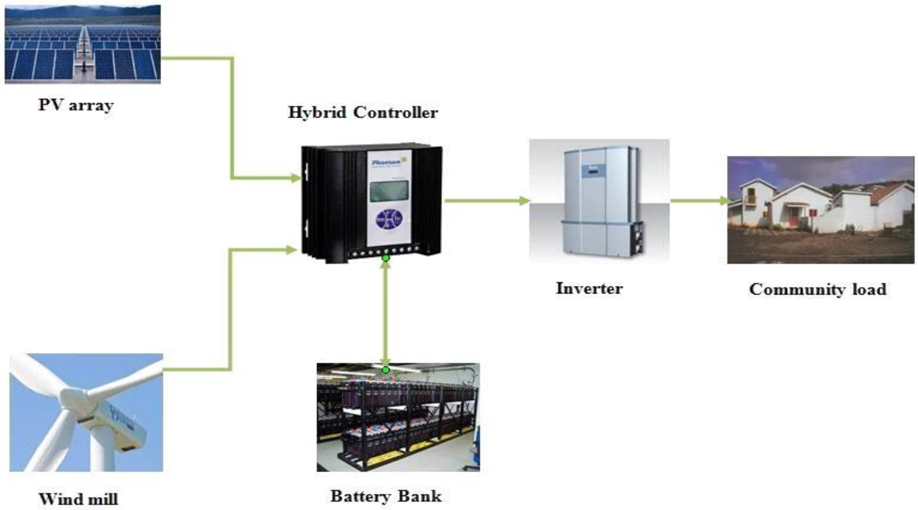

Figure 2: Description of the system

V. PERFORMANCE ANALYSIS OF THE PV-STANDALONE SYSTEM

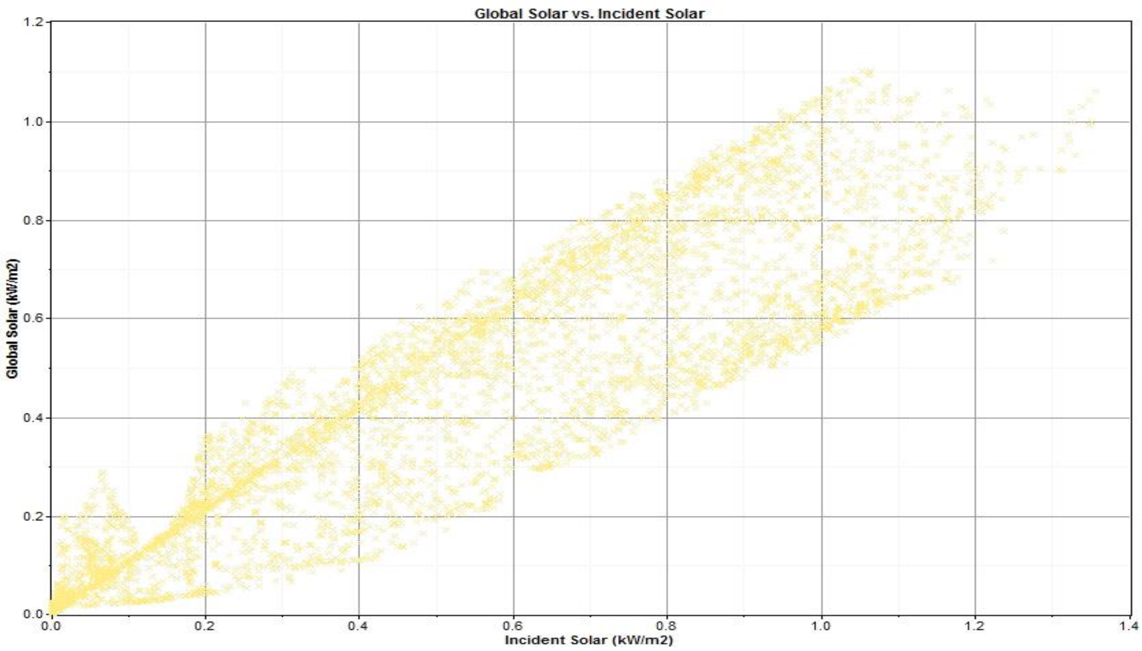

Figure 3: Solar Radiation and PV Output Power

The above figure 3 depicts the relation between the power output and the insolation level. It is observed that maximum output of 2.816 kWh occurs at an average radiation of at an average radiation of 0.333kW/m2 throughout the day.

A. Wind speed and wind Power

The relation of wind turbine output with pressure of wind is depicted in figure 2. The proposed site experiences moderate speed of wind throughout the year. The installed wind mill experience speed between 3 to 7 m/sec. The wind penetration at the proposed site is recorded as 3.76%. The installed capacity of wind mill is 1kW.

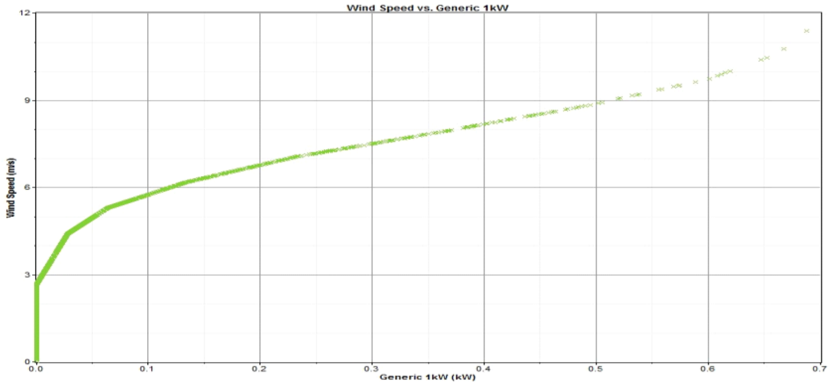

Figure 4: Wind speed and output power

Monthly power output from PV array

The monthly variation of output from the PV array is shown in the figure 4, the system suggest sufficient power is produced throughout the year from the PV and being highest in the month of September to December. So all through the year PV array can produced a reasonable amount of power. According to the climate condition the energy output is estimated as 7,654 kWh/yr.

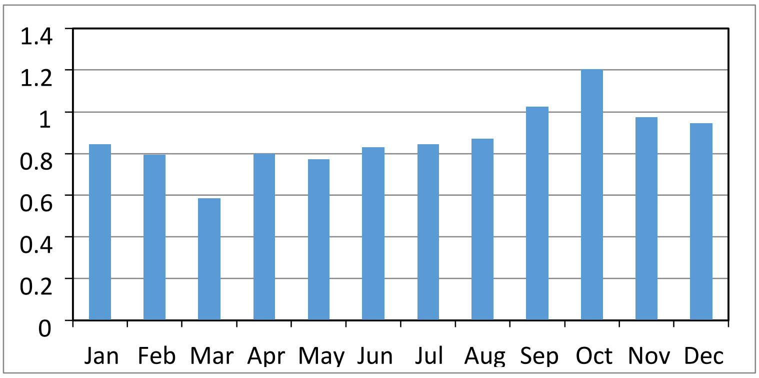

Figure 4: Monthly power output from PV array

B. Monthly Wind mill output power

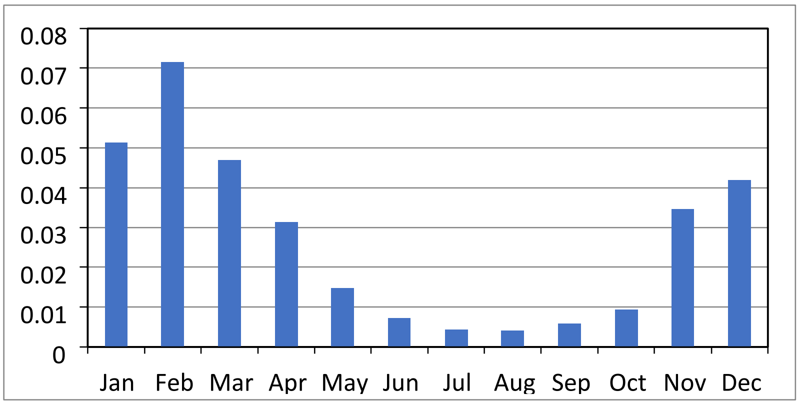

Figure 5: Wind mill power output

The proposed site is dominated by moderate speed. Generic1kW wind mill is included the scheme. The annual output is 233 kWh/yr. The output of wind mill and solar PV system are complementary in nature. During monsoon the power out from the solar declines rapidly due to the presence of cloud, but this deficit energy production from SPV can be managed by the increased energy production of the wind mill.

C. Battery Output

As per the system design the battery will act as a secondary source. It will absorb the excess energy during the operation of solar PV and wind mill.As shown in the figure 5. The stored energy will release to provide energy when the power output from the combined operation of the scheme not able to meet. The charge controller employed to command the battery unit. The total energy input and output from the battery is 4,823 kWh/yr. and

3,887kWh/yr. with losses of 903 kWh/yr. and depletion of battery storage is observed as 33 kWh/yr.

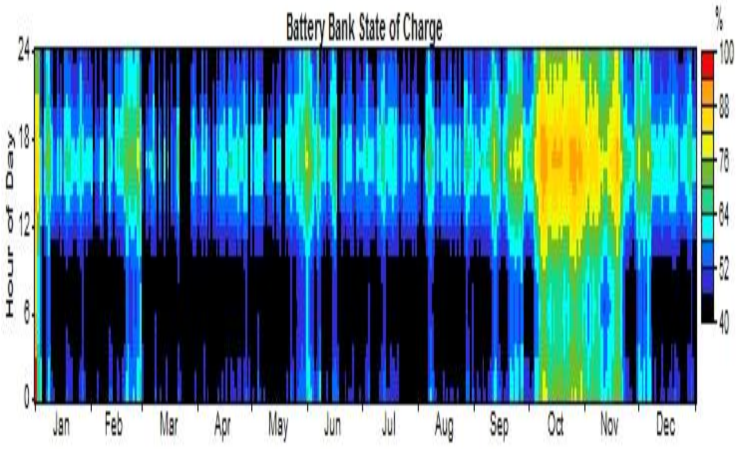

Figure 6: Battery state of charge

D. Battery SoC variation

In figure 6, October 4th to October 8th for the simulated year is chosen for observation of battery state of charge. The pattern of energy production as during sunny hour SPV produces power, the windmill operates when the wind pressure is in its operating range. Battery generally discharges from late evening to early morning if the wind mill is not providing enough power. The charging and discharging command are controlled by the charge controller. During excess energy production the battery charges and during deficit of energy requirement the battery discharges. The blue line shows Soc of battery. The monthly variation of SoC is given on the next figure 7.

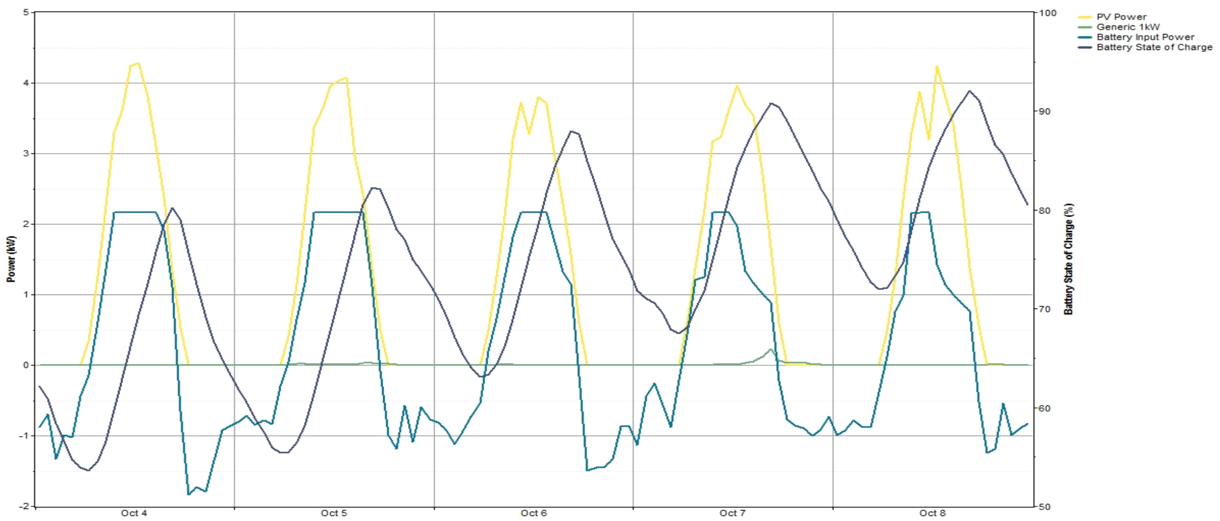

Figure 7: Battery state of charge monthly variation

Daily mean energy production and load demand The primary source of the proposed scheme involves SPV and wind mill. The system comprises 4 kWP of solar PV array and 1 kW of wind mill. The wind mill serves just 3% of load, while SPV serve for 97%. The source and load profile are producing feasible characteristics as maximum portion of the load can be served.

Daily mean energy production and load demand

Typical load curve smoothed by battery integration

It is observed that, the load on any power network that is connected to domestic and commercial consumers, changes in seconds. As the load changes the supply is also to be changed to maintain the power flow equilibrium. In the proposed scheme the power is produced by PV arrays, wind mill and back up is provided through series of battery. The power production from the PV arrays and wind mill are intermittent in nature because of it s dependency on weather. So to meet the change in load demand, the battery output must change accordingly.

It is also observed here that as the load changes the battery input and output varies to adjust the load demand. The system is equipped with charge controller which commands whether to charge or discharge the battery. This real time operation of charge controller in unison with battery bank smoothed the load curve.

Energy consumption of four typical days in a year

The electricity consumption on the proposed site is estimated as 17 kWh/day. The above figure represents example of load profile for four different seasons. 4th March represents a typical spring season average load which shown in blue line, similarly for summer 4th May average load represents summer season average load shown using grey line, 4th July represents monsoon season average load shown by green line and 4th January represents winter season average load represented in orange line. The peak load demand occurs during evening time throughout the year, as we considered domestic loads only.

Electricity consumption of four typical days in a year

E. Generation Mix

The below figures shows generation mix for different month. It is observed that through out the year the maximum portion of load are shared by the SPV as the region experience low wind speed. These properties makes such an combination feasible and enhances the reliability o as f the scheme.

Renewable penetration level

Novelty of the proposed scheme is the renewable penetration level achieved. In the proposed scheme the power is produced by using solar photo voltaic arrays, wind mill . The proposed scheme can achieve around 100% of renewable power production if we neglect the power used during the production of major components of the scheme and other accessories.

F. Hourly energy balance of the proposed system

The energy balance is depicted in the figure 8. The system is designed in such a fashion that during sunny hour the primary energy source are the solar PV, with wind mill which will be utilized to meet the load and the rest will be utilized to charge the battery units. To mitigate the intermittency nature of solar PV and windmill the battery bank charges and discharges continuously throughout the day. As the battery charges during high power generation the battery input is positive in reverse case the discharge is shown in negative origin.

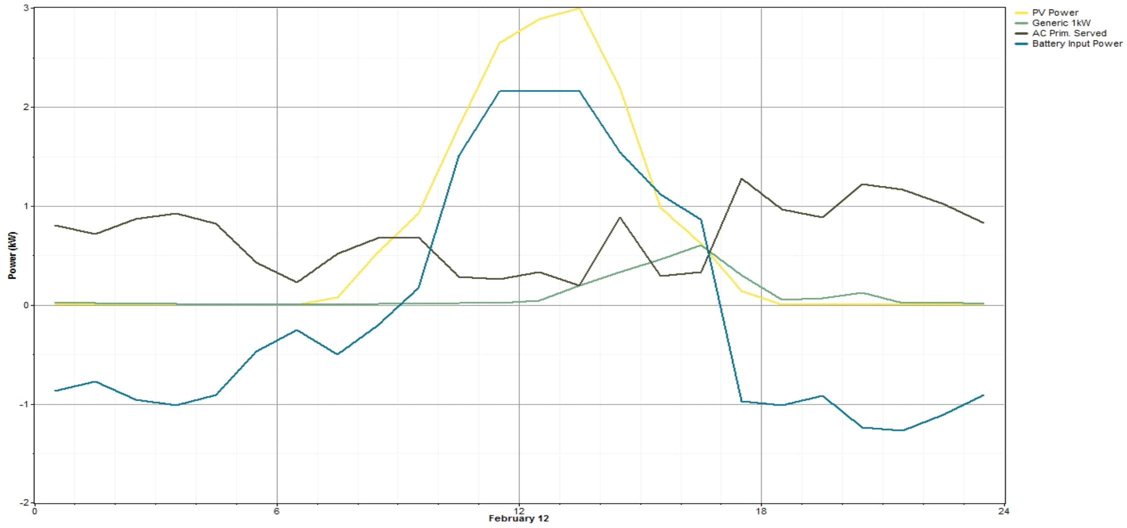

Figure 8: Hourly energy balance

G. Sensitivity Analysis

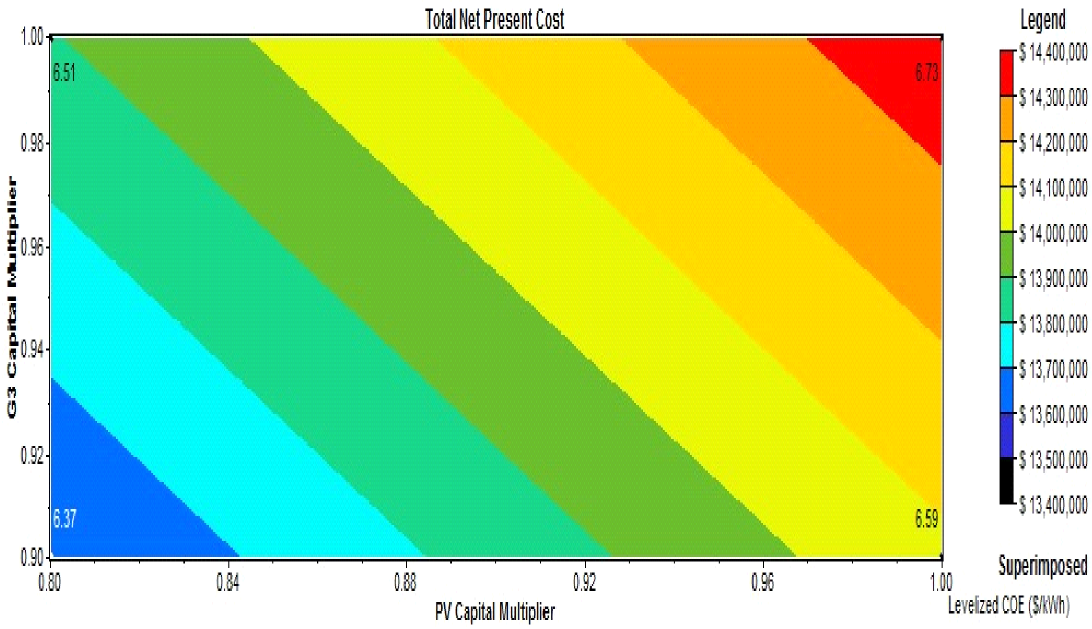

Figure 9: Surface plot of electricity charge

The sensitivity analysis provides safeguard to the project from the changing geo politics and the resulting un stability and fluctuation form the market. The system utilizes the trend to analyze the future cost of the project.
A 10% decline in capital cost PV, wind mill, battery and Converter has been considered. When merely the PV cost is reduced by the by 10%, the total COE and NPC are reduced by 5.03% each. The event where wind mill capital is slashed by 10% and its replacement cost slashed by 15%, the CoE and NPC decreased by 2.19% and 2.18 % respectively. When there is a 10% reduction in the converter cost and 15% reduction in converter replacement cost, the LCoE is decreased by 0.304%, and the NPC decreased by 0.303%. When capital cost and replacement cost of battery reduced by 10% and 15% respectively the LCoE reduced by 1.142% and NPC reduced by 1.147%. When there is simultaneous decline the LCoE and NPC reduced by 8.66% and 8.67% respectively. In all these supposition, operating cost found to be increased a bit with renewable fraction and capacity shortage of 1.00 and 0.13 respectively.

	PV (kW)	G1	S4KS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage
	4	1	8	2	$ 494,760	14,156	$ 675,721	9.540	1.00	0.13
	4	1	8	3	$ 501,540	14,836	$ 691,195	9.758	1.00	0.13
	5	1	6	2	$ 568,960	13,108	$ 736,523	10.587	1.00	0.15
	5	1	8	1	$ 572,980	13,476	$ 745,247	10.381	1.00	0.14
	5	1	6	3	$ 575,740	13,788	$ 751,997	10.810	1.00	0.15
	5	1	8	2	$ 579,760	14,156	$ 760,721	10.033	1.00	0.05
	5	1	8	3	$ 586,540	14,836	$ 776,195	10.236	1.00	0.05

Figure 10: Optimization result of PV-Wind Hybrid System

The first 4 column shows icon, next four column indicate number or size of each component, the next six column shows key simulation results, such as Initial capital cost of the system, Operating cost, Net present cost, Levelized cost of COE, Renewable fraction and Capacity shortage. The optimal configuration is the one having lowest NPC which comprises 4 kWP PV, 1 kW Wind mill 8 No. of S4KS2P battery bank and 2 kW converter. The initial capital cost is INR 4,94,760, operating cost INR 14,156/yr, total NPC INR 6,75,721. The COE is found to be 9.54/kWh and 100% renewable fraction.

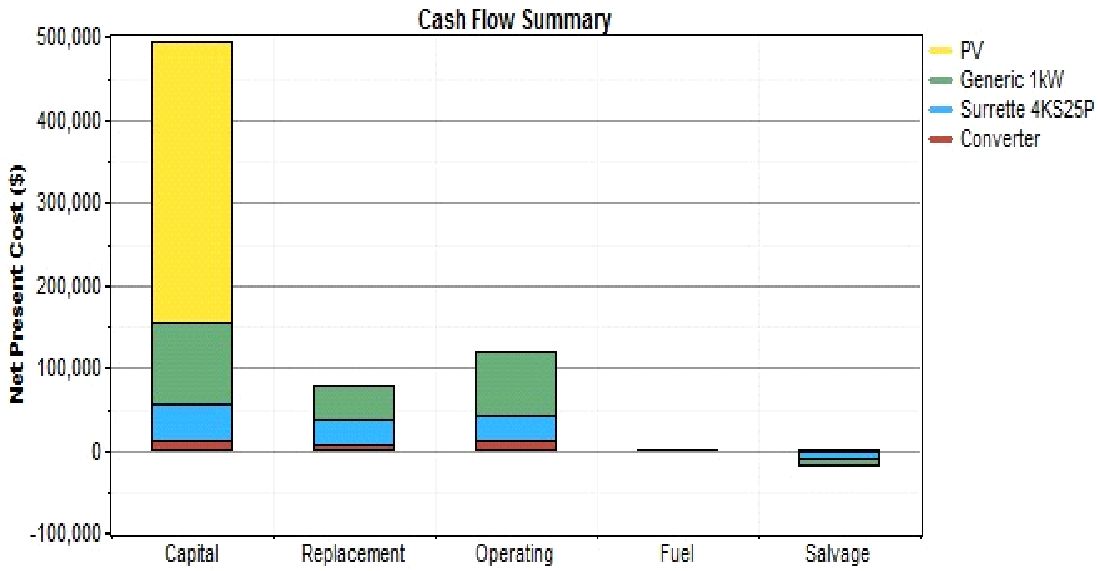

Figure 11: Cash flow outline of the project

The NPC table reveals Solar PV shares maximum cost followed by Generic 31kW. Minimum capital are shared by Battery bank and Converter. The solar PV shares 36.90% of total capital, followed by Generic 3 kW with 32.12%, PV with capital share of 16.69%. Battery and converter which shares least capital as 9.93% and 4.33% respectively. The below table 2 and 3 shows NPC summary of the most optimized model.

Table 2: Net Present Cost

Component	**Capital** (INR)	**Replacement** (INR)	**O&M** (INR)	**Fuel** (INR)	**Salvage** (INR)	**Total** (INR)
PV	340, 000	0	0	0	0	340’ 000
Generic 1kW	98,0 00	40,892	76,7 00	0	- 7,611	207, 981
Surrette 4KS25P	43,2 00	32,1 39	30,6 80	0	- 9,227	96,7 92
Converter	13,56 0	5,658	12,7 83	0	- 1,053	30,948
System	494, 760	78,689	120, 164	0	- 17,891	675,72 1

Table 3: Annualized cost

Component	**Capital** **(INR)**	**Replacement** **(INR)**	**O&M** **(INR)**	**Fuel** **(INR)**	**Salvage** **(INR)**	**Total** **(INR)**
PV	26,597	0	0	0	0	26,597
Generic 1 kW	7,666	3,199	6,000	0	-595	16,270
Surette 4KS25P	3,379	2,514	2,400	0	-722	7,572
Converter	1,061	443	1,000	0	-82	2,421
System	38,703	6,156	9,400	0	-1,400	52,859

VI. Conclusion

In this study Solar PV-Wind hybrid system is examined for a community load located in an Leh city of Ladakh UT of India. The results are promising for such scheme. The energy generation sources are complementary in nature. It concludes that with the integration of such system, the power output of the system will increase, the capacity shortage is 13 % which also increases reliability of the system, the levelized cost of energy is 9.540 INR/kWh, which might reduce in near future as the costs of such system are in declining trend. As both the sources are renewable, the scheme is eco-friendly and does not disturb the ecological balance of the proposed site.

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