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Design and Develop a Rotational Solar Collector Panel for Effective Trapping of Sunlight Radiations in Order to Optimise Power Generation in Solar Energy Systems

Frank Mwewa
School of Engineering, Information and Communications University, Zambia

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Corresponding Author: **Frank Mwewa**

Abstract
The growth or energy demand in response to industrialization, urbanization and social affluence has led to an extremely uneven global distribution of primary energy consumption in Zambia. The Sun, Wind, Waves and geothermal heat are renewable energy sources that will never run out. They are perpetual or self-renewing. The rate of consumption does not exceed rate of renewability. The cost of generating electricity from wind and solar power has decreased by 90% over the past 20 years. Maximizing power output from a solar system is desirable to increase the efficiency of a solar tracing system, therefore, the purpose of this project is to design and develop a rotational Solar Collector Panel for effective trapping of sunlight radiations in order to optimises power generation in solar energy systems. To maximize the power output from solar panels, we need to keep the panels aligned with the sun. In this paper, the design of an efficient solar tracking system based on Real Time Clock (RTC) using microcontroller is described. The proposed tracking system is a low cost, high accurate, more efficient with low power consumption.

Keywords: Renewable Energy, Geothermal Energy, Solar Power, Rotational Solar Collector, Sun

1. Introduction
This Chapter will discuss introduction, Motivation and significance of this study, scope of the study, problem statement, research objectives, Organization of the thesis and the summary. As the non-renewable energy resources are decreasing worldwide, use of renewable resources for producing electricity is increasing. Solar panels are becoming more popular day by day. Solar panel absorbs the energy from the Sun, converts it into electrical energy and stores the energy in a battery. This energy can be utilized when required or can be used as a direct alternative to the grid supply. Utilization of the energy stored in batteries is mentioned in below given applications. The position of the Sun with respect to the solar panel is not fixed due to the rotation of the Earth. For an efficient usage of the solar energy, the Solar panels should absorb energy to a maximum extent. This can be done only if the panels are continuously placed towards the direction of the Sun. So, solar panel should continuously rotate in the direction of Sun. This article describes about circuit that rotates solar panel(site).

1.1 Motivation and Significance of Study
Zambia's electricity sources include, hydro power, solar energy and small produce from coal and biomass. the country is basically self-sufficient in all the other electricity resources, as it has substantial unexploited reserves of these forms of energy. The country's economy has been growing at an average of 5 percent per annum over the past 10 years and demand for energy has also been rising(site). The demand for the most important energy source in the country electricity has been growing at an average of about 3 percent per annum mainly due to the increased economic activity in the country especially in the agriculture, manufacturing and mining sectors, as well as increased activity in the region. Furthermore, the country's growing economy has also lead to an increase in the demand for the other forms of energy such as solar energy. The demand for renewable energies has also seen significant growth in the recent years as the market explores alternative sources of energy, with renewable energies proving to be a viable alternative.
According to Mwila *et al* (2017), argues that as solar power generation continues to grow around the country, it is important to show the public how feasible solar power systems actually are in a suitable site. Solar power system is the most cost effective

way and environmental friendly method to bring just sufficient electricity for Zambia in this time of crises.

1.2 Scope of Study
This study was limited geographically to Zambia and it concentrated on how a solar collector panel can effectively utilize the sun light radiation for maximum optimization of power generation, with regard to system components, design and operation by developing a prototype of the system.

1.3 Problem Statement
Solar energy is one of the most commonly used types of renewable energy in both rural and urban setups of Zambia, this is because the country experiences a lot of sunlight annually. Making favorable conditions for the installations of solar systems. Therefore, looking at most of the solar panels are installed majority if not all are installed in a fixed position where they receive solar radiations from the sun. according to ……………, there is a lot of solar radiation that escapes as the sun rises and sets. For the solar collector panel to optimise the radiation from the sun, the collector panel has to be set at an angle of 90 degrees to the sun radiation. But even though it is at that angle, the sun's path changes throughout the year making it difficult for the collector panel to trap maximum amount of radiation and thereby producing insufficient or less output generated power. Designing solar systems requires knowledge of how sunlight availability in a day as well as in a year changes. Therefore, there is great need to undertake this research study.

1.4 Objectives of the Project
1.4.1 Main Objective
The main objective of this project was to design and develop a rotational Solar Collector Panel for effective trapping of sunlight radiations in order to optimise power generation in solar energy systems.
1.4.2 Specific Objectives
1. To assemble the circuit which will contain the microcontroller.
2. To write a code that will control the microcontroller.
3. To erect a stand for the solar collector panel.
4. To connect the motor to the microcontroller.

1.5 Research Questions
1. How do you assemble the circuit which will contain the microcontroller?
2. How do you write a code that will control the microcontroller?
3. How do you a stand for the solar collector panel?
4. How do you connect the motor to the microcontroller?

1.6 Organization of the Thesis
This thesis has five chapters organized as follows;
Chapter one discusses introduction, Motivation and significance of study, scope of study, problem statement, objectives, Organization of the thesis and the summary. Chapter two discusses introduction, Review literature and related works. Chapter three discusses introduction, Methodology and system components and summary. Chapter four discusses introduction, design, operation, protection and summary. Finally Chapter five has the conclusion and recommendations, references and appendix.

1.7 Summary
This Chapter discussed the introduction, Motivation and significance of this study, scope of this study, problem statement, and research objectives, Organization of the thesis and the summary of this chapter.

2. Literature Review
2.1 Introduction
This chapter will provide the literature review of solar systems and hydro power generation with the following approach; Solar power Generation background, four main renewable energy forms, Effect of climate on hydrogenation, Why solar power generation, Solar as an alternative through policy papers that analyze the effect of government policies and social-psychological, focus on consumer motivations to purchase solar systems and other related works technical papers dealing with a specific aspect of the technology, method of installment, or feasibility.

2.2 Review of the Literature
2.2.1 Background to Solar Trackers
Solar tracker has already passed fifty years since its beginning. The first successful solar tracker was built in 1968. However, it was a passive solar tracker. It was a non-motorized pole-top tracker that uses refrigerant and aluminum channel reflectors to shift PV panels toward the sun. Though, it was expected that to bring in the commercial market within 1970, the idea had not come into reality. Within a decade, the development in the field of photosensitive elements gave rise to the concept of active solar tracker. In 1977, ARCO Solar began manufacturing solar panels in response to the oil and energy crisis. The first large-scale solar trackers were built in 1983 on the Carrizo Plains in California. ARCO leased land on the Carrizo Plains and assembled two intricately designed and controlled dualaxis tracker PV power plants, totaling 5.2 MW. However, power from these plants was sold to the grid at a mere $0.04 per kilowatt-hour. Since the plants were not economically viable, they were eventually sold off and disassembled. Within 1980s the idea of closed loop optically controlled solar tracker came into reality and the research on its development along with commercial production is still going on.
Within 1990s, the research on solar tracker completely concentrated on electrooptical sensors. The key sensors were photo-conductors, photo-transistors and photo-diode. However, the idea of using solar cell for sensing the irradiance had also come into vision. But the technology of solar cell was not developed at that time. Also, it was comparatively many times costlier than other available sensors.
From 1995 to current time, a large number of people have conducted researches on single axis and dual axis solar tracking. Owing to the mechanical difficulties of dual axis solar tracker, the researchers gave primary concentration on single axis solar tracker. The single axis tracker at that time had three photo sensors, two sensors with comparator circuit was for sensing the position and the third for measuring the irradiance level. H-bridge driving circuit was used for controlling the motor. With the emergence of microprocessor, the control circuit was made intelligent. Dual axis tracking also used the same technology and research on it started widely from 2002. Recently, solar cells

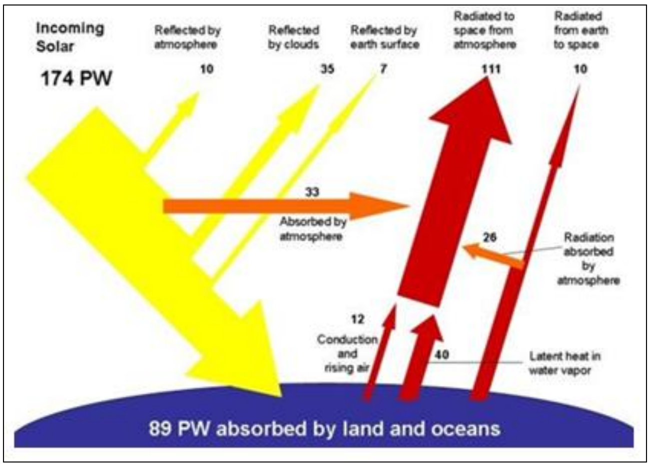
are replacing the traditional sensors for solar tracker. This thesis is based on this scheme.

2.2.2 Solar Energy

Solar energy is referred to the energy harnessed from sunlight. The energy from sun is considered unlimited and hence energy acquisition from sun is considered the leading energy source for future. Radiant light and heat from the sun, is harnessed using a different types of technologies such as solar heating, solar photovoltaic, solar thermal electricity, solar architecture and artificial photosynthesis. It is calculated that earth receives at about 1000 Watts per square meter at noon and hence direct conversion from photon energy to electricity has already been done and solar power plants are now setting up on large scale.

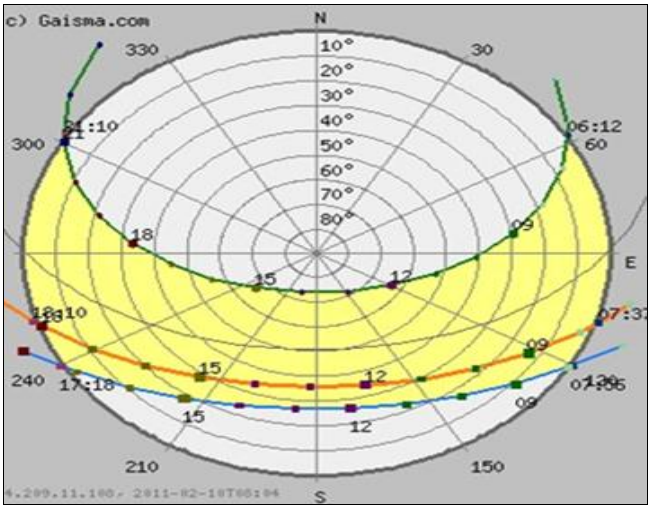
However, solar energy cultivation efficiency is not satisfactory. So it is desirable to extract as much energy as possible by reducing losses. Solar Fig 2: Available solar power energy has advantages over all other sources of energy. Most important fact is, except the additional installation cost and negligible maintenance cost it is quite free of cost and with no energy limitation. It does not emit heat and carbon dioxide or radioactive particle and solar energy does not create any noise. Hence, it's completely environment friendly.

Solar energy is a reliable source of energy in the hilly regions and isolated lands where transmission through cable is costly or impossible. Photovoltaic panels are used in rural areas for electrification. Also urban electrification by street lighting by photovoltaic panel is becoming popular. Modern electric devices also have the facility to run with solar power. Recently electric vehicles, building integrated solar system and smart grid system have started adopting solar energy widely. Space shuttles and satellites that are sent to space for long time have no other alternative energy then solar. So research has been made extensively in this regard.



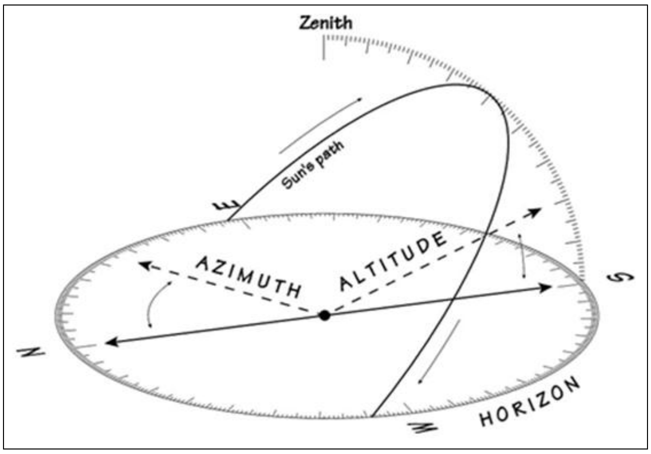
2.2.3 Sun Path, Azimuth & Altitude Angle

The position of sun varies from time to time and season to season due to earth's continuous and periodic rotation and revolution. As a result it has become necessary to locate the position of sun for a particular moment. The locations are placed on a special type of chart named Sun Path Diagram. A Sun Path Diagram shows the azimuth angle, elevation angle, sun paths throughout the years, sunrise and sunset time etc.



Solar azimuth, ψ, is the direction of sun from the Fig 3: Sun path diagram observer, expressed as the angular distance from the north point of the horizon to the point at which a vertical circle passing through the sun inters3ects the horizon.

Solar altitude, α, is the angular height of the sun measured from the Horizon. Above the horizon is positive, below is negative. The sun directly in the centre of the sky has a Solar Altitude of 90 degrees.



The declination angle, δ, is the angle of deviation of the sun from directly above the equator. This angle can be mathematically calculated by the following equation.

Azimuth and altitude angles:

( ) δ = 23.45sin

Here, n is the number specified for the days within the year and δ is positive for the angles north to the equator and negative for the angles south to the equator.

The zenith angle, υz, is the angle between the sun and a line perpendicular to the earth's surface. It is the complement of solar altitude. The zenith angle is given by the following equation:

$$\upsilon z = \phi - \delta$$

Here, ϕ is the latitude in degree.

2.2.4 Solar Irradiance

Solar irradiance is the measure of the power density of sunlight. Its unit is W/m2 and is an instantaneous quantity. The irradiance received by the earth from solar radiation is 1367 W/m2. After getting absorbed by atmosphere, as it passes through it, the radiation becomes 1000 W/m2 at surface. Solar radiation is affects the solar cell output performance and so it is a very important factor in this field. Sunlight consist energy which has wavelengths with in a wide range of electromagnetic wave spectrum. But no solar cell can absorb energy from the whole spectrum. A solar cell is mainly designed for absorption of a portion of the total radiation spectrum. Experiment has shown that a large amount of irradiance spectral is available in the visible spectrum from 390nm to 700nm which stands in the opposition of the ultraviolet (less than 390nm) and infrared light (greater 750nm). Photovoltaic solar cells are designed for the absorption of the visible spectrum only The direct normal solar irradiance is given by,

$$I_{t,n} = I_{b,n}\cos\upsilon_z + I_{d,n}$$

Here,

$I_{t,n}$ = the irradiance coming directly from the sun

$I_{d,n}$ = the diffuse radiation

Solar irradiance is a parameter directly related to solar energy received by solar panel and maximum when rays are perpendicular to panel plane. To achieve maximum solar energy it is necessary to rotate the panel face towards the sun. The device that is used for this purpose is called Solar Tracker.

2.2.5 Solar Tracker

A Solar tracker is a device that keeps track of the sun. It follows the path of the sun throughout daytime with the help of sensors. Since the sun's position in the sky changes with time and the altitude angle and azimuth angle varies continuously, solar trackers are used to align the energy collecting system. Solar trackers are used for solar panels in solar power plants where energy generation is desirable up to maximum limit. So, in solar tracking systems, solar panels are mounted on a structure which moves to track the movement of the sun throughout the day. Concentration of heat energy by optical devices (mirror, prism and lens) also requires solar tracking.

2.2.6 Types of Solar Tracker

Solar tracking system is classified by its degrees of rotation. According to degrees of rotation trackers can be grouped into two primary categories:

- Single Axis Solar Tracker
- Dual Axis Solar Tracker

Single Axis Solar Tracker

A single axis solar tracker follows the movement of sun either horizontally or vertically. As the name suggests, this type of tracker has only one axis for rotation. The horizontal type solar tracker is used in tropical regions where the sun gets very high at noon, but the days are short. On the other hand, the vertical type solar tracker is used in areas with high latitudes where the sun does not get very high, but summer days can be very long. In concentrated solar power applications, single axis trackers are used with parabolic and linear Fresnel mirror designs.

Dual Axis Solar Tracker

A dual axis solar tracker has two degrees of rotation. It can track sun both horizontally and vertically. This type of tracker can be used anywhere in the world and ensures maximum efficiency in gaining solar energy. Concentrated Solar Power (CSP) applications using dual axis tracking include solar power towers and dish systems. Dual axis tracking is extremely important in solar power tower applications because the angle error is crucial for longer distances between the mirror and the central receiver located in the tower structure. Design for dual axis tracking system is complex than single axis tracking and operation is more energy consuming. However, for large scale solar energy production dual axis tracking is more economic.

Methods of Solar Tracking

There are three methods of solar tracking.

- Active Tracking
- Passive Tracking
- Chronological Tracking

Active Tracking

The position of the sun is continuously determined by the sensors during the day. The sensor triggers the motion of motor or actuator in such a way so that the solar panel will always face the sun throughout the day. Active tracking is accurate with the help of sensors. But the main problem occurs when the sensors fail to discriminate between the measurements and give false trigger or miss original trigger during cloudy days.

Passive Tracking

Passive tracking method does not use sensors like active tracking. Instead of using sensors, a passive tracker moves in response to imbalance in pressure between two points at the ends of the tracker. This pressure imbalance is caused by heat from sun that creates gas pressure from compressed gas of low boiling point. The pressure moves the structure. This method does not have to rely on electrical sensors and requires negligible amount of power to operate. However, the mechanical design has to be very crucial to maintain accuracy.

Chronological Tracking

A chronological tracker is a timer-based tracking system. The structure is moved at a fixed rate throughout the day since the sun moves across the sky at a fixed rate of about 15 degree per hour. This method is better suitable for single axis tracking without sensors. For dual axis tracking a modified version can be implemented.

The position of sun throughout the day can be calculated and set by the program implemented on the controller module. The solar tracker rotates according to data sent from control unit's memory of pre-stored data or calculated from given formula. This method of sun-tracking is accurate and reliable. However, data storage, calculation continuous data transmission is power consuming and unnecessary rotation when sun light is too low can never be avoided.

All the three methods are applicable with single axis and dual axis tracking system. Which method is best suitable, is determined by the location of installation, purpose of generation and demand of solar power. Modern trackers combines both the sensor controlled method and sensor less control method at the same time to increase efficiency.

2.2.6.1 Basic Components of Solar Tracking System

A Solar tracker has several basic components [4]. The major components are described here- Sun Tracking Algorithm: Solar tracking can have open-loop control algorithm or closed-loop control algorithm. Open-loop control algorithm involves calculation of azimuth and altitude angle of sun on a purely mathematical platform based on astronomical references. The open-loop component is needed because the sun can be obscured by clouds, eliminating or distorting the feedback signals. Closed-loop control algorithm includes detection of the position of sun by real-time light-sensing method and is needed to eliminate errors due to variability in installation, assembly, calibration, and encoder mounting. These two methods can be combined together to keep balance between economic design and increased efficiency.

Tracker Control Unit:

The control unit executes the sun tracking algorithm and necessary calculations. It can also coordinate the movement of the positioning system. A microprocessor or a computer can be used as the centre of control unit. It normally has command input and data output mechanism for interfacing. For the trackers placed in remote region automatic tracking control mechanism is best suitable.

Positioning System and Drive Mechanism:

Positioning system moves the solar tracker according to the preference of control unit. It can be either electronic or hydraulic. Electrical systems utilize encoders and variable frequency drives or linear actuators to monitor the current position of the panel and move to desired positions. The drive mechanism includes mechanical devices- rotary motors, linear actuators, linear drives, hydraulic cylinders, swivel drives, worm gears, planetary gears, and threaded spindles. These drives can be of different types according to design method.

Sensors:

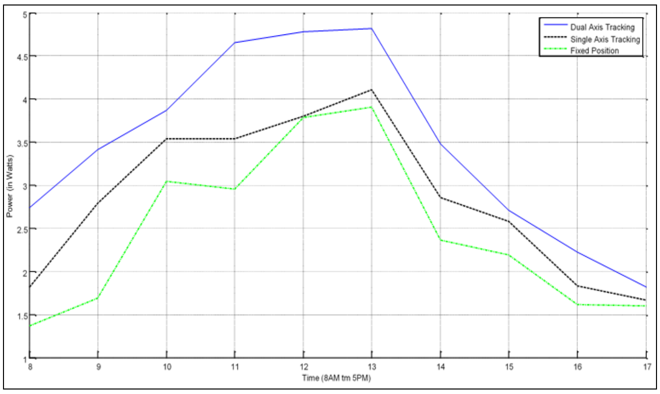
Sensors are used to detect position of sun accurately. For open-loop system light sensors are implemented to correct calculation and mechanical errors. Closed-loop system solely depends on several light sensing devices. Light intensity detecting device includes photo-resistor, photo-transistor, solar cell etc. Solar power based stations also use temperature, pressure, humidity, wind velocity, solar irradiance and other necessary parameters monitoring systems with trackers.

2.2.6.2 Advantages of Solar Tracker

The main advantage of using solar tracker is that it increases the availability of solar power from a location. A feasibility study was performed through an experiment prior to the design of solar tracker and it is found that power generation increased distinctively.

A 5 Watt solar panel was used for the experiment. Open circuit voltage, close circuit current, voltage at different load were measured and maximum power points were determined throughout the daytime of a regular sunny day and the values were plotted for comparison. The following figure shows the difference of power that can be obtained among the solar panel at foxed position, solar panel with single axis solar tracker and solar panel with dual axis solar tracker.

The detailed description along with the collected data sets on this experiment is available at the appendix section of this thesis paper.



It is found that the fixed 5Watts solar panel has generated 23.051 Watt-hour of energy. The energy with single axis tracking was 26.794 Watt-hour and dual axis tracking was 32.213 Watt-hour.

2.3 Related works

The Tasmanian Energy Crisis 2016

As described by Lucy (2016) Tasmania is part of Australia's liberalized National Electricity Market, being joined to the mainland via the Basslink underwater interconnector to Victoria. Its electricity generation is primarily hydro and, as a result, the state is highly dependent on rainfall for electricity generation. Peaking capacity is provided by four gas turbines, with base load capacity from a combined cycle plant, all of which comprise the Tamar Valley Power Station. Due to high water levels and the interconnector, the combined cycle plant was thought to be redundant and was decommissioned in 2014 to be subsequently sold. However, on 20 December 2015 Basslink had to be shut down due to a cable fault offshore. This event coincided with a particularly dry period, leaving dams severely depleted, which meant that Tasmania's security blanket for such times of drought had been lost. Actions taken to minimize the consumption of water from Hydro Tasmania's storages included:

- Recommissioning of the gas-fired Tamar Valley Power Station.
- Striking agreements with the three major industrial customers – the two Tamar Valley smelters.

Bell Bay Aluminium and TEMCO, and Norske Skog's paper mill at Boyer - to reduce their load by a combined 180 MW

- Deploying up to 200 MW of portable diesel generators.
- Bringing Hydro Tasmania's cloud seeding programme, usually scheduled to start in May each year, forward by a month.

Despite these actions, Georgie (2016) wholesale power prices surged by more than 350% as a result of the crisis, and the economic hit to the state was estimated to be in excess of A$560 million. Fortunately, the gas pipeline from the mainland was still operational so that emergency supplies for the gas-fired power plants could still be delivered. The moral of this event is very clear: energy security is an essential element of any power system. In addition, diversity of energy technologies is an important aspect of energy security, as is diversification of supply sources.

The Brazilian Drought Crisis 2014-16

Simon Romero (2015) [35] the 2014–16 Brazilian droughts was a severe drought affecting the southeast of Brazil including the metropolitan areas of São Paulo and Rio de Janeiro. As over seventy percent of Brazil's electricity is generated by hydropower there was concern that a lack of water may also lead to energy rationing in addition to water rationing Jon Gerberg (2015) [16]. Thermal plants were used to fill the energy gap, but the switch was very costly. In response to decreased hydroelectric power, rolling power cuts were also instituted. A novel approach to the problem was to install floating PV arrays on the dams to generate power when water supplies were depleted. The logic behind placing solar panels on dams is that hydro acts as a back-up for the variable output of the PV, and utilizes the same transmission infrastructure. Thus water is saved during daylight hours. In addition, one of the most expensive aspects of grid scale PV is its associated transmission requirements which are avoided in this situation. Floating solar panels are more efficient than land-based arrays, largely due to the fact that they have water on hand to cool them down. Phillips, Dom (2014) [28] Float voltaics is also appealing because it is cheaper to float panels over water than to rent or buy land. They can be constructed more quickly than land-based installations, and more easily tucked out of sight. Finally, floating arrays also shade the water and consequently reduce algae blooms and water evaporation. Brazil's first floating solar arrays came on-line in March 2016.

Technical aspects of solar

A number of reports focus on the technical aspects of solar energy adoption such as the best type of system for an area or the best angle for the panels. For example Payne (2000) explores the feasibility of a new type of PV technology. His focus is on how much more efficient the technology is and how much cost-savings it would generate. Holbert (2007) instead focuses on one area, Phoenix Arizona, and calculates the best direction and angle for solar panels to generate the most energy. As he is looking at just one town he is also able to discuss the specific regulations and incentives that affect the local solar market. Perez (2004) also focuses on the technical side of the discussion; although in his case he is looking into financial technicalities such as the proper way to measure profitability of solar systems for homeowners.

Papers Just as there have been a variety of government policies and incentives aimed at promoting residential solar panels over the last 40 years (both in the U.S. and in other countries around the world), there have been a number of studies done that attempt to determine how successful these policies and incentives were and what made them succeed or fail. Some studies focus on analyzing specific government programs, for example Hoffman and Kiefer's (2001) study on the German 1000 rooftop program or Haas' (1998) study on the Austrian rooftop program. Still other studies focus on a specific locality and try to determine the best policies for it, given local conditions. One such study is Holbert's (2007) study of the Phoenix area. Other studies apply a variety of methodologies in order to answer the question, such as Long's (1993) econometric analysis, Hasset's (1993) use of panel data, and Hayne's (2002) use of case studies. While the methodologies and specific focus of the studies are all very different, there are some overarching ideas and conclusions made about the residential solar panel industry. The first is that, in general, financial incentives work for developing the industry by lowering the costs of solar panels. This is because as the industry develops, suppliers and installers get better at making and installing solar panels. As a result, they reduce costs and can therefore charge customers less. Also as the market grows, suppliers are able to build bigger factories and take advantage of economies of scale. Where the studies differ is in what financial incentives work the best at doing this. Another common conclusion is that without the necessary infrastructure in place, financial incentives will have a very limited impact. In other words, if there are not enough installers or quality control checks, or if it is difficult to actually connect the solar panel system to the energy grid, then it will take a long time to completely install all the new solar panel systems that the financial incentives will bring. This will hurt the reputation of the program and the industry, leading to fewer consumers buying solar panels.

Similarly to the previous conclusion, many studies such as Haynes (2002) and Painuly (2001) have found that quality control is integral in both lowering costs and ensuring the reputation and thus success of a program or incentive. Programs or incentives that have a poor quality control process not only lead to more solar panel failures, thus damaging the reputation, but also fail to properly promote industry growth. This is caused by the fact that poor quality control means that installers will be sub-par and unlikely to improve and will also lead to poorly designed solar panels being supported on the market by the incentives, lowering the overall quality of the industry. Haynes (2002) also states that a stable and adequate source of funding is vital for any financial incentives. This is not quite as crucial at the residential level as it is at the utility level, where many incentives and contracts are very long-term, but it still plays a significant role in the residential market as well. For example, if funding runs out in a given year, or there is not a guarantee there will be enough funding, then consumers are more likely to wait and not purchase a solar panel system until they can be sure that they will receive the funds from the incentive.

Wireless Power transmission

Wireless Power transmission is the transmission of electrical power from the source to load without the use of wires. Saurabh, Dhruv Kapur and Raju J (2016) [34] in India designed and developed a Wireless transfer of electrical energy. Wireless transfer of electrical energy eliminates the use of copper cables and conducting wires. Previously wireless transfer of power had been achieved for AC source or for charged batteries. In this project research they had used output from the solar panel as the output. In this presented disclosure, solar panels were used as a main role in providing renewable source of energy instead of other non renewable sources. The panels took sunlight from the sun and convert it into electrical energy which was stored in batteries. This stored energy charged in battery was further converted into AC source by the inverter. Transmitter receives energy from the inverter, which transferred power in the form of electromagnetic waves through Transmitter and Receiver coil. Further, Receiver converts electromagnetic waves into voltage form which was same as applied at transmitting end. This whole arrangement was connected with solar system. Since the output from the solar panel was very small it had been stepped up to appropriate values using the DC-DC step up converter. The stepped up DC was then converted into an oscillating signal. This signal was then transferred wirelessly using a transformer. The electrical energy is transferred using the magnetic coupling that existed between the transformer setup. The oscillating signal was then passed through a rectifier circuit and converted into DC before it was fed into the load. The proposed wireless transmission was verified using MATLAB/SIMULINK.

From the overall experiment conducted from wireless power transfer by using solar energy below conclusions were deduced. Base on experimental result, the study on wireless power transfer had much aspect in terms distance, range of frequency and result show the closer the distance, the voltage transferred was higher. Distance of the nearest was the most efficient wireless power transfer, and wireless power transfer by using solar energy can be reach is up to 10 cm with 3.60 Volt. The high efficiency is at 0 cm with 98.78% and the lower efficiency is at 10 cm with 40%. In short this study had distance limitation and was not safe for commercial use.

Other Papers

There are a number of papers, especially in the last ten years, which look into what motivates consumers to purchase solar systems and go beyond just the financial aspects of that decision. Palm (2011) conducted a series of interviews with consumers in Sweden who had adopted green technology, either PV or microwind turbines, or were in the process of doing so, to uncover their motivations and any barriers to adoption. There were two major motivations reported for adopting green technology. One is for environmental reasons, both in the strict sense of wanting to reduce pollution and also as being an integral part of their self-image of living a green lifestyle. The other motivation is to be more independent, whether that is the desire to be more independent from the electricity companies, society, or to be more financially independent, the underlying motivation is that green technology makes them less dependent on others. The major barrier to adoption is the high upfront cost combined with the long pay-back period.

Faiers (2009) conducted an in-depth review of residential solar adoption in the UK in order to determine why several incentive programs were succeeding while another program was failing. Faiers analyzed differences in motivations of early adopters as compared to early majority adopters, the next consumer group to adopt a technology. What he finds is that early adopters base their decision primarily off of environmental concerns and their interest in solar technology. While those motivations are still important to the early majority, they also care about aesthetic, financial, and operational issues and find solar technology lacking in those regards.

Gillingham (2010) and Rothfield (2010) both look at the impact that previous adoption of solar technology in an area has on future adoptions in that area. They both used different methods: Gillingham ran three different experiments each analyzing different levels of data and Rothfield used a zero-inflated negative binomial model that allowed her to also analyze the effect of several other variables. In the end they both came to the same conclusion that a previous adoption in an area (both at the street level and the zip-code level) increases the likelihood of further adoptions in that area. The two most likely reasons for this are that seeing a neighbor with a solar system motivates people to adopt solar as well in order to not be outdone, or that they will learn more about solar systems from the neighbor and with this increased knowledge on the subject, feel confident enough to adopt.

New Zealand's

Hydroelectric generation contributes around 60% of New Zealand's total electricity supply, with many generators of widely varying sizes distributed throughout the country. Inflows (rainfall and snowmelt) can be stored in hydro lakes until needed. The lakes have quite limited operating ranges – for technical and resource consent reasons, each lake's level cannot be lowered below a certain point. It is not possible to completely empty a hydro lake. In the absence of inflows, the lakes can only hold enough water for a few weeks of winter energy demand. For security of supply hydro storage was divided into two categories: controlled and contingent storage. Generators can use controlled storage at any time using solar pumps to maintain water levels, but contingent storage may only be used during defined periods of shortage or risk of shortage. During sustained dry periods, controlled and contingent storage are important indicators of overall supply risks. Storage is expressed in gigawatthours– GWh (a measure of the energy that can be produced using the water). New Zealand has a liberalized power market, and therefore (the theory goes) as prices climb during periods of unusually dry conditions additional, fossil fuel, plants (currently moth-balled) would be encouraged to return to supplying the grid. However, at present, one of the generators is paid to keep a 500 MW gas and coal power station in reserve, which is really in conflict with the liberalized market model. The correct approach would be to offer a backup dry-year supply determines by auction, but the market is probably too small to deliver a competitive outcome. The New Zealand model clearly relies upon a surplus of generating capacity, particularly for dry years. Nevertheless, Zambia could perhaps adopt the concept of controlled and contingent storage, adapted for domestic conditions. Pump Storage Pumped storage projects store and generate energy by moving water between two reservoirs at different elevations. At times of low electricity demand, like at night or on weekends, excess energy is used to pump water to an upper reservoir. During periods of high electricity demand, the stored water is released through turbines in the same manner as a conventional hydro station, flowing downhill from the upper reservoir into the lower reservoir and generating electricity. The turbine is then able to also act as a pump, moving water back uphill. The power used to move water back uphill would generally come from surplus generation capacity from inflexible technologies such as nuclear, brown coal, solar, and wind. In other words, technologies which cannot be easily ramped down during times of low demand, or those that are variable in output and generate power when conditions are favourable irrespective of demand. According to the IEA (2010), pumped-storage hydropower is the largest and most cost effective form of electric energy storage at present. It claims that the current global capacity of pumped-hydro storage could increase tenfold as some existing hydropower plants could be transformed into pumped-hydro storage plants.

In a study conducted in Midwestern United States. Showed the main focus of the project was to determine the options that are available to replace grid-powered street lamps with a stand-alone system that has the reliability to work under the worst conditions. The renewable energy source selected for the project was a solar photovoltaic panel. The study was undertaken to determine the capabilities of a stand-alone systems and to determine if the long-term saving of electricity warrants the conversion to new lamps built off the power grid. The development of the world's power infrastructure involves expanding the use of renewable energy in combination with the existing power generators. The viability of solar energy in St. Louis is determined by weather conditions and the amount of solar insolation that the area received throughout the year. Heavy consideration to the localized conditions during the winter has the strongest impact on determining the feasibility of using solar energy in the Midwestern United States. The size of the photovoltaic system was dependent on the size of the load and availability of sunlight in the winter months. A prototype system was built to understand how the system would react under the changing weather conditions and solar insolation values. The system was designed to power the load and to be cost effective. The initial cost of the prototype system equipment for each lamp is to be considered against the cost of grid connected street lamps. The lowest overall cost would be used on future street lighting applications. A comparison will be made between commercially available stand-alone systems against the purchasing of individual parts for the prototype system. The load was a 50W high pressure sodium lamp, to match the standard lighting applications for side streets.

New Mexico, California, Thailand, and Spain

Past stand-alone research studies provided an increased level of understanding of how solar energy was utilized around the world, and how this project fits with the application of stand-alone street lighting. The idea of using solar energy to power a street light began in the 90s as a solution to the cost of operating street lights throughout the year. The design of the early systems incorporated a lamp load of less than 50W, and was used primarily for lighting paths or walkways. The majority of systems studied have used lamps of either the low pressure sodium lamp or the fluorescent lamp variety. The common areas where case studies have been done on the viability of powering street lights with solar energy were done in regions of high amounts of solar insolation. These areas include New Mexico, California, Thailand, and Spain. One of the earliest studies was conducted by the Parks and Recreation Department of Albuquerque, New Mexico. The design of the system used two 50W photovoltaic panels with a 35W low pressure sodium lamp. The stand-alone systems were designed to last for six hours a night and used a boost converter due to the design of a working maximum power point tracker was still in the development stage. The results of the study showed the potential of using solar energy to power street lights, and built the groundwork for future designs. Isolated parts of the world are ideal places to study the abilities of stand-alone lighting systems due to the lack of electricity to those regions. The test done in Thailand used a basic photovoltaic system that worked seven hours a day and established how different types of lamps worked 7in the remote villages. The categories that were instrumental in determining between the low pressure sodium (LPS), the high pressure sodium (HPS), and the fluorescent light were the lifespan of the bulb, cost, light output in lumens, wattage, and color rendering. The fluorescent lamp was selected due to its lower cost and the adequate production of light. This study conveyed the problems that affect the design of the system, due to the availability and cost of replacement parts. The HPS lamp worked more effectively than the other two lamps in the test, but cost seven times more than the fluorescent lamp. The LPS lamp cost more than the HPS and was difficult to purchase in Thailand.

Tanzania

According (BBC News 2015), The efficiency of hydroelectric dams depends on consistent rainfall, so droughts quickly cripple energy systems that are heavily reliant on hydropower. This causes serious blackouts in the affected states. Faced with drought that had cut hydropower production in the face of growing power demand, the Tanzanian government was planning to declare the water supplies of the Mtera and Kidatu hydropower facilities in the south of the country protected sites. The controversial move was to ban any economic activity - including irrigation-fed farming - from taking place near reservoirs or other listed water resources. It was an attempt to ward off competition for water that officials said was affecting power generation. (ibid 2015) But farmers said the move would devastate farming, herding, fishing and other ways of making a living in the area. But an increase in human activities such as irrigated farming, fishing and livestock rising was exacerbating the problem, according to the state-run power company TANESCO. Hydropower, which contributed about 57 percent of the electricity running through Tanzania's grid, has repeatedly suffered from water shortages due to recurring drought. In order to address the problem the state rationed water to local community and promoted the use of other energy source to TANESCO.

Malawi 2017/2018 power crisis

Declan Conway (2018) Malawi relies heavily on hydropower generation. Hydropower relies on the flow of water to drive turbines to generate electricity. Water flowing from a high to low elevation, for example from a reservoir behind a dam, can drive the turbines. Drought or successive dry years could result in insufficient water to drive electricity generating turbines and a shortage of electricity. There are past examples of where reductions in electricity production have been associated with drought, including blackouts in Malawi In 2017/2018 generation was reportedly dropped by half when water levels in the Shire river fell, resulting in power outages across the country Large parts of Malawi was plunged into darkness as water levels at the country's main hydro power plant fell to critical levels due to a severe drought, according to its electricity company. (ibid 2018) The impoverished southern African country which relies on hydroelectricity had been hit by intermitted blackouts since 2017 year, but the outages had recently worsened, lasting up to 25 hours. The state-owned Electricity Supply Corporation of Malawi (Escom) said that power output had been halved as water levels in the Shire River dropped to critical levels. The water from the river normally generates a total of 300 megawatts of electricity, which is 98% of the country's supply. "For the past three weeks, the available capacity was 160 megawatts," said Escom said in a statement. Affected areas included large parts of the capital Lilongwe and in the second city of Blantyre. A number of businesses and hospitals in the country had been forced to use diesel-powered generators to keep the lights on or as alternative power to reduce on over reliance on hydro power.

Like many sub-Saharan states, Zambia is heavily dependent on hydroelectricity, and recent drought has crippled the nation's power supply. Zambia's hydropower problems may only be a sign of things to come. Long-range models predict that climate change is likely to cause more droughts throughout much of sub-Saharan Africa. While hydropower is widely billed as sustainable due to its low emissions and high efficiency, the drought-induced Zambian energy crisis suggests that it may not be a reliable solution for African energy in a future marred by climate change. The persistent and long hours of load shedding experienced in 2015 by small and medium enterprises in Zambia adversely affected their business operations and financial viability. Furthermore, it affected the mining, manufacturing and commercial industries and the general populace in Zambia Mwila *et al* (2017). The nations could face devastating blackouts as rising temperatures dry up its hydropower dams. Based on recent years in which extremely dry conditions saw electricity drop off in large areas of the country. Hydropower technology is geographically dependent, due to resource inadequacy. It has several environmental consequences, damming the water and controlling the water flow brings great damage on the river ecosystems, migratory obstacles for the marine species, namely fish and slightly formation of carbon dioxide during the construction of reservoirs. (ibid 2017) Upfront costs – building a hydropower plant is expensive. As the electricity generated from hydro sources depends on the water availability, it may be ineffective during times of drought. Solar energy systems generally don't require a lot of maintenance. They only need to be kept relatively clean, so cleaning them a couple of times per year. Solar energy can be used almost anywhere to power a home, generate electricity and is the best alternative for hydropower generation in drought. Photovoltaic's (PV) is a science/technology of transforming incident Solar Radiation directly into Electricity. This is usually done in Photovoltaic Cells which are, basically, solid-state semiconductor devices that that emit electrons upon being shone upon by electromagnetic radiation of a given frequency (or wavelength) range which reaches the cell location. In outer space, all the solar radiation spectrum as emitted by the sun is available for conversion, whereas on earth, however, the solar radiation is modified after passing through the thick layer of the atmosphere, where some frequencies (wavelengths bands) are absorbed by various atmospheric components.

2.4 Summary

This Chapter has covered introduction, Review of the Literature, Related Works and Summary of this chapter.

3. Methodology

3.0 Introduction

This chapter gives the detail of methodology regard to study base line, system design and each major component used in this project with regard to system design requirements, types and operational conditions of each component.

3.1 Baseline Study

This project report has been approached primarily by literature and practical research. Focusing firstly on gaining a wide and comprehensive understanding of the chosen subject area, a literature review was completed. The literature review included the reading of a range of textbooks along with credible internet sources journals and practical experience. Relevant aspects of these sources were then used to formulate notes, which were then used in their relevant section of the report. The knowledge gained from the literature review was then applied to design and develop solar power plant and transmission line. Materials listed below were procured and arranged as the required by the designed and developed system. Below are the hardware specification and system block diagram.

Hardware Specification

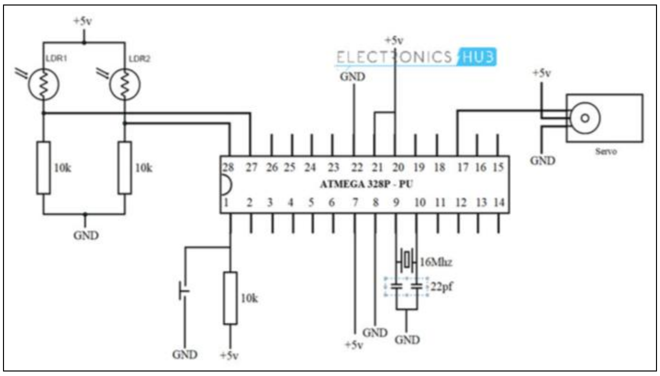
- Solar panel
- ATmega328 Micro Controller
- Light Dependent Resistor (LDR) x 2
- 10KΩ x 3 Resistor
- Servo Motor
- 16MHz Crystal
- 22pF Ceramic Capacitors x 2
- Push Button
- Breadboard
- Cardboard

3.2 System Design

The solar tracker designed here has one degree of rotation. The solar tracker can track the sun only in horizontal direction (that is, from east to west). The algorithm is based on the difference of solar irradiance at different position. Voltage detected by the solar panel at different position will be compared and the optimum position will be found. The motion of this tracker panel is controlled. The tracker sensor is a 5 Watts solar panel. For large scale power plant project, an individual tracker, placed on a high tower can be used to detect the position of sun and then the data can be used to rotate a set of solar panels to that specific direction according to signal. The design has three main units:

- Position Sensor Unit
- Motor Unit
- Controller Unit

The sensor unit performs the detection of difference of solar irradiance due to change in position of sun. The control unit decides on the motion of tracker analyzing the input detected by sensors and sends necessary signals to track the sun. The motor unit performs the tracking operation physically. Hence the control unit is a connection between the other two units.



The diagram above shows the system

Position Sensor Unit

The sensor unit consists of a 5 Watts monocrystalline photo voltaic panel. The panel generate voltage as light is incident on it. A small portion of the generated voltage can be measured by a microcontroller. Using these measurements and running the analysis tracking of sun is possible.

The specification of this solar panel is:

- Maximum Power Output 5W
- Open Circuit Voltage 10.8V
- Short Circuit Current 0.68A
- Voltage at MPP 8.6V
- Current at MPP 0.58A
- Cell Type Mono Crystalline

This type of sensor can be used with the solar tracker can be used in solar based power plant, where the tracker, placed at a position, tracks the sun and conveys the data of required rotation to the solar panels of the plant and then all the panels are oriented to the specified direction. For a single solar panel, the sensor panel can be attached to the main panel along with tracking mechanism.

Motor Unit

To track the sun in horizontal direction variable reluctance servo motor is selected. A variable reluctance servo motor is constructed from ferromagnetic material with salient poles. The stator is made from a stack of steel lamination. The rotor is either solid or laminated. When there is no current in any coil the rotor is completely free to rotate. There are three independent stator phases 1, 2 and 3 and each one can be energized by DC signal from the drive circuit.

Energizing one or more stator coils causes the rotor to step forward or backward to a position that forms a path with least reluctance with the magnetized teeth. It has a very high torque/inertia ratio giving high rate of acceleration and fast response.

The variable reluctance stepper motor is preferred for solar tracker design due to its micro-stepping facility. The solar tracker designed here can rotate by 7.5° per step if pulses for half stepping are applied. The pulse sequence for CCW rotation is 1, 1-2, 2, 2-3, 3 and 3-1. Repetition of the same sequence continues the rotation. Reversion is also possible by reversing the controller pulse sequence.

The motor must deliver sufficient torque to withstand the maximum wind speed and the weight of the structure. Hence torque calculation for the motor is performed. To calculate the torque required to withstand the wind velocity a maximum velocity of 49.71Mph (80km/h) is considered. The weight of the panel is 1.3 kg and the structure supporting the panel weighs about 4.7 kg. Hence, Motor used in design the proposed model weighs 6kg.

Surface area of the panel, A = 0.0621m2

Wind pressure, P = 0.00256 × 49.712 Psf =30.865kg/m2

Drag coefficient, Cd = 2.0 for flat panel

Force due to wind, Fw = A × P × Cd = 37.57N

Gravitational force Fg = 6 × 9.8N = 58.8N

The radius of the base structure is, r = 0.0127m

Torque required, T= (Fw + Fg) × r = 12.5 kg-cm

The variable reluctance servo motor selected for horizontal tracking. It has a holding torque of 20 kg-cm. Its phases are energized by 12 Volt, 2 Ampere DC adapter.

Controller Unit

The operation of the solar tracker is controlled by the controller unit. The microprocessor, being the brain of this unit, gives necessary instructions for operation. However, it is not capable of supplying necessary current for operating the motor. It requires assistance of relays or switches to control the motor. The unit has three voltage controlled switches to operate the motor. The designed controller unit has the following elements:

- ATmega32 Micro-controller
- 5 Volt Relay
- LM7805 Voltage Regulator

3.3 System Components

3.3.0 Solar Panel

The solar cell (photovoltaic cell) converts sunlight to electrical energy. A solar panel consists of several solar modules which further are comprised by many solar cells. Together do several solar panels make up a so called solar array? The cell is of semi-conductive material, often silicon Si, and aggregates a mass of p-n junction in the module. The process of how the electricity is generated follows in different steps. First a photon (radiation) is absorbed by the semi electric apparatus conductive material. Then the material emits an electron making the electron free to either dispatch into heat, return to its initial state in the material or travel down the module until it reaches a conductive electrode. When the latest process is realized, in mass, a direct current is generated. The direct current is then directed straight to either a battery or through an inverter which converts the DC to AC so it can be consumed. Depending on the nominal voltage of the battery or the inverter the array might need to be constructed with the modules being connected in parallel or series. This is in order to achieve system voltage of the inverter which often times is 12V, 24V or 48V depending on the system size. Michael Boxwell (2017) [23].

There are three different technologies used for producing solar panels. The cheapest solar technology is amorphous solar panels, also known as thin-film solar panels. This technology has matured significantly over the past few years and amorphous solar is now regarded as being highly reliable, with some significant benefits over traditional solar panels. Amorphous solar panels are the least-efficient panels available, typically converting around 6–8% of available sunlight to electricity. This means that you need twice as much space available for installing amorphous solar panels compared to crystalline panels. However, amorphous panels are good at generating power even on overcast and extremely dull days. In general, they are also far better in extreme temperature conditions, with significantly less power loss at higher temperatures than other solar panel technologies. Unlike other solar panel technologies, amorphous solar panels provide excellent performance even when partially shaded.

Polycrystalline solar panels are made from multiple solar cells, each made from wafers of silicon crystals. They are far more efficient than amorphous solar panels in direct sunlight, with efficiency levels of 12–16%. Consequently, polycrystalline solar panels are often around one third of the physical size of an equivalent amorphous panel, which can make them easier to fit in many installations. The manufacturing process for polycrystalline solar panels is complicated. As a result, polycrystalline solar panels are expensive to purchase, often costing 20–30% more than amorphous solar panels. The environmental impact of production is also higher than amorphous panels.

Monocrystalline solar panels are made from multiple smaller solar cells, each made from a single wafer of silicon crystal. These are amongst the most efficient solar panels available today, with efficiency levels of 15–19%. Monocrystalline solar panels have the same characteristics as polycrystalline solar panels. Because of their efficiencies, they are the smallest solar panels (per watt) available. Monocrystalline solar panels are the most expensive solar panels to manufacture and therefore to buy.

Hybrid solar panels combine monocrystalline solar cells and amorphous thin-film between each monocrystalline cell. This provides the benefits of the efficiencies of monocrystalline and the benefits of improved shade and high temperature performance from the amorphous technology. Hybrid panels provide efficiency levels of between 18—22% in optimum conditions, but really benefit from sub-optimal conditions where the real world performance can be 10-20% better than other solar panels. The downside is price. Price-wise, hybrid solar panels are expensive, around twice the price of monocrystalline panels.

The following Factors should be considered when designing solar power plant.

Solar panel is placed on a piece of cardboard (just for demonstration) and the bottom of the cardboard is connected to Servo motor. Solar panel consists of photovoltaic cells arranged in an order. Photovoltaic cell is nothing but a solar cell. Solar cell is made up of semiconductor material silicon. When a light ray from Sun is incident on the solar cell, some amount of energy is absorbed by this material. The absorbed energy is enough for the electrons to jump from one orbit to other inside the atom. Cells have one or more electric field that directs the electrons which creates current. By placing metal contact energy can be obtained from these cells.

3.3.1 ATmega328 Microcontroller

The ATmega328 microcontroller functions as the brain of the system. ATmega328 is a high performance, low power consuming 8bit microcontroller with built-in timer, counters, ADC (analog to digital converter) and internal memory. It has 40 pins with their distinctive features.

The noteworthy features of ATmega32 microcontroller are the followings:

- Operable up to 16 MHz clock cycle. For higher precision external crystal can be used through pin 12 and 13.
- 32 programmable input/output ports with 32x8 general purpose registers.
- 32K Bytes of self-programmable flash program memory.
- 1024 Bytes of EEPROM (Electrically Erasable Read Only Memory) and 2K Bytes of SRAM (Static RAM).
- Two 8-bit timer/counters and one 16-bit timer/counter with separate oscillator.
- 4 PWM channels.
- Master/slave SPI (Serial Peripheral Interface), byte oriented two-wire serial interface and programmable serial USART (Universal Synchronous Asynchronous Receiver Transmitter).
- Operating voltage range: 2.7-5.5 V.
- Actively consumes 1.1mA current at 1MHz, 3V. At Idle mode it is 0.35mA.

Voltage generated by the solar panel is sensed by the analog to digital converter (ADC) of ATmega32 microcontroller. The ADC of the microcontroller converts the analog values to digital values. The voltage generated from the solar panel may have values higher than 5 Volts, which is beyond the detection range of microcontroller's ADC. A voltage divider circuit with variable potentiometer is used to measure a portion of voltage.

The ADC converts an analog input voltage to a 10-bit digital value through successive approximation. The minimum value represents voltage at GND (pin 11 and pin 31) and the maximum value represents the voltage at the AREF (pin 32) minus 1 LSB. The internal voltage reference may thus be decoupled by an external capacitor at the AREF pin to improve noise immunity. The analog input channel and differential gain are selected by writing to the multiplexer bits in ADMUX (ADC multiplexer register). Any of the ADC input pins, as well as GND and a fixed band-gap voltage reference, can be selected as single ended inputs to the ADC. A selection of ADC input pins can be selected as positive and negative inputs to the differential gain amplifier. If differential channels are selected, the differential gain stage amplifies the voltage difference between the selected input channel pair by the selected gain factor. This amplified value then becomes the analog input to the ADC. If single ended channels are used, the gain amplifier is bypassed altogether.

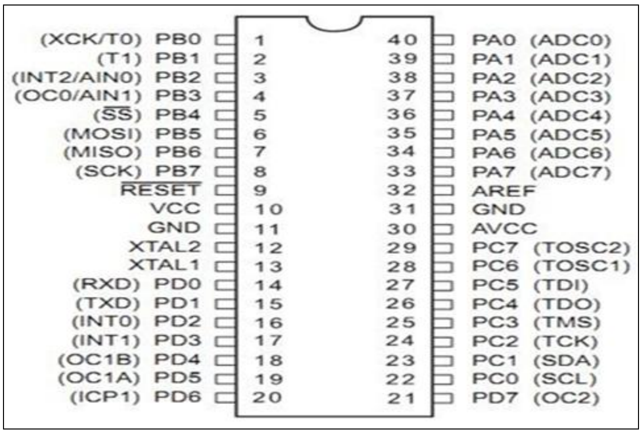
The ADC is enabled by setting the ADEN (ADC Enabler) in ADCSRA (ADC Control and Status Register, A). Voltage reference and input channel selections will not go into effect until ADEN is set. The ADC does not consume power when ADEN is cleared, so it is recommended to switch off the ADC before entering power saving sleep modes. The ADC generates a 10-bit result which is presented in the ADCH and ADCL (ADC High and Low Data Register). By default, the result is presented right adjusted, but can optionally be presented left adjusted by setting the ADLAR (ADC Left Adjust Result) bit in ADMUX. If the result is left adjusted and no more than 8-bit precision is required, it is sufficient to read ADCH. Otherwise, ADCL must be read first, then ADCH, to ensure that the content of the Data Registers belongs to the same conversion. Once ADCL is read, ADC access to Data Registers is blocked. This means that if ADCL has been read, and a conversion completes before ADCH is read, neither register is updated and the result from the conversion is lost. When ADCH is read, ADC access to the ADCH and ADCL Registers is re-enabled.

The motor control signals are generated from three output ports of the microcontroller. The number of pulses determines the number of rotation and the sequence of the pulses decides on the direction of rotation. A built-in timer of the microcontroller calculates the time difference between two operations and keeps track of overall time spent.

In ATMega32 there are 3 timers, two 8bit timers (Timer 0 & Timer 2) and one 16 bit timer (Timer 1). To generate time delay internal or external oscillator can be connected to the timer/counter register. For each tick in the oscillator the counter register counts one, so the register holds the number of ticks. Time can be calculated by counting the number of ticks. To count an external event, the source of the event will be connected the clock pin of the timer/counter register.

The relay used here is actually a 5 Volt DC voltage controlled mechanical switch with five pins. The switch changes its state when a 5 Volt DC signal is applied. The command signal is generated by the microcontroller.

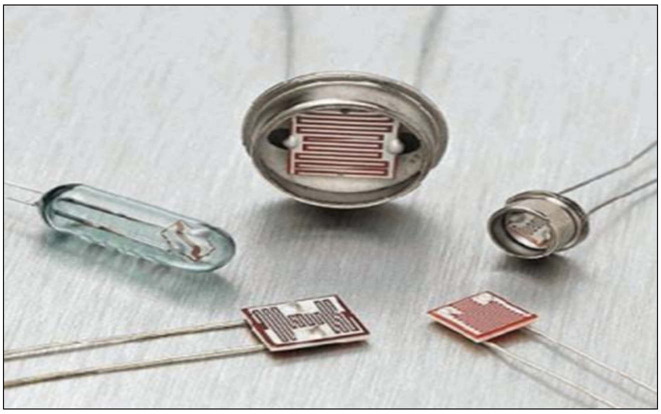
7805 is a three terminal voltage regulator for fixed 5 Volt DC. The regulator can provide local on-card regulation, eliminating the distribution problems associated with single point regulation. It is used for supplying fixed 5 Volt DC power for the microcontroller.



The figure above shows the microcontroller architecture

3.3.2 LDR

A light dependant resistor also known as a LDR, photoresistor, photoconductor or photocell, is a resistor whose resistance increases or decreases depending on the amount of light intensity. LDRs (Light Dependant Resistors) are a very useful tool in a light/dark circuits. A LDRs can have a variety of resistance and functions. For example, it can be used to turn on a light when the LDR is in darkness or to turn o a light when the LDR is in light. It can also work the other way around so when the LDR is in light it turns on the circuit and when it's in darkness the resistance increase and disrupts the circuit.



How it Works

The way an LDR works is that they are made of many semi-conductive materials with high resistance. The reason they have a high resistance is that are very few electrons that are free and able to move because they are held in a crystal lattice and are unable to move. When light falls on the semi conductive material it absorbs the light photons and the energy is transferred to the electrons, which allow them to break free from the crystal lattice and conduct electricity and lower the resistance of the LDR.

Light Dependent Resistors or LDRs are the resistors whose resistance values depend on intensity of the light. As the intensity of light falling on the LDR increases, resistance value decreases. In dark, LDR will have maximum resistance. LDR will output an analog value which should be converted to digital. This can be done using analog to digital converter.

ATmega328 has analog to digital converter internally. It has six ADC channels from ADC0 to ADC5 (Pins 23 – 28). The two LDRs are connected to ADC pins i.e. 27 and 28 in a voltage divider fashion with the help of individual 10KΩ Resistors. ADC conversion is done using successive approximation method.

3.3.3 Servo Motor

A servo motor is an electrical device which can push or rotate an object with great precision at some specific angles or distance. It is just made up of simple motor which run through servo mechanism. If motor is used in DC powered then it is called DC servo motor, and if it is AC powered motor then it is called AC servo motor. A high torque servo motor can be obtained in a small and light weight packages. Due to these features they are being used in many applications like toy car, RC helicopters and planes, Robotics, Machine etc.

Servo motors are rated in kg/cm (kilogram per centimeter) most hobby servo motors are rated at 3kg/cm or 6kg/cm or 12kg/cm. This kg/cm tells you how much weight your servo motor can lift at a particular distance. For example: A 6kg/cm Servo motor should be able to lift 6kg if the load is suspended 1cm away from the motors shaft, the greater the distance the lesser the weight carrying capacity.

Servo motor is used to rotate the panel. To drive the servo motor, a PWM Signal must be provided to its control pin and hence Pin 17 (which has PWM) is connected to the control pin of the servo motor. By connecting a battery to the solar panel, you can store the energy generated by the solar cells and this energy can be used when required. There are separate charge controller circuits dedicated to efficiently control the charge acquired from solar panels and charge the batteries.

16MHz Crystal

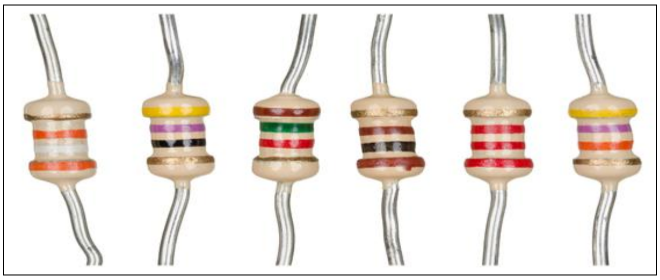
A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a precise frequency. This frequency is often used to keep track of time, as in quartz wristwatches, to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters and receivers. The most common type of piezoelectric resonator used is the quartz crystal, so oscillator circuits incorporating them became known as crystal oscillators, but other piezoelectric materials including polycrystalline ceramics are used in similar circuits.

A crystal oscillator, particularly one using a quartz crystal, works by distorting the crystal with an electric field, when voltage is applied to an electrode near or on the crystal, a property known as electrostriction or inverse piezoelectricity. When the electric field is removed, the

quartz which oscillates at a precise frequency generates an electric field as it returns to its previous shape, and this can generate a voltage. The result is that a quartz crystal behaves like an RLC circuit, but with a much higher Q.
Quartz crystals are manufactured for frequencies from a few tens of kilohertz to hundreds of megahertz. More than two billion crystals are manufactured annually. [citation needed] Most are used for consumer devices such as wristwatches, clocks, radios, computers, and cellphones. Quartz crystals are also found inside test and measurement equipment, such as counters, signal generators, and oscilloscopes.

22pF Ceramic Capacitor
A capacitor is a device that stores electrical energy in an electric field. It is a passive electronic component with two terminals. The effect of a capacitor is known as capacitance. While some capacitance exists between any two electrical conductors in proximity in a circuit, a capacitor is a component designed to add capacitance to a circuit. The capacitor was originally known as a condenser or condensator. This name and its cognates are still widely used in many languages, but rarely in English, one notable exception being condenser microphones, also called capacitor microphones.
The physical form and construction of practical capacitors vary widely and many types of capacitor are in common use. Most capacitors contain at least two electrical conductors often in the form of metallic plates or surfaces separated by a dielectric medium. A conductor may be a foil, thin film, sintered bead of metal, or an electrolyte. The non-conducting dielectric acts to increase the capacitor's charge capacity. Materials commonly used as dielectrics include glass, ceramic, plastic film, paper, mica, air, and oxide layers. Capacitors are widely used as parts of electrical circuits in many common electrical devices. Unlike a resistor, an ideal capacitor does not dissipate energy, although real-life capacitors do dissipate a small amount. (See Non-ideal behavior) When an electric potential, a voltage, is applied across the terminals of a capacitor, for example when a capacitor is connected across a battery, an electric field develops across the dielectric, causing a net positive charge to collect on one plate and net negative charge to collect on the other plate. No current actually flows through the dielectric. However, there is a flow of charge through the source circuit. If the condition is maintained sufficiently long, the current through the source circuit ceases. If a time-varying voltage is applied across the leads of the capacitor, the source experiences an ongoing current due to the charging and discharging cycles of the capacitor.

Resistors
A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistors that can dissipate many watts of electrical power as heat, may be used as part of motor controls, in power distribution systems, or as test loads for generators. Fixed resistors have resistances that only change slightly with temperature, time or operating voltage. Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity.
Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment. Practical resistors as discrete components can be composed of various compounds and forms. Resistors are also implemented within integrated circuits.
The electrical function of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than nine orders of magnitude. The nominal value of the resistance falls within the manufacturing tolerance, indicated on the component.



3.4 Summary
This Chapter has covered methodology, introduction, baseline study, system design project system components and Summary of this chapter.

4. Results
4.1 Introduction
The outline for this chapter is as follows introduction, Design, operation, protection and earthing and chapter summary. This chapter gives detail to the operation requirement of the system and installation of equipments discussed in chapter 3 furthermore the chapter provides more light and guidance to safety of personnel and equipment to ensure reliability and efficiency of power supply in regard to safety occupations.

4.2 Design
Assemble the circuit as described and upload the code to ATmega328 Microcontroller. Power on the circuit and place the set up directly under the Sun (on the rooftop). Based on the light falling on the two LDRs, the ATmega328 Microcontroller changes the position of the Servo Motor which in turn moves in the panel.

ATmega328 Microcontroller
ATmega328 is an AVR family micro controller. It is based on advanced RISC architecture. It is an 8-bit controller. It has 32K Bytes of Programmable Flash memory, 1K Bytes of EEPROM and 2K Bytes of SRAM. It has 23 programmable I/O pins. It supports peripheral features like two 8-bit timers, one 16-bit timer, 6 channel ADC with 10-bit resolution, programmable USART, Serial Peripheral Interface, 2 wire serial interface (I2C), etc.

Solar Panel
Solar panel is placed on a piece of cardboard (just for demonstration) and the bottom of the cardboard is connected to Servo motor. Solar panel consists of photovoltaic cells arranged in an order. Photovoltaic cell is nothing but a solar cell. Solar cell is made up of semiconductor material silicon. When a light ray from Sun is incident on the solar cell, some amount of energy is absorbed by this material. The absorbed

energy is enough for the electrons to jump from one orbit to other inside the atom. Cells have one or more electric field that directs the electrons which creates current. By placing metal contact energy can be obtained from these cells.

LDR

Light Dependent Resistors or LDRs are the resistors whose resistance values depend on intensity of the light. As the intensity of light falling on the LDR increases, resistance value decreases. In dark, LDR will have maximum resistance. LDR will output an analog value which should be converted to digital. This can be done using analog to digital converter.

ATmega328 has analog to digital converter internally. It has six ADC channels from ADC0 to ADC5 (Pins 23 – 28). The two LDRs are connected to ADC pins i.e. 27 and 28 in a voltage divider fashion with the help of individual 10KΩ Resistors. ADC conversion is done using successive approximation method.

Servo Motor

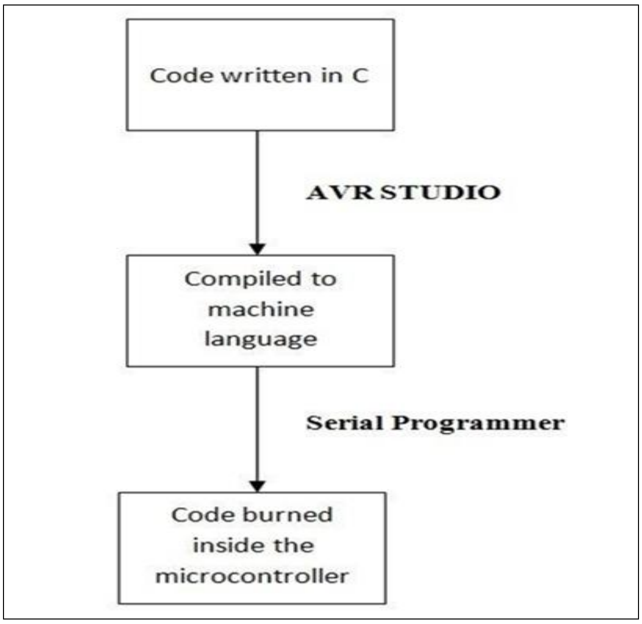
Servo motor is used to rotate the panel. To drive the servo motor, a PWM Signal must be provided to its control pin and hence Pin 17 (which has PWM) is connected to the control pin of the servo motor.

By connecting a battery to the solar panel, you can store the energy generated by the solar cells and this energy can be used when required. There are separate charge controller circuits dedicated to efficiently control the charge acquired from solar panels and charge the batteries.

Code

The microcontroller is programmed by code developed on AVR GCC platform in C programming language. AVR Studio is used to compile the code. AVR Studio converts the code written in C for ATmega32 to hex file. This is a type of hexadecimal file that the microcontroller can understand. This is also known as machine language. It is then burned into the microcontroller with the help of the software named Extreme Burner. A serial programmer is used to transfer the code from Serial programmer for microcontroller computer to microcontroller.

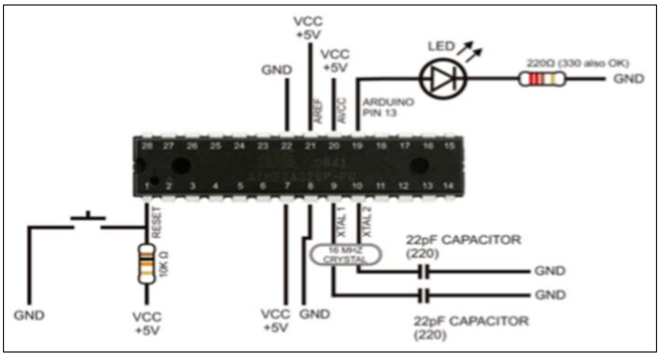
The series of operation is shown in the following flow chart:



Therefore, the code for the project is given below.

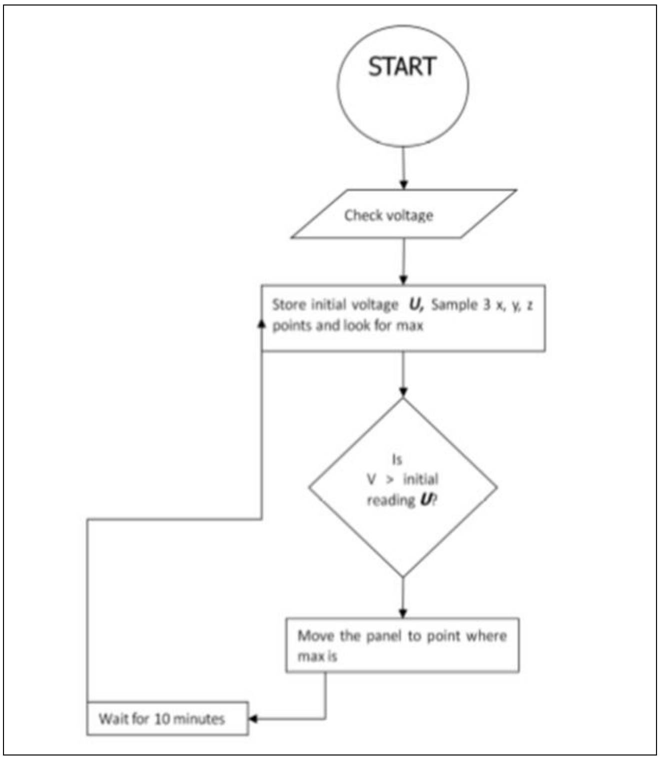
```
#include <Servo.h>
Servo myservo;
int ldr1 = 4;
int ldr2 = 5;
int val1;
int val2;
int pos=90;
void setup()
{
 myservo.attach(11);
 Serial.begin(9600);
 myservo.write(pos);
}
void loop()
{
 val1 = analogRead(ldr1);
 val2 = analogRead(ldr2);
 val1 = map(val1, 0, 1023, 0, 180);
 val2 = map(val2, 0, 1023, 0, 180);
 if(val1 > (val2+50))
 {
  if(pos<180)
   pos=pos+1;
  myservo.write(pos);
  Serial.println("backward");
  delay(10);
 }
 else if(val2 > (val1+50))
 {
  if(pos>0)
   pos=pos-1;
  myservo.write(pos);
  Serial.println("forward");
  delay(10);
 }

}
```



4.3 Operation

In this project Atmel ATmega328 8-bit microcontrollers are high performance RISC-based devices that combine 32KB ISP Flash memory with read-while-write capabilities, 1KB EEPROM, 2KB SRAM, 23 general-purpose I/O lines, 32 general-purpose working registers, serial programmable USART, and more. Atmel ATmega328 MCUs execute powerful instructions in a single clock cycle, allowing the device to achieve throughputs approaching 1 MIPS per MHz while balancing power consumption and processing speed. These Atmel MCUs are developed for use in industrial automation and home and building automation.



This allows current to flow in only one direction. By convention, current can only flow from the anode (positive) to the cathode (negative). Current is what determines how bright a LED is More current means more light LED current should typically be between 10 to 20mA. Therefore, a current limiting resistor is used to keep the bias current in the above range. When current flows through the LED; a forward voltage drop of about 1.6V will develop between its pins, depending on the current. Forward voltage drop is not just a function of current, but also LED color and temperature (because of the different LED chemistries) as shown in the table below.

Table 1: Showing LED Colour PD Definition

LED colour PD definition

LED colour	Potential difference/V
Infrared	1.6 V
Red	1.8 V to 2.1
Orange	2.2 V
Yellow	2.4 V
Green	2.6 V
Blue	3.0 V to 3.5 V
White	3.0 V to 3.5 V
Ultraviolet	3.5 V

To keep the bias current in between 10 and 20mA, the following applies. 5V Supply generated by LM7805 chip has been used in this system. Using Ohm's Law (V=IR); (Voltage applied - Forward voltage drop) / Forward current = Resistor value (5V - vdV) / Ida = Rd ohms Where 5V is the applied voltage and Ida is the forward bias current in amperes of the LED, vdV is the drop across the LED dependent on colour and Rd is the current limiting resistor of the diode.

4.3.0 Advantages of Sun Tracking Solar Panel

The solar energy can be reused as it is non-renewable resource.

This also saves money as there is no need to pay for energy used (excluding the initial setup cost).

Helps in maximizing the solar energy absorption by continuously tracking the sun.

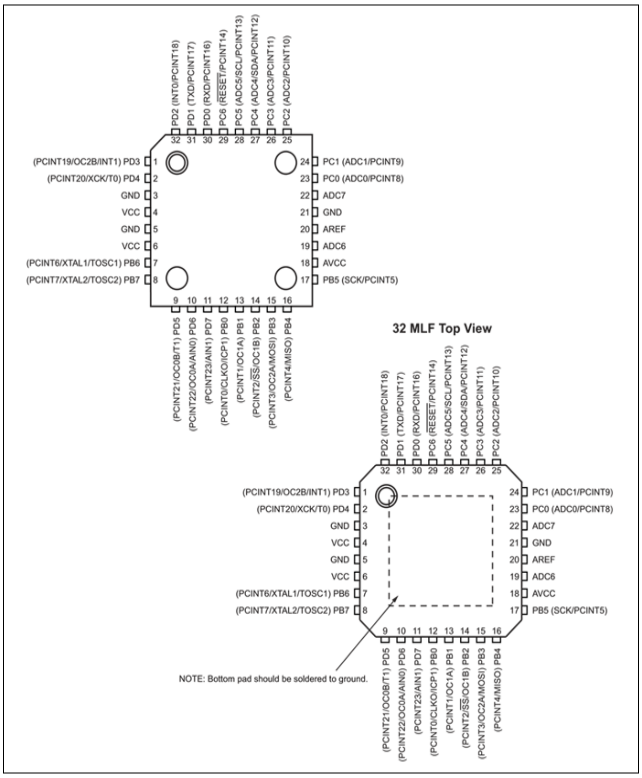
Sun Tracking Solar Panel Applications.

These panels can be used to power the traffic lights and streetlights.

These can be used in home to power the appliances using solar power.

These can be used in industries as more energy can be saved by rotating the panel.

4.3.1 Pin Configurations



4.3.2 Pin Descriptions

- VCC

Digital supply voltage.

- GND

Ground.

- Port B (PB7:0) XTAL1/XTAL2/TOSC1/TOSC2

Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Depending on the clock selection fuse settings, PB6 can be used as input to the inverting oscillator amplifier and input to the internal clock operating circuit.

Depending on the clock selection fuse settings, PB7 can be used as output from the inverting oscillator amplifier.

If the internal calibrated RC oscillator is used as chip clock source, PB7..6 is used as TOSC2..1 input for the asynchronous Timer/Counter2 if the AS2 bit in ASSR is set.

The various special features of port B are elaborated in Section 13.3.1 Alternate Functions of Port B System Clock and Clock Options.

- Port C (PC5:0)

Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The PC5..0 output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

- PC6/RESET

If the RSTDISBL fuse is programmed, PC6 is used as an input pin. If the RSTDISBL fuse is unprogrammed, PC6 is used as a reset input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running. The minimum pulse length is given in Table 28-4 on page 261. Shorter pulses are not guaranteed to generate a reset.

The various special features of port C are elaborated in Section 13.3.2 “Alternate Functions of Port C” on page 68.

- Port D (PD7:0)

Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, port D pins that are externally pulled low will source current if the pull-up resistors are activated. The port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

The various special features of port D are elaborated in Section 13.3.3 “Alternate Functions of Port D” on page 70.

- AVCC

AVCC is the supply voltage pin for the A/D converter, PC3:0, and ADC7:6. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter. Note that PC6..4 use digital supply voltage, VCC.

- AREF

AREF is the analog reference pin for the A/D converter.

- ADC7:6 (TQFP and QFN/MLF Package Only)

In the TQFP and QFN/MLF package, ADC7:6 serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels.

4.4 Summary

In nutshell the solar array, inverter and controller are protected by Ground fault protection. Ground fault protection ensures that if there is a short circuit within the solar array, the current flow is cut off immediately in order to avert damage of equipment; transmission line is protected by earth wire ground protection. The overhead earth wire or ground wire is the form of lightning protection using a conductor or conductor sand both transformers (step up and step down transformer) are protected by fuse protection. From the system operation it can be confirmed that solar is the good alternative for hydro power generation which is posing a challenge to the power generation in Zambia due to change in rain season.

5. Conclussion and Recommendation

5.0 Introduction

This is the final chapter and it is approached as follows Introduction, Discussion under Discussion the following will be covered the baseline study, Use of technology, Development of the system as a solution and possible application. Furthermore, this chapter will look at Summary, Conclusion and recommendations / Future works. Finally, the references and appendix are given at the end of the chapter.

5.1 Discussion

5.1.0 The Baseline Study

This project report has been approached primarily by literature and practical research. Focusing firstly on gaining a wide and comprehensive understanding of the chosen subject area, a literature review was completed. The literature review included the reading of a range of textbooks along with credible internet sources journals and practical experience. Relevant aspects of these sources were then used to formulate notes, which were then used in their relevant section of the report. The knowledge gained from the literature review was then applied to design and develop a rotational Solar Collector Panel for effective trapping of sunlight radiations in order to optimise power generation in solar energy systems.

5.1.1 Use of Technology

Implementation of this project on national scale will significantly help to reduce over reliance of hydropower which depends on water and as the result it is affected by poor rainfall season resulting into power deficit. Optimizing the generation of solar energy has tremendous projection scope in Zambia. This is due to the geographical location of the country.

5.1.2 Development of the System as a Solution

Zambia is slowly turning into the use of renewable energy and among those forms of renewable energies, it has been seen that solar energy is one the country is utilizing as a backup plan from hydro power ……………….. (2012). Due to that it has been seen that most of the solar panels are mounted in one fixed position therefore as the sun moves part of the radiations is not utilized. Therefore, the development of a solar tracking system is a specific device intended to move the photovoltaic modules in such a way that they continuously face the sun with the aim of maximizing the irradiation received by the PV array.

5.1.3 Possible Application

Zambia has great potential of investing in solar energy, as the country experiences a lot of sunlight radiation. This will not only increase the country’s generation capacity and diversify the generation mix but ensure security of supply that will support the development agenda of the nation. The difficult realities of climate change have taught Zambia over-reliance on hydropower won’t just do Mwansa *et al.* (2015) [24], insufficient electricity generation capacity serving domestic requirements, primarily non-mining sector activities, exacerbated by weather impacts on the main source of electricity in the country –hydropower, increase in population and industrial growth. Zambia is currently relying almost exclusively on hydropower while the local potential for other energy resources including solar renewable remains largely remain unexploited. Solar is the important alternative choice of future renewable energy that should be developed in Zambia. It is available, clean energy and cheap. Furthermore, Mwila *et al* (2017) argues that as solar power generation continues to grow around the country, it is important to show the public how feasible solar power systems actually are in a suitable site. Solar power system is the most cost effective way and environmental friendly method to bring just sufficient electricity for Zambia in this time of crises.

5.2 Summary
This chapter has covered Introduction, Discussion under Discussion the following were covered the baseline study, Use of technology, Development of the system as a solution and possible application. Furthermore, this chapter has looked at Summary, Conclusion and recommendations / Future works. Finally the references and appendix were given at the end of the chapter.

5.3 Conclusion
Solar energy is an unlimited source of energy. Solar tracker is used to harness this energy with more efficiency. This paper has demonstrated the implementation of solar tracking system in a cost effective way. Direct use of output data from solar panel makes the system independent of light sensor that requires external biasing circuit. The use of stepper motor ensures more accurate tracking with minimum error. Thus, the proposed design offers a better solution to the implementation of solar energy. In order to solve the power crisis and meet the future increasing need, solar power must be extracted as much as is possible. Maximum cultivation of solar power can be performed by using solar tracker modules. The tracker designed here is much reliable and less power consuming then traditional trackers. Hence, it can be a better solution to maximum solar power extraction.

5.4 Recommendation / Future Works
The researcher is recommending that this project should be performed in much efficient way. There is still room for improvement for this system and it is hoped that further study can be carried out to further develop the system:
- Use higher motors with large torque value for larger panel size.
- It will be better to use geographical equation algorithm for the real timing tracking.
- Use diffused reflection phenomenon.

6. Dedication
I cannot express my happiness in word today, thank you for instilling a strong passion for learning in me and for doing everything possible to put me on the path to greatness. It's sad to believe that my happiest moment has finally come. Without you in my life mum and dad I would not be where I am today.
I thank you.

7. Acknowledgement
Dad, mum, my dearest wife and all my friends i could not have undertaken this journey without your support thank you for always being my greatest supporter. When i think of you, you have been there for me thought out my journey, you are at the top of my list, your unweaving support has given me the strength to keep going.
When it was a kind word or throughout gesture, every little thing you did has made a big impact on my life. I do not know how i could have made it this far without you. Thank for being constant in my life that i can always rely on.
Thank for your support.

Abbreviations	Description
MPPT	Maximum Power Point Tracker
ICS	Improved Cooking Stove
FY	Fiscal Year
AEPC	Alternative Energy Production Centre
SHS	Solar Home System
NEA	Nepal Electricity Authority
DOD	Depth of Discharge
PWM	Pulse Width Modulation
PTs	Passive Trackers
ATs	Active Trackers
SAST	Single Axis Solar Tracker
DAST	Double Axis Solar Tracker
LDR	Light Dependent Resistor

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