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Modeling and Design for a Sun Tracker Prototype Using Solar Cell and Arduino

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ABSTRACT

Solar cells are devices that can convert sunlight into electrical energy directly using photovoltaic technology. One of the factors that influences optimal absorption from solar cells is the installation of the solar cell surface. Installing the solar cell surface perpendicular to direct sunlight will maximize the energy produced. But in reality, most solar cell installations are still static or permanent with a fixed elevation angle so that the solar cells cannot get the maximum intensity of sunlight because the sun always moves from east to west. Based on the existing problems, this prompted the author to create a prototype sun tracker to optimize solar cell absorption. This research uses experimental research methods with methods of data collection, observation, literature study and system development from planning, needs analysis, design, testing and results analysis. This system will work by directing the surface of the solar cell so that it is perpendicular to the direction of sunlight to Get maximum solar energy by using Arduino Uno as the main control which gets input values from the LDR sensor which is then processed and Arduino Uno will order the servo motor to move the solar cell towards the incoming sunlight. Monitoring this prototype work system uses a 16x2 LCD and also adds an IoT (Internet of Things) feature for monitoring the prototype work system remotely via smartphone.

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INTRODUCTION

The need for energy is increasing over time. This increasing need for energy cannot be met only by relying on fossil energy such as oil, gas and coal because its availability is decreasing over time[1]. Therefore, it is necessary to utilize other energy, namely renewable energy such as geothermal energy, solar energy, water energy, wind energy, tidal energy, biomass energy, biofuel energy and wave energy[2].

Renewable energy is an alternative solution to meet increasing energy needs[3]. The renewable energy source that is available directly is the sun. The sun can fulfill all human energy needs if it can be utilized effectively because the sun will continue to shine. The energy provided by the sun can be directly utilized in the form of electricity using solar cells[4].

Solar cell is a tool for converting sunlight energy into electrical energy. To utilize energy potential, photovoltaic technology is used[5]. What is meant by the photovoltaic effect is a phenomenon where an electric voltage appears due to the connection or contact of two electrodes connected to a solid or liquid system when receiving light energy[6].

Certainly, As of my last update in September 2021, there have been ongoing advancements in solar energy technology. Here are some potential new developments in the world of solar energy[7]:

1. Improved Solar Cell Efficiency: Ongoing research aims to enhance the efficiency of solar cells, exploring new materials and designs for more efficient photovoltaic technology[8].
2. Utilization of New Materials: The use of new materials, such as perovskite, has been a major focus. These materials could be integrated into solar cells to improve efficiency and reduce production costs[9].
3. Integration with Other Technologies: Solar cells are increasingly being integrated with other technologies, such as energy storage (batteries), smart grids, and the Internet of Things (IoT). This integration enhances the management and use of solar energy[10].
4. Solar Windows: Researchers are developing transparent solar panels or solar panels that can be embedded in building windows. This allows for solar energy utilization without compromising the functionality of the building[11].
5. Development of Smart Grid Infrastructure: Advanced smart grid infrastructure allows for better management of energy from renewable sources, including solar energy. This technology ensures that locally generated energy can be efficiently integrated into the power grid[12].
6. Use of Drones for Maintenance and Monitoring: Some projects are utilizing drones for routine inspections, cleaning solar panels, and monitoring overall system performance[13].
7. Innovations in Energy Storage: Energy storage is a crucial part of renewable energy solutions. New developments in battery technology and energy storage aim to improve the efficiency and reliability of solar energy systems[14].

One of the factors that influences the electrical energy produced by solar cells is the installation of the solar cell surface. Installing the solar cell surface perpendicular to direct sunlight will maximize the energy produced. But in reality, most solar cell installations are permanent with a fixed elevation angle so that the solar cell cannot get the maximum intensity of sunlight because the sun always moves from east to west. Therefore, efforts are needed to direct the surface of the solar cell so that it is perpendicular to the direction of sunlight to obtain maximum solar energy[15].

Based on the existing problems, the researchers wanted to develop from previous research the Prototype of a Sunlight Tracking System for an Arduino-Based Solar Power

Generation System which was carried out by research in 2018[16]. However, the prototype created did not have components to monitor the work results of the prototype. So that encouraged the author to create a prototype solar cell surface drive based on Arduino Uno by utilizing an LDR sensor and servo motor as a solar cell driver so that the surface can be perpendicular to the direction of incoming sunlight to get maximum solar energy as well as adding IoT components to monitor the work results of the prototype. which has been created.

METHOD

In the data collection method, the author uses observation technology and library literacy. This observation was carried out after identifying existing problems to determine what data was needed for the purposes of making a prototype solar cell drive control system to optimize the absorption capacity of the solar cell itself. Meanwhile, Library Literacy is used for data collection to obtain secondary data by conducting literature studies to obtain a theoretical basis for solving the problems studied. Data from the literature is useful as consideration for data obtained from research. In the research concept, the author organizes it into the following phases:

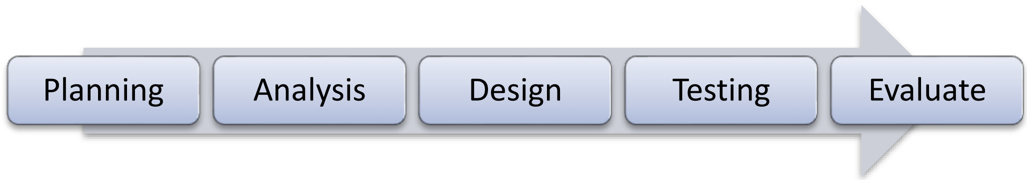

Figure 1, Project completion phase framework.

1. In planning the research, the author made observations to get an overview of the research object to be created. The main planning is to identify existing problems, namely the use of solar thermal energy as a substitute for fossil energy whose availability is decreasing and also to save energy. This is the basic purpose of creating this system.
2. This stage analyzes the system to be created which includes functional requirements analysis and non-functional requirements analysis. Functional requirements analysis aims to find out what services must be provided by the system, while non-functional requirements analysis aims to find out how well the services that have been provided work.
3. This stage includes design planning and program design. At this stage, when the author has started to determine the goals with the existing problems, then the author makes a design plan for the Fritzing software in order to make it easier to purchase the tools and materials needed to make this system. To design the program itself, Arduino IDE software and Blynk software were used.
4. At this stage, testing is carried out on the system with the aim of seeing all the errors and deficiencies in the system. System testing includes: program testing, device component testing and overall testing that must be tested.
5. The next step is analysis of the results or evaluation of the system that has been created. The extent to which this system has been successful. The success of the system itself will be assessed by the final output when the system is used. From the test data that has been carried out, it is concluded that the power produced by dynamic solar cells is greater than static solar cells.

RESULT & DISCUSSION

This research aims to create a prototype solar cell drive control system to optimize the absorption capacity of the solar cell itself. Making this prototype can later be used as a reference for making the original product because this prototype is a small scale depiction of the original product. Making this prototype uses an Arduino Uno as the main controller which has been programmed using Arduino IDE (Integrated Development Environment) software, a solar cell as a tool for converting sunlight energy into electrical energy, an LDR as a light detector or measuring the amount of light conversion, a servo motor as a solar cell driver, an LED as an indicator light, 16x2 LCD for manual monitoring of prototype work, NodeMCU ESP8266 as a connection to the internet (IoT), and a 4v battery as storage for electricity produced from solar cells.

The working system of this prototype, namely Arduino Uno, will compare the values of each LDR sensor. The value of LDR sensor 1 will be compared with the value of LDR sensor 2. If the value of LDR sensor 1 is greater than sensor 2 (value of LDR sensor 1 > value of sensor LDR 2) then the servo motor will automatically move and tilt the solar cell towards sensor LDR 1 whose value is higher until the values of LDR 1 and LDR 2 are the same, and vice versa. When the LDR 1 sensor value and LDR 2 sensor value are the same (LDR 1 sensor value = LDR 2 sensor value) then the servo motor will stop and remain silent. When LDR sensor 1 and LDR sensor 2 do not receive light, the servo motor will move towards the east (initial position) or towards the rising sun so that in the morning the surface of the solar cell is perpendicular to the direction of incoming sunlight and the servo motor will be ready moves when the LDR sensor starts to receive sunlight. The results of all prototype work system processes are also sent in real-time to the Blynk server for remote monitoring via the internet. From the results of this research, it is hoped that by using a solar cell drive control system, the absorption of solar energy can be further optimized through solar cell media. An explanation can be seen in Figure 2 below:

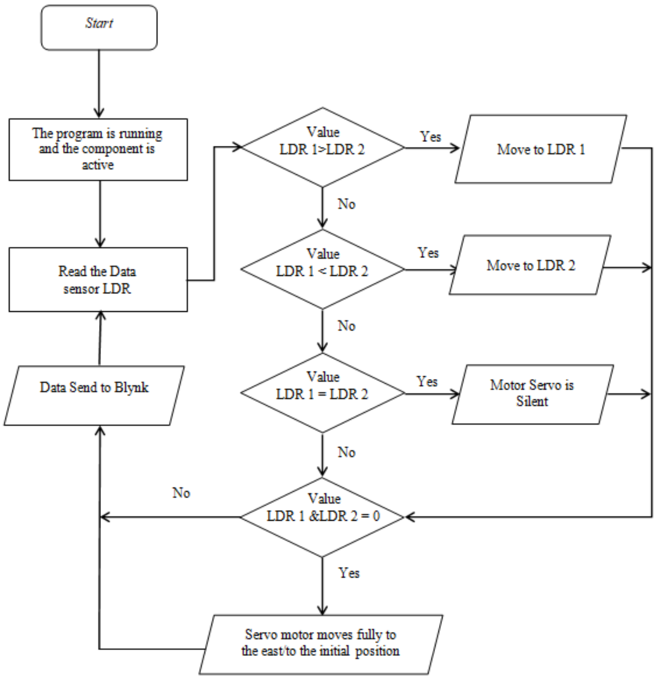

Figure 2, Flowchar of Design System

The schematic circuit is used for the initial stages of system design and simulation testing using fritzing software. This schematic image will later be used as layout material for the printing process on the PCB board. And this series of schematic drawings will determine the workflow of the system that will be created later.

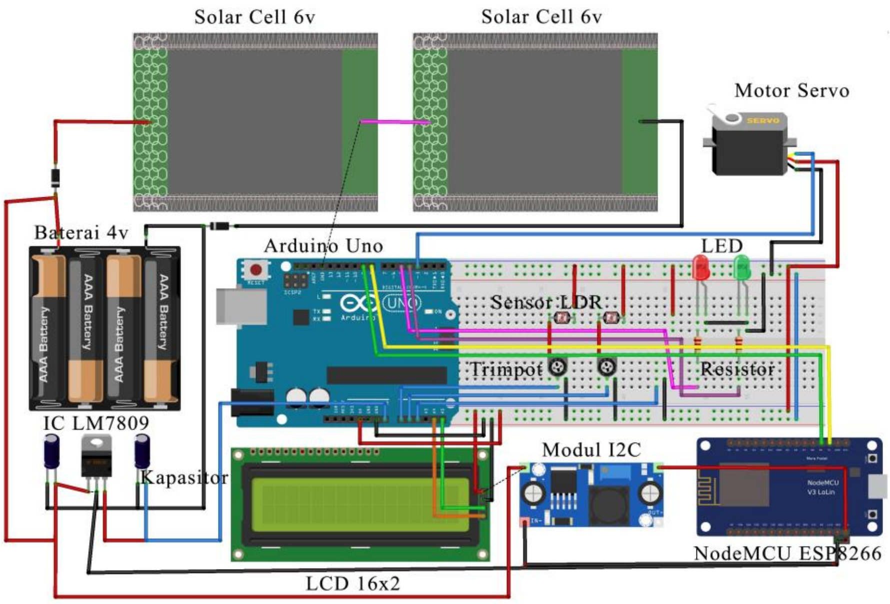

Figure 3, Schematic Design.

The next step is to arrange the circuit into a predetermined form based on the previous schematic design. This circuit is a prototype sun tracker based on Arduino Uno. The overall series of tools consists of several components, namely: Arduino Uno, 6v Solar Cell, LDR Sensor, LED, LCD16x2, I2C Module, NodeMCU ESP8266, DC Step Down Module, DC Servo Motor, 4v Battery, LM7809 IC Regulator, Push Button, Resistors, Capacitors, Diodes, Trimpots, Rainbow cables, PCB boards. Below is a picture of the entire tool set :

Figure 4, Prototype Model.

Next is the tool testing stage. Testing is carried out to find out how the system created in this research works as expected or not and is used to measure the capabilities of the system itself. This test aims to find out how much energy can be absorbed by dynamic solar cells and static solar cells. This test is carried out by placing the tool in an open place that gets sunlight. The test was carried out from 05.00 to 19.00 to find out how much voltage was absorbed by the dynamic solar cell, how much voltage was absorbed by the static solar cell, how much the surface slope of the dynamic solar cell changed every hour, and how much voltage entered the battery within 15 hours of testing.

Table 1, Prototype testing results at a certain time.

No.	**Time**	**Cornered**		**Batery Volt**		**Volt of Solar Cell**	
		Dynamic	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
1	05.00	15º	80º	11,5v	11,5 v	0,8 v	0,8 v
2	06.00	15º	80º	11,5v	11,5 v	4,2 v	1,3 v
3	07.00	15º	80º	11,5 v	11,5 v	5,8 v	2,5 v
4	08.00	26º	80º	11,6 v	11,5 v	6,2 v	3,3 v
5	09.00	49º	80º	11,7 v	11,5 v	7,5 v	4,9 v
6	10.00	71º	80º	11,8 v	11,6 v	8,7 v	6,2 v
7	11.00	80º	80º	11,9 v	11,6 v	9,8 v	9,6 v
8	12.00	87º	80º	12,1 v	11,8 v	11,6 v	11,6 v
9	13.00	97º	80º	12,5 v	12,0 v	13,2 v	13,2 v
10	14.00	112º	80º	12,6 v	12,2 v	13,1 v	12,1 v
11	15.00	132º	80º	12,6 v	12,3 v	12,6 v	8,8 v
12	16.00	141º	80º	12,6 v	12,4 v	11,4 v	4,2 v
13	17.00	156º	80º	12,6 v	12,4 v	6,3 v	1,3 v
14	18.00	160º	80º	12,6 v	12,4 v	1,2 v	0 v
15	19.00	160º	80º	12,6 v	12,4 v	0 v	0 v
	The total voltage absorbed by the solar cell					**112,4 v**	**79,8 v**

This IoT test aims to determine whether the data sent by the NodeMCU ESP8266 component is the same as the data displayed on the 16x2 LCD because this aims to monitor remotely via smartphone via the internet. If the NodeMCU ESP8266 component can send data to the blynk application with the same data as on a 16x2 LCD then the IoT test has been successful. The following is a picture of the test results that have been carried out :

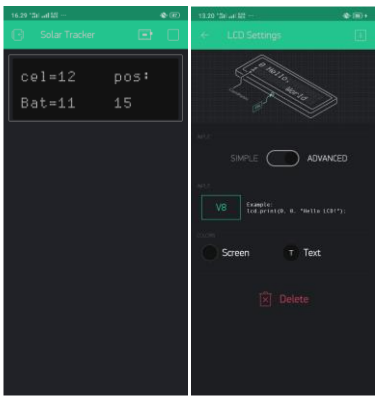

Figure 5, Interface IoT System

Based on the results of the tool testing that has been carried out, the author obtained some data. The average hourly charging voltage of a dynamic solar cell is 7.49 volts/hour and the average hourly charging voltage of a static solar cell is 5.32 volts/hour, calculated from the total amount of voltage absorbed divided by the duration of the test time. Following are the calculation data:

tD = 112.4 volts
tS = 79.8 volts
w = 15 hours

Calculation of the average dynamic solar cell charging per hour:

rD = tD/w
rD = 112.4/15
rD = 7.49 volts/hour

Calculation of average static solar cell charging per hour:

rS = tS/w
rS = 79.8/15
rS = 5.32 volts/hour

<u>Information :</u>
rD: Average dynamic solar cell charging per hour (volts/hour)
rS: Average static solar cell charging per hour (volts/hour)
tD: Total dynamic solar cell voltage (volts)
tS : Total static solar cell voltage (volts)
w : Testing time (hours)

The average difference in voltage per hour between charging dynamic solar cells and static solar cells is 2.17 volts/hour. calculated from the average hourly voltage absorbed by dynamic solar cells minus the average hourly voltage absorbed by static solar cells. Following is the data calculation:

rD = 7.49 volts/hour
rS = 5.32 volts/hour
sr = rD – Rs
sr = 7.49 - 5.32
sr = 2.17 volts/hour

<u>Information :</u>
sr: The difference between the average hourly voltage of dynamic and static solar cells
rD: Average dynamic solar cell charging per hour (volts/hour)
rS: Average static solar cell charging per hour (volts/hour)

The percentage of voltage absorbed from dynamic solar cells is 58.4%, while the percentage of voltage absorbed from static solar cells is 41.6%. Following is the data calculation:

tD = 112.4 volts
tS = 79.8 volts

Calculation of the percentage of voltage absorbed by dynamic solar cells:

pD = tD/(tD+tS) x 100%
pD = 112.4/(112.4+79.8) x 100%
pD = 112.4/192.2 x 100%
PD = 58.4 %

Calculation of the percentage of voltage absorbed by static solar cells:

pS = tS/(tD+tS) x 100%
pS = 79.8/(112.4+79.8) x 100%
pS = 79.8/192.2 x 100%
pS =41.6 %

Information :
pD: Percentage of voltage absorbed by dynamic solar cells (%)
pS: Percentage of voltage absorbed by static solar cells (%)
tD : Total dynamic solar cell voltage (volts)
tS : Total static solar cell voltage (volts)

The percentage difference between charging dynamic solar cells and static solar cells is 16.8% calculated from the percentage of voltage absorbed by dynamic solar cells minus the percentage of voltage absorbed by static solar cells. Following is the data calculation:

$pD = 58.4\ \%$
$pS = 41.6\ \%$

Calculation of the percentage difference between charging dynamic solar cells and static solar cells:

$sp = pD - pS$
$sp = 58.4\ \% - 41.6\ \%$
$sp = 16.8\ \%$

Information :
sp: Percentage difference
pD: Percentage of voltage absorbed by dynamic solar cells (%)
pS: Percentage of voltage absorbed by static solar cells (%)

From the results of the tests that have been carried out, the NodeMCU ESP8266 component works well. Data delivery is smooth, the data display in the Blynk application is the same as the data displayed on the 16x2 LCD which indicates that communication between the prototype and the Blynk application has no problems and is running well.

CONCLUTIONS

Based on the results of previous research and discussions, the following conclusions can be drawn:

1. A prototype of a sun ray tracker has been created to optimize solar cell absorption using two LDRs as light sensors where the output from the LDR sensor is in the form of an ADC value which will be processed by the Arduino Uno as the brain of the prototype controller to move the servo motor as the mechanical driver of the solar cell so that it always moves perpendicularly following the direction of incoming sunlight.
2. The average charging voltage for dynamic solar cells is greater than the average charging voltage for static solar cells, where the average charging voltage for dynamic solar cells is 7.49 volts/hour while for static solar cells it is 5.32 volts/hour.
3. The voltage absorbed by dynamic solar cells is greater than the voltage absorbed by static solar cells where the percentage of voltage absorbed by dynamic solar cells is 58.4% while for static solar cells it is 41.6%.
4. The percentage difference in charging voltage ratio between dynamic solar cells and static solar cells is 16.8%.
5. The IoT (Internet of Things) feature is very helpful in the remote monitoring process, making the maintenance process easier.

In the work and completion of this project, of course there are various kinds of shortcomings and errors, both in the system design and in the process of creating the final project that has been created. To correct the deficiencies in perfecting this system, the author makes a suggestion, namely, for further development, it is necessary to check and document the equipment before and after testing so that the impact on the components can be understood more deeply and the research results can be better. Opportunities that can be carried out in further research are that the prototype of a sun ray tracker for optimizing solar cell absorption can be developed using other sensors or other driving motors as mechanics.

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