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PV Power Generation for an Agricultural Load

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ABSTRACT- India is the 6th largest economy of the world. As per the data 49% of manpower is employed in farming, where as the farming sector contribution to the GDP is merely 16%. This is because of two main causes one is the disguised employment in the farming sector. The second reason being India's large portion of farming activities depend upon the monsoon. The changing weather pattern makes the corps production vulnerable. The security of crops can be provided by providing cost effective and continuous irrigation facilities, which will not only eliminate the dependency on the weather also help farmers to boost their economy by increasing the crops production. This might help to increase the socio-economic condition of the farmers. In this study, standalone solar PV is introduced and examined for the said reason. This technology involving renewable energy provides a novel solution for the challenging task because during sunny hour maximum water needs to irrigate the field, and during rainy season the water requirement is null or less. During both the seasons the model can work effectively, to provide cost effective and eco-friendly energy supply. The system is modeled and analyzed through HOMER.

KEYWORDS- PV, Renewable energy, HOMER, Eco-friendly, Economic

I. INTRODUCTION

After 75 years of independence the farming sector of India needs another revolution like the green revolution. The green revolution enhances the food security of India, and make it food exporter which was previously a food importer. But the socio-economic condition of the framers is still waiting for a revamp. Though during these 75 years many research are taken up in India, Government of India signs permanent peace agreement to provide subsidies to the farmers. Despite all these factors the income level of farmers is yet to be improved. There are many causes, the major being the global crisis of environment change, which alter the rainfall pattern, the depleting ground water creates another concern. The subsidized electricity imposes restriction on the pattern of its use, which creates hindrance in the agriculture activities. This paper tries to optimize the system and to maximize the irrigation facilities, so that farmer's vulnerability of the crop production will be removed. This will not only enhance the production of crop rather helps to improve the socio-economic condition of farmers. The present work aims to introduce the Solar PV system with battery bank and investigates the Standalone PV option for reliable, continuous and cost-competitive power supply.

II. LITERATURE REVIEW

Nema et.al (2009) audits the present status of the plan, activity and control necessity of the independent PV system in hybridised model [1]. Akikur et.al (2013) presents a review on solar based energy as an independent and hybrid power for source [2]. Liu et.al (2013) presents the review continues to investigate the fundamental obstruction and key factors that influence sustainable power application concerning Taiwan structures. [3]. Ali et.al (2010) presents the proposition of a solar PV system operating with different configurations [4]. Zhou et.al (2015) proposes an ideal facility activity control strategy for huge scope wind–photovoltaic (PV) – battery storage power units to address the power crisis [5].

III. MODELLING AND DESIGNING

A. Modelling

The major components of the proposed system (Table 2) include the primary source of energy the SPV, the backup energy the batteries connected in cascade to improve the storage capacity, the load to be served and other accessories to operate the system effectively and efficiently. The load and the power source are complementary in nature and adequately designed fulfil the energy requirement. The maximum requirement falls in day time because at that time the motor or pump will operate. The system power producer also operates during the day time and hence the energy requirement and energy production both are high during day time. But the source employed in the scheme has intermittent characteristics that means the power output will change as the weather changes. To overcome these challenges the batteries are put in operation. The battery will not only improve the supply reliability rather it also required to maintain the equilibrium of power flow. The excess energy will be stored in it and the deficit portion will be taken as required to maintain the equilibrium of energy flow. The night load is quite low, the battery can easily serve the load.

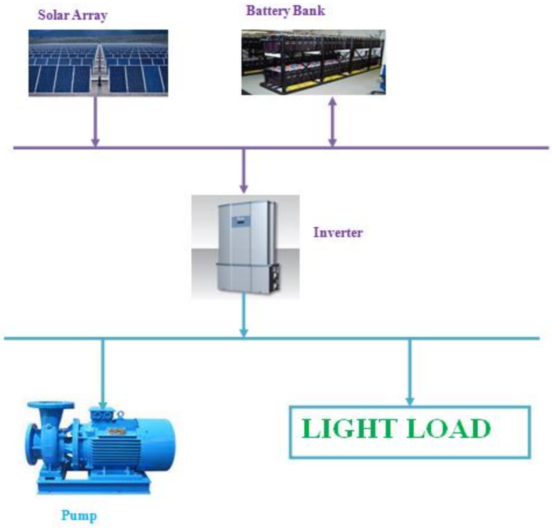

Figure 1: PV Model for pumping

B. Load Profile

The proposed scheme is developed for irrigating farm land. The scheme is designed to serve a Pumping load of 20 kWh. The pump is designed to lift water from a height of 15 feet across the river and to irrigate the land over there through different channels. However this load is not constant. With the weather condition the requirement will be changed. The system observes that the agricultural land requires more water during sunny hour and the system can produce maximum energy during that time only. In the reverse time the water is required less, the energy production is also less. The water requirement and energy required are creating a reasonable characteristics. The load is synthesized in HOMER. The loads are assumed on an average basis.

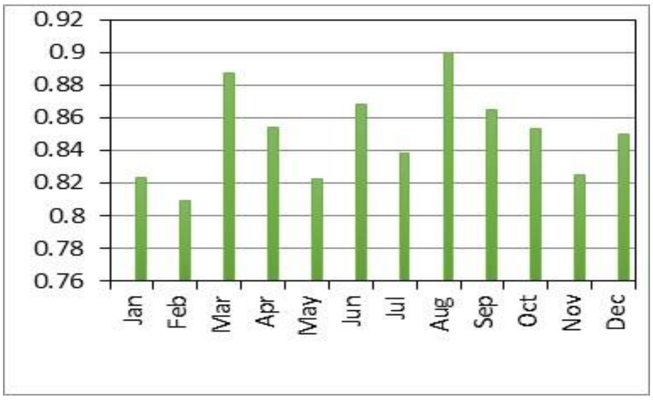

Figure 2: Load profile

Table 1: Components used

Name of the Component	Specification
PV	7.00 kW
Inverter	3.00 kW
Battery	30.4 kWh
Pump	15.00 feet
Load	20.0 kWh

C. Mathematical Formulation

The modelling 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 [6,7]. Shockley diode equation is used to express relation between voltage and current of PV cell, expressed as

$$I = N_{Ph} I_{Ph} - N_P I_0 \left(e^{\frac{1}{Vt}\left(\frac{V}{N_S}+\frac{I_{RS}}{N_P}\right)} - 1 \right) - \frac{N_P}{R_P}\left(\frac{V}{N_S}+\frac{I_{RS}}{N_P}\right)$$

D. IEC 61724 Standard

This International Standard recommends procedures for the checking of energy-related PV structure characteristics, for instance, in-plane irradiance, display yield, amassing data and yield and power conditioner data and yield; and for the exchange and examination of noticed data. The inspiration driving these techniques is to assess the overall show of PV structures orchestrated as autonomous or utility cross section related, or as hybridized with non-PV power sources like engine generators and wind turbines.

E. Energy Balance Equation

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

$$\mathrm{E_{in}} = \mathrm{E_A} + \mathrm{E_{BU}} + \mathrm{E_{FUN}} + \mathrm{E_{FSN}}$$
$$\mathrm{E_{use}} = \mathrm{E_L} + \mathrm{E_{TUN}} + \mathrm{E_{TSN}}$$

F. Simulation Methodology

Hybrid optimized model for electric renewables (HOMER) programming [10], the environmentally friendly power-based framework advancement device created by the United States (US) national renewable energy laboratory (NREL) is utilized in this work for demonstrating and reproduction reason. There exists wide utilization of this miniature force improvement programming in different going before half and half energy framework examines in various nations and liked here also to reproduce a doable cross breed framework for the site. It is an adaptable instrument that models a blend of ordinary energizes and sustainable power to decide the savviest design for every framework. Info data to be given in HOMER incorporates: electric burden (essential energy interest), inexhaustible assets (sun-oriented radiation), and hydro assets, part specialized subtleties/costs, kind of dispatch system, and so on.

IV. RESULTS AND DISCUSSION

A. Average Rainfall at the Site

The Fig. 3 depicts the actual rainfall on the proposed site. This data is taken from the district administrative portal mentioned for the year 2017 which is latest. The rainfall data enable the system to estimate the shortfall of water. The pattern is very much scattered. The monsoon lasts for three months from June second week to August. The rainfall post monsoon is due to the occurrence of number of low-pressure regions on the Bay of Bengal.

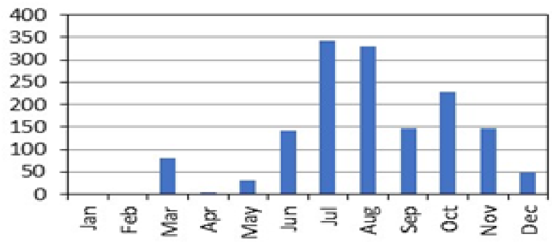

Figure 3: Annual average rainfall

B. Monthly Power Output from PV Array

The power out of PV changes as the weather changes. The objective of the PV to feed continuous power to the pump for smooth operation of the system. The Fig. 4 shows that the average energy production from the PV. However, the highest and lowest energy productions are different from the average. It is estimated that 6,964 kWh of energy is being produced by the model. The capacity shortage is 6.5% and the excess energy is 27.5% for the proposed model.

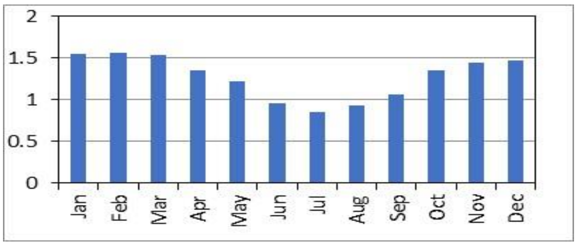

Figure 4: Average daily PV power output

C. *Battery Output*

The model considers the battery as secondary source of power. The battery will be operated only during the light load hours. So the battery can effectively manage the energy balance. The battery also plays a significant role to enhance the supply reliability and smoothens the energy survey too.

The battery annual throughput will be 1,598 kWh. The nominal capacity is 30.4 kWh. The battery frequency histogram is shown in Fig. 5. It is observed that the SoC (Fig. 6) of battery significantly stays around 80 percent and above. That shows the battery is getting adequate amount of energy to charge and discharge.

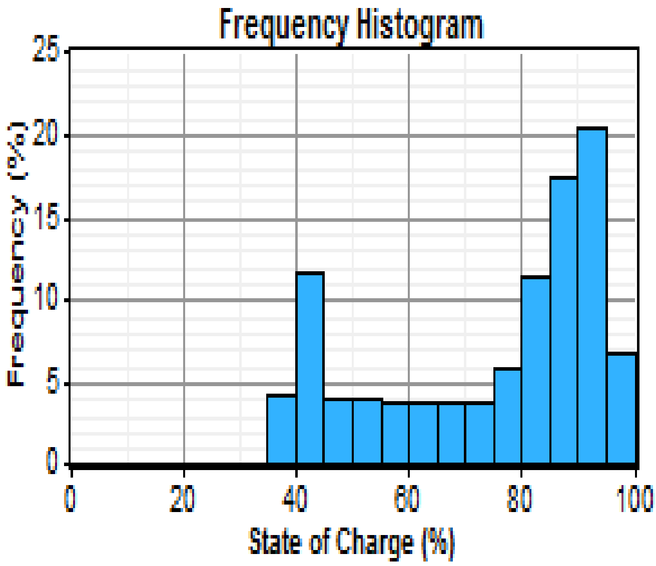

Figure 5: Frequency Histogram of battery SoC

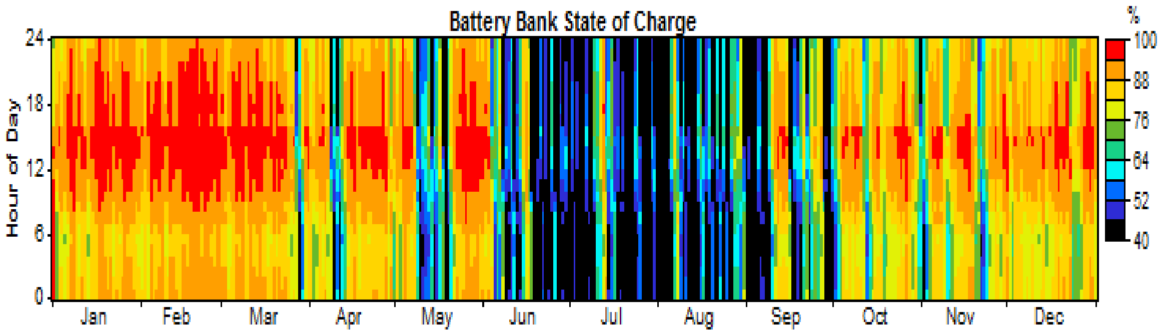

Figure 6: Battery state of charge

C. Predicted Daily Water Volume Pumped

The water will be lifted from the river flowing through the site. The water needs to be lifted up to a height of 15 feet. The water lifting capacity of the pump reduced drastically during May to September that can be fulfilled by the monsoonal rain prevailing that time. During other months like Jan to March the rainfall is minimum and the system shows that the maximum water can be lifted during that time as shown in Fig.7. This shows the complementary nature of the scheme. The scheme is can work in equilibrium with the monsoonal pattern and help the farmer by reducing the dependencies over the weather.

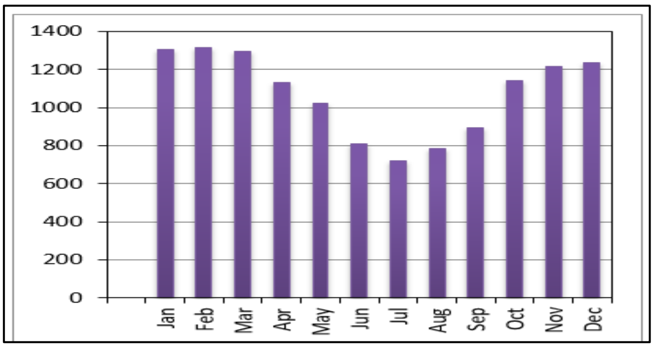

Figure 7: Water Volume Pumped

D. Battery state of Charge for a Typical Day

10th January of the simulation year as shown n Fig. 8, is taken for observation of Soc of the incorporated battery with the model. It is observed that, the battery will be charged during available of extra power, and state of charge will increase and when the PV power does not able to cater the need the power will be drawn from the battery, so the state of charge declines.

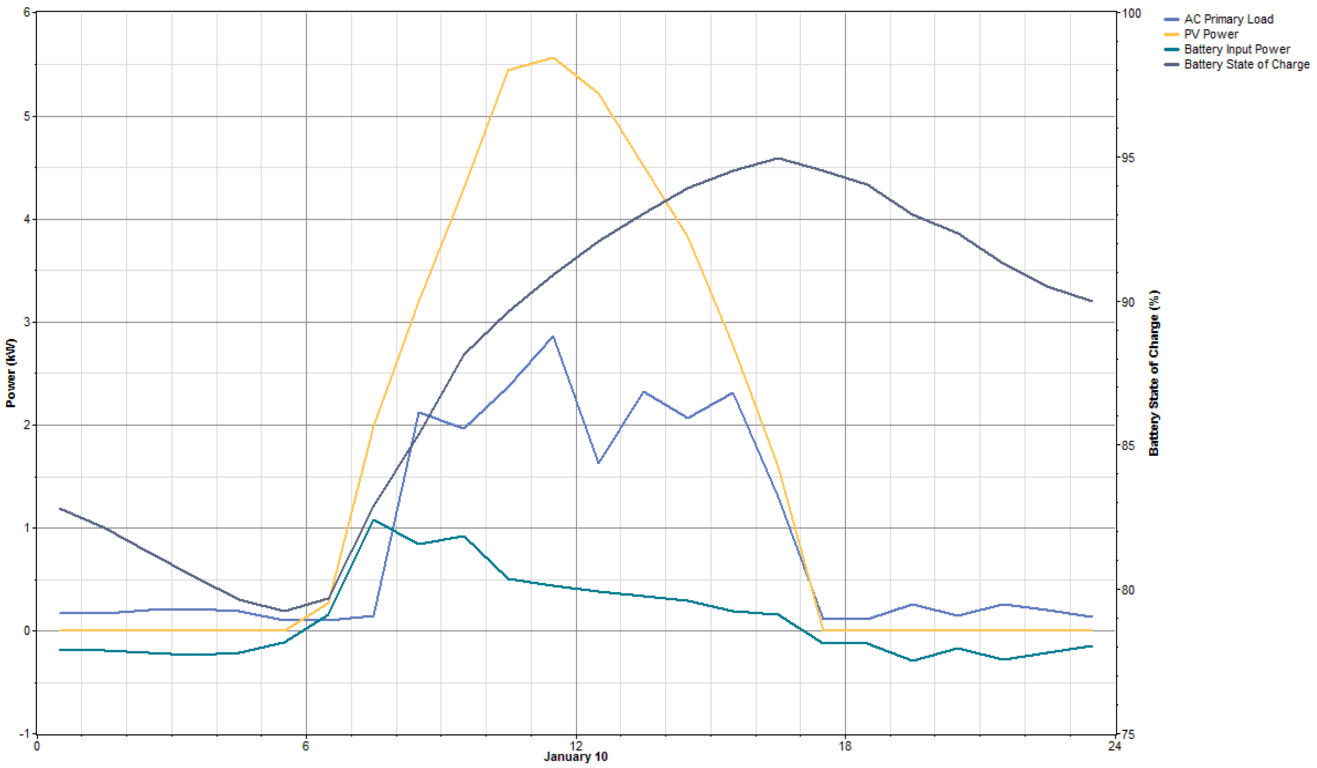

Figure 8: Battery Soc for a typical day

E. Hourly Energy Balance of the Proposed System

The orange colour shown in Fig. 9 represents the power output from the PV and the battery power shown in grey colour bar. The load is shown in blue line. From evening like 7 PM to next day early morning the battery entirely served the load. It can be observed that during that time frame the power output from the PV is exactly same as the power needed. From 6 AM to evening the two sources like PV and battery working in unison to serve the load. The battery charges during these time and discharges according to the system need. Dump load protect the system by providing UN useful extra power.

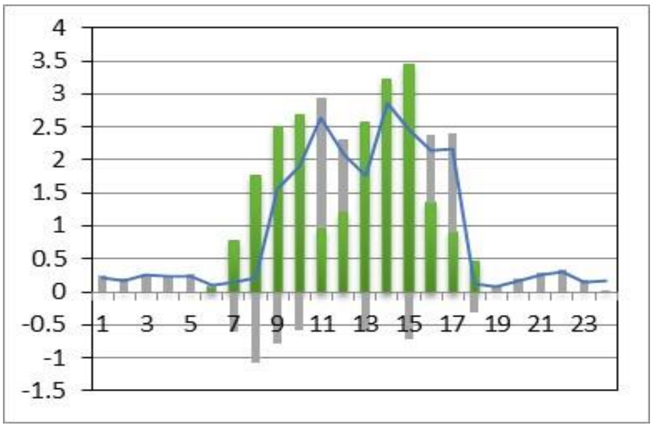

Figure 9: Hourly energy balance

F. Emission

The model comprises the renewable power production unit the PV. The PV is gaining popularity world-wide ad it is eco friendly and does not pollute the environment. Table 2 shows the pollution that is emitting from the system. This proves the sustainability of the system as it is able to even curtail the pollution by generating power by means of eco-friendly generator.

Table 2: Emissions from the system

Pollutants	Emissions (kg/yr)
Carbon dioxide	0
Carbon monoxide	0
Unburned hydrocarbons	0
Particulate matter	0
Sulphur dioxide	0
Nitrogen oxides	0

V. CONCLUSION

The study contains the performance of the pump load to irrigate a farm land. The results re inspiring. The scheme water capacity surpasses the need of the farm land. It concludes that with the integration of battery, the power quality as well output of the system increases, the schemes employed in the study are also complementary in nature, the capacity shortage is 9 % which also increases reliability of the scheme, the labialised cost of energy is estimated as 7.512 INR/kWh, proposed scheme is also having negligible emission and hence eco friendly.

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