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Self-consumption and Cost analysis of on-Grid Solar Photovoltaic System for Industrial Load: A Case study

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Abstract:

Solar energy is dependent on time and seasons, which results their output in variable nature. The power generation cost from these resources is also high in developing countries due to import and tax. Therefore supportive policies and schemes like feed in tariff and net metering were introduced. But these schemes are not much attractive for consumers due to their insufficient FIT (Feed in Tariff) rates. These shortcomings can be avoided through self-consumption technique for roof top solar PV system, as this technique results in cheaper generation of electricity. This research work is done for installation of on grid PV system along with the cost analysis and self-consumption for industry of Kotri Sindh Pakistan. Proposed system results in the reduction of energy cost about 35.23% with respect to time of use rating model. Furthermore, proposed model guarantees the security of power by completing about 97% of annual energy demand. This proposed model can be used throughout the world by just applying required data sets of that area.

Keywords: Self consumption, Self-sufficiency, Net metering, Feed In Tariff, Store on grid, rooftop, Solar PV system.

1. Introduction

On global level most of the electrical power is generated through fossil fuels resulting in negative environment impacts like global warming issues [1]. Thus, the electricity generation sectors in all the countries around the world are focusing on increasing the penetration of renewable resources in their systems, since they are neither exhaustible nor polluting the environment [2]. But the output of renewable resources such as solar is always varying with time, depends upon the weather conditions. Also generation cost will be still high for developing countries having limited industrial capacity and financial resources. Therefore, supportive and policy schemes e.g. net metering and Feed in Tariff are important for distributed energy generation especially for PV system [3].

2. Literature Review

This study compares the net metering and feed in tariff schemes using different retail cost rate and PV system size, net metering supportive scheme is concluded as better as compare to that of feed in tariff scheme. In near future, battery storage system based PV system is going to be more efficient and profitable [4]. Self-sufficiency rate with the adoption of battery increase more with respect to that of demand side management [5]. Feed in tariff scheme result in reduction of electricity bill by 49.56% with battery based PV system and 33.65% without battery energy storage system by 2011 also withe the reduction of subsidies [6]. Self-sufficiency rate varies between 30 to 37% for average single house in Europe, Maximum charging and discharging power of batteries also impacts the SSR [7]. Self-sufficiency and self-consumption increase up to 30% with ALR of 6, but there is decrease of self-consumption and self-sufficiency with increase in capacity of battery with ALR (array to load ratio) above 6 [8]. In this paper presents the simulation of 700kWp using PVSYST software in Daikunfdi Afghanistan along with their performance evaluation.

It is found that system produce 1266MWh annually with performance ratio of 0.797, while system will provide more better results with power factor 0.7-0.9 [9]. An algothim for determination of suitable area for grid tied roof top PV system for industries of Uganda is proposed. Limitation of this algorthim is that it can only be adopted in those countries that haven't building foot prints and LiDAR data sets [10]. This paper analyzed the installation and performance evaluation of 2kW on grid solar PV plant in Bhubaneswar using PVSYST software for residential load having daily demand of 8.9kWh. It is found that on daily base 33.23kWh energy is in excess, which is fed to the grid

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[11]. Scheme based on storage system on grid for solar photovoltaic system is proposed, that result in energy security and reduction of energy cost, but benefits are not analyzed [03]. Benefits of store on grid scheme are analyzed and found that it can play crucial role as a support scheme for solar pave system [12]. Most of the research work is being done on design and installation of solar photovoltaic system. Limited work is done on solar photovoltaic system with supportive schemes and policies like Net metering and Feed in Tariff. Therefore this work is on self-consumption based scheme for solar photovoltaic system. In proposed model after completing the requirement of electrical power, surplus electrical power can be sell to grid. Furthermore in the situation when requirement is not completed by battery storage then electrical power can also be buy from utility as shown in Fig 01. Feasibility analysis of proposed model is being made on industrial area of Kotri Sindh Pakistan as case study site by comparing the cost of energy generation with time of use rate of energy cost.

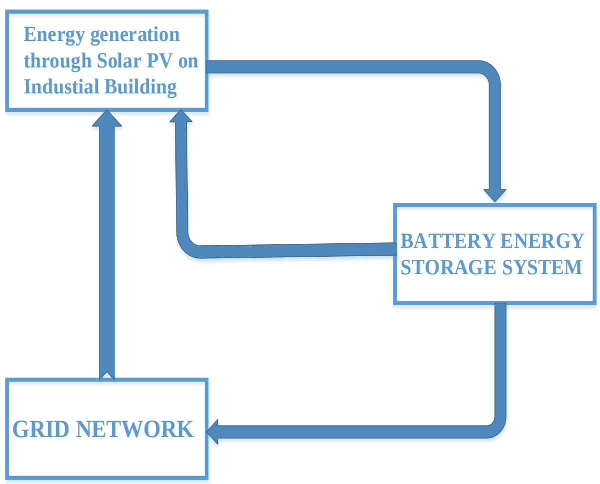

Fig. 01. Layout of proposed solar PV system model

3. Methodology

In this paper load of different industries in Kotri, Sindh is being collected. Previously much research is done for the solar energy scenario in Pakistan and off grid PV generation in different areas of Sindh. But this paper is especially for self-consumption and cost analysis for grid connected solar PV system for industrial load. It is estimated that along with completion of basic needs huge amount of money can be sell to grid. This paper is divided in different sections, section 3 contain system sizing and cost analysis of PV system, and section 4 contain results, proposed work is concluded in section 5, , and in section 6 references are given. There are three main objectives for this research study.

3.1 Collection of data

For the research study, data has been collected from different sources.

3.1.1 Proposed site for PV installation:

This research study is done on industrial load of Kotri Sindh Pakistan, having longitude and latitude of 25.3523° and 68.2724° respectively as shown in Fig.02. Suitable area for installation of rooftop solar PV system is evaluated as 4768 m^2 through online Google map as well PV Syst Software.

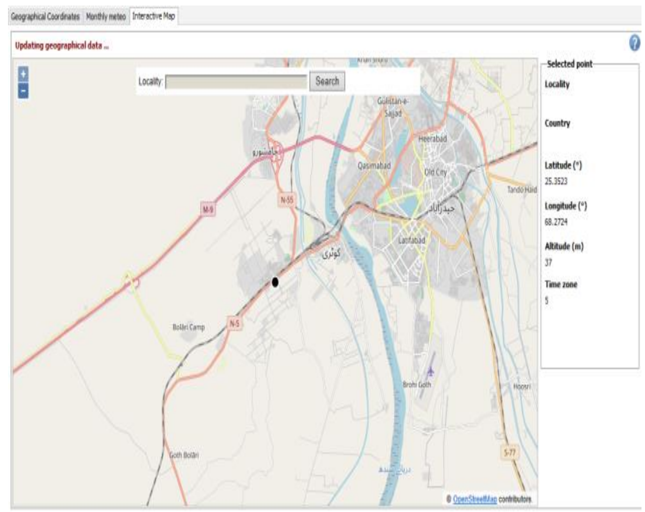

Fig. 02 Proposed site for PV system installation

3.1.2 Load Estimation

The daily energy demand on average basis for different industries of Kotri is given in Fig.03.

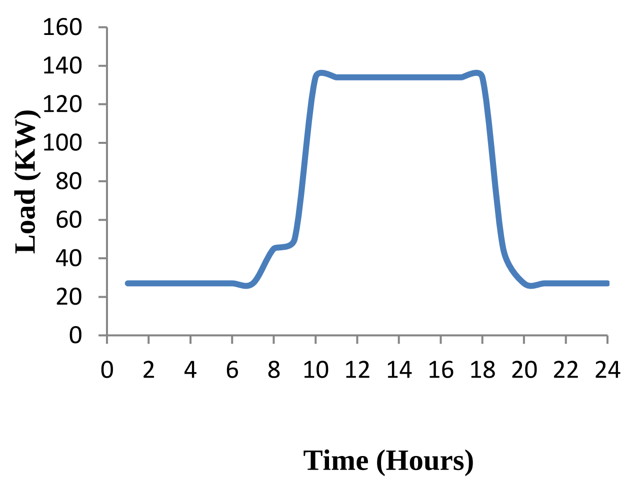

Fig 03. Daily load demand

3.1.3 System Sizing:

Installed capacity of PV system for proposed site is 724.4kW as per present suitable rooftop area.

3.2 System Modeling:

3.2.1. Orientation and Inclination

The parameters of azimuth and tilt angle are included in the orientation and inclination. The tilt angle for the PV module is set to 25 degrees in order to maintain maximum power from PV panels. The PV module's azimuth angle is set to 0 degrees, or true south as shown in Fig:04

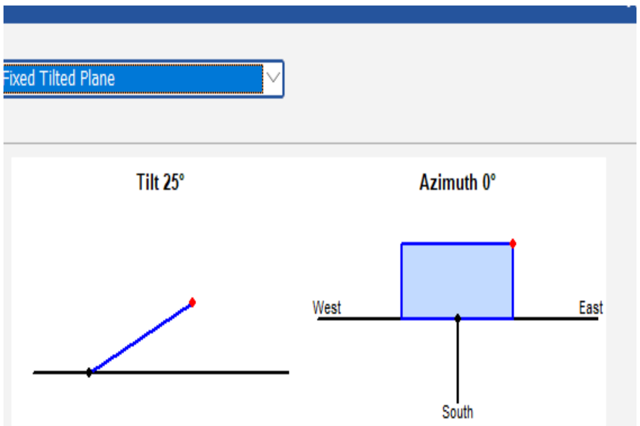

Fig:04 PV module's azimuth angle and Tilt angle

3.2.2 Solar PV Module:

Mono crystalline Solar panel of 6298 PV modules of Sun-style international company (Sunstyl-115-BK-Black) with power rating of 115Wp each is used. Other parameters or specification of the PV module are given in Fig.05.

3.2.3 Inverter:

700 kWAC, Voltwerk VIS 700 inverter is used in order to generate 724.4 kW power, parameters/specifications are given in Fig.5.

3.2.4 Battery:

Lithium Ion batteries of 51Ah Polytechnic manufacturer (US2000B 50Ah) 480 batteries (8 batteries in series and 60 batteries in parallel) are used with voltage of 48volts with global capacity of 3036Ah, with life period of 5 years.

3.3 Cost Analysis:

- PV Energy prosumer cost is calculated as:

$$C_{load}^{PV} = \text{LCOE}_{PV} E_{load}^{PV} \quad \dots\dots(01)$$

- Prosumer store on grid cost is calculated as

$$C_{load}^{SOG} = P_{fee}^{SOG} E_{drawn}^{SOG} \quad \dots\dots(02)$$

- Utility Energy cost to prosumer is calculated as:

$$C_{load}^{Grid} = \left(\frac{Po+Pp}{2}\right) E_{load}^{Grid} \quad \dots\dots (03)$$

Here P_o is price of electricity during off peak hours, and P_p is the price of electricity during peak hours.

$$\text{Total cost} = C_{load}^{PV} + P_{fee}^{SOG} + C_{load}^{SOG} + C_{load}^{Grid} \quad \dots\dots (04)$$

4. Results and Discussion

This section provides the results of proposed simulation based on grid solar PV system sized on the base of 4768m^2 areas. Monthly energy generation through installed PV system is maximum in the month of March, and minimum in December as shown in Fig.06. Energy taken from gird is maximum in the month of December, and minimum in the month of June, while Energy feed into grid is maximum in the month of March can be observed from Fig.07. It can be said that about 96% of the total annual load demand of the industry will be completed through installed PV system, and 4% would be from the grid. Annually industry requires 6.12 Million rupees through proposed SoG model, while through time of use scheme model it would pay 9.46 Million rupees.

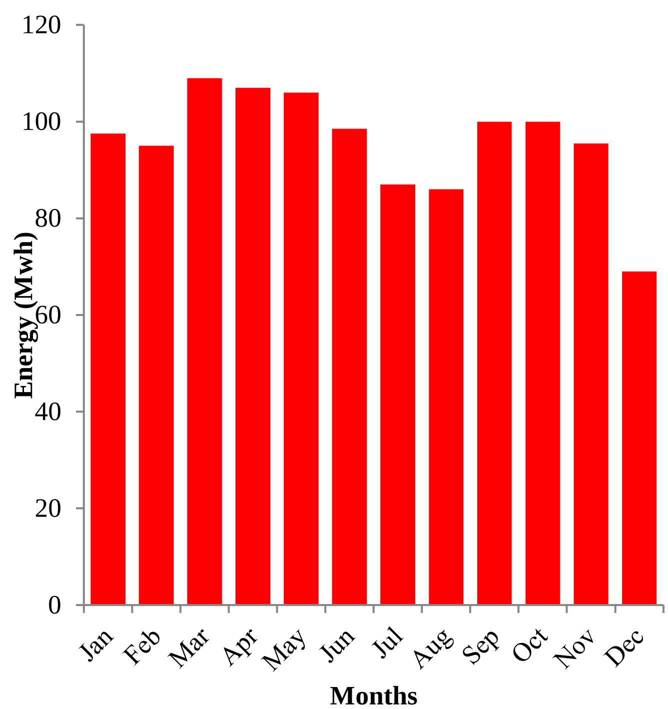

Fig 06 Monthly Energy Generaion of Solar PV system

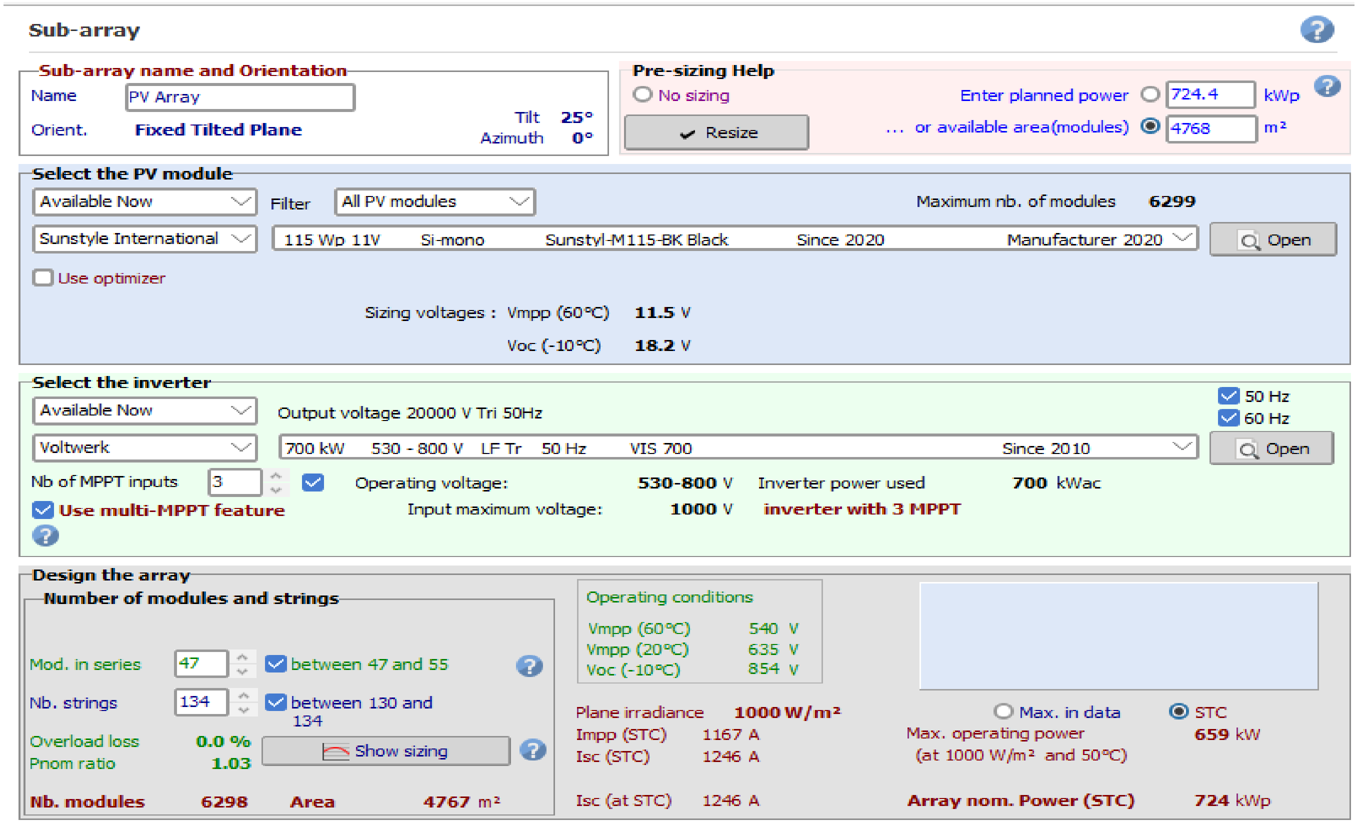

Fig: 05 PV System Design Parameters using PV SYST Software

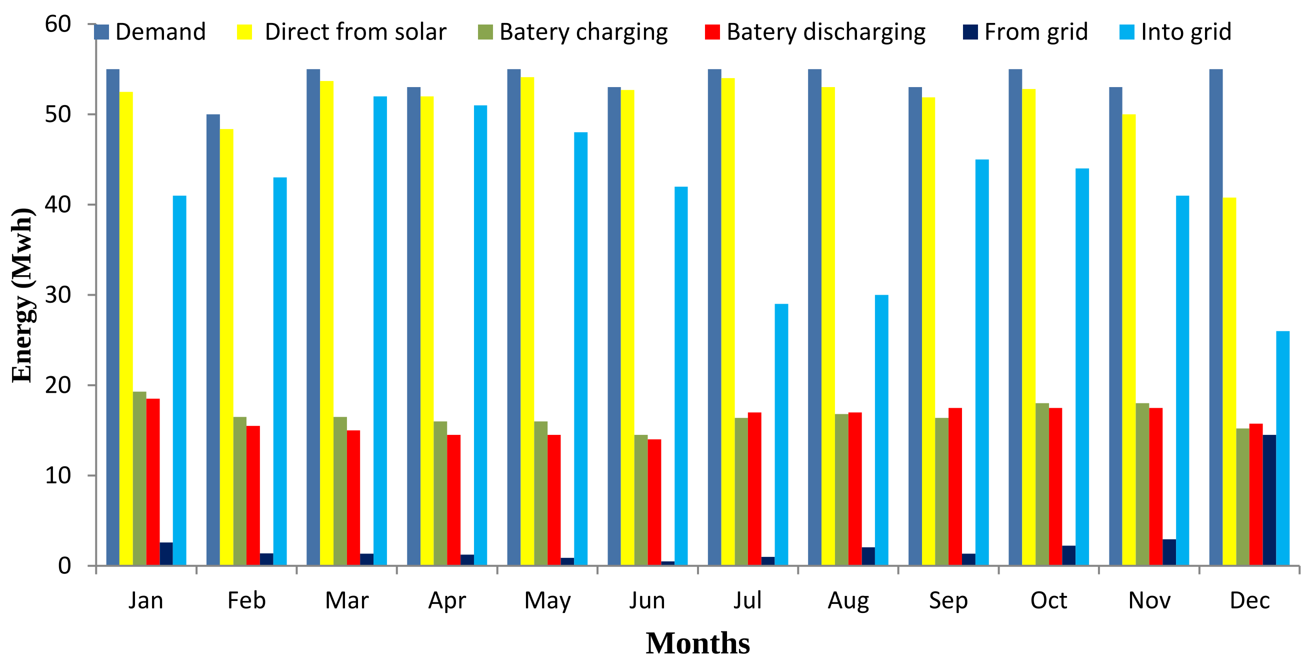

Fig.07 Monthly Energy demand-supply balance

5. Conclusion:

Proposed model is based on the concept that prosumer is required to pay store on grid fee for storing the energy in battery owned by grid operator. Prosumer will be provided energy from grid at low rate with respect to time of use rate at the time when there is no sufficient energy from battery energy storage system. Store on grid fee will be 2.40PKR/kWh; utility will sell energy to the prosumers at rate of 17.23PKR/Kwh. This result in 35.23% reduction in annual energy cost for the proposed SOG model as compare to TOU rate model. Our proposed model can fulfill 96% of the total annual load demand of industry, also IPP feeds 38% of total energy generated to grid. Therefore prosumer can get annually benefits of 8.8 Million rupees, while Utility will get annual profit of 0.6 *Million* rupees.

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