Modelling and Simulation of 12 MWP Independent Power Plant using Photovoltaic Energy Resources to a Grid Network

Abdulwahab Deji[1], Sheroz Khan[2], Mohammad Hadi Habaebi[3]

[1]Department of Electrical Computer Information and Telecommunication Engineering, Waidsum University Malaysia.
[2]Department of Electrical Engineering Onaizah College Saudi Arabia.
[3]Department of Electrical and Computer Engineering, International Islamic University Malaysia.

Abstract

This paper proposes a renewable energy resource (photovoltaic) to generate green and halal energy for household and feeding the excess energy into the Nigeria National Grid Network. The energy demand in third world nation like Nigeria will increase in nearest future. The renewable energy is one of the alternative energy sources that could satisfy the increasing energy demands. Nigerians depends heavily on fossil fuel to generate its electricity needs. Fossil fuels are depleted and the main source of pollution. Photovoltaic (PV) systems generate electricity directly from the sunlight without any emission of global warming gases, and the fuel is free. In order to optimize the performance of PV systems their operation should be well understood. In this paper, we present the modelling of a real 1.2 MWp photovoltaic system. The PV power plant is tied to the grid. The PV array, the DC/DC converter and the DC/AC inverter are modelled and implemented in Matlab/Simulink. The controller of the grid-connected inverter is modelled to achieve constant voltage, constant frequency and to be synchronized with the grid. The system is simulated under Nigeria weather conditions and the results are acceptable.

Keywords: Renewable Energy Resource, PV System, Grid Array, Mega Watts Power,, Load utilization, PV Power Plant, DC/AC Inverter, Solar Energy Generation, Load Power Metrics, , Green Energy, , PV to Load Ratio

INTRODUCTION

The energy demands and the negative environmental effects fossil fuel have necessitated the use of renewable energy sources. Producing an electric power from a halal and renewable energy can reduce the number of concerns regarding the inefficient use of electrical energy from fossil fuel. Also, a renewable energy development is one of the methods to cut the consumption of the oil and gas for export, thus reducing the dependency in such resources for electricity generation. Furthermore, these sources are clean, pollution free, and can be found globally with regard to the system size.

The Photovoltaic (PV) system can be grid connected or stand-alone. The PV technology is one of the fastest growing technologies where the increase in the installed PV systems is more than 29% as shown in Figure 1. The PV system has its own uniqueness compared to other systems, as the sunlight is free, sustainable and the solar radiation is directly converted into an electrical energy. Again, the absence of mechanical moving parts and the long life of the solar panels amount to a new uniqueness in feature. Many research papers showed that the solar PV energy is feasible in many countries [25]. The authors in [2] and [43-44] have discussed the feasibility of the rooftop PV systems in the United Arab Emirates. Ahmad Zahedi [3] has investigated the solar PV in Morocco and it is found that it is cost effective. To encourage the customers to install PV systems, Chile implements a net metering [4]. Spain has developed policies for implementing grid-connected PV systems [5]. A techno-economic analysis for PV systems in India is presented in [6]. In [7], the design and the economic feasibility of PV systems to power a small village in rural areas in Yemen have been investigated. Two options are considered: on-site PV system and off-site PV system. The off-site PV system is proved to be cost effective[44]. The potential of the grid-connected PV system for different locations in Bangladesh has been investigated in [8]. The feasibility study is carried out for 14 locations across Bangladesh for 1 MWp grid-connected PV system. The authors have showed that it is technically feasible to install a 50.147 GWp in Bangladesh. The performance of 15 MWp solar plant installed in Mouritania is analyzed in [9], where the thin film PV technology is implemented in the plant. A feasibility study for PV system in Cameron is carried out in [10].

FIGURE 1. The global annual installed solar PV capacity [1].

In all the contemporary research works, the PV systems have been technically and economically feasible. Nigeria has a high potential for solar energy harvesting. Matussin in [11] has discussed the renewable energy in Brunei Darussalam for a system which consists of 1.2 MWp installed capacity which are coming from Tenaga Suria Brunei (TSB) solar PV power plant, and it proves that the implementation of the solar PV power plant in Brunei Darussalam can reduce the use of the natural gas which helps in reducing the overall CO_2 emission from the conventional power plants since the country runs on natural gas for electricity generation [40, 41, 42].

To optimize the performance of grid-connected PV systems, the modelling system is essential. In [12 and 44], a model of single-phase grid-connected PV system is presented, the model is implemented in Matlab/Simulink. The modelling of three-phase grid-connected PV system is presented in [13, 37, 38 and 39]. The controller of the DC/AC three-phase inverter is designed to achieve constant DC link voltage while synchronizing the frequency and control the power factor [34, 35 and 36]. The performance analysis of grid-connected PV system using Matlab is introduced in [14 and 44]. A modelling and simulation study for a 45.35 kWp grid-connected PV system in Malaysia is investigated in [15]. In [16 and 44] the model of single-phase grid-connected PV system is implemented in Matlab Simulink. The simulation results are verified through practical implementation [30, 31, 32 and 33]. The sizing and the modelling of 1.5 MW grid-connected PV system is presented in [17-18 and 43-44]. The system is then implemented in Matlab/Simulink.

In order to understand the operation of the PV system and to increase their energy yield, their operation under Nigeria weather conditions should be investigated [26, 27, 28and 29]. In this paper, we present a model of the grid-connected PHCN PV power plant in Nigeria. The model of the PHCN PV power plant is implemented in Matlab/Simulink. In the next sections, the model of the grid-connected PV system is described. This includes the model of the PV array, DC/DC converter, Maximum Power Point Tracker (MPPT), the inverter and its controller. These models are then implemented in Matlab/Simulink. The PV grid connected system is then simulated under different weather conditions.

SOLAR ENERGY RESOURCE IN NIGERIA

Nigeria has high potential of solar energy availability. The solar radiation in Nigeria is shown in Figure 1. The solar radiation is in the range between 4.7 to 5.8 kWh/m^2 per day, which is considered as high range level globally. The irradiation is obtained using different sources such as NASA statistical data, estimation using Angstrom method, and measured data. The estimated values are higher than the measured and NASA statistical data, whereas both the measured and the data from NASA are approximately equal. However, all data values are realistic since they are within the reasonable global range of the irradiation. On this article, the NASA statistical data has been used to design the PV system due to its reliability and its regular updates as well as the flexibility to access the irradiation history from previous years up to date. The tilt angle of the PV array is one of the most important parameters in PV system design, Pacudan [19] has explained the significance of the tilt angle in order to achieve a maximum solar radiation which will improve the energy generation of the solar PV array. Based on the measured data from PHCN project in Nigeria, the 5° tilt angle gives a better overall electricity output compared with 15° tilt angle [19]. Figure 3 shows the aerial view of the PHCN PV power plant (PVPP). The configuration of the PVPP is shown in Figure 4. The PV system consists of six PV arrays each one is rated 2000 kWp. Each array is connected to a DC/DC converter to harvest maximum power and the output of each two DC/DC converter is connected to a DC/AC inverter [30-39]. The three inverters are connected to isolation transformer. Then the three transformers are connected to 415-V/11-kV transformer. Saloman et al [20] have discussed another important factor such as the power quality, protection coordination and grid synchronization. These factors could lead to power system instability if the PV penetration level is high. [35, 36 and 38]

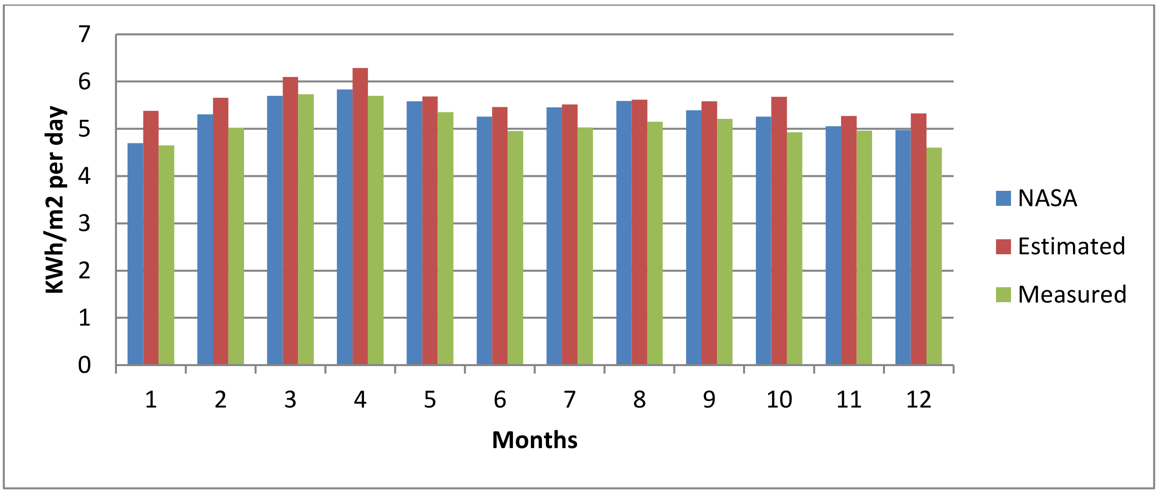

FIGURE 2: The Solar Radiation in Nigeria

FIGURE 3: The aerial view of PHCN PV power plant

THE MATHEMATICAL MODEL OF THE PROPOSED IPP PV POWER PLANT

The grid-connected PV system used in the modelling is shown in Figure 5. The PV array is composed of series and parallel connection of Sharp Monocrystalline Photovoltaic Module (NUS0E3E). The PV array is rated 2000 kWp. The PV array is connected to a DC/DC Buck converter equipped with MPPT. The output of the DC/DC converter is connected to a three-phase DC/AC inverter with 400 V output voltage. The controller of the inverter has to achieve: 1) constant amplitude voltage, 2) constant frequency, and 3) synchronize the output voltage with the grid voltage. The output of the inverter is then fed to step-up transformer to connect the system to the 11 kV grid. In the following sections the mathematical model of each component in the system is presented.

The PV Array

There are many methods in the literature for modelling PV modules [21, 22 and 23]. The model used in this paper is based on the single-diode model and extracting some of the parameters from the manufacturer data sheet. The electrical circuit model is shown in Figure 6. The model is with middle complexity where the temperature dependence of I_0, I_{ph}, and V_{oc} is included. Also, the parasitic resistances R_s and R_{sh} and their temperature dependence are taken into account. The ideality factor is used as a variable to match the simulated data with the manufacturing data. The mathematical model of a solar cell based on the single diode model is given as [22-29]:

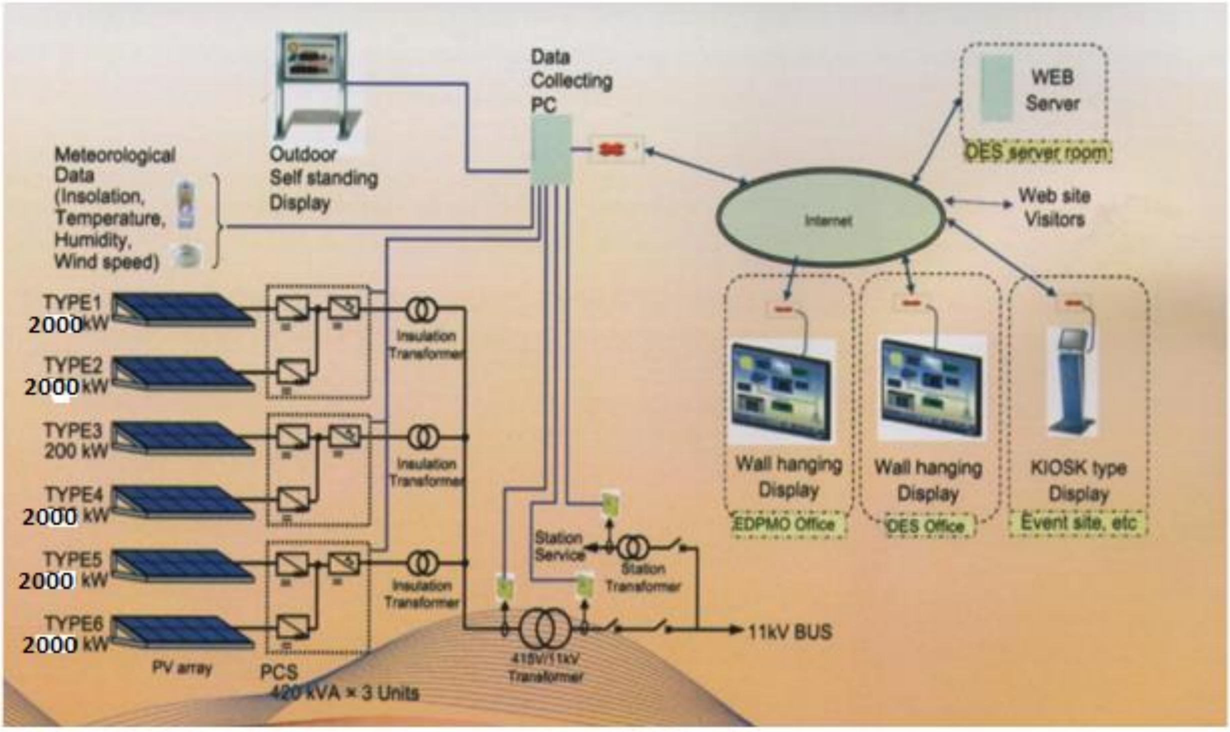

FIGURE 4: The configuration of the 12 MWP PV system

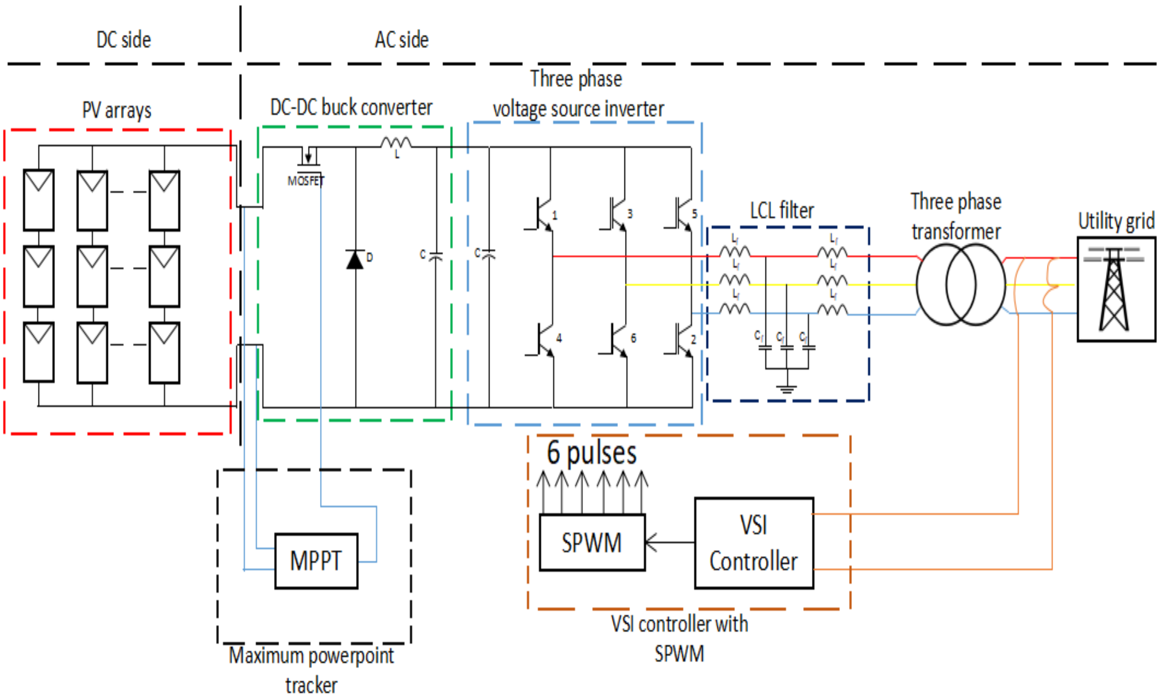

FIGURE 5. PHCN grid-connected PV system

$$I(T,G,V)=I_{ph}-I_0(e^{(V+IR_s)/nV_{th}}-1)-(V+I\cdot R_s)/R_{sh}=I_{ph}-I_D-I_{sh} \qquad (1)$$

where the variables in (1) are given by [22];

$$I_{ph}=I_{ph0}\cdot G/G_{nom} \qquad (2)$$

$$I_{ph}(T)=I_{ph}+K_0(T-T_{meas}) \qquad (3)$$

$$K_0 = (I_{ph}(T_2) - I_{ph}(T_1))/(T_2 - T) \quad (4)$$

$$I_0 = I_{SC(T_1)} \cdot (T/T_1)^{3/n} \cdot \exp[-E_g / V_s(1/T - 1/T_1)] \quad (5)$$

$$I_0(T_1) = I_{SC(T_1)} / (e^{qV_{OC(T_1)}/nkT_1} - 1) \quad (6)$$

$$R_s(T) = -dV/dI_{V_{OC}} - 1/(I_{0(T_1)} \cdot q/nkT_1 \cdot e^{qV_{OC(T_1)}/nkT_1}) \quad (7)$$

$$R_{sh} = V_{OC} / [I_{ph} - I_0(\exp(qV_{OC}/nkT_{meas}) - 1)] \quad (8)$$

$$R_{sh}(T) = R_{sh} \cdot (T/T_{meas})^{\alpha} \quad (9)$$

The parameters in the model are explained briefly. I_{ph} is the photo generated current in Amperes. I_{ph0} is the photo generated current at the nominal radiation. I_0 is the diode dark saturation current. I_D is the diode dark current. I_{sh} is the shunt current. R_s is the series resistance. R_{sh} is the shunt resistance. G is the solar radiation in W/m^2. The G_{nom} is the radiation the PV module is calibrated at, n is the ideality factor, e is the electron charge. k is Boltzmann's constant. V_g is the semiconductor energy gap. V_{th} is the thermal voltage, K_0 is the short-circuit current temperature coefficient. The manufacturer provides the following: N_s (the number of cells in series), N_p (the number of cells in parallel), the short-circuit current, the open-circuit voltage, the short-circuit current temperature coefficient. The solar cell of the modelled circuit is given in Figure 6.

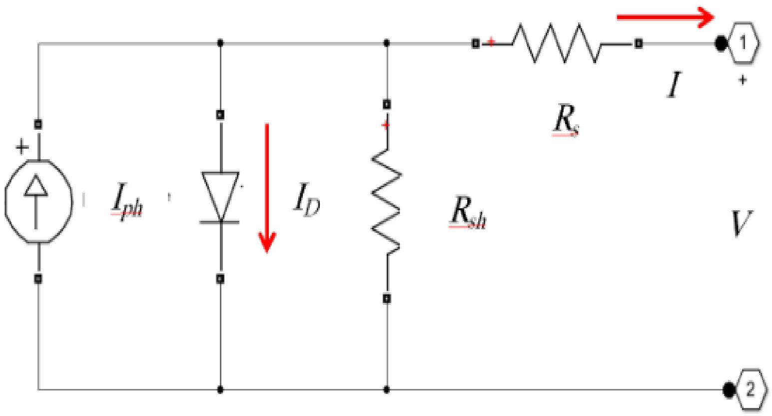

FIGURE 6. Circuit model of a solar cell

The DC/DC converter and the MPPT

The main role of the DC-DC converter is to match the PV array to the load and to achieve maximum power point tracking. The value of the filter inductance that determines the boundary between the continuous conduction mode (CCM) and discontinuous conduction mode (DCM) is given by the following equation [24]:

$$L_b = (1 - D)R/(2f) \quad (10)$$

Where; L_b is filter inductance, D is the duty cycle, R is resistance, f is the switching frequency. L should be less than L_b. In order to limit the peak-to-peak value of the ripple voltage below a certain value of the ripple voltage, V_r, the filter capacitance, C must be greater than the minimum capacitance, C_{min} which can be found using the following formula [24]:

$$C_{min} = (1 - D)V_o / (8V_r L f^2) \quad (11)$$

Where; C_{min} is minimum capacitance, V_o is output voltage, L is filter inductance. The Perturb & Observe (P&O) technique is widely used method for MPP tracking due to its simple structure and ease of implementation and it is implemented in this simulation model.

Three-phase Voltage Source Inverter (VSI) with LCL Filter

The three phase VSI provides a three-phase voltage, where the amplitude, phase, and frequency of the voltage should always be controlled. The main function of the LCL filter is to reduce the high-order harmonics in the output side of the inverter. The filter circuit consists of specially designed inductor and capacitor to block certain unwanted harmonics. The control strategy of the VSI controller consist of the inner control loop and outer control loop. The inner control loops independently regulate the output current in the rotating reference frame, whilst the outer loop works in the voltage control mode to produce the d-q axis current references for the inner loop by regulating the voltage at given reference values. The block diagram of the inverter controller is shown in Figure 7. The input DC voltage is regulated by PI controller. The output of this loop is the reference I_d current and is given by:

$$I_d^* = K_p(V_{dc}^* - V_{dc}) + K_I \int (V_{dc}^* - V_{dc})dt \quad (12)$$

The reference voltage V_d and V_q are generated by two different loops given by:

$$V_d^* = RI_d + V_d - \omega LI_q + Ld(I_d)/dt \quad (13)$$

$$V_q^* = RI_q + V_q + \omega LI_d + Ld(I_q)/dt \quad (14)$$

By substituting (12) into (13) and (14):

$$V_d^* = RI_d + V_d - \omega LI_q + K_{pd}(I_d^* - I_d) + K_{Id} \int (I_d^* - I_d)dt \quad (15)$$

$$V_q^* = RI_q + V_q + \omega LI_d + K_{pq}(I_q^* - I_q) + K_{Iq} \int (I_q^* - I_q)dt \quad (16)$$

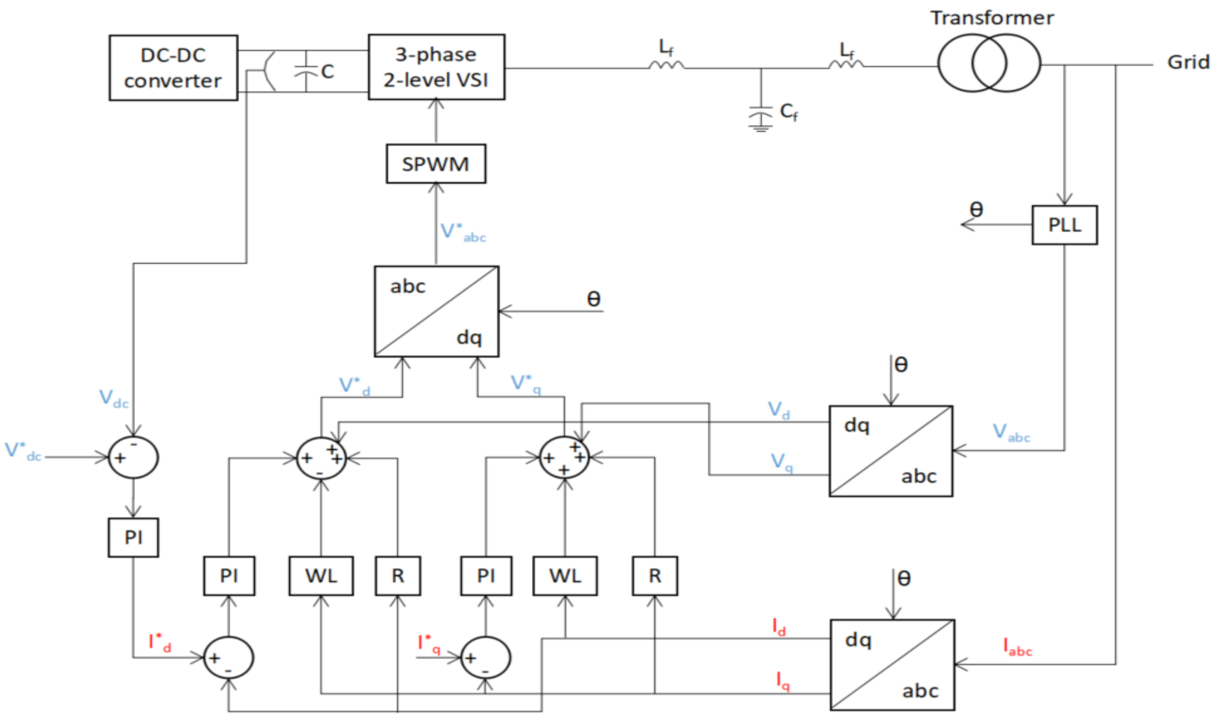

FIGURE 7. The structure of the three-phase grid-connected inverter

RESULTS AND DISCUSSIONS

The model has been implemented in Matlab/Simulink as shown in Figure 8. The parameters of the system are given in Table 1-3. The PV array current and the PV array output power are shown in Figure 9 and 10, respectively. The radiation and the temperature are varying. It can be seen that the PV array current and PV array power increase as the radiation increases. The output voltage of the inverter is shown in Figure 11, and it is clear that the AC voltage signal has a stable amplitude and frequency with low harmonics. The output voltage of the transformer is shown in Figure 12 and 13. From Figure 13, the output voltage is maintained at 11 kV even with the change in the temperature and the radiation, which shows successful operation of the inverter controller.

Table 1: The parameters of the PV array

Number of series modules	18
Number of parallel modules	62
The PV module	NUS0E3E
Number of series cells	48
The open-circuit voltage	30
The short-circuit current	8.37
Maximum Power	180
Maximum Power Voltage	23.7
Maximum Power Current	7.6
αPmax	-0.485 %/C
αIsc	+0.053 %/C
αVoc	-104 mV/C
Efficiency	13.7 %

Table 2: The parameters of the DC/DC converter

Switching device	MOSFET
Switching frequency	20 kHz
Filter Inductance	10 mH
Filter Capacitance	1.042 µF

Table 3: The parameters of the three-phase inverter

Filter inductance, L1	5 mH	K_{pd}	0.4
Filter inductance, L2	22 µH	K_{Id}	20
Filter capacitance	10 mF	K_{pq}	0.4
K_P	5	K_{Iq}	20
K_I	5		

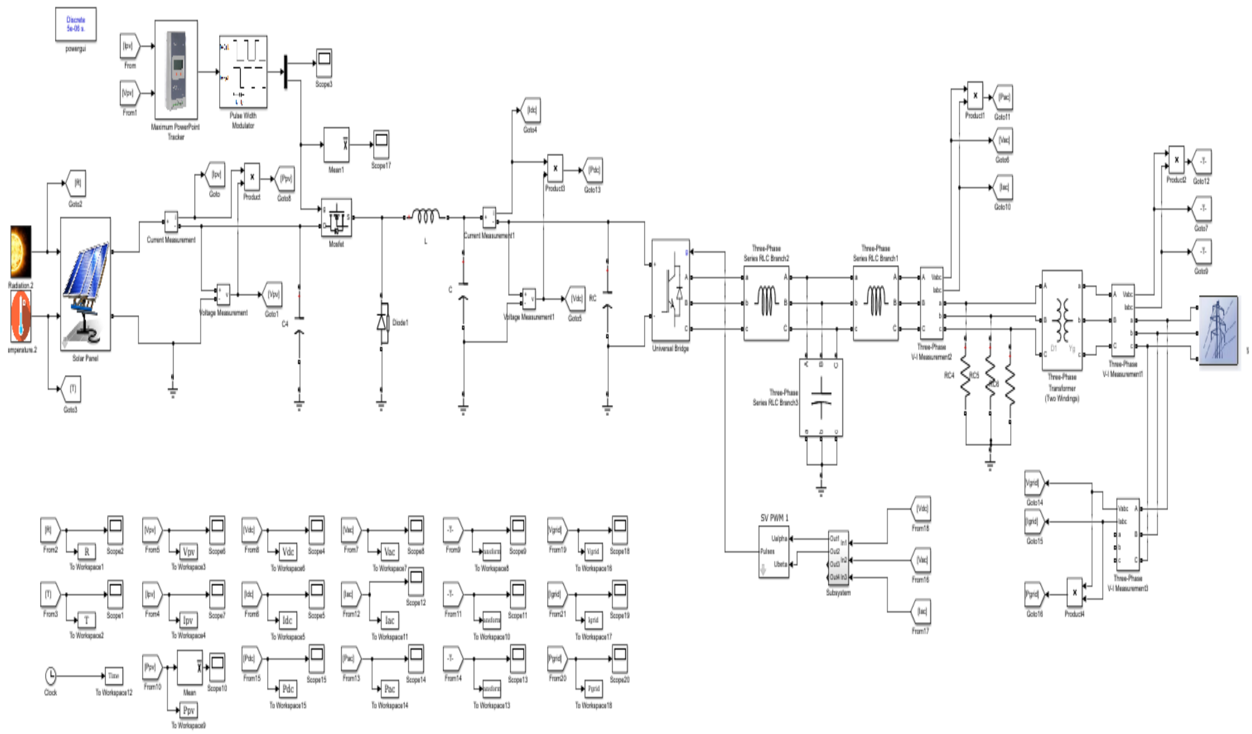

FIGURE 8: The structure of the three-phase grid-connected inverter

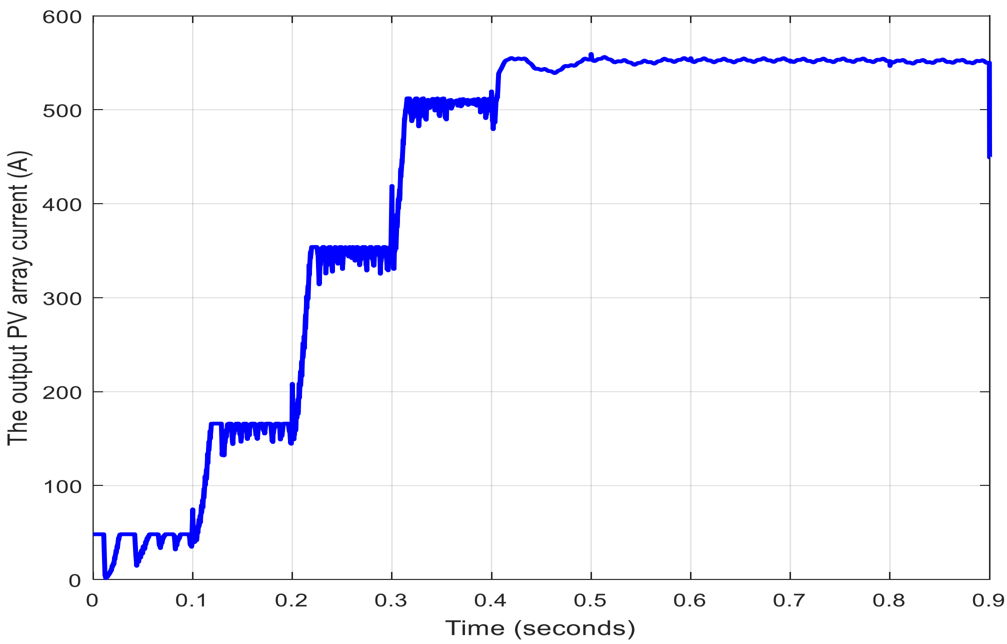

FIGURE 9: The PV array current

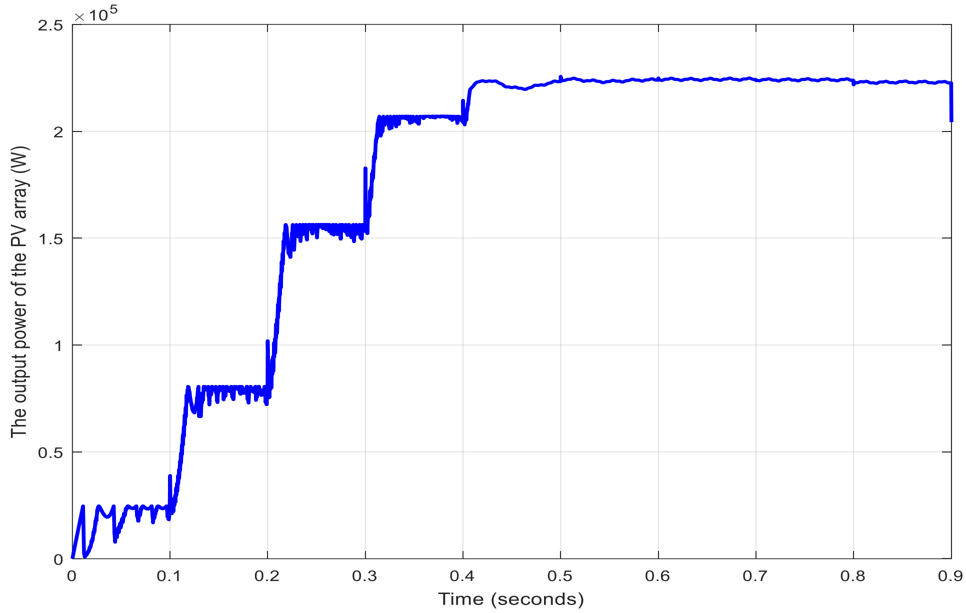

FIGURE 10: The PV array power

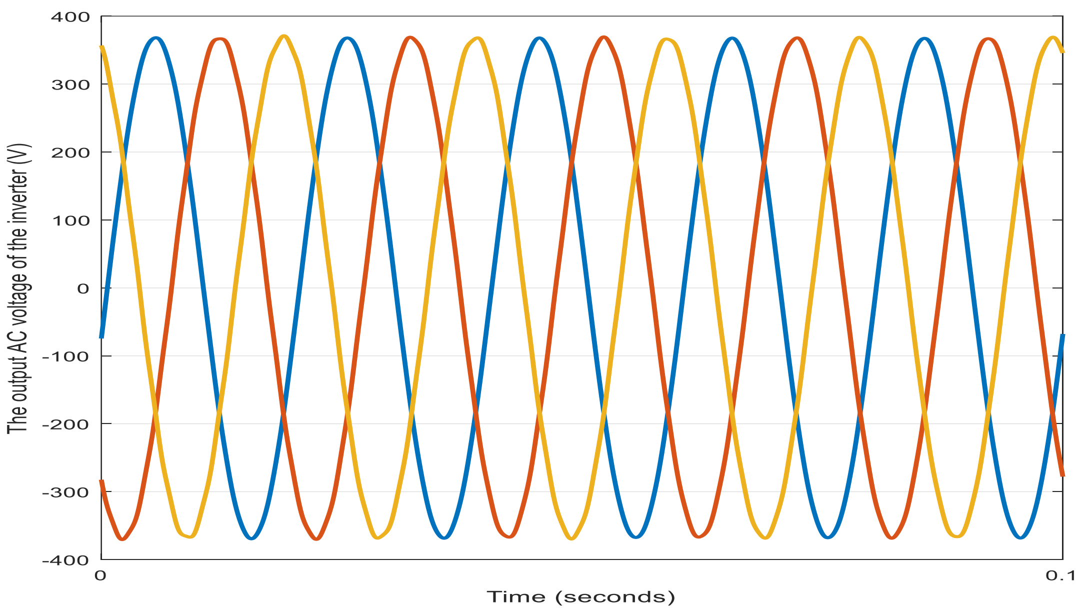

FIGURE 11: The output voltage of the inverter

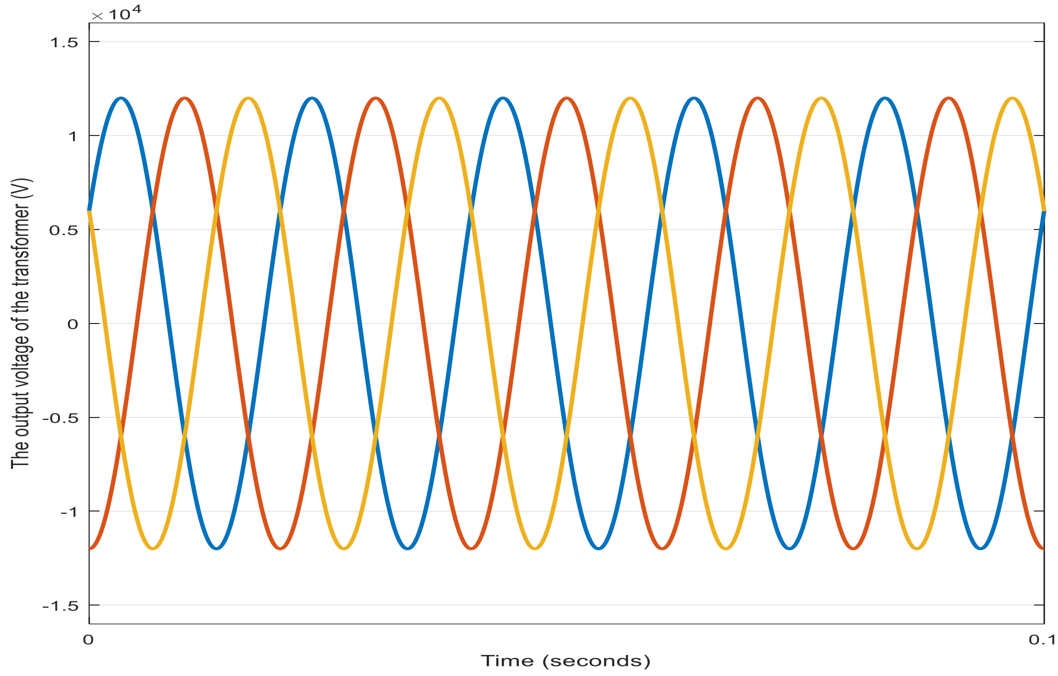

FIGURE 12: The output voltage of the transformer

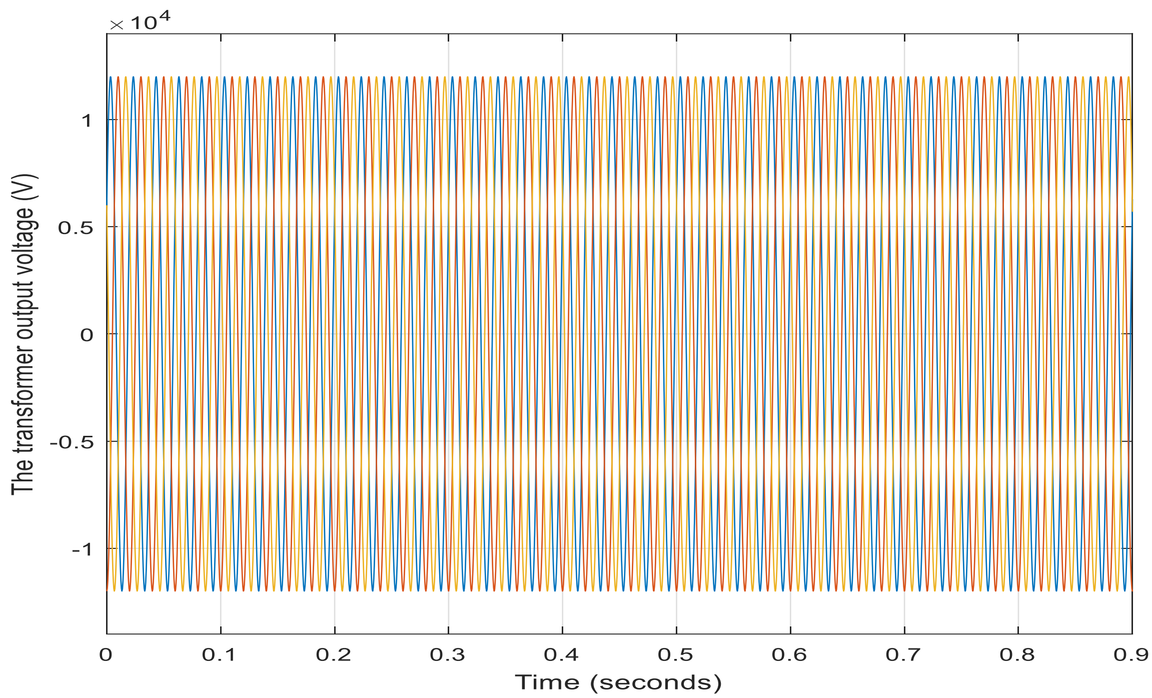

FIGURE 13: The output voltage of the transformer

CONCLUSIONS

In this paper, we present a model for grid-connected PV system. The PV array, the DC/DC converter with MPPT, the DC/AC inverter and the transformer are mathematically modelled and implemented using Matlab/Simulink. The output of the DC/AC inverter has a constant magnitude and constant frequency even when the solar radiation and the temperature are varying. The results of the simulation show a successful operation of the system model and the controller. The output power increases with increasing the radiation which proves the successful operation of the MPPT. The output of the inverter has very low harmonics which shows a correct selection of the filter parameters. The proposed simulation model will be validated with the real measurement data from PHCN PV power plant. This model will be used to investigate and improve the performance of the real time system.

REFERENCES

1. Aiman Nouh, Ashraf Khalil, Muhanad Saqier, "Small Solar Photovoltaic Power Plant Connected to the Utility Grid," Scientific Research & sustainable Development Conference, Benghazi, Libya, 2017, pp.1-19.
2. Robin Mills, Steven Griffiths, "Potential of Rooftop Solar Photovoltaics in the Energy Evolution of the United Arab Emirates," Energy Strategy Reviews, vol. 9, pp. 1-7, 2016.
3. Ahmad Zahedi, "How Expensive is Grid-Connected Solar Photovoltaic in Marrakesh: An Economic Analysis," 2015 3rd International Renewable and Sustainable Energy Conference (IRSEC), pp. 1-5, 2015.
4. Marcelo F. Valdes, Danilo Jara, Andrea Watson David Watts, "Potential Residential PV Development in Chile: The effect of Net Metering and Net Billing schemes for Grid-Connected PV Systems," Renewable and Sustainable Energy Reviews, vol.41, pp. 1037-1051, 2015.
5. D. L. Talavera, E. Munoz-Ceron, J. P. Ferrer-Rodriguez, G. Nofuentes, "Evolution of The Cost and Economic Profitability of Grid-Connected PV Investments in Spain: Long-term review according to the different regulatory frameworks approved," Renewable and Sustainable Energy Review, vol. 66, pp. 233-247, 2016.
6. G. D. Agrawal, Sanjay Mathur, Anuj Mathur, Mevin Chandel, "Techno-Economic Analysis of Solar Photovoltaic Power Plant for Garment Zone of Jaipur City," case studies in Thermal Engineering, vol. 2, pp. 1-7, 2014.
7. Ali Q. Al-Shetwi, Muhamad Zahim Sujod, A. Al Tarabsheh, Ibrahim A. Altawil, ‘’Design and Economic Evaluation of Electrification of Small Villages in Rural Area in Yemen Using Stand-Alone PV System’’, International Journal of Renewable Energy Research, Vol.6, No.1, 2016.
8. Md. Alam Hossain Mondal, A.K.M Sadrul Islam, "Potential and Viability of Grid-Connected Solar PV System in Bangladesh," Renewable Energy, vol. 36, pp. 1869-1874, 2011.
9. Mamadou Lamine Ndiaye, Menny El Bah, Abdoulkarim Mbodji, Ababacar Ndiaye, Papa Alioune Ndiaye Cheikh, El Banany Elhadj Sidi,"Performance Analysis of the First Large-Scale (15 MWp) Grid-Connected Photovoltaic Plant in Mauritania," Energy Conversion and Management, vol. 119, pp. 411-421, 2016.
10. M.B. Manjia, K.E. Enongene, J.H.M. Tah, C. Pettang, F.H. Abanda, "A Feasibility Study of a Residential Photovoltaic System in Cameroon,’’ Sustainable Energy Technologies and Assessments, vol. 17, pp. 38-49, 2016.
11. Muhammad Nabih Fakhri Matussin, "The Impact of Tenaga Suria Brunei Power Plant of Natural Gas Saving and CO2 Avoidance," Renewable Energy in Developing Countries, pp. 57-70, 2018.
12. Selim Borekci, Ekrem Kandemir, Ali Kircay, ‘’ A Simpler Single-Phase Single-Stage Grid-Connected PV System with Maximum Power Point Tracking Controller’’, Elektrpnika IR Elektrotechnika, Vol. 21, NO. 4, pp.44-49, 2015.

13. K. Boudaraia, H. Mahmoudi and M. El Azzaoui, "Modeling and control of three Phases grid connected photovoltaic system," *2016 International Renewable and Sustainable Energy Conference (IRSEC)*, Marrakech, 2016, pp. 812-816.
14. W. Cai, H. Ren, Y. Jiao, M. Cai and X. Cheng, "Analysis and simulation for grid-connected photovoltaic system based on MATLAB," *2011 International Conference on Electrical and Control Engineering*, Yichang, 2011, pp. 63-66.
15. Atiqah Hamizah Mohd Nordin, Ahmad Maliki Omar, Hedzlin Zainuddin, ‘’Modeling and Simulation of Grid Inverter in Grid- Connected Photovoltaic System, INTERNATIONAL JOURNAL OF RENEWABLE ENERGY RESEARCH, Vol. 4, No. 4, pp.1-9, 2014.
16. M. E. Ropp and S. Gonzalez, "Development of a MATLAB/Simulink Model of a Single-Phase Grid-Connected Photovoltaic System," in IEEE Transactions on Energy Conversion, vol. 24, no. 1, pp. 195-202, March 2009.
17. Ali Q. Al-Shetwi, Muhamad Zahim Sujod, ‘’ Sizing and Design of PV Array for Photovoltaic Power Plant Connected Grid Inverter’’, Third National Conference for Postgraduate Research (NCON-PGR2016), Pahang , Malaysia, 2016.
18. Ali Q. Al-Shetwi, Muhamad Zahim Sujod, ‘’ Modeling and design of photovoltaic power plant connected to the MV side of Malaysian grid with TNB technical regulation compatibility’’, Electrical Engineering, Volume 100, Issue 4, pp 2407–2419, 2018.
19. Dr. Romeo Pacudan, “1.2 Mwp Tenaga Suria Brunei Solar PV Power Generation Demonstration Project,” Report on module performance assessment, Brunei National Energy Research Institute, 2015.
20. J. Saloman, T. S. Sirish, “Performance Analysis of Grid Connected Solar PV System under Grid Abnormal Conditions,” International conference on Signal Processing, Communication, Power and Embedded System, pp. 1653-1659, 2016.
21. J. A. Gow, C. D. Manning, "Development of a photovoltaic array model for use in power-electronics simulation studies", lEE Proceedings-Electric Power Applications, Vol 146, No. 2, pp. 193-200, 1999.
22. G. Walker, “Evaluating MPPT Converter Topologies Using a Matlab PV Model”, Journal of Electrical and Electronics Engineering, Australia, Vol. 21, No. 1, pp. 49-56, 2001.
23. Hansen A. D., Sorensen P., Hansen L. H., Binder H., "Model for stand-alone PV system", Roskilde: Rio National Laboratory, 2000.
24. Muhammadd H. Rashid, “Power Electronics Handbooks,” *Second Edition Book*, 2007.
25. Abdulwahab, D. (2011). Development of Differential Sensor Interface for GSM Communication (Masters dissertation, Kulliyyah of Engineering, International Islamic University Malaysia).
26. Abdulwahab, D. (2016). Development of Differential Inductive Transducer System for Accurate Position Measurement (Doctoral dissertation, Kulliyyah of Engineering, International Islamic University Malaysia).
27. Abdulwahab, D., Khan, S., Chebil, J., & Alam, A. Z. (2011, May). Symmetrical analysis and evaluation of Differential Resistive Sensor output with GSM/GPRS network. *In 2011 4th International Conference on Mechatronics (ICOM) (pp. 1-6). IEEE.*
28. Abdulwahab, D., Khan, S., Chebil, J., Ahmed, M. M., Naji, A. W., & Alam, A. Z. (2010, May). Identification of linearized regions of non-linear transducers responses. *In International Conference on Computer and Communication Engineering (ICCCE'10)* (pp. 1-4). IEEE.

29. D. Abdulwahab, S. Khan, M. H Habaebi, (2023). "*Mathematical Differential Analysis of Atlantic Ocean Wind to Electrical Energy Generation in Lekki Peninsular Lagos Nigeria*", Journal of Electrical Electronics Engineering Research
30. D. Abdulwahab, S. Khan, J. Chebil and A. H. M. Z. Alam, "Symmetrical analysis and evaluation of Differential Resistive Sensor output with GSM/GPRS network," 2011 4th International Conference on Mechatronics (ICOM), Kuala Lumpur, Malaysia, 2011, pp. 1-6, doi: 10.1109/ICOM.2011.5937149.
31. D. Abdulwahab et al., "Identification of linearized regions of non-linear transducers responses," International Conference on Computer and Communication Engineering (ICCCE'10), Kuala Lumpur, 2010, pp. 1-4, doi: 10.1109/ICCCE.2010.5556753.
32. D. Abdulwahab et al., "Identification of linearized regions of non-linear transducers responses," International Conference on Computer and Communication Engineering (ICCCE'10), Kuala Lumpur, 2010, pp. 1-4, doi: 10.1109/ICCCE.2010.5556753.
33. Deji A., Sherifah OM., 2023. The Mediating Effect of Entrepreneur Cash Waqf Intension as means of Planned Behaviour for Business Growth. International Journal for Multidisciplinary Research. Volume 5, Issues 6, page 1-22.
34. Deji A., Sheroz K, Musse M.A, Jalel C. (2011). Design of Differential Resistive Measuring System and its
applications. A book chapter in IIUMPRESS on Principle of Transducer Devices and Components. Chapter 17, page 107.
35. Deji A., Sheroz K., Musse M.A., (November 2023) "*Analytical Modeling of Electrical Frequency and Voltage Signal from a Differential Inductive Transduction for Energy Measurement.* International Journal for Multidisciplinary Research. Volume 5 Issue 6 Page 1-19.
36. Deji A., Sheroz K., Musse M.A., (November 2023) "*Kinematic Motion Modelling from Differential Inductive Oscillation Sensing for a Sevomechanism and Electromechanical Devices and Applications.* International Journal for Multidisciplinary Research. Volume 5 Issue 6 Page 1-15.
37. Deji A., Hanifah A.M., Sherifah O.M., (December 2023) "*The Adoption of Information System Technology in Piloting the Current State of Health Institution in Tier Three Nations.*" International Journal for Multidisciplinary Research. Volume 5 Issue 6 Page 1-13.
38. Deji A., Sheroz K, Musse M.A, Jalel C. (August 2014). Analysis and evaluation of differential inductive transducers for transforming physical parameters into usable output frequency signal August 2014 International Journal of the Physical Sciences 9(15):339-349.
39. Deji A., Sheroz K, Musse M.A, Jalel C. (2011). Design of Differential Resistive Measuring System and its applications. A book chapter in IIUMPRESS on Principle of Transducer Devices and Components. Chapter 17, page 107.
40. Deji A., S. Khan, J. Chebil and A. H. M. Z. Alam, "Symmetrical analysis and evaluation of Differential Resistive Sensor output with GSM/GPRS network," 2011 4th International Conference on Mechatronics (ICOM), Kuala Lumpur, Malaysia, 2011, pp. 1-6, doi: 10.1109/ICOM.2011.5937149.
41. Elfaki, H. M. O. A., Sherifah O.M., Deji A., (2023). Factors Related to Financial Stress Among Muslim Students in Malaysia: A Case Study of Sudanese Students. *Academy of Entrepreneurship Journal*, *29*(6). Page 1-15
42. Elzanati, W. M., & Ameen, S. Y. (2013, November). Cost effective air-conditioning for bahrain domestic

applications. In 2013 *7th IEEE GCC Conference and Exhibition (GCC)* (pp. 535-540). IEEE.

43. Khan S., A. Deji, A.H.M Zahirul, J. Chebil, M.M Shobani, A.M Noreha. (Setember 2012) "Design of a Differential Sensor Circuit for Biomedical Implant Applications". *Australia. Journal of Basic and Applied. Sciences., 6(9): 1-9.* 10.1002/9781118329481.ch1.
44. Deji, A., Khan, S., Habaebi, H.M., Musa. O.S. (2024). Technical Engineering Evaluations and Economic Feasibility Study of Solar Powered Air Conditioning System in Tier Three Nations. *Academy of Entrepreneurship Journal*, *30*(S1), 1-19.