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Implementation of fuzzy logic MPPT based on Arduino in small scale PV pumping system

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ABSTRACT

The performance of photovoltaic (PV) affected directly by climatic changes, The controller maintain maximum potential energy conversation to operate the pimping system at nominal conditions, fuzzy logic intelligent controllers are successfully suitable and applicable in engineering and applied science. The aim of this paper is present an experimental approach in Implementation of fuzzy logic maximum power point tracking (MPPT) with boost converter based on Arduino Mega micro-controller to maximize energy production in different weather condition applied to small scale pumping system for water and chemical fluid analyses in isolated area. The system is supplied by 20 (W) solar photovoltaic (PV) panel. This paper present a real-time MATLAB/Simulink fuzzy logic method controlling and monitoring MPPT application using an low cost Arduino Mega micro-controller combined with (LV25, LP55) sensors controlling boost converter interconnected with solar panel and plastic pump.

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1. INTRODUCTION

The need for energy is daily increasing in all countries, in the ruler and isolated areas solar energy developing into most economical future renewable energy (RE) source for electricity production applied worldwide [1], photovoltaic systems are built from interconnected components to retch the load requirements in most verity conditions (temperature, solar irradiation, load limits) [2], however to achieve the maximum power production boost converter control the output voltage upgrade stability of power based on software controlling for optimal power point tracking (MPPT) [3].

The successful development of low cost micro-controllers that can be used in varying industrial fields and human life enhancement, moreover computer since played a role in artificial intelligence programming to make systems more protective and reliable, in last three decades several MPPT algorithms tested to the maximum power point of the photovoltaic generator, some MPPT techniques rich better results in specific conditions but with the sudden variation efficiency decrease [4], fuzzy logic controller has improve height performance in optimization of output electric power to supply pumps [5], [6], intended for chemical fluid analysers plastic pumps are made to transport substances that would corrode or harm other kinds of pumps. They are more affordable and lighter than metal pumps, and they offer a wide range of chemical resistance [7].

This paper explains an experimental result of photovoltaic system to feed fluid pump based on Arduino Mega micro-controller occupied with sensors (LV25, LP55) in real time MATLAB/Simulink fuzzy logic controller proving the efficiency of energy conversation to the pump. The rest of paper is organized as follows: i) Proposed control method in section 2; ii) The experimental tests and discussion of the system results are presented in section 3; and iii) Finally, the concluding remarks stated in section 4.

2. PROPOSED CONTROL METHOD

To produce maximum power from our system, we developed new simple law based on the selection of fuzzy logic trapezoidal membership, which is able to find the voltage value for the PV panel. First we take the measurements of PV panel voltage and current to help us designing the fuzzy logic controller in Arduino Mega drive a boost converter to determine the appropriate voltage to extract maximum power from the PV panel for each irradiation and temperature conditions [8], [9].

The design of fuzzy logic controller Figure 1 require three steps: the first step; fuzzifcation of input voltage and current with trapezoidal function, the second step: the fuzzy rules as shown in Table 1 which defines the system responses for each condition, then the last step is the defuzzifcation to go back to reel value in this case the duty cycle output for the boost converter insulated gate bipolar transistor (IGBT) switch [10], [11].

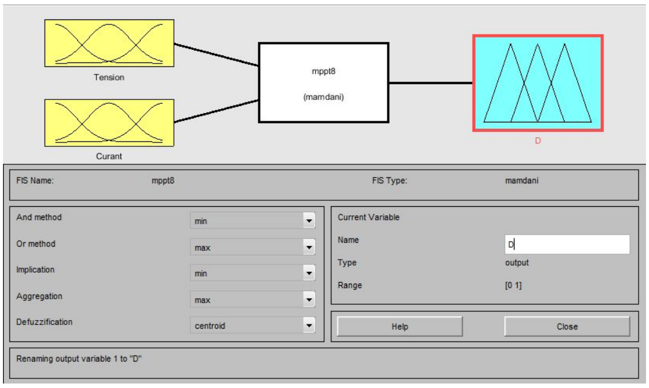


Figure 1. Fuzzy logic designer

Table 1. Fuzzy rules

I /ΔV	LOW	MIDUME	HIGH
LOW	H	H	L
MIDUME	H	M	L
HIGH	H	L	L

2.1. Boost converter

The variation of sunlight during the day makes output voltage of solar panel not stable, the increase and decrease of system Figure 2 power cant mange to power the loud as desired [12], to avoid this problem a boost converter electronic circuit Figure 3 is needed to control output voltage [13], [14]. The electronic elements of boost converter are: capacitor, inductor, IGBT, diode, the selected components characteristic are demonstrated in Table 2 [15]. The relation between input and output voltages of the boost converter is given as (1),

$$V_{out} = \frac{1}{1-D} V_{in} \tag{1}$$

with D is the duty cycle which given as (2),

$$D = \frac{T_{on}}{T_S} \tag{2}$$

with T_{on} is the on-state time of the IGBT and T_S is the total switching time [16].

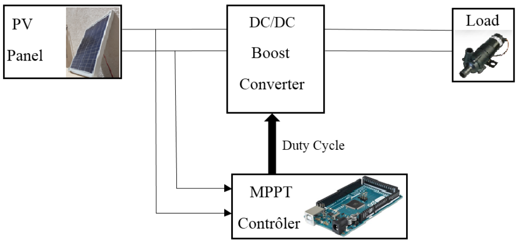


Figure 2. Photovoltaic system

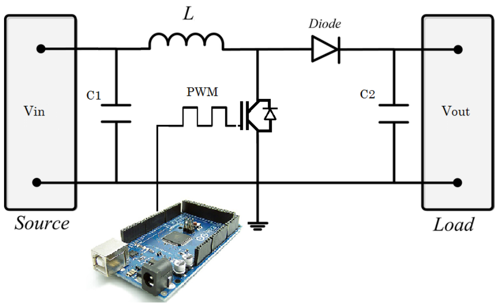


Figure 3. Boost converter electronic circuit

Table 2. Boost converter setup

Boost converter setup	
C1	220 μf
C2	220 μf
L	0.1 H
f	1 KHz
Controller type: Arduino Mega	
IGBT type: BUP314	
Diode type: BYV32-200	

2.2. Arduino Mega

The measurement principle adopted in this test bench is to take the current Ipv supplied by PVG and voltage Vpv between its terminals. These quantities Ipv and Vpv are delivered by the current and voltage sensors connected to the inputs of the analogue to digital converter integrated into the Arduino board type Mega 2560 [17]. A processing unit, built around the micro-controller of the Arduino Mega board; is programmed to ensure the automation of the pumping station [18]. This unit captures the information delivered by the various sensors and controls the actuators accordingly to a computer via a RS232/USB serial converter cable facilitate the communication and programming with Arduino software or MATLAB, the main characteristic are illustrated in Table 3 [19], [20].

Table 3. Arduino Mega data

Microcontroller	ATmega2560
Operating Voltage	5 V
Input Voltage (recommended)	7-12 V
Input Voltage (limits)	6-20 V
Digital I/O Pins	54 (14 provide PWM output)
Analog Input Pins	16
DC current per I/O Pin	40 mA
DC current for 3.3 Pin	50 mA
Flash Memory	256 KB
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

2.2.1. Current sensor LA55

Current transducer LA55-P is electronic component for measuring several types of currents (DC, AC, pulsed,...) with galvanic separation between the primary circuit up to 50 A and the secondary circuit [21], the relationship between primary circuit current and the secondary circuit current is (3), with I_s: secondary circuit current, N: spears number, I_p: primary nominal current, R_m: measuring resistance, V_m: measuring voltage [22].

$$I_s = N * I_p/1000 V_m = I_s * R_m \tag{3}$$

2.2.2. Voltage sensor LV25

Electronic voltage transducer LV25-P measurement of currents (DC, AC, pulsed,...) with galvanic separation between the primary circuit and the secondary circuit [23], the relationship between primary circuit voltage with maximum value of 500 V and the secondary circuit voltage is (4), with V_p: primary circuit voltage, R_1: primary circuit resistance, V_m: measuring voltage, I_s: secondary circuit current, R_m: measuring resistance [24].

$$V_p = I_p * R_1 V_m = I_s * R_m \tag{4}$$

3. EXPERIMENTAL RESULT AND DISCUSSION

The simulation studies are carried out using MATLAB (R2017a version). Seeking to validate the theoretical concepts and simulation studies experimental prototype of the system is developed in laboratory which is shown in Figure 4. In this section, we present the tests results of our pumping system. (PV panel, sensors, fuzzy logic MPPT controller, Arduino Mega, DC-DC converter, pump unit).

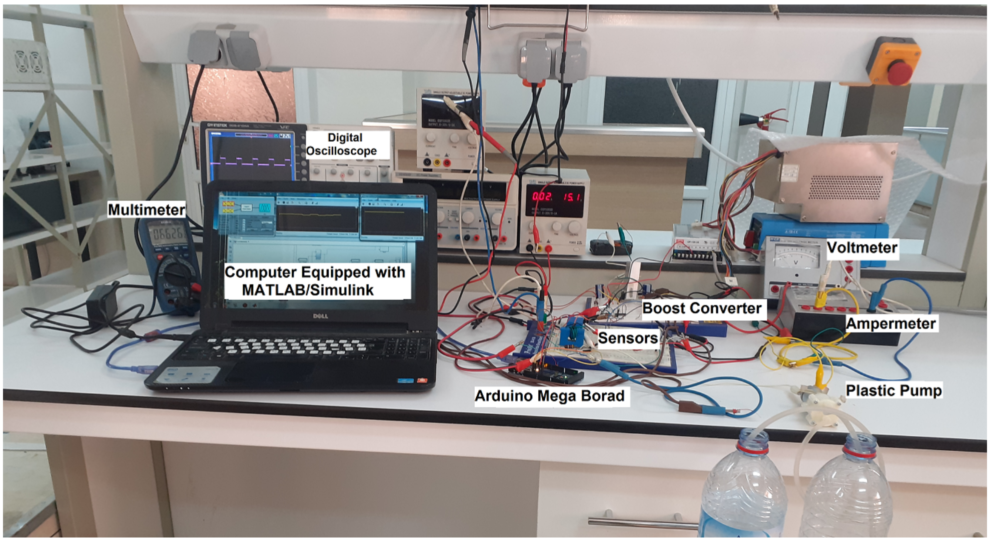
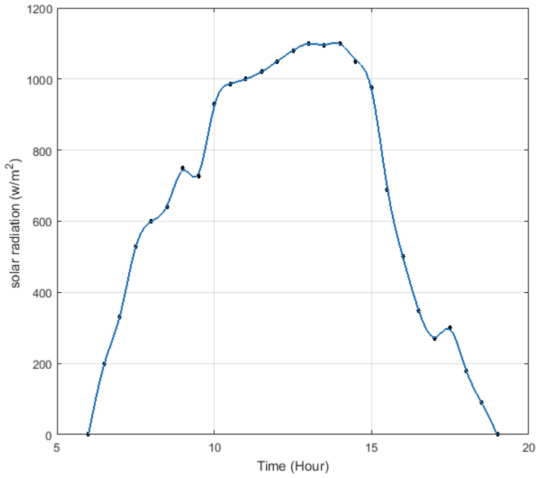


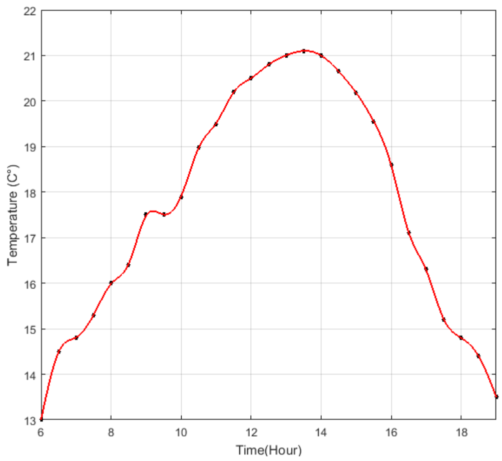
Figure 4. Experimental test bench

3.1. PV System test site climatic data

Figures 5(a) and 5(b) show ambient temperature and irradiation of testing field clear sky in 7th March 2021 to view the variation form and the amount of ambient power available during the testes, these figures shows maximum solar radiation of 1.1 kW/m^2 with 21.2 °C, so PV generation power quality accessible is very approximate to the PV standard conditions. It is clear from graphs that solar radiation intensity increases from 6 AM to 15 PM and decreases from 15 PM to 19 PM in case of clear sky. The temperature values variation depend on climatic conditions of the test area more than the weather, in this test day the temperature between 13 °C at 6 AM and 21.2 °C at 13:30 PM.



(a)



(b)

Figure 5. Ambient climatic conditions (a) radiation and (b) temperature

3.2. Practical voltage and current sensors output

First for a given insolation, to trited the sensors and upgrade the accuracy of measurement, we regulate the Arduino sensors (voltage, current) output monitor by MATLAB/Simulink 2017a software on Dell computer with Intel core i3, 2.4 GHz processor, 4 GB of RAM memory and windows 7 operating system. The results have the same values measured by amperemeter and voltmeter Figure 6, this figure reveal the steady state performance LV25 and LA55 with high precision. Moreover the outputs of the sensors are given to the analogue inputs converted to digital signal by Arduino Mega board Processor. The Arduino Mega selected pins for sensors are POWER GND pin with ANALOG IN A0 pin For LA 55 current sensor and POWER GND pin with ANALOG IN A2 pin for LV 25 voltage sensor. The dynamic performance and precision of the sensors give the overall system more feasible efficiency in extracting the maximum power.

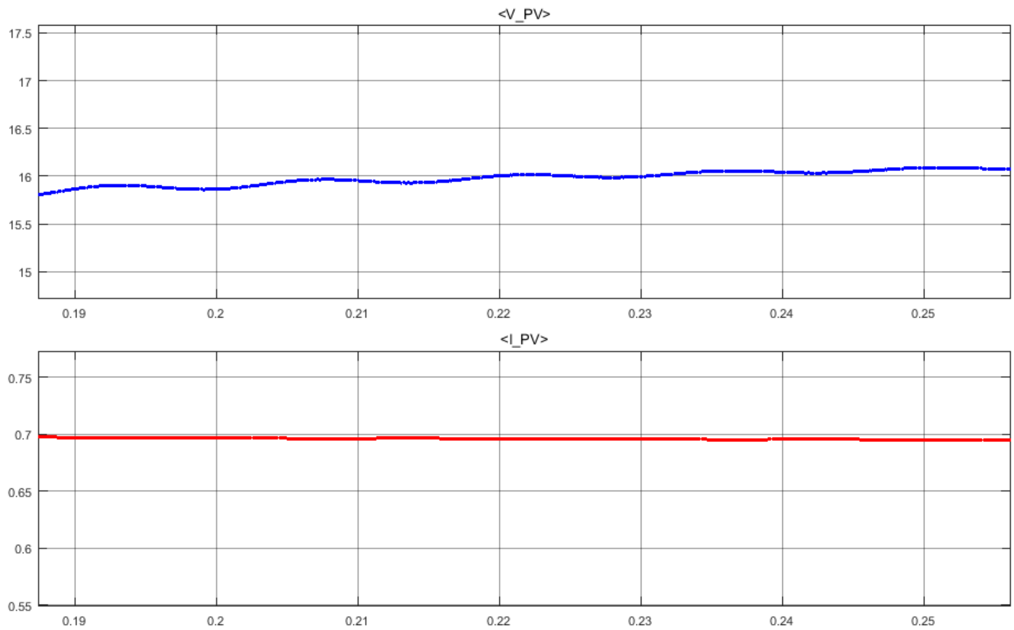


Figure 6. Arduino sensors voltage and current output

3.3. Arduino Mega PWM signal

We tested the destined MATLAB/Simulink simulation by the implementation in Arduino Mega PWM signal output, the feedback results shown in Figure 7 match the form and variation values of duty cycle rate with simulated control system, good accuracy. Experimentally obtained rectangular waveform depicted. The obtained practical responses completely verified with high accuracy.

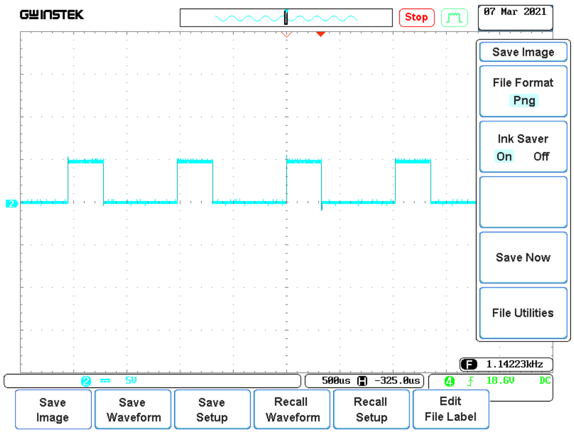


Figure 7. PWM output signal of Arduino Mega

3.4. Arduino Mega PWM signal amplification

The IGBT gate of boost converter need 15 volt to function for that we managed to amplify Arduino Mega 5 volt PWM signal via electronic driver the result illustrated in Figure 8, as well as it can be seen clearly, the very quickly and efficiently signal pursuit. Therefore the generate PWM signal have required characteristics which provides optimal control of boost converter.

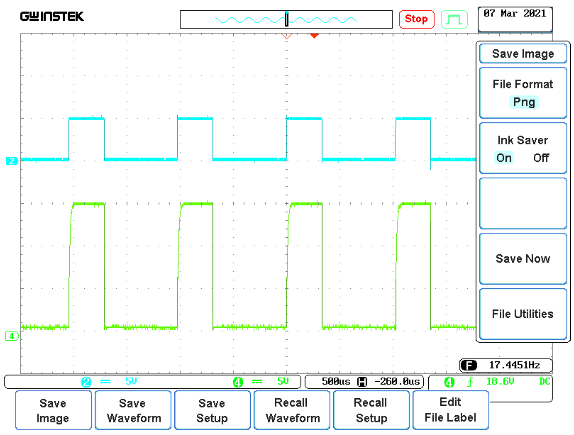


Figure 8. Amplified Arduino Mega PWM signal

3.5. Experimental power point tracking

The experiment's results presented below Figures 9 and Figure 10 shows the generated power and the maximum power point tracking. Compared to the theoretical reserves, it is one can see a perfect match reflecting the effectiveness of the proposed control algorithm (strategy). After analysing these figures, we notice that the system pursuit the MPP with stable response and accurate variation form in energy conversation reference to ambient insolation power available, as result system reaches 92% of maximum power from the hardware components tested in ideal conditions.

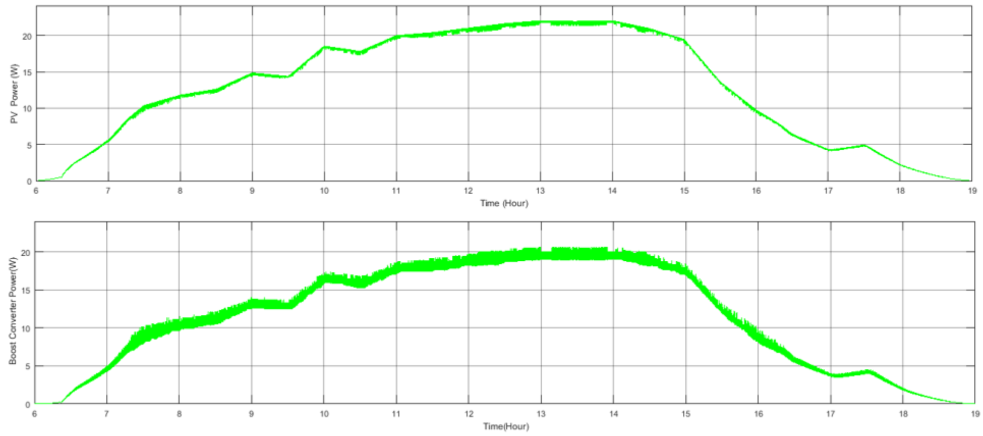


Figure 9. PV panel power and chopper output power

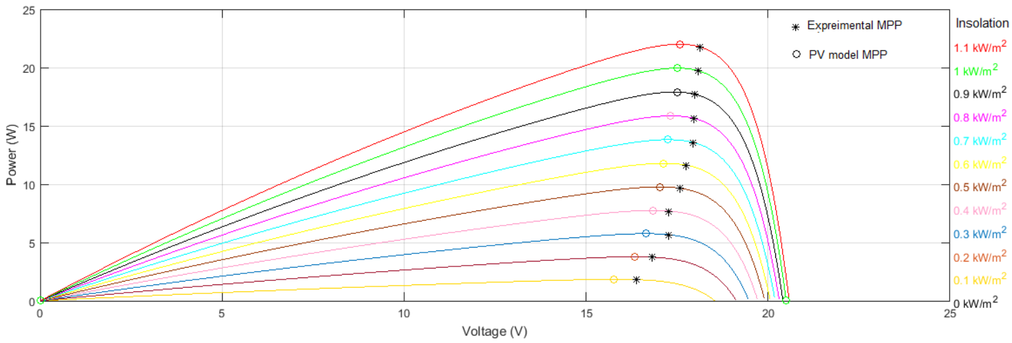


Figure 10. Excremental MPP function of voltage

3.6. Pump unit performance

To evaluate the effectiveness of the pump Figure 11 depicts pump discharge function of pump power. As the energy in pump increases, the pump discharge will also increase [25]. Moreover voltage stability and required current supply maintain the nominal pumping unit power delivered. Therefore the high performance of pumping unit during transient and dynamic conditions improve the optimal power conversation and reliable system operation.

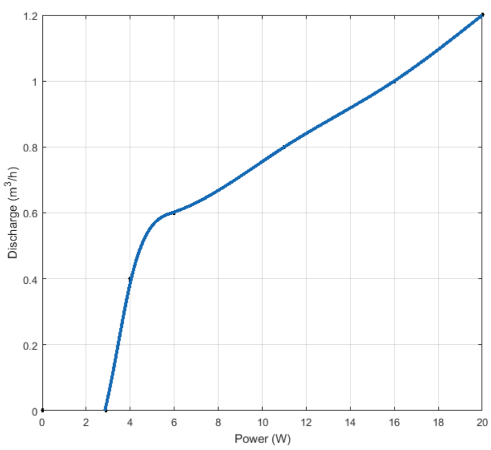


Figure 11. Discharge function pump power

4. CONCLUSION

This paper presents experimental study of using Arduino Mega micro-controller equipped by voltage and current sensor in real time MATLAB/Simulink, fuzzy logic control method for pumping. The main problem in PV systems, high cost and low efficiency due the influence of climatic conditions on the PV output, finally after testing the proposed system with variant temperature and irradiance profiles. We found that fuzzy logic controller prove low cost solution in Arduino Mega controller for pumping systems and high efficiency of the last to minimise the oscillations and successfully monitor the maximum power point while the outside environment conditions varies.

REFERENCES

[1] M. Elyaqouti, S. Hakim, S. Farhat, L. Bouhouch, and A. Ihlal, "Implementation in Arduino of MPPT using variable step size P&O algorithm in PV installations," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 8, no. 1, pp. 434–443, 2017, doi: 10.11591/ijpeds.v8i1.pp434-443.

[2] A. H. Numan, Z. S. Dawood, and H. A. Hussein, "Theoretical and experimental analysis of photovoltaic module characteristics under different partial shading conditions," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 11, no. 3, pp. 1508–1518, 2020, doi: 10.11591/ijpeds.v11.i3.pp1508-1518.

[3] A. Saadi and A. Moussi, "Optimisation of Chopping ratio of Back-Boost Converter by MPPT technique with a variable reference voltage applied to the Photovoltaic Water Pumping System," *2006 IEEE International Symposium on Industrial Electronics*, 2006, pp. 1716–1720, doi: 10.1109/isie.2006.295829.

[4] P. Santra, "Performance evaluation of solar PV pumping system for providing irrigation through micro-irrigation techniques using surface water resources in hot arid region of India," *Agricultural Water Management*, vol. 245, p. 106554, 2021, doi: 10.1016/j.agwat.2020.106554.

[5] F. Chabni, R. Taleb, A. Benbouali, and M. A. Bouthiba, "Digital Control Fuzzy Logic for a Water Tank Level Using Arduino," *Algerian Journal of Signals and Systems*, vol. 1, no. 1, pp. 2–10, 2016, doi: 10.51485/ajss.v1i1.12.

[6] S. Assahout, H. Elaissaoui, A. El Ougli, B. Tidhaf, and H. Zrouri, "A neural network and fuzzy logic based MPPT algorithm for photovoltaic pumping system," *International Journal of Power Electronics and Drive System (IJPEDS)*, vol. 9, no. 4, pp. 1823–1833, 2018, doi: 10.11591/ijpeds.v9.i4.pp1823-1833.

[7] J. Li, L. Tang, and Y. Zhang, "The influence of blade angle on the performance of plastic centrifugal pump," *Advances in Materials Science and Engineering*, vol. 2020, pp. 1–20, 2020, doi: 10.1155/2020/7205717.

[8] O. Djamel, G. Dhaouadi, S. Youcef, and M. Mahmoud, "Hardware Implementation of Digital PID Controller for DC–DC Boost Converter," in *2019 4th International Conference on Power Electronics and their Applications (ICPEA)*, 2019, pp. 1–4, doi: 10.1109/icpea1.2019.8911129.

[9] R. A. Mejeed, S. S. Oudah, and R. Y. Abed, "Design of solar photovoltaic pressurized drip irrigation pumping system at Al-salman District in Samawa Governorate," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 10, no. 3, pp. 1628–1637, 2019, doi: 10.11591/ijpeds.v10.i3.pp1628-1637.

[10] P. Zhai and E. D. Williams, "Analyzing consumer acceptance of photovoltaics (PV) using fuzzy logic model," *Renewable Energy*, vol. 41, pp. 350–357, 2012, doi: 10.1016/j.renene.2011.11.041.

[11] T. A. Wani *et al.*, "A review of fuzzy logic and artificial neural network technologies used for MPPT," *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, vol. 12, no. 2, pp. 2912–2918, 2021, doi: 10.17762/turcomat.v12i2.2327.

[12] F. Satybaldiyeva, R. Beisembekova, A. Saribayev, G. Z. Yessenbekova, and A. Kultas, "Development of models of the maximum power of the solar energy tracking system based on a photopanel," *Journal of Theoretical and Applied Information Technology*, vol. 99, no. 6, pp. 1402–1413, 2021, [Online]. Available: http://www.jatit.org/volumes/Vol99No6/14Vol99No6.pdf.

[13] K. Benlarbi, L. Mokrani, and M. S. Nait-Said, "A fuzzy global efficiency optimization of a photovoltaic water pumping system," *Solar energy*, vol. 77, no. 2, pp. 203–216, 2004, doi: 10.1016/j.solener.2004.03.025.

[14] C. Robles Algarín, J. Taborda Giraldo, and O. Rodriguez Alvarez, "Fuzzy logic based MPPT controller for a PV system," *Energies*, vol. 10, no. 12, p. 2036, 2017, doi: 10.3390/en10122036.

[15] D. P. Kothari, A. Pathak, and U. Pandey, "Comparative study of different solar photovoltaic arrays configuration to mitigate the negative impact of partial shading conditions," *Journal of Mechanics of Continua and Mathematical Sciences*, vol. 16, no. 2, pp. 102–111, 2021, doi: 10.26782/jmcms.2021.02.00009.

[16] N. Hashim, Z. Salam, D. Johari, and N. F. N. Ismail, "DC-DC boost converter design for fast and accurate MPPT algorithms in stand-alone photovoltaic system," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 9, no. 3, pp. 1038–1050, 2018, doi: 10.11591/ijpeds.v9.i3.pp1038-1050.

[17] O. A. Ahmed, H. K. Sayed, K. A. Jalal, D. Y. Mahmood, and W. H. Habeeb, "Design and implementation of an indoor solar emulator based low-cost autonomous data logger for PV system monitoring," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 10, no. 3, pp. 1645–1654, 2019; doi: 10.11591/ijpeds.v10.i3.pp1645-1654.

[18] M. Lutfi, "Datasheet arduino mega 2560," 2017, [Online]. Available: http://eprints.polsri.ac.id/4613/8/FILE VIII.pdf.

[19] W. Gao, X. Luo, Y. Liu, Y. Zhao, and Y. Cui, "Development of an Arduino-based integrated system for sensing of hydrogen peroxide," *Sensors and actuators reports*, vol. 3, p. 100045, 2021, doi: 10.1016/j.snr.2021.100045.

[20] R. Anbalagan, M. Z. Hussain, D. Jayabalakrishnan, D. B. N. Muruga, and M. Prabhahar, "Vehicle to vehicle data transfer and communication using LI-FI technology," *Materials Today: Proceedings*, vol. 45, pp. 5925–5933, 2021, doi: 10.1016/j.matpr.2020.08.786.

[21] V. Shah and S. Payami, "An integrated driving/charging four-phase switched reluctance motor drive with reduced current sensors for electric vehicle application," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 10, no. 6, pp. 6880–6890, 2021, doi: 10.1109/jestpe.2021.3120468.

[22] M. Chojowski, A. Dziadecki, M. Baszyński, R. Dudek, A. Stobiecki, and J. Skotniczny, "Wide Bandwidth and Inexpensive Current Sensor for Power Electronics—An Augmented LEM Current Sensor," *Energies*, vol. 14, no. 14, p. 4194, 2021, doi: 10.3390/en14144194.

[23] M. Kaczmarek, A. Szczesny, and R. Nowicz, "The study of electronic voltage transducers operation in conditions of dips and interruptions of measured voltage," *Bulletin of the Polish Academy of Sciences. Technical Sciences*, vol. 60, no. 3, pp. 645–649, 2012, doi: 10.2478/v10175-012-0076-8.

[24] M. H. M. Hariri, M. K. M. Desa, S. Masri, and M. A. A. Mohd Zainuri, "Design and Implementation of Three-phase Voltage and Current Transducers for Digital Signal Processing TMS320F28335," *Journal of Electrical Systems*, vol. 17, no. 1, pp. 141–153, 2021, [Online]. Available: http://journal.esrgroups.org/jes/papers/17_1_10.pdf.

[25] H. Suehrcke, J. Appelbaum, and B. Breshef, "Modelling a permanent magnet DC motor/centrifugal pump assembly in a photovoltaic energy system," *Solar energy*, vol. 59, no. 1–3, pp. 37–42, 1997, doi: 10.1016/s0038-092x(96)00117-x.

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