DESIGN AND PERFORMANCE ANALYSIS OF DUAL AXIS ROBOTIC SOLAR PANEL TRACKER

A Project

by

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DECLARATION

We thus certify that the undergraduate thesis work described in this thesis was completed by us under the guidance of Md. Faruque Hossain, Lecturer, Sonargaon University (SU) Department of Mechanical Engineering, and that this report has not been submitted in whole or in part to any other university for another degree, award, or other reason. We hereby certify that Sonargaon University's (SU) Department of Mechanical Engineering is the sole owner of all copyrights to this practicum report. It is strictly forbidden to reproduce or use in any way without Sonargaon University's (SU) explicit approval.

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ABSTRACT

This project presents the design, construction, and performance analysis of a **Dual- Axis Robotic Solar Panel Tracker** aimed at maximizing the efficiency of solar energy harvesting. Conventional fixed solar panels suffer from energy loss due to the changing position of the sun throughout the day and across seasons. To overcome this limitation, this system utilizes a dual-axis tracking mechanism that enables the solar panel to follow the sun's trajectory both horizontally (azimuth) and vertically (elevation).

The system is developed using an **Arduino/PIC microcontroller** integrated with four **Light Dependent Resistors (LDRs)** placed at the corners of the panel to detect the intensity of sunlight. Based on the sensor feedback, two **Servo Motors** are controlled to orient the panel at an optimal 90-degree angle to the sun's rays. Additionally, the project incorporates a **Maximum Power Point Tracking (MPPT)** algorithm or charge controller to optimize the power output and battery charging efficiency.

Experimental results indicate that the dual-axis tracker significantly enhances the energy output compared to static solar systems. Performance analysis shows an efficiency improvement of approximately **25% to 40%**, depending on weather conditions. This project demonstrates a cost-effective and sustainable solution for improving solar power generation in residential and industrial applications.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Though in this era electricity is one of the most important part of our life, approximately 1.6 billion people still living without electricity. It's only for the high cost of power grid building and maintains. This vast quantity of energy crisis can be meeting up by renewable energy across the developing world. As people are much concerned with the fossil fuel exhaustion and the environmental problems caused by the conventional power generation, renewable energy sources and among them photovoltaic panels and wind-generators are now widely used. So Solar Energy is a good choice for electric power generation. The solar energy is directly converted into electrical energy by solar photovoltaic module. Photovoltaic sources are used today in many applications such as battery charging, water pumping, home power supply, satellite power systems etc. They have the advantage of being maintenance and pollution-free but their installation cost is high and in most applications; they require a power conditioner (dc/dc or dc/ac converter) for load interface. Since PV modules still have relatively low conversion efficiency, the overall system cost can be reduced using high efficiency power conditioners which, in addition, are designed to extract the maximum possible power from the PV module. In PV power systems maximum power point trackers (MPPTs) has an important role. It's minimizing the output power of a PV system and also the arrow efficiency as well as its cost is lower than the other power system. An important characteristic of solar panels is that the available maximum power is provided only in a single operating point given by a localized voltage and current known, called Maximum Power Point (MPP). Another problem is that the position of this point is not fixed but it moves according to the irradiance, the temperature and load. Because of the relatively expensive cost of this kind of energy we must extract the maximum of watts of solar panels. In this project we develop a Microcontroller based dedicated MPPT controller for solar PV module based on the incremental conductance method [1-3].

1.2 Historical Background

The history of solar energy utilization dates back to ancient times, but the concept of solar tracking is a relatively modern development in the field of renewable energy. The first significant breakthrough in solar cell technology occurred in 1954 when Bell Labs developed the first silicon photovoltaic (PV) cell. Initially, these cells were fixed in a single position, which limited their energy absorption to only a few hours of peak sunlight.

As the demand for more efficient energy systems grew in the 1970s and 1980s during the global energy crisis, researchers began looking for ways to maximize the power output of expensive solar panels. This led to the invention of "Passive Trackers," which used thermal expansion of gases to move the panels. While innovative, these systems were slow and often inaccurate due to environmental temperature changes.

The real revolution in solar tracking began with the advancement of microelectronics in the 1990s and early 2000s. The introduction of affordable microcontrollers (like PIC and Arduino) and light-sensitive sensors (LDRs) made it possible to design "Active Tracking Systems." Initially, "Single-Axis Trackers" were developed to follow the sun from East to West. However, it was soon discovered that because of the Earth's tilt and seasonal changes, the sun's elevation also varies. This realization birthed the **Dual-Axis Robotic Solar Tracker**

1.3 Earlier Research

Early charge controllers were only able to reduce the amount of voltage from the PV panels if too high for the batteries. Since the voltage from the PV panels would be lower at high temperatures, the PV panels had to be over sized to ensure that the minimum voltage at high temperatures would be at least as high as the battery to be charged plus voltage headroom enough to force current into the battery. At any temperature lower than the maximum, the excess voltage from the PV panels would have to be discarded by the charge controllers. Because PV panels are the most expensive component of the system, the need for extra (or larger) PV panels negatively impacted the cost-effectiveness of such PV power systems. People those days could not use microcontroller for the management of the total system.

This system was first commercially introduced in Australia. Stuart Watkinson and his friend Barry James Aston was first founded "Australian Energy research Laboratories (AERL)," in September 1985.

The US department of Energy's solar Energy research center in Colorado along with Florida State University's solar research center at Cape Canaveral was also involved in early trials of the product. [4-5]

1.4 **Recent research**

Newer and more efficient charger controllers have emerged that provide a better match between the PV panels and their load. Their goal is to use all the power from the PV panel(s) regardless of the voltage and current at any amount of insolation or at any temperature. The newer charge controllers employ a DC to DC converter section that is adapted to dynamically charge the battery (or to directly power a load) at the exact voltage and current that is most appropriate for that battery (or load). Although the newer charge controllers provide improved system efficiencies relative to the older models, they too often suffer from several shortcomings. More particularly, the charge controllers are slow to adapt to changing conditions of the PV panel(s) over the course of any given day, including low light conditions in the morning, evening and during cloud cover and also temperature changes sometimes associated with the changes in insolation.

MPPT charge controllers are now commercially manufactured by several companies, such as outback power, Xantres XW-SCC, Blue Sky Energy, Apollo solar, Midnight solar, Morning star and a few others. [5]

1.5 **State of art technology**

PV technology, PV panels produce current using solar energy. It depends on the amount of solar radiation hitting the cells of the panel.

Theoretically, the maximum amount of power from sun the earth surface is about 1KW per square meter at equator on a clear day. The batteries store the power and supply the power at night time for producing current. Depending on the nature of PV panel, it has a basic current vs voltage curve which changes with the change of temperature and the amount of sunlight on the angle which the sun of sunlight on the sun strikes the panel, higher temperature, lower voltage and increase amount of sunlight, increase the output current.

By using MPPT algorithm, it increases the efficiency of the PV panel and insures the maximum use of the power of sunlight. Sometimes there may be difference voltage and current between PV panel and the batteries, to maintain this mismatch, there use a microcontroller. A charge controller works as DC-DC convertor. [5-6]

1.6 Objective of this work

1. To Design of Dual Axis Robotic Solar Panel Tracker,
2. Performance Analysis of Dual Axis Robotic Solar Panel Tracker.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Solar panel is made of tiny combination of solar cell and solar cell is the devices that are designed to convert light to electrical energy. Solar panel is mainly made from semiconductor materials such as silicon (Si), cadmium sulphide (CdS) and gallium arsenide (GaAs) can be used to make solar cells. The main purpose of using solar panel is getting the maximum energy by converting light energy to electric energy. Using solar tracker is the best way for getting the maximum energy because its keeping the panels aligned with the sun's position and it's also an effective solution for get energy with solar panel.

2.2 Block Diagram of This Proposed Project

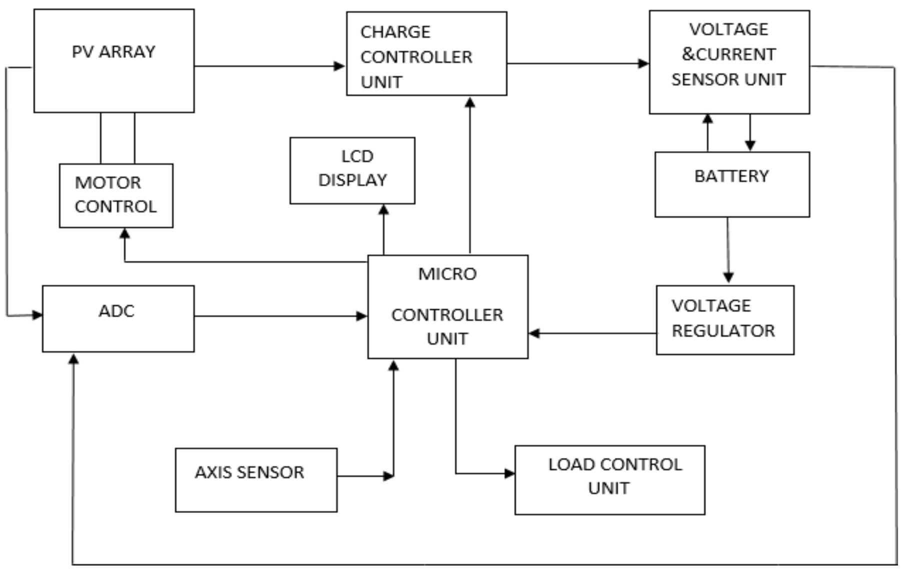

Figure 2.1: Block Diagram of the proposed system

2.3 **The Model of the Project**

Figure 2.2: Dual axis solar tracker Robot

2.4 **Solar panel**

Solar panel is mainly designed as a panel which absorbed the sun's rays and convert light into electricity. Most of the time the most powerful source of light available is the Sun, called Sol by astronomers. It is called photovoltaic which means, basically, "light-electricity."

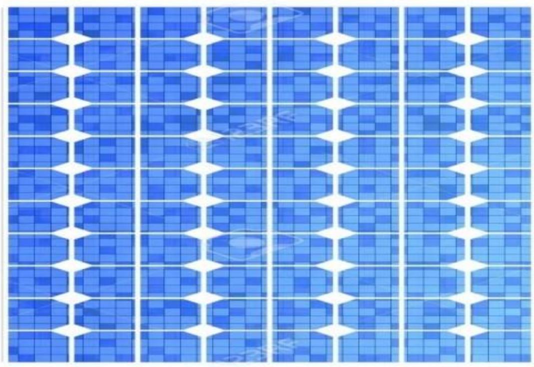

Figure 2.3: Solar panel Module

A solar panel is a collection of solar cells. Lots of small solar cells spread over a large area can work together to provide enough power to be useful. Solar power generating systems take advantage of this property to convert sunlight directly into electrical energy. Solar panels also called "solar modules produce direct current (DC), which goes through a power inverter to become alternating current (AC) — electricity that we can use in the home or office or other sectors.

When sunlight hits the semiconductor, an electron springs up and is attracted to the n-type semiconductor. This causes more negative electrons in the n-type semiconductor and more positive electrons in the p-type, thus generating a flow of electricity in a process known as the photovoltaic effect. The majority of solar modules use wafer-based crystalline silicon cells or thin-film cells based on cadmium telluride or silicon.

2.5 Photovoltaic cell model

A simplest equivalent circuit of a solar cell is a current source in parallel with a diode. The output of the current source is directly proportional to the solar energy (photons) that hits on the solar cell. During darkness, the solar cell is not an active device; it works as a diode, i.e. A p-n junction. It produces neither a current nor a voltage. The diode determines the IV characteristics of the cell.

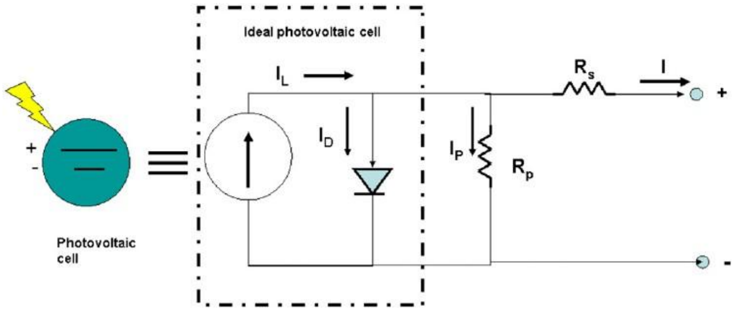

Figure 2.4: Circuit diagram of a PV Cell

2.6 Solar Irradiation: Sunlight

Electromagnetic radiation means which the sun delivers energy to the earth. The radiation flows evenly distributed from a surface which is close to spherical. The sunlight covers a broad range of wavelengths from roughly 250 nm (UV) over the Visible range (400-700 nm) up to several thousands of nm (IR).

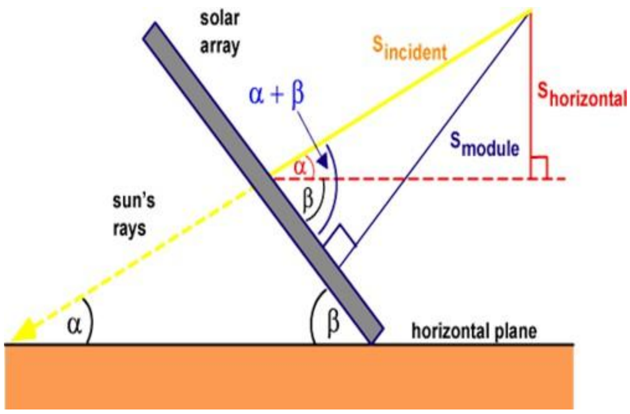

Figure 2.5: Solar Irradiation Sunlight

There is solar fusion that results from the temperature and pressure at the core of the sun. Protons converted into helium atoms at 600 million tons per second. Fusion gives rise to lots of energy in form of gamma rays that are absorbed by particles in the sun and re-emitted. This spectrum contains visible light and near-visible radiation, such as x-rays, ultraviolet radiation, infrared radiation, and radio waves. The visible light and heat of the sun makes life possible, and is called daylight or sunshine. Majority of the sun's harmful radiation deflects by the earth atmosphere.

2.7 **Types of Solar Trackers & System**

Solar Trackers are almost worldly used in case of Solar Thermal Technology because it generates high amounts of energy from sunlight .It's a way to install the pv panel that the sunlight reach them at perpendicularly or reduce the incidence angle as much as possible. Using tracker on solar panel makes this system smart and the tracker track the sun rays and it's rotate the panel according with rays. There are two types of tracker system and they are single axis solar tracker and dual axis solar tracker.

2.8 **Dual axis solar tracker**

Dual axis tracking system uses the solar panel to track the sun from east to west and north to south. Dual axis solar tracker has two axis of freedom that act as axes of rotation. These axis are fixed with respect to the ground axis consider as a primary axis. But this one is also costly and complicated then single axis solar tracker. Dual axis solar tracker will be reliable and accurate and it is maximize the output to static and single axis tracking system. This system uses four LDR's, two motors and a controller. The four LDR placed on at four different directions. The controller detects the signal from the LDR's and commands the motor to rotate the panel in respective

Figure 2.6: Dual axis solar tracking

2.9 Performance and Efficiency Calculation

To analyze the performance of the **Dual-Axis Robotic Solar Tracker**, we compare the power output of a fixed solar panel with the power output of our tracking system.

1. Solar Panel Efficiency Formula: The efficiency η of a solar panel is calculated using the following equation[3]:

$$\eta = \frac{P_{max}}{P_{in}} \times 100\%$$

Where:

- $P_{max} = V_{oc} \times I_{sc} \times FF$.
- V_{oc} is the Open-Circuit Voltage.
- I_{sc} is the Short-Circuit Current.
- FF is the Fill Factor.
- P_{in} is the Solar Input Power (standardized at $1000\ \mathrm{W/m^2}$).

2. Comparative Power Analysis (Example Case): Based on experimental observations, the power output is measured for both systems at a specific time:

- **Fixed System Power (P_{fixed}):** $12.0\ \mathrm{Watts}$
- **Dual-Axis Tracker Power ($P_{tracker}$):** $16.5\ \mathrm{Watts}$

3. Percentage Efficiency Gain: The improvement in efficiency is calculated as follows:

Conclusion: The calculation demonstrates that the dual-axis tracking system provides a significant power increase. This aligns with the project's finding that tracking efficiency improves by approximately **25% to 40%** depending on weather conditions.

2.10 **Efficiency of Solar panel**

The efficiency is the parameter which is most commonly used to compare with one solar panel to anthers panel. Efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun. The efficiency of a solar cell is determined as the fraction of incident power which is converted to electricity and is defined as:

$$P_{max} = V_{OC} I_{SC} FF$$

$$\eta = \frac{V_{OC} I_{SC} FF}{P_{in}}$$

Where V_{oc} is the open-circuit voltage;

where I_{sc} is the short-circuit current; and

where FF is the fill factor

where η is the efficiency.

where η is the efficiency.

The input power for efficiency calculations is 1 kW/m^2 or 100 mW/cm^2. Thus the input power for a 100 × 100 mm^2 cell is 10 W and for a 156 × 156 mm^2 cell is 24.3 W.

There are several benefits that solar energy has and which make it favorable for many uses.

2.11 **Advantages**

- Solar energy is a clean and renewable energy source.
- It is pollution free.

- Solar cells are free of any noise. On the other hand, various machines used for pumping oil or for power generation are noisy.
- Solar energy can be used in very remote areas where extension of the electricity power grid is costly.
- Once a solar panel is installed, the energy is produced at reduced costs.

CHAPTER 3

COMPONENTS, DESIGN & IMPLEMENTATION

3.1 LDR (Light Dependent Resistor)

LDR (Light Dependent Resistor) is called as light detecting sensor to build solar track which has included phototransistors, photodiodes and LDR. It is a made up of semiconductor materials which has high resistance. LDR is the most common in electronics and it is spread used in many types of electronics. LDR can use for street lamp, outside lights, a number of indoor home appliances, and so on. It is utilize the light sensor circuit for automatic switch OFF the loads based on daylight's intensity by helping of a light sensor. In daylight the rays of sun falls on the photovoltaic panel and photo resistor and when the light falls on the resistor, then the resistance changes. This resistor's has different functions and resistance. Using LDR in a circuit or in a electronics project it is make circuit effective and the collection of LDR parts of the circuit are easily available and accuracy of this circuit is more than accuracy of other circuits. It is so much helpful for saving energy. There are two types of photoresist or based on material used and they are Intrinsic Photo Resistors and Extrinsic Photo Resistors. Intrinsic Photo Resistors are made up of pure semiconductor devices like silicon or germanium. When the light falls on the Intrinsic Photo Resistors, the electrons get excited from the valence band to the conduction band and number of charge carriers increases on a resistor. Extrinsic Photo Resistors are doped with impurities and this impurity creates a new energy bands above the valence band.

3.2 Working Principle of LDR

Photo conductivity is an optical method, which the material's conductivity is increased when light is absorbed by the materials. When the light (photon) falls on the materials, the electrons in the valence band of the semiconductor material are excited to the conduction band. These photons in the incident light should have energy greater than the band gap of the semiconductor material to make the electrons jump from the valence band to the conduction band. The result of this process is more and more current starts flowing through the device when the circuit is closed and hence it is said that the resistance of the device has been decreased. This causes the free electrons or holes to conduct electricity and thus dropping the resistance (< 1 Kilo ohm). This is the working principle of light dependent resistor. The equation to show the relation between resistance and illumination can be written as:

$R = A.E^a$

Where E – Illumination (lux)
R – Resistance (Ohms)
A, a – constants

The value of 'a' depends on the CdS used and on the manufacturing process. Values usually range between 0.7 and 0.9.

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3.3 **The Design and implementation of using Four LDRs**

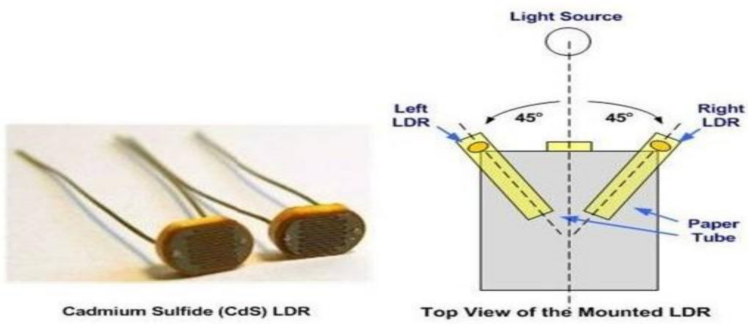

Figure 3.1: quadrant wise LDR positioning

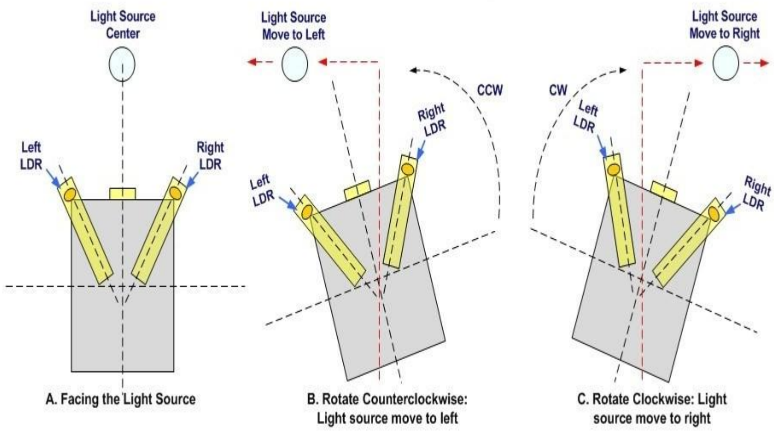

Figure 3.2: Sensing Element and Signal Processing

There are several method was proposed and used to track the position of sun light. We used four LDRs to track our module properly. A Light Dependent Resistor separated by a small plate to act as a shield to sunlight, as shown in the next figures. The two LDRs are connected to a bridge and the output of the bridge is connected to a comparator When LDR1 has higher light intensity than LDR2 then the resistance of LDR1 is smaller than that of LDR2 then voltage at AIN0 is higher than that of AIN1 and the output of comparator is high.

3.4 **LCD (2 Line 16 Carriers)**

LCD (Liquid Crystal Display) screen is an electronic display module. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

Figure 3.3: LCD

A **16x2 LCD** means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. A register which commanded storage the command instructions to the given LCD like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD.

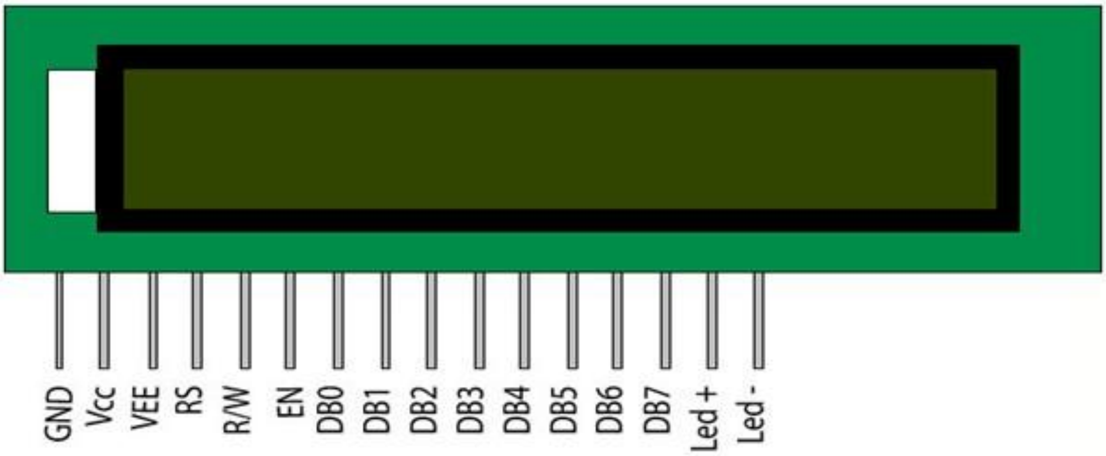

Figure 3.4: LCD (2*16) Pin

3.5 **Pin Features**

- 5*8 Dots with cursor
- 16 Characters *2 line display
- 4-bit or 8-bit MPU interfaces
- Display mode & Backlight Variations
- ROHS Compliant

3.6 **Pin Description**

16 pin LCD description given bellow:

Table 3.1: Pin LCD Description

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast adjustment; through a variable resistor	V_{EE}
4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8-bit data pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight V_{CC} (5V)	Led+
16	Backlight Ground (0V)	Led-

3.7 **Servo Motor**

Servo motor is a self-contained electric devices and simple electrical motor, which is controlled with the help of servomechanism. It is a motor which has a output shaft and can be moved to a specific angular position by sending it a coded signal. The servo motor will maintain the position of the shaft .When we changed the coded signal, the angular position of the shaft will changed. Servo motors are used for various applications. They are normally small in size and have good energy efficiency. The cost of this motor also less than others motors and also simple to used. Servos are found in many places from toys to home electronics to cars and airplanes.

Figure 3.5: Standard Servo Motor SG-90

The motor is controlled with an electric signal that determines the amount of shaft movement. In a market there are found two types of servo motor, one are made up of metal gear and another are made up of plastic gear. The metallic one is much heavier than other gear one. The size of metallic gear servo motor is also bigger than plastic gear servo motor.

3.8 **Components of servo motor SG-90**

Figure 3.6: Physical Construction of Servo SG-90

SERVO MOTOR SG-90:

It is tiny and lightweight with high output power. This servo can rotate approximately 180 degrees and it works just like the standard kinds

Specifications:

- Weight: 9 gm
- Dimension: 22.2 x 11.8 x 31 mm approx.
- Stall torque: 1.8 kgf cm
- Operating speed: 0.1 s/60 degree
- Operating voltage: 4.8 V (~5V)
- Dead band width: 10 µs

3.9 **Working Principle of Servo Motor**

Let us consider an example of servomotor that we have given a signal to rotate by an angle of 45° and then stop and wait for further instruction.The shaft of the DC motor is coupled with another shaft called output shaft, with help of gear assembly. This gear assembly is used to step down the high rpm of the motor's shaft to low rpm at output shaft of the servo system.

The voltage adjusting knob of a potentiometer is so arranged with the output shaft by means of another gear assembly, that during rotation of the shaft, the knob also rotates and creates an varying electrical potential according to the principle of potentiometer . This signal i.e. electrical potential is increased with angular movement of potentiometer knob along with the system shaft from 0° to 45°.

As the angle of rotation of the shaft increases from 0° to 45° the voltage from potentiometer increases. At 45° this voltage reaches to a value which is equal to the given input command voltage to the system. As at this position of the shaft, there is no difference between the signal voltage coming from the potentiometer and reference input voltage (command signal) to the system, the output voltage of the amplifier becomes zero.

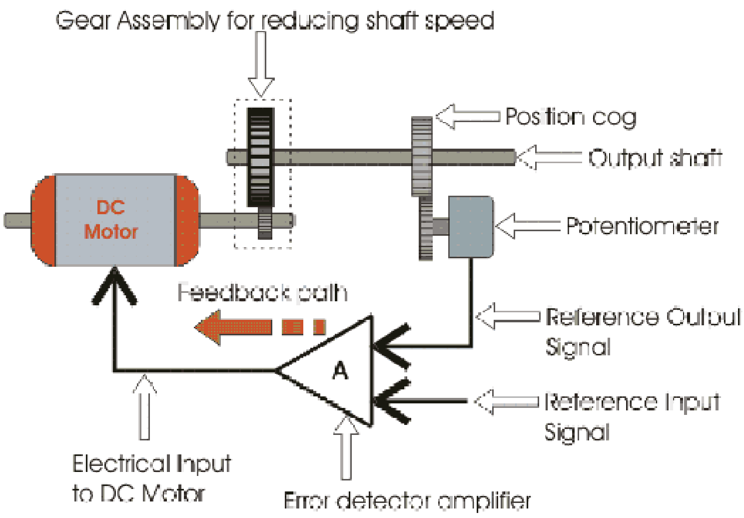

Figure 3.7: Inside look of Servo motor

As per the picture given above the output electrical voltage signal of the amplifier, acts as input voltage of the DC motor. Hence the motor will stop rotating after the shaft rotates by 45°. The motor will be at this rest position until another command is given to the system for further movement of the shaft in desired direction. From this example we can understand the most basic **servo motor theory** and how **servo motor control** is achieved.

3.10 **Advantages & Disadvantages of using Servo motor**

There are some advantages and disadvantages of using servo motor. In below we discussed about advantages and disadvantages of servo motor.

Advantages:

- Servo motors are the better option for high speed and high torque.
- Servo motors are available at much faster speed.
- Servo motors are accurate positioning.
- Servo motors also maintain torque at high speed, up to 90%.
- Servo has efficiency of about 80-90%.
- Servo motors are small is size.
- Servo motor has a resonance and vibration free operation.

Disadvantages:

- Servo motors are expensive to buy.

- Servo motors have requires setup to stabilize feedback loop. Servo motor can be damaged for overloading.
- Servo motor has poor motor cooling. Servo motor design more mechanically complex.

Servo motor maintenance requirements will also increase

3.11 **Microcontroller**

A microcontroller is a single chip micro-computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Basically microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems.

3.12 **Block Diagram of PIC16F877A**

Device	Program FLASH	Data Memory	Data EEPROM
PIC16F874	4K	192 Bytes	128 Bytes
PIC16F877	8K	368 Bytes	256 Bytes

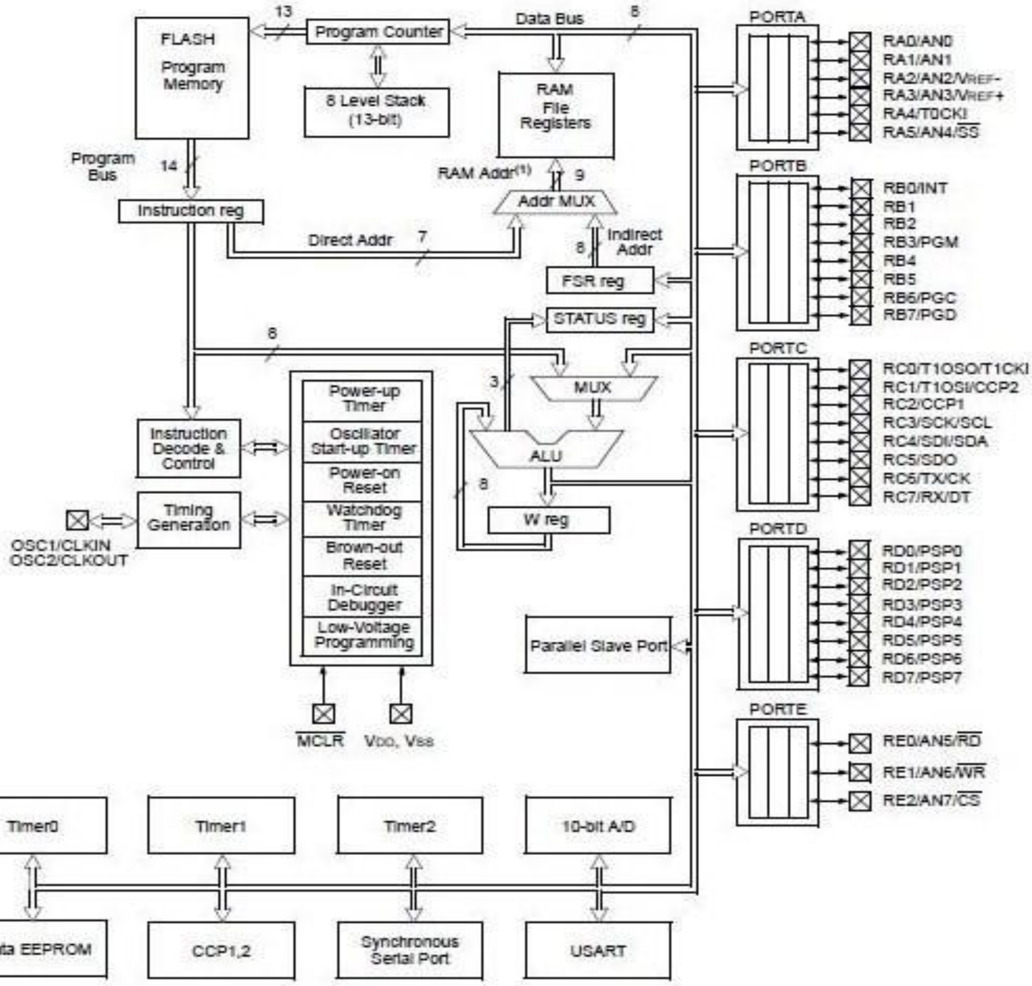

Figure 3.8: Block Diagram of PIC16F877A

3.13 **PIC16F877 Development Board**

The immensely popular PIC16F877 development board for the PIC16F877 enables easy development and testing of various solutions. PIC16F877 is already included together with power supply components and crystals.

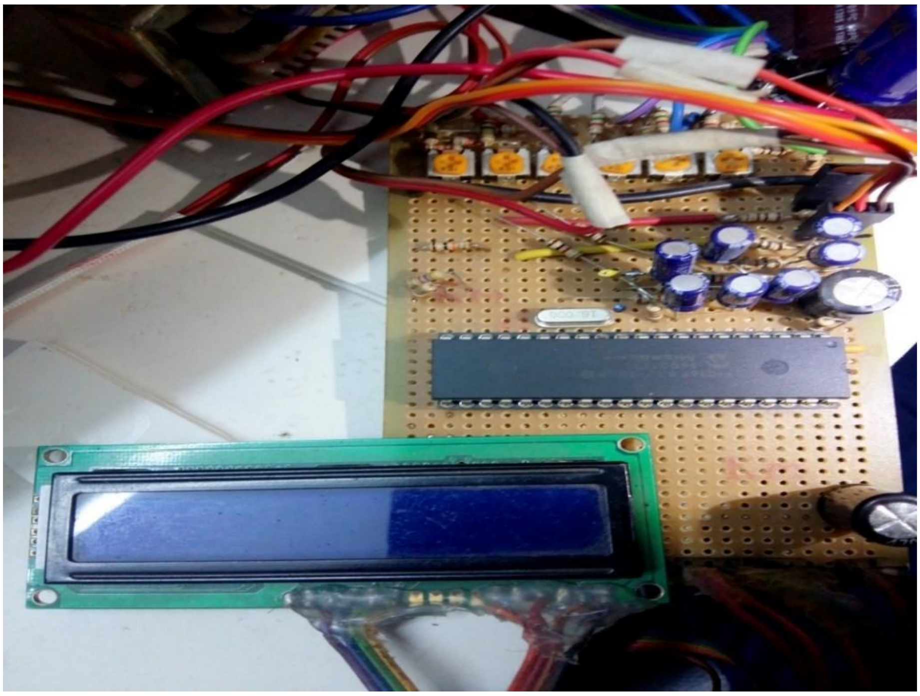

Figure 3.9: Pic16F877 development board

CHAPTER 4

DISCUSSIONS AND CONCLUSIONS

4.1 Discussion

In this work, a MPPT charge controller is presented. A microcontroller is used to control the maximum power point tracking algorithm, which is used in PV systems to maximize the photovoltaic array o/p power.

An optimized and effective technique has been proposed considering the discussed drawbacks. The proposed system was simulated and constructed, and the functionality of the suggested control concept was proven. The proposed system was simulated and constructed, and the functionality of the suggested control concept was proven. From the results acquired during the simulations and hardware experiments, it was confirmed that, with a well-designed system including a proper converter and selecting an efficient and proven algorithm, the implementation of MPPT is simple and can be easily constructed to achieve an acceptable efficiency level of the PV modules. The results also indicate that the proposed control system is capable of tracking the PV array maximum power and thus improves the efficiency of the PV system and reduces low power loss and system cost. This method protects the MPPT effects from environmental variations and leads us to proper direction to the tracker which makes it independent of environmental changes (particularly irradiation and temperature). The method has been modified based on the incremental conductance and the simulated result offers high efficiency during stable conditions as well as fast changing conditions and hence it maintains the advantage of the existing methods. The work executed in this project deals with analyzing and modeling of transformer less PV systems related to the leakage current phenomenon that can degrade solar panel performance and pose human. Additionally leakage current is an unwanted loss especially when it comes to distributed generation system. One of the major tasks of this research was to investigate and verify the transformer less topologies and control strategies that would minimize the leakage current of PV inverter topologies so that it can comply with the standard requirements, safety of human interaction and mitigation of unwanted losses. [7-8]

4.2 **Suggestion for Future work**

The main objective of this project is to achieve the highest performance a solar charge controller using MPPT system. This system successfully uses MPPT algorithm to reach our goal. Reaching a stable, true MPP at steady state instead of oscillating around this point would improve the system's efficiency and improve reliability.

4.3 **Development of microcontroller**

Development of different Microcontroller based dedicated MPPT controller for solar PV module based on the different algorithm such as observe & perturbation, computational method etc. This can be a low cost embedded controller. Or to incorporate the power supply into the system that draws energy from the solar panel or an energy storage element that is in turn charged by the solar panel. This extension would allow the system to be deployed to remote locations. Converting the whole system into a single Integrated Circuit

4.4 **Development of MPPT system & PV panels**

The PV panels that are being used for tests of the diagnostic methods in this thesis can be considered as a small-scale representation of a photovoltaic array. A full-scale residential PV system should be also considered for field testing. New kind of topologies or control strategies can be introduced which can handle the elimination or minimization of the DC part in the injected AC current. Besides this only real power output for AC is analyzed here. Development of a high Power Output MPPT system. [9]

4.5 **Conclusion**

The rapid increase in energy demand cannot be resolved easily until there is an alternative way to meet the demand. The micro grid can undertake to solve this sort of situation in future. Solar, wind and biomass energy is the main source of energy used for optimizing the overall system and hence to make it efficient. So the user will become less compulsive on the convenient fossil fuel energy. The stored energy also plays a significant role to avoid the imbalance of the power system. To ensure the photovoltaic generator operating its maximum power point, MPPT controllers are often used. These controllers are intended for MPP tracking and to thus minimize the error between the operating power and the reference maximum power which is variable according to the load and of the weather conditions. The MPPT based charge controllers are best suitable for wind and solar systems as they track the maximum power in case of power fluctuations at the input side due to environmental condition variation. Hence it is recommended to use the MPPT based charge controllers. Use of microcontroller based systems provides huge computational capability and reduction in the hardware. The MPPT charge controller operates with high efficiency (90% or even higher) as compared to existing charge controllers. [10]

4.6 Future Scope

In future, solar energy will be very important source. So, using MPPT solar charge controller can generate a huge amount of current successfully. In this way, the cost of the production can also be reduced. In a word, it can develop a high power output MPPT system with a low cost .This complete system schematic includes the feature of maintenance free use, no requirement of fuel or lubricant, stainless steel hardware, built-in over-load, over-charge, low voltage protection, temperature compensated charging and low battery disconnect facility. Moreover, it ensures maximum continuous power at full load and simultaneously pollution free and noiseless maintenance. Furthermore it has the ability to charge the battery in low voltage so it will get sufficient backup in case of power failure.

4.7 Recommendation

Future studies into maximum power point tracking could include the use of a different DC/DC converter and also some different MPPT algorithm such as Current MPPT (CMPPT) for example, could be implemented. Another extension of this project could be to design the DC/DC converter in full. The converter design could be done to optimize the components and in turn increasing the power efficiency. By optimizing the DC/DC converter the MPPT algorithms would achieve improved efficiencies and power tracking capabilities. Finally a future work can also improve the developed software in order to efficiently use the capabilities of the microcontroller. A final prototype could then be design and implemented in order to have a final portable prototype for the solar charger. The whole system into a single integrated.

REFERENCES

[1] Mihnea Rosu, Hamzescu, Sergiu Oprea, 2013 Microchip Technology Inc., U.S.A., ISBN: 9781620772164.

[2] Trishan Esram, IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 22, NO. 2, JUNE 2007.

[3] Mr. S. K. Patil, Mr.D.K.Mahadik, IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), ISSN: 2278-2834-, ISBN: 2278-8735, PP: 27-33.

[4] Australian Energy Research Laboratories (AERL), website. [Online]. Available: http://www.aerl.com.au/hydro-wind-solar-mppt/aerl-mppt-range-history.html

[5] John E. Pfeifer, Fabio A.M. Pereira, Herbert E. Flynn, " DEVELOPMENT OF A MICROCONTROLLER BASED SOLAR PHOTOVOLTAIC MPPT CHARGE CONTROL SYSTEM Using INCREMENTAL CONDUCTANCE METHOD",academia.edu(May 15, 2008), Publication number:US20080111517 A1.

[6] Chekireda, C. Larbesa, D. Rekiouab, F. Haddadc, Energy Procedia, Volume 6, 2011, Pages 541–549

[7] C. Liu, B. Wu, and R. Cheung, "Advanced algorithm for MPPT control of photovoltaic systems," in Canadian Solar Buildings Conference Montreal, Solar Buildings Research Network, 2004.

[8] J.-M. Kwon, K.-H. Nam, and B.-H. Kwon, "Photovoltaic power conditioning system with line connection," Industrial Electronics, IEEE Transactions on, vol. 53, no. 4, pp. 1048– 1054, 2006.

[9] T. Kerekes, R. Teodorescu, P. Rodriguez, G. Vazquez, and E. Aldabas, "A New High-Efficiency Single-Phase Transformer less PV Inverter Topology," IEEE Transactions on Industrial Electronics, vol. 58,pp. 184-191, 2011