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# SOLAR ELECTRIFICATION IN AGRICULTURE

**P.W.Choudhary[*1] & P.S.Dorale[2]**

[*1,2]Assistant Professor, Department of Electrical Engineering, Mauli College of Engineering & Technology, Shegaon, India

## ABSTRACT

Solar photovoltaic (SPV) pumps are a robust and well-accepted technology today, some important reasons being a drop in photovoltaic prices and development in power electronics components used in the system. SPV pumps are being promoted to reduce fossil fuel usage through reduction in diesel consumption and the attendant reduction in greenhouse gas emissions, to address the shortfall in grid connectivity, and, to provide improved livelihood opportunities for poor farmers. The objective of the solar electrification in agriculture is to improve energy access, replace diesel pumps and deploy solar technology in rural areas. This paper addresses all issues related to solar electrification in agriculture. A case study was conducted for two adjacent districts, Akola and Buldhana. Also different schemes of Government of Maharashtra are discussed.

***Keywords:*** *Solar Photovoltaic pumps, Agriculture challenges, Government schemes.*

## I. INTRODUCTION

Applications of SPV for irrigation have come up in the last couple of decades with many countries adopting it. Bangladesh, Benin, Zimbabwe along with India are a few countries that are promoting SPV pumps through various schemes. Most poor farmers do not have a reliable source of irrigation and unreliable monsoons over the past few years have forced farmers to look at alternate sources such as diesel pumps where a water source exists, or practice deficit irrigation.

In India, solar irrigation pumps were earlier introduced by Ministry of Non-Conventional Energy Sources (MNES) now Ministry of New and Renewable Energy (MNRE) for drinking water supply and irrigation. From 1992 to 2014 about 13964 solar pumps have been disseminated. A majority of India's population is dependent on agriculture for livelihood. However, canal irrigation is limited to some areas only and hence in most parts farmers rely on pump sets for irrigation. A study conducted by KPMG for Shakti Sustainable Energy Foundation estimated 18 million pumps which are connected to the grid and 7 million pumps running on diesel.

In India, several state governments have, or are in the process of, instituting schemes to promote solar pumps for different reasons. In Rajasthan close to 20,000 solar pumps have been distributed till 2015 to address the long wait time for a grid connection. In Bihar 1,560 solar pumps have been installed since 2013 to address the poor grid penetration and cut down diesel usage. Karnataka and Gujarat have introduced schemes for net-metering in grid connected SPV pumps.

Maharashtra has good grid penetration with 3.8 million cultivators using electricity for irrigation, out of a total of 11 million cultivators. Others either employ diesel pumps or practice rain-fed irrigation. The Ministry of Power announced an Off-grid Solar Pumping Programme for FY 2014-15 with MNRE deciding a target of one lac solar pumps in the country.

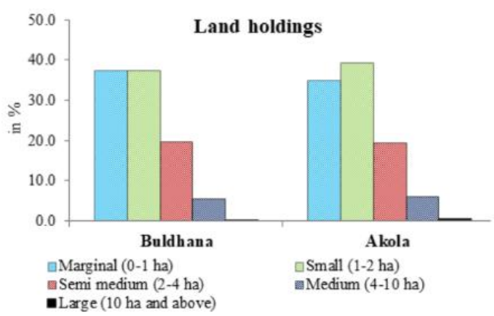
## II. SCHEMES OF GOVERNMENT OF MAHARASHTRA

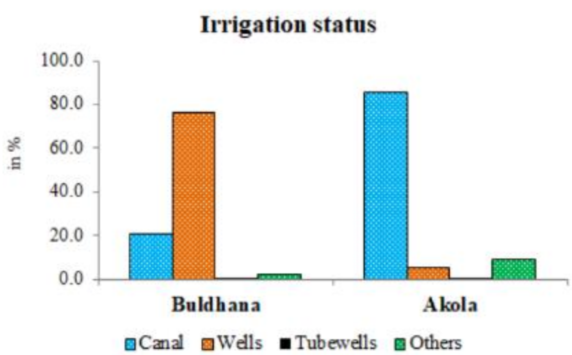
In Maharashtra, the honorable Chief Minister Shri. Devendra Fadnavis declared that 5 lakh solar agricultural pumps would be implemented. MEDA requested MNRE to revise it to 10,000 pumps, which was later revised to 7,540 pumps.AC solar pumps of capacities 3, 5, 7.5 HP and DC pumps of capacities 3, 5 HP were to be disseminated under this scheme. These systems were meant to be off grid, and equipped with manual tracking. 80% of the total numbers of pumps were to be distributed in the suicide prone districts of Vidarbha region of Maharashtra i.e. Akola, Amravati, Buldhana, Wardha, Washim and Yavatmal. The project was initially applicable only to farmers having land holdings less than 5 acres but that was later revised to 10 acres. With land holdings up to 5 acres a farmer could avail a subsidy of 95% subsidy, and between 5-10 acres a subsidy of 85%. The connections were subject to the condition that she/he did not have a grid-based agricultural connection, and in addition had a water source on their farm. Farmers could apply for the scheme by filling out a form available in the local MSEDCL office which after review by MSEDCL office would be sent to the district level office and after scrutiny will be approved. The farmers had to pay the upfront cost of 5% of the system cost after the order has been sent to them. The vendors would then be instructed to set up the system on their fields.

## III. SURVEY CONDUCTED IN AKOLA & BULDHANA DISTRICTS

Through the above schemes a heavy subsidy is given to the farmer. 3-5 HP SPV pumps cost ~Rs. 3,25,000-6,75,000. Governments have declared subsidies of 80 – 95 %. It is important that solar PV schemes are targeted to the appropriate beneficiaries as these schemes often end up benefitting richer farmers. In this work we develop a framework to determine pump sizes appropriate for small and marginal farmers in a particular district, using secondary datasets. The study was conducted for two adjacent districts, Akola and Buldhana, because the solar PV scheme of the government of Maharashtra was focused in the six districts of Akola, Amravati, Buldhana, Washim, Wardha and Yavatmal, comprising the Vidarbha region of the state. We present secondary level datasets that are used to identify factors determining typical pump sizes, i.e., cropping pattern, daily peak irrigation requirement of the crops, cultivated area, rainfall, water head, and solar insolation. The calculations for the required pump models for typical heads and land holdings has only been presented for Buldhana, since the two districts are agro climatically similar.

Surveys were conducted with 19 SPV pump beneficiaries in 10 villages of Buldhana and Akola –locations shown in Fig.1.1. The surveys are used to ratify the framework and also to understand the effect of the scheme. We also look at net-metering. Since irrigation is a very seasonal requirement, maximum use of the PV panels can be made if they are grid connected. In addition, net-metering can be an incentive for efficient water use. The danger here is that farmers could game the system depending on the net-metering tariff. To avoid this, the tariff should be low in the season of low water requirement and high in the watering season. We use the developed framework to find the expected usage pattern of the system, and hence the pattern of power fed back on the grid over the year.




Buldhana have open-wells to satisfy their irrigation needs. The agricultural census data lists canals as the irrigation source for 85% farmers in Akola and 20% in Buldhana. One of the criteria for the scheme is that the farmer needs to have a water source on their farms, hence open wells which are the next largest source, have been considered. Tube wells and open wells are the same for purposes of our framework. To understand the water head, we used the Minor Irrigation Census 2006-07 data which suggests that in Buldhana, 90.6% of the open wells in 1366 villages have depth less than 20m. In addition to land holdings, water source and water head, the cropping pattern needs to be known. From the crop statistics published for Maharashtra for the year 2015-16 we identify the maximum area under cultivation for the 2 districts. As seen in Fig. 4.2, soybean, cotton, pigeonpea, gram and maize are the major crops grown in these 2 districts. Soybean, cotton, pigeon pea and maize are kharif crops and in general farmers cycle through these crops over the years. Gram is a rabi crop. In our interviews and surveys, we found that maize cultivation has reduced drastically this year due to infestation by wild animals. The animals feed on maize and farmers have stopped cultivating maize in the past few years for fear of destruction of the produce. Maize has thus not been included in the calculations

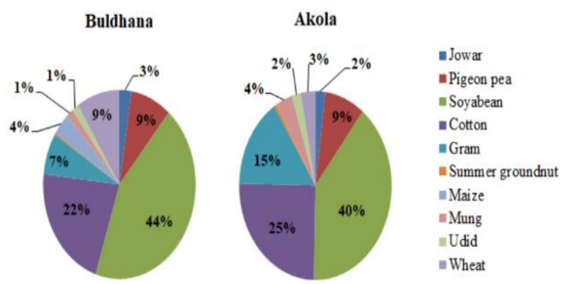



*Fig.1 Crop statistics for Buldhana and Akola for 2015-16*

## IV. OVERVIEW OF SOLAR PV PUMPS

A Solar PV pump is a device used to pump water by using the energy of the sun. The power for the pump is generated by a set of SPV arrays calibrated and matched to deliver the power to the pump. A normal mechanical pump like a submersible, surface or deep well can be attached with the power conditioning systems to work as an SPV pump. Solar water pumping system consists of a set of solar PV panels or array, a motor pump set, and a controller or some set of electronics. The building block of an array is a Photovoltaic (PV) cell. PV cells are semiconductor devices that convert sunlight into direct current electricity. The PV cell circuits are sealed in an environmentally protective laminate which makes up the module. These modules assembled together for the ease of field installation are called as panels. Solar array is a complete power generating unit consisting of solar modules connected to each other in series and parallel to deliver the power to the final system.

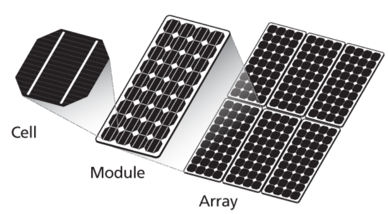



***Figure 1: PV array***

The array is mounted on a suitable structure which has provisions for tracking the sun. The motor can be a D.C (brush or brush less) or an A.C. induction motor. The electronics include Maximum power point tracking (MPPT), controls and protection. An MPPT is an algorithm that is included in charge controllers used for extracting maximum available power from the solar array. MPPT checks the output of the array and compares it to the load, then fixes the best power that a PV array can produce to convert the voltage to get maximum current. In case of an A.C motor, the controller includes an inverter of some kind, and usually a Variable frequency drive (VFD) is also present. A VFD is a motor controller that works by varying the frequency and voltage supplied to a motor. Frequency is directly related to the motor's speed and when the application does not require the motor to run at full speed it ramps down the frequency and voltage requirement to meet the electric motor's load. A VFD helps the motor to work even at low levels of solar insolation.

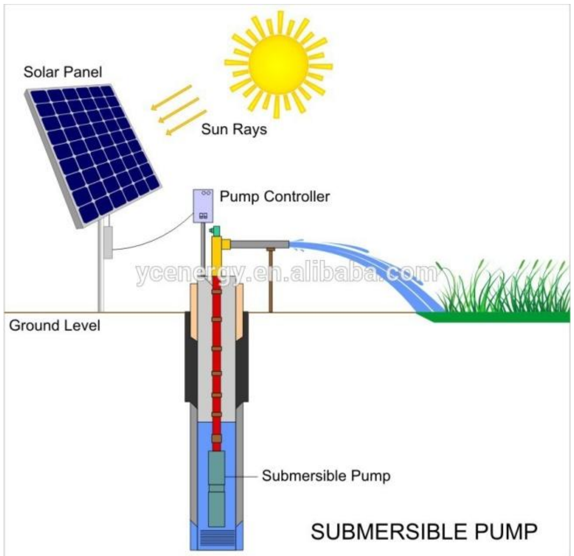



*Figure 2: Solar water pumping system*

## V. ADVANTAGES, DISADVANTAGES, COMPARISON WITH GRID, DIESEL

*Table 1: Comparison of diesel, grid connected and solar pump*

| Types | Advantages | Disadvantages |
|---|---|---|
| Diesel pump | Fast and easy installation | High operational costs along with fluctuating fuel |
| | Easily movable | High maintenance cost |
| | Low capital cost | Shorter life |
| | Suitable for intermittent irrigation | Air pollution, GHG, loss of foreign |
| Grid connected pumps | Economics favorable if the grid is | Expensive for remote locations |
| | Subsidized supply | Hours of pumping dependent on utilities |
| | Electricity supply taken care by the utility. | Power surges results in pump breakdowns, Night time supply. |
| Solar pumps | Low maintenance cost | High investment cost |
| | Long lifetime | Fluctuating output based on cloudy |
| | Daytime supply of water | Repair requires skilled technicians |

## VI. SCHEMES IN OTHER STATES OF INDIA

Solar pumps scheme in India started in 1992 when Ministry of Non-Conventional Energy Sources (MNES) which is Ministry of New and Renewable Energy (MNRE) introduced the Solar pumping programme for drinking water. The Ministry of Power announced off-grid solar pump scheme with a target of 1 lac pumps in the year 2014-15. In India several states have provided subsidies for solar pumps to farmers. Rajasthan and Bihar were one of the first few states to implement the programme. The states have implemented schemes differently based on the farmer conditions in their regions. The different schemes in India and the subsidy and capacities offered are summarized in Table 2.6. Rajasthan was the flag bearer in 2010, offering 86% capital subsidy on small irrigation pumps. Bihar followed suit in 2013-14 by launching the Bihar Saur Kranti Sinchai Yojna offering about 90% subsidy on the capital cost.

## VII. SOLAR PUMP CHARACTERISTICS

To find out the appropriate pump size requirement we need to know the irrigation requirement,head, and in case of a solar pump, we also need to know the solar insolation. We will beassuming a typical land holding with the dominant cropping pattern and typical head for the region.After estimating a typical land size and cropping from section 3.3, we calculate the monthly irrigation requirement for a farmer. The maximum possible water demand in any month for a farmer growing any of the dominant set of crops in the district is used to determine the pump size.

It is important to know that the solar insolation varies across different months and the output from the pump would vary during these months. The monthly daily average solar insolation datails obtained from the NASA metrology site by entering the co-ordinates for the region. The MNRE specifications for pumps are given for a daily solar insolation of 7.15 kWh/m2 incident on the surface of the PV array. For the purpose of identifying the solar pump characteristics, we need to consider the solar insolation in the month with peak demand. The solar pump capacity is identified based on the solar insolation for the peak demand month. The scheme promoted both AC and DC pumps with specifications that meet MNRE guidelines. DC pumps require less maintenance; however maintenance is more convenient for AC pumps since they are the commonly used induction pumps with an established ecosystem in rural India. In general, DC pumps give 10% more water output but cost 20% more. For our calculations, we have considered AC pumps. We have assumed that the performance of the pumps meet the MNRE specification. Under this specification, the panels are expected to be manually tracked in an East-West direction three times a day and set to three optimum positions marked by the manufacturer. Generally, this would lead to a solar insolation of more than 7.15 kWh/m2 in most places of India.

## VIII. SOLAR FEEDERS FOR AGRICULTURE

Maharashtra energy minister said the state government will take up a pilot project in which 40 lakh solar feeders for agriculture sector will be set up in the state. The project has already been running successfully in Sanganmner tehsil of Ahmednagar. "A separate solar feeder will help take the burden off from the current electricity supply to agriculture. Solar energy, which is cheaper, will provide huge financial relief to the farmers," the minister said.

## IX. ACKNOWLEDGEMENTS

We would like to thank MSEDCL offices for providing information and data during the course of our study. We would also like to acknowledge Ms. Namita Sawant & Dr. Priya Jadhav ,CTARA,IIT Powai for guiding us throughout this survey.

## X. CONCLUSION

The surveys in Buldhana and Akola were conducted in Dec 2016. As per the survey results many farmers are in still not ready to take solar pump connection though government providing 95% subsidy through scheme. Comparison of solar pump and diesel pump is made. Solar is clean source of energy and government is focusing to implement it through different schemes. Farmers are against the Night supply provided by MSEDCL. So Solar Electrification is good alternative.

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