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Priority Based Hybrid Renewable Energy Model for J&K

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Abstract: ***This paper presents energy requirements of J&K state of India with the present policies and future planning for the best utilization of the available resources. There will be acceleration in the future developmental graph in the country like India resulting in bulk of the energy demand. The procedures and methods applied currently adopted in renewable field aims for exploring possible energy production while considering the environmental impact. The hilly region such as J&K and Ladakh region has tremendous amount of renewable energy potential. The presentation of this paper aims the cost analysis of hybrid power system in the region. For optimization and sensitivity analysis, HOMER pro version 3.23.8 is used. The renewable resources for selected area are analyzed in Global Solar atlas (GSA) and Global wind atlas (GWA) and the result is compared with the meteorological tower data set. The modeling of the hybrid system is purposed on a 10% of load variability and as a result of the study, the levelized cost of energy (LCOE) from the hybrid system is obtained 0.0466 USD/kWh which will be 30 to 50 percent cheaper than the priceofelectricityfrom conventional system.***

Index Terms: Renewable Energy, Optimization, Hybrid Power System, Solar Energy, Wind Energy.

I. INTRODUCTION

Energy is an important factor for the economic growth and the levels of energy are the indications for the sustained developments of the state as well for the country [20]. For maintaining the economic growth, the growth in power sector is also essential. There has been multiplication in energy demand since a decade now due to the change in modernization, industrialization and the adopted life styles of the people. Mostly the energy demand is fulfilled in our country by the use of the conventional energy sources, but there is always a threat of the accumulation of greenhouse gases such as carbon and as such questions on energy security gets raised. There are many findings regarding several fold increase of the Green House Gas concentration from the report released from Fifth IPCC Assessment Report. The environmental degradation is likely to be more by the states in which there is more utilization of the conventional energy sources. There should be proper planning towards the decreasing the emission of the Green House Gases while fulfilling the demand of the energy services globally[1].

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To cater the purpose of national solar energy mission which is aimed to enable various civilization to acknowledge about the future climatic condition and so ready them effectively to a process of developing process and programs.

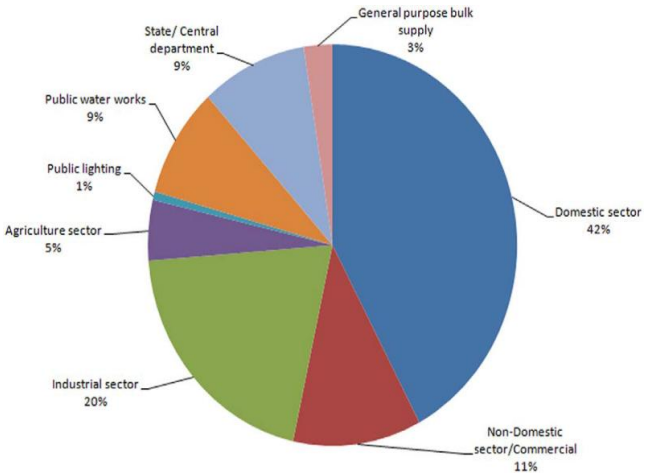

Fig. 1 Sector wise Energy Consumption

There is main agenda for state like Jammu & Kashmir to energize it through various hydel power projects. As such the study on the potential of solar and hydro are increasingly monitored [2]. In the remote and hilly areas like Ladakh, there is impossibility of feeding through Grid electricity due to its geography and households scattered all along the area.

There is already the issue of load variations, poor power evacuation facility, mismatch in load profile and high AT&C losses in the field of power sector already in the state. Climatic conditions are not as per the power utilization of the area. The requirement of the remote area energy can only be met with the identification and utilization of the renewable energy sources and can promote low carbon growth[3].

The hydro power plants, thermal power plants and the dg sets are the main sources of feeding the power in the state. 2,648.46 MW of total power generation capacity under central and State sector falls in the state of J&K. NEWNE grid and thermal power generation units and gas and diesel based power units are the most reliable sources for the state, as the power demand rises during the winter seasons and its own hydro power plant generation gets reduced.

Due to the high rate of AT&C losses and involving the power thefts, the power crises are faced by the state.

State owned power house generation is 2,562.723 million units out of total 17,323 million units of power demand.

The domestic sector consumes bulk of the energy in the state. There has been an increase of per capita energy consumption from 849.98 kWh in 2010-11 to 882.82 kWh in 2011-12 due to urbanization and modernization. There has been an increase of 2 to 6 % annual rate of energy demand gradually in last five years. The power demand is expectingto reach 19,500 million units during 2020-21 of the state as per the sixteenth All India Power Survey [5].

In mostly areas of the J&K fire wood and chips followed by LPG are primary sources in the rural areas. Cooking fuel demand in urban areas are is fulfilled through LPG. The lighting for Urban areas is fulfilled by the electricity and so is the case with the rural areas, but kerosene is also used as an alternative. It is difficult to provide the electricity at cheaper rates despite 97% villages are already electrified.

There is legacy of state owned electricity supply industries with tariff setting that leads to excessively cheap electricity for consumers lying in domestic premises. Non-technical losses are higher due to pilferages and failure of collecting bills, bulks of arrears or debt and poor commercial performance as a method of ability to collect revenues to accomplish costs [6]. So on commercial terms, as a result it is difficult for the sector to finance its investment needs on commercial terms and there is frequent equipment failure (e.g., as measured by transformer failures and low generation availability) often suffers from poor maintenance, and with power curtailments and frequent load shedding.

II. RENEWABLE ENERGY POTENTIAL IN THE REGION

It has been previously observed that the basic requirements of energy in Jammu and Kashmir state is fulfilled by the fossil fuels but the high prices in their markets make an atmosphere of insecurity in energy, so there must duly be a policy that will interface between the state and the center governmentso that non-conventional energy resources are mainly used to reduce the effect of Green Houses Gas (GHG). Over the recent years now the graph of the usage of renewable resources is growing in the state of Jammu and Kashmir with also reduction in emission of Green House Gases, not only this but in the acceptable economic cost the employment and the energy security is also grown. So there is utmost need of the usage of the renewable energy resources by improvement in policies, procedures and programs sothat there is increase in access of the energy.Just like the policies same as New Zealand, the role of renewable energy can be enhanced [7].

III. HYDRO POWER POTENTIAL

There has been over 20,000 MW potential of hydro power in the state of Jammu and Kashmir, out of which 16,000 MW has been identified. 2400 MW has been built already and 900 MW are under process so far [8].The Indus basin comprising of three western rivers, The Indus, The Jhelum and The Chenab and further three eastern rivers, The Sutlej, The Beas and The Ravi flows through both Pakistan and India. The signed treaty allows the rights of J&K to allow water storage on upper Chenab, The Jhelum and The Indus for hydroelectric purpose and further diversion within these basins. But the state government of Jammu and Kashmir has framed a policy to use small electric projects in turn to encourage the energy from these systems. So a goal of common development of the region is attained.

IV. SOLAR AND WIND: STATUS AND POTENTIAL

In the Solar sector, by introducing the Jawaharlal Nehru National Solar Mission (JN NSM), India has launched an ambitious plan in year 2009 to become main contributor as leader in solar energy. In order achieve such heights there is plan of installing increased number of grid-connected solar capacity at the end of year 2022. As such between 2010 and 2013 target of adding 1000 MW capacity. So by the end of 2022 the combined capacity increase would be 20,000MW. There is plenty of solar energy in Leh area of Jammu and Kashmir. Here falls about average annual solar radiation of 5.54 kWh m^{-2} day^{-1}. In the month of September, the maximum radiation is received. Fig 2 shows the average monthly variation of solar radiation in Leh. On a tilted surface, average solar radiation at tilting angleof35°isabout6.36kWhm^{-2} day^{-1}. For most of the part of year ambient temperature remains sub-zero in Leh. However, during January to February it reaches to a low of about -28°. The average hourly variation of temperature in Leh, Ladakh is shown in figure.

Ladakh, a very low populated place falls under the jurisdiction of mighty Himalaya region. Its population is estimated to be 289 Thousand (2.8 Lakhs) in 2020.By mid of year 2020 the projected population of Ladakh would be 289,023. There is 59,146 sq. km area of Ladakh, which is obviously greater than the area of state of Himachal Pradesh (55,673 sq. km) or the state of Punjab (50,362 sq. km). The main and famous district of Ladakh is Leh with a population of 133,487, which is roughly believed to be equal to the country like Saint Lucia. So out of a total of 640, it is ranked 609th in India. The population density of the district is 3 inhabitants per square kilometer (7.8/sq. mi).There has been the construction of 45 MW of a power project namely Nimoo-Bazgo. Further under a centrally sponsored scheme (RGGVY) Rajiv Gandhi Grameen Vidyutikaran Yojana, there has been 6 No's of 66/11 KV Substations coupled with 66KV, 11KV and LT network.So to this Hydel project, Leh and adjoining areas were connected. That are supplying power to this limited area but again in winter, the available power from the hydel project is not sufficient owing to harsh weather. As Ladakh is the northeastern region of the state of Jammu and Kashmir.The load is not too much as it is scattered over small regions and the small hybrid resources like Solar, wind, Hydro, Geothermal makes it a renewable energy (RE) based decentralized power generation area. Presently, Hydro and Solar plays an important role in rural electrification and power generation of the Ladakh region.

For about 60 of the total electricity generation, hydroelectricity from small hydroelectric plants accounts it (nearly installed capacity of 9 MW). About 25 average households in Ladakh, currently 7000 solar photovoltaic (UV) domestic lighting systems provide electricity to it.

TABLE: 1

Year	2019	2020	2021
Population (millions)	3.21	3.24	3.27
No of Households (Thousand)	102.3	106.7	110.9
Connection rate (%)	53.2	74.5	79.2
GrossElectricity Demand(GWH)	482.6	574.9	618.5
Net Electricity Demand (GWH)	301.2	432.3	542.6
Peak Demand (MW)	64.1	93.3	101.7

V. METHODOLOGY

The methodology for this work is firstly data collection from different areas,overview the power sector and renewable energy sources and data qualification and analysis and other data validation, the suitable site selection criteria will be developed. For introducing of criteria,the hybrid solar and wind energy site selection in the world is reviewed,location criteria and solar power plant location criteria are selected according to J&K land area conditions.

Methodology of hybrid power system has beengiven in Figure above.GIS and Homer software has been used in the work. GIS is the only useful tool to analyze geospatial data and apply the MCDA system for favorite site selection.The GIS model and criteria applicationshave also been explained in detail. The output of the GIS model after the criteria application is the implementation area for the wind farm and solar plant installation. In GIS it is possible to manage the result data according to the resource category or administration boundaries.In the study,J&K renewable energy resources are reviewed andanalyzed and the power sector has been studied thoroughly. The solar and wind energy-producing northern states like Himachal Pradesh and Punjab's information have been reviewed to develop and define appropriate criteria for suitable site selection in J&K. To measure the wind for 12 months, the initial data were collected from the ACEP survey which was funded by USAID back in 2012. The data were collected from six selected sites using NREL's modeled wind resource map and global solar horizontal irradiation was also measured. For data validation, the meteorological tower data of the selected sites by ACEP were compared with GSA and GWA data. The GSA is provided by the World Bank Group and funded by the ESMAP and through the GSA portal a summary of solar potential and solar resources are provided globally whereas,

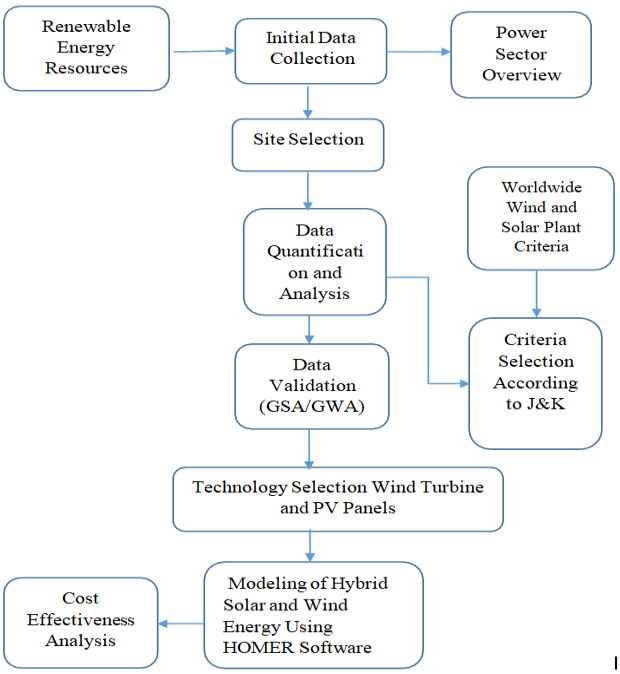

Fig. 2 Methodology of Hybrid Power System

the GWA provides the potential wind resources information. Following the data validation process, in this study, it was tried to select economic and reliable technology for solar panels and wind turbines for better functioning and power generations. The more cost-effective renewable technologies are the cheaper the power production would get and subsequently would encourage a higher shift towards utilizing renewable energy projects and ultimately reduce global warming caused by fossil and thermal energy productions in the country. The HOMER software is used for the design of on-grid, off- grid, and hybrid power systems for remote, stand-alone, and distributed generation applications. Nowadays, Advanced software like HOMER is used for design and implementation of the remote, stand-alone, on-grid, off-grid and various applications of distributed generation. This very software has been developed in United States through one of the laboratory known as National Renewable Energy Laboratory. Both conventional and nonconventional technologies are considered here in it. Being a simulation model, all possible combinations of the equipment will go to simulate a feasible system as considered. Many factors like annual interest rate, project lifetime, economic factors of the projects annual interest rate, systems capital cost, replacement cost, Levelized cost of energy(LCOE), operation and maintenance cost(O&M) are defined in this advanced software HOMER. It does simulation, sensitivity analysis as well as optization.

VI. SITE SELECTION

Siteselectioncriteriaarecrucialforanykindof Energygeneration andinstallation.Applicable environment, technical and economic factors are considered for site selection for getting the bestresultofgeneration.

Therearesomeconstraintsforinstallationforbothwindturbines andsolarPVpanelslikelocationswithlowersolarirradianceorle sswindspeedthesearethemainconstraintsthatsuchinstallation wouldnotbeprofitableandbeneficial.Thepurposeof this study is the modeling of the hybrid system so we have to select the best and suitable area where the installation of both wind turbines and PV panels isapplicable. For an investment with a wind resources assessment, a constantly high wind speed brings the best in return, so the amount of energy wind turbine can producecan be possibly estimated. So the calculation of mean annual power available per square meter of the swept area of a turbine is Wind power density. Further it is obvious that Variation of it withdifferentheightofabovethegroundand effect of air density and wind speed are included in the calculation of power density. Using measured air temperatures, and calculated average wind shear coefficients, the wind power densityat 10m, 50m, and 100 m turbine hub heights are calculated for Leh according to NREL cast 50m is good falls under 4 class and considered excellent. The wind frequency rose shows how the wind speed direction is typically distributed at a particular location, and they affect the production of energy and structural performance of wind turbines.Wind blows from two sides east and west. Generally, the wind speed is higher at night time compared to, adayateachmonth,increasesfrom6:00pmto6:00 am.

TABLE II

Specifications	Location		
Height	10m	50m	100m
Wind Speed [m/s]	4.91	7	7.69
Power Density [W/m^2]	200	450	550

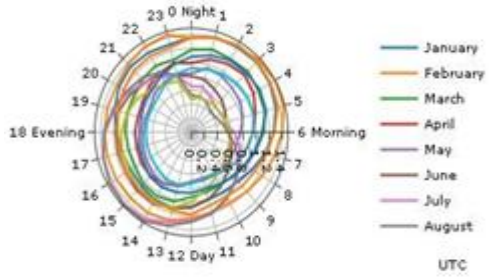

Fig. 4 Wind Frequency at, Leh

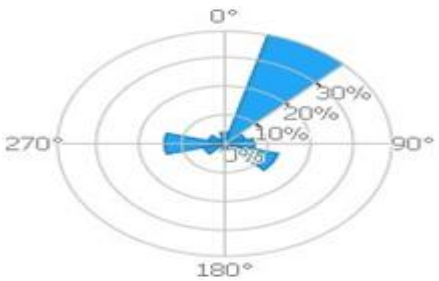

Fig. 3 Wind Speed Variability Hourly vs monthly at, Leh-Ladakh

VII. ECONOMIC MODELING OF THE HYBRID SYSTEM

For economic modeling, the cost of the energy, NPC, and annualized cost of the system (ACS)isindispensable.Inthisstudythecostofthesolarpanelisest imated at approximately 1340 USD/kWp with 20 years of warranty, 67% of the total cost is estimated for the replacement cost for O&M 10 USD/kWp is calculated. 214USD/kW is estimated for a converter for replacement and O&M costs 199.02$/kW and 2.57$ iscalculated respectively. A wind turbine is estimated at 251759USD/100kW 75% of the total cost is estimated as replacement cost and 2% is estimated O&M cost. The wind turbine's cost includes the installation, transport, and the manufacturing cost, the discount rate is considered 8%, and the inflation rate is considered2%.

TABLE: III

PV Parameters	**Value**
Manufacturer	Suntech
Maximum Power at STC (Pmax)	370
Optimum Operating Voltage (Vmp)	26.4 V DC
Dimension	1482 × 992 × 35mm
Derating Factor	90%
Open Circuit Voltage	>40
Short Circuit Current	7.95 A
Warranty	25 years
Wind Turbine Parameters	**Value**
Manufacturer	Kingspan Renewables Ltd.
Rated Power	5.2kW
Peak	6.1kW
Survival Wind Speed	80m/s
Cut out speed	5.9m/s
Cut in speed	3.5m/s
Lifetime	25years

For calculating COE, the annualized cost of producing electricity i.e. (the total annualized cost minus the cost of serving the thermal load) by the electric load served is divided by this HOMER software. The NPC of a system is defined as the present value of all costs included by the system in its total life time and the subtraction of the present value of all the earned revenues over it. The costs included are fuel costs, replacement costs, capital costs, O&M costs, the costs of buying power from Grid and the emission penalties. Grid salesrevenue and salvage value are included in revenues.In each year of the project lifetime, HOMER calculates the total NPC by summing the total discounted cash. HOMER's main economic output is the total NPC. It is the value in all system configurations by which it ranks in the optimization results and calculates the total annualized cost and the LCOE on this basis.

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

VIII. RESULTS

To get satisfied power quality mechanism, Grid-connected inverters were not so efficient traditionally. Due to their limitations, conventionally used inverters cannot provide smart mechanism and economical for PV generation. It needs large number of PV panels for its functioning as far as ordinary system is concerned. While within a narrow range, priority based hybrid system can operate fully. Thus limitations and issues are taken in consideration in modified and smart mechanism, and by reducing the number of PV panels and expanding the operation range, besides injecting active power, it provides quite smart and efficient mechanism. To maximize the output usable power, Priority based hybrid system also compensates the reactive, unbalanced and harmonic power.So practically to prove the problem definition, there is importance of results for development and research. Hybridsolarphotovoltaic(PV)andwindenergysystemsareanef fectivesolutioninparticular for standalone and grid-connected applications. Integrating the two sources of energy can provide better reliability. The drawback of all renewable energies is their intermittency and hybridization of renewable energies reduce this drawback since the weakness of one system can be complemented by the strength of anotherone. The solar system like On-grid solar system has also many names such as grid-tied system, grid back feeding, grid intertie and utility-interactive system. Homeowners can send the surplus energy to utility grid and thus save more money by using net metering instead, and also utility grid acts as a virtual battery by storing the energy in batteries.

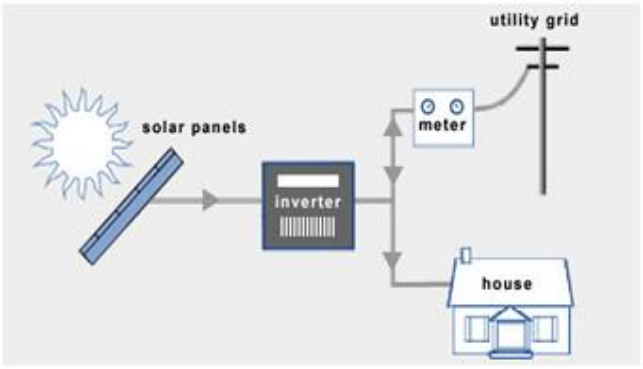

Fig.5 On Grid system

As such the overall efficiency of the off-grid gets decreased as it needs battery bank and generator for backup making it too expensive.If we see from the figure that the overall system is comprising of the equipment's like inverter, generator, solar charge controllers and battery storages.

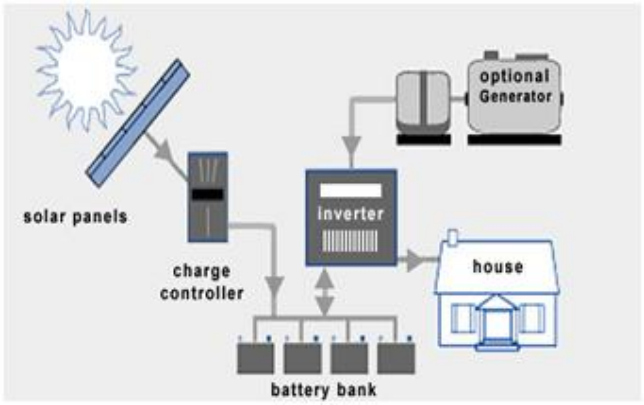

Fig.6 Off Grid system

A Hybrid system model is comprised of both the type of grids, i.e. on-grid and off-grid and took the advantage of this combination. As it requires less equipment's, so it is much cheaper than off-grid systems. There is no effect of faults and power failures in off-grid system. Mostly the utility grid system equipment's are, Battery bank, Charge Controller, Power meter and Battery based grid-tie inverter.

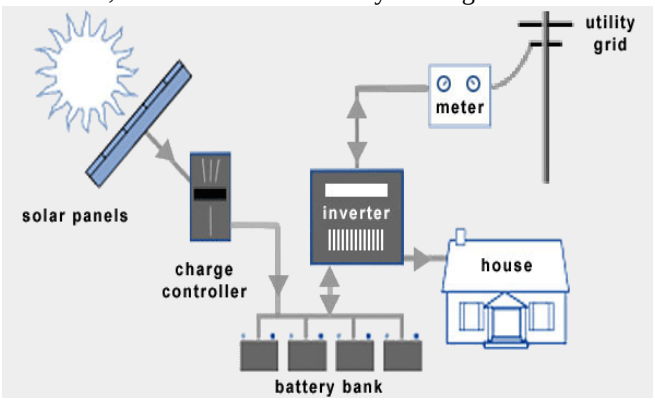

Fig.4.3 Hybrid Grid system

The system is designed for the peak load of 1800 kW for Leh Ladakh, as total load demand is 13112 kWh/d in Leh. HOMER Pro, an advanced software designs the on-grid of RE system, so as to meet the on load demand of particular selected areas.Windspeedand solar irradiance are sensitivity variables considered.For solar PV, search space is ranged from 0 to 2500 kW, for wind turbines ranged from 0 to 10 turbines 100kW and for converter 0 to 2500kW is considered as variables. The analysis performed for four different configurations: Grid alone, PV/Grid, Wind/Grid, PV/Wind/Grid are shown in figure above for location of Leh and Kargil in Ladakh region. For said location the figure above shows the minimum and economically feasible generation of electricity costby PV-Wind-Grid model hybrid system.

TABLE: IV

Model Name	NPC (USD)	COE (USD/kWh)	Operating cost (USD)	Initial Cost (USD)
PV-Grid	6.23 M	0.04	235, 640	2.01M

Wind-Grid	6.12 M	0.07	376, 761	3.76M
PV-WindGrid	6.18 M	0.09	109, 321	5.98M
Grid	6.45 M	0.03	179, 133	1.89M

The NPC is USD 6.45M and the COEis 0.03 USD/kWh. In all different cases that have been studied, the cost of the hybrid system remains optimal, the COE and NPC remain lower than the grid alone. remains below theCOE fromthegridonlyandtheoperatingcostofthesystemalsoremain slessthanotherconsidered configurationforthehybridsystem.It has been cleared that the hybrid system for the location NPC, the cost of energy, and other economic parameters are feasible and economical. PV-Grid would be feasiblewhen the wind speed is decreased but for completing the weakness of each other the integration of both systems is purposed, and the significance of hybrid system is the high GHIinsummerandhighwindspeedinwinterthatmakesthesyste mbetter.AtallthePV-grid and wind-grid would be 10 to 20 percent costly compare to the hybrid solar and wind energy on-grid. The COE for PV-wind-grid would be 10 to 30 percent cheaper compared to the grid alone and other analyzedmodels.

TABLE: V

Site	GHI [kWh/m²/day]	Wind speed (m/s)	Hub Height (m)	NPC USD	COE kWh/USD
Leh, ladakh	3.12	6.01	40	6.11M	0.0241
Kargil, Ladakh	4.44	4.32	30	9.04M	0.0078

The main purpose of the sensitivity analysis is to find the economical and feasible model, different values are considered in this study, In Leh when the GHI is 3.12 [kWh/m²/day] at 6.01 m/s wind speed, the COE is 0.0241 USD/kWh in 40m height of hub, the NPC cost increases and the feasibility of the system also come down as the generation decreases. At Kargil, there is high GHI and wind speed in each month the feasibility of the system is much higher when the GHI 4 [kWh/m²/day] and 4.32 m/s wind speed at 30.00 m hub height the COE comes 0.0078 USD/kWh, and the most economical parameter in Leh is with 4.44 [kWh/m²/day] GHI 4.32 m/s wind speed at hub height 0f 30m the COE is 0.0078 USD/kWh and the NPC is also much lower than models. As location for Leh has good potential for wind and solar energies, it will become a boosting area for the renewable energy generations as compared to the other location like Kargil.

IX. CONCLUSION

As we know that globally energy demand is growing day by day. On one hand energy consumption is very high as compared to the energy generation. The supplied energy does not meet the requirement so nonconventional energy system is a good alternate option. One of the good practice is to use nonconventional resources along with renewable energy sources that will increase the reliability of the system as well as it will allow higher power demands to be fed. Prioritizing the various available sources makes the selection and utilization economic. The priorities may be decided according to the availability of source, usage cost, its effects on the operation of other equipment (noise due to generators, smokes etc.). The project involves four different sources with different parameters to allow microcontroller to judge the selection of best available source to use. For economic comparison and finding the cost-effectiveness of the HREs configuration, the key performance factors like NPC, COE, and several sensitivity analyses such as GHI, Wind speed, and Hub height have been studied.

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