Output Optimization of Solar Photovoltaic (PV) Panel by Modeling and Designing of Reflectors & Solar Tracker

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This dissertation is submitted to Faculty of Engineering and Technology, International Islamic University Islamabad Pakistan for partial fulfillment of the degree of **MS Electronic Engineering** With specialization in Energy Engineering at the Department of Electronic Engineering

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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

In the Name of Allāh, the Most Gracious, the Most Merciful

DEDICATION

Dedicated to my beloved Parents

CERTIFICATE OF APPROVAL

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ABSTRACT

Pakistan has been suffering from serious problem of load shedding since last decade. It becomes worst during the summer season and load shedding reached up to sixteen to twenty hours a day in most part of the country. It left drastic effects on the life of a common and economy of country got disturbed adversely. The demand supply gap of power must fulfill by practicing energy efficiency and diverting resources to renewable energy like sun and wind power. Fortunately potential of solar power inside of country is very large and minimum solar insolation level is higher than world average insolation level. To overcome this dilemma an exertion has been made by conducting practical work over optimization in power of solar photovoltaic panel in local environment of Islamabad by modeling and designing of reflector and solar tracker. Owing to less solar cell efficiency, work has been carried to improve output power of solar panel adopting radiation level enhancement through sun tracker designing and reflectors. The designed solar tracker was microcontroller base and time delay generation inside it based on local sun rise and sun set timings. Output power was measured hourly basis by measuring current and voltage at four different days with four modifications i.e. initially stand-alone panel then with reflectors then solar tracker then reflectors plus tracker at fourth stage.

Remarkable result were achieved while conducting research, 25% extra power produced by using reflectors and solar tracker and fill factor improve from 0.56 to 0.70. Feasibility study made over project showed good result for the use of solar tracker along with reflectors. The result data generated will help reference work for further research in this area and leads to much better and an efficient solar photovoltaic system.

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All praise to Almighty Allah (SWT), the Lord of the Universe. It is undeniable that all the manifestation of the nature bears eloquent to the act that Allah (SWT) is the creator, maintainer and regulator of the world. Countless thanks to the most merciful, omnipotent, omnipresent and omniscient "Almighty Allah" (SWT), I bow my head and heart who blessed me with the vigor, audacity, and comprehension to successfully complete this project to which I have sacrificed a world of love, passion and endeavor.

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MUHAMMAD YASIR AAMMAR

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LIST OF ABBREVIATIONS

PV	Photovoltaic
KW	Kilo Watts
Kg	Kilo grams
DC	Direct Current
AC	Alternating Current
m^2	Meter square
AL	Aluminum
Si	Silicon
Mm	Millimeter
°C	Centigrade
R & D	Research and Development
MPPT	Maximum Power Point Tracking
RPM	Revolution per Minutes
N-cm	Newton centimeter
KWh	Kilo Watt hour

CHAPTER 1

INTRODUCTION

1.1. Introduction

Presently due to demand supply gap of power inside of country, an efficient practice of energy and progress of sustainable energy resource are foreseeable. It has insist numerous national and worldwide companies to devise a plan and implement major work plan for the energy conservation and construction of renewable energy resource like energy from sun and wind preferably. Fortunately the geographical location of Pakistan exists among those countries where sun warms the surface throughout the year and therefore has a strong potential for solar power generation and strong potential of wind on coastal areas [1].

Although several energy power project have been started by the government to overcome short fall of energy, yet plenty of time needed for them to be in operational state. We are also running most of our power plant with efficiency not up to the mark hence we can demolishing energy demand supply gap by making them efficient and optimizing power of currently working power plants and renovating generating sources towards renewable energy resources expeditiously. Harvesting energy from renewable energy source is now a day major concentration around the globe especially solar and wind energy.

The contribution of solar energy inside of country's generating capacity is in friction regardless of maximum solar insolation through ought the country.

Pakistan receives $4.45 - 5.83\ kWh/m^2$ per day of global horizontal insolation as an annual mean value with 5.30 kWh/m^2 per day over most areas of the country [2, 3]. The minimum level of solar radiation 4.45 kWh/m^2 per day is higher of the world average solar radiation level 3.61 kWh/m^2 per day [13].

The main reason behind this unawareness, high capital cost of solar system, no research work and less solar system efficiency. In rural areas where the transmission lines are unavailable, people utilizing solar power by photovoltaic power generation system. The panels are fixed and working with less efficiency.

Inside of laboratory the mono crystalline solar cell's efficiency recorded up to 30% but in practical efficiency achieved from 14% to 18% [4].

Certainly, solar cell efficiency low yet the output power from the module can maximize by best use of solar irradiance. This research work will draw attention on the provision of solar photovoltaic model with enhanced features of reflectors addition around panel and real time base tracker designing to attain maximum power from available solar irradiation. Moreover the real time base comparison in output of fix panel & panel with enhance features will result in its optimization achieved.

1.2 Classification of solar power generation

Solar power generation has been classified into two main technologies:

- Solar PV (photovoltaic) power generation.
- Solar thermal power generation.

Solar photovoltaic is the production of power by converting sunlight into electricity while solar thermal is the use of sunlight as a heat and this heat can be used for different purpose like power production, solar space or room heating, solar geysers, solar cookers and solar refrigeration system

1.2.1 Solar PV (photovoltaic) generation

In this type of solar technology sun light is directly converted into electricity by the emission of photo electrons from the surface of germanium or silicon. When photons from sun light fall on the surface of solar panel they emit electrons from the germanium or silicon and emitted electrons are called photo electrons, causes electric current flow in circuit. Greater the number of photon falls onto the surface of panel greater the number of electron emits resulting greater amount of electricity produce through this phenomena. The material used inside panel also classified in following categories:

- Single-crystal or Mono-crystalline Silicon
- Polycrystalline or Multi-crystalline Silicon
- Ex. Amorphous silicon or Cadmium Telluride

Single-crystal or Mono-crystalline Silicon is more efficient compare to others while each of crystalline technology has its own pros & cons subject to their specialty are discussed below in Table 1:

Table 1 : Characteristics of mono, poly and amorphous crystalline

Mono Crystalline	**Multi crystalline**	**Amorphous Silicon**
○ Efficiency in practice having range 12-16% ○ Laboratory efficiency range 25% ○ Most expensive to produce ○ Circular (square-round) cell creates wasted space on module	○ Efficiency in practice having range 10-12% ○ Laboratory efficiency range 20% ○ Less expensive to produce compare to single crystal ○ Square shape cell fit into module efficiency using entire space	○ Efficiency in practice having range 6-8% ○ Laboratory efficiency range 13% ○ Least inexpensive technology to produce ○ Better performance in low light & can be deposited on flexible substrate

1.2.2 Solar Thermal generation

Solar thermal power generation is somehow different from solar PV in the sense; here heat is responsible for generation of power. Heat is being responsible for steam generation which has ability to rotate turbine shaft and further generation of power. Utilization of solar heat is coming from an ancient days in different ways yet the purpose is same today that is utilizing heat energy coupled from the sun for diverse purpose beside power generation like solar space room heating, solar stove, solar geysers and desalination plants for water cleaning purpose.

Solar collectors are the essential part in solar thermal power generation. Their working function is to intercept light from the sun and focus onto small absorber area. These collectors can provide high temperatures more efficiently than flat-plate collectors, since the absorption surface area is much smaller. However, diffused sky radiation cannot be focused onto the absorber. Most concentrating collectors require mechanical equipment that constantly orients the collectors toward the sun and keeps the absorber at the point of focus.

There are four basic types of concentrating collectors are listed below:

- Parabolic trough system
- Parabolic dish
- Power tower
- Stationary concentrating collector

Towers and troughs are the best suited for large, grid-connected power projects in the 30-200 MW size, whereas, dish/engine systems are modular and can be used in single dish applications or grouped in dish farms to create larger multi-megawatt projects. Parabolic trough plants are the most mature solar power technology available today and the technology most likely to be used for near-term deployments. Power towers, with low cost and efficient thermal storage, promise to offer dispatch able, high capacity factor, solar-only power plants in the near future.

1.3 Why Solar Energy in Pakistan

It has been observed that those countries lie on the earth equator or nearby received abundant amount of solar energy. The reason is that sun rays falls perpendicularly over these areas, fortunately, geographical point of view Pakistan is best suitable place where abundant amount of sun light falls throughout the year.

The lowest solar radiation intensity $76.49\,W/m^2$ observed at Cherat during December and the highest $339.25\ W/m^2$ at Gilgit. The average monthly solar radiation intensity remains $136.05\ to\ 287.36\,W/m^2$ inside the country. The results indicate that the values of solar radiation intensity greater than 200 W/m^2 were observed in the months: February to October in Sindh, March to October in almost all regions of Baluchistan, April to September in KPK, Northern Areas and Kashmir regions while March to October in Punjab. For 10 hours day, average solar radiation intensity ranges from $1500\ to\ 2760\,W/m^2$ in Pakistan especially in southern Punjab, Sindh and Baluchistan regions throughout the year. In an area of 100 m^2, 45 MW to 83 MW power per month may be generated in the above mentioned regions [1].

1.4 Problem Statement

To optimize the output of solar PV panel in local environment of Islamabad by the designing of solar tracker and modeling of reflectors around panel. The designed solar tracker will be microcontroller base and delay generated inside it real time base. The output power of the solar panel will be observed throughout the day with four different combination that is fix panel only facing toward south, fix panel along reflectors, movable panel by solar tracker and then panel with reflector only as well as solar tracker. The data calculated, would suggest the best optimization in the output of solar panel moreover its feasibility discussed with these modification.

1.5 Proposed Methodology

Initially hardware will be designed comprises of the following components

- Solar tracker
- Reflectors adjustment
- Panel support or stand

Microcontroller based solar tracking device will be designed to keep solar panel aligning towards the sun throughout the day. Program burn inside of microcontroller and delay generation in program base on local sun rise & sun set timing on that very day of result analysis. Use of the steeper motor in tracker and its degree of rotation guarantees the very precise movement of the panel along with sun. In next phase mirror will use as reflectors and assembled in frames around the solar panel boundary. In third phase pole mount stand will be designed to hold solar panel and in cooperate solar tracker inside it .The circular steel pipes will be used to assemble the stand, providing support to the solar PV panel along with reflectors and tracker. Rotation of solar panel with solar tracker made possible by frictionless ball bearing.

On completion of hardware structure, the output power of the panel will be measured by millimeter on whole day during sun shine hours with following stages.

1. Fix stand-alone panel facing south
2. Fix Panel with reflectors only
3. Panel with tracker only
4. Panel with reflectors as well as tracker

By using power equation with these four combinations the result will compare. Output recorded data would suggest the optimization of the solar photovoltaic panel. The feasibility of tracker and reflector on output power of the solar panel would be executed.

1.6 Thesis Organization

In 2nd chapter literature review will be discussed on solar photovoltaic system and factors affecting on its efficiency, moreover effect of temperature, shading, degradation, soiling on solar panel will be discussed. Chapter three will elaborate construction of hardware used in project that is solar tracker, reflectors and supporting stand. Chapter four will be on experimentation and result while last chapter shows suggestion and further research scope of the project. Feasibility study will discuss in last chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Solar Energy in World

Presently world has been consuming 13000 GW of primary energy. World's electric power consumption is about 4800 GW while during a year the earth receives around 178000 terawatt of energy from the sun which means that it is 15000 times more than the energy consumption of the whole world. Today 50% of this energy is absorbed by the earth and 30% is reflected back into space by the atmosphere also hydrological cycle is powered by the remaining 20% and only 0.6% of this amount is going into photosynthesis [5].

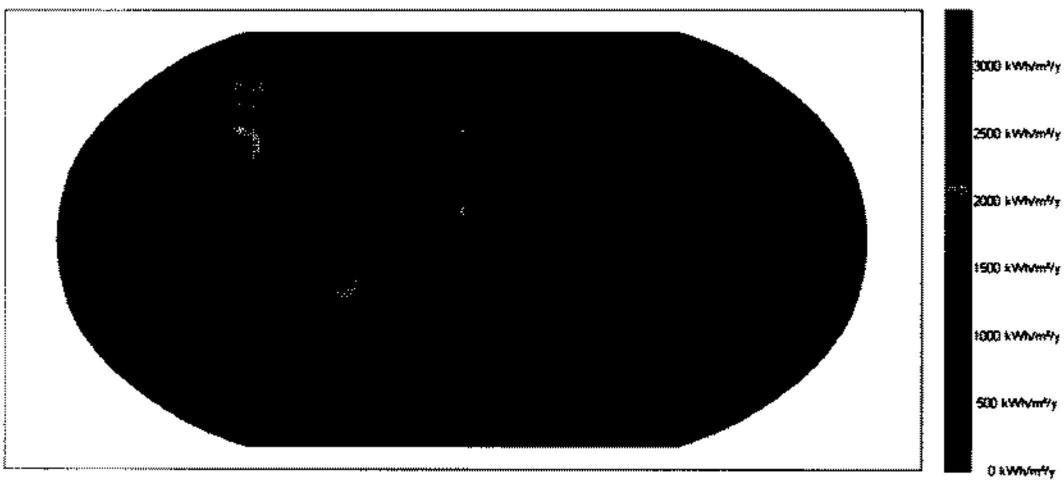


Figure 1: Countries having largest solar potential around world [19].

The earth most abundant sun energy areas are located in North Africa, Middle East, South Africa, India, Australia, North America and South America.

The distribution of sun energy over the earth surface is not uniform this is due to the fact that areas where sunlight fall direct over the surface or near to the equator has stronger potential compare to the areas away from equator.

2.2 Solar energy survey in Pakistan

Geographical point of view Pakistan is among those countries where sun warms the surface throughout the year therefore has a strong potential for solar power generation.

The lowest solar radiation intensity level has been recorded $76.49\ W/m^2$ observed at Cherat in the month of December and highest $339.24\ W/m^2$ in Gilgit while average monthly solar insolation remains 136.05 to $287.36\ W/m^2$ in the country [1].

It has been observed that the value of solar radiation intensity greater than $200\ W/m^2$ were observed in February to October in Sindh, March to October in almost all regions of Baluchistan, April to September in KPK, Northern Areas and Kashmir regions while March to October in Punjab. Solar insolation estimated for 10 hours a day reached its value from $1500\ W/m^2\ per\ day\ to\ 2750\ W/m^2\ per\ day$ in Pakistan especially in southern Punjab, Sindh and Baluchistan regions throughout the year. In an area of hundred meter-square 45 MW to 83 MW power per month may be generated in the above mentioned regions [1].

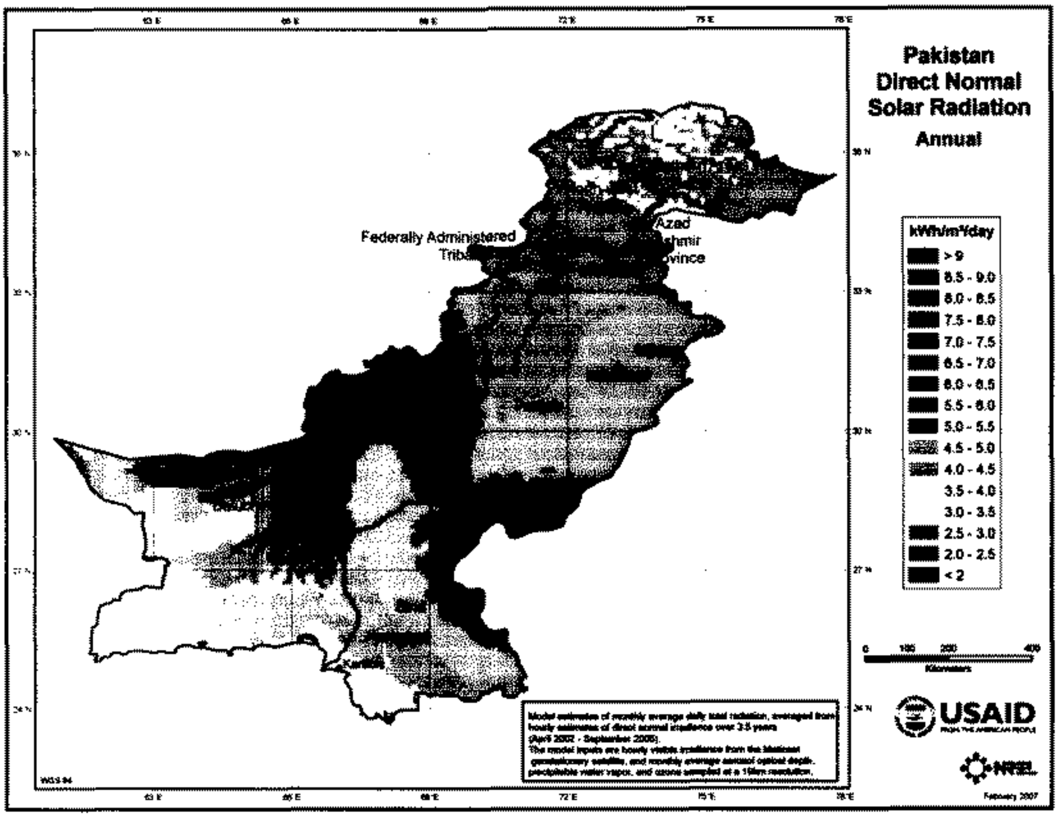


Figure 2: Solar energy potential in Pakistan [3].

2.3 Solar Photovoltaic System & its Components

The word "photovoltaic" is a combination of two words: phos which is the Greek word for light, and volt, which is the unit of electric voltage. The first photovoltaic cells have been used in space ships and satellites at the end of the 1950s. Since then, there have been many further developments. Today, the most common standard module is made from high-grade silicon that is based on crystalline silicon cells (c-Si), also known as solar grade silicon [5, 16].

This common solar cell is treated with positively and negatively charged semiconductors, called phosphorous and boron. The actual transformation of solar energy into usable electrical power takes place at the atomic level. For example, if a photon hits a solar cell, it detaches the negatively charged electrons from their atoms through the impact and excites the electrons within the cell. This effect is called "doping" and initiates the flow of electrons from the negative semiconductor (phosphorous) to the positive semiconductor (boron).Finally known as the PV effect; this is what generates electricity [5,15].

Solar photovoltaic system comprises with the following basic components

- Solar photovoltaic panel
- Solar charge controller
- Panel support or frames
- Batteries
- Inverter

2.3.1 Solar PV panel

Solar photovoltaic panel is the fundamental part of the solar photovoltaic system. It converts sun energy into electricity. The solar cell alone does not able to generate bundle of electricity so the number of these cell are connected internally to make module. Module is connected to make arrays, have greater ability to produce photoelectric current. The size of the panel can be calculated with following formula [14].

$$pv\ module\ size = \frac{total\ daily\ watt\ hour}{average\ dialy\ solar\ insolation} \times 1.3$$

2.3.2 Solar PV charge controller

Solar charge controller as does name implies controls the charge moving from solar panel to the batteries and avoid it from over charged .If the battery gets over charged it will damage soon. Charge controller exists in all shapes, size and features.

They range from 4.5 amp control to up to 60 to 80 amp MPPT programmable controller with computer interface. Generally three types of charge controller exist. Simple charge controller also called 1or 2 stage controller, three stage or PWM and maximum power tracking point (MPPT) charge controller. Among these charge controller the MPPT charge controller work with maximum efficiency 94% to 98% range. Few charge controllers use a technique of pulse width modulation technique in this technique controller sends out a series of short pluses to the battery with a rapid response of on-off switch. Then controller constantly checks the state of the battery to determine how fast to send pulses, and how long (wide) the pulses will be. In a fully charged battery with no load, it may just "tick" every few seconds and send a short pulse to the battery. In a discharged battery, the pulses would be very long and almost continuous, or the controller may go into "full on" mode. The controller checks the state of charge on the battery between pulses and adjusts itself each time [6].

2.3.3 Solar PV panel support

Normally two types of supporting systems are used for panel support that is roof mount system and pole or also called ground mount system. Each of this has its own specification. Roof mount system is preferable for safety places especially where there is an occurrence of danger to panel assembly from animal. It is also preferable where shortage of space on the ground exist. But in some cases it is unfeasible where load is heavy and having danger of falling roof or to poor roof support. Roof mount system has a draw back for connecting tracker to the panels for increasing efficiency because the angle, with which you fixed the solar panel on the roof, will be same throughout the year irrespective of the fact that sun changes its position horizontally and vertically during the whole year.

Pole mount supporting system has certain advantages over roof mount system. As efficiency of PV module is closely related to temperature. Each degree rise in temperature after 25 degree centigrade causes decrease in efficiency [12]. Pole mount system is preferable in this regard due to air flow around it and advantage of tracking mechanism of sun is related with only pole mount system.

2.3.4 Batteries

Unavailability of the sun during night hours and cloudy weather can create a serious problem for users if the backup supply does not available. For a grid tie system it does not matter but for stand-alone system we must have batteries to provide constantly supply to the load during unavailability of sun.

The size of the battery is calculated by the following formula [14].

$$battery\ capacity = \frac{daily\ load(watt \times hour)}{battery\ effeciency \times DOD \times battery\ voltage} \times autonomy$$

Autonomy is the number of days of storage of charge and DOD is stand for depth of discharge. The maximum percentage of full rated capacity that can be withdrawn from a battery is known as its Allowable Depth of Discharge.

The allowable depth of discharge for Lead Acid Battery is 80% [6].

2.3.5 Inverter

Inverter is the essential part in solar photovoltaic system because our load is driven by alternating current and the power generated from solar photo voltaic panel is direct current. Inverter hence converts ac into dc.

For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you will be using at one time. The inverter size should be 25-30% bigger than total Watts of appliances. In case of appliance type is motor or compressor then inverter size should be minimum 3 times the capacity of those appliances and must be added to the inverter capacity to handle surge current during starting. For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation [6].

2.4 Optimization in the Solar Photovoltaic System

The performance of the Solar Photovoltaic System is very crucial among the designer, manufacturer, fitter and the end users. The system working with low efficiency can create a lot of problem at demand side management. Since solar photovoltaic system's efficiency is narrowly connected with solar panel efficiency. Any improvement made in optimization of output panel can increase overall performance of the system many folds.

Here literature review conducted on the optimization in solar photovoltaic system by labeling factors effecting on performance of the solar photovoltaic panel. The following factors can effect on solar panel output.

2.4.1 Tilt angle of the solar panel

The angle made by the solar panel with horizontal plane is known as tilt angle of the solar panel. In our daily life the sun changes its position from east to west as well as it also moves from north to south throughout the year.

In order to keep solar panel oriented toward the sun its tilt angle must be changed if not, then efficiency will go down, can create problem at load side.

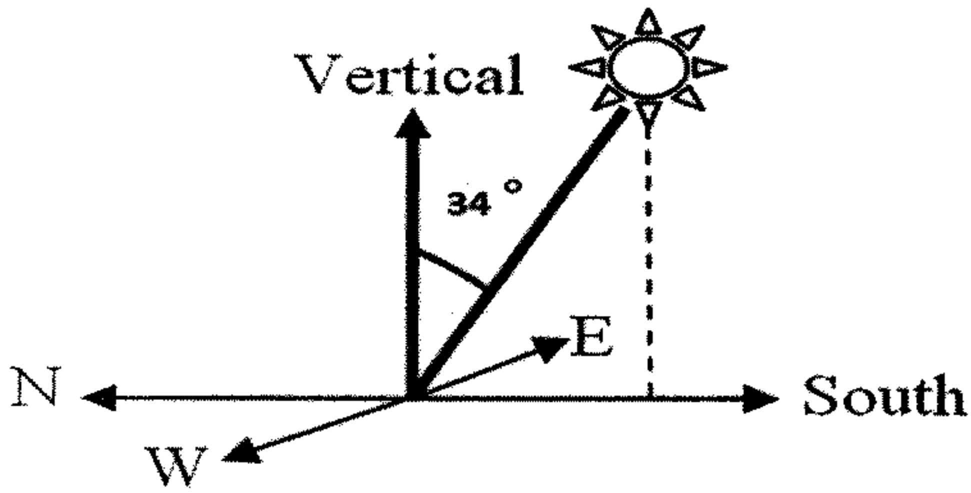


Figure 3 : Changing tilt angle of the sun [18].

Tilt angle on earth is different for different location, related to earth geographical location. Sun gets higher in summer on the sky so on summer solstice, on that day it will be more exact 23.45° higher than equinox (the day at which sun arrives exact over the equator, happen twice a year) while in winter it gets lower on the sky, on winter solstice till it reaches 23.45° below equinox.

Islamabad has latitude 34° approximately so in summer when the sun reaches highest on the sky then the position of the sun will $34° - 23.45° = 10.55°$ away to the south of vertical.while in winter when it gets to the lower position then position of the sun will be at $34° + 23.45° = 57.45°$ to the south of vertical.it means that tilt angle of the panel must be vary with changing angle of the sun between $10.55°$ to $57.45°$.One must have to change the tilt angle or other words vertical angle of the panel throughout the year in order to optimize efficiency of the panel.

Solar trackers are employed to keep panel facing towards sun throughout the day.

It has been estimated that the yield from solar panels can be increased by 30 to 60 percent by utilizing a tracking system instead of a stationary array [7].

2.4.2 Orientation angle of the solar panel

For a fixed panel whether it is pole mount or the on the roof the orientation of the panel usually towards the south but in order to optimize the output the sun rays must fall normal to the plane of the solar panel all over the day. Fixed panel achieve this during limited time of the day. To achieve this usually solar trackers are employed that keep panel facing the sun throughout the day.

Trackers are the intelligent electro-mechanical components that work on data stored inside it and force the panel to follow sun. Electro-mechanical components include motors, gears, drivers that are controlled by electrical signals.

Trackers are characterized by several criteria the first one is rotatory axis trackers, the second is orientation and third criteria on which it can be classified is activity type [8].

Rotatory axis trackers are either single axis or dual that is horizontal and vertical axis. For dual axis rotation horizontal axis rotation changes with the changing position of the sun from east to west and vertical axis rotation are changes with changing position of the sun from north-south. For a single horizontal axis rotation the vertical rotation remain fix at a particular angle or manually adjustable throughout the year [8].

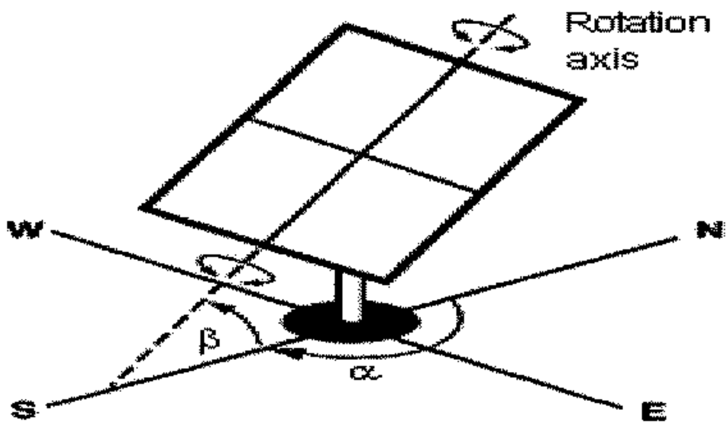


Figure 4 : Principle of the single-axis solar tracking system [8].

Some other tracking devices follow a comparison mechanism between the past accounted sun trajectory and the recent path of the sun further intelligent device decide to keep solar panel on correct path of the sun. Some other trackers are activity based, upon which one can decide whether they are active or passive. Active trackers are based on sensors that respond to the sun light while the passive are programmable microcontroller based.

2.4.3 Shading

Another important factor that can effect on the performance of the solar photovoltaic system is shading. Once panel or some part of it gets shaded by tree or building then its output power goes down several times. PV modules consist of small photovoltaic cells that are serially connected in string. Each cell produces 0.5volt under normal conditions while a module containing 20 cells will produce 0.5x20=10volt under normal condition.

A cell under shade does not produce same amount of power compared to un-shaded cell. Despite of producing power shaded cell start to consume it because cells are connected serially in a string hence any difference in power create difference in the voltage, power consumed by the cell causes to heat up, any attempt to draw maximum power from inverter causes burning of cell [9].

Figure 5 : Effect of shading on solar PV panel [9].

2.4.3.1 Optimization in power during shading

Inverter is connected serially to the strings of solar cells and its basic function is to draw the maximum power from panel by changing current-voltage and convert direct current to alternating current. Let us observe how inverter preforms it.

As shown in figure no 6, ten modules are connected serially to the inverter & each string of module contains 10 cells. Module no 3 has a single cell came under shade. For this we assume that it receives 20% less light compare to its neighboring cells. Since all modules are connected serially to the inverter, current will remain same through all modules. Here inverter has to make decision in order to draw maximum power from modules.

There are two possibilities happen for the inverter to perform.

- Activating by pass diode & extracting maximum power form module
- keeping by pass diode & extracting maximum power from module

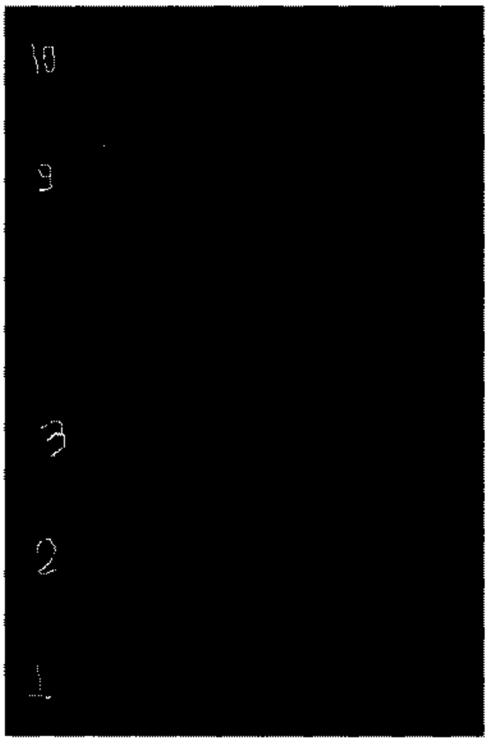


Figure 6 : By pass diode effect on solar panel output [9].

Activating by pass diode of the shaded string, inverter will get maximum power from remaining 9 modules i.e. 9*10%=90%, while from module 3 whose cell is under shade, will receive 33% less power compare to un shaded cell i.e. 1*6.6%=6.6%. The total power from first string 90%+6.6%=90.6%. In second case in which by pass diode remain off power will br reduced to 80%. So the net power of the all modules will 10*8%=80%[9].

Now a days with maximum power point tracker such as "SolarEdge" suggests are available.SolarEdge is the provider of power optimizer ,solar inverter & monitering solution for photovoltic arrays, its basic aim is to optimize power in photovoltic system.

If we use MPP tracker with above system the result will be different .Power from the nine module will be 100 % while the module no.3 has 80% due to flow of small current through it. So the net power will in this case be 9*10%+1*8%=98%.

2.4.4 Soiling of panel

Soiling of panel is the term referred to the accumulation of dirt over the surface of solar panel. As solar panel has to deploy in an open environment so in tropical areas like Pakistan and India so much dust accumulate over the panel hence reduce its output if it does not clear with the passage of time. Although the power does not cut of completely like shading but it lessen over several times and efficiency disturbed badly.

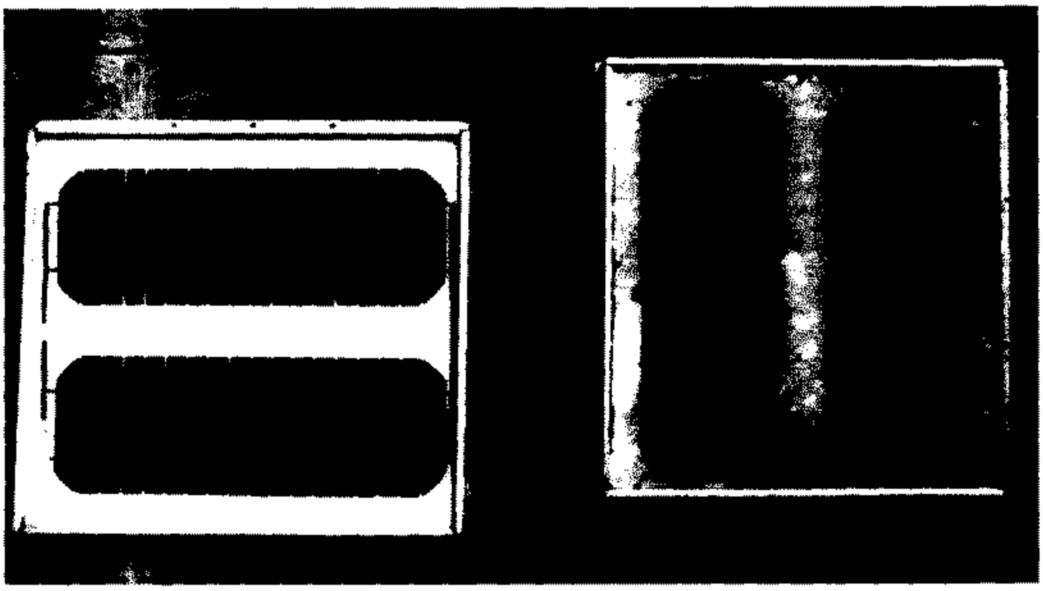


Figure 7 : Soiled Vs. unsoiled solar PV panel [10].

It has been observed that 50% power drops due to the soiling if panel does not clear in a month for single time [10]. Often rain washes the dust but the areas like Thar & Cholistan the rain does not falls several month so for better performance of the solar system panel must clean manually single time over the month.

2.4.5 Temperature

Temperature has vital role on the performance of photovoltaic cell or module. At 25 degree centigrade its performance maximum but as the temperature rises the rate of recombination increases, only few of photon able to create electron from semiconductor that is responsible for generating current while rest of them result in generating heat due to excessive recombination rate. This heat accumulates back of the panels by the process of convection. It is necessary to flow of air beneath the panel surface & panel must not adjust in the vicinity of trees or air blocked area.

It has been observed that a solar PV module convert 6 to 20% of incident light into electricity by taking consideration of solar cell type and weather conditions while rest of incident light responsible for generating heat[11].

A simple rule is that rise in temperature 10 degree centigrade, lowering effective power output 4%-5%.

A crystalline silicon solar cell electrical power depend upon its operating temperature and it has been seen that it's open circuit voltage decrease significantly $2.3\, mV/°C$ with increasing temperature result in reduction of output power 0.4%-0.5% per degree centigrade rise in temperature[12].

Different methods for cooling back of the panel are used to perform solar cell at maximum efficiency. In the optimize model a fan is placed underneath of the panel for cross air flow as shown in figure 8.

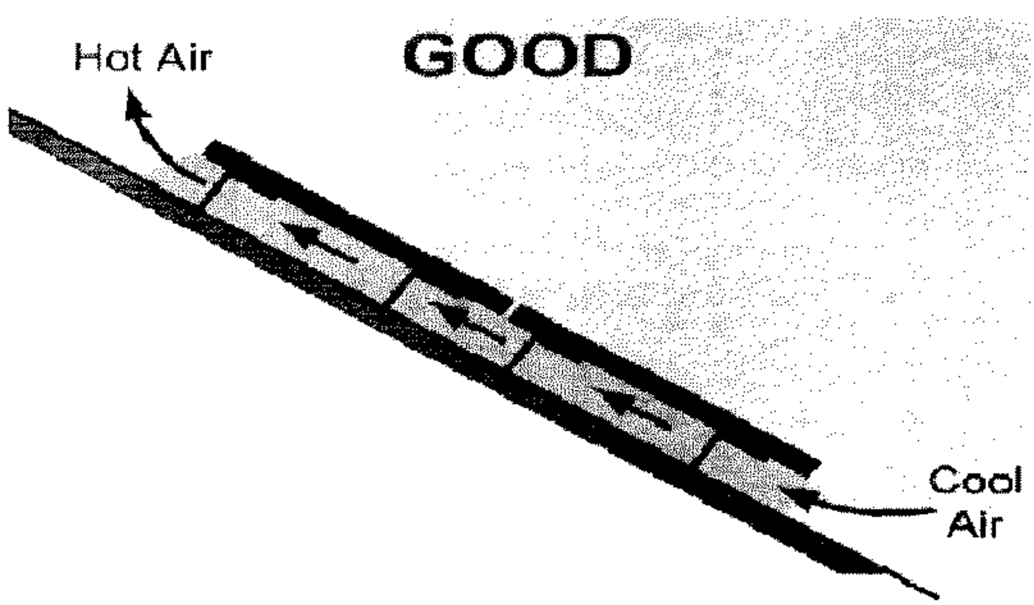


Figure 8 : Effective dissipation of heat from the panel [17].

In different research techniques cooled water pipes are used. Water cooling pipes are passed below the panel surface, cooled water enter at inlet of pipes, circulate below the module and take off heat by natural conviction.

2.4.6 Degradation of solar PV panel

Degradation of panel is the loss in generating capacity of the solar panel with the passage of time. The efficiency of solar panel demoralize with the passage of time.

Manufacturer claim the efficiency of mono-crystalline panel about 14%-16% while multi-crystalline is 12% approximately [5].

A work on degradation of panel tells 0.5% loss of efficiency per annum that means 80% loss in efficiency occur after 25 years of period. Companies warranty on degradation less than 0.9% per annum, yielding minimum 80% efficiency after 25 years [17].

CHAPTER 3

MODELING & DESINING OF PV SYSTEM

Design of photovoltaic system has been comprised into three main sections i.e. designing of solar tracker, reflector adjustment around the solar panel at specific angle & designing of supporting structure frame to hold solar PV panel and solar tracker.

3.1 Tracker Designing

Microcontroller and real time based tracker is designed whose basic function is to keep solar panel align towards the sun throughout the day. Term real time here used for the delay generation inside code for the difference of the sun rise and sun set time over that day. Further it has divided into three main sections i.e. Microcontroller section, Steeper motor & Driver circuit.

3.1.1 Section one (microcontroller)

Atmel 89c51, family of 8051 microcontroller has been used due to its excessive use in electronic projects, 4K byte on chip ROM, and two timers. Externally 11MHz crystal is connected for clock frequency to pin 18 and 19 as AT89c51 have on-chip oscillator but do not have internal clock like AVR. Pin 31-EA connected to +5v as it has on chip ROM and understood that program will not store on external memory. Pin 20 is grounded and pin 40 is provided +5v.

3.1.1.1 Code for microcontroller

//This program generates the delay of 66ms initially using timer 1, mode 1(16 Bit)

```
void delay_ms(unsigned int x)
{
        unsigned int y=o;
        for(y=0;y<x;y++)
        {
        TMOD = 0x10;                    //Timer 1, mode 1 (16 BIT )timer
                                        //GATE1=0; C/T1 =0; T1M1=0; T1M0=1;
                                        //GATE0=0; C/T0 =0; T0M1=0; T0M0=0;
        TL1 = 0x63;                     //initial values
        TH1 = 0x12;                     //1263 = 4707, 16bitmax value = 65536
                                        //65536-60829 = 4707,
        TR1 = 1;                        //Start Timer 1
        while(!TF1);                    //Wait until Timer1 overflow occurs
        TR1 = 0;                        //Stop Timer 1
        TF1 = 0;                        //TF1 = Timer 1 Overflow. This bit is set by
                                        //the microcontroller when Timer 1 overflows.
        }
        return 0;
```

//program of stepper motor

```
#include <AT89x51.h>
#include <REGX51.H>
#include<stdio.h>
void delay_ms(unsigned int x)
{
        unsigned int y=o;
        for(y=0;y<x;y++)
        {
        TMOD = 0x10;                    //Timer 1, mode 1 (16 BIT) timer
                                        //GATE1=0; C/T1 =0; T1M1=0; T1M0=1;
                                        //GATE0=0; C/T0 =0; T0M1=0; T0M0=0;
        TL1 = 0x63;                     //initial values
        TH1 = 0x12;                     //1263= 4707, 16bitmax value = 65536
                                        //65536-60829 = 4707,
        TR1 = 1;                        //Start Timer 1
        while(!TF1);                    //Wait until Timer1 overflow occurs
        TR1 = 0;                        //Stop Timer 1
        TF1 = 0;                        //TF1 = Timer 1 Overflow. This bit is set by
                                        //the microcontroller when Timer 1 overflows.
```

```
	}
	return 0;
}
void main()
{
	P2 = 0x00;				//port 2 used as output
	while(1)
	{
		P2 = 0x03;			//0011
		delay_ms(1000);
		P2 = 0x06;			//0110
		delay_ms(1000);
		P2 = 0x0C;			//1100
		delay_ms(1000);
		P2 = 0x09;			//1001
		delay_ms(1000);
	}
	return 0;
}
```

3.1.1.2 Time delay generation

Time delay generated inside microcontroller to control steeper motor rotation is based on sun rise and sun set timing since the panel remained align toward sun with changing position of sun over the sky. Sun rise and sun set timings are taken from weather forecast. Here given below how delay has generated in above code.

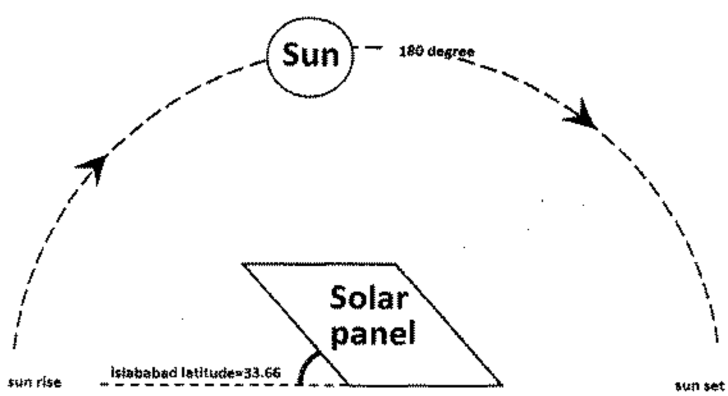


Figure 9 : Time delay generation over sunrise and sunset timing

The angle subtended by the sun over the sky between sun rise and sun set is 180°approximately. Solar photovoltaic panel has to move also 180° from east to vest horizontally in order to track the sun. It has been observed that steeper motor's shaft moved two complete rotations around its axis plus 260° in order to move PV panel hence

Time delay generation in microcontroller as discussed above based upon real time so it involves some basic mathematics.

Shaft of steeper motor moved = 2 x complete rotation+260°

$$=2x360°+260° =980°$$

Step angle of the steeper motor = 1.8°

Steps needed to accomplish one rotation= (360°)/ (1.8°) =200 steps

980° rotation will take steps= (980°)/ (1.8°) =544 steps

Steeper motor shaft has moved 544 steps during the availability of sun to align panel towards the sun.

The experimentation and calculation have to perform in the month of December, during which the sun light available from morning 7:00 AM to 5:00 PM in evening. So sun available over the sky for 10 hours approximately.

Hence 544 number of steeper motor's steps must be completed in 600 minutes.

One step will take= (600 min)/ (544 step) =1.1 min/step or 66 sec

Microcontroller must have to provide single on its port 2 after 66 sec.

3.1.1.3. Algorithm for delay generation

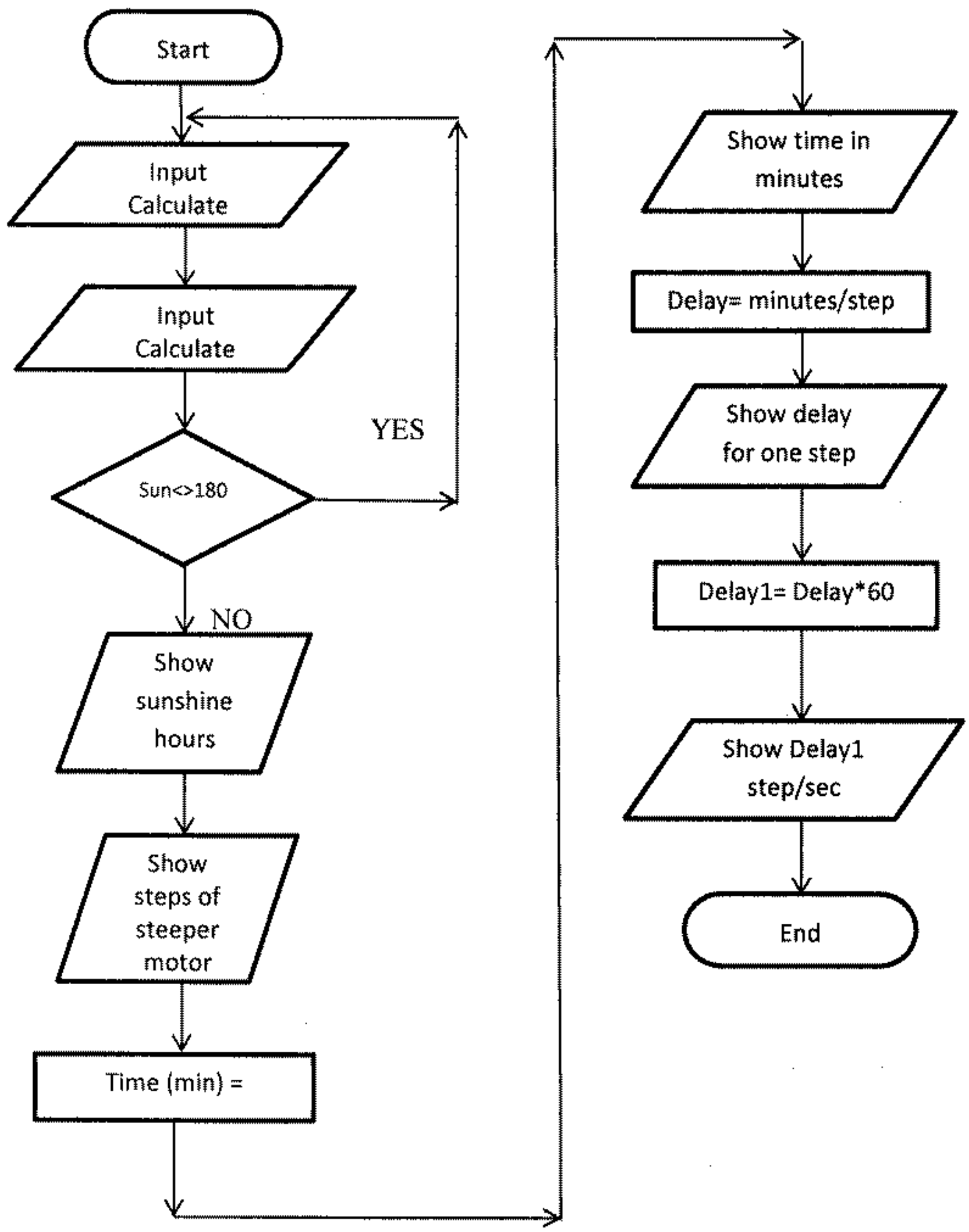
- **Pseudo code**

// Following Pseudo code represent the time delay calculation i.e. "Delay1" for steeper motor, for solar tracker

Use variables: Hours of type integer, Steps of type integer, Delay, Delay1 & Time of type real

```
Start program
WHILE sun <> 180
        CALCULATE Hours
        CALCULATE Steps
ENDWHILE
DISPLAY "number of sunshine hours", Hours
DISPLAY "number of steps taken by steeper motor", Steps
Time = Hours * 60
DISPLAY "number of hours calculated in minutes", Time
Delay = Time / Steps
DISPLAY "calculated delay in min / step", Delay
Delay1 = Delay* 60
DISPLAY "calculated delay for one step of steeper motor in sec", Delay1
End program
```

- **Flow chart**


Start
Input
Calculate
Input
Calculate
YES
Sun<>180
NO
Show
sunshine
hours
Show
steps of
steeper
motor
Time (min) =
Show time in
minutes
Delay= minutes/step
Show delay
for one step
Delay1= Delay*60
Show Delay1
step/sec
End

3.1.2 Section two (Steeper motor)

In designing of solar tracker steeper motor has been employed compared to dc motor as holding torque does not provided by dc motor also it does not rotate to specific degree as steeper motor does. Steeper motor exist in two different types that is Unipolar & Bipolar with different number of wiring combination.

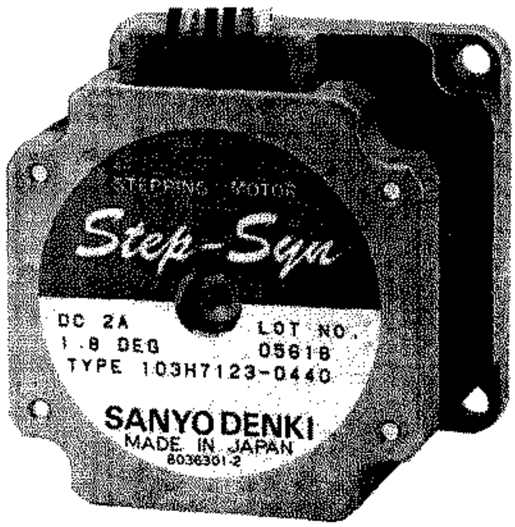


Figure 10 : Unipolar, six wires steeper motor

3.1.2.1 Unipolar vs. bipolar steeper motor

Unipolar steeper motor contain one wiring also called "common wire" with center tap per phase through which supply voltage is provided and each phase also contain single wire through ground connection is provided. While in bipolar steeper motor only a single wire each phase is provided.

- In unipolar flow of current remain only in one direction so wiring connection are permanent, does not require any reversibility but in case of bipolar current has to reverse in order to move shaft both clock-wise and anti-clock wise direction.

- Driver used in Bipolar steeper motor is complex compared to unipolar .Mostly H-bridge driver configuration is used for bipolar steeper motor while unipolar steeper can be drive with simply use of transistors. Hence driver for unipolar steeper is also cost effective.
- Torque provided in case of bipolar 30% stronger than that of unipolar. While both can be drive in full mode and half mode step sequence.

In the development of solar tracker six wires unipolar Sanyo Denki direct current steeper motor have been used with step angle 1.8°.

Table 2: Specification of L293D integrated circuit

Characteristic of 103H7123 Steeper motor	
Basic step angle	1.8°±0.09°
Current rating	1.5 amp
Unipolar holding torque	86 N-cm
Mass	0.65kg
Back electromotive force	31 V/k-rpm
Rotor inertia	210 $kgm^2 \times 10^{-7}$
Theoretical acceleration	50000 rad×sec^2

3.1.2.2 Full step mode sequence

Basically steeper motor can drive in two step mode sequence:

- Full step mode sequence.
- Half step mode sequence.

Here sequence has developed to rotate shaft for "Full step mode" sequence due to steeper motor full degree step angle rotation and small time delay generation in microcontroller programing. While in "Half step mode sequence" the step angle gets lower to half hence number of steps gets double to complete one rotation. The generated sequence for steeper motor is given below.

Table 3: Code sequence of steeper motor wires

A	B	C	D
0	0	1	1
0	1	1	1
1	1	0	0
1	0	0	0

The above generated sequence is given to the 4 phases of steeper motor in such a way that A & C is allotted to the two opposite phase and B & D to the another two opposite phase. This sequence also decides the clockwise and anticlockwise rotation of motor if u allows above sequence A, C, B, & D to the wire 1, 2, 3 & 4 correspondingly then rotation will clockwise otherwise by interchanging sequence D, B and C, A to 1, 2, 3 & 4 will rotate in anticlockwise. In the designing of tracker the first sequence has been made to utilize because clockwise rotation of motor.

3.1.2.3 Wire selection criteria

Steeper motor used in the designing of tracker contain six wires with two center tap and four individual wires for each coil. To configure wire with exact sequence, the center tap and phase wire must be known to designer if not then motor become halt and result in damage of external electronic circuit. Although configuration of wires can be performed with different method but here the method of resistance is used to configure wires in a sense that the wires connected with each coil end and at center tap must have resistance half of the resistance between the two internally connected coils ending wires as shown in fig below

The resistances between the wires observed are listed below

Table 4 : 1st Combination of steeper motor wires

Wires Combination	Resistance
Yellow-Red	6.6 ohm
Yellow-Black	3.7 ohm
Red-Black	3.7 ohm

The above table shows that resistance between the Red-Yellow wire is double than the Yellow-Black & Red-Black. It means that the combination with lower resistance 3.7 ohm contain common that is Black is configured as center tap.

Table 5: 2nd Combination of steeper motor wires

Wires Combination	Resistance
Blue-Orange	6.6 ohm
Blue-White	3.8ohm
Orange-White	3.8 ohm

Similarly the common or also called center tap wire configured is white which has lower resistance among blue & orange.

By knowing the center tap wires the other coils wires must have to be determining in order to a lot exact sequence. To know this the center tap wires are connected with positive supply end and the negative with other individual wires respectively. The motor shaft rotation in clockwise or anticlockwise direction decided the coil position, whether it is left or rights of center tap wires.

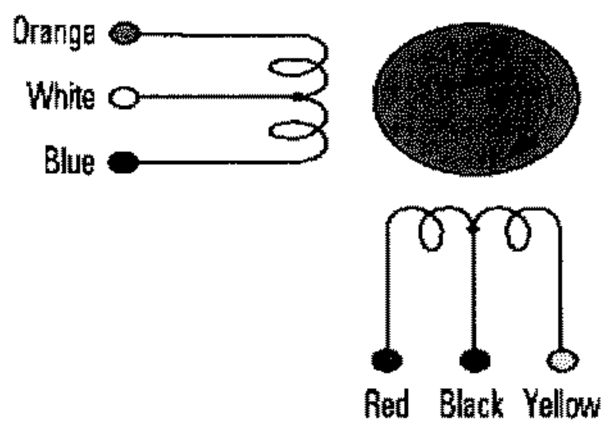


Figure 11 : Wires selection of steeper motor

3.1.3 Section 3(Driver circuit designing)

For tracker designing microcontroller port 2 has been programed for delay generation. Microcontroller generate current on its output only in few mA that is insufficient to drive steeper motor so there is always needed a driver to drive steeper motor.

3.1.3.1 L293D Integrated circuit

The driver circuit has been designed by in model designing by using L293D IC. It is an H-bridge integrated circuit and H-bridge circuit has capacity to move motor in both directions either clockwise or anticlockwise. Also has ability to drive steeper motor needed supply voltage from 9v to 36v by connecting with microcontroller which does not drive steeper motor isolate.

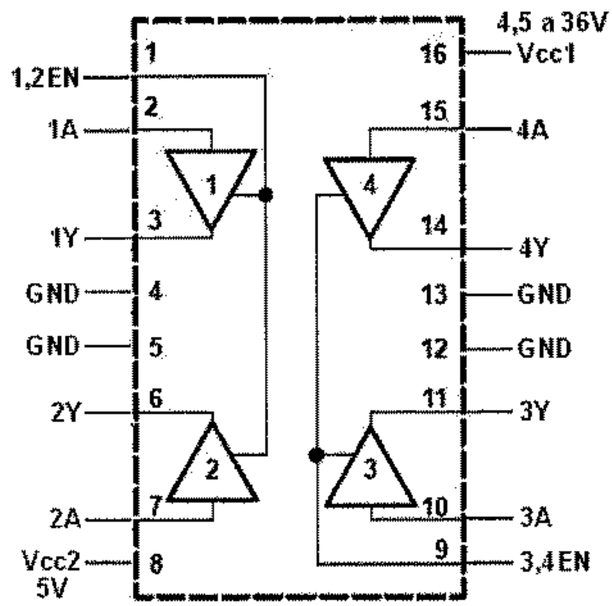


Figure 12 : L293 integrated circuit pin diagram

Here 9v operating voltage, Sanyo Denki steeper motor has been interfaced by connecting port 2 of microcontroller with the input pins 2,7,10 & 15 respectively. Vcc1 is provided +5v for the internal operation of circuit and Vcc2 is the required voltage of steeper motor is connected by 9v. Pins 1, 9 & 8 are enables and connected to +5v for operation otherwise circuit does not performed its operation while the 1Y, 2Y ,3Y & 4Y are output pins are connected to steeper motor wires.

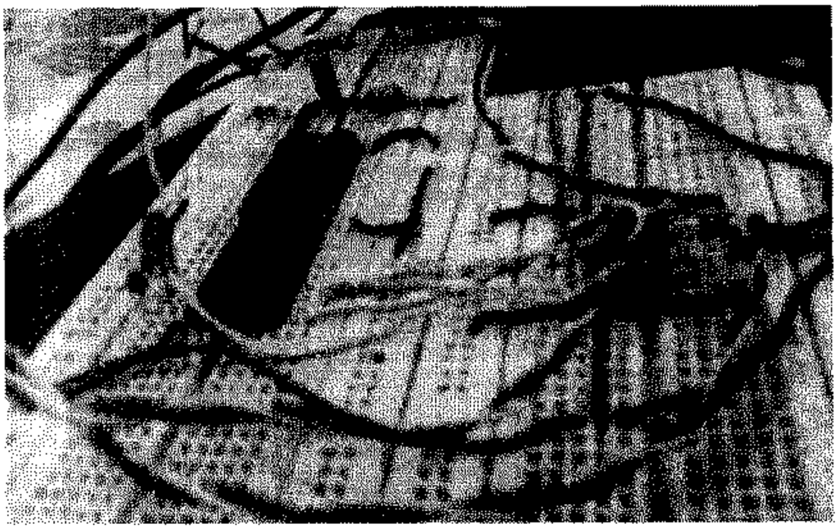


Figure 13 : Electronic circuit used in solar tracker

3.2 Reflectors adjustment around Panel

The output power of the solar photovoltaic panel is dependent upon the number of photon fall on its surface. Although sun rays falls directly over the panel but some of them are being utilized to generate electric current and others gets reflected back into atmosphere. To converge these reflected rays and the additional rays from the sun reflectors are modified around the boundary of panel.

3.2.1 Framing of reflectors

To hold and fix reflectors firmly around the solar panel the two aluminum frames has been designed having length 20 inches and width 12 inches, equal to the length and width of the solar panel.

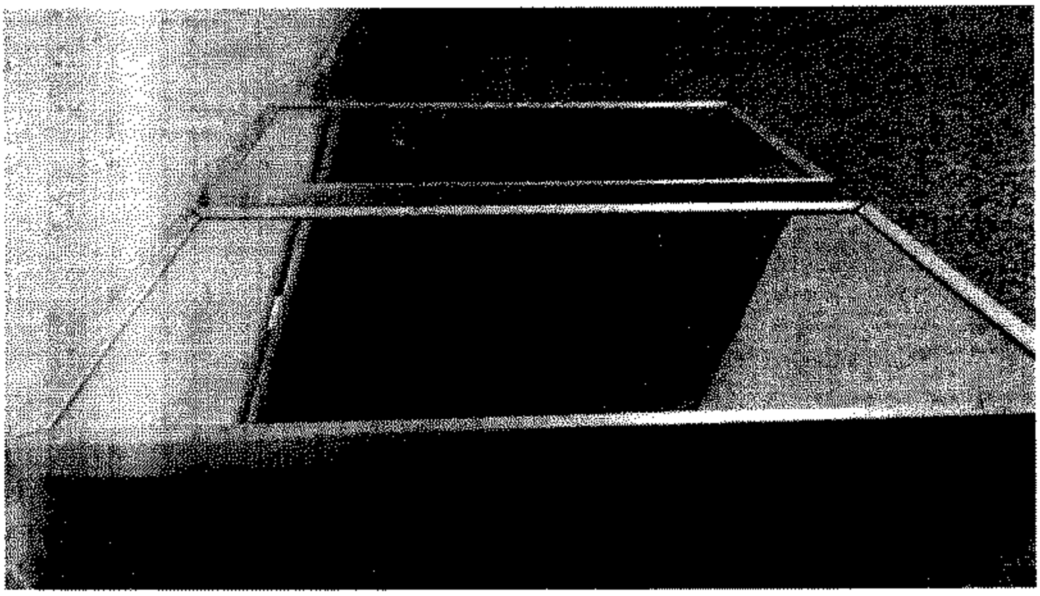


Figure 14 : Reflectors designed for hardware

Aluminum has preferred over the other metal for the framing due to project demand as tracker has to adjust inside stand to move panel along with sun. Steeper motor must have enough holding & rotating torque to move panel & reflectors easily. If the weight gets heavier on panel the motor could not performed it's require action. So far aluminum is light metal having specific weight $2.7gm/cm^3$, which is almost third times less compared to steel. Another specialty of aluminum is durability and resistance to corrosion. Naturally it has protected oxides film coating made it highly resistance to corrosion. Others actions like painting, anodizing or lacquering make it highly corrosion proof. Solar panel has to stand in an open atmosphere, faces bad weather condition due to heavy rain so aluminum is the best choice to avoid corrosion.

Frames of reflectors are totally fixed at particular angle by keeping in mind that maximum light concentrate at the panel surface. Two aluminum strips has been used for this purpose to hold reflectors.

3.3 Designing of supporting stand

To hold solar photovoltaic panel, usually roof mount & pole mount systems are employed. Here in the optimization of the solar PV panel the pole mount system or stand has designed by keeping in mind the advantage of tracking mechanism inside it because roof mount panel free from this tracking mechanism.

3.3.1 Material selection for support

Steel has been employed in order to support solar panel along with reflectors and solar tracker inside it.

I. Durability

As Steel is the most durable and also stronger one, having ability to carry load without any bending & deformation at atmospheric temperature and pressure. In this model designing, not only panel has to support but also steeper motor and gears of the solar tracker needed support inside of stand.

II. Reliability

Solar panel and its support have to stand in an open atmosphere, face bad weather condition throughout the years hence the performance of the panel degrades 0.5% annually as estimated by the engineers & scientist. Similarly if the panel support is not resistible to corrosion then after few years it has to replace with new one and that may be not feasible economically. On a huge scale where ground mount system support and solar thermal power generation is harvested through the parabolic trough or dish system are made of steel. In this model designing steel pipes are painted to avoid from corrosions and prolong its life.

III. Operating cost

Solar power generation is environment friendly power generating, to make it economically feasible several attempts are being in progress. In the designing of this model economic feasibility is preferred. On the designing supporting stand steel was also a best option as it is affordable and not as expensive as copper or aluminum.

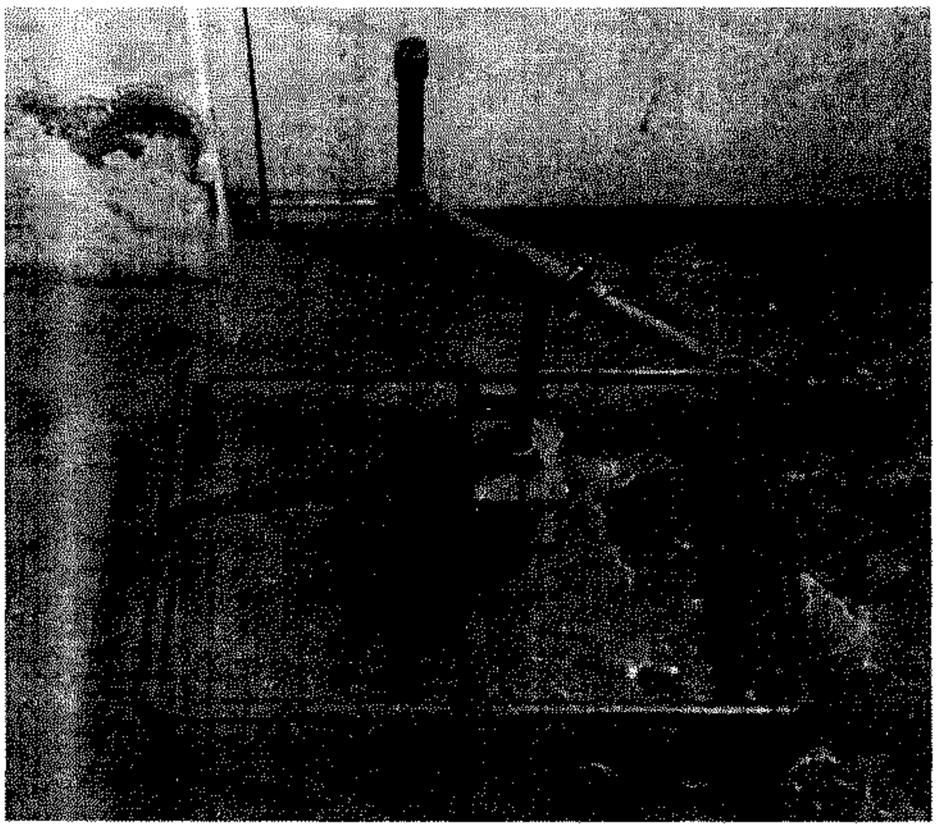


Figure 15 : Supporting Stand for solar panel and solar tracker

Steel circular pipes are used in the development of supporting stand. The length and width of stand is 66 cm and 52 cm respectively. To carry panel sturdily the base of stand is attached with four circular pipes to provide holding force. On the center of its base a steel circular pipe having length is 70 cm pivoted perpendicularly. It is pertinent to mention here that the pivoted pipe has to rotate freely to provide tracking mechanism for solar PV panel so this steel pipe was pivoted on the base of stand through frictionless bearing. Two circular bearing are being utilized for the sole purpose. These bearings are fixed inside wooden pieces which are further attached to stand by long nut bolt. The below end of the perpendicular pipe is connected with circular white gear for the rotation of solar panel, through torque provided by steeper motor. Teethed belt has used for the rotation of these gears such that no lose or extra motion can exist while the belt in motion. Because any extra or lose motion could be result in misalignment of the solar panel towards sun. The arrangement of steeper motor made possible inside of stand through steel strip and nut bolts. The whole assembly kept movable from one place to another. The frame is also painted to avoid corrosion as it has to keep in an open atmosphere.

3.4 Complete Structure designed

Designed hardware in cooperated with solar tracker inside supporting stand, reflectors around solar panel boundary and solar panel over stand. Steeper motor fixed by metallic strip at the corner of base and circular gears just below of the perpendicular pipe in order to provide precise rotation with shaft of the motor. Reflectors were made to fix by two steel strips at specific angle, keeping in mind maximum reflection over the surface of solar panel.

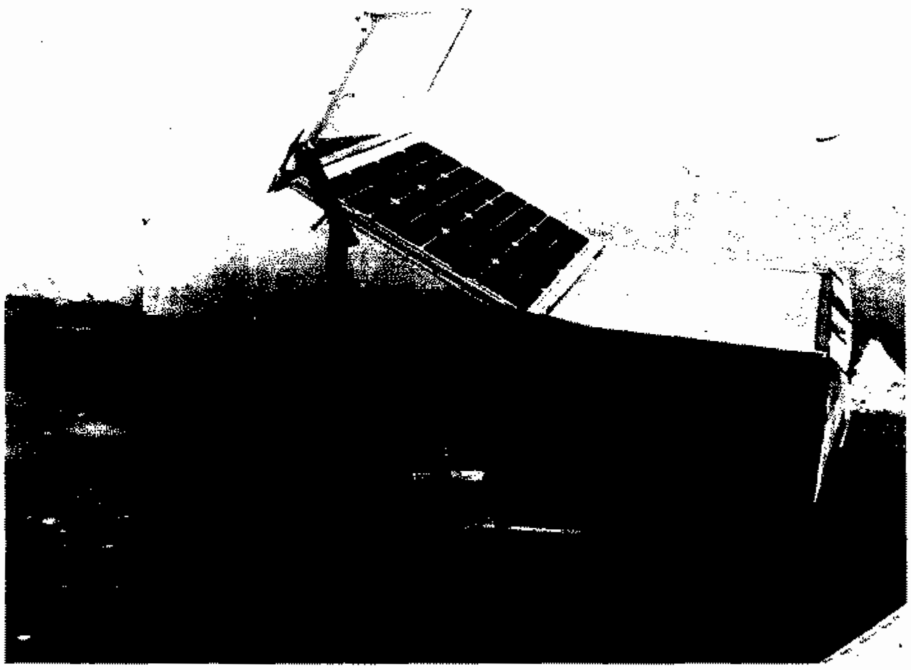


Figure 16 : Designed Hardware

CHAPTER 4

EXPERIMENTATION AND RESULTS

To perform experiment & evaluation of the result, output power of the solar photovoltaic panel has measured with following changes at four different stages.

1. Fixed solar panel only.
2. Fixed solar panel + reflectors.
3. Moveable panel along with solar tracker.
4. Moveable panel along with solar tracker + reflectors.

These four changes made across the solar panel at four different sunny days keeping in mind that solar irradiance level remain same at each day of observation. The experimentation and observation conducted in the month of December at Islamabad location. The readings were taken hourly basis from 7:00am to 5:00pm during sunshine hours. Output power has been measured in term of voltage into current by using power equation.

$$\text{Power} = \text{voltage} \times \text{current}$$

The very first stage at which stand-alone solar photovoltaic panel at fixed orientation, facing towards south with average tilt angle of the sun has adjusted. Next day two mirrors working as reflectors were fixed at top and bottom side of the solar panel, adjusting by two metallic strips and ensuring maximum reflection at panel's surface. At third day reflectors removed and designed solar tracker being fixed in the stand of solar panel to keep following solar panel throughout the day. At fourth day both reflectors and solar tracker were adjusted and output power measured throughout the day.

4.1 Solar panel specifications

A 20watts mono-crystalline solar photovoltaic power panel has been utilized with maximum peak current 1.30A and peak voltage 15.30V while short circuit current 1.47A and open circuit voltage 21.6V in this project. Panel possessed length 21inches and width 12inches respectively.

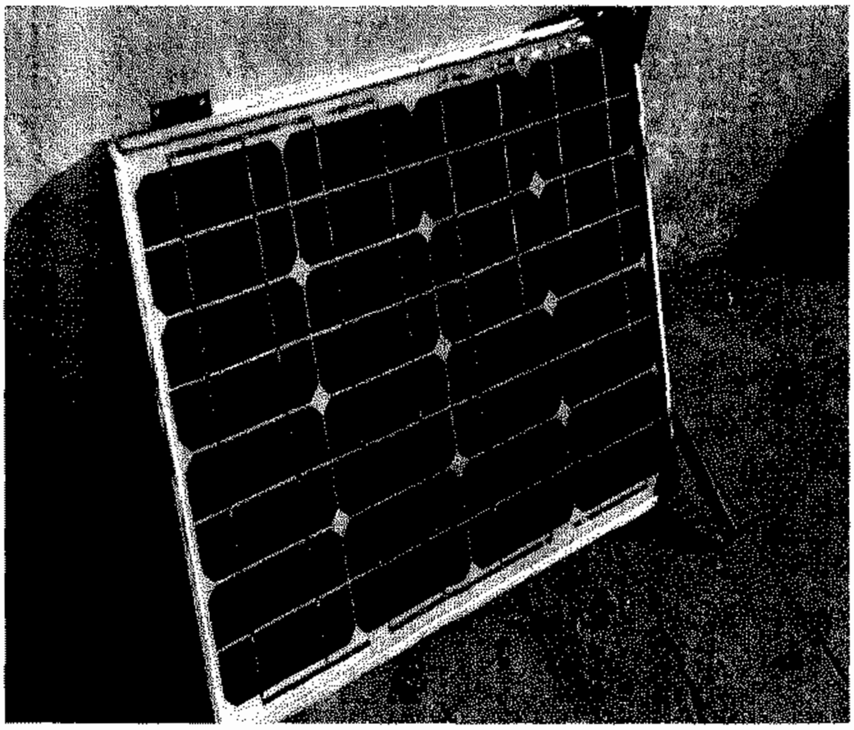


Figure 17 : 20 W mono-crystalline solar panel

The employed solar photovoltaic panel in hardware designing possess following feature

Table 6: Solar panel specification

1	Maximum peak current	1.30A
2	Maximum peak voltage	15.30V
3	Short circuit current	1.47A
4	Open circuit voltage	21.6V
5	Output power	20W
6	Fill factor	0.66
7	Storage & operating temperature	-40°C to 80°C

4.2 Fixed panel only

Initially the solar PV panel was adjusted with its length along east-west and facing towards the south. As the panel was fixed and no tracker involve, in that case its orientation didn't changes throughout the day yet it was fixed according to average tilt angle (the angle made by the sun along vertical line by changing its position north-south over sky throughout the year) of the sun at Islamabad's latitude i.e. 34°.

Output current and voltage measured by multi meter after each hour from 7:00 am to 5:00 pm. Power was being measured in term of voltage and current after each hour by multi meter.

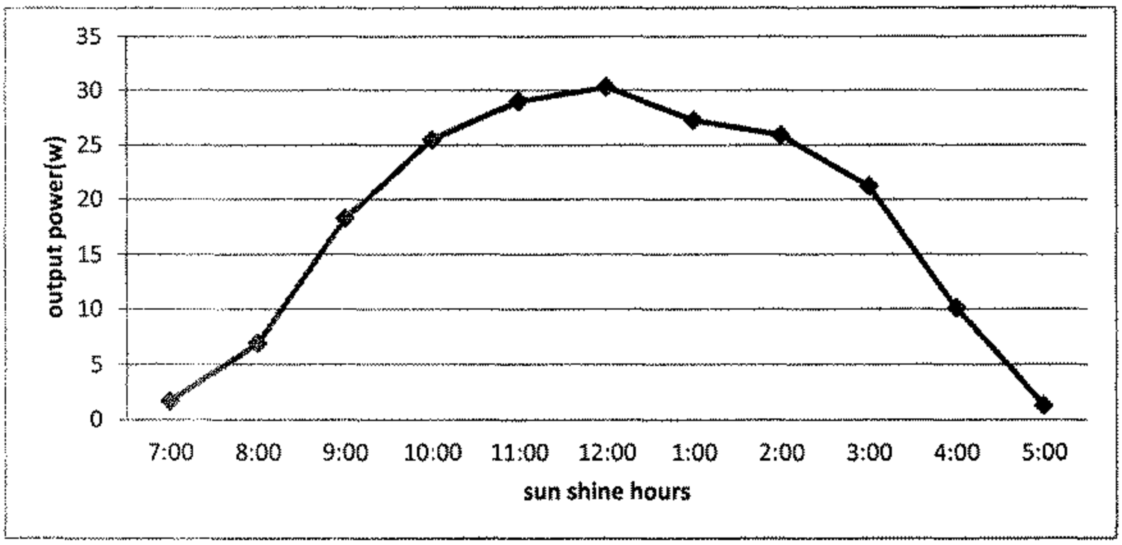


Figure 18 : Output power of stand-alone solar panel

Average current produce over day = 0.93 A

Average voltage = 19.21 V

Average power of stand-alone solar panel=17.94 W

4.3 Fixed panel + Reflectors

During 2nd phase, two reflectors having length and width 50cm x 20cm, were fitted at the top and bottom of the panel endorsing the maximum reflection towards the panel surface. These reflectors kept fixed around the panel boundary by using aluminum strips.

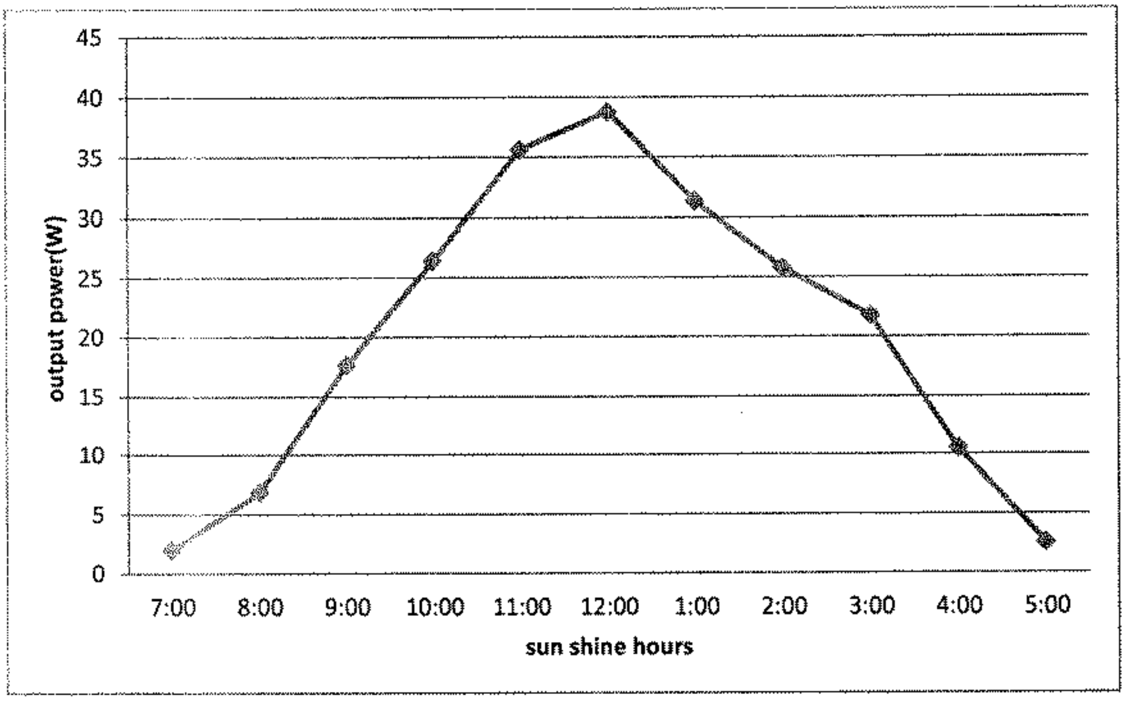


Figure 19 : Output power of solar panel with reflector addition

Average current produce over day = 1.00A

Average voltage = 19.52V

Average power of solar panel with reflectors= 19.91W

4.4 Moveable panel with solar tracker

In 3rd phase of experiment, panel didn't kept fix while it moved by the designed solar tracker. The tracker tracked the sun on horizontal axis while changing sun position from east to west on real time basis while vertical adjustment of panel made manually at best optimization tilt angle of the sun in the month of December. Tilt angle at Islamabad's geographical location calculated and it changes from 11° to 57° from vertical to the south in summer to winter respectively. By that modification solar photovoltaic panel oriented toward sun throughout the day.

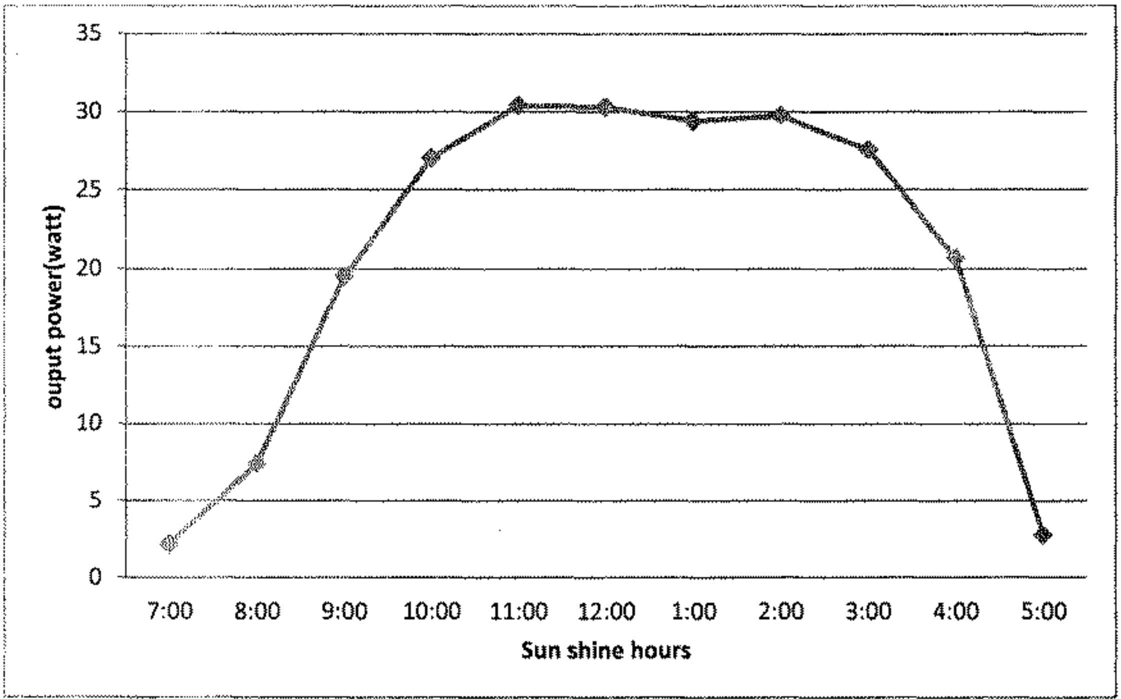


Figure 20 : Output power by using solar tracker along panel

Average current produce over a day = 1.06A

Average voltage = 19.34VS

Average power of moveable solar panel with solar tracker = 20.61W

4.5 Movable panel with solar tracker + Reflectors

In 4th and last stage panel solar panel modified with reflectors and tracker.

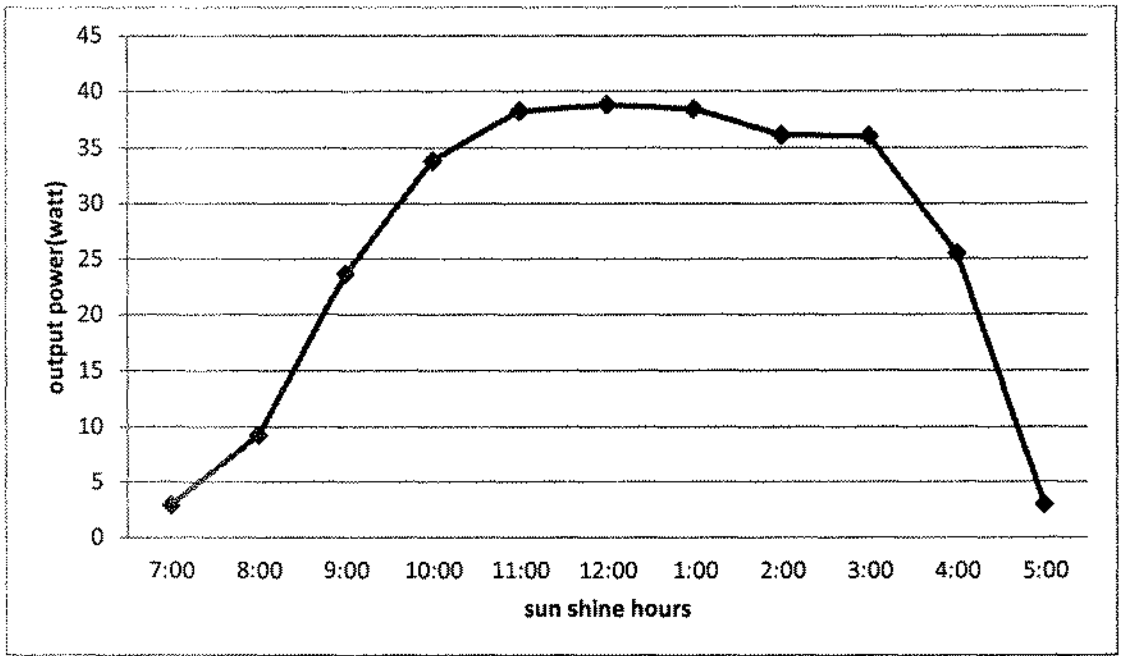


Figure 21 : Output power of panel by using both reflectors and tracker

Average current produce over a day= 1.30 A

Average voltage = 19.78 V

Average power of solar panel with tracker and reflectors = 22.47 W

4.6 Evaluation in all four stages output power

Comparison of all four stages output power is given below.

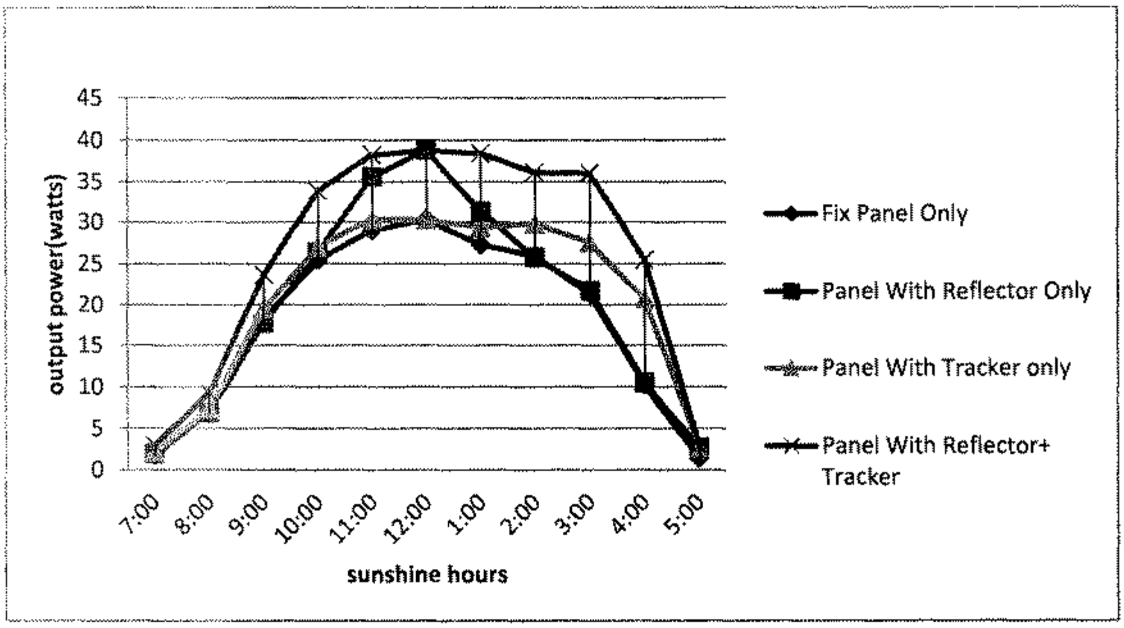


Figure 22: Power comparison at four stages

By inspecting the above graph of photovoltaic panel at four different stages the maximum power increase by the addition of reflectors and solar tracker across panel. The peak power at this stage maximum compared to fix panel moving panel without reflectors. Further power at each hour shows highest compared to other three. The output powers get maximized by the reflectors during noon when sun reached higher position over sky, due to better reflection on panel surface. Modification made in solar panel by the solar tracker didn't provided tremendous power achievement but the overall power maximized.

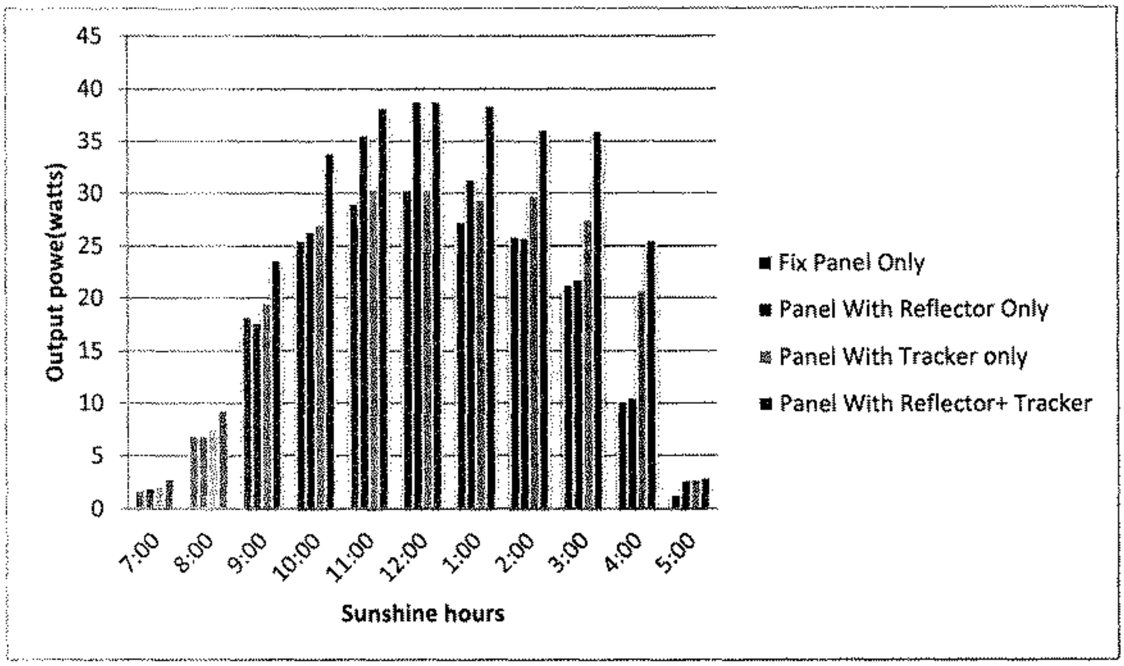


Figure 23 : Power generation at four stages

4.7 Conclusion

The research work conducted regarding optimizing power of the solar panel by increasing irradiance level onto the solar panel surface showed significant result. Although voltage measured from solar panel output did not bring any significant changes with all these modifications but the photo electric current does. The modification of reflectors and solar tracker along with solar PV panel proved helpful in the enhancement of output power by Increasing current.

Table 7: Net result of Average current, voltage, power and fill factor

	Fix panel without reflectors & tracker	Fix panel with reflectors	Moveable panel with tracker	Moveable panel with tracker + reflectors
Average current (A)	0.93	1.00	0.92	1.30
Average voltage (V)	19.21	19.52	19.34	19.78
Average power (W)	17.94	19.91	20.61	22.47
Peak power (W)	30.30	38.78	30.38	38.78
Fill factor	0.56	0.62	0.64	0.70

- Reflectors proved helpful in optimizing power especially at noon when the sun got higher over the sky due to better projection of sunlight over the panel's surface. The peak power for the combination of fix panel+ reflectors took place at 12:00 PM and retained the highest peak power. 10% efficiency increased over this stage compare to fix panel.
- Peak power of the solar panel remained same as the peak power of the panel without tracker but the average power with the solar tracker higher to the average power of the panel without tracker. 15% power optimization took place with solar tracker compare to fix panel.
- Significant optimization in output happened at the last stage of modification that is modification of reflectors plus solar tracker. The above four stages comparison of power curve has highest power throughout the day with solar tracker + reflectors. Peak power at each hour compared to the others persisted higher. 25% power increase at this stage.

- It has been observed from above conducted research work, optimization in power occurred due to increase in photo electric current not voltage. The average voltage level at all four stages remained almost 19 volts. It means that photovoltaic current is responsible for increase in output power of solar panel.
- Fill factor improved by these modification. It reached at value 7 at with solar tracker and reflectors along solar panel.

CHAPTER 5

CONCLUDING DISCUSSION

5.1 Scope of project in future

Contribution of solar power generation to country's generation capacity almost nil and those individually bases photovoltaic power generation systems are working without any efficient ways as in western countries. The above mentioned conducted research work provided a model of solar photovoltaic power generation system with optimizing power techniques by the use of solar tracker and reflectors around solar panel. As we have observed the power of modified solar system with solar tracker and reflectors exhibited significant changes in output such techniques can also be implemented over the recently and forthcoming solar photovoltaic power generation system in order to make system efficient. Here experiment performed over 20 wattage solar panel and yielded significant enhancement of power similar method can result gigantic enhancement from bigger solar photovoltaic panels. Above performed all tests and modifications displays that the work is feasible for the climate conditions of Pakistan yet advancement in solar power generation research work is still required in this area. Generation of extra watts or units defiantly reduce electricity prices and bring in affordable range for middle society.

5.2 Feasibility study

Feasibility of the project made on the basis of power produced at each stage over the cost spent on component used at that stage. Estimate of power production has been made for twenty years of period by considering 0.5% degradation rate of solar cell efficiency. As wattage of the solar panel is low that is 20watts so cost per watt has considered here regardless of cost per unit as the panel incapable for generating 1000 watts in one hour.

Table 8 : Power generation estimate of 20W solar panel over 20 years

Years of production	Degradation of solar cell efficiency	Watts produced by fix panel only	Watts produced by fix panel + reflectors	Watts produced by addition of tracker	Watts produced by tracker + reflectors
After 5 years	2.5%	29626	32879	34035	37106
After 10 years	5%	48639	58320	26013	28712
After 15 years	7.5%	63377	74654	60048	65818
After 20 years	10%	77102	89898	92205	101226

Table given above shows the number of watts generated at four different stages by making modifications of tracker and reflectors around solar panel. Moreover total number of watts estimated mathematically over twenty years of period, each year decrease in efficiency 0.5%.

5.2.1 Manufacturing Cost

Manufacturing cost of hardware include cost of solar panel, solar tracker, mirrors & their frames and supporting stand. The graph below shows the cost spent over each part.

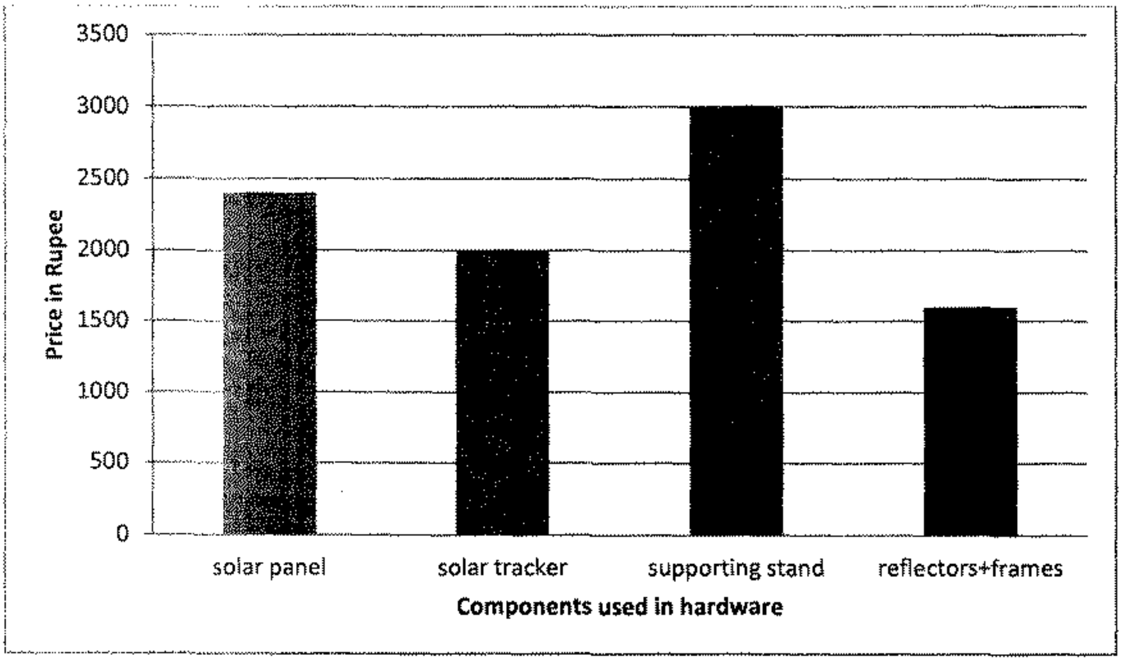


Figure 24 : Cost analysis of project

5.2.2 Maintenance cost

Maintenance cost of the hard ware is zero as solar panel once used is then irreparable. Manufacturing companies claim twenty five years for the average life of the solar panel. Frames of reflectors made of aluminum to withstand in open atmosphere for long period. Supporting stand for panel and tracker made of steel circular pipes to provide durability and painted to avoid corrosions.

5.2.3 Energy Consumption Cost

No energy consumption in this project except solar tracker which has been run in this project with 9 volt dry cell battery owing to low watts small solar panel and exact calculation of improved power by the solar tracker. Such a tracker would prove helpful with big wattages solar panel by providing extra amount of power at output with the consumption of few amperes in solar trackers. So there is no energy consumption cost considered.

Feasibility study of the project made over by comparing money spent over the solar tracker and reflectors with their effects on wattages produce. Power produced with reflector and tracker compared with standalone solar panel.

Table 9 : Feasibility analysis

	Fix panel only	**Panel with reflectors**	**Panel with tracker**	**Panel with tracker and reflectors**
expected watts generated 0ver 20 years	77102	89898	92205	101226
Cost of component	3000+2400 =5400	3000+2400+1600 =7000	3000+2400+2000= 7400	3000+2400+20 00+1600=9000
Watts per rupee	14.2	12.84	12.4	11.24

5.3 Recommendations

The above research conducted regarding optimization in output power of solar panel showed that significance power optimization achieved by the reflectors modified around solar panel but that enhance in output power occur maximum during the noon while during sun rises and sun set, reflected light from mirrors could not reach over the panel surface. Here two reflectors modified on top and bottom of the solar panel due to increasing strength of torque produced by tracker with increasing load. One may use single mirror for each side for better performance.

Use of solar tracker resulted in overall increase in the power of solar panel over a day compare to fixed solar panel yet energy consumption by the solar tracker not considered despite of it operated with dry cell battery. It is certainly suggested to use solar tracker with bulky solar panel over a large scale power production as the power consumption for solar tracker result in very large impact over output power optimization.

Solar tracker designed here was microcontroller base and delay generated inside it for one particular day. it can be made as more advance and implemented for whole year by making it intelligent, programed for whole year on sunset and sunrise timings.

Feasibility of the project made on per watt power generation at four different stages due to low wattage of solar panel. It may be calculated for per unit power optimization with same concept for higher wattage, 1KW or higher wattages solar panel or higher also feasibility can be discussed by comparing with unit cost production.

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