

**DEVELOPMENT AND PERFORMANCE EVALUATION OF A
SOLAR POWERED LOW HEAD PORTABLE PUMPING
SYSTEM**

M.Tech (Agril. Engg.) Thesis

by

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INDIRA GANDHI KRISHI VISHWAVIDYALAYA,
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SOLAR POWERED LOW HEAD PORTABLE PUMPING
SYSTEM**

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidhyalaya, Raipur

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Nomita Verma

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THE DEGREE OF**

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CERTIFICATE -I

This is to certify that the thesis entitled "**Development and Performance Evaluation of a Solar Powered Low Head Portable Pumping System**" submitted in partial fulfilment of the requirements for the degree of "**Master of Technology in Agricultural Engineering**" of Indira Gandhi Krishi Vishwavidhyalay, Raipur, is a record of the bonafide research work carried out by **Nomita Verma** under my/our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or certificated course. All the assistance and help received during the course of the investigations have been duly acknowledged.


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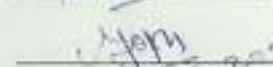
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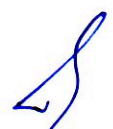
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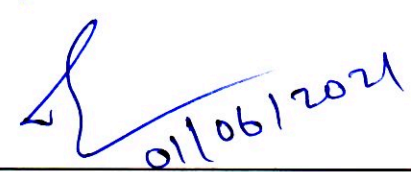
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TABLE OF CONTENTS

Chapter no.	Title	Page no.
	ACKNOWLEDGEMENT	i
	TABLE OF CONTENTS	iii
	LIST OF TABLES	vi
	LIST OF FIGURES	vii
	LIST OF SYMBOLS	ix
	LIST OF ABBREVIATIONS	x
	THESIS ABSTRACT	xi
I	INTRODUCTION	1-3
II	REVIEW OF LITERATURE	4-13
	2.1 General	4
	2.2 Utilization of Renewable source of energy	6
	2.3 Development of PV pump	7
	2.4 Performance evaluation of solar powered pump	10
	2.5 Comparison of PV Pump with other pumping system	13
III	MATERIALS AND METHODS	15-41
	3.1 Site selection	15
	3.1.1 Experimental site	15
	3.1.2 Geographical situation	15
	3.2 Climatic condition	15
	3.3 Design considerations	17
	3.3.1 Physical and economical consideration	17
	3.3.2 Functional requirement	17
	3.4 Design parameters	17
	3.5 Materials required for development of pumping system	18
	3.5.1 Solar panel (PV)	18
	3.5.2 Pump	21
	3.5.3 Storage battery	23

3.5.4 Charge controller	25
3.5.5 Inlet pipe	26
3.5.6 Joints/ Connector	27
3.5.7 Outlet pipe / Main pipe	28
3.5.8 Filter box	29
3.5.9 The water sources	30
3.6 Installation of solar powered water pumping circuit diagrams	30
3.7 Working principle	31
3.8 Line diagram of installation of the developed system	31
3.9 Performance evaluation of developed low head solar powered water pumping system	32
3.9.1 Measurement of total head	32
3.9.2 Measurement of total horizontal distance	34
3.9.3 Determination of total discharge	35
3.10 Testing of the developed system	36
3.11 Cost analysis of developed system	36
3.11.1 Composition of cost of installation	36
3.11.2 Total life in hours and years	37
3.11.3 Annual fixed cost	37
3.11.4 Variable Cost	39
3.11.5 Total cost of operation	40
3.12 Cost Economics	40
3.12.1 Comparison of solar water pumping system with diesel pumping system	40
3.12.2 Comparison of solar water pumping system with electrical pumping system	41
3.12.3 Comparison of solar water pumping system with human powered water pumping system	41

IV	RESULTS AND DISCUSSION	43-51
	4.1 Development of solar powered low head portable water pumping system	43
	4.2 Performance evaluation of developed pumping system	45
	4.2.1 Measurement of discharge rate at different total head for one pump	46
	4.2.2 Measurement of discharge rate at different horizontal distances for one pump	47
	4.2.3 Measurement of discharge rate at different total head for combination of five pumps.	48
	4.2.4 Measurement of discharge rate at different horizontal distances for combination of five pumps.	50
	4.3 Cost economics of solar powered water pumping system	51
V	SUMMARY AND CONCLUSION	53
	REFERENCES	56
	APPENDICES	59
	Appendix A	59
	Appendix B	61
	Appendix C	64
	RESUME	66

LIST OF TABLES

Tables	Particulars	Page no.
3.1	Raipur weather by month (weather averages)	16
3.2	Technical specification of solar panel used in this system	21
3.3	Specification of selected submersible pump	22
4.1	Testing of single pump discharge rate at different total head	46
4.2	Testing of one pump discharge at 1m constant total head and different horizontal distance	47
4.3	Testing of discharge rate at different total head for combination of five pumps	49
4.4	Testing of discharge rate at constant total head (1 m) and different horizontal distances for combination of five pumps	50

LIST OF FIGURES

Figure	Particulars	Page no.
3.1	Graph between temperature ($^{\circ}$ c) and months	16
3.2	100 watt solar panel use for study	20
3.3 (a)	DC Submersible pump used for study	22
3.3 (b)	DC Submersible Pump installed in the water source	23
3.4	Lead Acid Storage Battery	24
3.5	12V, 10A Charge Controller Used in this study	25
3.6	5m Inlet Pipe used for making a parallel combination of pumps	26
3.7	Jointer for making a parallel combination of pumps	27
3.8	Outlet pipe for handling the combined discharge of pumps	28
3.9	Filter Box (approx. 5 litre capacity)	29
3.10	Water Source (KVK Nallah field)	30
3.11	Line diagram of installation of the developed system	31
3.12	Total Dynamic Head (TDH) of submersible water pump	32
3.13	Block diagram of arrangements of main pipes and laterals with micro sprinkler in the field	34
3.14	Actual field area with two row of laterals.	35
3.15	Determination of discharge rate in KVK field using volumetric method	36

4.1	Schematic Diagram of solar operated water pumping system	44
4.2	Developed low head solar powered pumping system	45
4.3	Relationship between total head and discharge rate for a single 12 V/8 Watt DC submersible pump used in the study	46
4.4	Relationship between different horizontal distances and discharge rate	48
4.5	Relationship between different total head and discharge rate for five pumps	49
4.6	Relationship between different horizontal distance and discharge rate for five pumps	51

LIST OF SYMBOLS

Symbol	Description
mm	Millimetre
cm	Centimetre
m	meter
%	Percentage
i.e.	that is
h	Hour
kg	Kilogram
^o C	Degree Centigrade
Rs.	Rupees
viz.	Namely
wh	Watt hour
≈	Approximately equal to
hp	horse power
V	Volt
DC	Direct Current
PV	Photovoltaic
lph	Litre per hour
lpd	Litre per day
kWp	Kilo Watt Power
Ah	Ampere hour

LIST OF ABBREVIATIONS

SVCAET&RS	Swami Vivekananda College of Agricultural Engineering and Technology & Research Station
M. Tech.	Master of Technology
ICAR	Indian Council of Agricultural Research
IGKV	Indira Gandhi Krishi Vishwavidhyalaya
Engg.	Engineering
et al.	et alia
etc.	Et cetera
KVK	Krishi Vigyan Kendra
CREDA	Chhattisgarh Renewable Energy Development Agency
PVWP	Photovoltaic Water Pumping

THESIS ABSTRACT

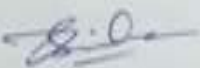
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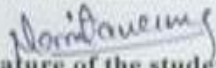
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Date 26/02/21


Signature of head of the department

ABSTRACT


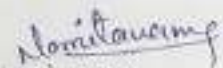
The study is undertaken to develop a solar powered low head portable pumping system followed by its performance evaluation. Testing of discharge rate of developed system with a different total head and different horizontal distances was done. The solar powered water pumping system is mainly designed for small-field irrigation, with replacement of traditional system that allows use of natural energy i.e. exhaustible and not environmental friendly. The main reason for

making use of solar system is because it is environment friendly, abundance in nature, minimal operating cost, easy to use technology and portability in many cases. Solar system is of prime importance in hilly regions where, the cost and troubles of transmission is too high. The cost of solar powered water pumping system is less as compared to other traditional systems. A solar water pumping system is developed and tested at KVK nallah field and satisfied results are obtained.

The developed pumping system consists of solar panel, DC submersible pump, storage battery, charge controller, switch, inlet pipe, outlet pipe, jointer/connector and a filter box. Solar panel of 100 W, 18.06V and DC submersible pump of 8 W, 12 V was taken for the project. Lead acid storage battery of 12 V, 10 A was taken and used when there are cloudy weather. Combination of five DC submersible pumps was taken and each pump was connected to inlet pipe of 0.5 inch diameter. Inlet pipe was then connected to one outlet pipe with the help of jointer. All five pumps were placed in a plastic box and many small holes were made in box which now acts like filter box. Mud, sands, algae were filtered with the box and clean water goes to pump. The total cost of developed system is Rs. 11700. Maintenance of the developed system is low, only solar panel should be well maintained.

Testing of system was done at different total heads and different horizontal distances and discharge rate was calculated. The discharge rate of single pump at total head 1 m and 3.5 m was found 558.4 lph and 277 lph respectively and at constant total head 1 meter and horizontal distance 5 m and 30 m discharge rate was 560 lph and 216 lph respectively which are found to be low for irrigation in the agriculture field. So, parallel connection of five pumps setup has been developed. The discharge rate for combinations of five pumps at total head 1 m and 3.5 m was found 2730 lph and 1230 lph and at constant total head 1 m and horizontal distances 5 m and 30 m discharge rate was found 2720 lph and 1193 lph. Discharge was taken constant and cost economics to discharge the taken amount of water was calculated. At the 2 meter total head and 25 meter horizontal distance, the total discharge (lph) by the developed pump is near by 1850 lph and 14800 l/day. Total cost of irrigation was calculated as Rs. 14.09 per day which is

very low as compared to diesel, electrical and human power pumping system. Total cost of irrigation was found 78.07 Rs/day with diesel powered pumping system (3 hp), 17.69 Rs/day with electrical powered pumping system was and 454.64 Rs/day with human powered gym cycle operated pumping system.

शीर्षक शीर्षक का नाम	सारांश
छात्रों का नाम प्रमुख विषय मुख्य सलाहकार का नाम व पता	शीर ऊर्जा घलित निम्न शीर्ष की पोर्टेबल पंपित प्रणाली के विकास और प्रदर्शन के मूल्यांकन नोमिता वर्मा मुदा एवं जल अभियांत्रिकी डॉ. जितेन्द्र सिन्हा सहा-प्राध्यापक (मुख्य-सलाहकार) मुदा एवं जल अभियांत्रिकी स्वामी विवेकानंद कृषि अभियांत्रिकी एवं प्रौद्योगिकी महाविद्यालय एवं अनुसंधान केंद्र रायपुर इंदिरा गांधी कृषि विश्वविद्यालय रायपुर, छत्तीसगढ़ कृषि अभियांत्रिकी में स्नातकोत्तर (मास्टर ऑफ टेक्नोलॉजी) मुदा एवं जल अभियांत्रिकी
पूर पता	
उपरोक्त से सम्बन्धित किया जाना है।	
 मुख्य सलाहकार के हस्ताक्षर	 छात्रों के हस्ताक्षर
दिनांक 26.02.21	विभागाध्यक्ष के हस्ताक्षर

सारांश

शीर ऊर्जा घलित निम्न शीर्ष की पोर्टेबल पंपित प्रणाली के विकास और प्रदर्शन के मूल्यांकन के लिए किया गया है। इसमें अलग-अलग कुल शीर्ष और अलग-अलग क्षैतिज दूरी के एक विकसित प्रणाली के निर्वाह दर का परीक्षण किया गया है। शीर ऊर्जा संचालित पंपिंग प्रणाली को मुख्य रूप से छोटे पैमाने पर सिंचाई के लिए विकसित किया गया है। जो पारंपरिक प्रणाली में प्राकृतिक ऊर्जा के प्रतिस्थापन के साथ उपयोग किया जा सकता है, जो पर्यावरण के अनुकूल है। शीर ऊर्जा स्रोत को लागू करने की मुख्य कारण इसकी प्रचुर मात्रा में उपलब्धता है और यह किसी अन्य ईंधन संसाधनों की तुलना में अधिक अस्थिर है। शीर ऊर्जा घलित पंपिंग

प्रणाली को पहाड़ी की तुलना में सौर ऊर्जा संचालित पंपों की लागत कम है। सौर संचालित पंपिंग प्रणाली का कृषि विज्ञान केन्द्र (के.वि.के.) रायपुर के नाले के क्षेत्र में परीक्षण किया गया, और परीक्षण के दौरान संतोषजनक परिणाम प्राप्त हुए हैं।

विकसित पंपिंग प्रणाली में एक 100 वॉट सोलर पैनल, 8 वॉट डी.सी. सबमर्सिबल पंप, स्टोरेज बैटरी, 12 वोल्ट चार्ज कंट्रोलर, स्विच, इनलेट पाइप, मेन पाइप, ज्वाइंटर, कनेक्टर और फिल्टर बॉक्स शामिल हैं। 100 वॉट का सोलर पैनल (18.06 वोल्ट) और 8 वॉट का डी.सी. सबमर्सिबल पंप (12 वोल्ट) प्रयोग के लिए लिया गया था। 12 वोल्ट की लीड एसिड स्टोरेज बैटरी ली गई थी और प्रत्येक पंप 0.5 इंच व्यास के इनलेट पाइप से जोड़ा गया था। इनलेट पाइपों को एक ज्वाइंटर की मदद से एक आउटलेट पाइप में जोड़ा गया था। सभी पांच पंपों को एक प्लास्टिक बॉक्स में रखा गया था और बॉक्स में कई छोटे छिद्र किये गये थे जो एक फिल्टर बॉक्स की तरह काम करता है, और कीचड़, रेत, शैवाल को फिल्टर बॉक्स की मदद से फिल्टर किया जाना और साफ पानी पंप में जाता था। जिससे पंप सुरक्षित रहता है और खराब नहीं होता।

प्रणाली का परीक्षण विभिन्न कुल शीर्षों पर किया गया और विभिन्न क्षैतिज दूरी और निर्वहन दर की गणना की गई थी। कुल शीर्ष और 3.5 लीटर पर एकल पंप का निर्वहन दर क्रमशः 558.4 लीटर प्रति घण्टे और 277 लीटर प्रति घण्टे है। कुल शीर्ष 1 मीटर और क्षैतिज दूरी 5 मीटर और 30 मीटर का निर्वहन दर 560 लीटर प्रति घण्टे और 216 लीटर प्रति घण्टे पाया गया जो कि कृषि क्षेत्र में सिंचाई के लिए कम प्रतीत हुई इसलिए प्रवाह दर को बढ़ाने के क्रम में पंपों की प्रणाली तैयार किया गया। कुल शीर्ष 1 मीटर और 3.5 मीटर पर पांच पंपों के संयोजन के लिए निर्वहन दर 2730 लीटर प्रति घण्टा और 1230 लीटर प्रति घण्टा और कुल शीर्ष 1 मीटर और क्षैतिज दूरी 5 मीटर और 30 मीटर के लिए निर्वहन दर 2720 लीटर प्रति घण्टा और 1193 लीटर प्रति घण्टा पाया गया। इस प्रणाली के विकास की कुल लागत 11700 रुपये थी। निर्वहन दर को निरंतर लिया गया और पानी की ली गई मात्रा का निर्वहन करने के लिए लागत की गणना की गई। 2 मीटर कुल शीर्ष और 25 मीटर क्षैतिज दूरी पर, विकसित प्रणाली द्वारा कुल शीर्ष का निर्वहन प्रति दिन 1850 लीटर प्रति घण्टा और 14800 लीटर प्रति घण्टा के पास है। सिंचाई की कुल लागत की गणना 14.09 रुपये प्रति दिन की गई जो डीजल एवं बिजली और मानव शक्ति जिन चक्र संचालित पंपिंग प्रणाली की तुलना में बहुत कम है। डीजल चलित पंपिंग प्रणाली (3 अश्वशक्ति) 78.07 रुपये प्रति दिन के साथ, विद्युत संचालित पंपिंग प्रणाली के सिंचाई की कुल लागत 17.69 रुपये प्रति दिन और मानव शक्ति जिन चक्र संचालित पंपिंग प्रणाली के साथ 454.64 रुपये प्रति दिन है।

CHAPTER I

INTRODUCTION

There is an abundance of solar energy. Solar energy is readily available. No other renewable energy source is like solar energy. Solar energy is a solution to the today's energy shortages and also provides energy-friendly climate. Photovoltaic generation is a powerful approach to the solar energy usage. A series of photovoltaic cells, called solar panel are now widely used anywhere and everyday to operate power water heater, to run street lights and to cope with domestic loads. Solar panel costs have been steadily decreasing, promoting their usage in various industries. One of the applications of this technology is used in the production of agricultural irrigation systems.

In India, solar energy operated irrigation systems can be a suitable alternative for farmers in the current state of energy crisis. The solar-powered pumping system can be used anywhere, but it is suitable for rural areas which are already facing energy shortages in particular. This is a green way to produce energy that, after an initial investment is made, provides free energy. These would be done for conservation of electricity and take a proper utilization of sun rays for producing energy. India has sunlight throughout the year due to its geographical position, making it a perfect location for the use of solar energy. Hydraulic output power of less than a kilowatt is required for small farms, villages, and animal herds in developing countries.

For lifting water from nallah, river, pond also which is nearby the small farms, users can utilise the solar energy as the form of electricity by the solar panel. Solar energy not only serve for lifting water through pumping system but it is also used for multi purposes like maize shelling, heating water and also lighting of the room. The pumped water flow rate depends on the solar radiation incident and on the size of the photovoltaic (PV) series. A properly engineered PV system results in significant long-term cost savings as opposed to traditional pumping systems. In addition, in place of battery requirements for electricity storage, tanks can be used for water storage. The solar powered automated irrigation system

offers a sustainable solution for improving the efficiency of water use in agriculture using a renewable energy system that eliminates the workmanship needed for floating irrigation. In order to avoid environmental degradation and to promote the production of electricity from local resources, renewable energy is used.

A solar water pump can prove to be a reliable and efficient source of water for a farm during the summer time or during the time when sun rays are very intense, the water requirement is very high. For farmers, a solar water pump is an useful technique. They can efficiently deliver water from rivers, lakes, ponds etc. using this pump. When using a solar water pump rather than a fuel-powered pump, farmers and zealous gardeners can save on their irrigation budget.

Over the past decade, the need for the efficient use of water and energy resources has become a vital issue and will become more important in the future. The availability of Renewable Energy Sources (RESs) such as solar photovoltaic, solar thermal, wind, biomass and various hybrid forms of energy sources provides best alternatives for energy related problems in India. The concept of integrating RESs, such as solar photovoltaic, with water pumps has been suggested by several researchers around the world to meet energy demands and reduce the environmental impact.

In rural areas the most common useful is a electrical motor pump set and the most common problem associated with this electric motor pump set is heating of the copper coil as a results of which copper coil gets burnt and the farmers and users really suffered lot. Because of this overheating and burning of coil so often they have to visit to the nearby technician or to the city to get it repaired. Many of these potential consumers are too far from the electricity grid to access the power source economically, and because of the high cost of imported fuel and inadequate maintenance and repair capacities, engine-driven pumping appears to be prohibitively costly as well as unreliable.

There are about 37.46 lakh farm families in Chhattisgarh state, with around 76% farmers residing under the small and marginal category of farmers (Source:-

Directorate of Agriculture, Chhattisgarh Raipur). Many of them are involved in Badi system of cultivation, growing vegetables utilizing shallow water or surface water. On the other hand Chhattisgarh Renewable Energy Development Agency (CREDA) is providing solar pump set in the range of 3hp and 5hp but not in the range of that marginal farmers need.

The home stead garden (0.2 ha.) locally known as 'Badi' covers 5% area of total area of Chhattisgarh. The soil of badi are entisols and inceptisol, fenced, upland and sloppy. Each badi contains one shallow dug well. Most of the farmers having badi in their backyard and they use to practice vegetable farming for their own consumption. It was found that other pumping systems are so costly and non affordable for small farmers and also a lot of maintenance required so they use human power for irrigation. So it was realized that a kind of solar powered system should be developed where upon the same panel can be used for water pumping and other requirement of the farmers.

As per small and marginal farmer requirements and keeping cost in the mind, low head portable pumping system has developed by using materials which is easily available. The developed system is of low cost than 3hp & 5hp solar pumping system.

Keeping all these points in the mind, the present study is proposed with following objectives:

Objectives:

1. Development of a solar powered low head portable pumping system.
2. Performance evaluation of the developed system.
3. Cost economics of developed pumping system.

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with the past research work done in the most relevant topic of our research. The information of published work on solar powered pumping systems used for irrigation or other pumping systems discussed in this chapter.

The review and information related to the study are presented under the following heads:

- General
- Utilization of Renewable source of energy
- Development of PV pump
- Performance evaluation of solar powered pumping system
- Comparison of PV Pump with other pumping system

2.1 General

Campana *et al.* (2014) designed a PV water pumping system for irrigation equipped with a novel control system for water savings. The control unit interacts between water demand and supply. In addition, the novel control scheme replaces the traditional safety approach with a strategy based on accessibility and reaction to ground water supplies. The developed system is a solution for water saving. The monthly average daily crop water requirements are equivalent to 50 m³ /day and the system is shut down once the requirement is met with. The PVWP system without a control system works indiscriminately and results in high water consumption. Using the devised control system, 75% of the water can be saved. The novel management method can make use of the surplus power produced both in on- and off-grid applications by PVWP systems. The new control system results in both water savings and energy usage optimization.

Maurya *et al.* (2015) searched for sustainable solution enhancing water use efficiency in irrigation and opinioned the photovoltaic solar powered water pumping system as one of the friendly solution as it can operate the automatic irrigation system. Tracking arrays can be introduced to enhance the regular pumping rates and overcome the problem associated with scattered irrigation points that too without an electric grid. It provides energy for the pumping requirements for sprinkler irrigation. Compared to diesel-powered pumping systems, the cost of the non-subsidized solar PV water pumping system was found to be 64.2% of the cost of a diesel pump over a 10-year life cycle. In the range from 5 m to > 200 m head and with outputs up to 250m³/day, solar pumps are available for pumping from anywhere. Photovoltaic pumps are usually economical compared to diesel pumps of up to approximately 3kWp for water supply in the village and to around 1kWp for irrigation.

Anoop and Reema (2017) conducted their research on evolution of solar powered water pumping system. Agriculture is one of the most essential processes that ensure humanity's long-term viability. Agriculture's scientific progress has a direct impact on the country's economic and overall growth. Increased agricultural production would be aided by the implementation of improved irrigation methods. Solar water pumping was a major innovation in irrigation. There are several areas where irrigation cannot depend on electricity or other currently available options. Solar Water Pumping is an excellent solution in such conditions. For limited, remote applications, photovoltaic power is cost-competitive with conventional energy sources. Photovoltaic power will become more cost-competitive and popular in the future as fossil fuel prices increase and the mass production of photovoltaic cell gives advantage, to reduce the cost of electricity in terms of peak watt cost, economically. The solar water pumping system is a project that is good for the environment and sustainable world.

Biswas *et al.* (2018) utilized the data from an existing project located in Lalmonirhat, Bangladesh and developed a dynamic model for solar water pumping system having energy storage. The system components comprises of a photovoltaic solar power array of 38.4 KW, a pump with discharge capacity of 1,930 m³ of

water each day, an inverter and an AC motor. The modeling and simulation was carried out using MATLAB software, making use of two different types of energy storage system as given below:

- (i) Electricity by means of a battery bank and
- (ii) Water collected in a big tan water tank.

2.2 Utilization of renewable source of energy

Malhotra (1984) examined the potential of renewable sources of energy in Indian arid zone for pumping irrigation water and worked out the energy requirement. Depending on the size of the plot under cultivation, proposals have been made for energy alternatives to pump water for small, marginal and large farms. Solar cell pumps are suitable for small and marginal farms, windmills for small farms and a mixture of these two, or biogas engines, for large-scale farms.

Singh and Mishra (2015) carried a study in utilization of Solar Energy for Driving a Water Pumping System. They proposed the solar water pumping system has long existence and it is free of maintenance. PV is getting pervading than ever with increasing efficiency and decreasing module cost of PV. Firstly solar energy is converted in to electrical energy and then electrical energy which drives the motor pump is converted into mechanical energy which delivers the water from source tank to delivery tank. Solar energy can also applicable in water supply for drinking and village use, livestock watering, process industry and irrigation.

Singh and Garg (2015) carried a study in scope of development of Photovoltaic Water Pumping System for Rural Irrigation. In the rural areas where high irrigation cost is the major issue, PVWP system is a cost effective application. For irrigation of fields and orchards the photovoltaic system can be helpful to meet the demand of water in rural areas. The life cycle cost (LCC) analysis also conducted to determine the system's economic viability. The installed solar PVWP system has various components i.e. solar panel, controller and DC submersible motor. Solar DC Pump is an Integral product of it. In terms of productivity, cost effectiveness, and reliability the PVWP system has very good performance. It

improves the water supply to livestock, pump water, cost effective and eco-friendly way in remote locations.

Tambe and Parashar (2017) conducted their studies on solar powered irrigation system. Solar water pumping based on photovoltaic (PV) technology that converts light energy into electrical energy and helps to run a DC or AC motor based water pump. In Drip irrigation system with solar energy, it shows efficient work and reduced losses of water and cost of commercial energy about 90%. it requires only 2 solar panel to irrigate 1 acre of land. The cost of the solar panel was 39160/- as installation cost and 1000/- maintenance cost. It will be sufficient for cultivation area of 1 acre at 53.79 Watt. The Battery with the solar panel gives a backup of 2-4 days. The maintenance cost of Drip irrigation system is low and is reliable for 4-5 year.

2.3 Development of PV pump

Pande *et al.* (2003) designed and developed a PV pump operated drip irrigation system for arid regions. A PV pump operated drip irrigation system for arid regions was planned and built. Due to changes in irradiance and pressure compensation in the drippers, they considered distinct design parameters such as pump capacity, water demand, and diurnal variation in pump pressure. After the development, authors stated that a photovoltaic device (900 W Power PV array, 800 W DC motor-pump mono-block) can supply 70-100 kPa pressure on the delivery side during different hours of the day with a discharge of 3.4-3.8 l/h from each dripper. The emission uniformity was found to be 92-96 percent in the overall area of 1 ha. It is proposed that testing PV water pumping systems is important. It is proposed that PV water pumping systems for water harvesting tanks with lower suction heads for rising orchards in arid regions need to be tested on a large scale.

Ghoneim (2005) conducted research on design optimization of photovoltaic powered water pumping systems. The PV collection, DC motor, centrifugal pump, a storage tank that serves a similar function to battery storage, and a maximum power point tracker to increase the system's efficiency are all part of the direct coupled photovoltaic water pumping system tested. The pumped water would be used to meet the needs of 300 people in a remote part of Kuwait. Assuming a daily water consumption rate of 40 litres per person, a total volume of 12 m³ should be

pumped daily from a deep well throughout the year. To determine the output of the proposed system in the Kuwait environment, a computer simulation programme is being created. A PV array component model with maximum power point tracker, as well as component models for the DC motor and centrifugal pump, is included in the simulation software. The efficiency of amorphous silicon solar cell modules is simulated using a five-parameter model. To achieve the best performance for the proposed system, the size of the PV array, PV array orientation, and pump–motor–hydraulic system characteristics are varied. To determine the economic feasibility of the optimised photovoltaic driven water pumping system, the life cycle cost approach is used. The proposed photovoltaic driven water pumping system is found to be less costly than the expense of the traditional fuel system at current PV module rates. Furthermore, the anticipated decrease in photovoltaic module prices in the near future would make water pumping systems powered by photovoltaic technology more feasible.

Raghav *et al.* (2013) conducted their research on design of solar power based water pumping system. They designed a solar powered water pumping system mainly for irrigation purpose for farmers in today's scenario with high power cuts and less rainfall. They Installed a 1.5 KW solar powered pumping system and found high initial cost Rs.143250 for 1.5 KW means 1.5 units. The Module costs represent only 40-60% of total solar system cost and the remaining is accounted by inverter, PV array support, electrical cabling and installation. The payback period for the system in place of traditional system was calculated and found that If Rs. 5.50 taken for unit thus payback period is 7 years 13 years of profit and If Rs. 3.50 taken for unit payback period is 9.6 years 10 years profit.

Hossain *et al.* (2014) designed solar pump irrigation system for green agriculture. In various locations, four solar pumps (submersible form, 1,050 W power) have been installed to irrigate rice, wheat and vegetables. The solar pumps were used during the 2010-2011, 2011-2012 and 2012-2013 winter seasons for drip irrigation and furrow irrigation for the cultivation of brinjal and tomatoes. In Gazipur in 2010-2011, and in Jamalpur in 2011-2012, there were no major variations in the yields of brinjal between drip and furrow irrigation. In 2012-2013, however, the yield of brinjal from drip-irrigated plots (43.9 t/ha) was significantly

higher compared to furrow-irrigated plots (38.6 t/ha). In Jamalpur, in terms of tomato production, there was no major difference between drip and furrow irrigation methods. Tomato yields from drip irrigated plots in Gazipur were significantly higher than those from furrow irrigated plots in both 2011-2012 and 2012-2013. Water savings for Brinjal and tomato were 53.3 percent and 56.2 percent respectively by drip irrigation over furrow irrigation. The summer tomato yield in the drip-irrigated plot was 33.7 t/ha while in the furrow-irrigated plot it was 31.9 t/ha during 2011-2012. The summer tomato water requirements for drip and furrow irrigation methods were 225 mm and 429 mm, respectively. Approximately 430 mm of water was required for wheat cultivation and the yield was 3.0 t/ha. During 2011-2012 and 2012-2013, Boro rice was cultivated in Magura and Barisal district. The total water requirement for Boro rice cultivation during the cropping season was 1,024 mm in Magura and 1,481 mm in Barisal. The use of solar pumps was found to be economical for the production of wheat (BCR 2.31), tomato (BCR 2.22) and brinjal (BCR 2.34), but not for the production of boron rice (BCR 0.31). Solar pumps can be promoted for the production of non-rice crops as an environmentally sound and renewable technology.

Girish et al. (2016) designed and developed water lifting device based on impulse using the energy of falling water, without using electrical diesel or solar power. Hydraulic rams are relatively inexpensive to buy and install where gravity flow are available. With the use of contraction in the drive shaft, the flow rate and delivery head can be increased. The supply head is an essential factor which determines both the delivery head and the flow rate. By having parallel pumps, the flow rate can be increased but it's legitimate to have a series of pumps to increase delivery head. Also, a reservoir is mandatory before the second pump to have continuous flow and supply head.

Frenjo *et al.* (2017) designed and developed Solar Powered Water Pumping system for Small Scale Irrigation. At 30 ° south to east, the 12 V, 1.11-amp PV panel could give 12 V. The controller is used to allow flow of current during poor battery condition. Under fully charged battery condition the flow rate of 3.33 lps was achieved. With a change in location of the panel, the voltage output at the PV

panel was found to be varying. It was concluded that a solar powered pumping system is acceptable for small scale irrigation.

Mohtashim and Vagh (2018) developed and tested a solar power water pumping system for domestic purpose. Solar power is suitable for irrigation systems in parks, allotments, greenhouses, and polytunnel systems. Pump is powered by solar energy so that power can be made available 24 hours a day by installing a suitable deep-cycle leisure/marine battery, allowing watering in the evening - the perfect time to water plants in the summer so that the water has time to soak into the soil. A typical pump with an electric motor is a solar-powered pump. The motor's electricity is generated on-site by a solar panel that converts solar energy into direct-current (DC) electricity. A solar-powered pump allows a DC motor to work without external electrical components since the electrical output from a solar panel is DC. If the pump is operated by an alternating-current (AC) motor, an inverter is needed to convert the DC electricity produced by the solar panels to AC electricity. The solar energy water pump system is powered by a DC motor due to the increased complexity and expense of an AC system, as well as the lower performance of an AC system.. The solar water pump frame, DC motor, pump, solar panel, suction line, distribution pipe, ON/OFF control switch, and water tanks are all included. The power produced is greater than the 48 watts needed to drive the pump.

2.4 Performance evaluation of solar powered pumping system

Kelley et al. (2010) expressed that with sufficient solar array it is possible to have a commercially feasible PV irrigation. The number of panels and the required area are the issues for power production, which is remarkably important in agriculture as it directly affects the area left for planting. They demonstrated that only a small percentage of land needed for panels on the two-acre plot. This advocates the viability of the use of solar PV to operate drip system of irrigation.

Himran *et al.* (2013) studied the performance of solar cell panel system with 100 watt motor-pump unit for pumping water at different lifting heads and found the best point of best efficiency both experimentally and analytically. It was

designed for operating the pump coupled by dc-motor. They found that at 800 and 1000 W/m² solar radiation, it could provide a lifting head from 1m to 7m. At 200 W/m² radiation, even for 1 m, the pump does not lift water. The analysis shows that the best efficiency point of the solar cell panel system output occurs at the 2.89 m pumping head.

Khan *et al.* (2013) designed and analyzed a low cost solar water pump for irrigation in Bangladesh. A buck converter is designed and manufactured to enhance the dc pump's performance. All components of the system, except the solar panels, are locally procured. Using locally available technology, dc solar pumps are designed and implemented to investigate ways of reducing reliance on diesel and electricity-driven water pumps in agriculture. Maintenance of solar water pump will be easy and less because of these dc pumps will not required any inverter and battery. Comparison of the BUET designed pump with the study's results carried out at the Bangladesh Agricultural Research Institute (BARI), Dhaka, on various types of solar pumps. For tomato and brinjal (egg apple) irrigated by solar energy by drip and furrow irrigation, the gain cost ratio was 3.45, 3.71 and 1.57, 1.37 respectively. Rice cultivation by means of a solar water pump is currently not economically feasible.

Kumar *et al.* (2014) analyzed the performance of a water pumping system supplied by a photovoltaic generator (PVG) with different maximum power point tracking technique (MPPT). The PVG powers an induction motor that drives a centrifugal pump. For power conditioning, a boost converter and inverter are connected between the PVG and the motor. The design and comparison of three MPPT techniques are discussed. Incremental conductance (IC), constant voltage controlled (CVC), and fuzzy dependent perturbation and observation are examples of these techniques (FPO). The FPO Rule Base is built with only nine rules so that it can be applied on processors with limited memory and speed. The performance of the system is evaluated using simulation models that have been developed. In addition, a comparison of these methods is provided. The simulation results show that the FPO scheme outperforms the others.

Yannopoulos *et al.* (2015) discussed the evolution of water lifting devices (pumps) worldwide over the years. It is a fact that in many parts of the developing

world, ancient pumping technologies are still in use today. Research objectives should be pursued to establish cost-effective methods and practices focused on the modernization of low-cost historical water lifting technologies by replacing natural energy sources for muscle strength (human or animal). As a result of recent technical advances in the renewable energy field, this is possible.

Elrefai *et al.* (2017) designed and evaluate the performance of a Solar Water Pumping System in Egypt. A direct coupled solar water pumping system without using batteries was designed with the technical, economic and environmental design considerations. Performance of the developed solar water pumping system was evaluated under three parameters: yield factor (YF), wire to water energy efficiency (WWEE) and system performance index (SPI). The developed system attached with monitoring system to evaluate real time data of the operation parameters of the system. Solar water pumping system of 45 kWp in El Wahat, Egypt is considered. The daily water volume was found 788 m³ in average over one year with the data recorded by monitoring system. It was found that in summer season maximum output water volume was 887 m³ with 5 (kWh/kWp/day) yield factor.

Priyanka *et al.* (2018) conducted research work for evaluating the variation in discharge and efficiency of solar water pumping system comprising of 32 modules of 255.8 watts each and a 7.5 hp DC centrifugal mono block pump. The PV array produced power in the range of 7051.40 watts to 7848.22 watts from 10:30 am to 4:30 pm in the month of December 2014 during normal climatic conditions. The reduction in power generation was observed in the range of 10.16 percent during midday conditions. The maximum power of the PV array was 7848.22 watts (12:30 pm), while the V_{mp} and I_{mp} produced 490.82 volts and 15.99 amps, respectively. In the morning, the pump delivered a discharge of 33.40 m³ /h (10.30 am-11:30 am) with a head of 22.8 m. In noon conditions, the pump delivered 41.82 m³ /h (12:30 pm) discharge at the head of 22.8 m and 66.06 percent pumping efficiency was measured. The power output from solar array was improved from 7051.40 to 7848.22 watt with increase in solar intensity.

2.5 Comparison of PV Pump with other pumping system

Abul- Aligah (2011) conducted his research on the design of photovoltaic water pumping system and compares it with diesel powered pumping system. He found that Solar cost ranges from one tenth to one fourth ($1/10$ - $1/4$) the Net Present Cost of the diesel option. The break-even point for a single case is 1 year for pumping systems with an output of 10,000 litres a day from a head of 80 meters. The study also notes that for pumping systems with a hydraulic load of 1,000 or less, the break-even point is less than 2.5 years.

Sikha (2018) prepared a report for Shiv Shakti alternative energy limited in the Evaluation and Impact Assessment of the Solar Irrigation Pumps Program in Chhattisgarh and Andhra Pradesh. She concluded that the impact of solar irrigation systems, as well as maintenance, is currently encouraging. Crop yields and incomes have grown. Water intake is acceptable. Other social and company advantages are yet to be thoroughly investigated.

Ibrahim (2019) evaluate the performance and optimal sizing of solar water pumping system and compared to convention diesel of remote site in Egypt. To build a solar water pumping system, data on system components and climate data from various locations were gathered. The maximum pumping power needed of the solar PV water pumping system for a 121 m³/hr supply is 443 kW peak (8477 kWh/day) of inhabitants residential, livestock, and crop irrigation of agriculture remote site without grid power in Fayoum Region, Egypt. In addition, to enhance system reliability, a battery bank has been used as a backup during days of autonomy. 2.57 kW PV and 2.11 kW converter for on-grid system, 3.83 kW PV and 1.71 kW converter and 10 units of 12 V batteries for PV/battery off-grid system, and 3.10 kW PV for diesel system are the best configurations for this proposed system. It was also discovered that the net present cost of a solar water pumping system in on-grid mode is 3 times that of a PV-battery off-grid system and 4 times that of a conventional diesel system. Solar water pumping systems have an energy cost of 0.07 \$/kWh for on-grid systems, 0.332 \$/kWh for PV-battery off-grid systems, and 0.434 \$/kWh for diesel systems. Over the course of a year, the system with the required configuration pumps an average hourly water

volume of about 121.4 m³ using a unit of 0.05 cent/m³. Solar water pumping systems have been found to have a return on investment of 4–6 years. Over the project's lifespan, the CO₂ performance of the on-grid solar water pumping system is 6 times lower than that of the conventional diesel system. Energy costs rise as the full capacity of the water storage tank is increased, according to sensitivity analysis. In addition, as the discount rate rises, the NPC and COE rise with it. The output of the pumping power is about 10 HP.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and instruments used and methodology adopted to conduct the research work. The details of materials used, experimental methodology and measurement techniques adopted during the course of investigation are described in this chapter.

3.1 SITE SELECTION

3.1.1 Experimental site

Before the real project is designed and developed, site selection for this experiment is necessary. The sites must be near water resource available and where farming operations also perform. With these points taken into mind, the experiment site near KVK nallah, IGKV Raipur (CG) was selected to conduct this project work.

3.1.2 Geographical situation

Raipur is situated at 21° 14' 02" N latitude and 81° 43' 11" E longitude in central part of Chhattisgarh and an altitude of 302 m above the mean sea level.

3.2 Climatic Condition

Raipur has a tropical hot and humid. Temperatures remain moderate throughout the year, except during March to June, which can be extremely hot. The temperature in April-May sometimes rises above 48°C. These summer months also have dry and hot winds. In summer, the temperature can also go up to 50°C. The city receives about 1300 mm of rain, mostly in the monsoon season from late June to early October. Winter starts from November and may last upto first week of February, which is mild in nature (Anonymous, 2012). Average temperature is 35.1 °C (95.2 °F) May is the hottest month of the year. In January, the average temperature is 20.0 °C (67.9 °F). It is the lowest average temperature of the whole year. The average temperatures vary during the year by 15.1 °C (59.2 °F).

RAIPUR AVERAGE TEMPERATURE

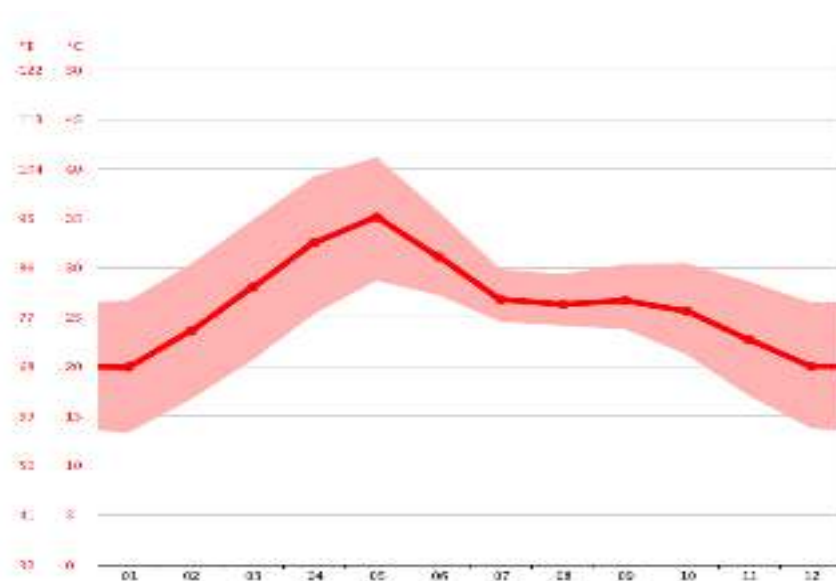


Fig 3.1:- Graph between temperature ($^{\circ}$ c) and months

Table 3.1: - Raipur weather by month (weather averages)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Avg. Temp $^{\circ}$ C	20 $^{\circ}$ C	23.6 $^{\circ}$ C	28 $^{\circ}$ C	32.6 $^{\circ}$ C	35.1 $^{\circ}$ C	31.1 $^{\circ}$ C	26.8 $^{\circ}$ C	26.3 $^{\circ}$ C	26.7 $^{\circ}$ C	25.6 $^{\circ}$ C	22.7 $^{\circ}$ C	20 $^{\circ}$ C
Min. Temp $^{\circ}$ C	13.3 $^{\circ}$ C	16.7 $^{\circ}$ C	20.7 $^{\circ}$ C	25.4 $^{\circ}$ C	28.7 $^{\circ}$ C	27.2 $^{\circ}$ C	24.6 $^{\circ}$ C	24.1 $^{\circ}$ C	23.8 $^{\circ}$ C	21.2 $^{\circ}$ C	17.1 $^{\circ}$ C	13.8 $^{\circ}$ C
Max. Temp $^{\circ}$ C	26.7 $^{\circ}$ C	30.3 $^{\circ}$ C	34.9 $^{\circ}$ C	39.3 $^{\circ}$ C	41.2 $^{\circ}$ C	35.7 $^{\circ}$ C	29.8 $^{\circ}$ C	29.4 $^{\circ}$ C	30.4 $^{\circ}$ C	30.4 $^{\circ}$ C	28.6 $^{\circ}$ C	26.5 $^{\circ}$ C
Rainfall mm (in)	15 (0.6)	11 (0.4)	12 (0.5)	16 (0.6)	22 (0.9)	213 (8.4)	398 (15.7)	379 (14.9)	241 (9.5)	69 (2.7)	13 (0.5)	12 (0.5)
Humidity (%)	53%	46%	35%	29%	29%	55%	81%	84%	81%	70%	61%	57%
Rainy days (d)	1	2	2	3	3	13	19	19	14	6	1	1

(Source: - <https://en.climate-data.org/asia/india/chhattisgarh/raipur-5085/>)

3.3 Design Considerations

Attention was provided on the following design aspects while designing of solar powered portable water pumping system

1. Physical and economical consideration
2. Functional requirement

3.3.1 Physical and economical consideration

Following points was considered.

1. Developed system should be simple in design and easy to operate.
2. Materials and spare parts were easily available at nearby market.
3. Total cost of system should be low.
4. It should save not only time but also human power required.

3.3.2 Functional requirement

1. Developed system should have good discharge rate.
2. Water should be lift up to desired head of farmers.

3.4 Design Parameters

Following parameters has been considered during the research implementation -

1. **Water requirement:** - The first step in designing a solar powered low head portable pumping system is determining the overall water requirement for the field operation. The total volume of water required is for small area like badi-bakhri and garden for vegetable. The system is designed for low water requirement field where vegetables have to be grown.
2. **The density of water:** As the water density increase due to the content of sand and mud, its flow rate is highly affected. The water with more sand and mud may clog the waterline and pump and also lower the flow rate. Water near the nallah and river is highly polluted and contains garbage soaps, detergent, waste food, paper, cloth, agriculture waste etc So, it is necessary to remove these materials from water before the entering to

pump otherwise it may clog pump and waterline therefore filter box is needed with pump which filter the other contamination of soil.

3. **Head:** Head height from water to reservoir will determine the power required to pump the water from the ground. If the height of total head is more power requirement will also be more and pump with more power must be used to lift upto particular head.
4. **Size of field:** The size of the field will determine the required water for irrigation.
5. **Solar radiation:** The efficiency of the solar panel is depended on the light intensity arrives on the panel. If more radiation is available on the field the induction of DC current in the solar cell will be more.

3.5 Materials Required for Development of Pumping System

There are different materials and components which are used to construct the solar energy operated water pump. These systems and components were well constructed together to produce the final project result. The materials are selected considering the overall cost such as initial cost, and operational cost.

Components of solar powered pumping system

The solar power pumping system consists of following components:

1. Solar panel
2. Pump
3. Storage battery
4. Charge controller
5. Inlet pipes
6. Jointer/ connector
7. Outlet pipes
8. Filter box

3.5.1 Solar panel (PV)

It is most important components of the machine as it is the main source of power for the developed water pumping system. Photo-voltaic cells, frequently

referred to as solar cells, convert the light part of the solar spectrum (sunlight) into electricity. Sunlight falling on the cell reaches the junction between the two layers in the form of photons of energy and knocks electrons across the junction. This results in the development of a potential difference across the two layers. Direct current (DC) electricity can be drawn across the two layers through an external circuit.

The efficiency of solar cells in converting incident solar energy into electrical energy depends on the illumination spectrum intensity, material of construction and design of the cell, atmospheric temperature and dustiness of the sky around the solar panel. The solar panel is mounted on a suitable frame which can adjust the array to the direction of the sun rays. The angle of the array has to be changed 3 or 4 times a day.

The amount of energy extracted from a PV module is determined by the weather. In fact, the maximum power point (MPP), which is dependent on the intensity of illumination, is the optimum operating point for such a module. A PV module is connected to a DC–DC converter or a DC–AC converter (inverter) operated by maximum power point monitoring in order to obtain maximum power from it (MPPT). Between the PV panels and the pump, a linear current booster is mounted, which turns on the pump during low light conditions. The pump voltage and panel output must be taken into account when sizing linear current boosters. The circuit breakers are mounted in the box to allow for the safe and fast shutoff of the panels in the event that the device needs operation. Circuit breakers may also be used as a switch to turn on and off the pump. To generate a certain amount of pressure and flow, a pump only requires a certain amount of electricity. As a result, the PV array size must be configured for the amount of power available.

The solar panel selected to perform the project was DC photovoltaic (PV) cells which is made of semi-conducting materials that convert the sun light ray directly to electricity (shown in fig. 3.1). When sun light strikes the cell, it dislodges and liberates electrons within the material which then move to produce a direct electrical direct current (DC). This direct current then used to charge the storage battery and operates the pumping motor. The purpose of photovoltaic panel

is to convert the sun light, which is abundantly found, into electrical energy. The photovoltaic (PV) cells taken for this project was 1095 X 665 X 35mm size and voltage 18.06 V connected to a 12 V battery.



Fig. 3.2: - 100 watt solar panel use for study

Table 3.2 Technical specification of solar panel used in this system

S. No.	Specification	Value
1	Module, CC	E100-72
2	Rated maximum power(Pmax), %	100 W +-3
3	Rated operating current(Imax), A	5.54
4	Open circuit voltage(Voc), V	22.45
5	Short circuit current(Isc), A	5.99
6	Maximum system voltage, V	1000
7	Module dimension (L×W×T), mm	1095*665*35

3.5.2 Pump

The submersible pump unit is more suitable for the photo-voltaic system. This arrangement eliminates the suction pipe and foot valve and results in higher efficiency of the pumping unit.

A DC submersible pump was used for water lifting. The advantage of the submersible pump is that it has no above ground working parts; it can be used where flooding may be a hazard, for surface water pumping or lifting. The submersible pump consists of a pump and motor assembly, a discharge column, a head assembly and a waterproof cable to conduct the electric current to the submerged motor. The motor is fixed directly below the intake of the pump. The pump element and the motor operate entirely submerged. Efficiency is increased by the direct coupling of the motor and its effective cooling by submergence in water.

For the study, 12V solar powered brushless water pump motor is taken. Horse power is 0.0321 hp (8W). This type of solar powered water pump has the capability to lift water at maximum 80-500cm head and discharge will be maximum

at that head 350-700L/H. The size of the components may be increased based on the size of the irrigation.

Table 3.3 Specification of selected submersible pump

S. no.	Specification	Value
1	Company	AISHANG
2	Power, W	8
3	Voltage, V	12
4	Maximum head, m	5
5	Flow rate, l/m	10

Capacity of only one pump is low and rated power is only 8 watt while the rated power being generated by the panel is 100 watt. So it was felt to have a combination of pumps than a single pump. This way a combination of five pumps of same specification is taken for the project. As the operational head in the field to be irrigated was less than 2 meters. So it was realized to increase the discharge only than increasing the operational head. Hence, a parallel combination has been attempted in this study to get increased discharge.



Fig 3.3 (a): - DC Submersible pump used for study



Fig. 3.3 (b):- DC Submersible Pump installed in the water source

3.5.3 Storage battery

The solar storage battery stores the solar energy in the form of electrical energy. It serves as the power house of the system. The energy converted into electrical form by the solar panel was stored in the battery for the work. The solar panel is the recharging unit of the battery. For this project, the storage battery which is used is 12V, 10Ah and come to operation when there is no sun light or the sun is covered with cloudy and the pumping motor is needed to operate. The most common type of battery found in PV system is the lead acid battery. Therefore, the storage battery that is used is lead acid battery, because this type of battery has higher performance characteristics and suitable for air transportation.

The lead acid battery contains various parts i.e. container, plate, active material (Lead peroxide, sponge lead, dilute Sulfuric Acid), separators, battery terminals. The main part of the led acid battery is container and plates. Container stores chemical energy and plate converts the chemical energy into electrical energy. As sulfuric acid dissolves, the molecules split into two types of ions: positive hydrogen ions ($2H^+$) and sulphate negative ions (SO_4^-) that can freely move around. When two electrodes are submerged in solutions and connected to a

DC supply, hydrogen ions become positively charged and pass towards the electrodes, where they are connected to the supply's negative terminal. Negatively charged SO_4^- ions gravitated toward the electrodes attached to the supply main's positive terminal (i.e., anode). Each hydrogen ion takes one electron from the cathode, and each sulphate ion takes two negative ions from the anodes, reacting with water to create sulfuric and hydrogen acid. The oxygen formed by the equation above reacts with the lead oxide to form lead peroxide (PbO_2 .) As a result, although the lead cathode remains as lead during charging, but the lead anode is converted to lead peroxide. If the DC supply is disconnected and the voltmeter is connected between the electrodes, the potential difference between them will be shown. If the electrodes are connected by wire, current can flow from the positive plate to the negative plate through an external circuit, indicating that the cell will supply electrical energy.

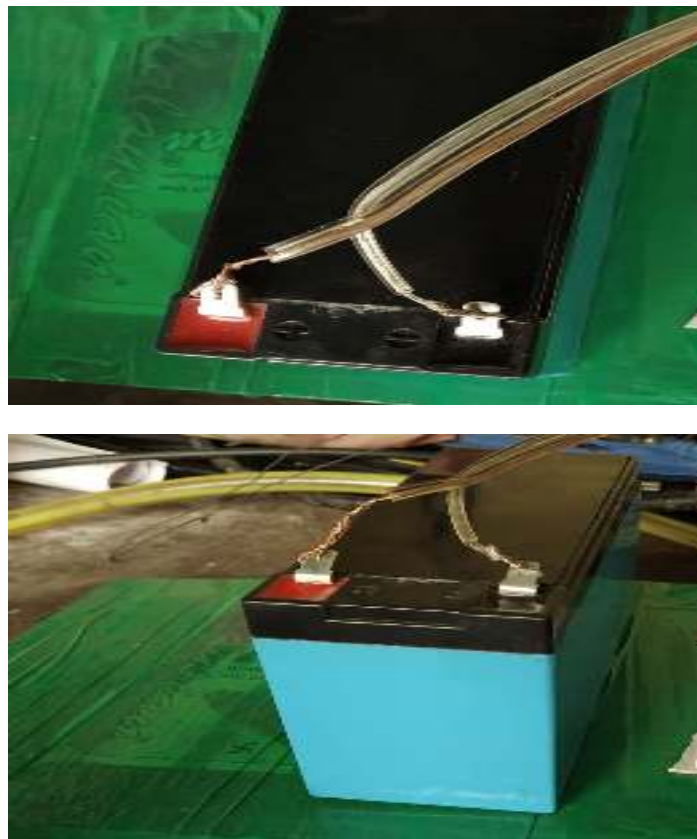


Fig.3.4:- Lead Acid Storage Battery

3.5.4 Charge controller

The charge controller is the component in the circuit which is used to control the condition of the charging, that is whether the storage battery is fully charged, 50% charged or discharged and controls the itself indicating whether the panel is in operation or not. As the battery voltage rises to a certain amount, the most simple charge controller regulates the system voltage and opens the circuit, stopping the charging. More charge controllers used a mechanical relay to open or close the circuit, stopping or starting power to electric storage devices. Solar power systems typically use 12V batteries.

Solar panels are capable of providing much more voltage than is needed to charge the battery. The charge voltage could be maintained at its optimal level while the time required to fully charge electric storage devices was reduced. This allows the solar systems to perform at their best all of the time. The power dissipation in the wires from the solar panels to the charge controller is significantly reduced by running higher voltage in the wires. The reverse power flow can also be controlled by solar charge controllers. When no power is coming from the solar panels, the charge controllers open the circuit, separating the solar panels from the battery devices and stopping the reverse current flow.



Fig. 3.5:- 12V, 10A Charge Controller Used in this study

3.5.5 Inlet pipe

Inlet pipe is used in portable water pumping system to lift the water from nallah, river and other water sources. Five inlet pipe which is connected to the five DC solar water pump by each is taken. The inlet pipe is small in diameter. The plastic pipe of diameter is 0.5 inch has been selected. This inlet pipe is used to take water from nallah, river and other water sources and deliver to main pipe through the jointer. Length of inlet pipe changes according to height of the water level from surface and also with the distance required to connect outlet pipe. In our study, 5 m length of inlet pipe was used.



Fig. 3.6:- 5m Inlet Pipe used for making a parallel combination of pumps

3.5.6 Jointer/ Connector

The jointer can be made of iron, steel, rubber or any other material, jointer made up of stainless steel has taken for our experiment. Jointer is used to connect inlet pipes with the outlet pipe. Jointer is made of palm shape to lessen the water losses due to friction and also for making parallel combination of pumps. The diameter of five sides of jointer where inlet pipes has to connect is of 0.5 inch each and connected with the five inlet pipes. The one side of jointer is of 1.5 inch diameter and it is connected with the outlet pipe.



Fig. 3.7:- Jointer for making a parallel combination of pumps

3.5.7 Outlet pipe / Main pipe

The outlet pipe is also called the main pipe, which deliver the water to plants. The outlet pipe taken for this experiment has diameter of 1.5 inch and total 30 m length. Length of outlet pipe can be increase or decrease as per the requirement. Outlet pipe is connected to laterals and water is supplied to the field. Water is supplied to the vegetable grown field in two rows with micro sprinkler irrigation system and discharge rate is calculated.



Fig. 3.8:- Outlet pipe for handling the combined discharge of pumps

3.5.8 Filter box

To protect the submersible pump by algae, and other waste material present in the water source (nallah, river, etc) filter box is needed. The filter box taken for this experiment has made up by the waste plastic box which shoppers throw. A plastic box (approximately 5 kg capacity) has taken, many small holes made on the plastic box to enter only water and restrict the other large size particles. The 5 DC submersible pumps with pipe is packed with this plastic box and it is covered by the cover of plastic box and tighten up.



Fig.3.9:- Filter Box (approx. 5 litre capacity)

3.5.9 The water sources

The water sources is used to supply of water for irrigation in field which is near by the nallah, river water which is pumped and after or simultaneously irrigating the farm lands which is near by the river and nallah.



Fig. 3.10:- Water Source (KVK Nallah field)

3.6 Installation of Solar Powered Water Pumping Circuit Diagrams

1. Photovoltaic cells (100 Watt) receive energy from solar rays and store it in the battery (12 V).
2. The battery is connected to the pump.
3. The five DC submersible pumps each connected to inlet pipes is covered with the filter box and then submerged in water.
4. Each pump is connected to the 0.5 inch inlet pipe and the five pipes have one outlet pipe.
5. The diameter of outlet pipe is 1.5 inch.
6. Outlet pipe is then connected to laterals and water is supplied to the field.
7. The developed solar powered low head portable water pumping system receives energy from sun and used to lift the water to the field.

3.7 Working Principle

The developed water pumping system is based on working principle of solar energy. When the solar energy strikes the solar panel, it converts the solar energy into electrical energy then it is stored in battery. Battery is connected to charge controller which controls power transmission in cloudy weather. In case there is sufficient sun rays solar panel is directly connected to pump and water started lifting and water supplies to the field through inlet and outlet pipes. Both inlet and outlet pipes were connected with jointer/connector. Mud, sand in water is filtered with filter box before water goes to the pump.

3.8 Line Diagram of Installation of the Developed System

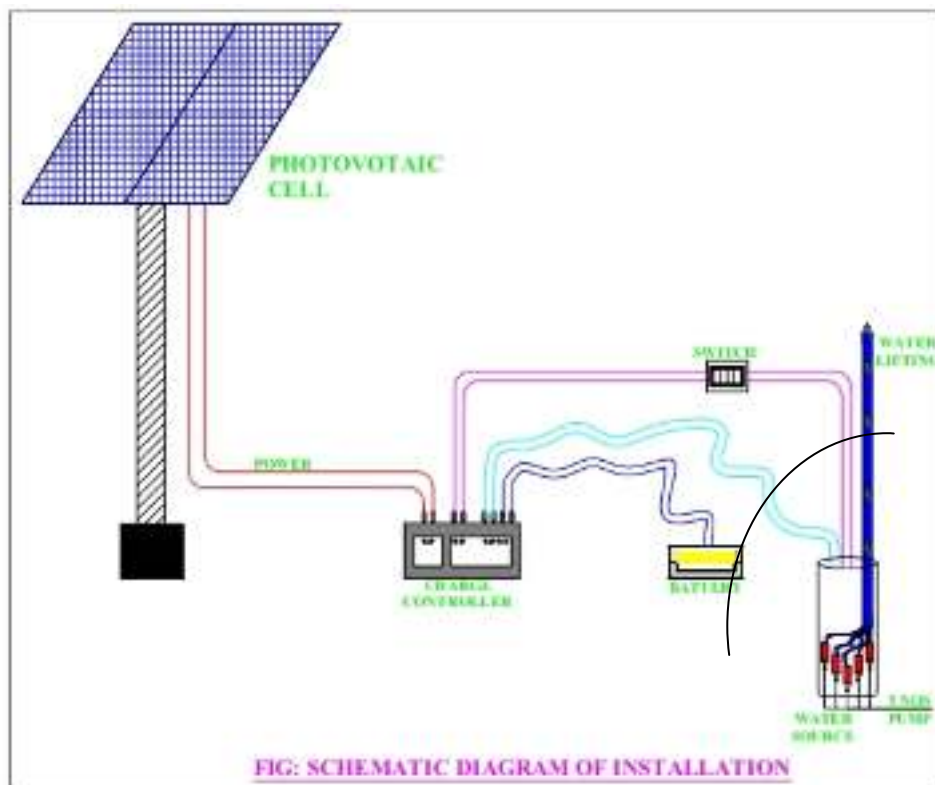


Fig. 3.11 Line diagram of installation of developed pump

3.9 Performance Evaluation of Developed Low Head Solar Powered Water Pumping System

3.9.1 Measurement of total head

Total dynamic head (TDH) is the total equivalent vertical distance that the pump must move the water, or the pressure the pump must overcome to move the water to a certain height. Head is the term relating meter of water in a column that exerts a certain pressure. Static head is the major part of TDH and refers to the total vertical lift (distance) from the water level in the well to the discharge level.

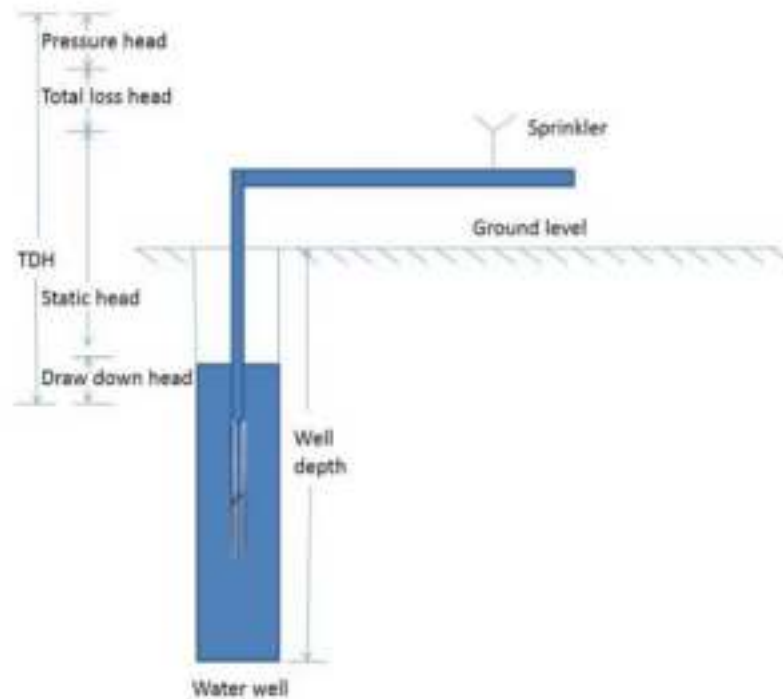


Fig 3.12: - Total Dynamic Head (TDH) of submersible water pump

To select the pump of suitable capacity, Total dynamic head (TDH) and flow rate (m³/h) should be accurately determined. The Total Dynamic Head consists of static head H_{st} (m), drawdown head H_d (m), total loss head H_l (m) and pressure head H_p (m). The down of water level determined by drawdown head H_d

after pumping. The friction head H_f (m) determines the loss of pressure in pipe due to friction. The friction head can be calculated by Darcy formula as:

$$H_f = 4 K_f \times \frac{8lQ^2}{d^5\pi^2g}$$

Where,

K_f = friction loss which depends on Reynolds number,

l = pipes length (m),

D = pipe diameter (m),

g = acceleration gravity (m/s) and

Q = flow rate (m³/s).

Head loss due to fittings of pipe is also considered. It can be calculated by following formula:

$$H = K_{fi} \times \frac{8Q^2}{d^4\pi^2g}$$

Where,

K_{fi} = fitting loss factor.

The total losses head H_l is the sum of the friction head H_f (m) and the fitting losses head H_{fi} (m) expressed as:

$$H_l = H_f + H$$

Total Dynamic Head can be determined as:

$$TDH = H_{st} + H_d + H_l + H_p$$

The required hydraulic power P_h (W) can be determined by:

$$P_h = \rho \times g \times TDH \times \frac{Q}{3600}$$

Where,

ρ = water density (kg/m^3).

The required pump capacity is determined by dividing the hydraulic power over the selected pump efficiency given as:

$$P_2 = P_h / \eta_{\text{pump}}$$

In our study 12V (8W) capacity of DC submersible pump is used which is easily available in market.

3.9.2 Measurement of total horizontal distance

Total horizontal distance means the distance on a line parallel to the horizon (not parallel to the slope). Horizontal distance was calculated from the delivery head to the field where irrigation has to be done. Total horizontal distance was measured by steel tape.

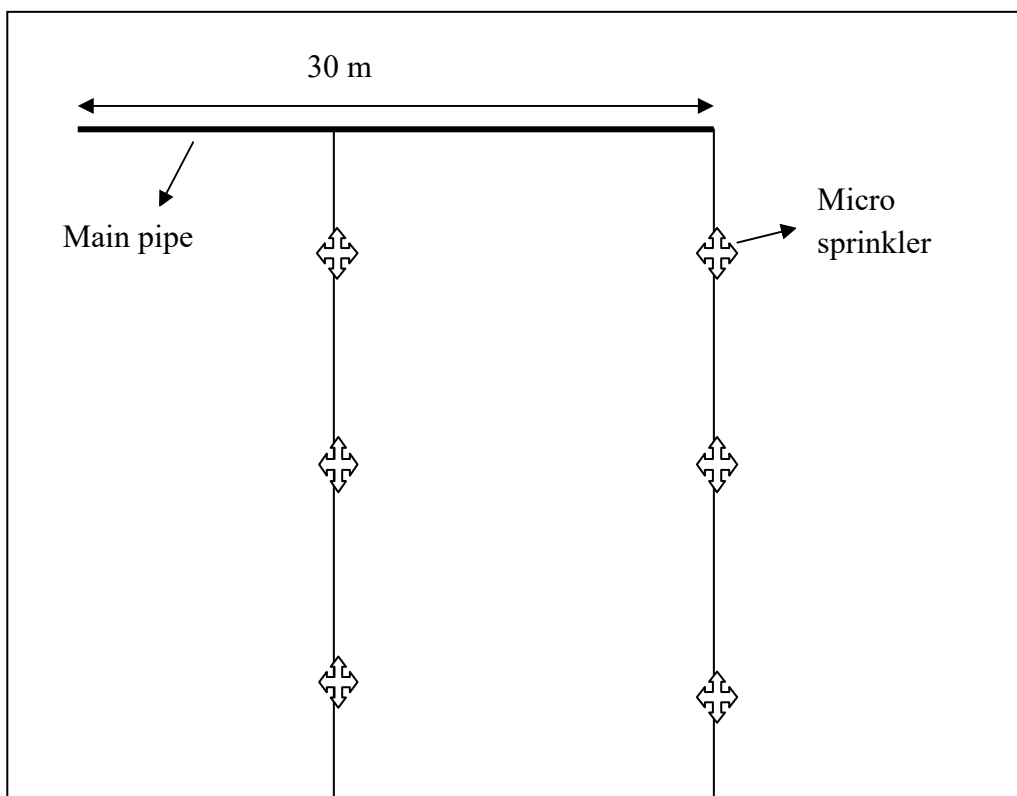


Fig 3.13: - Block diagram of arrangements of main pipes and laterals with micro sprinkler in the field

Two parallel rows with laterals are connected with main pipe and micro sprinklers attached with that. Discharge rate with the different horizontal distances were calculated.



Fig 3.14:- Actual field area with two row of laterals.

3.9.3 Determination of total discharge

Volumetric method was used to calculate discharge. In this method, a measuring cylinder of 2 litre capacity was taken and water was collected in it. The total time required to fill the cylinder was counted using a stopwatch. Then the calculation of discharge rate is done by following formula:-

$$Q = \frac{V}{T}$$

Where,

Q = Discharge rate, (litre per minute)

V = Volume of measuring cylinder (litres)

T = Time required to fill, (second)



Fig 3.15:- Determination of discharge rate in KVK field using volumetric method

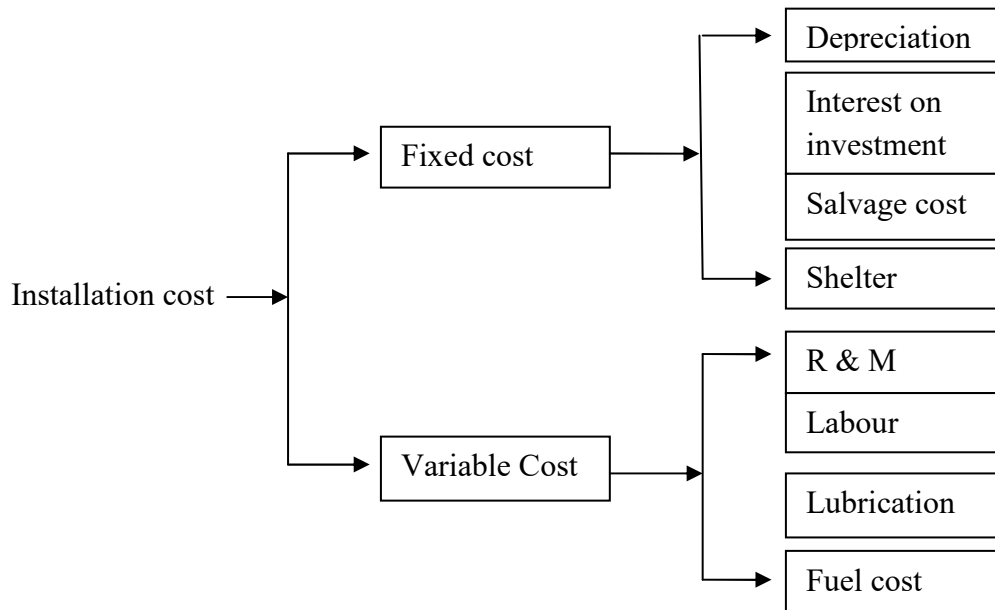
3.10 Testing of the Developed System

The developed solar powered pumping system is tested at different total heads and different horizontal distances. Discharge rate is calculated by volumetric method. The total head is increased by lifting the height of the outlet pipe/delivery pipe and the total horizontal distance is also increased. The discharge rate at different total heads and different horizontal distances is calculated. Calculation of discharge rate per day is taken as the average discharge rate at 10 am, 12 noon and 2 pm. A measuring cylinder of 2 litres is taken for the discharge rate calculation.

3.11 Cost Analysis of Developed System

3.11.1 Composition of cost of installation

Installation costs are divided into two categories – fixed costs and variable costs or operating costs. Total operational cost of the system is the sum of fixed cost and variable cost of the system.



3.11.2 Total life in hours and years

Total life in hours and years should be assumed before the calculation of fixed cost. Total life in years may be decided by the assumed total life in hours and the expected operating hours per year which are introduced as follows:

Operating hours per year is assumed with the product of period of working seasons, rate of available working days in the season, working hours per day and rate of actual operating time in the working hour.

3.11.3 Annual fixed cost

Fixed costs are related to system ownership and occur regardless of whether or not the system is used. Fixed costs per hour are inversely proportional to the amount of annual use. Fixed cost is the total cost of depreciation, interest on investment and shelter.

a) Depreciation

Depreciation is the reduction in the value of a machine with the passage of time. The straight line method is the most practical and the most common method to calculate depreciation. It is the simplest method and gives a constant annual charge for depreciation throughout the life of the machine. Depreciation is the loss of value of a machine with the passing of time.

$$D = \frac{C-S}{LXH}$$

Where,

D = Depreciation per hour

C = Purchase price,

S = Salvage value, Rs. (Which is generally 10% of purchase price)

L = Life of machine, year

H = No. of operating hours per year

b) Salvage cost

Salvage value of most of the agricultural machines and implements is around 10%, but in this case the items like solar panel, submersible DC pumps, rubber pipes, cables have been used. Out of these only solar panel may have some salvage value while other doesn't have. So, a salvage value of only 5% has been adopted in this study.

Life value of most of the diesel and electric pumps are generally 10 years but in this case submersible DC pumps has been used in which no fuel and electricity required. Based on experimental work, life value of brushless water pump found 2 years. So, life value of pump is considered 2 years. In case of the solar panel it does not damage or depreciate. So, Solar panel has more life up to 15 years.

c) Interest on investment

Interest on the investment in a farm machine is a legitimate cost, since money spent in buying a machine cannot be used for other productive enterprises. The rate of interest should reflect prevailing rates. With straight line depreciation, the average investment is equal to one half the sum of the new cost and the trade in or salvage value.

$$\text{Interest (Rs/hr)} = \frac{C+S}{2} \times \frac{i}{H}$$

Where,

i = % rate of interest per year = 12 % per year

d) Shelter

Shelter = 1% of purchase price of machine (Rs.)

Total fixed cost

TFC = Depreciation + Salvage + Interest on investment + Shelter

3.11.4 Variable Cost

Operating costs are directly related to the amount of use and include repairs and maintenance, fuel and lubricants and servicing.

a) Repairs and Maintenance

Repair costs are difficult to estimate because of wide variation resulting from differences in operating conditions, management, maintenance programs, local costs, etc. The repair and maintenance rate is taken as 6%.

$$\text{Repair and maintenance cost (Rs/h)} = \frac{C \times m}{H}$$

m = repair and maintenance rate 6%.

b) Wages to operator

No any labour required to operate the developed system. So the wages to operator is nil.

c) Fuel cost/ Electric cost

Developed system is solar operated pumping system. So no any fuel and electric cost required. Therefore, fuel and electric cost were taken is nil.

d) Lubrication cost

No any resistive material used in the developed pumping system. So, no lubrication required.

Total variable cost,

$TVC = \text{Repair \& Maintenance cost} + \text{Wages to operator} + \text{Fuel cost} + \text{Lubrication cost}$

3.11.5 Total cost of operation

Total cost of operation is the sum of total fixed cost and total variable cost of the system.

$\text{Total cost, } TC = \text{Fixed cost} + \text{Variable cost}$

3.12 Cost Economics

3.12.1 Comparison of solar water pumping system with diesel pumping

Agriculture is completely dependent on hand pumps or water from distant rivers in rural areas where sufficient electrical power is not available for water pumping. At that time, the best option is solar-powered water pumping, which can also be achieved with diesel-powered engines. The distinctions between these two systems are that, when considering cost and reliability, diesel powered motors have a low capital cost but a high operating and maintenance cost. The capital cost of

solar water pumping is high, but the operational and maintenance costs are low. Solar water pumping needs a significant initial investment and the system must be properly maintained since the panels must be washed. This system is totally eco friendly and can be maintained by local staff. Diesel motors have a low initial investment, but they become more expensive as time goes by, and they require proper maintenance and operation. The diesel-powered device is environmentally dangerous, and there is a risk of combustion. The diesel-powered system necessitates a large amount of storage space.

“Shakambari Yojana” launched by Chhattisgarh government in the year 2005-06 to enhance the irrigation facilities and for proper utilization of irrigation water. Provisions of 75% subsidy is given on diesel/ electrical/ kerosene/ open well submersible pump up to 5 hp has been made 50% subsidy is given on dug well only to small and marginal farmers. The unit cost of different pumps has been revised by the government ranging from Rs. 5200 to Rs. 22500.

Cost of irrigation with both the system was calculated by taken discharge rate constant and other cost to get that much discharge into consideration. With constant discharge total fixed cost and variable cost of the solar powered system and diesel powered system of same power was calculated and compare between them.

3.12.2 Comparison of solar water pumping system with electrical pumping system

In remote area where reach of electricity is the major problem solar water pumping system is the best alternative. Cost of irrigation with solar energy pumping system and electrical energy pumping system is not having a huge difference.

Cost of irrigation with both the system was calculated by taken discharge rate constant and other cost to get that much discharge into consideration. With constant discharge total fixed cost and variable cost of the solar powered system and electrical powered pumping system of same power was calculated and compare between them.

3.12.3 Comparison of solar water pumping system with human powered water pumping system

The water pumping system used in rural area and used by small and marginal farmer are human powered pumping system. Many of the farmers are involved in Badi system of cultivation, growing vegetables utilizing shallow water or surface water. Badi covers 5% area of total area of Chhattisgarh. Each badi contains one shallow dug well and they use human power for irrigation.

Cost of development of dug well and its maintenance are taken into consideration. Cost of irrigation with both the system was calculated by taken discharge rate constant and other cost to get that much discharge into consideration. With constant discharge total fixed cost and variable cost of the solar powered system and human power pumping system with gym cycle was calculated and compare between them.

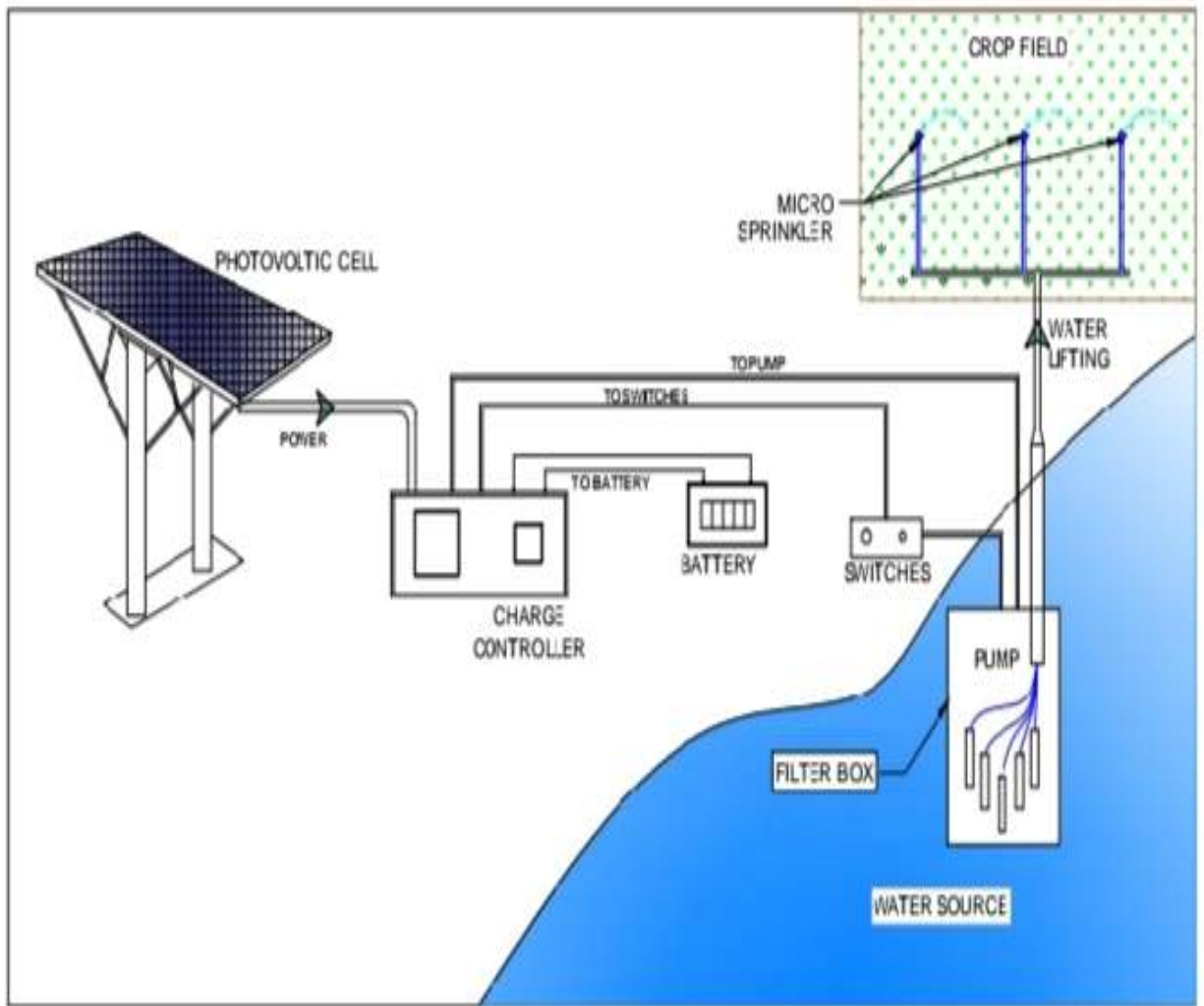
CHAPTER – IV

RESULTS AND DISCUSSION

This chapter deals with the results and discussion of the experiments described in the chapter III in order to fulfill the objectives of the project work. The performance of the developed solar powered low head portable water pumping was evaluated at the KVK nallah field, IGKV, Raipur (C.G.), considering cost of operation. The components used in this project were easily available at market. Results drawn from the experiment are discussed below:

4.1 Development of Solar Powered Low Head Portable Water Pumping System

The development and installation of solar powered low head portable pumping system was done as described in the chapter III (3.6). Photovoltaic cells (100 Watt) receive energy from solar rays and store it in the battery (12 V). The battery is connected to the pump. The five DC submersible pumps each connected to inlet pipes is covered with the filter box and then submerged in water. Each pump is connected to the 0.5 inch inlet pipe and the five pipes have one outlet pipe. The diameter of outlet pipe is 1 inch. Outlet pipe is then connected to laterals and water is supplied to the field. The developed solar powered low head portable water pumping system receives energy from sun and used to lift the water to the field.



**SCHEMATIC DIAGRAM OF
SOLAR OPERATED WATER PUMPING SYSTEM**

Fig 4.1: - Schematic diagram of solar operated water pumping system



Fig 4.2:- Developed low head solar powered pumping system

Installations were made carefully and discharge was calculated. Solar panel converts solar energy to electrical energy and then power is transferred to pump. Pump starts to lift the water to the head and water is then supplied to field through outlet pipe.

4.2 Performance Evaluation of Developed Pumping System

The position of PV panel determines the output voltage of the solar panel and it also depends on the head. So, at different head and also at different horizontal distances the discharge varies. The time and good weather condition is very essential for good discharge. The record is done from solar panel, direct reading. The recording is done in two-hour interval for eight hours. The results of the investigation are given below:

4.2.1 Measurement of discharge rate at different total head for one pump

Discharge rate of the solar powered pumping system was tested at the different total heads for single pump. It has been found that discharge rate at total head 1 meter was maximum i.e. 558.4 litre per hour and gradually decreases with total head increases. At 3.5 meter total head, the discharge was found to be 277 liter per hour. Discharge rate at different total heads are shown in the table below:-

Table 4.1: Testing of single pump discharge rate at different total head

Total head (m)	Discharge (lph)
1	558.4
2	461
3	372
3.5	277

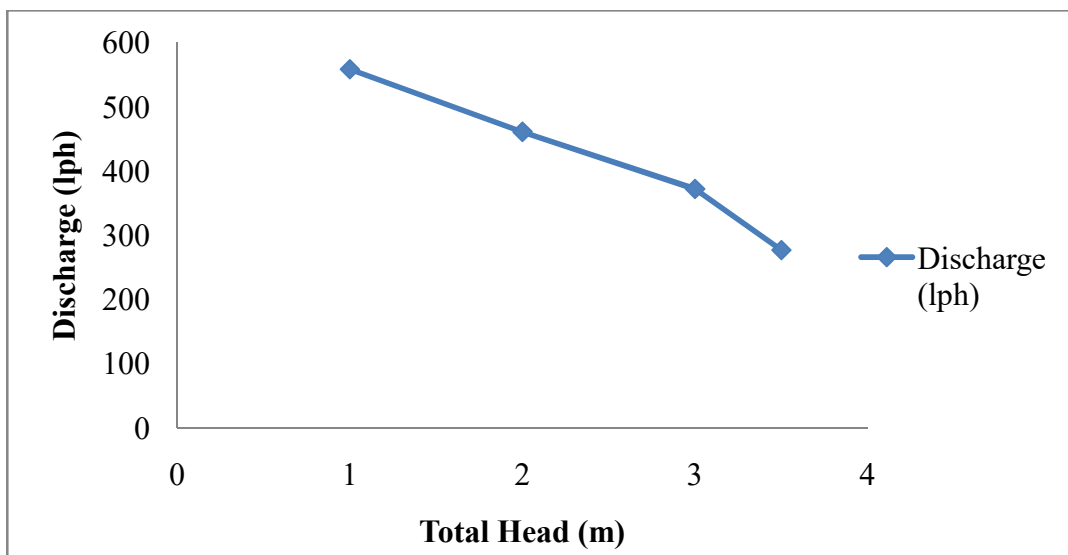


Fig 4.3:- Relationship between total head and discharge rate for a single 12 V/8 Watt DC submersible pump used in the study

Data revealed that discharge rate was gradually decreases as the total head increases. The system gives satisfactory performance result up to 3 to 3.5 m total head. Similar findings were reported by Hiranman et al. 2013, where best efficiency point of the performance of solar cell panel system occurs at the pumping head 2.89 m. At total head more than 3.5 m the discharge rate was very low. Hence, parallel combinations of five pumps have been developed.

4.2.2 Measurement of discharge rate at different horizontal distances for one pump

Discharge rate of the solar powered pumping system was tested at the different horizontal distances for single pump. It has been found that discharge rate at total head 1 meter and horizontal distance 5 m was maximum i.e. 560 liter per hour and gradually decreases with horizontal distances increases. At 30 m horizontal distance discharge was found 216 liter per hour. Discharge rate at different horizontal distances are shown in the table below:-

Table 4.2: Testing of one pump discharge at 1m constant total head and different horizontal distance

Total head	Horizontal distance (m)	Discharge (lph)
1	5	560
1	10	498
1	20	369
1	30	216

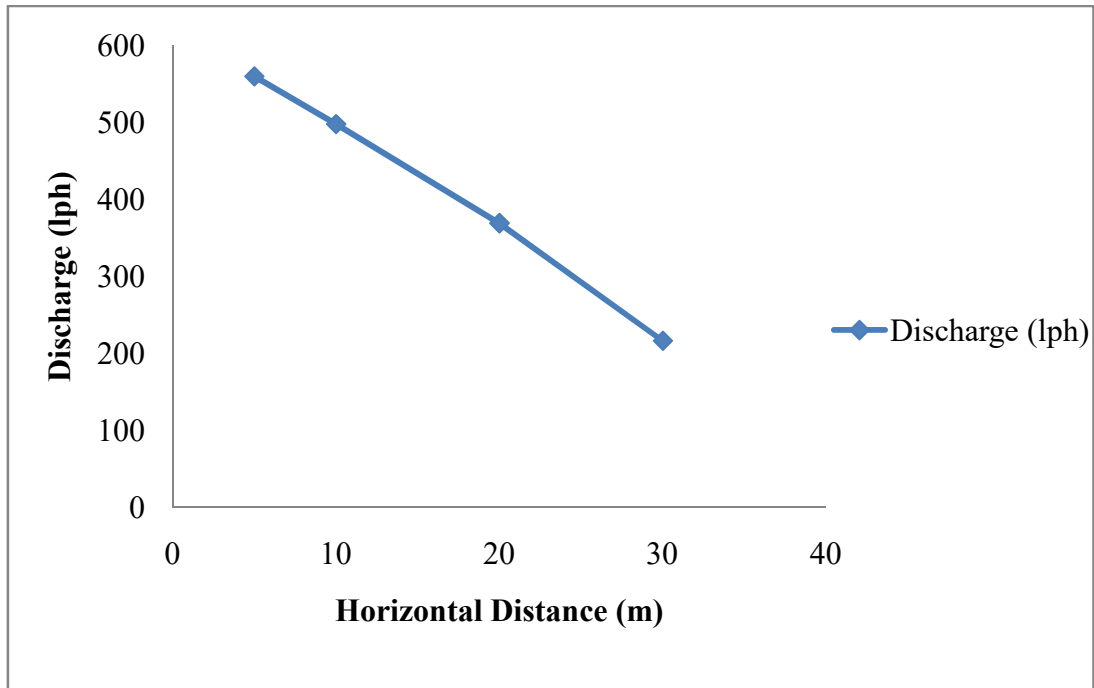


Fig. 4.4 Relationship between different horizontal distances and discharge rate

Data shows that discharge rate gradually decreases as the horizontal distance increases. The discharge rate found at 5 m distance was 560 lph or 9.34 liter/min using 100 watt solar panel satisfactory. The results are in proximity of the reported work of Yusuf et al. 2017 while using a 20 watt solar panel the optimum discharge is 6.09 liter/min.

4.2.3 Measurement of discharge rate at different total head for combination of five pumps.

Discharge rate for the combination of five pumps of pumping system was tested at the different total heads. The pumps were arranged in parallel combinations. The discharge rate at total head 1 meter was found maximum i.e. 2589 lph and gradually decreases with total head increases. At 3.5 meter total head discharge rate was found 1230 litre per hour. Discharge rate at different total heads are shown in the Table below:-

Table 4.3: Testing of discharge rate at different total head for combination of five pumps

Total head (m)	Discharge (lph)
1	2730
2	2335
3	1848
3.5	1230

With the increase in numbers of pump, discharge rate has also increased. Maximum discharge rate found at 1 m head and minimum at 3.5 m head. Increase in total head results very low discharge.

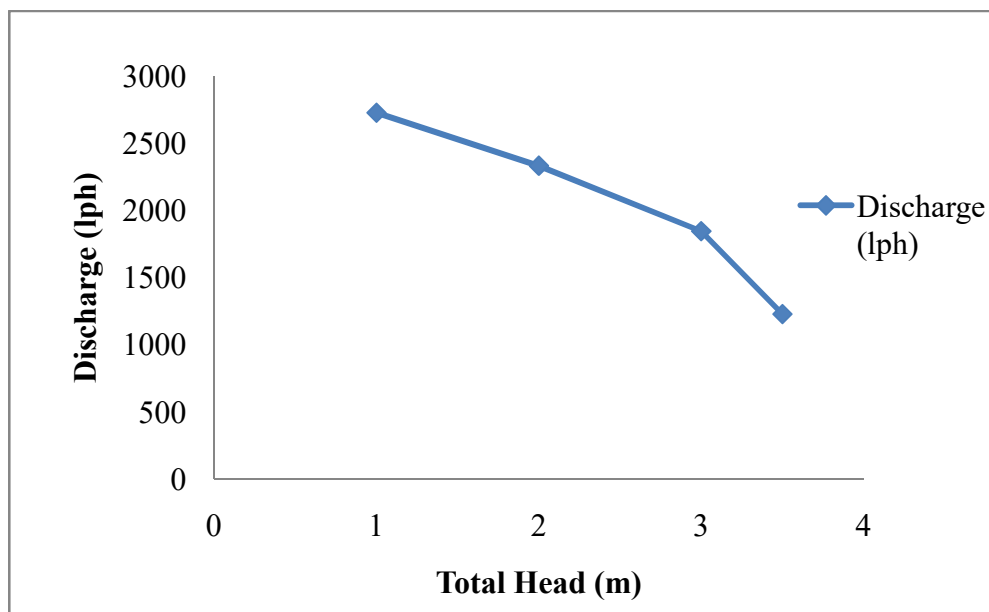


Fig 4.5: Relationship between different total head and discharge rate for five pumps

4.2.4 Measurement of discharge rate at different horizontal distances for combination of five pumps.

Discharge rate for the combination of five pumps of pumping system was tested at the different horizontal distances. The discharge rate at total head 1 meter and horizontal distance 5 m was found maximum i.e. 2720 lph and gradually decreases with horizontal distances increases. At 30 m horizontal distance discharge rate was found 1193 litre per hour. Discharge rate at different horizontal distances are shown in the table below:-

Table 4.4: Testing of discharge rate at constant total head (1 m) and different horizontal distances for combination of five pumps

Total head	Horizontal distance (m)	Discharge (lph)
1	5	2720
1	10	2458
1	20	1867
1	30	1193

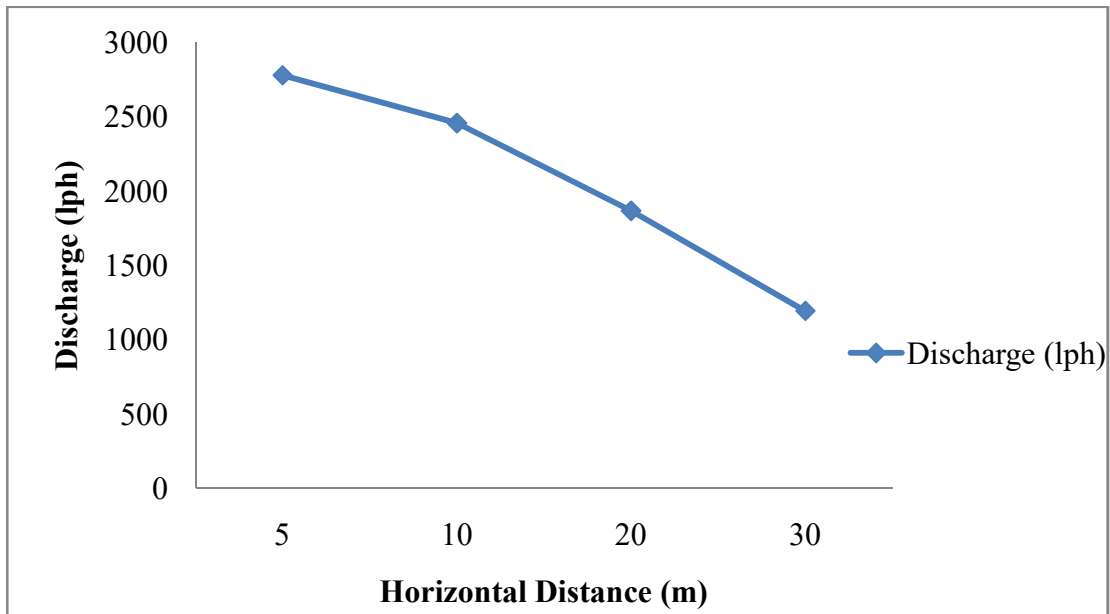


Fig.4.6 Relationship between different horizontal distance and discharge rate for five pumps

Data shows that discharge rate decreases with the horizontal length increases. Most of the marginal farmers needed to lift the water up to 1 m head and up to length 25-30 m for irrigation of the field. The discharge rate at 1 m total head and 25 m horizontal distance was found 1867 lph and 14936 liter per day which is sufficient to irrigate vegetable crops grown by them in badi-bakhri.

4.3 Cost Economics of Solar Powered Water Pumping System

Cost economics of developed solar powered low head portable pumping system to pump unit quantity of water was calculated and compared with diesel electrical and human power pumping system and the calculations are presented in appendix-III.

Discharge was taken constant and cost economics to discharge the taken amount of water was calculated. As the farmers need, at the 2 meter total head and 25 meter horizontal distance, the total discharge (lph) by the developed pump is near by 1850 lph and 14800 l/day.

Total cost of development of system was 11700 Rs. Total life cycle of the system was assumed 3 years and annual use was 2920 hour. Total cost of irrigation was calculated 14.09 Rs/day which is very low as compared to diesel, electrical

and human power pumping system. Total cost of irrigation was found 78.07 Rs/day with diesel powered pumping system (3 hp) which is given in Shakambari Yojana to small and marginal farmers, 17.69 Rs/day with electrical powered pumping system (0.5 hp) and 454.64 Rs/day with human powered gym cycle operated pumping system.

SUMMARY

The present research work entitled “Development and Performance Evaluation of a Solar Powered Low Head Portable Pumping System” was conducted at department of Soil and Water Engineering and tested at a nallah near Krishi Vigyan Kendra IGKV, Raipur (C.G.).

Solar powered irrigation system can be a suitable alternative for farmers in the present state of energy crises in India. These would be done for conservation of electricity and take a proper utilization of sun rays for producing energy. For lifting water from nallah, river, pond also which is nearby the small farms, users can utilise the solar energy as the form of electricity by the solar panel. The flow rate of pumped water is dependent on incident solar radiation and size of photovoltaic (PV) array.

There are around 37.46 lakh farm families in Chhattisgarh. The home stead garden (0.2ha.) locally known as ‘Badi’ covers 5% area of total area of Chhattisgarh. The soils of badi are entisols and inceptisol, fenced, upland and sloppy. Most of the badi contains one shallow dug well. Most of the farmers having badi in their backyard and they use to practice vegetable farming for their own consumption. The pumping system was mainly designed for small farmers of rural areas where the electricity is not available or available at non affordable cost. On the other hand Chhattisgarh Renewable Energy Development Agency (CREDA) is providing solar pump set is the range of 3 hp and 5 hp but not in the range of that marginal farmers need. As per small and marginal farmer requirements and keeping cost in the mind, low head portable pumping system has developed by using materials which is easily available. The developed system is of low cost than 3hp & 5hp solar pumping system.

Keeping all these points in the mind, the objectives of the present study are as follows:

Objectives:

1. Development of a solar powered low head portable pumping system.
2. Performance evaluation of the developed system.
3. Cost economics of developed pumping system.

The developed system was tested for single pump under the following conditions i.e. varying total head from 1 m to 3.5 m and different horizontal distance from 5 m to 30 m. Single pump was found insufficient to discharge required water to irrigate the field. So, parallel connections of five pump setup were taken to get higher discharge rate. It has been found that the developed system was able to lift water up to 3.5 m and achieved discharge rate 1230 liter per hour and also supplies up to 30 m horizontal distance with 1193 liter per hour discharge rate. Discharge rate gradually decreases with the total head and horizontal distance increases. Table based on results of various experiments conducted under the study were drawn.

FINDINGS

The developed solar powered portable pumping system was tested for its performance in field. Based on the experiment conducted following results were obtained:

1. It has been found that discharge rate at total head 1 meter was maximum i.e. 558.4 liter per hour and at 3.5 meter total head discharge rate was found 277 liter per hour for one pump.
2. It has been found that discharge rate at total head 1 meter and horizontal distance 5 m was maximum i.e. 560 lph and at 30 m horizontal distance discharge rate was found 216 liter per hour for one pump.
3. The discharge rate at total head 1 meter was found maximum i.e. 2730 lph and at 3.5 meter total head discharge rate was found 1230 liter per hour for combination of five pump.

4. The discharge rate at total head 1 meter and horizontal distance 5 m was found maximum i.e. 2720 lph and at 30 m horizontal distance discharge rate was found 1193 liter per hour for combination of five pumps.
5. Total cost of development of system was 11700 Rs. Total life cycle of the pump was assumed 3 years and annual use was 2920 hour. Total cost of irrigation was calculated 14.09 Rs/day which is very low as compared to diesel which is 78.07 Rs/day (3 hp), electrical 17.69 Rs/day (0,5 hp) and human power gym cycle operated pumping system 454.64 Rs/day.

CONCLUSIONS

The present study can be concluded as follows:

1. As per the design consideration the Low head portable solar power pumping system has been developed utilizing 100 watt solar panel and 5 number of 8 watt/12 volt DC submersible pumps.
2. The performance of the Low head portable solar power pumping system was tested and found satisfactorily in the field. The developed system is found very useful for small scale farming i.e. Badi-bakhari.
3. The cost of development of system was also not so high and it was found 11700 Rs. Total cost of irrigation was calculated 14.09 Rs/day which is very low as compared to diesel which is 78.07Rs/day (3 hp), electrical 17.69 Rs/day (0.5 hp) and human power gym cycle operated pumping system 454.64 Rs/day.

SUGGESION FOR FUTURE WORK

1. Pumps can be tried as series connection with solar panel for vertically water lifting.

BIBLIOGRAPHY

- Abu-Aligah, M. (2011). Design of Photovoltaic Water Pumping System and Compare it with Diesel Powered Pump. *Jordan Journal of Mechanical & Industrial Engineering*, 5(3).
- Anoop J R & Reema N (2017). Evolution of Solar Powered Water Pumping System. *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 6.
- Biswas, S., & Iqbal, M. T. (2018). Dynamic modelling of a solar water pumping system with energy storage. *J. Sol. Energy*, 2018, 1-12.
- Campana, P. E., Zhu, Y., Brugiati, E., Li, H., & Yan, J. (2014). PV water pumping for irrigation equipped with a novel control system for water savings. *Energy Procedia*, 61, 949-952.
- Chhattisgarh Renewable Energy Development Agency, Raipur (C.G.)
Directorate of Agriculture, Raipur, Chhattisgarh.
- Elrefai, M., Hamdy, R. A., ElZawawi, A., & Hamad, M. S. (2016, December). Design and performance evaluation of a solar water pumping system: A case study. In *2016 Eighteenth International Middle East Power Systems Conference (MEPCON)* (pp. 914-920). IEEE.
- Frenjo, A., Wogasso, A., & Rajesh, R. (2017). Designing and Developing Solar Energy Operated Water Pump for Small Scale Irrigation. *Int J ChemSci*, 15(4), 194.
- Ghoneim, A. A. (2006). Design optimization of photovoltaic powered water pumping systems. *Energy conversion and management*, 47(11-12), 1449-1463.
- Himran, S., Mire, B., Salam, N., & Sule, L. (2013, January). The Best Efficiency Point of the Performance of Solar Cell Panel System for Pumping Water at Various Lifting Heads Using 100 W Motor-Pump Unit. In *Proceedings of*

World Academy of Science, Engineering and Technology (No. 78, p. 707). World Academy of Science, Engineering and Technology (WASET).

Hossain, M. A., Hassan, M. S., Ahmmed, S., & Islam, M. S. (2014). Solar pump irrigation system for green agriculture. *Agricultural Engineering International: CIGR Journal*, 16(4), 1-15.

Ibrahim, M. M. (2020). Performance Evaluation and Optimal Sizing of Solar Water Pumping System Compared to Conventional Diesel of Remote Site in Egypt.

Kelley, L. C., Gilbertson, E., Sheikh, A., Eppinger, S. D., & Dubowsky, S. (2010). On the feasibility of solar-powered irrigation. *Renewable and Sustainable Energy Reviews*, 14(9), 2669-2682.

Khan, S. I., Sarkar, M. M. R., & Islam, M. Q. (2013). Design and analysis of a low cost solar water pump for irrigation in Bangladesh. *Journal of Mechanical Engineering*, 43(2), 98-102.

Kumar, B., Chauhan, Y. K., & Shrivastava, V. (2014). Performance analysis of a water pumping system supplied by a photovoltaic generator with different maximum power point tracking techniques. *Songklanakarin Journal of Science & Technology*, 36(1).

L.V. Girish, PurandaraNaik, H.S. BhanuPrakash, M.R. Sunil Kumar Mechanical Engineering Department, MITE, Moodabidri, VTU, Karnataka, India.

Malhotra, K. S. (1984). Potential for pumping irrigation water with renewable sources of energy in Indian arid zone. *Energy in agriculture*, 3, 245-251.

Mohtashim, M., & Vagh, K. N. (2018). Development and testing of solar power water pumping system for domestic purpose. *International Journal for Research in Applied Science and Engineering Technology*, 6(4), 42-47.

Maurya, V. N., Ogubazghi, G., Misra, B. P., Maurya, A. K., & Arora, D. K. (2015). Scope and review of photovoltaic solar water pumping system as a

sustainable solution enhancing water use efficiency in irrigation. American Journal of Biological and Environmental Statistics, 1(1), 1-8.

Pande, P. C., Singh, A. K., Ansari, S., Vyas, S. K., & Dave, B. K. (2003). Design development and testing of a solar PV pump based drip system for orchards. Renewable Energy, 28(3), 385-396.

Priyanka, V. Raghavendra, Vijaykumar Palled and Veerangouda, M. 2018. Performance Evaluation of Solar Water Pumping System. Int.J.Curr.Microbiol.App.Sci. 7(05): 133-142.

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Raghav, M. B., Bhavya, K. N., Suchitra, Y., &Rao, G. S. (2013). Design of Solar Power Based Water Pumping System. International Journal of Engineering Research & Technology, 2(10).

Singh, B., & Mishra, A. K. (2015).Utilization of solar energy for driving a water pumping system. Int Res J EngTechnol, 2, 1284-1288.

Singh, S., & Garg, V. K. (2015). Photovoltaic water pumping system for the development of rural irrigation. Krishi Sanskriti, 2(5), 3.

Suman, S. (2018).Evaluation and Impact Assessment of the Solar Irrigation Pumps Program in Andhra Pradesh and Chhattisgarh.

Yannopoulos, S. I., Lyberatos, G., Theodossiou, N., Li, W., Valipour, M., Tamburrino, A., &Angelakis, A. N. (2015). Evolution of water lifting devices (pumps) over the centuries worldwide. Water, 7(9), 5031-5060.

<https://en.climate-data.org/asia/india/chhattisgarh/raipur-5085/>

APPENDICES

APPENDIX- A

Table – A1: Testing of single pump discharge rate at different total head

Total head (m)	Discharge (lph)
1	558.4
2	461
3	372
3.5	277

Table - A2: Testing of one pump discharge at 1m constant total head and different horizontal distance

Total head (m)	Horizontal distance (m)	Discharge (lph)
1	5	560
1	10	498
1	20	369
1	30	216

Table -A3: Testing of discharge rate at different total head for combination of five pumps

Total head (m)	Discharge (lph)
1	2730
2	2335
3	1848
3.5	1230

Table -A4: Testing of discharge rate at different horizontal distances for combination of five pumps

Total head (m)	Horizontal distance (m)	Discharge (lph)
1	5	2720
1	10	2458
1	20	1867
1	30	1193

APPENDIX B

Cost analysis of developed solar powered low head portable pumping system

Table B-1 Total cost of low head portable pumping system

S. No.	Material	Quantity	Price (Rs.)	Amount (Rs.)
1	Solar panel	1 (100watt)	4000	4000
2	Solar pumps	5	750	3750
3	Inlet pipes	5 (5m)	30	150
4	Outlet pipes	1 (30m)	40	1200
5	Battery	1	1500	1500
6	Charge controller	1	750	750
7	Jointer	1	350	350
	Total capital cost			11700

Cost Analysis of System

1. Total cost of fabrication = 11700 Rs.

2. Assumptions,

- a. Expected life of machine = 5 year
- b. Annual use of machine = 2920 h
- c. Salvage value of the system = 5 % of initial cost

3. Fixed cost of the developed implement

a) Depreciation

$$D = \frac{C-S}{LXH}$$

Where,

D = Depreciation per hour

C = Purchase price, Rs = 11700

S = Salvage value, Rs. (Which is 5% of purchase price)

L = Life of machine, year

H = no of operating hours per year

$$D = \frac{11700-585}{5 \times 2920}$$

$$= 1.26 \text{ Rs/h}$$

$$= 10.15 \text{ Rs/day}$$

b) Interest on Investment

$$\text{Interest (Rs/h)} = \frac{C+S}{2} \times \frac{i}{H}$$

Where,

$i = \% \text{ rate of interest per year} = 12 \% \text{ per year}$

$$i = \frac{11700+585}{2} \times \frac{0.12}{2920}$$

$$= 0.25 \text{ Rs/h}$$

$$= 2.01 \text{ Rs/day}$$

Total fixed cost (Rs/day) = Depreciation + Interest

$$= 10.15 + 2.01$$

$$= 12.16 \text{ Rs/day}$$

a) Repair and maintenance

The repair and maintenance cost is taken 6% of initial purchase price.

$$\text{Repair and maintenance cost (Rs/h)} = \frac{C \times m}{H}$$

$m = \text{repair and maintenance rate } 6\% \text{ of initial cost}$

$$= \frac{11700 \times 0.06}{2920}$$

$$= 0.24 \text{ Rs/h}$$

$$= 1.92 \text{ Rs/day}$$

b) Labour charge = no any labour required.

Total variable cost = 1.95 Rs/day

Total cost of pumping per day = Fixed cost + variable cost

$$= 12.16 + 1.92$$

$$= 14.08 \text{ Rs/day}$$

APPENDIX C

Table C-1 Comparison of solar powered pumping system with diesel, electrical and human powered pumping system

Observation/ Particular	Solar power pumping system (0.0321 hp)	Diesel power pumping system (3 hp)	Electrical power pumping system (0.5hp)	Human power gym cycle operated pumping system
Discharge (lpd)	14800	14800	14800	14800
Working Hours	8	0.17	3	10
Life Cycle, y	3	8	10	8
Annual Usage, h	2920	62	1825	2190
Capital Cost, Rs.	11700	20000	4500	7000
Salvage Cost, Rs.	585	2000	225	350
Depreciation cost, Rs./day	₹ 10.15	₹ 6.16	₹ 1.17	₹ 2.28
Interest %	2.01	3.61	0.77	1.2

Total Fixed Cost	₹ 12.17	₹ 9.78	₹ 1.95	₹ 3.49
Labour Cost, Rs./day	0	0	0	450
Repair & maintenance cost Rs./day	1.92	3.28	0.73	1.15
Electric Cost, Rs./day	0	0	15	0
Diesel Cost, Rs./day	0	45	0	0
Lubrication Cost, Rs./day	0	20	0	0
Total variable cost, Rs./day	1.92	68.28	15.73	451.15
Total Cost, Rs./day	₹ 14.09	₹ 78.07	₹ 17.69	₹ 454.64

RESUME

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