A New Approach in Controlling A Single Axis Solar Tracker Based on Photovoltaic Output

IGNA Dwijaya Saputra
Dept. of Electrical Engineering
Politeknik Negeri Bali
Badung, Bali, Indonesia
dwijaya_s@pnb.ac.id

I Made Sajayasa
Dept. of Electrical Engineering
Politeknik Negeri Bali
Badung, Bali, Indonesia
msajayasa@pnb.ac.id

I Ketut Suryawan
Dept. of Electrical Engineering
Politeknik Negeri Bali
Badung, Bali, Indonesia
suryawanpnb@pnb.ac.id

IBK Sugirianta
Dept. of Electrical Engineering
Politeknik Negeri Bali
Badung, Bali, Indonesia
ibksugirianta@pnb.ac.

I Made Purbhawa
Dept. of Electrical Engineering
Politeknik Negeri Bali
Badung, Bali, Indonesia
purbhawa@pnb.ac.id

IGP Mastawan Eka Putra
Dept. of Electrical Engineering
Politeknik Negeri Bali
Badung, Bali, Indonesia
mastawan@pnb.ac.id

2021 7th International Conference on Electrical, Electronics and Information Engineering (ICEEIE) | 978-1-6654-3232-0/21/$31.00 ©2021 IEEE | DOI: 10.1109/ICEEIE52663.2021.9616737

***Abstract*— Harvesting energy from the sun is a trend in this era. One of the strategies in collecting this solar energy is using a solar panel with a solar tracker to find an optimum value of this power. There are many strategies to track sunlight movement both on the single-axis or double axis. In this paper, a new method in finding an optimum energy collection is proposed. This new approach applies a mini solar tracker driven by a micro servo motor as a sunlight sensor. This method's strategy is to multiply the output voltage and current from the mini solar panel to get a maximum power value at a specific degree for driving the larger servo motor at larger PV. As a result, energy supply to the larger motor is reduced. The results show that this strategy can find optimum power from the sun's energy.**

Keywords— Solar Tracker, Photovoltaic, Arduino, Servo Motor

I. Introduction

The development of the use of solar panels around the world is currently increasing. Data in 2015 states that around 200GW has been installed worldwide [1]. In general, there are two types of photovoltaic (PV) or solar panels, the roof-top and the ground-mounted installation—this PV with a certain angle of inclination according to the panel installation area. The amount of electrical energy produced depends on the angle of the light falling onto the solar panel. The maximum energy obtained is if the light comes perpendicular to the cell in the solar panel. By looking at the sun's movement rising in the east and set in the west, solar panels need to follow the sun's movement to obtain optimum energy. Currently, the installation of solar panels is in a static model, which difficult to change the angle of the installation after determining the angle at the beginning of the installation.

There are several ways in sensing the movement of solar panels, such as using light sensors based on photodiodes [2 – 4], photoresistors [5 – 7], pyroelectric devices [8, 9], or Cryogenic sensors [10]. Most of these sensors implement complex systems or systems that are expensive. Other sensors use photovoltaic, but the sensors are not dynamic; only a few (2-4) PV sensors are placed in several directions [11].

In this paper, a new approach for controlling a single-axis solar tracker is presented. This approach will make the sun detector at the right angle throughout the day, from morning to evening, and make the controller so that the sensor moves to scan the sun's fall angle with the maximum perpendicular. The design of this solar panel operates by driving the servo motor according to sensor input so that the solar panel matches the direction of sunlight with a microcontroller.

II. Method

A. Proposed Method

There are several methods used in solar trackers. Based on the drives used, there are active solar trackers and passive solar trackers [12]. Active solar tracker uses intelligent drive systems such as fuzzy logic [13, 14] and Neural networks. Microprocessor and sensor drives and combined microprocessor-based sensors are also included in this category [12]. Meanwhile, passive solar trackers use a Thermo hydraulic actuator, bimetallic thermal actuator, or shape memory alloy thermal actuator [15, 16].

Another way is using a method based on the degree of freedom. This method uses one axis (vertical, horizontal, or inlined axis) or two-axis, namely looking at Tip – Tilt, Azimuth – altitude, or a combination thereof. One of the studies that developed one axis is sending data via Radio Frequency to a computer via a USB port [17]. As for the two-axis as in the study [18 – 20]. The two-axis solar tracker simulation model using Matlab software is simulated by adding PID (proportional integral derivative) control [21]. The control system on the solar tracker obtains an input signal from the sensor used. There are several control methods used, including using a PLC (Programmable Logic Controller) [22 - 24] or a microprocessor [25, 26]. A high precision tracking of the sun (TS) is another method for solar tracker that includes astronomical formula [27] and also comparing to a tracking the best orientation (TBO) [28].

In this paper, a single axis solar tracker is proposed with a new approach to sensor the light from the sun by using a small solar cell or solar panel. Using this strategy, the movement of the tracker will be focused at the mini-PV before producing the degree information for driving the larger motor. Consequently, this solar tracker needs less energy compare to direct sensing at the larger PV. This energy consumption for the motor will be observed in the later research.

In general, the design of a single-axis solar tracker with a dynamic sensor can be seen in Fig. 1. A mini photovoltaic is used as a light sensor, while a mini servo motor moves the PV. The movement of the sensor makes the PV produces a voltage and current. These values vary that depends on the angle of the mini PV to the sun. The microprocessor will record data in

978-1-6654-3232-0/21/$31.00 ©2021 IEEE

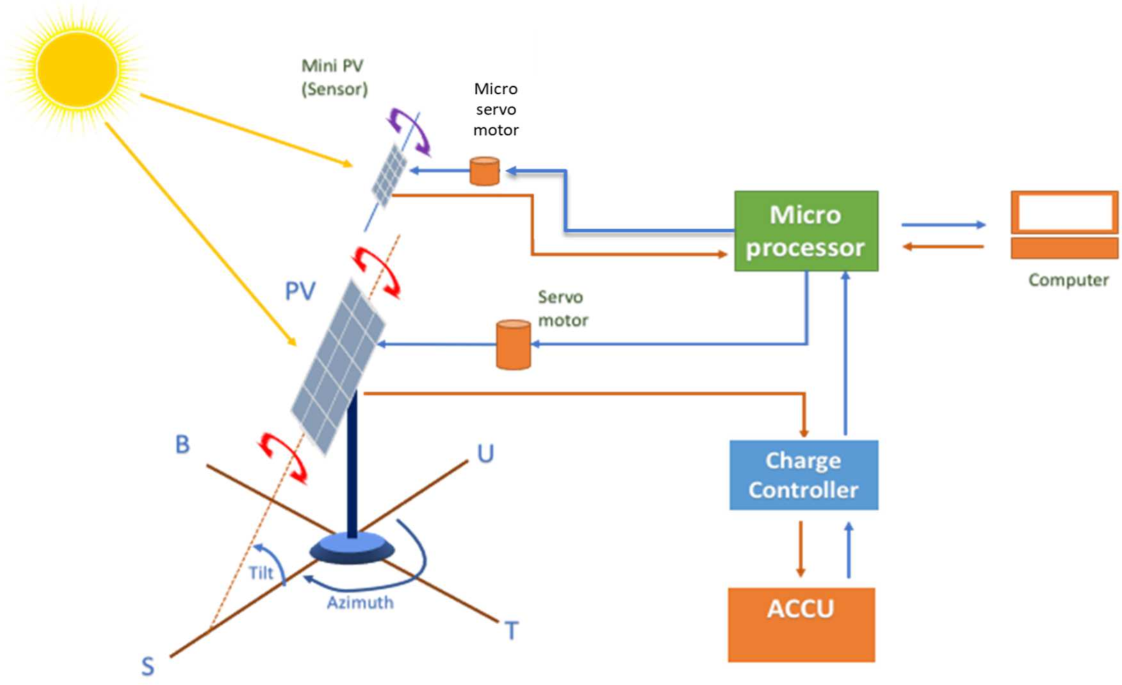

Fig. 3. Single axis solar tracer diagram with dynamic sensor

the form of current and voltage and the mini PV angle for 30 seconds and then be processed to find the optimum value.

Furthermore, after obtaining the optimum value according to the analysis in the microprocessor, a signal driven will be produced by a microprocessor for driving the first and the second PV via a servo motor. This process is repeated after some time. This delay time is set to the most efficient value, or it means using less power. Thus, this process will constantly continue so that the PV will move in the sun's direction and then produce the optimum energy.

The programming process can be done with a USB connection to a computer and store monitoring data from the sensor output, which can be used for later data analysis purposes. As for the mechanical PV, movement will be designed using a system that is as simple as possible and with good movement angle accuracy.

In addition, there is an accumulator that serves to supply the two servo motors and the microprocessor used. Using a mini servo motor makes the required power becomes small, so it does not interfere with the system. In order to supply the mini servo motor, a dc-to-dc power supply circuit is added according to the voltage and current required for the driving motor. At the same time, the battery will also be filled by solar panels through the charge controller.

B. Research Stages

This research was conducted in the New Renewable Energy Laboratory of Electrical Engineering Bali State Polytechnic. The stages of this research are shown in Fig. 2.

The initial survey was conducted to determine the requirements and the system's configuration and to determine the output of mini solar cells as sensors.

Furthermore, the solar tracker model is made based on a microcontroller with a driving motor using a servo motor. As

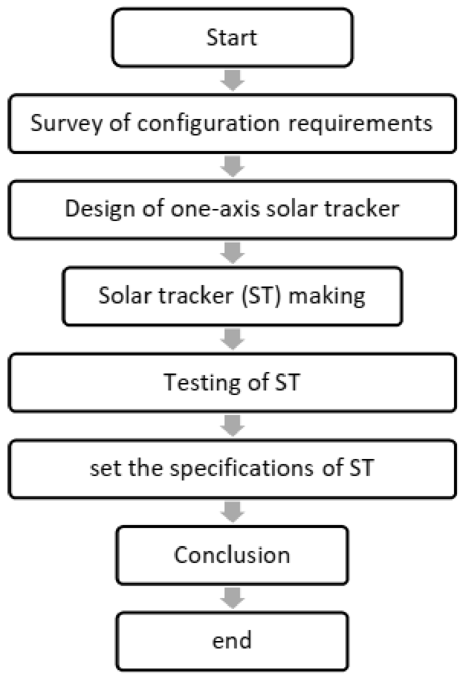

Fig. 1. Research Stages

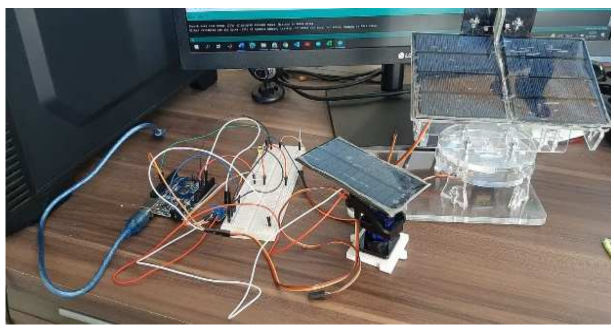

Fig. 2. Developed the prototype of proposed system of solar tracker

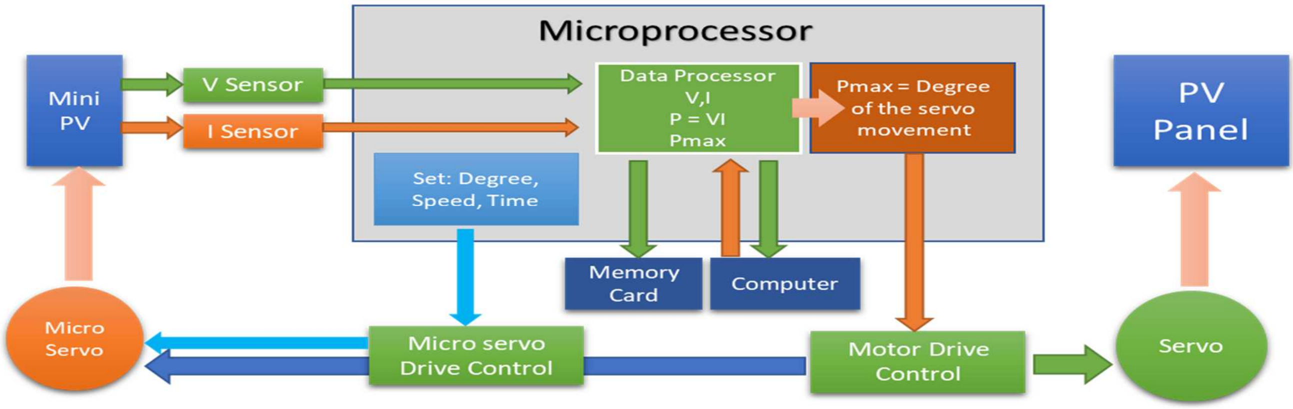

Fig. 5. Data Acquisition for the proposed system

a result, the servo motor can rotate according to the desired angle with a command input from the microprocessor. This tracker is then tested according to standards and sets its specifications. Finally, conclusions are drawn from the performance of this method.

III. Result and Discussion

The developed solar tracker must be low-cost, so Arduino Uno is used as the microprocessor, used as a data processing area, and then the micro-servo motor drive and provides input signals for large servo motor drives shown in Fig. 3.

The component used is a mini solar panel measuring 11 x 6 cm with an output of 6 volts which also functions as a solar light sensor with a specific angle setting, which is driven by a micro servo. Voltage and current sensors are installed to determine the output, then processed in the microprocessor to obtain the maximum voltage and current at a certain angle. The resulting angle then drives both a micro servo and a large servo motor of the big solar panel. All data from voltage and currents sensors and processed data in microprocessor are stored in memory card for data record and for other application. Fig. 4. shows the process of acquiring data.

Micro-servo motion settings are carried out with several variations to obtain optimum results. Due to the sun moving about 15 degrees in one hour, the servo movements on this research were set to move 20 degrees every 10, 15, 20, 30, and 60 minutes to ensure the degree of the sun's movement. The number of data is 20 with 1 data per degree, and the time interval of the movement is every 500 ms. In general, the code of the program for this proposed method can be described in Listing 1.

LISTING I. GENERAL PROGRAM FOR PROPOSED METHOD

```
d, v, i    //Data of  degree (d), voltage (v) and
current (i) are acquired from the pv
P = v . i  //Data v and i is multiply to find power
(P)
for n =(1,20),  n = n + 1 //Repeated action for 20
data
Pmax = Max(Pn)   //find the maximum of p
dn = at pmax //find the degree (dn) of movement where
the p is maximum
if dn < = 0 then dn = 0
else
dn        // drive both servos using this degree
information
end
```

TABLE I. OUTPUT DATA OF THE MINI PV

Degree	Current (mA)	Voltage (V)
1	1,24	0,620
2	1,26	0,630
3	1,24	0,620
4	1,31	0,655
5	1,31	0,655
6	1,34	0,670
7	1,31	0,655
8	1,21	0,605
9	1,29	0,645
10	1,21	0,605
11	1,21	0,605
12	1,24	0,620
13	1,24	0,620
14	1,18	0,590
15	1,21	0,605
16	1,24	0,620
17	1,21	0,605
18	1,16	0,580
19	1,21	0,605
20	1,16	0,580

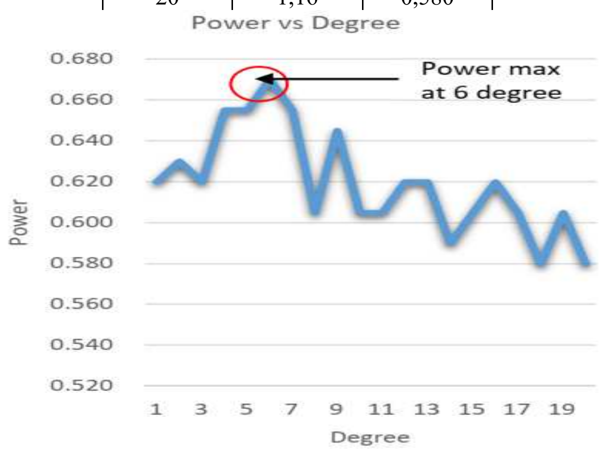

Fig. 4. Graph of Power versus Degree

All data is stored in a memory card for later use, such as data analysis. Data was collected from 08:00 in the morning until 16:00 or in 8 hours. So, for 10 minute- intervals, the number of data would be 960, while for 60 minute-interval would be 160. The example data of the output of both sensors, current and voltage, for 0 – 20 degrees are presented in Table I. These data then were multiplied to find power (p) values, and the results can be seen in Fig. 5.

TABLE III. OUTPUT DATA OF THE MINI PV AT 09:20AM

Degree	Current (mA)	Voltage (V)	Power (mW)
1	22.2	6.01	133.42
2	25.1	6.25	156.88
3	26.3	6.88	180.94
4	27.5	6.89	189.48
5	25.4	6.85	173.99
6	25.2	6.85	172.62
7	25.1	6.81	170.93
8	25.0	6.76	169.00
9	24.8	6.71	166.41
10	24.3	6.66	161.84
11	24.3	6.61	160.62
12	24.1	6.46	155.69
13	23.9	6.31	150.81
14	23.6	6.23	147.03
15	23.1	6.18	142.76
16	22.6	6.10	137.84
17	21.0	6.04	126.80
18	20.8	5.98	124.32
19	20.2	5.92	119.50
20	19.5	5.86	114.17

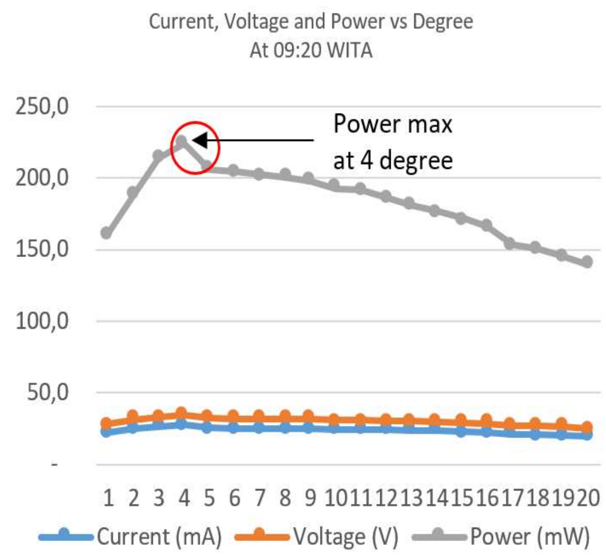

Fig. 6. Graph of Power versus Degree

Fig. 5 shows the multiplication result of current and voltage data from the mini solar cell outputs. In this case, the acquiring data is at every one degree, so the number of the data collection is 20 both for voltage and current for 20-degree movements. The process after collecting the data is multiplying voltage and current to get the power. At the maximum power, the degree of the movement for the second solar panel can be found. In this case, the maximum value is at 6 degree. This degree's value is then used to drive both mini servo and big servo motor.

TABLE IV. PERFORMANCE OF THE SOLAR TRACKER

No	Condition	Operates	Acurrate
1	Normal/sunny day	yes	96 - 100%
2	Partly Cloudy t <= 80minutes 	yes	90 – 100%
3	Cloudy t <= 80minutes 	yes	70 – 100%
4	Cloudy t > 80 minutes 	yes	50% - 100%

Table II and Fig. 6 show another example of the output of mini PV at 09:20am in the morning and their projection in a graph. As shown in Fig. 6, the maximum power is found at 4 degree movement from the current position. Performances of the solar tracker is evaluated for movement of the tracker based on the motion of the sun. The result can be seen in Table II.

On the normal or sunny day, this tracker operates accurately. On the cloudy condition it operates correctly if the period of the cloud is less than 80 minutes. For the cloudy day more than 80 minutes, the error incerase gradualy. This is because the movement of the tracker is 20 degree for every period. It means duration for reaching 20 degree is 80 minutes where for 1 degree motion of the sun needs 4 minutes. In the cloudy condition especially happens for long period, sometime this tracker produces error value.

IV. CONCLUSIONS

The new approach in the solar tracker is proposed by using a mini solar tracker to find an optimum point of the sunlight in harvesting solar energy from the sun. This method is collected data voltage and current from the mini solar panel to get the optimum power at a specific point. This method is applied by using Arduino as a microprocessor and using a micro servo for the rotation of the mini solar tracker. The results show that this strategy can detect the specific movement of the sunlight and produce the optimum power of the solar panel. The performances of the solar tracker are good in sunny day, but less effective in the cloudy condition for more than 80 minutes. For further research, the angle of movement and delay time should be checked in a long-term period to find an optimum setting for this solar tracker. It is also possible to find out the energy efficiency of the motor.

ACKNOWLEDGMENT

The authors thank the Center of Research and Community Service, Politeknik Negeri Bali, for funding this research.

REFERENCES

[1] A. Maleki, I Sadeghkhani, B. Fani, “Statistical sensorless short-circuit fault detection algorithm for photovoltaic arrays”, Journal of Renewable and Sustainable Energy, 11(5), 053501, 2019.

[2] Yong-Nong Chang, "Cubic Composite Sensor with Photodiodes for Tracking Solar Orientation", Journal of Nanomaterials, vol. 2013, Article ID 619105, 7 pages, 2013. https://doi.org/10.1155/2013/619105.

[3] G.M.Tina, F.Arcidiacono, A.Gagliano, “Intelligent sun-tracking system based on multiple photodiode sensors for maximisation of photovoltaic energy production”, Mathematics and Computers in Simulation, Volume 91, May 2013, pp. 16-28.

[4] M. Haryanti, A. Halim and A. Yusuf, "Development of two axis solar tracking using five photodiodes," 2014 Electrical Power, Electronics, Communicatons, Control and Informatics Seminar (EECCIS), Malang, Indonesia, 2014, pp. 40-44, doi: 10.1109/EECCIS.2014.7003716.

[5] Dadi, V., Peravali, S. Optimization of light-dependent resistor sensor for the application of solar energy tracking system. SN Appl. Sci. 2, 1499 (2020). https://doi.org/10.1007/s42452-020-03293-.

[6] J. Parthipana, B. Nagalingeswara Rajub, S. Senthilkumara, “Design of one axis three position solar tracking system for paraboloidal dish solar collector”, Materials Today: Proceedings, Volume 3, Issue 6, 2016, pp. 2493-2500.

[7] Ilham, D.N., Fadhila, F., Nababa, E. B., Suherman, Cabdra R. A., “Optimizing solar panel output by using light sensors, driving motors and fuzzy controller”, 1st South Aceh International Conference on Engineering and Technology IOP Conf. Series: Materials Science and Engineering 506 (2019) 012042 IOP Publishing doi:10.1088/1757-899X/506/1/012042 1.

[8] S. H. Krishnan, D. Ezhilarasi, G. Uma and M. Umapathy, "Pyroelectric-Based Solar and Wind Energy Harvesting System," in IEEE Transactions on Sustainable Energy, vol. 5, no. 1, pp. 73-81, Jan. 2014, doi: 10.1109/TSTE.2013.2273980.

[9] Puneet Azad Khushboo Rahul Vaish, “Solar Energy Harvesting Using Pyroelectric Effect Associated with Piezoelectric Buzzer, Physic Status Solidi Sa, Applications and Materials Sciemce, Volume 216, No 20 October 2019, https://doi.org/10.1002/pssa.201900440.

[10] Jose I. Rodriguez1, “ Feasibility of Passive Cryogenic Cooling for Solar Powered Outer Planetary Missions”, 47th International Conference on Environmental Systems ICES-2017-341 16-20 July 2017, Charleston, South Carolina.

[11] Stamatescu, Iulia, Fagarasan, Ioana, Stamatescu, Grigore, Arghira, Nicoleta, Iliescu, Sergiu Stelin, Design and implementation of a solar tracking algorithm. Procedia Eng. 69, 500–507. http://dx.doi.org/10.1016/j.proeng. 2014.03.018.

[12] Suryono, S., Jatmiko, E. S., Ainie, K. R. S., and Tahan, P., “Using a Fuzzy Light Sensor to Improve the Efficiency of Solar Panels”, The 2nd International Conference on Energy, Environmental and Information System (ICENIS 2017), E3S Web Conf. Volume 31, 2018, https://doi.org/10.1051/e3sconf/20183101007.

[13] D. Fontani, P. Sansoni, F. Francini, D. Jafrancesco, L. Mercatelli, E. Sani, "Pointing Sensors and Sun Tracking Techniques", International Journal of Photoenergy, vol. 2011, Article ID 806518, 9 pages, 2011. https://doi.org/10.1155/2011/806518.

[14] Anshul Awasthi, Akash Kumar Shukla, Murali Manohar S.R.,Chandrakant Dondariya, K.N. Shukla, Deepak Porwal, Geetam Richhariya, “Review on sun tracking technology in solar PV system”, Energy Reports 6 (2020) 392–405.

[15] Poulek, V., New low cost solar tracker. Sol. Energy Mater. Sol. cells 33, 1994, pp. 287–291. http://dx.doi.org/10.1016/0927-0248(94)90231-3.

[16] pveducation, Fixed or tracking array. 2019. https://pveducation.com/solarconcepts/fixed-or-tracking-array/ (accessed Feb 27 2021).

[17] E. Kabalcı, A. Calpbinici and Y. Kabalci, "A single-axis solar tracking system and monitoring software," 2015 7th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), Bucharest, Romania, 2015, pp. SG-17-SG-22, doi: 10.1109/ECAI.2015.7301193.

[18] Seme, S., Srpcic, Gregor, Kavsek, Domen, Bozicnik, Stane, Letnik, Tomislv, Praunseis, Zdrravko, Stumberge, Bojan, Hadziseimovic, Miralem, “Dual axis photovoltaic tracking system-design and experiment investigation”, Energy, http://dx.doi.org/10.1016/j.energy.2017.05.153.

[19] Flores-Hernandez, D.A., Palomino-Resendiz, S., Lozada-Castillo, N., Luviano-Juarez, A., Chairez, I., Mechatronic design and implementation of a two axes Sun tracking photovoltaic system driven by robotic sensor. Mechatronics 47, 2017, pp. 148–159, http://dx.doi.org/10.1016/j.mechatronics.2017.http://dx. doi.org/10.1016/j.rser.2014.11.09069009.014.

[20] Abdollahpour, Masoumeh, Golzarian, Mahmood Reza, Rohani, Abbas, Zarchi, Hossein Abootorabi, “Development of a machine vision dual-axis solar tracking system”. Sol. Energy 169, 2018, 136–143. http://dx.doi.org/10.1016/j.solener.2018.03.059.

[21] S. Ozcelika*, H. Prakashb, R. Challooc, “Two-Axis Solar Tracker Analysis and Control for Maximum Power Generation”, Procedia Computer Science 6 (2011) 457–462.

[22] B. K. S. Vastav, S. Nema, P. Swarnkar and D. Rajesh, "Automatic solar tracking system using DELTA PLC," 2016 International Conference on Electrical Power and Energy Systems (ICEPES), Bhopal, India, 2016, pp. 16-21, doi: 10.1109/ICEPES.2016.7915899.

[23] Md. E Hoque, F. Rashid. S Shahriar. K. Islam, “An Automatic Solar Tracking System Using Programmable Logic Controller”, Conference: International Conference on Mechanical, Industrial and Energy Engineering 2018, Khulna, Bangladesh, 2018.

[24] O. T. Mahmood, "Programmable logic controller based design and implementation of multiple axes solar tracking system," 2013 International Conference on Electrical Communication, Computer, Power, and Control Engineering (ICECCPCE), Mosul, Iraq, 2013, pp. 101-106, doi: 10.1109/ICECCPCE.2013.6998742.

[25] B. Koyuncu and K. Balasubramanian, "A microprocessor controlled automatic sun tracker," in IEEE Transactions on Consumer Electronics, vol. 37, no. 4, pp. 913-917, Nov. 1991, doi: 10.1109/30.106958.

[26] S. Jain, R. Jain, “Microcontroller Based Solar tracking System for enhancing efficiency of a Photovoltaic system”, Int. Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol. 4, Issue 9 (Version 4), September 2014, pp.73-78.

[27] G. N. Ryavkin, E. V. Solomin and O. J. Abdalgbar, "Solar Tracker with Self-Deploying System," 2020 International Ural Conference on Electrical Power Engineering (UralCon), 2020, pp. 87-92, doi: 10.1109/UralCon49858.2020.9216230.

[28] C. D. Rodríguez-Gallegos, O. Gandhi, S. K. Panda and T. Reindl, "On the PV Tracker Performance: Tracking the Sun Versus Tracking the Best Orientation," in IEEE Journal of Photovoltaics, vol. 10, no. 5, pp. 1474-1480, Sept. 2020, doi: 10.1109/JPHOTOV.2020.3006994.