

Running Head: PV SYSTEM

Design and Performance Evaluation of a Solar PV System for Powering Irrigation in Isolated
Regions

[Name of writer]

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This dissertation is an opportunity for me to extend my regards to my research supervisor, my beloved friends, and my family for their untiring support that they furnished throughout my research. I am grateful to them for their belief in me and the guidance that they provided me without which I would have never been able to work on and complete this research. It also signifies my own views and does not closely relate to the university.

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DECLARATION

I, (Your name), would like to declare that all contents included in this study stand for my individual work without any aid, and this proposal has not been submitted for any examination at academic as well as professional level, previously. It is also represents my very own views and not essentially those that are associated with other university.

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Abstract

Introduction: The irrigation is known to be a well-established process on various farms and it is being used across the world. The process facilitates in the diversification of crops and leads to cause an increase in the crops yield. Though, the typical system of irrigation makes use of an increased amount of energy by using the conventional energy through generators and electric motors.

Aim: The main aim of this research is to carry out a review in order to evaluate the effectiveness of Solar PV systems for empowering irrigations to isolated areas.

Methodology: The qualitative literature review methodology is being used in this research. The main purpose of the study was to locate the information or knowledge on any particular topic for recognizing the study parts for future. For establishing any search of literature, it is important to comprehend any research and its role in informing the practice as well as questioning. The literature is not only a summary of different studies but it have a specific pattern of organization which consists of synthesis and summary. It provides the information regarding the parts of topic that have been searched along with the use of methodology.

Analysis: There are about 6 studies that have been selected after the inclusion and exclusion criteria. These studies have shown that there are various applications of photovoltaic energy in the field of agriculture that gives electrical energy in different conditions specifically in the areas that do not have availability of electricity. The review of photovoltaic irrigation system has been provided along with the methods of increasing the efficiency of system.

Discussion: The solar powered photovoltaic systems gives a solution of increasing the efficiency of water in the field of agriculture by making use of the renewable energy system. The use of this photo irrigation systems facilitates in the conservation of energy and it will further contribute towards the socioeconomic development. This is identified to be an efficient solution for the farmers. This system further decreases the use of grid power and it is also easier to implement it.

Conclusion: It can be concluded that the major benefit of PV pumps as compared to the engine pumps is that they do not need any maintenance, fuel and they have a long useful life.

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Design and Performance evaluation of a solar PV system for powering irrigation in isolated regions

Introduction

The solar energy is the rich energy source present in the world. The solar power is helpful in dealing with the energy crisis but it is also an environmental friendly type of energy. The PV or photovoltaic creation is a competent method for using the solar energy. The solar panels are now being utilized for powering the heaters, for the street lights and fulfilling the domestic loads. The solar panels cost has been decreasing that increases its use in different sectors. This technology is also used in the irrigation systems for farming. The solar powered irrigation system is a suitable substitute for farmers in the recent condition. It is a method of energy production that gives free energy after making the initial investments (Harishankar et al., 2014).

The generation these days is heading towardsultratechnology. The pumping of water has a huge history and there are several methods that have been developed to pump water. There are several resources that are being used by people including animal power, solar, wind, hydro power and the fuels for various generators. Some of the common pumps that are utilized in the remote communities are hand pumps, solar submersible pumps, direct drive diesel, and the borehole pumps.

Advantages of Solar Pump in Irrigation Area

The major advantages of PV systems is that it has decreased operating cost. This is because there is no need of fuel for these pumps like diesel or electricity so the cost of operation is minimal. When a solar system is designed properly then it does not requires any maintenance

apart from the cleaning of these panels once in a week. It is an important benefit that the system provides with maximum output of water when it is required most that are the dry months. These panels are not necessary to be placed beside the well. These panels can be placed up to 20m away from the well or at a place where water is required. These pumps can be turned on or off according to the requirement if the period between two operations is about 30 seconds.

Aims

- To design as solar PV for the requirements in the isolated regions.
- To assess the effectiveness of Solar PV systems for empowering irrigations to isolated areas

Objectives

- To explore the requirement of irrigation in the isolated regions.
- To explore the previous knowledge regarding assessment of solar PV system and their performance.
- Determine power requirements of the irrigation system.
- To design a solar PV system to meet the irrigation demand.
- Assess of the performance of the design system.

Research Question

- What are the component ratings that can be implemented to suffice the long-term objectives?
- How to solve the basic issues that result in the loss of power for solar PV systems?
- What can be the specific design for the powering of irrigation?

Literature Review

Photovoltaic Cells

These cells are the devices that capture the light and transform into electricity. These cells are connected in series, connected among glass or plastic sheets along with a support a metal frame. These frames are considered as the panels or solar modules. They are mainly used for giving power to the different appliances like calculators, wrist watch, home systems and the power plants. The PV cells are composed of silicon wafers. The silicon wafers are known to be the semi conducting materials which resemble to those that are used in the computer chips. After the absorption of sunlight by these materials, the electrons are loosed from the atoms due to solar energy that facilitates the electrons to move through the materials in order to create energy. The process of conversion of light to the electricity is called as a photovoltaic effect (Archer and Green, 2014).

PV Applications

There are many of the solar panels that are used in several applications. These applications are varied from simple lanterns to the huge power plants. They are used for household and rural purposes like lighting. They are also used in communities, institutes, industries and lightening purposes for the powering of televisions sets and computers. The panels are further used for telecommunication purposes and water pumping systems. Sometimes these systems are present in those isolated areas where they do not have access to rural areas. The panels are further used refrigeration and cold storage of vaccines at the health centers in rural areas. These solar refrigerators can also be used for storing the blood plasma. The world health

organizations (WHO) supports those programs that have solar power for the medical purpose (Palma, 2015).

System Components

The complete system of solar pumping consists of the panels, support structure, pump, cables, electronic regulatory parts, and pipes. The solar panels are known to be an important part of the system and used for solar pump operation. Many solar panels are connected with each other for creating the DC electricity (Yalla, 2013). The connections in solar panels are made using the series or parallel combination for acquiring the required voltage and pump power. The second part is the solar pumps. These pumps are submersible or centrifugal which are directly associated with the solar arrangement by making use of DC power that is created by solar panels. The solar pumps are present in different capacities that mainly depend on the water requirement. The third part is tracking mechanism and support structure. The support structure gives stable condition to the solar panels and protect them from natural calamities. In order to acquire maximum water output, a tracking device is used which is manual for supporting the structure. The process of tracking increases water output and it helps the panels to face the sun because it moves across the sky. The foundations include array and pump and they are mainly provided in order to give pump and support structures. The electrical interconnections is a collection of cables of proper size, connectors, switches and junction boxes are given along with the installation. The earthing kit is given for safety purposes in the condition of lightning or short circuit. The pipes and fitting is needed for the connection of pump as a part of installation (Panaras et al. 2013).

Working of Solar Pump

A solar panel of 50 watts can give power to a 12 volt pump that can 1300 to 2600 L/h. The standards fitting of plastic and half inch piping associates these elements for a water saving tank of 500 to 1000 L. A strong stand must be created so that it can provide flow of gravity along with the construction of a frame in order to provide the optimum angle for solar panels. There is some need of multiple filters for the protection of pump life and decrease clogging in tubes and sprinkler emitters. When the solar pump is connected with the affordable drip irrigation kits with a huge variety of crops in order to increase the efficient condition of water, irrigation of hilly terrains and decrease the fertilizer loss (Si et al. 2014).

Aspects

Generally, the investment that is needed for a PV pumping system is \$2.5 to \$3 per watts peak. For instance, the cost of a 900Wp unit will be \$2250 to \$2700 but along with the use of subsidies it can be decreased up to \$500. In order to use the solar energy in an optimum way, the PV system, the ground water pump and the water distribution systems are needed to be matched completely. The PV power should also include the demand of power pump in a proper way. This is identified by an association among the efficiency of pump, overall head and the discharge flow. It mainly depends on the pump type that is mainly based on the depth of water source. The positive pumps of displacement are needed for the large heads and the centrifugal pumps are used that are provided in the below figure. The PV panel electrical outputs are mainly rated according to the STC conditions of 1000W m⁻² incident solar radiation with an operating temperature of 25°C and the complete air mass of 1.5 (Dursun and Saygin, 2005).

The conditions of environment that are fulfilled outside the body will result in decreasing the performance of PV from STC rating. In addition, the magnitude of STC mainly depends on the technology of module. The conditions of loss are sustained because of an inefficient condition in the transfer of energy from panels of PV to load like the battery bank or a pump that results in decreasing the secondary performance. There have been various studies that have studied the performance of PV modules and the further research is required in the field of PV systems. An additional noteworthy aspect will be the ability for a typical potential solar radiation, water output, and the PV power output for the method of irrigation scheduling. The water pumping systems that are powered by PV are being studied in several studies from past several years. The studies that are mainly based on DC motors because the energy that is being acquired from the solar panels is direct current (Dursun and Saygin, 2005). It shows that the proper results can be acquired from performance analysis (Kolhe et al., 2004).

The advantages of PV irrigation system are over flood irrigation for providing complete use of water sources, growing of weeds and the complete prevention of erosion (Cuadros et al., 2004). Some other advantages are reduction in moisture stress (Pande et al., 2003), less cost of operation, opportunity for the local energy sources and providing a similar point of view with need of water (Ghoneim, 2006). In the condition of automation, the wireless technologies have been developed and the main focus of researchers is on the automatic irrigation process in agriculture system with the help of sensors (Kim and Evans, 2009). The main advantage of using a wireless sensor is to decrease piping and wiring cost. Moreover, it is also feasible to install and uphold the wireless sensor over a huge area (Dursun and Ozden, 2010). The pump energy that is mainly used for the agricultural process of irrigation is mainly provided from fossil fuels or the electrical energy.

The solar energy is sensitive to environment and it needs clean area. However maintenance is not required. The solar energy is considered as an alternative energy source for the different countries like Turkey that have an increased amount of solar irradiation rate. It means that the requirement of PV irrigation system does not requires water (Anis and Metwally, 1994). In the summer season, the acquired amount of solar energy is increased and the water requirement of trees is also increased. The cost of solar PV has been decreased and the cost of diesel is known to be increasing continuously. In the current situation, the cost of solar PV is very less as compared to diesel. The cost of solar PV has become half of the cost of diesel within three to four years and it is heading towards the grid parity. There are also several telecom towers that are related with the diesel producing sets that have a capacity of about 3 to 5 kW. A few telecom towers are located in the semi urban and urban areas but most of the urban towers are present in rural areas and they are being controlled by the diesel producing sets. Moreover, it is stated that the off-grid potential very higher in some regions across the world (Arora, 2014).

The solar pumps of water are considered to be a luxurious technology at times, that is not durable and is not able to pump enough water. Though, the solar water pumps have been improved in the previous years and the pumps that are available in the market today are identified to be an improved version of the past technology. For example, the submersible pumps have an ability to pump about 200m heads. There are also some of the pumps that have an ability to pump huge amount of water up to a distance of large volumes. For instance, these pumps can transfer about 10,000 litres of water up to a distance of 100m or the 20,000 liters of water up to a distance of 50m each day. This performance can be increased by using the dual system (Dursun and Ozden, 2010).

These pumps have very less maintenance requirements about 3 to 5 years. Their performance is optimum which shows that few solar panels can pump large amount of water. The genset can be used in order to pump up the additional amount of water with the similar pump in the overcast or night days. These pumps can be installed easily and they have an optimum quality and reliability. In addition, the solar pumps are also identified to have the following provided features. These pumps do not require much attention because they initiate operation automatically. Some of the pumps can pump over all the days and they are useful for boreholes. The weaker boreholes can be utilized in an effective manner by a decreased volume pump because of pumping to about 8 to 10 hours in a day. In many of the cases, a solar pump is identified to be a perfect solution for the diesel option that needs operation of funds, investment of time for operation of pump and logistics of fuel. The tracking arrangement can be utilized in order to increase the daily rate of water pump. There are no risks of borehole contamination and they provide clean solutions (Dursun and Ozden, 2010).

The photovoltaic technology can be utilized for the production of electricity from an incoming solar light. There are various attempts that have been made for monitoring, improvement and evaluation of the several components of a PV system. Huang and Sun, (2007) have tried to bring improvement in the PV module, Hohm and Ropp, (2003) worked on the controller, Achalhou et al., (2012) worked on a battery, Vick and Clark, (2011) worked on the pump and the pump motor. In addition, many other similar studies have been carried out for the improvement of efficiency level of PV system parts. In addition, many of these aspects are also required to be considered for an optimum PV system design. There are some of the factors that are needed to be considered for an optimum design of PV system in order to acquire the reliability of system in a specific environment. This includes a complete examination of

meteorological, physical, and managerial variables with a purpose of acquiring the reliability of PV system. It is a technique which is a combination of water requirements, center pivot irrigation, soil moisture status, PV array output, and energy storage is needed for the assessment of center pivot irrigation system in the context of reliability. This type of holistic approach can be very helpful for the effective management of the system. The environmental conditions that are present outside the laboratory will result in decreasing the performance of PV. The significant environmental conditions that can be considered are wind speed, temperature, ambiance and insulation (Van Dyk et al., 2005). The PV system is also known to have a flexible setup. An efficient use of solar energy is when the solar panels are associated with the load.

Specifically, the water pumping process can be successful in decreasing the middle stage known as battery bank for the storage of energy. Water can be pumped in daytime by having a direct association between the pump and the PV array. An efficient type of direct connect system is when the water is being pumped into the elevated storage tank. Therefore, the electrical energy obtained from the panels is transformed into the potential energy that can be used on demand by gravity (Hamidat et al., 2003). In addition, the complete efficiency of sunlight is identified to be higher than 3% (Daud and Mahmoud, 2005). It is very easy to implement this system and this is an environment friendly way out for the irrigating fields. This system is identified to be successful when it is implemented over the bore holes because they pump over the complete day. The solar pumps further provide with the complete and clean solutions without any danger of borehole contamination. This system needs minimum maintenance and care because it can be started on its own. In order to increase the daily pumping rates, the tracking arrangement can be implemented. This system determines regarding the application and feasibility of solar PV in order to give energy to the pumping needs for sprinkle irrigation. However, there is an increased

capital investment needs for implementation of this system but the complete benefits are higher and it is also known to be economical (Harishankar et al., 2014).

After the economic analysis, it has been identified that the PV pumping system for irrigation is easy as compared to the diesel pumping system. In the economic perspective, the PV pumping system for one season irrigation is more than the diesel engine pumping system because of an increased cost of PV module and its parts (Haque, 2001). The technology used in the irrigation system can result in decreasing the gap among consumed energy and conservation of resources by decreasing the waste of resources. The major benefit of this project is the optimization of power use by resource management of water and the saving of free subsidiary energy of government. This provides with an efficient and economical method of irrigation that will further facilitate in the automation of the agriculture sector (Yalla et al., 2013). The development of a grid system can be very expensive in many of the countries because the rural villages are present far away from the current grid lines. Even if the fuel is available in the country then it is difficult in many regions to transport the fuel. There are several place across the globe where are no roads or supporting infrastructure present. The use of renewable energy is very attractive for the water pumping applications in the different remote regions of several developing countries.

The transportation of renewable energy systems like the photovoltaic pumps is very easier as compared to the different types because they can be transported easily in different pieces and they are collected on the location (Khatib, 2010). The cost analysis of life cycle includes both the systems that shows that the PV water pumping system is highly economical selection over the diesel water pumping system (Narale et al., 2013). Cuadros et al. (2004) is an important method that is helpful for identification of size and capability of solar based irrigation

systems as the cost of photovoltaic systems is very high. The feasibility is focused not only in terms of PV system cost along with the land area that is needed for the implementation.

According to Glasnovic and Margeta (2009), there are different areas that can be irrigated in an economical way. In the same way, Kelley et al. (2010) has suggested that PV irrigation is economically and technically practical in the condition when there is sufficient land present for the solar arrangement. An important issue about the use of solar panels for creating power is the amount of panels needed and the area they would occupy.

In the condition of agriculture, it is specifically important because it directly effects the area that is left for planting. This indicates that there is a little amount needed on a two acre plot for panels. This determines the application and feasibility of use of the solar PV for providing energy for the pumping needs for the drip irrigation. Some of the important aspects that are considered for the pumping requirement calculation. Therefore, the area of solar panel includes selected crop, number of peak sun hours, and size of planting region, pump efficiency, elevation of pumps, and the efficiency of solar arrangement. These aspects are considered to be affecting the feasibility of these systems. The research has shown encouraging results for the use of solar panels with respect of area needed to be created to produce power for the pumping need for drip irrigation of hot peppers on a two acre plot (Persad et al., 2011). The particular studies have focused by looking at the use of PV systems on several small farms. There have been several feasibility studies which have assessed the technical or the economic feasibility of PV irrigation. There are several studies that were location specific and size specific. Those studies that focused on the systems related with the requirements of power on the order of 1 kW have been conducted in different countries across the world like India, Namibia and Jordan (Meah et al., 2008). It has been identified by the literature that PV irrigation system is a technically reasonable for the small

systems that are of a single acre (Kelley et al., 2010). The solar pumps are known to be very successful in Asia and Purohit and Michaelowa, (2005) stated that there were about more than 7000 pumps in the operation across Asia. Though, the solar powered tube wells cannot be searched easily and there is low possibility of their existence.

The cost of PV cells is following the More's Law and the diesel price is increasing, the pumping by the help of solar pumps is identified to be an economical idea. The water pumping process is identified to be highly reliable and economic way of using the PV system. There are many of the PV systems that depend on the storage of battery for the power of lights and other appliances at night time. Several of the PV systems do not make use of the batteries and the modules directly give power to the pump. In the absence of batteries, the PV pumping system is identified to be very simple and it has only different three parts. These parts are pump, pump controller and the solar array. The only component of the system that is moving is the pump. It has been warranted that the solar modules can remain productive for a period of 20 to 25 years. The life of several pumps can be of 5 or more than ten years. Apart from the damage to controller and pump, the only maintenance that is required in this period is the cleaning of solar module after every 2 to 4 weeks. The local labors can also perform this job as well (Aligah, 2011). Hammad (1999) carried out a research that is associated with the use of photovoltaic produced electricity for the pumping of water from the 13 different wells that are present in the south east and east desert of Jordan that is also known to be difficult topographical situation. It is the ability of these pumps to pump about 40-100 m³ of water each day in order to fulfill the daily demand of people who live in those areas. A completely automated irrigation system is built, created and tested by using the digital controller and the solar PV cells. This system is identified to be compact, reliable, portable and economical. It can facilitate in saving the electricity bill and

bills of water that can be helpful in the justification of the initial cost which is a bit higher than the conventional system. In addition, it also causes less damage to the environment along with decreasing the utility from an extra load. The PV system can be used in gardens, parks, lawns and big farms. Moreover, it can also be used like a worldwide solar based controller for controlling the building doors, air-conditioning, control systems and the water heaters (Ali, et al., 2001).

The technology of solar water pumping is available at commercial level and it has proved the different records of reliability, needs minimum manpower after initiation of work and the cost of maintenance is also identified to be affordable and minimal. There are different advantages of PV pumps like they mainly operate on sunlight that is available freely without any cost and there is no use of electrical or fuel cost. These systems are also known to be have a long working and a reliable friendly life (Yingdong et al., 2011). A major advantage of using the solar energy to pump water is that the huge amount of water is needed during day time and at the same time, the maximum energy is produced by PV panels along with the huge quantity of water. These solar pumps are present in those locations that are not associated with the national electric grid (Sahin and Rehman, 2012). The PV systems for the pumping of underground water are also being used in the Upper Egypt region which also indicates that the cost of water unit that is pumped by PV systems is less than the pumping used by diesel systems (Yiu et al., 2011).

There are certain limitations of using the PV pump. It is not necessary to use the pump in the places of high requirement. The maximum capacity that is present with the use of solar panels is very low. In addition, the output acquired from the solar DC pump is higher than a normal pump. The yield of water of the solar pump is changed with respect to the sunlight. The yield is very high in afternoon and it is lower in evening and early morning. Therefore, it is

required to operate the pump during afternoon. The solar panels can also be theft in some of the regions and it is needed that the farmers must be taking needed steps. The PV system must be protected from being theft or other natural hazards like rain or lightening.

Methodology

Review Method

The search of literature is defined as a systemic approach for retrieving, identifying and bibliographic material to manage the studies. The main purpose of the study was to locate the information or knowledge on any particular topic for recognizing the study parts for future. For establishing any search of literature, it is important to comprehend any research and its role in informing the practice as well as questioning (Parahoo 2006). The main argument for this particular research study is to carry out a review to examine the design and performance evaluation of a solar PV system for powering irrigation in isolated regions.

The literature review is an important step in the process of research. The literature review means identification of documents and the articles that include the published or unpublished on the specific topic. It consists of information, ideas and evidences that are extracted from a specific point of view in order to acquire the specific views regarding the nature of any topic. Silveira et al. (2001), stated that the information which is acquired for the review should be read in a systematic way, synthesized and critically appraised into the logical literature review and the coherent structure. The literature is not only a summary of different studies but it have a specific pattern of organization which consists of synthesis and summary. It provides the information regarding the parts of topic that have been searched along with the use of methodology. In

addition, it also indicates about the research gaps and the further research that must be carried out for providing the evidences.

The main aim of literature review is to provide the complete coverage of literature along with introducing the research insights and major developments that can be translated back in the practice setting along with highlighting those areas that require further investigation (Bryman, 2015). A literature review facilitates in providing more than the critical appraisal of the articles. In addition, it must also provide a structure on which the research can be based. The gaps in the knowledge base are needed to be identified along with the weakness and strength of the previous studies. According to Yin (2013), a literature review is considered to be fundamental when all the studies that have been developed in the modern era. After getting an understanding about the previous research, the conclusion and results of a previous research can be compared by the previous results. The thinking of new researchers can be more systematic and logical. The main aim of literature review is to summarize the literature that is present on any of the provided topics. It facilitates the researchers to get associated with the topics for examining the evidences or interpretations of existing knowledge.

The literature review is known to be a type of research which has an aim to provide the credible recommendations for research. The critical literature review facilitates the researchers to use the research evidence in practice apart from depending on the individual studies. The literature review is known to be a complete research methodology. In addition, they provide with a solid background for the investigation of the research paper. The detailed knowledge of field literature is important for many of the research papers (Polit & Beck, 2013). The research imagination can also be stimulated by the help of a critical literature review (Yin, 2013). An important way of dealing with the research problem is to focus on how different people are

dealing with it. The different positive benefits can be acquired by the researchers in order to create the new ideas for working. The use of photo voltaic or the solar power pumps for irrigation of water is identified to be a useful method. Several authors have tried to assess the effectiveness of Solar PV systems for empowering irrigations to isolated areas and the literature review is a best method to provide an overview for a specific topic (Parahoo, 2006). The limitations of the current practice can also be identified. The relevant research papers have been selected for the review.

Qualitative Design

The major point in this specific research is to carry out a review in order to explore the solar PV requirements in the water pump irrigation. In order to carry out a literature review, the qualitative research design is identified to be an appropriate research design. It is useful to examine the different projects. It further facilitates in legalization and authentication of data that is collected from the primary sources. It further facilitates in the refining of research and adds a primary hand to it. There are different researchers who state that secondary data is important because it indicates about the past studies. Creswell (2009) stated that the qualitative research consists of the exclusive steps about enquiry and analysis with the researchers interpreting about what they hear, understand and see. The method that has been used in this research process is qualitative. In comparison to the quantitative research, the qualitative research is very subjective and it is mainly based on the several method of collection of information. This research is more or less a literature review and it is mainly based on the basis of actual resources.

Critical Analysis

The critical analysis is central process of any research study. It involves critical thinking which applies logical and rational thinking while deconstructing the text. It is a complex, intellectual activity involving analysis and critical comment on the material formerly gathered. Browne and Keeley (2001) defined the critical thinking as a set of awareness which interrelates with the research question under study which is expected to be critically analyzed. It is an ability to answer and ask the critical question at a specific time and it desires to use the critical questions actively). Consequently, it is not just a descriptive list of the set of accessible summary and material. Without a critical appraisal and systemic literature any academic study cannot be applied to a methodology or in any way put in to the knowledge (Hart, 2005). Critical appraisal of the literature also offers a room for the comparison of the results of diverse researches.

Literature Search and Sources

The search of literature is a basic element of writing a literature review. It must be carried out in an unhurried and systemic approach. The literature search is a fundamental part of any research and it can be carried out in a manual way or by the use of computer technology.

Hart, (2005) has provided with a complete list of searching the sources to provide with the research information like journals, reports, and theses. They further facilitate in providing the useful information as a guide to convey the research information. The journals can be helpful in providing the useful information as a basis to convey the research. The updated information can also be provided by the journals on a particular topic. The preferred source of research are journals which indicate about the original research. The professional journals consists of several sources of information. Books can also be used as a source of information and they are usually

present in the research that have a strong theoretical base. They include the subject area in a thorough way and provide with the clarification of the theoretical argument and discussion.

Search Strategy

There is no single way that makes sure that the retrieved information is associated with the research question. Along with the increase in the use of computers, the electronic search is identified to be an important part of the search strategy (Aveyard, 2007). The electronic search for database is identified to be an initial point for searching the literature (Burns and Groove, 2010). This method of search gives a reviewer with a list of abstracts or the bibliographic information. It is also used when the multiple concepts are needed to be associated with each other. The electronic databases are considered to be time saving because the record in computer is present a month before they are appeared as a complete form. The databases that were used in this research are Elsevier, ScienceDirect, Sage, and Emerald.

The keywords are known to be an important concept or the research variable for a specific topic or a research problem. The synonyms can also be used as the keywords as a major variable of the research problem or the topic (Burns and Grove, 2010). The keywords in this research are “photovoltaic power systems”, “photovoltaic pump”, “rural development”, “solar pump”, and “irrigation technology”. In many of the databases, the phrases can be used and words can also be used in the form of a single term. The Boolean search is a common way to search the phrases or phrase in the database. By the help of using a Boolean search, it is required to collect ideas, select the search places in a record and showing of relationships in a database record, paragraph or a sentence. The Boolean search consists of terms like “AND”, “OR” and “NOT”. The term “AND” is used mainly for searching the existence of two or more than two term in the

similar citation. The term “NOT” is used for the search of one idea but not another in a similar citation. The term “OR” is used for the search of presence of any group of terms in a similar citation (Burns and Groove, 2010). The Boolean search has been used in this study to extract the related terms or phrases that facilitate the searching.

Apart from the advancement in electronic searching, the computerized tools of searching are not completely comprehensive and they will fail to recognize the relevant literature in the topic. It is because the relevant literature can be categorized by using the different keywords and they cannot be identified by one specific searching strategy (Aveyard, 2007). The effectiveness of searching technique is also based on the keywords that are being used in the research process. The wide range keywords may have excessive search results but a particular keyword can provide the improper results.

Inclusion and Exclusion Criteria

In order to completely focus on the literature search process, the inclusion and exclusion criteria can be used to recognize the literature which deals with the research question and they must be referred in a frequent way in the search process. It is stated by Aveyard (2007) that criteria is needed to be planned for the search of literature and making sure to not to be sidetracked with the data that is not relevant to the research. There are different studies that have same hypotheses and research questions. However, these studies make use of various sample collection methods, operational definitions, specific research designs and the specific methodology (Hart, 2005). The use of inclusion and exclusion criteria can facilitate in obtaining the relevant research studies from information for discussion and time saving for the researcher at the end. Generally, the literature must have a relatively broader criteria of inclusion. Apart

from the negative and positive research, the criteria of exclusion must be examined carefully. The selection criteria of inclusion studies must be clear for protecting from the bias. The primary studies can only be included in the literature review and they are identified as the secondary sources. In this condition, the author has interpreted the work of an individual who have introduced their own point of views and perceptions (Burns and Grove, 2010).

The strategy of search in this research is mainly based on the evidence that are present in the previous ten years and they are mainly the primary studies. The search of literature will only include the material that is published in English language and due to this reason it will not be an issue to reject any search due to the reason of translating complications. All of the studies were focusing on the solar panels only. The criteria of exclusion had those studies which has not been published as the complete manuscripts or that are not present in the peer review literature. The studies that were not have solar panels as irrigation method were not included. In addition, those studies which were the conference papers or the government reports were also not present in search of literature. The research will only be restricted to extract the literature that is present in English language.

Ethical Considerations

The researchers have always been struggling with the ethical issues in eth designing of studies that are ethical and methodology rigorous. The code of ethics are always applied to develop the guideline researchers. The major ethical issues that are included in many of the guidelines are respect for human dignity, justice, beneficence and non-maleficence (Polit and Beck, 2013). During the analysis of literature, it is required that the author must remain bound ethically to make sure the literature is in an air and balance way. Hart (2005) has stated that it is

needed to make sure that the research findings of all the people are present in and honest and fair manner. Therefore, the author needs to explore the background and justification of research. The potential conflict of interest and publication bias is also needed to be examined for the dissemination of opinion and rationalization of result.

Limitations

There can also be a possibility of publication bias in this review. However, from the published literature, the comprehensive search for the appropriate articles includes by the means of a strategy for systemic review for the purpose of avoiding the bias. It was made possible by initially contacting the corresponding and first authors of the research. Though, there are no unpublished or negative studies as it the occurrence of these studies is also possible.

Results

Singh et al. (2010) carried out a research that indicates about the utility interface solar power converter for supplementation of the lack of grid power supply for the water pumping system that is used in rural areas. The power supply system includes solar array, PWM converter including the PWN control strategy, water storage tanks, energy storage devices and the submersible pump. The model of this system has been created for the optimum operation and the prototype solar power converter has been created to operate a half hp pump motor. The life cycle cost analysis of the solar power convertor has been carried out and compared with the conventional DG set. It has been carried out in a 60% to 70% of the grid power saving.

Mansaray (2014) carried out a research which showed that it is associated with the design of photovoltaic pumping systems for the remote areas of the countries that are in a developing

state. In this research, a design procedure is explained that made use of energy demand structure, hydrological data, and solar radiation levels at the location as input parameters is explained. The design procedure in this research has been applied to a case study for adjusting the PV pumping system for an island located in Sierra Leone. In this research, a simulation program has also been used in order to estimate the long term performance of PVP systems. This program is also used to quantify the design studies. The information gained from the simulation is mainly used for developing an economical final system layout.

Khan et al. (2012) carried out a research where it was stated that Bangladesh is a region in which the energy disaster is considered as an important issue and the country does not have any problem of sunlight ($\sim 4.5 \text{ kWh/m}^2\text{-day}$). This country is not much successful in making use of the solar energy in order to give electricity for the people who are living in the remote areas. The solar photovoltaic pumping is another method to decrease the crisis of energy in Bangladesh. This research mainly deals with the analysis of performance and design of a DC photovoltaic water pumping system. The DC solar water pump is created and it has been experimented in order to explore the results with an uninterrupted association with the solar arrangement. There are different methodologies to increase the efficiency level of the system. Many of them have been discussed for the implementation of the system. At the final stage, the DC-DC buck converter is being designed and it has been created to provide an increased performance of the system. The inverter and battery is not used in the projected system that provides with zero maintenance. All of the parts in the system are acquired from the local market of Bangladesh and the overall cost is also decreased as a result. There is a huge prospect of DC water pumping system in order to solve the energy crisis in the season of irrigation and it can be used in the cultivation of land across the year.

Kumar and Singh (2014) conducted a research regarding the application of single ended primary inductor convertor present on the PV system of water pumping. A permanent brushless magnet DC (BLDC) motor is used in order to operate the centrifugal pump that is attached to the shaft. The soft starting of BLDC motor is acquired by the control of SEPIC with the incremental conductance maximum power point tracking (INC-MPPT). The SEPIC consists of advantages of non-inverting polarity output voltage, low input current pulsation and the simple gate drive circuit. Apart from this, SEPIC is controlled as a DC-DC buck boost convertor that can increase or decrease the input voltage level present at the output. This condition gives the elasticity of optimizing the operating point of SPV array at the level of voltage. The steady state and dynamic performance of the BDLC motor associated to the centrifugal water pump controlled by the SPV array, SEPIC is evaluated. In addition, the proper condition is confirmed by the simulated results by making use of Simulink and MATLAB environment.

Meah et al. (2008) stated that many regions across the world and specifically in United States are rural. The electrical distribution lines are not present in different parts of the villages, ranches and farms. The cost of distribution line extension can have a range of \$10,000 to \$16,000 per Km. Therefore, the availability of electricity to the small projects of water pumping are not attractive economically. However, the sunlight and ground water is available due to which the SV powered pumping of water is highly cost effective in the areas of small scale applications. There are several western states like Wyoming who are facing drought from six years and there is lack of water for several applications. The researchers and climatologists who are present in this state are predicting drought for about 5 to 10 years. The surface of water is also affected in the condition of drought and it takes more time to create an effect on the underground aquifers. In order to decrease the effects on wildlife and livestock, the governor of

Wyoming planned solar water pumping initiative in association with the University of Wyoming, ranching organizations, electric cooperatives and county conservation districts. The author further stated that there are various advantages over the traditional systems. For instance, the propane or diesel engines need expensive fuels but they also create air pollution and noise in different remote areas. The solar systems are identified to be environment friendly, without any fuel cost, and lack of maintenance. In this research, the site selection, installation, monitoring of performance and design of the solar system for water pumping has been provided. This research also gives economic, environmental, and technical advantages of the SPV water pumping system as compared to the electric utility and the stand alone generator.

Karampuri et al. (2014) conducted a research in which the solar photo voltaic system that is providing power to OEWIM (Open-End Winding Induction Motor) by the help of a dual inverter. This induction motor is then connected to a centrifugal pump that is being used for water pumping. The inverter controlled motor is selected because it needs low voltage that can facilitate in arrangement of PV modules that can avoid the large strings. In the given system, a single source of PV is connected with the inverters that facilitate in the zero sequence current and results in providing harmonics to the system. In order to decrease the zero sequence current in the SAZE (Sample-Averaged Zero-sequence Elimination), the technique of PWM (Pulse Width Modulation) is adopted. This process further allows the fixing of one inverter by the other that is being switched. This decreases the loss of switching and the efficiency level can be increased that is known to be an important factor which must be considered in a PV system. In addition, the above process, also decreases current wave at the higher modulation indices. The tuning of modulation index is carried out by the help of MPPT process that is known as Maximum Power Point Tracking. The process of modulation index helps in differences in the ambient temperature

and insolation. The research further consists of an explanation about the control process for the acquired system and its simulation results under different conditions of environment.

Water Requirement of Plants

The supreme amount of water that is needed for the system has been considered with respect to the equation and it is provided in the below table

Month	Requirement of water of the plant (irrigation to be take place in June)
Jan	6.78
Feb	8.30
March	9.26
April	13.17
May	17.22
June	5.81
July	4.62
Aug	5.02
Sep	7.23
Oct	8.65
Nov	7.86
Dec	7.45

Table 1: Monthly Requirement of Water for the Plants

According to the equation:

$$\text{power} = Q(\text{m}^3/\text{s}) * H_p (\text{m}) * \text{density} * 9.81$$

$$= 9.720 \text{ m}^3 \times 1.5 \times 1000 \times 9.81$$

$$= 143029.8$$

Discussion

Increase in PV Pump Efficiency

According to the research of Singh et al (2010), the traditional technology that is being used for accessing water from the available sources like open well or bore well water pump for lifting water and storing it in the overhead tanks. These pumps are provided with power by alternative diesel generating or conventional supply of grid. However, an increased cost of fuel that is being used by the DG set and non-availability of proper grid supply have allowed the scientists and engineers to look for an alternate energy resource for producing electrical power (Lindgrin, 2002). The solar photovoltaic energy is considered to an important source of energy that is preferred due to sun fuel, lower maintenance, straight forward technology and reliable use. The solar cells are expensive but the efforts are being carried out to make it affordable to use for the conversion of power but also for creating the roof cover or exterior wall of the water pump house or the farm house. In addition, the requirement of electricity is also increasing each day and the grid supply extension has decreased due to the restricted resources like fossil fuel and more. Moreover, it is not possible to expand these resources due to several economic and technical reasons. This condition has caused the researchers to improve the solar power convertor to produce power that can fulfill the increasing demand of energy for the rural areas and the country related with the weak grid supply.

In the research of Singh et al (2010), the investigations have been made for developing the solar power convertor as a modified and an alternative source to grid for the agricultural and the household applications for rural areas in villages. The system consists of following features that the technology being used in this proposed scheme is very simple, fast response, cost effective with respect to stability and control under load conditions or the solar radiation. This

system can also be managed up to a higher rating in an effective way. It can be maintained easily with the sinusoidal quality, a bit of harmonic content and decreased loss of switched. The feature of load power and adaptability of inverter and PWM control strategy provides with the constant efficiency with an increased value and less than THD value which is not associated with the different level of load demand and the soar isolation.

Mansaray (2014) conducted a research in which the simulation of time step was carried out in the solar photovoltaic pumping system by making use of interactive simulation of renewable electrical energy supply systems (INSEL) software. The time step simulation is a tool that is being used for the pumping of system analysis and optimization of design. This is necessary for increasing the efficiency of time and decreasing the needed size of solar PV generator. The checking of system that is designed in this work by the help of time step simulation is made possible to differentiate the behavior of system by changing the irradiations. These irradiations can further result in a final and optimized design of a system. This ideal design can be considered as impractical if the theory is highly complicated. Therefore, the analysis facilitates in derivation of the simplified rules of design and the problem comprehension. The solar PVP system installers require simple guidelines of design or an easy way of using the integrated model of computer. This simulation process indicates that the final layout of the system is known to be the selected one pump system and the collection of rain water in the month of July, August and September as the back-up. An increase in the size of solar PV generator can accomplish the system issues overall in the year but it can result in severe increase in the system cost.

Designing of a Solar PV Pump

The solar water pumps are designed specifically to fulfill the needs of water in the water scarcity areas. There are three different types of pumps according to the applications. The pumps are submersible, water floating and surface pumps. A submersible pump is one that extracts water from wells, shallow wells, ponds, rivers, lakes and the springs. In addition, a floating water pump is one that extracts the water from reservoirs that have the height ability in accordance with the ability of water. There are different types of pumping with respect to the pumping principle. These are the centrifugal pumps in which the liquid is drew by the help of using a centrifugal force that is created by impeller. In addition, the casing allows the liquid to the outlet along with the rotation of impeller. There is an increased velocity of the liquid and pressure. The screw pumps are those in which a screw is stored in the liquid in the suction area of the pump casing and it also forces it in the outlet. The third is the piston pump type in which screw holds the liquid in eth suction area of the pump and allows it to the outlet. The piston pumps are those in which the motion of these piston brings water in a chamber by making use of the inlet valve and moves it outside by using the outlet valve.

The process of pump selection in the solar water pumping process is mainly done by the help of its use like the water height, water quality and the requirement of water. There are different types of motors which are available in the market. These types are permanent, magnet, brushless, brushed, asynchronous, synchronous, brushed, reluctant and many more. The arrangement of PV pump can be associated directly with the motor in a condition when the application requires DC motor. If the AC motor is required by the application then the controller is required to be presented in among the motor and PV array. The pump and motor are created in combination for the floating and the submersible systems. In this condition, the consumer have a

choice to select the pump and motor in a separate way and explore the performance with the help of a panel and a controller. It is important to use the PV controller along with using an AC motor. The controller separates the PV arrangement from the system of pump and motor for an increased safety. Moreover, it also provides with the motor and pump with an optimum current and voltage for the site conditions. The pump and motor is also controlled by the pump and motor from being dried with the optimum current and voltage being dried for the conditions of site. The controller further provides protection to the pump from running dry and causes conservation of water by turning off the system after the tank is full. In addition, a highly vulnerable part in the SPV water pumping system is controller because it consists of electronic parts and it is required to be used in several environmental conditions.

The main aim of the final output of design and installation is to give sufficient water to the wildlife and livestock. The design process further needs process information regarding the water requirement, source of water, solar radiation, and the duration of system in an year. The system design initiates from the information about the requirement of water for a specific application, characteristics, water sources and the facilities of storage. An aim of this step is to give sufficient water to the wildlife and livestock but also to conserve water so that it can be used in the future. The unnecessary overflow of water can be handled easily by making use of a storage tank and an automatic float switch. This design further contains the sizing of solar panels, sizing of pump, and the selection of controller. The system of solar water pumping must provide enough water across the year. In order to make sure about the fulfilling of requirements in the worst condition is the winter or fall operation that is considered for the design.

The sizing of pump requires three different types of information like requirement of water, overall water head, continuous flow of water, and the rate of recharge of the well. In the

sizing of pump, it is also important to consider the cloudy days by permitting the 5% design of the pump. In this process, a complete cloudy day can be covered in the 20 days but the tank must be full for storing extra water. A pump can be selected that uses the total head but the requirement of water each minute must be less than the recharge rate. The total requirement of power can be initiated from the selection of pump and the traditional design of practice needs about 20% power in order to secure the complete flow of water. In the next stage a controller is selected by making use of the information regarding the power of solar array, open circuit voltage, power and the nominal voltage.

Conclusion

It can be concluded that the photovoltaic systems are mainly designed to provide irrigation and water in those areas where no supply of electricity is. The major benefit of PV pumps as compared to the engine pumps is that they do not need any maintenance, fuel and they have a long useful life. In addition, there is no contamination of these pumps takes place and it is very easy to install them. A highly important characteristic is that these pumps use energy of sun as their major source of operation. The maximum requirement time of water matches with the maximum sunlight. In comparison to the diesel pumping system, the cost of solar PV water pumping system has been identified to be 63% of the cost of a diesel pump for a lifetime of ten years. These pumps have the ability to pump up to a distance of about 200m head with an output of about 250 m³ each day. Generally, the photovoltaic pumps are economic in comparison with the diesel pumps. They can supply about 1kWp for irrigation and about 3kWp for the village water supply. The solar photovoltaic pumps mainly represent the low maintenance, environment friendly and cost effective option for the irrigation pump that run on the diesel or grid electricity.

It has been estimated that the potential for solar PV pumping of water for different regions across the world is 9 million to 70 million PV pumps which is equivalent to about 255 billion litres each year of diesel savings. A solar system of pump irrigation method needs to consider the condition that the requirement for irrigation system water is different across the year. The peak requirement in the irrigation system season is double as compared to the average demand. This shows that the solar pumps for irrigation are not used completely for each year. The system of distributing water to the irrigation and its application requires attention. The irrigation pump system must decrease the loss of water without placing an additional head on the irrigation pumping system of low cost.

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