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Review of Solar Operated Automatic Irrigation System: Comparative Study Analysis

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Abstract: -- Agriculture plays a vital role in India's economy. Over 58 % of the rural households depend on agriculture as their principal means of livelihood and irrigation technologies are going to be point of focus in future developments.Irrigation is the procedure through which farming efficiency can be increased when deficiency of rain is there. This calls for focused attention to promote improved water management practices in irrigation projects suffering from operational deficiencies and integrated water resources development and management approach. Typical irrigation systems consume great amount of conventional energy through the use of electric motors and pumps powered by diesel. The variation of spatial and temporal distribution of available water for irrigation makes significant demand on water conservation techniques, this can be done by automation in irrigation by using solar energy which is free and able to help in reducing waste of water and time, both for farmers.

The main objective of this review paper is to present a comprehensive literature review starting from conventional irrigation system technology to the latest trends of solar power based automatic irrigation system available commercially and available in research stage. Also comparisons between solar based automatic irrigation system with existing technologies, based on various parameters like energy efficiency, feasibility, economic viability is carried out in depth & conclusions are presented in the forms of remarks.

***Index Terms*:-- solar pumps, automation, irrigation, microcontroller. moisture sensor, relay, solar panels**

I. INTRODUCTION

India has around 18 million grid connected and 7 million diesel-operated irrigation pumps. The grid based pumps consume nearly 20% of electricity which require 85 million tons of coal on an annual basis. The diesel based irrigation pumps consume 4 billion liters of diesel per annum. To be able to support the needs of the agriculture sector while simultaneously reducing its dependence on conventional energy sources like diesel and grid electricity, it is essential to explore and promote alternative energy sources for irrigation application. Solar photovoltaic (SPV) powered pumps can serve this purpose.[1]

Scarcity of electricity coupled with the increasing unreliability of monsoon rains and prevalent costly diesel pumping systems pose an economic risk to small and marginal farmers.[2] A complex set of factors including global warming, competitive land use and lack of basic infrastructure is creating new challenges for India's vast agrarian population. The ever increasing mismatch between demand and supply of energy, and electricity in particular, is posing challenges especially to farmers in remote areas. This coupled with the increasing unreliability of monsoon rains is forcing farmers to look at alternate fuels such as diesel for running irrigation pump sets. Currently, India uses 12 million grid based (electric) and 9 million diesel irrigation pump sets (C-STEP 2010).[3][4] However, the high operational cost of diesel pump sets forces farmers to practice deficit irrigation of crops, considerably reducing their yield and income. Solar water pumping systems constitute a cost effective alternative to irrigation pump sets that run on grid electricity or diesel. Solar Photovoltaic (SPV) sets constitute an environment-friendly and low-maintenance possibility for pumping irrigation water. Studies estimate India's potential for Solar PV water pumping for irrigation to be 9 to 70 million solar PV pump sets, corresponding to at least 255 billion ltr/year of diesel savings (HWWI 2005).[5] However, solar PV water pumping systems remain a rather unknown technical option, especially in the agricultural sector. They have not yet been seriously considered in agricultural planning in the country, nor has the private sector taken an active lead.

II. SOLAR PV WATER PUMPING - TECHNOLOGY OVERVIEW

A Solar PV water pumping systems is essentially an electric pump running on electricity generated by a solar photovoltaic array. Components of a solar PV water pumping system:

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1. Solar PV array: The Solar PV array is a set of photovoltaic modules connected in series and possibly strings of modules connected in parallel.

2. Controller: The Controller is an electronic device which matches the PV power to the motor and regulates the operation of the pump according to the input from the solar PV array.

3. Pump Set: Pump sets generally comprise of the motor, which drives the operation and the actual pump which moves the water under pressure.

Water pumping motors are "alternating current' (AC) or 'direct current' (DC):

1 AC Motors: AC Motors require inverters to convert DC to AC. Solar pumping systems use special electronically controlled variable frequency inverters, which optimises matching between the panel and the pump.

2 DC Motor: The DC Motors with permanent magnet are generally more efficient. DC Motors may be with or without carbon brushes. DC motors with carbon brushes need to be replaced after approximately every 2 years.[6][7]

Brushless designs require electronic commutation. Brushless DC Motors are becoming popular in the solar water pumps. Main solar water pump technologies:

1 Centrifugal Pump: Centrifugal pump uses high-speed rotation to suck in water through the middle of the pump. Most AC pumps use such a centrifugal impeller.

2 Positive Displacement Pump: The positive displacement pump is currently being used in many solar water pumps. The pump transfers water into a chamber and then forces it out using a piston or helical screw. Positive displacement pumps generally pump slower than centrifugal pumps but have good performance under low power conditions and achieve high lift. However, when operating at low power, the performance of the centrifugal pump drops dramatically [8]

***Types Of Pump*:**

1 Surface Pump: Placed besides the water source (lake, well, etc.).
2 Submersible Pump: Placed in the water source.
3 Floating pump: Placed on top of the water. Surface pumps are less expensive than submersible pumps but they are not well suited for suction and can only draw water from about 6.5 vertical meters. Yet they are excellent for pushing water over long distances.

Solar PV water pumping in India commonly uses three pumping configurations:

1. DC drives powering a brushless DC motor.
2. AC drives powering a centrifugal pump unit.
3. DC drives with brushed positive displacement pumps.

Each of the above technologies has specific features that make it suitable for particular applications. The efficiency of positive displacement pumps decreases with the shallowness of the borehole, while DC drive powering a brushless DC (BLDC) motor has the highest efficiency and least requirement for maintenance even under low power conditions. Yet, AC drives powering a centrifugal pump unit have a deep reach, are easily available, reasonably priced and can be serviced by the existing trained manpower. This explains why AC drives are the preferred choice among users and system integrators.

III. POTENTIAL FOR SOLAR IRRIGATION IN INDIA

The potential of solar PV water pumping in India is huge and the market has clearly started to develop. There are reportedly more than 12 million electric and 9 million diesel irrigation pump sets in operation. The potential has been estimated by different previous studies as below. Centre for Study of Science, Technology and Policy (C-STEP)."Harnessing Solar Energy – Options for India" (2010) estimates that 9 million diesel water pumping sets are in use in India. If 50% of these diesel pumps were replaced with solar PV pump sets, diesel consumption could be reduced to the tune of about 225 billion litres/year. As per the study conducted by HWWI, titled "CDM Potential of SPV Pumps in India" (2005) about 70 million solar PV pumps can be installed by 2020. Of these, 14 million are likely to be installed in Uttar Pradesh and 11 million in Bihar.[9] [20]

The KPMG report titled "The Rising Sun" (2011) estimates solar-powered agriculture pump sets to be approximately 16,200 MW by 2017-22. However, the potentials as mentioned above are likely to be realized

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depending upon the extent of government support and market conditions.

Previous experience:

1993-2010: MNRE – Promotion of solar PV water pumping systems for irrigation and drinking water. The first signs of a market for solar PV water pumping in India became visible in 1993-94. MNRE (then called the Ministry for Non-Conventional Energy Sources or MNES)[21] felt that the solar PV water pumping was a technically proven product and could be suitable for replacing diesel powered pumps at unelectrified locations, provided the ecosystem for the delivery of the systems was strengthened. Consequently, MNRE initiated a programme for the deployment of 50,000 solar PV water pumping systems for irrigation and drinking water across the country[10]. Key aspects of the programme were: y Objective: Commercialization of solar PV water pumping systems over a five year period across 29 states by strengthening the production base and creating the required institutional infrastructure for marketing and after sales support. y Assumption: The programme was based on the assumption that the economies of scale and technology up-gradation would drive down the costs of SPV water pumping systems, making the system economically viable. y Implementing Agencies: Indian Renewable Energy Development Agency(IREDA)and State Nodal Agencies (SNAs). y Intermediaries: Mainly non-banking finance companies (NBFCs), which procured the system from the manufacturers and channelized the financing, capital and interest subsidies from IREDA to the end users. y Financial Assistance: MNRE subsidized the capital cost of the solar pump and the interest costs. Besides channelizing this financial assistance to the end user, IREDA provided financing for the unsubsidized portion of the system costs from its own funds. In case of SNAs channelizing MNRE's financial assistance, the IREDA financing was not available to the end user. From 1993 -2000 the programme was implemented mainly by IREDA, using the NBFC intermediaries. The latter took advantage of the availability of capital subsidies, low cost financing and 100% depreciation in Year 1, in order to provide the end users the system at a concessional rate. However, after 2000 the programme was mainly implemented through the SNAs. The SNAs were able to bring in a component of subsidy from the respective state Governments. The subsidies component received through SNAs was reduced after the initial stage from Rs. 135/Wp to Rs. 100/Wp.

Ongoing Programmes

2010-2017: Jawaharlal Nehru National Solar Mission (JNNSM) With the launch of the Jawaharlal Nehru National Solar Mission (JNNSM) in 2010, the solar water pumping programme of the MNRE was clubbed with the off-grid and decentralized component of the JNNSM[11]. Key aspects of the programme are as follows: y Objective: Commercialization of solar PV water pumping systems. y Financial Support: Solar PV water pumping systems are eligible for a financial support from MNRE through a capital subsidy of 30%. Currently, the financial assistance available is 30% subsidy subject to a benchmark price of Rs. 190 per peak watt (Wp). y Private Sector Vendors: The farmers are free to procure systems from any of the empanelled manufacturers that agreed to supply the pumps as per the rate approved by the programme. These include M/s. Topsun Energy Ltd.; M/s Waaree Energies Pvt. Ltd.; M/s. Jain Irrigation Systems Ltd.; and M/s. Rajasthan Electronics and Instruments Ltd. y Results: Several states have taken up initiatives to implement solar PV Water pumping programmes using the financial assistance available under JNNSM and funds from the respective state Government budgets.[12] The states of Gujarat, Chhattisgarh, Uttar Pradesh, Maharashtra, Tamil Nadu and Bihar have programmes in their pipelines.

Technology Development

Since most of the activities in the area of solar PV water pumping systems for irrigation and drinking water have revolved around the MNRE and other Government funded/ subsidized programmes, the specifications of the system, including capacity of the pump and the size of the solar array were determined by the programme design. Hence, there has not been much innovation in this field by the private sector. Technical specifications under MNRE During the early days of solar PV water pumping in India, the 900 Wp[13] solar array with the 1HP centrifugal DC mono-block surface pump was the only approved specification. Later, falling water tables and the need for larger quantities of water for irrigation, as the pumps were mainly acquired by large farmers who had large landholdings, led to the addition of larger capacity surface pumps, submersible pumps and large solar PV arrays. During the second half of the MNRE solar PV water pumping programme, the 1,800 Wp solar PV array with the 2HP centrifugal DC mono-block surface pump and submersible pumps of 1 HP and 2 HP motors with 1200 Wp and 1800 Wp solar PV array respectively were added to the list of approved

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pumps. Under the JNNSM support for solar PV water pumping systems, MNRE has broadly specified that the capacity of solar PV array should be in the range of 200 Wp to 5,000 Wp and the capacity of the motor pump set should be 1-5 HP. MNRE specifications also allow the use of submersible pumps based on the technical need of the particular case. The table 4 below provides the indicative technical specifications provided by MNRE.[14]

Table : MNRE Indicative Technical Specifications for Surface Pumps and Submersible Pumps

Description	Model 1	Model 2	Model 3	Model 4
Centrifugal DC monoblock				
Solar PV Array	900 Wp	1,800 Wp	2,700 Wp	n/a
Motor Capacity	1 HP	2 HP	3 HP	n/a
Max. TDH*	10 mtrs.	15 mtrs.	25 mtrs.	n/a
Submersible motor with electronic controller				
Solar PV Array	1,200 Wp	1,800 Wp	3,000 Wp	4,800 Wp
Motor Capacity	1 HP	1 HP / 2 HP	3 HP	4.6 HP
Max. TDH*	70 mtrs.	70 mtrs.	120 mtrs.	160 mtrs.

*Max. TDH – Maximum Total Dynamic Head

Table-[21] Tech. specifications for pumps(www.mnre.gov.in)

Solar pumping technology has been continuously improving since the early 1980s. The typical solar energy to hydraulic (pumped water) energy efficiency was only 2% in 1980. Yet efficiency increased for PV arrays from 6-8% to 12-14% and for motor pump sets from 25% to 70% by using positive displacement pumps with high pump and power conditioning). Diaphragm pumps have an efficiency of around 45% and centrifugal pumps of 20%.[15]

IV. CHALLENGES AND SOLLUTIONS FOR GROWTH OF SOLAR PV PUMPING IN INDIA

Many factors hamper the scaling up of the Indian Solar PV water pumping market. Barriers can be market and technology related as well as of regulatory nature:

Market Related

- Higher upfront capital cost for the farmers as against to the low capital cost of conventional pumps.
- Lack of awareness about the technology and the products among consumers and other stakeholders (e.g. financial institutions).
- Lack of relevant infrastructure support, i.e. networks for market promotion and infrastructure for after-sales service.
- Danger of theft of solar modules/pumps.

Potential Solutions:

Subsidies/Innovative Finance

Solar PV water pumping systems' adoption is depending on the ease of access to subsidies and/or mechanisms to bring the costs of acquiring solar PV water pumps at par with the costs of conventional pumps. Subsidy should be based on the market price (not benchmark price), and the time lag between installation and release of subsidy should be minimized. MNRE should include solar PV water pumping systems along with other off-grid systems for which subsidies are offered through NABARD and the banking sector.

Leasing Mechanisms

Leasing out solar PV systems facilitates in developing a new revenue stream and is also suitable for small scale agricultural practices.

Innovative Consumer/ Business Finance

Need for a well-designed loan product at reasonable rates of interest and repayments linked to savings from diesel/ income from selling of crops; smart business finance for Small and Medium Enterprise (SMEs) to facilitate the entry of multiple players in this sector.

Awareness Campaigns

Inform farmers, financial institutions and other stakeholders about solar PV being a competitive option and its benefits vis-a-vis diesel powered irrigation pump sets.

Localized Service Infrastructure

Market promotion and improved local after-sales infrastructure (training of existing local pump technicians/sales outlets) to build confidence among farmers and financial institutions

Portable/Community Owned Systems and Insurance

Portable and/or community owned systems as well as an insurance mechanism can facilitate mitigation of the risk.

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Regulatory:

- Lack of market oriented policies.
- Free/highly subsidized electric power supply for agriculture
- Restrictions for innovative finance, i.e. accelerated depreciation, carbon financing etc.

Potential Solutions:

Innovative Policies and Financial Engineering

Policies, regulations and procedures are required to help the private sector innovate financially and thereby, reduce costs.

Policies for a Level Playing Field

Policies, regulations and procedures are required to create a level playing field for solar PV water pumping vis-à-vis conventional irrigation systems (electricity/diesel powered pump sets).[16]

Single-Window' Approach

For solar PV water pumping to be promoted on a large-scale, a 'single window' led by a joint 'mission' is required. All the different ministries and departments need to have a unified approach to cover the different aspects of bringing the solar PV water pumping system to the farmer.

Tenancy Reform

Agricultural management including the deployment of solar PV water pumping systems will immensely benefit from tenancy reforms.

Leasing Mechanisms

Leasing out solar PV water pumping systems will allow tapping into the market even for a short period and small-scale agricultural practices.

Group Investments

Designing a water pumping model which can be owned by a women self-help-group (SHG) or a joint liability group (JLG) (which is recognized by the banks)

Technology Related :

The 'one-size-fits-all' approach discourages research and development (R&D). Most manufacturers fail to meet the specific needs of the end user (the farmer) as their customers are the SNAs and Government programmes.

Lack of standardization and quality assurance as most system integration efforts are led by programme specifications rather than the end user's needs.

Potential Solutions:

Standardised Products that Cater to the Local Needs

Technology providers need to standardise products to minimize failures. Yet, they also need to offer different types and sizes to cater to the different market segments of farmers (surface and submersible pumps, etc.).

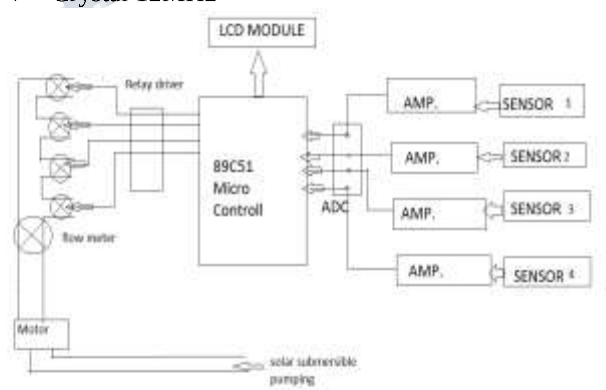
Promotion of Local Manufacturing

To decrease cost and enhance post sales services, locally manufactured BLDC motors need to be promoted.

V. POWER CIRCUIT

List of Components:

- Humidity sensor of good quality (Tensiometer - available in the market)
- Solar panel (100W,24V)
- Battery
- Microcontroller AT89C2051
- Op-amp LM324
- Transistor BC547
- Relay 12v, 100 ohm
- Motor-pump set
- Resistors, Capacitor 1uF, 33PF
- Crystal 12MHz



[2] circuit for solar powered automatic irrigation system by using microcontroller AT89C51

Working:

Above diagram shows the circuit for this project. Whole project is powered by solar panels of 200W, 24V ratting. Humidity sensors penetrated in 300-400 cm approx. depth gives signal to microcontroller to judge on condition of soil – 'Dry or wet'. Micro controller 8051 is programmed such that depending upon condition of soil, it would operate relay circuit. The signals for big land mass is taken by using more number of Humidity sensors.[17][18][7]

VI. CONCLUSION

- ❖ With the implementation of community based management, the community takes ownership of the water supply installation and becomes responsible for the operational costs. When a solar pump system is installed then the community does not collect money as there are no operational costs. This leads to a crisis when the system requires a service or replacement after a few years of operation. Hence the system of collecting a water tax seems more suitable.

- ❖ The use of batteries can be replaced by having a larger water storage system in the form of a tank. In our experience, we discovered from the local people that even in cloudy conditions, the pump was able to fill up the tank, which is a positive sign for shifting towards tank storage rather than battery storage.

- ❖ Corrosion is a major problem for the pump as well as the panel holdings. Corrosion prevention measures can be installed so that the pump casing is not corroded.

- ❖ Solar pumps do not utilize boreholes to the full extent – a borehole with a safe yield of 5m3/hour will deliver more in 8 hours when pumped with a diesel engine than with a solar pump. It is understood that tracking will provide a better utilization factor but still not the same capacity as diesel.

- ❖ The perception of the people still remains that solar pumps are high capital cost and as such are only a viable option in case of support from larger organizations like a farmer community or the government.

- ❖ Contrary to popular perception, even urban settings provide for feasible deployment of solar pumps, mainly when the quantity of water to be pumped and stored is larger in quantity, thus making it more economically feasible.

- ❖ PV water pumping technology is reliable and economically viable alternative to electric and diesel water pumps for irrigation of agriculture crops.

- ❖ PV water pumping for urban, rural and community water supplies and institutions, is another potential feasible sector but is not still widely utilized. The remote inaccessible locations with no grid electricity also need special attention. These sectors still depend on conventional electricity or diesel based pumping system resulting in increased recurring costs to the users.

- ❖ Keeping in view the high installation costs of solar water pumps especially for large irrigation and water supplies, more incentives are required to be provided by governments to make the technology further attractive alternative to diesel and electrical water pumping.

- ❖ Factors affecting the performance and efficiency improving techniques, use of highly efficient PV modules including bifacial modules and degradation of PV generator are areas for further research for lowering the cost, improving the performance and enhancing pumping system lifetime.

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