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Cost Analysis of Proposed Photovoltaic based Power system model using HOMER software

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Abstract— *In recent power crises, more than two billion people lacking access to electricity due to gap of electrification around the world. So a additional power source whose power efficiency is high is in great demand. Solar energy is the one of the clean energy source available in abundance, having least operating cost. In this paper the data of Saharanpur city (UP) is taken for the analysis because people facing shortage of electricity and to compensate the problem a proposal is made which provide the best solution to load shedding and improve living standard of people. The aim of the work is to replace the existing power system model having inverter, battery and generator with the proposed power system model. In the proposed model, the generator is replaced by photovoltaic system. HOMER (Hybrid optimization model of Electrical Renewables) software is used for the simulation of existing & proposed power system model. HOMER software optimize the cost analysis and results shows 18% savings due to proposed model and 21% amount of reduction in carbon contents to the atmosphere.*
Keywords—HOMER, photovoltaic, carbon emmision, inverter

I. INTRODUCTION

Energy is the best gift of nature to us, as it exists in different forms and as boon to the mankind. For a continuous development of any country, energy is the basic demand. To meet increase in the energy demand, consumption of fossil fuel is increases day by day. The reserves of fossil fuel are going to be exhausted in coming few years. Also, emission of various pollutants gases in the environment are another major issue. The other conventional resource like nuclear fuels is costly and wide precautions has to be maintained in its safe utilization.

Global environmental concerns and the ever increasing need for energy, coupled with a steady progress in renewable energy technologies are opening up new opportunity for utilization of renewable energy resource. Energy conservation and renewable sources of energy are the two options for sustainable energy supply. A hybrid energy system, provide more system efficiency and greater balance in energy supply. Battery storage and inverter hybrid solar-wind generation can provide continuous power supply throughout the day in many remote areas.

Most of the energy, which includes fossil fuels like oil, natural gas and coal, is derived directly or indirectly from the sun. So converting solar energy directly into electrical energy by using PV installations is the most recognized way to use solar energy. The photovoltaic effect has been discovered in first half of the 19^{th} century. In 1839, a young and French physicist Alexander Edmond Becquerel observed a physical phenomenon or effect that allows the conversion of light into electricity. The solar cell's work is based on principle of photovoltaic effect. In recent years, many scientists through their research have contributed to the development of this effect & technologies. Photovoltaic cells produced are mainly made of crystalline silicon asset conductor material. The Sun is the only resource that is required for the operation of PV systems and its energy is almost inexhaustible. The efficiency of PV cell is 15 % which means it can convert $1/6^{th}$ of solar energy into electricity & also it has no moving part, noise and pollutants emitted to the atmosphere.

II. PHOTOVOLTAIC SYSTEMS

A. Network-connected photovoltaic systems (on-grid)

Photovoltaic modules convert solar energy into DC current, while photovoltaic inverter adjusts the produced energy in a form which can be submitted to the public grid. The AC voltage is supplied to the electricity network through the protection and measuring equipment The meter is installed at the point of connection, a Single phase, two-tariff, electronic system for single-phase, and a three phase, two tariff, electronic system for two-phase and three phase systems. In such installations it is regularly proposed to setting up a fuse in front of and behind the counters in order to permit replacement of the meter at a no-load condition. The exact conditions of connection are synchronized with the local distributor of electric energy. Power OFF buttons must be provided both on the side of photovoltaic modules as well as on the side of network connection. The output voltage of the inverter must be in accordance with the Regulation on standardized voltages for low voltage electricity distribution network and electrical equipment. Standard sizes of the nominal voltage is 230V, up to 400V between phase and neutral conductor, between phase conductors, the quad-phase network nominal frequency of 50 Hz, and, under normal conditions, it should not differ from the nominal value by more than ± 10%.

B. Network-connected home systems (possibility for own consumption)

These are the most popular types of solar photovoltaic systems that are suitable for home and commercial installations in developed and urban areas. Connection to the local electricity network allows selling to the local distributor of electric energy any excess of electricity generated and not used in the household consumption, because the PV system is connected to the network via a home installation in parallel operation with the distribution system. Also the home is supplied with electricity from the grid when there is no sunny weather.

C. Standalone systems (off-grid) or isolated systems

These systems are used in rural areas where there is no electricity network and infrastructure. The systems are connected to a reservoir of energy (battery) by a control over the filling and Empty. The inverter can also be used to provide alternating current for standard electrical equipment and appliances. Typical stand alone photovoltaic installations are used to ensure the availability of electricity in remote areas

III. Literature Review

F. Jiang et al. [6] The solar energy has been accepted worldwide as a high potential alternative energy. Current research and markets have shown that solar photovoltaic is amongst the fastest growing and most promising forms of renewable energy for electricity generation. Solar energy demand has grows at about 25% per annum over the past 15 year while solar energy (PV) prices have decline on average 4% per annum over the past 15 year. Author presented the study on the feasibility of solar energy in Singapore. Analysis on the 8.99 KW solar systems has been performed to find the efficiency of different types of PV module and performer of grid connected solar system. The solar system consists of three types of solar PV system, i.e.2.7 KW mono crystalline silicon, 3.06 KW poly-crystalline silicon and 3.12 KW thin film silicon solar PV and the impact on the radiation on PV system. The conventional efficiency of mono crystalline PV system reaches 8.12%, polycrystalline PV system 7.45% and thin film PV system 6.75%.

H.J.liu et al. [16] The effect of power quality during the grid connected process, the power flow in the micro-grid is analyzed based on the characteristics of the frequency and active power, and the time when the difference value of the voltage between main grid and micro-grid become zero is chosen as the best chance to connect. By the simulation tool Matlab/Simulink, different grid connected processes are simulated and compared. The frequency and active power fluctuation are analyzed. The Author indicate that the control method is effective in dominating the micro-grid during connect and has a great effect on the power quality in the micro-grid.

Bindu U Kansara et al. [12] Modeling and Simulation to design a micro grid of Distributed Generation System Using HOMER Software is done. A micro grid is an integrated form of distributed energy resources (DERs) which are connected together to serve electrical power to the selected consumers or can exchange power with the existing utility grid under stand alone or grid connected mode. Distributed generators can provide high reliability by providing on site generation. As a result of this many hybrid systems came in existence like PV cells, fuel cells, micro turbines, wind, diesel and small hydro systems. The distributed generation system having Photo Voltaic (PV), wind turbine and diesel generator is simulated and analyzed. This paper gives simulation results of PV-Wind-Diesel hybrid system. HOMER (Hybrid Optimization Models for Energy Resources) power optimization software by NREL (National Renewable Energy Laboratory) is used to simulate and analyze the PV-Wind-Diesel hybrid system.

Kavita Sharma et al. [17] This paper describes a new and evolving Electrical Power Generation System by integrating simultaneously phtovoltaic Solar Energy, solar energy with Nano-antenna, Wind Energy and non-conventional energy sources. It is possible to have an uninterrupted power supply irrespective of the natural condition without any sort of environment pollution. This process yields the least production cost for electricity generation reveals a new step. The set-up consists of combination of photo- voltaic solar-cell array and Nano-antenna array, a mast mounted wind generator, lead-acid storage batteries, an inverter unit to convert DC power to AC power, electrical lighting loads and electrical heating loads, several fuse and junction boxes and associated wiring, and test instrument for measuring voltage, currents, power factors, and harmonic contamination data throughout the system. This hybrid solar-wind power generating system will extensively use in the Industries and also in external use like home appliance.

IV. PROBLEM FORMULATION & OBJECTIVE

India is blessed with an abundance of non-depleting and environmentally friendly renewable resources, such as solar, wind, biomass, hydro and cogeneration & geothermal. Greenpeace International European energy report 2012 says that 69% energy comes from renewable energy sources in 2050. India having 152,000 MW renewable energy potential, but 35,776.96 MW installed and solar having 50,000 MW potential and only 3743.97 MW installed till now. It is observed that there is a huge difference between solar energy potential & installation. By installing more solar power plants in India, it is possible to decrease the carbon emissions in huge quantity. The main objective of the research work is to study the solar energy potential and to replace the existing power system with the new power system model which includes PV cells, Inverter and Battery in place of Inverter & Battery. The cost comparison of existing & power system model including emission of carbon content is also done in the work.

HOMER Software is used in the proposed work to optimize the cost analysis. HOMER is designed to analyze the configuration of renewable power systems and it can simulate grid connected and off-grid micro grid systems. HOMER compares different designs based on technical and economic characteristics in research of the optimal solutions.

V. METHODOLOGY

In this research paper, a proposal is made for the small area in Saharanpur city in UP state in which the existing power system is replaced with the PV panels. The cost analysis is done in dollars and 1 dollar is equal to Rs 62. The city has total 80 nos. of consumers with maximum peak demand of 125 KW and minimum load flow of 60.8 KW. The total average load in KW is 74.3. To model a system containing PV array, the solar resource data for the location has been collected from the National Metrological department is shown in the figure-1. Solar resource data indicate the amount of global solar radiation (beam radiation coming directly from the sun, plus diffuse radiation coming from all parts of the sky) that strikes Earth’s surface in a typical year. The clearness index is the ratio of the solar radiation striking Earth’s surface to the solar radiation striking the top of the atmosphere. A number between zero and one, the clearness index is a measure of the clearness of the atmosphere.

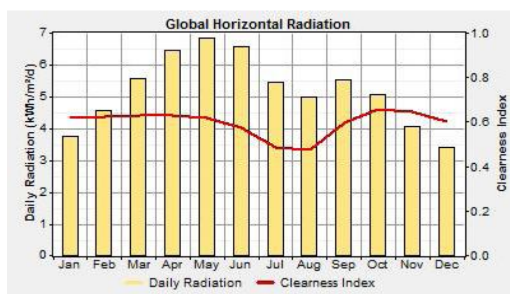

Fig-1 Clearness index graph

Figure-2 shows the existing power system in the Saharanpur city contains Inverter, Battery and Generator which are used

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when the electric supply interrupts. When the grid supply is continuous, Converter (Rectifier) changes the alternating current (AC) into the direct current (DC) and store in the battery. Now if the grid supply is interrupted then the Converter (Inverter) changes the Direct current (DC) in to the Alternating current (AC). Generator is used when the battery fully discharge.

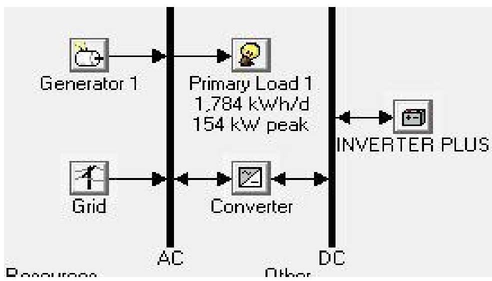

Fig-2 Existing power system model

The proposed power system model in which a photovoltaic system, inverter and battery are used is shown in figure-3. In the day time battery is charge from the photovoltaic system which produced direct current (DC). When the grid supply is interrupt then this direct current (DC) are converting in to the alternating current (AC) with the help of Converter (Inverter).

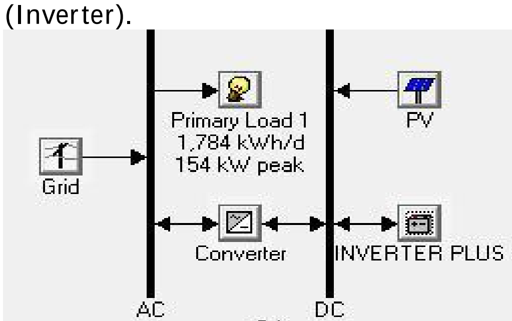

Fig-3 Proposed power system model

HOMER uses inputs which describe technology options, component costs, and resource availability to simulate different system configurations, or combinations of components, and generates results that you can view as a list of feasible configurations sorted by net present cost. HOMER also displays simulation results in a wide variety of tables and graphs that help you compare configurations and evaluate them on their economic and technical merits

To explore the effect that changes in factors such as resource availability and economic conditions might have on the cost-effectiveness of different system configurations, one can use the model to perform sensitivity analyses.

HOMER simulates the operation of a system by making energy balance calculations for each of the 8,760 hours in a year. For each hour, HOMER compares the electric and thermal demand in the hour to the energy that the system can supply in that hour, and calculates the flows of energy to and from each component of the system. For systems that include batteries or fuel-powered generators, HOMER also decides for each hour how to operate the generators and whether to charge or discharge the batteries.

HOMER performs these energy balance calculations for each system configuration and determines whether a configuration is feasible or it can meet the electric demand under the conditions that you specify, and estimates the cost of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and interest.

After simulating all of the possible system configurations, HOMER displays a list of configurations, sorted by net present cost (sometimes called lifecycle cost), that you can use to compare system design options.

The total Net Present Cost of the existing power system which includes different components is shown in Table-1. The annually cost of power system is Rs 35242474 ($568427).

Table-1 Net Present cost of existing power system

Component	Capital cost ($)	Replacement cost ($)	O& M cost ($)	Fuel ($)	Salvage ($)	Total ($)
Generator	6240	0	0	74029	-141	80127
Grid	0	0	277525	0	0	277525
Exide	62700	70096	16012	0	-3285	145523
Converter	14600	8947	10675	0	-1550	32672
Other	0	0	32580	0	0	32580
System	83540	79044	336792	74029	-4977	568427

The results of Net Present Cost for proposed power system model by every component obtained by using HOMER software is shown in Table-2. Here capital cost of Photovoltaic is highest, cost of the converter is lowest and overall net present cost Rs. 29229652 ($471446).

Table-2 Net Present Cost for proposed power system model

Component	Capital cost ($)	Replace-ment cost($)	O&M cost ($)	Fuel ($)	Salvages ($)	Total ($)
PV	98640	0	27670	0	0	126310
Grid	0	0	279989	0	0	279989
Exide	14630	24196	5380	0	-810	43396
Converter	7300	6764	7686	0	-461	21289
Other	0	0	461	0	0	461
System	126438	30959	321187	0	-1270	471446

The overall cash flow analysis of each component for existing & proposed models is shown in Figure-4 & Figure-5 respectively.

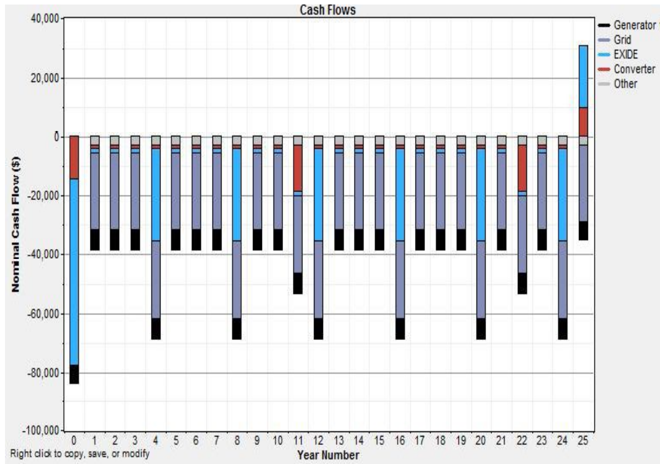

Figure 4: Nominal cash flow by component in existing model

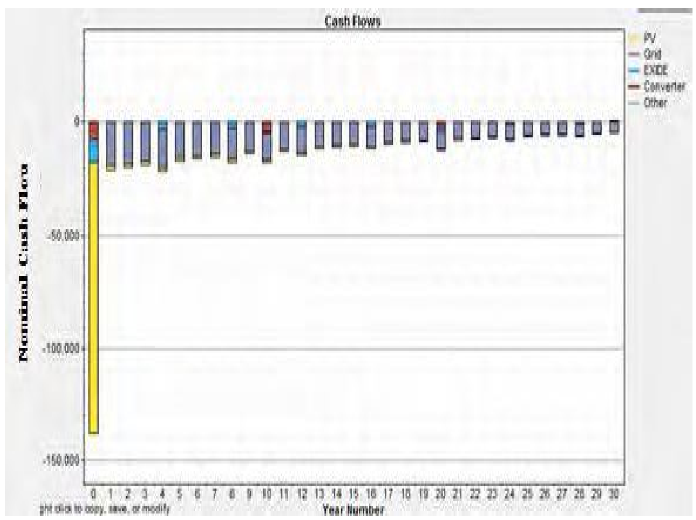

Figure 5: Nominal cash flow by component in proposed model

The production of electricity in the existing power system which includes generator and power grid, is 28105 Kwh/yr. by the generator and 623219 Kwh/yr by the power grid. This is 4% and 96% of the total electricity produced by the generator and the grid.

Table-3 Emission comparison of models

Pollutants	Existing power model	Proposed power model
	Emission (kg/kwh)	**Emission (kg/kwh)**
Carbon dioxide	416702	327653
Carbon monoxide	16883	13998
Hydrocarbon	12771	10369

Sulfur dioxide	1753	1421
Nitrogen oxides	1338	695
Particulate matter	4.25	0
Total	44951.25	379879

The production of electricity in the proposed power system model which includes PV array and power grid is 740864 KWh/yr. Electricity produced by the photovoltaic array is 222427 KWh/yr. which is 30% of the total production and the power grid 518438 KWh/yr. which is 70% of the total. With the replacement of the system there is saving in energy purchased from the grid is 104781 KWh/yr

Table-4 Results of cost comparison

Particular	Existing system	Proposed system	Saving ($)
NPC cost summary	$5,68427, Rs.35242474	$4,71446, Rs.29229652	$96981, Rs.6012822
Energy purchase from grid annually	$6,23219 Rs.38639578	$5,18438, Rs.32143156	$10,4781, Rs.6496422
Emission ton/yr.	439.88	379.78	60.1
No. of battery used	300	70	230
Converter	200kw	100kw	100kw
Carbon Content	449151.25tonne	354136 tonne	$95015.25, Rs 5890945.5

VI. RESULTS AND DISCUSSION

It is analyzed from the results obtained from the technology used in proposed power system model that it is best suited for the selected site among all the other renewable resources. Result of the cost analysis of existing and proposed model is shown in Table-4. There is total 18% saving in cost and 21% in carbon emissions with the rescplacement of the existing system to the proposed one.

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