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MICROCONTROLLER BASED SOLAR TRACKING SYSTEM DESIGN AND GRID CONNECTED PHOTOVOLTAIC SYSTEMS

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ABSTRACT

In the era of ever-rising demands of electrical energy, the concerns related to scarcity and environmental damages associated with the application of fossil fuels have increased. Renewable energy resources have proved to be a blessing. With their world-class ability to produce zero greenhouse emissions and diversifying the energy supply in turn reducing the dependency on fossil fuels, renewable energy resources have been gaining quite a lot of popularity in the electricity generation sector. Aiming to create a more well developed, efficient, and reliable system, this paper focuses on the concept of employing the best possible application of the most abundant source of energy - Solar Energy. The system is based on mechanically tracking the position of the Sun and orienting the Solar Panel with respect to the Sun's radiation for achieving the maximum output by incorporating the application of Microcontroller. The proposed system focuses on the design and simulation of a Microcontroller-based solar tracking system on Proteus 8 professional software. The paper also incorporates the concept of 'Grid-connected Photovoltaic systems' as a dominant phenomenon and advancement for increasing the efficiency of the solar tracking system.

Contribution/Originality: This study is one of very few studies which have investigated solar tracking system using PIC microcontroller as an effective tracking mechanism for increasing the efficiency of the solar energy system. Further, grid-connected photovoltaic systems are found to be effective in utilizing the output produced from the solar energy system.

1. INTRODUCTION

Energy is one of the most vital elements for the survival of mankind. As the demand for energy continues to escalate, the department of energy, majorly consisting of numerous processes of extraction, conversion, distribution, and consumption of this requisite element has been evolving persistently. Simultaneously, various supplementary techniques and raw materials for the generation of energy have been taken into consideration in order to achieve efficiency with the required output (Ghosh & Roy, 2016).

The paucity of the fossil fuels such as coal, oil, and natural gas has posed to be an intimidating challenge for the country as this source of energy is meagre and has led to some serious issues of emission of greenhouse gases leading to global warming (Desai & Devnani, 2016).

With the ever-rising demands, Energy crises have been a concern for the production plants across the country and hence the concept of renewable energy has been coherent for sustainable power generation contributing

towards achieving the required demands at its best (Mustafa, Al-Ammri, & Ahmad, 2017).

Sun being the most abundant source of energy is being utilized in the best possible way. Made possible by the introduction of photoelectric implementation and invention of solar cells a semi-conductive material deployed for the conversion of light to direct current, are efficient and popular in rural areas where the settlement of transmission lines is not economical (Gaafar & Zobaa, 2016).

2. BASIC METHODOLOGY

The basic mechanism of generation process of electricity revolves around the conversion of light energy received by the silicon solar cells of the photoelectric panels, keeping the Photoelectric panels in a direction perpendicular to the sun's radiated energy (Abo-Al-Ez, Hatata, & Kandil, 2015). Keeping the panels perpendicular maximizes the output. The titled position of the panels results in reduced collection of solar energy by the module (Nanda, Dasgupta, & Rout, 2017). In order to orient the payload towards the sun and minimize the angle of incidence between the approaching sunlight and the photoelectric module thereby maximizing the output, a device called 'Solar Tracker' is employed (Kassem & Hamad, 2011).

3. NOMENCLATURE

1. **Declination Angle** (δ_0) It is defined as the angular distance of position of sun with respect to north or south of the earth's equator (Elsherbiny, Anis, Hafez, & Mikhail, 2017).

2. **Elevation Angle/ Altitude Angle**(h_s) - It is defined as the angle measured between the observer's Imaginary line and the sun with the horizontal plane of position of the observer (Stjepanović, Stjepanović, Softić, & Bundalo, 2009).

3. **Latitude** (w) – It is defined as the point indicating the location of the angle made by the radial line Connecting the line of projection on equatorial plane with the earth's center (Elsherbiny et al., 2017).

4. **Solar Azimuth Angle** (Y_s) – It is defined as the angular distance between the lines of projection of center of the sun onto the horizontal plane due to S-direction (Sumathi, Jayapragash, Bakshi, & Akella, 2017).

4. DESIGN OF SOLAR TRACKING SYSTEM

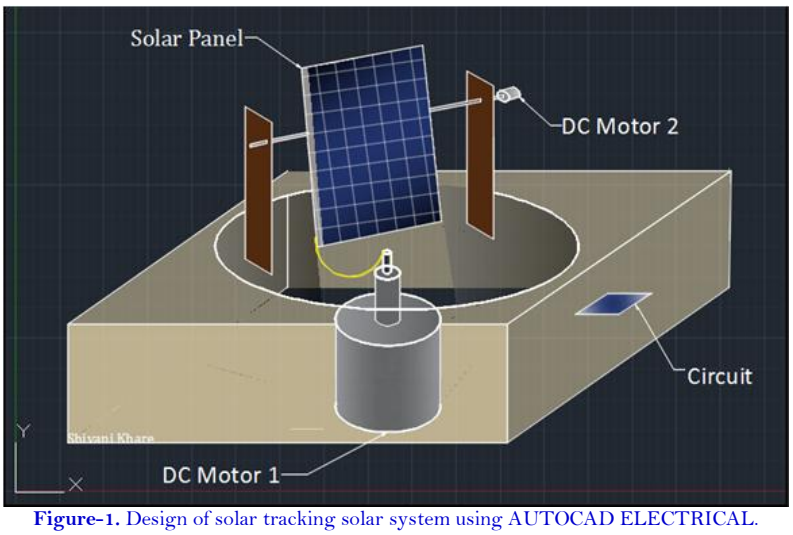

Figure-1. Design of solar tracking solar system using AUTOCAD ELECTRICAL.

5. SOLAR TRACKING METHODS

Solar Tracker is based on the mechanism dealing with detection of higher light intensity which results in actuation of motor in the equivalent direction to follow the sun's rays effectively (Phyu & Wai, 2014). Figure 1 above shows the design of Solar Tracking System using AUTOCAD ELECTRICAL. This mechanism is popularly known as real – time tracking or servo mechanism. Real time mechanism of tracking was proved to be more efficient than open loop type tracking since open loop type mechanism involved external disturbances in the system resulting in decreased efficiency (Khanna, 2016). Based on the various domains, solar trackers are divided into -

5.1. Based on Axis

(i) Single Axis Solar Trackers – The motion of this category of trackers is restricted to one degree and are available in types including horizontal, vertical, tilted and polar aligned (Sumathi et al., 2017).

(ii) Dual Axis Solar Trackers – The motion of dual axis tracker occurs in two different directions. The axis which is fixed with respect to ground is primary and the one referenced to the primary axis is the secondary axis of the tracker.

(a) Tip-Tilt Dual Axis Tracker – The panel array of this type of tracker is mounted on the pole tip wherein the east west movement occurs by rotating the array about the top of the pole. These trackers are known to reduce the up-sun shading thereby maximizing the total collected power.

(b) Azimuth – Altitude Dual Axis Tracker – The construction of this type of tracker is such that the primary (azimuth) axis is held vertical to the ground keeping the secondary (elevation) axis perpendicular to the azimuth axis (Parameswari, Kavithamani, & Vedha, 2016). The tracker is driven by application of a large ring mounted on the ground and an array placed on rollers (Mustafa., Shakir, Mustafa, & Naiyf, 2018).

5.2. Based on Active Materials

Figure 2 below shows Classification of Solar Tracking systems based on Active Materials.

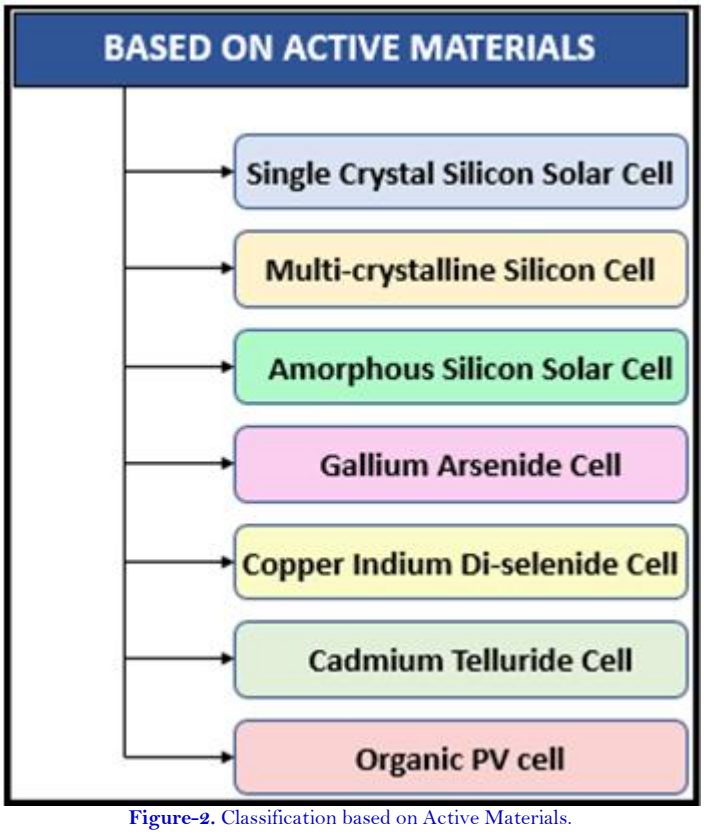

Figure-2. Classification based on Active Materials.

5.3. Maximum Power Point Tracker

An adaptation of dc-dc switching voltage regulator, Maximum Power Point Trackers (MPPT) are desired to interpose when the operating point is different from the maximum power point. Buck Boost connection scheme is employed wherein the voltage and current sensors are attached to the feedback loop in order to vary the witching times (Abo-Al-Ez et al., 2015). Operation of MPPT involves 3 strategies –

(i) By monitoring the Output Power.

(ii) By Fixing the voltage at the output as a fraction of Voc.

(iii) By keeping a check on Static and Dynamic Impedances.

Main features of MPPT include reduction in complexity of system with efficiency being high (Kassem & Hamad, 2011). MPPT can be applied to other renewable energy sources such as wind turbines as it enables extraction of maximum power from the photovoltaic panel forcing the module to function at voltage near to maximum power point (Armstrong & Hurley, 2005).

5.4. Based on Driver mechanism

i) Passive Tackers – Operation of this kind of trackers is based on the mechanism of imbalance caused due to collision of solar heat particles (Mpodi, Tjiparuro, & Matsebe, 2019). The major phenomenon of these trackers is Thermal Expansion. The major advantage of these are trackers are they are less complex.

ii) Active Trackers – This type of trackers deploy the application of gears and motors to maintain the motion of the tracker. These trackers are classified as single and dual axis (Mpodi et al., 2019). The advantage of these trackers are they are more accurate and efficient as compared to passive.

a. Auxiliary bifacial solar cell trackers – This type of trackers consist of PV cell which senses the location of sun, thereby providing the required tracking energy when associated with a permanent magnet DC motor.

b. Chronological Trackers – This type of tracker makes use of geographical data for calculations of relative path of sun for a period of time (Mpodi et al., 2019).

6. PROBLEM STATEMENT

The major issue of untracked solar panels is that it involves various drawback. Solar panel systems without a tracker affect the efficiency of the whole system. These systems are not capable of orienting themselves in accordance to the maximum light intensity. Due to this restricted movement, the light intensity is not effectively utilized and hence the output obtained is much less leading to decreased efficiency.

7. PROPOSED DESIGN SYSTEM - MICROCONTROLLER BASED SOLAR TRACKING SYSTEM

The controlling of the proposed Microcontroller based solar tracking system depends on tracking the direction of sunlight during the day for the predominant purpose of maximizing the efficiency of the solar photovoltaic module. The amount of light congregated, superiorly depends on the angle of incidence of light source to the surface of the cell. When the light incident on the PV module is perpendicular, maximum power output is accomplished.

8. COMPONENTS

8.1. Microcontroller

Also called as 'Embedded Controller', Microcontroller is defined as a single chip integrating the major components of a microcomputer. Owing to a strong control mechanism, the applications of the device extend to the fast-growing sector of robotics, data acquisition systems and adaptive control systems. The microcontroller used in the proposed mechanism is PIC16F876. Figure 3 below shows the Block Diagram of Microcontroller.

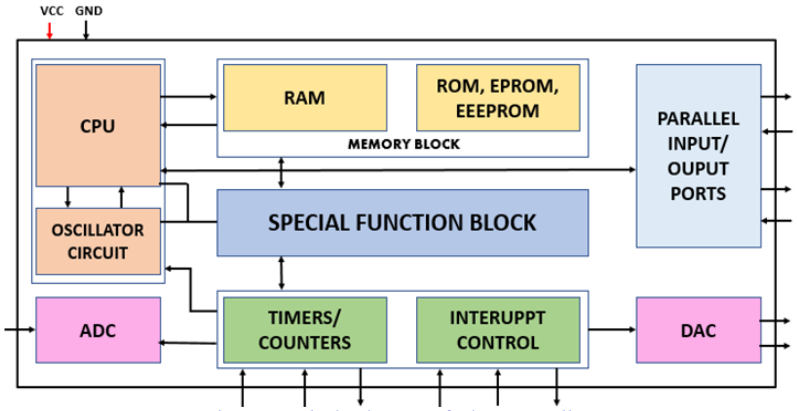

Figure-3. Block Diagram of Microcontroller.

8.2. Light Dependent Resistor (LDR)

Exhibiting the ability of light detection, LDR's are light controlled variable resistor whose resistance value decreases as the light intensity increases. Figure 4 below shows the Circuit Diagram of LDR.

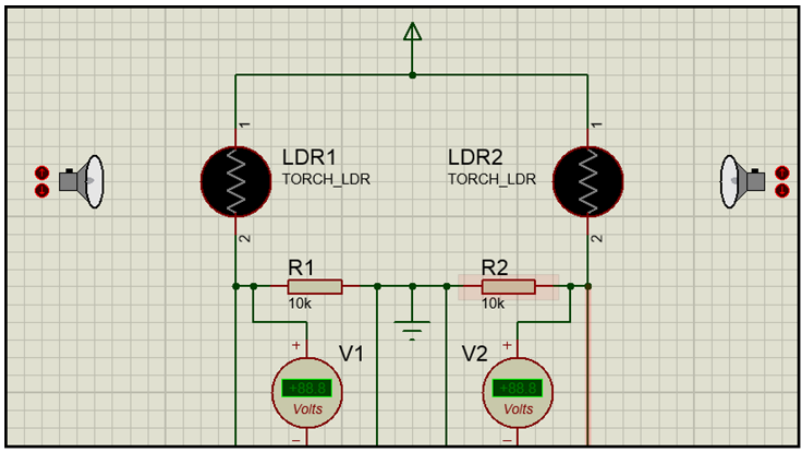

Figure-4. Circuit Diagram of LDR.

8.3. Driver circuit (ULN2003A)

An array consisting of NPN Darlington transistors, used for interfacing with a stepper motor, ULN2003 is capable of 500mA, 50V output in which the drivers can be placed parallel for large output current. Figure 5 below shows the Circuit Diagram of Driver Circuit.

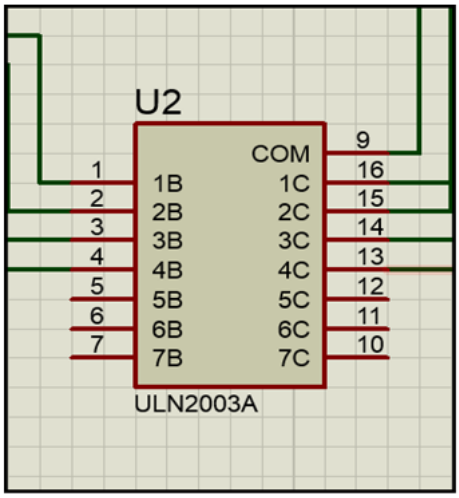

Figure-5. Circuit diagram of driver circuit.

8.4. Stepper Motor

Brushless Dc electric motor, capable of dividing one full rotation into steps, consists of multiple tooth electromagnets which serve as stator oriented around the rotor. The property of stator changes and hence it serves for attraction and repulsion of the rotor resulting in stepping phenomena of the motor. Figure 6 below shows the circuit diagram of Stepper Motor.

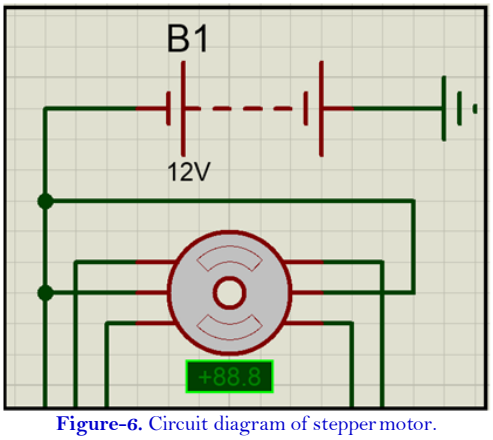

Figure-6. Circuit diagram of stepper motor.

9. SOLAR TRACKING MECHANISM

The software's employed in the proposed system are MIKRO C for programming of the microcontroller and PROTEUS 8 Professional which enables simulation of the system. These two software's form the backbone of a microcontroller-based system wherein system's flexibility can be tested before the hardware process begins. PROTEUS VSM works with .hex files. This .hex file contains the code that will be loaded into the microcontroller for simulation. In order to maintain the maximum power output, it is necessary to maintain the incident angle close to 90 degrees which is possible by the proposed system. Hence the overall system revolves around sensing the maximum intensity of light thereby positioning the solar panel in the equivalent direction. Figure 7 below shows the circuit diagram containing two LDR's which serve for the sensing mechanism to track the light intensity. The LDR's are connected to the microcontroller which is the main processor enabling reversals in direction when the intensity of light falling on the sensor switches. A driver circuit is then connected to the microcontroller which serves to drive the stepper motor connected on the other side of the driver circuit.

i) ***Case 1*** - When the light falling on LDR1 is higher than LDR2.

The resistance of LDR1 is lower than LDR2. The voltage across LDR1 is comparatively higher than LDR2 which is measured by a DC voltmeter connected across the LDR. The stepper motor begins to rotate the solar panel in counter clockwise direction.

ii) ***Case 2*** - When the light falling on LDR2 is higher than LDR1, the resistance of LDR2 is lower than LDR1. The voltage across LDR2 is comparatively higher than LDR1 which is measured by the DC voltmeter connected across the LDR. The stepper motor begins to rotate the solar panel in clockwise direction.

iii) ***Case 3*** - When the light falling on LDR1 and LDR2 is of equal intensity. A stable position of motor is observed.

10. POSSIBLE ADVANCEMENTS IN SOLAR TRACKING SYSTEM

In Stand Alone systems, Maximum power point tracker is generally incorporated to adjust the operating point in order to extract the maximum power. Array output after conversion to alternating current is then fed to load and the excess output is used to charge the battery. The surplus output after the charging of battery is shunted to dump heaters. In a grid interactive system, the surfeit power is fed directly to the grid and the operation of dump heaters is eliminated.

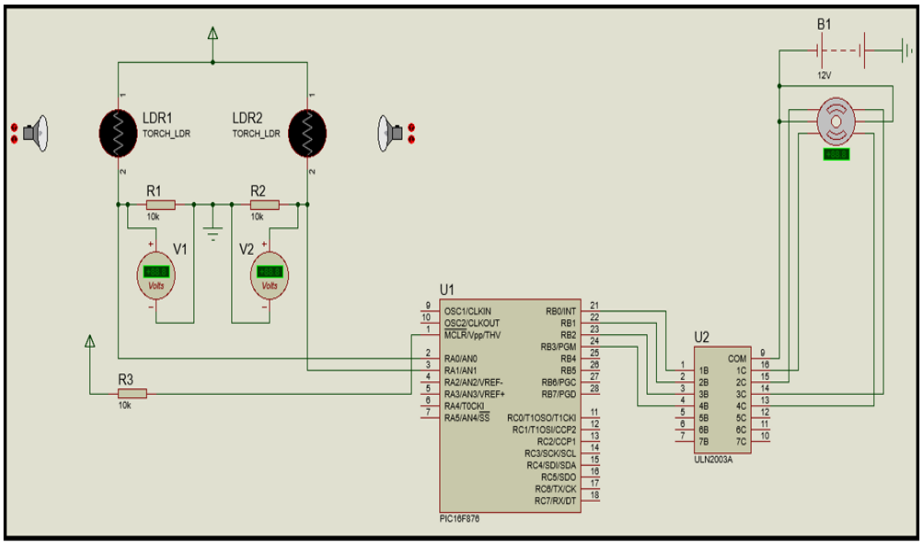

Figure-7. Simulation circuit diagram for microcontroller based solar tracking system.

10.1. Process

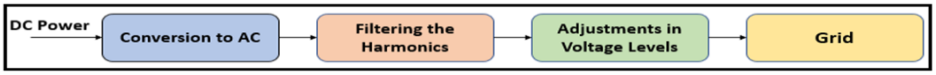

Figure-8. Process of grid – connected photovoltaic systems.

Supply of power is maintained in these types of systems and application of battery is eliminated. The structure is simple with low operating cost. Figure 8 above shows the process of Grid – connected Photovoltaic Systems. The major added advantage of on-grid PV systems is the concept of net-metering which plays a major role in incentivizing the solar power.

10.2. Net Metering

The method by which commercial or domestic consumers can generate their own electricity using solar generation system, and export the surplus energy to the grid thereby gaining extra revenue, in turn making up for the shortfalls occurring through the grid.

i) *Case 1* - Amount of generation exceeds the amount of consumption. Owner gets compensated for the amount exceeded.

ii) *Case 2* - Amount of consumption is more than that of generation.

The energy is imported from the grid and the owner is only supposed to pay the net amount.

11. CONCLUSION

In the proposed method of interfacing of Microcontroller with the Stepper Motor, the efficiency of the solar tracking mechanism is improved. The proposed system has been implemented on condensed complexity architecture. The controlling technique which is the brain of the whole system is applied to rotate the solar panel along its axis. The tracker is now able to align the solar panel in the direction of maximum intensity of sunlight throughout the day, thereby increasing the collecting capacity of the solar tracking system. Further, the technique of connecting the solar energy system to the grid has been proposed in this paper with an aim to increase the output, in turn reducing the wastage of the surplus energy produced. The concept of Net Billing/Net Metering and various related advantages have been discussed.

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