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[Rumbayan* *et al.*, 6 (11): November, 2017]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

A CONCEPT OF SOLAR TRACKER SYSTEM DESIGN

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DOI: 10.5281/zenodo.1066204

ABSTRACT

Improvement of solar panel efficiency is an ongoing research work recently. Maximizing the output power by integrating with the solar tracker system becomes a interest point of the research. This paper presents the concept in designing a solar tracker system applied to solar panel. The development of solar panel tracker system design that consist of system display prototype design, hardware design, and algorithm design. This concept is useful as the control system for solar tracker to improve the efficency of solar panel as the green energy system. For future work, the prototype of solar tracker construction will develop to implement the proposed system and design algorithm.

KEYWORDS: Green Energy System; Control System; Solar Tracker; Prototype Design; Hardware Design; Algorithme Design

I. INTRODUCTION

Technology for green energy system becomes interested to be developed. Green energy technologies are getting important in the recent years. Solar energy is gaining the focus as an important means of implementing renewable energy uses. One of the renewable energy resources is solar energy which is currently widely used to be source of electrical energy through solar cell devices.

The use of solar panel in Indonesia has started to bloom, this is something positive that the people of Indonesia began to switch to energy that is environmentally friendly and renewable. Many of residential around the world used electric solar system as a sub power at their houses. This is because solar energy is an unlimited energy resource, set to become increasingly important in the longer term, for providing electricity and heat energy to the user [1]. Energy efficiency is a very popular topic in the world today. Renewable energy becomes a solution to energy problems that occur in the world. Renewable energy has an edge that will never run out and always exist.

Indonesia has a tropical climate with optimal sun exposure compared to other hemisphere countries. In order for solar cell to absorb the sun's energy optimally must be faced with solar cell right in front of the sun. So the need for a solar energy optimization system that can be realized through a system that orient and automatically confront solar cells to the sun. By playing the role of a control system that is supported by sensor devices, actuators and controllers, the solar cell disk will remain intact facing towards the sun. A solar tracker is a device for orienting a solar photovoltaic panel, day lighting reflector or concentrating solar reflector or lens toward the sun [2].

II. THEORY

2.1. Control system

A process control system consists of four essential elements: *process*, *measurement*, *evaluation*, and *control*. A block diagram of these elements is shown in Figure 1-3. The diagram also shows the disturbances that enter or affect the process. If there were no upsets to a process, there would be no need for the control system. Figure 1 also shows the input and output of the process and the set point used for control [3] .

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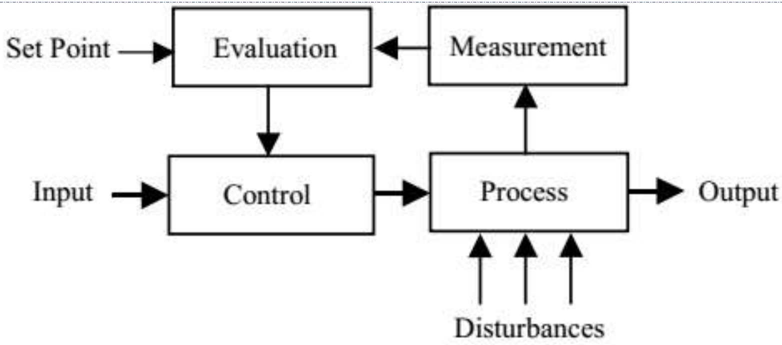

Figure 1. Four elements of a control system [3]

The control element in a control loop is the device that exerts a direct influence on the process or manufacturing sequence. This final control element accepts an input from the controller and transforms it into some proportional operation that is performed on the process. In most cases, this final control element will be a control valve that adjusts the flow of fluid in a process. Devices such as electrical motors, pumps, and dampers are also used as control elements. An advantage of the closed loop control system is the fact that the use of feedback makes the system response relatively insensitive to external disturbances and internal variations in system parameters. It is thus possible to use relatively inaccurate and inexpensive components to obtain the accurate control of a given plant, whereas doing so is impossible in the open-loop case [4].

2.2. Solar Cell

Renewable energy has become an integral part of the global energy structure and it will be the world's second largest power source in 2015. In 2035, power generation of renewable energy will account for about one-third of electricity output, and the solar energy will be the fastest one among it. And one type of renewable energy is solar cell [5]. Solar cells collect solar radiation from the sun and actively convert that energy to electricity. Solar panels are comprised of several individual solar cells. These solar cells function similarly to large semiconductors and utilize a large area p-n junction diode [6].

Solar cells are devices which convert solar energy directly into electricity, either directly via the photovoltaic effect, or indirectly by first converting the solar energy to heat or chemical energy. Assemblies of cells used to make solar modules which are used to capture energy from sunlight, are known as solar panels. The energy generated from these solar modules, referred to as solar power. Cells are described as photovoltaic cells when the light source is not necessarily sunlight (lamplight, artificial light etc).The amount of power available from a PV device is determined by -the type and area of the material, the intensity of the sunlight , the wavelength of the sunlight. Components of solar cell compilers are P*olycrystalline silicon*, or *multicrystalline silicon*, (poly-Si or mc-Si) made from cast square ingots—large blocks of molten silicon carefully cooled and solidified. Poly-Si cells are less expensive to produce than single crystal silicon cells, but are less efficient. Polycrystalline are only capable of achieving around 10% efficiency [7].

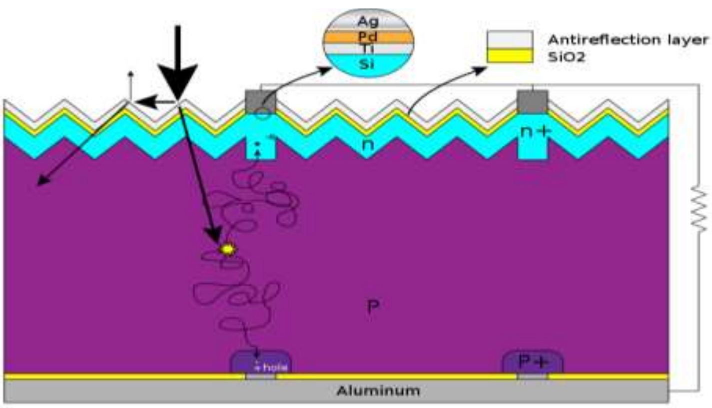

Figure 2. Silicon Solar Cell Structure [7]

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2.3. Sensors and Actuators

Essentially, sensors are needed to monitor and *learn* about the system. Sensors are needed to measure (sense) unknown signals and parameters of an engineering system and its environment. Essentially, sensors are needed to monitor and *learn* about the system. This knowledge will be useful not only in operating or controlling the system but also for many other purposes such as process monitoring; experimental modeling (i.e., model identification); product testing and qualification; product quality assessment; fault prediction, detection, and diagnosis; warning generation; and surveillance. As an example, a common application of sensors is in automobiles where a vast variety of sensors are used in the powertrain, driving assistance, safety and comfort, and so on. Actuators (e.g., stepper motors, solenoids, dc motors, hydraulic rams, pumps, heaters/coolers) are needed to *drive* a plant. As another category of actuators, *control actuators* (e.g., control valves) perform control actions, and in particular they drive control devices [8].

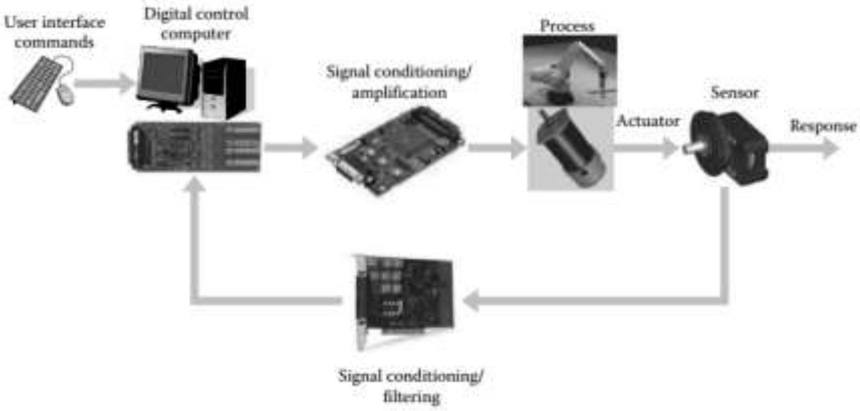

Figure 3. Sensors and Actuators in a feedback control system [8]

III. MATERIALS

The description of the method in the study is shown in the block diagram of the control system. The solar tracker system is designed to keep track of sunlight. The concept of control design in this system includes the system diagram that contains the constituent components with the relationship of system components and their relevance to the input / output of the whole system [9]. The block diagram of the control system contains the main components used to control the plant from the system. In this journal will be explained in detail about these components. Here is a block diagram of the control system for the solar tracker system.

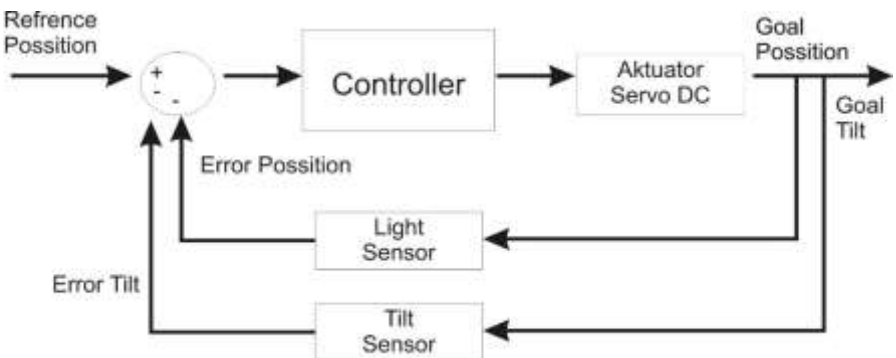

Figure 4. Block diagram Control System Solar Tracker

3.1. Sensors

The sensors is the most important component in a closed-loop control system where the sensors becomes a feature for a closed-loop control system. A closed-loop control system can be defined as a system in which its output is compared to a command, with the result used to force the output to follow the command. Sensors can be used in engineering systems for various purposes. sensors needed to monitor and learn about the system [10]. The sensor is an instrument that detects physical environmental phenomena that are converted into an electrical signal [11]. Sensors usually perform the detection of physical symptoms in the system output as seen in the picture

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above. Sensors in this solar tacker system there are 2 types used are light sensor and tilt sensor. The light sensor uses a light dependent resistor (LDR) sensor to detect the position of the sun. LDRs or Light Dependent Resistors are very useful especially in light/dark sensor circuits. Normally the resistance of an LDR is very high, sometimes as high as 1000000 ohms, but when they are illuminated with light resistance drops dramatically [12]. This sensor is placed at the ends of the solar cell. There are 8 parts of the sensor used in this system

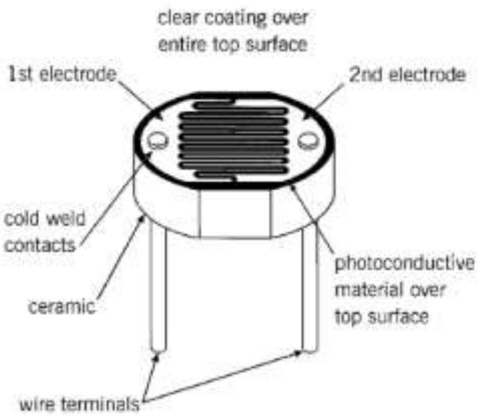

Figure 5. Light Dependent Resistor [13]

In addition to the light sensor used in this system, also used a tilt sensor to measure the slope of the solar cell in the light of the sun catch. We can do motnitoring how big the slope that has happened in solar cell. Then the slope data will also be the history data to be entered in the database. So we can see the behavior of the solar cell at certain times. A wide range of tilt sensors are used in control instrumentation. in this system using accelerometer sensor to detect the slope of the solar cell. The slope of the solar cell is only detected on one axis only the x-axis.

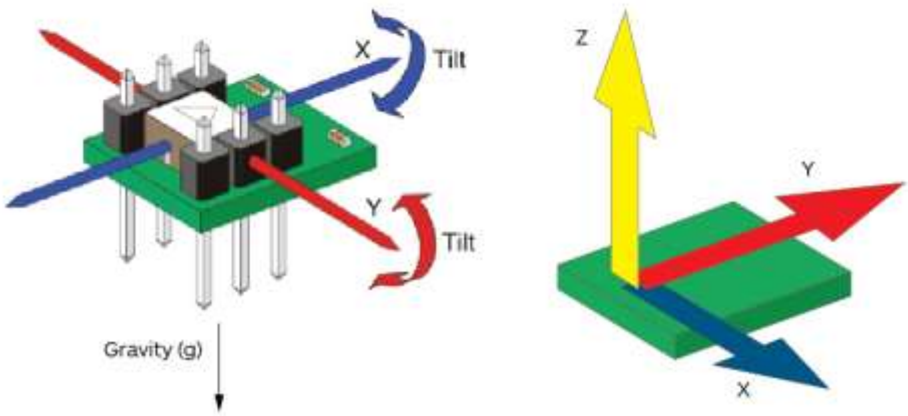

Figure 6. Principle of Accelerometer Sensor [14]

An accelerometer is an instrument that measures the acceleration of a vibrating body. Accelerometers are widely used for vibration measurements and also to Record earthquakes with using 3-axis are x-axis, y-axis and z-axis [15]. In its simplest form, the conventional accelerometer consists of mass ethan, spring, and position detector. Under Stady-State conditions, constant endurance masses will move from a stationary position to a new position determined by the balance between the mass time, acceleration, and strength of spring recovery. Using a simple mechanical spring, the acceleration is directly proportional to the distance through which the resistive mass of the equilibrium position [10].

3.2. Actuator

The function of an actuators is to give engineering signals to the plant, so the plant can behave as expected. Usually the output engineering signal from the actuator is mechanical energy consisting of speed and torque for each time. With rotational motion is the motion often generated by actuators in control instrumentation. In this system using servo motor actuator with the characteristic of power supply is DC (Direct current). Servo motors

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have different behavior with ordinary DC Motor. The different is that servo motors can only rotate at certain degrees and do not have continuous rotation like DC motors. The preferred advantage of the servo actuator is having a large torque. But the movement of this actuator is slow. So in the application is often used to lift heavy objects such as in industrial robots. Servo motors are closed loop systems with potentiometers inside. Potentiometer is used to detect the position of the rotating dc motor inside. Another superior feature of the servo actuator is having a gearbox combination to transmit dc motors inside the servo to produce a large torque. In depth the following components and materials composing the servo motor. Servo motor contains motor which is attached to a sensor for position feedback. Servo motor very suitable solar tracking system and used mostly electronics devices. It also low cost and reliable [16].

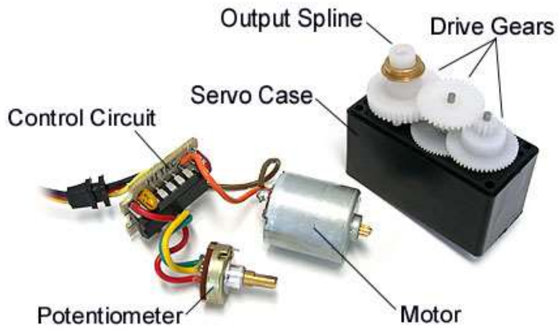

Figure 7. Servo DC Materials [17]

3.3. Controller

The controller is the center of the system. The algorithm that makes this intelligent system is in the controller. The algorithm is manifested through commands created in the form of embeded programs. Embeded system is a mini computer that is very widely used in electronic goods. The most popular type of embeded system is a microcontroller. Microcontroller is a board that is widely used to support the automation process. Many microcontroller applications are used in robots because these instruments are very reliable used to control actuators and receive signals from robot sensors. The solar tracker system in this solar cell uses microcontroller as its controller. With a relatively low power microcontroller system is very feasible to use for power saving. Microcontrollers in this system are also compatible with servo actuators, light sensors and slope sensors are used.

IV. RESULT OF DESIGN

The results of the research in the form of solar tracker system design for solar panel that consists of system prototype design, hardware design, and algorithm design.

4.1. Prototype Display Design

Solar cells used in this design have the following types and specifications.

- Model : MY50M-12
- Tipe : Polycrystalline sillicon solar cell
- Max Power : 50 Watt
- Voltage at Pmax : 17.6 Volt
- Current at Pmax : 2.85A
- Temperature Range : -45C - +80C
- Dimension : 670mm x 530mm x 30mm

Solar cell types are widely used to meet electricity in residential areas. This type is small and has a low price. This solar panel is modified by adding a light sensor around it. So the dimensions of this solar cell to be 770mm x 630mm x 330mm. The image and dimensions of the modified solar panel are shown in the Figure 8.

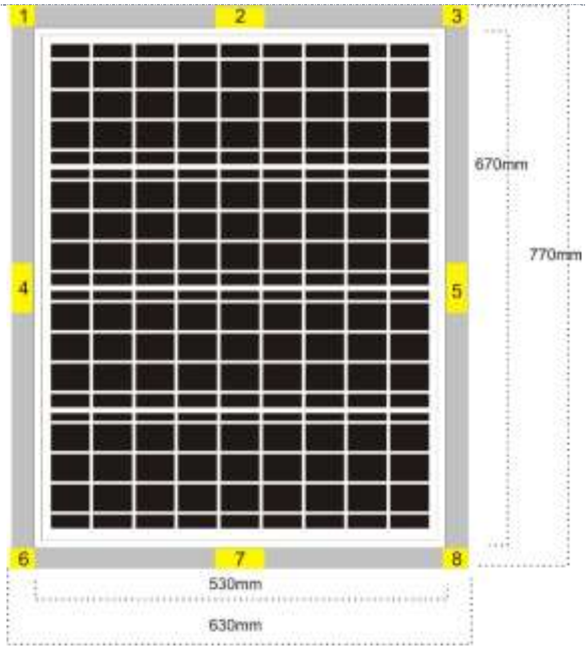

Figure 8. Modified Solar Panel Design

In the modified solar panel there are sensors around it that are placed in 8 positions marked with yellow areas and numbers in sequence. So we can call the sensor parts are top-left, top-center, top-right, middle-left, middle-right, bottom-left, bottom-center, bottom-right. This solar cell has 17 x 9 cell resolution. Solar panel placed standing on pole with a distance of 500mm above ground. This solar panel will be more optimal if placed on the roof of a building or a house that has a flat pedestal field. Specifically solar tracker system design in solar cell is shown in Figure 9.

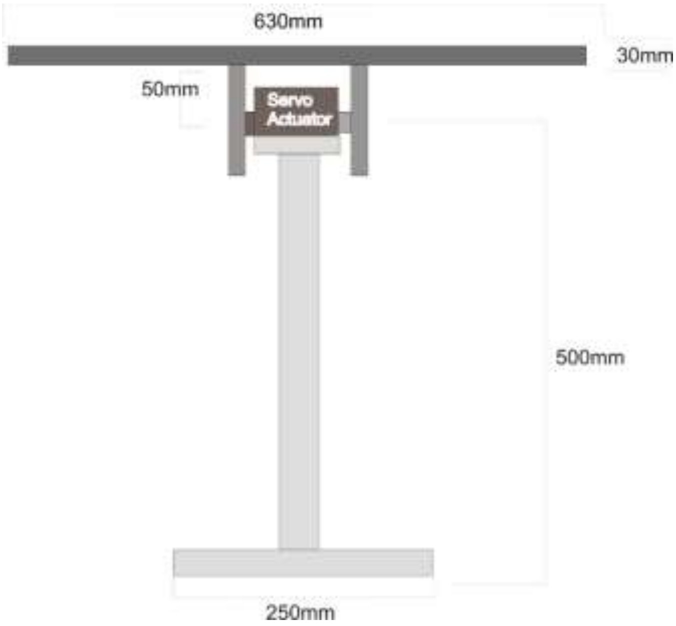

Figure 9. Prototype Front Design

In the Figure 9 shows that the servo actuator is placed under the solar cell disk. The function of the servo actuator is to rotate the solar cell disk to make the disc right facing the sun. The goal is that sunlight can be captured optimally with maximum absorption. The illustrations of the solar cell discs are shown in the Figure 10 which shows the prototype of this system from the side view.

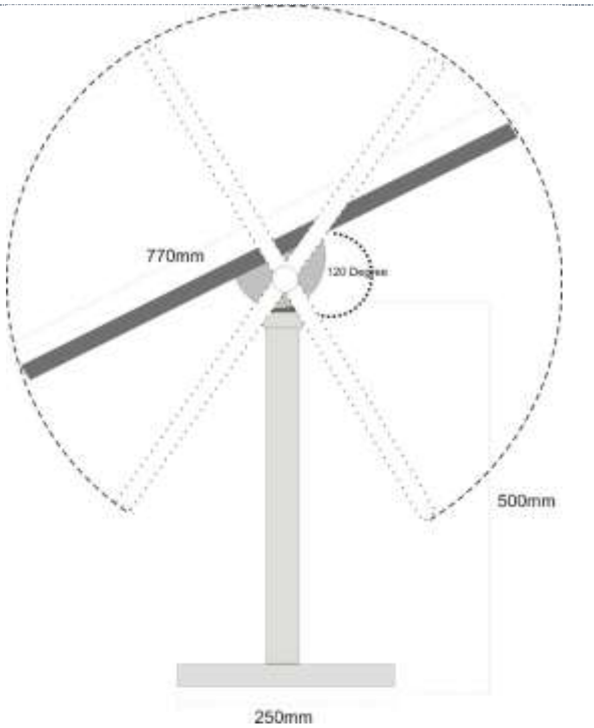

Figure 10. Prototype Side Design

The Figure 10 shows the maximum magnitude of turning angle of the solar panel is 120̊ with the rotary axis is only for x-axis that can spin forward and backward.

4.2. Hardware Design

The design of the hardware includes the design of sensors, actuators and controllers. For the sensor on the solar tacker system in the solar cell uses light sensors to detect the presence of sunlight. Based on figure 6 puts 8 positions placed around the solar cell. Each of these sensors there are 4 pieces of LDR sensor placed with diamond arrangement. The layout of the sensor is shown in the Figure 11.

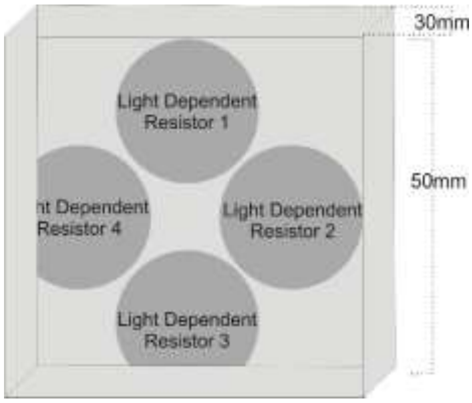

Figure 11. LDR Sensor Package

Package of LDR light sensor dimension 500mm x 500mm x 30mm. This sensor package is protected by dark walls to avoid reflection of light and sunlight. It can disrupt the performance of the sensor. LDR light sensor gives output a maximum voltage when receiving the light from the sun to the maximum. Also it gives output a small voltage even no voltage if the sensor detects minimal light or no light. This sensor is quite suitable linear used to detect visible light. The analog voltage output of the LDR light sensor will be continued on the controller and then processed. Because the microcontroller can only process digital data then the analog signal must be converted into digital signal first through the process of ADC (Analog Digital Conversion). The microcontroller

ISSN: 2277-9655
Impact Factor: 4.116
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used by this system is Arduino Uno as it simple and more compatible in processing sensor data and moving actuator action. The LDR light sensor is connected parallel with the 10k ohm resistor then the sensor output part is directly connected to the arduino analog pin as show in the Figure 12. Arduino is a single board microcontroller which is a open source computing and development board [18].

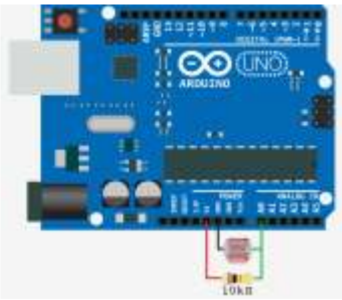

Figure 12. Wire of Arduino Uno with LDR Sensor

Once the sensor data is processed, the system must try to move the solar panel disk to direct the sunlight. To move it, this system uses servo actuators (Figure 13). Servo used is dc servo motor with mega torque specification which is capable of lifting the load with maximum torque of 44 Kg.cm type like this is only owned by Hitech servo with HS-M7990TH type with the advantage of metallic gear. With operating voltage specifications 6 - 7.4 volts and torque strength 36 - 44 Kg.cm. The speed of this servo is 0.21 - 0.17 (second @ 60°) with dimensions of 43.8mm x 22.4mm x 40.00mm.

Figure 13. Servo HS-M7990TH.

4.3. Algorithm Design

The design of the algorithm is made so that the system is able to follow the sun intelligently. The solar cell position movement algorithm performs action based on sunlight detection result from 8 light sensor LDR package. Here is the logic table of sensor detection results and the action output of the servo actuator.

Table 1. Action Actuator Logic based on sensor detection results

ACTION SERVO	SENSOR							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
STOP	1	1	1	1	1	1	1	1
STOP	0	0	0	0	0	0	0	0
CW	1	0	0	0	0	0	0	0
CW	1	1	0	0	0	0	0	0
CW	0	1	0	0	0	0	0	0
CW	0	1	1	0	0	0	0	0
CW	0	0	1	0	0	0	0	0
CW	1	1	1	0	0	0	0	0
CW	1	0	0	1	0	0	0	0
CW	1	1	0	1	0	0	0	0

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CW	0	0	1	0	1	0	0	0
CW	0	1	1	0	1	0	0	0
STOP	0	0	0	1	0	0	0	0
STOP	0	0	0	0	1	0	0	0
STOP	0	0	0	1	1	0	0	0
CCW	0	0	0	1	0	1	0	0
CCW	0	0	0	1	0	1	1	0
CCW	0	0	0	0	1	0	0	1
CCW	0	0	0	0	1	0	1	1
CCW	0	0	0	0	0	1	0	0
CCW	0	0	0	0	0	1	1	0
CCW	0	0	0	0	0	0	1	0
CCW	0	0	0	0	0	0	1	1
CCW	0	0	0	0	0	0	0	1
CCW	0	0	0	0	0	1	1	1

Based on the table there are 3 types of action servo actuator movement that is CW (clockwise), CCW (counter clockwise) and STOP (idle). While logic 1 is interpreted as a sensor receiving sunlight and logic 0 is the sensor does not receive sunlight. So that can be made a flowchart to describe the algorithm of solar system followers in the solar cell shown in the Figure 14.

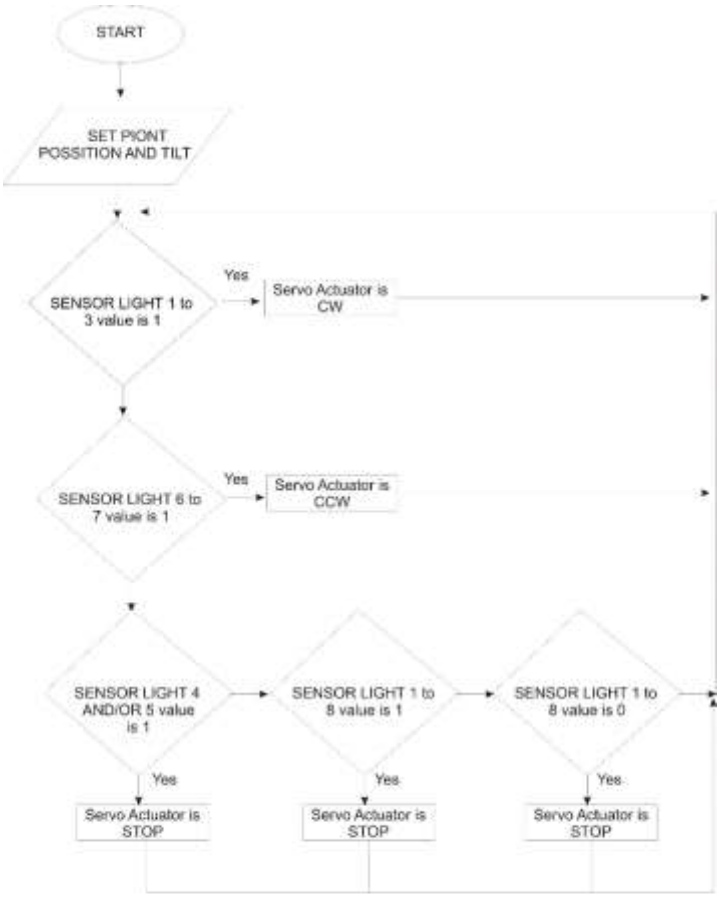

Figure 14. Flowchart of System Design

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Based on the actuator action type, the decision algorithm of this system can be divided into three parts of the sensor detection results ie sensors 1 to 3, sensors 6 to 8 and sensors 4 to 5. With ideal conditions of this system is if all sensors ie 1 to 8 detect sunlight defined by logic 1.

V. CONCLUSION

Concept in designing a solar tracker system applied to solar panel has been presented in this article. The result of solar tracker system design for solar panel consist of system display design, hardware design, and algorithm design. The sensor device used is the tilt sensor and LDR as light sensor placed in 8 positions. As for the system actuators use servo actuators with mega torque specifications that will be expected to direct and confront the solar cell disk right into the sunlight.

This system controller device uses a microcontroller that will process the sensor detection and process based on embedded logic and then will give the action of rotation on servo actuator. The intelligent algorithm of this system is shown through 24 logic sensor readings with servo movement in the form of output of this algorithm. For future work, the prototype of solar tracker construction will develop to implement the proposed system and design algorithm.

VI. REFERENCES

[1] M. Lokhande, *Automatic Solar Tracking System*, International Journal of Core Engineering & Management (IJCEM) Volume 1, Issue 7, ISSN: 2348 9510, October 2014.

[2] S. Rana, *A Study On Automatic Dual Axis Solar Tracker System Using 555 Timer*, International Journal of Technical Research and Applications e-ISSN: 2320-8163, www.ijtra.com Volume 1, Issue 4 (sept-oct 2013), PP. 77-85, 2013

[3] T. Hughes, “Measurement and Control Basic”, 3rd edition, ISA Press, 2002.

[4] K. Ogatha, “Modern Control System”, Fourth Edition, Pearson education International, Tehran, 2002.

[5] X. Jin, G. Xu, R. Zhou, X. Luo, Y. Quan, *A Sun Tracking System Design For a Large Dish Solar Concentrator,* International Journal of Clean Coal and Energy, 2013, 2, 16-20, May 2013.

[6] R. Banerjee, *Solar Tacking System*, International Journal of Scientific and Research Publications, Volume 5, Issue 3, ISSN 2250-3153, March 2015

[7] R. Swami, *Solar Cell*, International Journal of Scientific and Research Publications, Volume 2, Issue 7, ISSN 2250-3153, July 2012

[8] C. De Silva, “Sensors And Actuators”, Second Edition, CRC Press Taylor and Francis Group, 2016

[9] Dwisnanto Putro, Jane Litouw, *Robot Pintar Penyambut Costumer Pada Pusat Perbelanjaan Kota Manado*, Jurnal rekayasa Elektrika, Universitas Syah Kuala, Vol 13, No.1, ISSN. 1412-4785, 2017.

[10] S. Solomon, “Sensors handbook”, Second edition, Mc Graw Hill, ISBN: 978-0-07-160570-0, 2010

[11] Dwisnanto Putro, Feisy Kambey, *Sistem Pengaturan Pencahayaan Ruangan berbasis Android pada Rumah Pintar*, National jurnal of Electrical Engineering, Andalas University, Vol 5, No.3, ISSN. 2302-2949, 2016.

[12] Gouthami. C, Santosh. C, A. Pavan Kumar, Karthik. A, Ramya.K.R, *Design and Implementation of Automatic Street Light Control System using Light Dependent Resistor*, International Journal of Engineering Trends and Technology (IJETT) – Volume 35 Number 10 - May 2016.

[13] A. Marc, Photoresistor VT90N2 LDR, May. 7, 2015. [Online] Avaible : https://arduinodiy.wordpress.com/2013/11/03/measuring-light-with-an-arduino. [Accessed: Oct. 25, 2017]

[14] IEEE GlobalSpec, Specifying an Accelerometer: Function and Applications, July. 27, 2015. [Online] Avaible : http://insights.globalspec.com/article/1263/specifying-an-accelerometer-function-and-applications. [Accessed: Oct. 25, 2017]

[15] N. S. Marne, M. S. Nagmode, R. D. Komati, *Vibration Measurement System with Accelerometer Sensor Based on ARM*, International Journal of Emerging Technology and Advanced Engineering, Website: www.ijetae.com, ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 4, April 2014

[16] N. Sharma , B. Sharma, *An Analysis of Automatic Dual Axis Sun Tracking Solar System*, International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering ISO 3297:2007 Certified Vol. 4, Issue 12, December 2016

[17] ServoCity, How Does a Servo Work?, [Online] Avaible : https://www.servocity.com/how-does-a-servo-work. [Accessed: Oct. 25, 2017]

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

[18] C. Srijesh, C. Arpan, C, Susan, *Dual Axis Self-tracking Solar Panel*, International Journal of Computer Applications (0975 – 8887) Volume 141 – No.14, May 2016

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Rumbayan , M., & Putro, M. D. (2017). A CONCEPT OF SOLAR TRACKER SYSTEM DESIGN. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, *6*(11), 440-450.