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PERFORMANCE ANALYSIS OF SOLAR OPERATED AGRICULTURE PUMP

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ABSTRACT

India is a nation comprising 638,000 villages, with over seventy percent of its population engaged in agriculture and allied activities. Unfortunately, the availability of electricity is often marred by frequent load shedding, adversely affecting crop cultivation. Moreover, in remote areas where providing electricity lines is impractical, access to sufficient water for agriculture becomes challenging.

The deployment of solar-operated pumping systems presents a viable solution to these challenges, enabling remote control of these systems. Solar-powered smart irrigation systems offer benefits such as enhancing soil fertility and reducing electricity costs for farmers. This system integrates a solar-powered water pump and serves as a proposed solution to the prevailing energy crisis faced by Indian farmers.

In the context of reducing dependence on grid power, this technology demonstrates significant electricity savings. In this research work Experimental study on the Solar operated hydraulic pump is carried out, different parameters pertaining to solar panel, charge controller, hydraulic pump is studied. In this research work solar panels of 2700 W capacity is utilised. The hydraulic pump capacity is of 3 HP used for research work which is used for pop sprinkler application. The experimental work is done between 28th January to 28th March 2022. Power produced by solar panel is almost constant between 12.00 to 2.00pm and then after reducing gradually. Even though the power varies the charge controller maintains constant rpm around 2600 form 10.00am to 4.00pm. The discharge of the pump is about 800 lit/min between the 11.00am to 2.00pm. After considering various losses, the observed efficiency of the solar panels ranges between 11% to 13.5%. Notably, the implementation of this research work results in an annual savings of Rs 58,401. Payback period for the solar pump system calculated is 2.73 years.

Keywords: Solar, Hydraulic Pump, Charge, Agriculture Application.

1. INTRODUCTION

In emerging nations like India, a pressing challenge revolves around securing a reliable source of electricity for water pumping, particularly in rural areas distant from existing grid lines. Establishing a conventional grid system often proves economically unfeasible due to the remote nature of these settlements, compounded by the lack of infrastructure like roads. Even if gasoline is abundant nationwide, its transportation to isolated rural areas presents logistical hurdles.

Renewable energy emerges as an attractive solution for water pumping applications in India's rural regions. Among these options, solar-operated photovoltaic water pumping systems stand out as a sustainable alternative to meet agricultural irrigation needs. Their transportability, especially in fragmented pieces, eases deployment in remote areas, facilitating accessibility and installation.

Recognizing that the Indian economy heavily relies on agriculture, it's crucial to acknowledge the pivotal role farmers play in both food and energy production. As vital contributors to society, farmers have the potential to generate energy from various renewable sources like wind, solar, or biomass. This energy not only sustains their own operations but can also be surplus for resale, contributing to the broader energy ecosystem.

Solar energy, being abundant and environmentally friendly, holds significant promise in addressing contemporary energy challenges. Solar panels have seen widespread adoption in diverse applications, including street lighting, water heating, and domestic power supply. The declining cost of solar panels further incentivizes their utilization across sectors, including agriculture, where they power irrigation systems.

Solar energy's compatibility with irrigation, particularly in arid regions, stems from its alignment with crop water demands. The abundance of sunlight corresponds with periods of increased water requirement, creating a symbiotic relationship between solar power availability and irrigation needs.

Various research proposals aim to enhance irrigation systems through technological advancements. For instance, Archana and Priya [1] propose a sensor-based system for controlling water supply based on plant root zone conditions. R. Subalakshmi [2] suggests automating irrigation using microcontrollers and GSM technology, providing real-time alerts based on soil moisture, temperature, and humidity. G. Parameswaran and K. Sivaprasath [3] advocate for a smart drip irrigation system incorporating IoT technology to monitor soil parameters and update irrigation status remotely. S. Reshma and B.A. Sarath [4] propose an IoT-based automatic irrigation system using wireless sensor networks, offering a web interface for remote monitoring and control. Additionally, Jaime Gutierrez [5] suggests a gateway device utilizing solar panels and cellular internet for data transmission and irrigation scheduling.

In India, where conventional agricultural systems relying on diesel, petrol, and electricity gridlines are predominant, transitioning to solar power and integrating modern technologies holds promise for sustainability and efficiency. By incorporating more parameters and leveraging modern advancements, agricultural systems can evolve to meet the evolving needs of farmers and the environment.

Numerous studies have been dedicated to improving the efficiency of water pumps by harnessing solar energy. For instance, P. E. Campana and colleagues conducted research on understanding the water requirements of various crops and determining the corresponding solar power needs [6]. Their work involved dynamic modeling and sizing of photovoltaic water pumping systems to achieve economic optimization. They found that the fluctuating water demands of crops significantly affect the sizing of these systems, and consistent water pumping efficiency is crucial for determining the optimal size of the photovoltaic array. Additionally, factors such as groundwater availability play a vital role in evaluating the effectiveness of motor-pump setups.

Another significant study by A.A. Ghoneim and team focused on a comprehensive five-parameter model, validating it with high precision within a narrow margin of 2.5% [7]. Meanwhile, Campana and Zhang explored the economic optimization of photovoltaic water pumping systems specifically for irrigation purposes [8]. They developed discrete models for various components of the system, including PV output voltage characteristics, inverter-water pumping system dynamics, crop growth patterns, and groundwater supply. Through their modeling efforts, they managed to reduce the size of the PV module significantly.

Deveci and Onkul's research provided insights into the development of cost-effective solar-powered drip irrigation models [9]. They discovered that while increased solar panel temperatures did not impact overall system efficiency, they did observe divergence in maximum power point tracking (MPPT) due to enhanced solar radiation. However, this divergence could be effectively managed through MPPT controllers. Additionally, they noted an increase in flow rate during specific times in direct-coupled PV-based water pumping systems, particularly at higher solar intensities.

Other studies, such as the work of R. Lopez-Luque and Tomas Correa with Rocha Silva, delved into similar aspects of optimizing standalone photovoltaic water pumping systems [10][11]. These researchers emphasized methods like MPPT and Minimum Loss Point Tracking (MLPT) to improve system efficiency. They found that implementing MLPT alongside MPPT could significantly boost pump output, particularly in environments with relatively constant solar radiation.

Despite these advancements, there exists a technological gap concerning water pumps. Many farmers already utilize conventional pumps for irrigation due to the financial constraints associated with specially designed solar pumps. Hence, there is an opportunity to explore the performance of existing water pumps powered by solar PV arrays. This paper aims to address this gap by presenting research comparing the performance of an existing 3-phase submersible pump when powered by both conventional and solar photovoltaic systems.

2. EXPERIMENTAL SETUP

In the current research work solar energy will be used for conservation of water by using sprinkler system. Main component used is Solar Panel, Monoblock Pump, Solar Pump Controller, Moisture Sensor, Sprinkler System. Figure1 shows experimental set up installed. The Solar Panel of capacity 2700watt generates the DC electricity supplied to the Charge controller. This Charge controller converts DC to AC, also converts this into the required format to the hydraulic pump. Charge controller maintain the voltage high so that pump will run properly.

Charge Controller is basically a voltage and current regulator, it regulates the voltage and current coming from the solar panels.

The charge controller converts high solar Output DC from Solar Panel into AC to run a standard AC 3HP Pump/Motor.

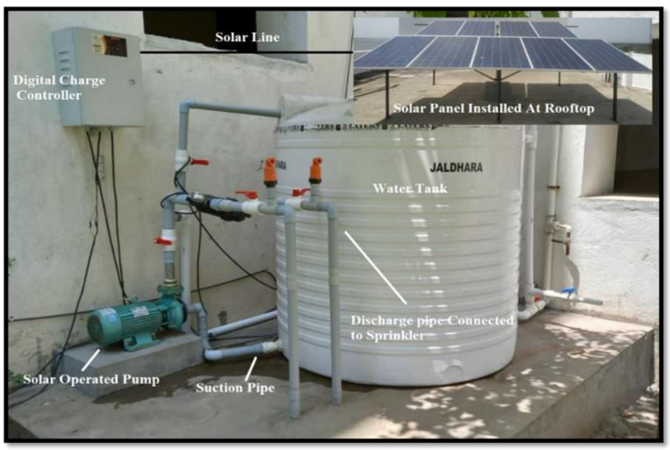


Figure 1 Experimental Set up

Figure 2 shows the layout of the pop up sprinkler system installed. These pop up sprinkler are used for lawn irrigation purpose.

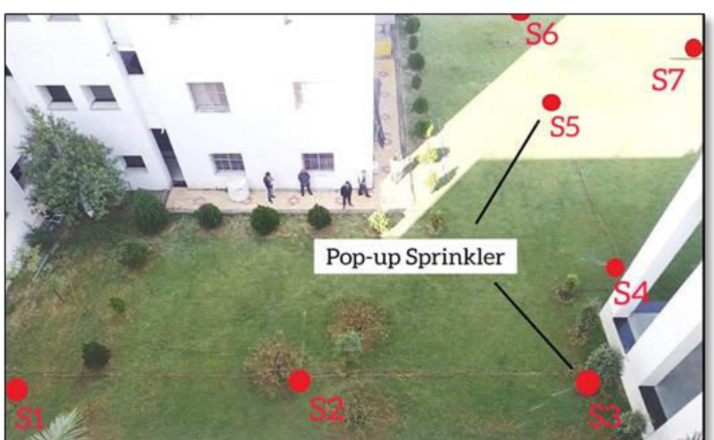


Figure 2 Layout of Pop-up Sprinkler

2.1 PERFORMANCES ANALYSIS

At Solapur location the solar panel performance is analysed at panel angle of 20°. with horizontal. Solar panel performance, Hydraulic Pump performance and cost calculation are analysed in this section.

3. SOLAR PANLE PERFORMACE

Variations in Solar Intensity

Following observation and results shows the variations of solar intensity.

Figure 3.shows that solar intensity changes with time and day. Solar intensity increases from morning to afternoon and drops from afternoon to evening. Maximum solar intensity observed between 12 Noon to 1PM.

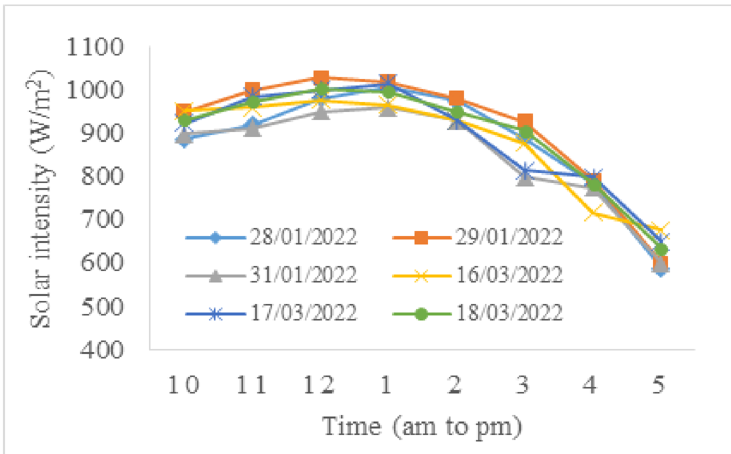


Figure 3 Variations in Solar Intensity throughout day

3.1 Current Variations

Figure 4 shows that current changes with time and day. Current increases from morning to afternoon and drops from afternoon to evening . Maximum current observed between 12 Noon to 2 PM. It is obseved on date 28/01/2022 at 12 PM, current is minimum on date 28/01/2022 at 5 PM.

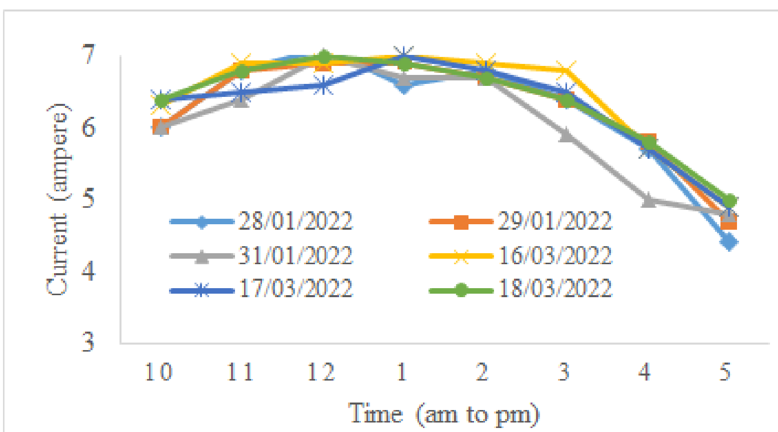


Figure 4 Current Variation throughout day

3.2 Voltage Variation

Figure 5 shows that more or less voltage remain Constant. This is because of charge controlled. Charge controller supplies constant voltage to pump. Voltage supplied it in the range 300- 320V.

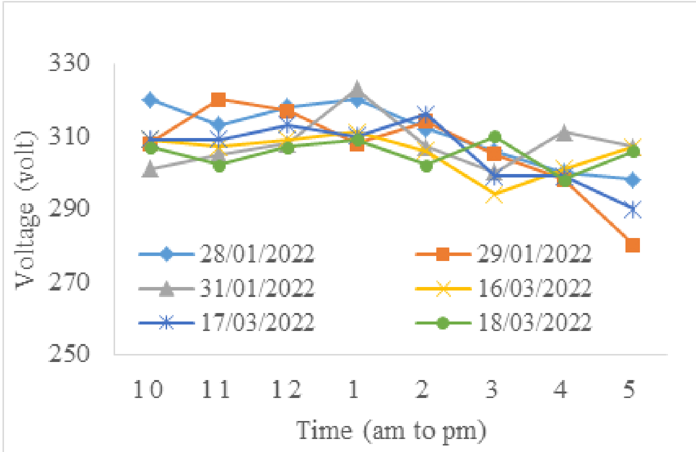


Figure 5 Variation of Voltage with Time

Variation in Power of Solar Panel

Figure 6 shows that power of solar panel changes with time and day. Power of solar panel increases from morning to afternoon and drops from afternoon to evening. Maximum power of solar panel observed between 12 Noon to 2 PM. It is observed maximum power of solar panel on date 28/01/2022 at 12PM and is minimum on the same date i.e. 28/01/2022 at 5PM.

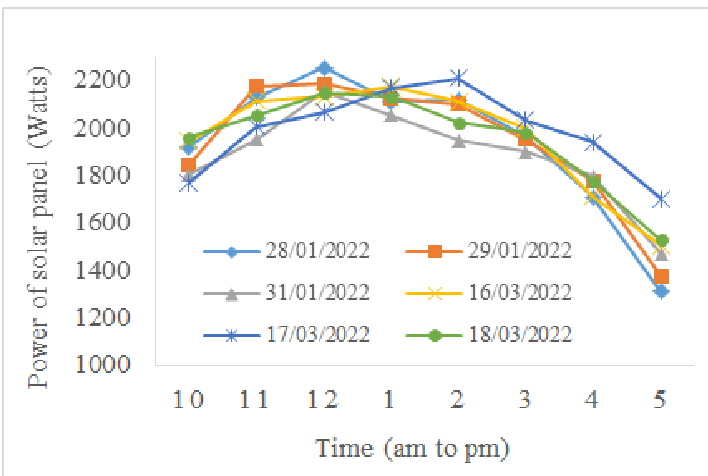


Figure 6 Variation of Power produced by Solar Panel with time

Variation in Efficiency of Solar Panel

Figure 7 shows that efficiency of solar panel changes with time and day. Efficiency of solar panel increases from morning to afternoon and remain constant in the range between 11%-13.5%. Maximum efficiency of solar panel observed between 2PM to 5PM. It is observed maximum on date 18/03/2022 at 5PM and minimum on date 28/01/2022 at 10PM.

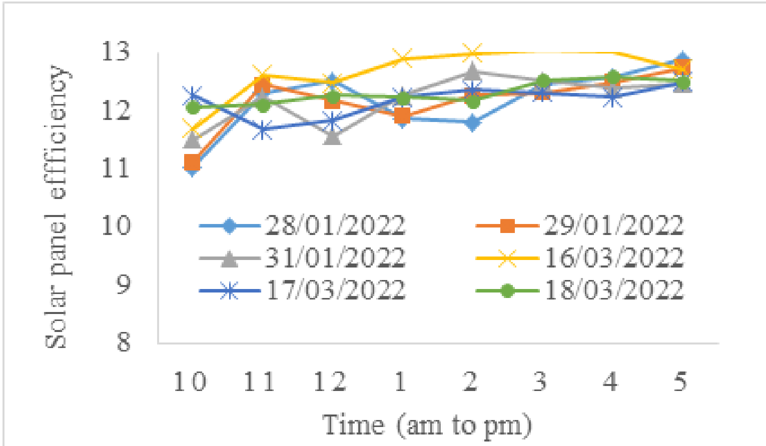


Figure 7 Variations in Efficiency of Solar Panel with time for various dates

4. TESTING OF HYDRAULIC PUMP

In this section solar panel is tested with various parameter following are the results.

Variation in RPM of Pump

Figure 8 shows that RPM of pump changes with time and day. RPM of pump remain constant from morning to afternoon in the range between 2300-2700 RPM and drops afternoon. Maximum RPM of pump on date 18/03/2022 at 3PM and minimum on date 16/03/20220 at 5PM.

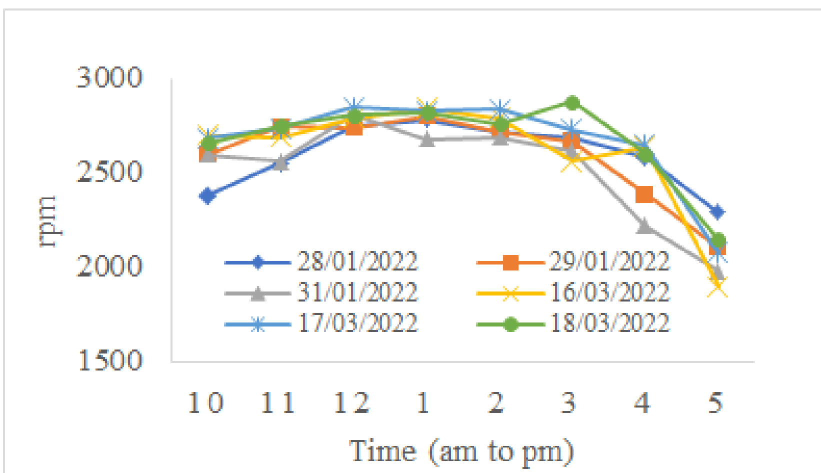


Figure 8 Variations RPM of pump with time for various dates

Variation in Discharge of Water

Figure 9 shows that discharge of water (in Litre / min) with time of day. Discharge of water increases from morning and remains constant in afternoon in the range between 700-800 and drops from afternoon to evening. Maximum discharge of water observed between 11AM to 2PM. It is observed maximum on date 17/03/2022 at 1PM and minimum on date 28/01/2022 at 5PM.

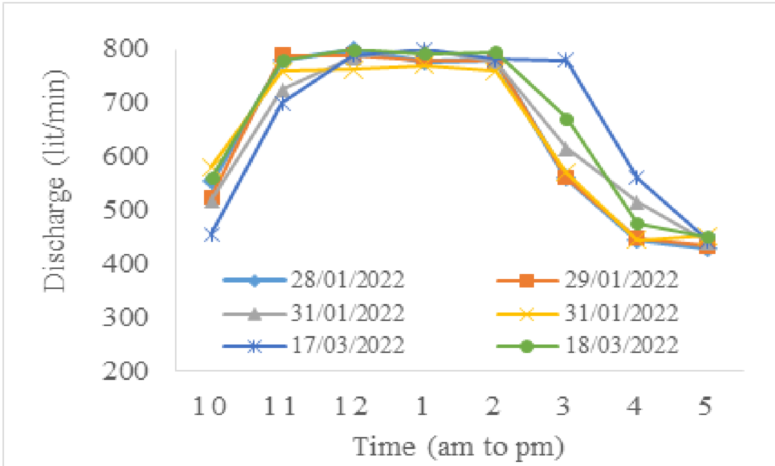


Figure 9 Variations of discharge of pump with time for various dates

5. COST SAVING RESULTS

Variation in Electrical Cost Savings Following observations and results shows the variation in electrical cost savings.

Figure 11 shows that electrical cost saving with time and day. Electrical cost saving increases from morning to evening and drops from afternoon to evening. Maximum electrical cost saving observed between 12.00 PM to 2.00 PM. It is observed maximum on date 28/01/2022 at 12.00 noon and minimum on date 28/01/2022 at 5 PM.

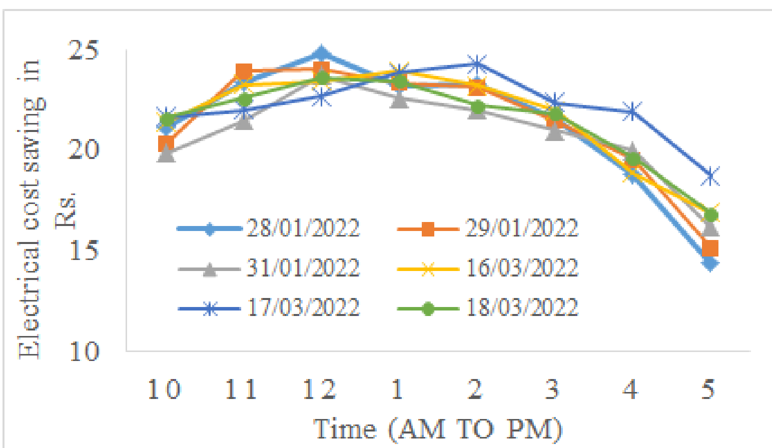
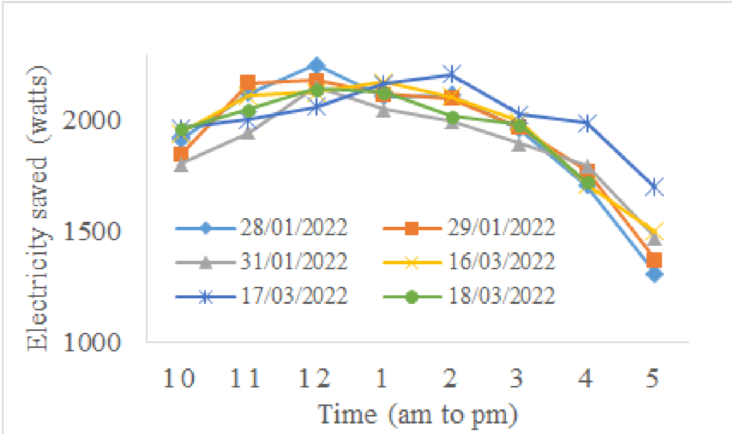


Figure 10 Cost saving with time on various dates

Variation in Electricity Saved in Watts
Following observations and results shows the variation in electricity saved in watts.

Graph 10 shows that electricity saved in watts with time and day. Electricity saved in watts increases from morning to evening and drops from afternoon to evening. Maximum electricity saved in watts observed between 12PM to 2PM. It is observed maximum on date 28/01/2022 at 12PM and minimum on date 28/01/2022 at 5PM.



Graph 10. Variations in Electricity Saved in Watts

6. PAYBACK PERIOD CALCULATION

Total Cost of Solar Operated Automatic Water Sprinkler System for Smart Agriculture is **1,60,000/-**

Pump is running pump 10 am to 5 pm

Pump specification hp/Kw = 3.0 / 2.20

1 Kw = 1000 J/S

3 hp = 2250 W = 2.25 KW

According to unit of Electricity,

1000 w = 1 Unit

2.25 w = 2.25 Unit Per Hrs.

Current 1 Unit cost Rs. 10.3/-

Considering running time = 7 Hrs

Unit calculations

07 * 2.25 = 15.75 Unit Per Day

15.75 * 30 = 472.5 Unit Per Month

01 Unit = 10.3/-

472.5 Unit = 4866.75 /-

In One Year = 4871.9*12

= 58,401/- per year

Payback Period $= \frac{\text{Initial investment}}{\text{Cash flow per year}}$

$= \frac{160000}{58401}$

= 2.73 Years

7. CONCLUSIONS

This research work will be very useful for rural area where electricity is not available or load shading is frequent. This research work set up saves 15.7 units of electricity daily. Cost saved per day is 161.7 Rs, 4871.9 Per months and 58,401 Per year. Maximum power produced by solar panels is 2257 W observed between 12 Noon to 2 PM. RPM of pump is more or less constant in the range 2300-2700 RPM. Efficiency of solar panel is observed in the range of 11%-13.5%. Maximum efficiency of solar panel observed at 2PM in the afternoon. Discharge of water increases from morning and remains constant in the afternoon in the range between 700-800 LPH and drops from afternoon to evening. Maximum discharge of water observed between 11AM to 2PM. The smart irrigation system implemented is cost effective for optimizing water resources for agricultural production. The payback period calculated is 2.73 years.

REFERENCES

1] Archana and Priya," Design and Implementation of Automatic Plant Watering System" International Journal of Advanced Engineering and Global technology, vol-04, Issue-01, Jan-2016.

2] R. Subalakshmi and Anu Amal, "GSM Based Automated Irrigation using Sensors" presented at Special Issue published in International Journal of Trend in Research and Development (IJTRD), ISSN: 2394-9333, March-2016.

3] G. Parameswaran and K. Sivaprasath," Aarduino based smart drip irrigation system using iot" presented at international journal of engineering science and computing (ijesc), ISSN no 2321 3361, Volume 6 Issue No. 5, may-2016.

4] S. Reshma and B.A. Sarath Manohar Babu," internet of things based automatic irrigation system using wireless sensor networks" presented at international journal and magazine of engineering, technology, management and research, ISSN no 2348 – 4845, vol-03, issue-09, sep-2016.

5] Joaquin Gutierrez and Juan Francisco, "automated irrigation system using a wireless sensor network and GPRS module" presented at idea transactions on instrumentation and measurement, Volume 1, Issue 10, April 2015

6] Pietro Elia Campana, Hailong Li, Jinyue Yan. J. Dynamic modelling of a PV pumping system with special consideration on water demand Applied Energy (2013), p. 11.

7] Adel Ghoneim, "Design optimization of photovoltaic powered water pumping systems", Energy Conversion and Management 47(11-12):1449-1463.

8] P. E. Campana, H. Li, J. Zhang, R. Zhang, J. Liu, J. Yan, "Economic optimization of photovoltaic water pumping systems for irrigation", Energy Conversion and Management 95(2015), pp. 32-41.

9] Onur Deveci, Mert Onkol, Hakki Ozgur Unver, Zafer Ozturk., "Design and development of a low-cost solar powered drip irrigation system using Systems Modeling Language, " Elsevier Ltd. (2015), pp.1-32.

10] R. Lopez-Luque, J. reca, J. Martinez., J, Optimal design of a standalone direct pumping photovoltaic system for deficit irrigation of olive orchards, Applied Energy 149 (2015), pp. 13-23.

11] Tomas Perpetuo Correa, Seleme, Issac Seleme Jr, Selenio Rocha Silva., Efficiency optimization in stand-alone photovoltaic pumping system, J. Renewable Energy41(2012), pp. 220-226.

12] Bureau of Indian Standards, IS14153 (1994), pp. 1-8.