International Conference on
Contemporary Technological Solutions towards fulfilment of Social Needs

A Survey on Grid Connected Solar Photovoltaic System

Priynka Verma (M.Tech Student)
Department of Electrical & Electronics Engineering
RKDF University, Bhopal
Email: priyankavermaggits@gmail.com

Chirag Gupta (Professor)
Department of Electrical & Electronics Engineering
RKDF University, Bhopal
Email: cgupta.011@gmail.com

***Abstract*— The evaluation of power electronics has emerged since last few decades ago. The advancement in the power engineering has made many advantages as per cost, performance and size point of view. In recent years, the power electronics is used in many aspects of commercial, utility, military, transportation, aerospace, etc. The photovoltaic based energy generation is the modern way of generating the energy and is adopted all over the world. But the efficiency in power generation by the photovoltaic system varies with the climatic condition. The technique called maximum power point tracking (MPPT) helps in efficiency optimization. This paper presents the survey over the existing energy optimization techniques; further efficiency optimization for future study is mentioned. This paper consists of various modules related to Solar PV technology, MPPT algorithms, DC/DC converters, and grid connected PV inverter topologies, power quality issues with grid connected PV systems have been studied, which form the back bone of the articles.**

***Keywords*—Photo Voltaic model, Grid Connected Solar PV Systems, MPPT, DC-DC converter**

I. INTRODUCTION

The demand for electric energy is expected to increase globally due to the rapid population growth and industrialization. This rapid increase in the energy demand requires electric utilities to increase their generation. In the last six decades, India's energy use has increased 16 times and the installed energy capacity by 84 times, still India is facing the problem of acute power deficit. The present scenario indicates that India's future energy requirements are going to be extremely high. In order to meet the ever increasing power requirements, huge amount of power needs to be generated in the existing power sector. According to Ministry of Power statistics, the installed power generation capacity of India as on May 31, 2016 was 303083 MW. Further, the total demand for electricity in India is expected to cross 950,000 MW by 2030 and it is beyond doubt that a substantial contribution would be from renewable energy.

Power electronics (PE) is intended to convert and control the electrical energy by using semiconductor device (switching mode). The PE adopted in many aspects of commercial, aerospace, etc. [1]. One of the applications in power engineering is DC-DC converter gives regulated voltage. The dc-dc converters can be applied in power systems, fuel cell power system, photovoltaic power system, UPS systems, hybrid electric vehicles/electric vehicle, textile mills, home appliances, wind systems, robotics, paper mills, pumps, etc. With all the applicability in various high-efficiency power equipment, PE also provides high productivity along with enhanced product quality that will help in modern automated business units [1, 2, 3] .

Today, the world has adopted many renewable and easily available resources to generate the electric power. Among these resources, the solar rays of the sun are easily available resources by which the electric energy is generated. The solar-based energy system is commonly known as photovoltaic (PV) system. The cost of a photovoltaic cell is very high and its efficiency varies with climatic conditions like rainy, foggy, etc., and even depends on the shadows of the building, falling over the solar panel. In today's generation, the supply power needs to meet the entire load. It is being surveyed that efficiency of supply is needed to achieve the overall load. The proper optimization approach will help in achieving the load needs. In that sense over the year's study has taken place to meet the load needs. The fact is that the optimization concept of a power electronics composed of many aspects like mass, efficiency, temperature, etc. The DC-DC converter also helps to achieve the better efficiency in PV models.

II. SOLAR PHOTOVOLTAIC TECHNOLOGY

A system that generates the electrical energy by exposing to the solar radiations or by the photoelectric effect is known as photovoltaic or PV system. A PV system consists a number of solar cells which can be connected in parallel or series array pattern based on the voltage or current requirement.

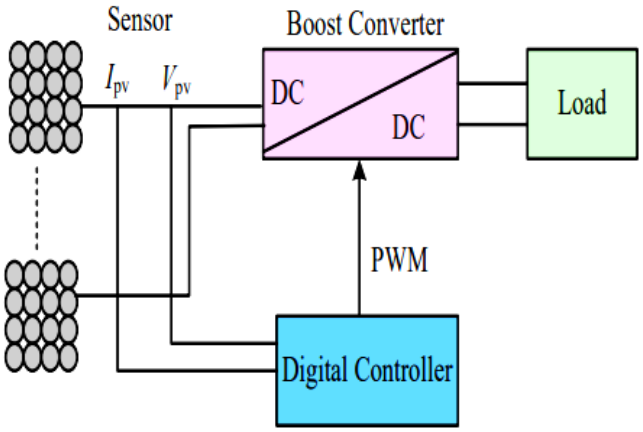

Figure 1 Block Diagram of Photovoltaic System

The connection of PV cells or solar cells can be done parallel to get the maximum output current, while the solar cells series connection is done to have maximum output voltage [6, 7]. Recently many countries are adopted the PV-based energy generation unit to get the long-term solution for the load

demands. The maintenance cost of PV cell is very less. The non-linearity in the PV system is a major issue that can affect the efficiency of power generation and also, the irradiation issues like a cloud, buildings shadows, etc. The block diagram of PV generation is represented with Figure 1 [7]. India is blessed a vast solar energy potential, which is about 5000 trillion kWh/year (MNRE). Out of which we are able to exploit the small amount of power i.e. 6762 MW as on 31stMay 2016. Three major families of PV cells are mono crystalline technology, polycrystalline technology and thin film based technologies. The mono crystalline and polycrystalline technologies are based on microelectronic manufacturing technology and their efficiency is in general between 10% and 15% for mono crystalline and between 9% and 12% for polycrystalline. For thin film cells, the efficiency is 10% for a-Si, 12% for CuInSe2 and 9% for Cd-Te. The mono crystalline cell has the highest efficiency.

2.1. *Types of Photovoltaic System*

The functionality, configurations and operation of PV system are classified as grid interfaced PV system and standalone PV system [7].

- *Grid interfaced PV System*: These systems are made to operate the PV system in parallel and interfaced with the grid. This system mainly composed of DC to AC conversion unit known as an inverter. This type of PV system can be operated by interfacing with grid [3].

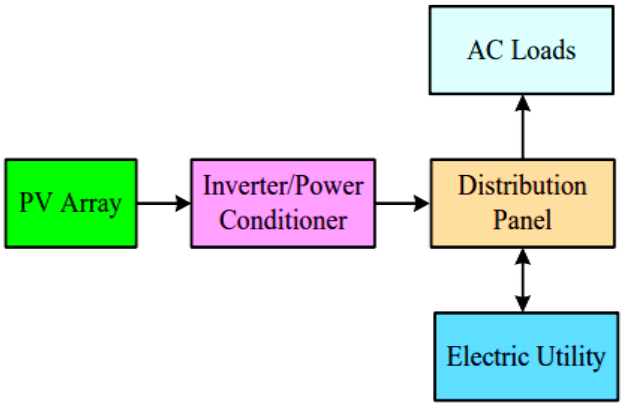

Figure 2 Block Diagram of Grid Interfaced PV System

- *Standalone PV Systems*: These systems operate without any dependency over the grid and also on supply loads. This PV system is directly coupled system and works during the sun light and it will not store the generated power. These systems are used for running the fan, water pumping, etc. [6, 7].

2.2 MODELING, DESIGN AND SIMULATION OF PV ARRAY

A circuit model of PV cell is necessary in order to study the photovoltaic system. Output parameters of solar cell depend upon the meteorological parameters like solar irradiance and temperature etc. The output power produced by solar cell is not sufficient for use. So the solar cells are grouped together to make panels and arrays.

Natrajan Pandiarajan et.al [10] presented circuit model of photovoltaic module for a common use of material scientists and power electronic circuit designers for developing the better PV power plans. The authors presented the detailed modeling procedure for the circuit model with equations using simpower system block of MATLAB/ Simulink. This paper also presented the MPPT control with DC/DC boost converter with appropriate simulation results.

M. Abdulkadir et.al [13] proposed a user friendly model using Simulink. Authors accounted the effect of varying irradiance and temperature on the developed model. They verified the proposed model with practical model of 36W PV module.

Samer Said et.al [14] considers the PV cell as the main building block for simulation and monitoring the performance of PV array. The proposed model simulated for various temperature & isolation values and P-V, I-V characteristics obtained for different parameters. The authors also studied different patterns of partial shading on PV arrays. This paper describes a model of PV array which is suitable to simulate the dynamic performance of PV base power generating systems.

$$I = N_p I_{PH} - N_p I_s \left[\exp\left\{\frac{qV}{N_s AkT}\right\} - 1\right] \qquad (2.1)$$

By-pass diode significantly affects the output characteristics of PV array in case of shading. Authors simulate the presented model for comparing the shaded and unshaded PV array characteristics. This study consists of two major sections; one is under uniform insolation and another is under partial shaded conditions. Presented results conclude that presence of multiple peaks (local peaks) reduces the MPPT efficiency because it fails to observe the global peak.

Kashif Ishaque et.al [5] presented a two diode model of PV cell. The proposed model gives better accuracy at low values of solar irradiance and allows predicting solar PV system performance more accurately. Authors estimate the values of Rp and Rs so that the input parameter can be reduced to four and hence computational time can be reduced. A standard PV module datasheet is used as information to PV simulator. Large array simulation is supported by the simulator and that can be interface with different power converter & MPPT algorithms. Model accuracy verified by using five different modules from various manufacturers.

Output current equation of two diode model PV cell is given as

$$I = I_{PV} - I_{o1}\left[\exp\left\{\frac{V+IR_s}{\alpha_1 V_{T1}}\right\} - 1\right] - I_{o2}\left[\exp\left\{\frac{V+IR_s}{\alpha_2 V_{T2}}\right\} - 1\right] - \left\{\frac{V+IR_s}{R_P}\right\} \qquad (2.2)$$

Where,

I_{O1} and I_{O2} are the reverse saturation currents of diode 1 and 2 respectively

$\alpha 1$ and $\alpha 2$ represents the diode ideal constant.

VT1 and VT2 are thermal voltages of their respective diodes.

J.A Gow et.al [6] developed a general model of solar PV array which can be implemented on various simulation platforms. Model is used to obtain P-V and I-V characteristics for the cell by taking temperature and irradiance as input parameter. The developed model is suitable for the use with power electronics interface.

2.4 power electronics interface

Power electronic converter is used to interface the PV array to dc bus to perform three major functions including step up/step down

the PV voltage, regulate the varying dc output voltage of PV array and implement the MPPT of solar array to ensure operation at maximum efficiency. However, there are various topologies of DC-DC converter including buck, boost, push pull, half bridge, full bridge, fly-back, buck-boost etc. The choice of topology depends on system requirements and its applications.

Yungtaek Jang et.al [7] developed a new two inductor, two switch boost converter topology. Proposed converter gives a wide range of output voltage regulation with a variable load and input voltage. An auxiliary transformer is also incorporated with this converter to couple the current paths of the two boost inductors. Authors verified the performance of proposed two inductor boost converter with a 1KW prototype circuit designed for 40-70V battery voltage input and deliver upto 2.9 A at 380V output.

Ahmed H. El Khateb et.al [8] presented a combination of cuk and buck DC-DC converter for a standalone PV system. A MPPT control technique is implemented with the converter to provide a constant voltage/current to battery even under the changing atmospheric conditions. The proposed system has been tested under different operating conditions.

Hyuntae Choi et.al proposed a solution to reduce the transformation stages without changing the standard architecture of the system. A high gain DC-DC converter has been proposed in this paper for multi string PV system architecture. Authors simulate a 1MW PV system by using MATLAB/Simulink and PLECS block set.
Performance of the system has been analyzed for three different cases.

a) Constant solar irradiance.
b) Fast changing irradiance.
c) Grid voltage sag.

T.Shanti et.al [9] proposed a boost converter and line commuted inverter with maximum power point tracking control for solar photovoltaic power generation systems. The proposed controller delivers the maximum power to the utility grid. Author developed a laboratory purpose prototype for the proposed system and verified the results.

Amudhavalli D. et.al [10] proposed a new topology of DC-DC boost converter for solar photovoltaic power generation system. This topology comprises a interleaved soft switching boost converter (ISSBC) with maximum power point tracking control. Proposed converter minimizes the switching losses by adopting a resonant soft switching method. Advanced P&O MPPT technique has been used in this work to increase the efficiency of the system. The model has been simulated on MATLAB/Simulink platform as well as hardware implementation also done by using this boost converter topology authors are able to reduce input current ripple and output voltage ripple.

ain purpose for developing this project is to identify the extreme and harmful conditions which are limited to human instincts, so in order to avoid human losses and to damage control we design a robotic vehicle which is operated remotely by a mobile phone controlled by DTMF Technology. The status of the location is indicated by the alarm and display on the LCD, like the presence of harmful gases and/or occurrence of fire. These are carried by increasing the sensitivity and with the faster response time. This study deals with the feasibility using the DTMF technology over the conventional RF transmission and overcoming the limitations in RF technology like limited RF range, response time. Most of these wireless robots are categorized under the autonomous robots to operate remotely. The operation of the robot is initiated with a phone call to the mobile phone on the robot i.e. receiver side from the mobile phone on the transmitter i.e. controller side, then the DTMF technology comes into play once the keypad. We have studied the different paper related to this work.

Humayun Rashid, *et al." Multiple Sensors Based Fire Extinguisher Robot Based on DTMF, Bluetooth and GSM Technology with Multiple Mode of Operation", 2016*, During this paper, the design of a multiple sensors based fire extinguisher robot together with the development and operation is proposed. Basically, 3 different sensors of flame sensor, temperature sensor, and smoke sensor have been used to ensure proper detection of fire [1].

J. Setiawan, *et al. "Virtual Reality Simulation of Fire Fighting Robot Dynamic and Motion" 2016*, in this paper robot is controlled by both DTMF remote control and Android Smartphone and is operated in three different modes. Autonomous mode, it is activated by the robot itself based on the situation. Line following mode, a black drawn line to detect fire and the third mode is complete manual operation using remote control [2].

J. Undug, et al., *"Fire Locator, Detector and Extinguisher Robot with SMS Capability", 2015*, In this paper, the robot is designed to pass the information to the receiver via short message service, SMS sent to the pre-defined mobile number saved in the microcontroller's ROM [4].

Pal, Sagarika *"Remote Position Control System of Stepper Motor Using DTMF Technology", 2011,* In this paper the design of system where the position of the stepper motor is controlled by a remote transmitter device using DTMF technology. Once a call from the transmitter established to the mobile phone on the receiver side the DTMF technology sends the signals to change the position of the stepper motor [5].

III. MAXIMUM POWER POINT TRACKING

MPPT control is necessary in order to track the maximum power point of the PV array. These MPPT techniques are based on the reference voltage or reference current signal of the PV system which is adjusted in order to achieve maximum power point. These techniques includes perturb and observe, incremental conductance, constant voltage, open circuit voltage, short circuit current, extreme seeking control and hybrid etc. To get the maximum power efficiency even in the different climatic condition and also under different load condition, maximum power point tracking (MMPT) technique is used. There exist various MPPT techniques to improve the efficiency in the photovoltaic system like Incremental conductance (IC) type, artificial neutral network (ANN), perturbation & observation (P&O) type, fuzzy logic (FL) type, particle swarm optimization (PSO), etc. All the above MPPT techniques will overcome the issues like non-linearity in PV module and shadows on PV module.

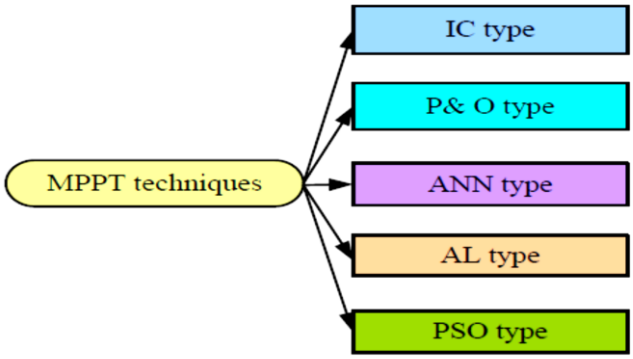

Figure 3. MPPT Techniques

A. Incremental Conductance (IC) Type of MPPT

This MPPT technique gets better power tracking. The technique tracks the nature condition rapidly [12]. For MPPT, ratio of change in current (dI) and change in voltage (dV) ,calculation along with conductance (I/V). The working flowchart from the left and right side of this MPPT technique is represented [7].

B. Perturbation and Observation (P&O) type of MPPT

This technique is very useful and easily adoptable for PV array which is radiation direction perturbed. In this case, the power is drained because of PV array increases, the operating point will move towards maximum point and brings back to radiation direction. If the power drain by PV array decreased, then automatically the operating point will move away from the radiation direction. A drawback of this MPPT technique works at steady state. The moving of operating point towards MPPT will make wastage of energy [12, 13, 14]. The response speed of this technique is very slow and incremental power change can be measured as ΔP. In case ΔP is positive, the operating point will move to attain MPPT and if ΔP is negative, the operating point will take to reverse direction. [7].

C. Artificial Neural Network (ANN) type of MPPT

This type of MPPT technique is a multilayered feedback Neutral Network (MFNN) having back-propagation based network. A two-stage offline ANN will estimate the issues or level of irradiation and temperature of the MPPT of PV module voltage and current. This MPPT mechanism offers better performance under the different environmental condition and also under steady and transient states [14].

D. Fuzzy Logic (FL) type of MPPT

This is a proper way to measure an input space to output space. FL is a set theory, where a single member will have sets with a membership degree. An FL-based MPPT includes blocks like fuzzification, inference and defuzzification [13, 14].

E. Particle Swarm Optimization (PSO) type of MPPT

This type of algorithm helps to minimize the steady-state oscillation to zero, if the MPP is attained. This mechanism tracks MPP under extreme climate conditions like isolation, fluctuation and also under partial shading. This mechanism tracks the MPP successful but at a lower speed.

IV. ISSUES IN PHOTOVOLTAIC SYSTEM

We know that the solar energy is easily available and it is free of cost. By using the energy conservation law, it can be possible that the solar energy can be used to produce the electrical energy and such systems are considered as photovoltaic systems. The main drawback of the PV system is that the power efficiency decreases, when the climatic conditions vary and also the shadows on the PV arrays also decrease its efficiency. Some of the important issue in PV systems is given below:

A. Intermittent Generation

The constantly changing environment condition needs proper weather forecast to schedule the better power generation.

B. Transmission System Issue

The transmission of high energy over the existing transmission line is quite tough and is one of the notable points in PV system.

C. Distribution System Issues

The distribution of power to the different sectors is very tough in PV system.

D. Integrating Energy Storage

To attain the better efficiency, we can integrate grids and PV module but the storage system for this generated energy is very difficult.

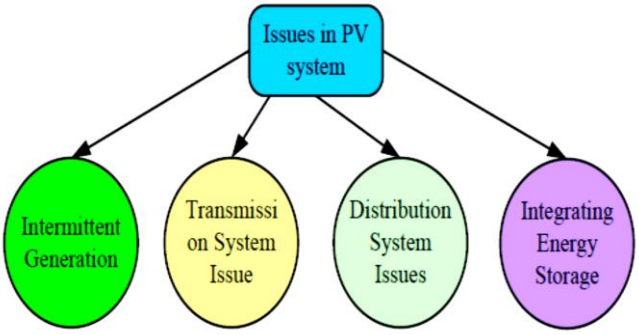

Figure 4 Issues of PV Systems

V. PV SYSTEM ADVANTAGES AND DISADVANTAGES

The following table gives the PV system advantages and disadvantages.

TABLE I
PV SYSTEM ADVANTAGES ALONG WITH DISADVANTAGES

Advantages	Disadvantages
➢ Decreases electricity bill ➢ Decreased PV panels cost has made affordable. ➢ Produces free electricity ➢ Generates power even in cloudy condition. ➢ Less maintenance needed ➢ Environmental friendly	• Cost is high • Needs proper roof top to install it • Roof or tree shades may affect the power generation

VI. FUTURE WORK

Power efficiency is a key driving force due to the continual increase of energy consumption and costs. Therefore, now the development focuses on high-efficiency power supplies, which

enable cost and cooling effort reduction. From the survey, research carried by various researchers, it is known that efficiency is the major concern for power generation. Many efficiency enhancement mechanisms are presented but are failed to provide the accuracy. The recent survey analysis says that the efficiency optimization is still an active topic for research in PE. The work that had been carried out by the researchers, the designing of MPPT controller, should be extended by tracking a larger number of input parameters which are varying to the time such as parameters variations of the system.

- Can computationally evolve up with a technique for MPP distributed architecture of DC-DC controller with the aid of mathematical modeling.
- Can apply multivariate optimization technique on multiple conditions of power and voltage for evolving up with a predictive technique ensuring efficient controller synchronization.
- Can perform comparative analysis of the outcome of the proposed system with the existing significant system.

VII. CONCLUSION

The Photovoltaic systems are offering a better solution to the largest issue of environment i.e., electrical power demand. To meet this power demand, many efficiency enhancement mechanisms of PV systems are presented. Among these mechanisms, the Maximum Power Point Tracking is most trustworthy and it is best suited for PV system. The use of DC-DC converter in between the grid and PV module can bring efficiency optimization. This survey paper gives the existing MPPT mechanisms for power efficiency enhancement. The recent research work provides an idea of the research gap. By considering the research gap, future scope of research is given.

References

[1] N Pandiarajan,R Ramaprabha and M Ranganath, “Application of circuit model for photovoltaic energy conversion system”, International Journal of Advanced Engineering Technology. pp. 118-127, 2011.

[2] M. Abdulkadir, A. S. Samosir and A. H. M. Yatim, “Modeling and simulation based approach of photovoltaic system in Simulink model”, ARPN Journal of Engineering and Applied Sciences, vol. 7, 2012.

[3] Samer Said, Ahmed Massoud, Mohieddine Benammar and Shehab Ahmed,“A MATLAB/Simulink based photovoltaic array model employing Simpower system toolbox”, Journal of Energy and Power Engineering, vol. 6, pp. 1965-1975, 2012.

[4] K Ishaque, Zainal Salam and Hamed Tahri, “Accurate MATLAB Simulink PV systems simulator based on a two-diode model”, Journal of power electronics, vol. 11, pp. 179-187,2011.

[5] J. A. Gow and C. D.Manning, “Development of a photovoltaic array model for use in power-electronics simulation studies”,IEE Proceedings on Electric Power Applications, vol. 146, pp. 193–200, 1999.

[6] Yungtaek Jang, Senior Member and Milan M. Jovanovic, “New two inductor boost converter with auxiliary transformer”, IEEE transactions on power electronics, vol. 19, pp. 169-175, 2004.

[7] Ahmad H. El Khateb, Nasrudin Abd Rahim, and Jeyraj Selvaraj, “Cuk – buck converter for standalone photovoltaic systems”,Journal of Clean Energy Technologies, Vol. 1,pp. 69-74, 2013.

[8] T.Shanthi and N.Ammasai Gounden “Power electronics interface for grid connected PV array using boost converter and line-commutated inverter with MPPT” International Conference on Intelligent and Advanced Systems, pp. 882-886, 2007.

[9] Mohan, Ned, and Tore M. Undeland. Power electronics: converters, applications, and design. John Wiley & Sons, 2007.

[10] Erickson, Robert W., and Dragan Maksimovic. Fundamentals of power electronics. Springer Science & Business Media, 2007.

[11] Rashid, Muhammad H. Power electronics: circuits, devices, and applications. Pearson Education India, 2009.

[12] Zhou, Siyuan, and Gabriel A. Rincon-Mora. "A high efficiency, soft switching DC-DC converter with adaptive current-ripple control for portable applications." IEEE Transactions on Circuits and systems Part 2 express BRIEFS 53.4, 319, 2006.

[13] Bose, Bimal K. "Power electronics and motor drives recent progress and perspective." IEEE Transactions on Industrial Electronics 56.2, pp. 581-588, 2009.

[14] Selvaraj, Jeyraj, and Nasrudin A. Rahim. "Multilevel inverter for grid-connected PV system employing digital PI controller." IEEE Transactions on Industrial Electronics 56.1, pp.149-158, 2009

[15] Zhao, Qun, and Fred C. Lee. "High-efficiency, high step-up DC-DC converters." IEEE Transactions on Power Electronics 18.1, pp. 65-73, 2003

[16] F Z Hamidon, P D Abd Aziz and N H Mohd Yunus, “Photovoltaic array modeling with P & O MPPT algorithms in MATLAB”, international conference on Statistics in Science, Business, and Engineering, pp. 1-5, 2012.

[17] A R Reisi, Moradi M H and S Jamsab, “Classification and comparison of maximum power point tracking techniques for photovoltaic system: A review”, Renewable and Sustainable Energy Reviews,vol. 19, pp. 433-443, 2013.

[18] M. Abdulkadir, A. S. Samosir, Member and A. H. M. Yatim, “ Modeling and simulation of maximum power point tracking of photovoltaic system in Simulink model”, IEEE International Conference on Power and Energy, pp. 325-330, 2012.

[19] Hairul Nissah Zainudin and Saad Mekhilef, “Comparison study of maximum power point tracker techniques for PV systems”, Proceedings of the 14th International Middle East Power Systems Conference (MEPCON’10), pp. 750-75, 2010.

[20] Mostafa Mosal, Haitham Abu Rubl, Mahrous E, Ahmed and Jose Rodriguez, “ Modified MPPT with using model predictive control for multilevel boost converter”, IEEE Conference on Industrial Electronics Society, vol. 38 , pp. 5080-5085, 2012.

[21] S K Khadem, M Basu and M F Conlon, “Power quality in grid connected renewable energy systems: Role of custom power devices”, International conference on renewable energies and power quality (ICREPQ’10), 2010.

[22] Masoud Farhoodnea, Azah Mohamed, Hussain Shareef and Hadi Zayandehroodi, “Power quality analysis of grid connected photovoltaic system in distribution networks”, Przegląd Elektrotechniczny, 2013.