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Solar System Analysis for Different LOADS in Stand-Alone Mode

Sanyam Indurkhya
M.Tech scholar
Truba Institute of Engineering & Information Technology
Bhopal, M.P, India
sanyamindurkhya@gmail.com

Shravan Vishwakarma
Assistant Professor
Truba Institute of Engineering & Information Technology
Bhopal, M.P, India

Abstract: **Distributed generators using environmentally friendly energy sources such as wind, small water and solar energy have become an important part of the future smart grid/micro grid concept. Design of an autonomous photovoltaic system to study the reaction of solar modules to variable irradiation conditions and their effect on loads. The autonomous system must include a battery storage system to handle non-linear load responses on the AC side. And improve the output power of the photovoltaic system using the MPPT algorithm specially designed to drive linear and non-linear loads on stand-alone systems. And causing the system to respond to varying levels of radiation in the environment and achieve an uninterrupted regulated output of the system. The system examined the behavior of linear and non-linear loads with constant irradiation of 1000 wb / m^2 and then modified it to a value between 1000 wb / m^2 and 200 wb/m^2. The harmonic content in the line voltage increased to 3.34% with a non-linear load by 0.54% with a linear load.**

Keywords: **THD, DG, PV system, MPPT.**

I. INTRODUCTION

Distributed generators (DGs) using environmentally friendly energy sources such as wind, small hydro and solar power have become an important part of the future smart grid / micro grid concept. These energy sources meet both the growing demand for electricity and environmental regulations. Photovoltaic is one of the most widespread renewable sources because it is clean, inexhaustible, low maintenance and distributed all over the world. Normally, DGs are small 1 KW to 100 MW active power generators which are connected at the distribution level [1][2]. Active government measures have been taken to encourage the need to use solar energy, which is abundant in nature, and to install autonomous photovoltaic technology (photovoltaic roof) to meet increasing load demands and reduce electricity bills. It also motivates the use of green electricity to generate electricity. The costs of photovoltaic modules are also falling, solar-based DG units play an increasing role in the electricity system of the near future. The development of power electronics technology plays a key role in the integration of DG units which transform the vertical energy system into a horizontal system. DGs can be designed to provide auxiliary services such as reactive power management, load balancing, voltage management and harmonic reduction to the consumer [3]. The most important types of interfaces for electrical systems are synchronous machines, asynchronous machines and electronic power converters [4]. Current synchronization and regulation play an important role in meeting standards for connecting DG units to the public electricity grid. Therefore, the control strategies applied to the interconnection of the DG units are very important.

II. LITERATURE REVIEW

Leonardo P.Sampaio et al. [5] this article proposes an active and reactive power flow control methodology applied to an inverter connected to the three-phase grid, in which local and / or regionalized power flow control is considered in the next distributed generation scenario. The main idea of the methodology is to obtain the best regulators with the lowest possible gains by placing the poles in the area of the left half of the s-plane, obtaining quick responses with reduced vibrations.

Moacyr A. G. de Brito et al. [6] this article proposes an active and reactive power flow control methodology applied to a low voltage three-phase line inverter. The control technique is designed using feedback linearization and pole positioning is achieved using linear matrix inequalities (LMI) and stability concepts D. Through multi-loop control, the power circuit uses power transfer terms active and reactive adapted to obtain the voltage level and power transfer angle to control the flow of energy between the distributed generation (DG) and the power grid.

Anubrata Das et al. [7] the use of solar photovoltaic (PV) inverters that directly feed the grid is increasing in this document. As PV penetration increases, there are more frequent fluctuations in common coupling point (PCC) voltage. This occurs due to the weather-dependent properties of the active power generation of photovoltaic inverters. Voltage fluctuations can also violate ANSI C84.1.

G. Uicich et al. [8] Closed-loop stability analysis of line-switched converters (LCCs) is mainly based on modeling the linear transmission of small signals for the power stage. The inaccuracies derived from using these simple frequency domain models have led to conservative compensation strategies with reduced circuit bandwidths. This paper presents a nonlinear time domain approach to modeling LCC under integrated control.

III. OBJECTIVE

- Designing of stand-alone solar PV system to study the response of the solar modules towards variable irradiation conditions and its effect on the loads. The standalone system shall comprise of battery storage system to handle the nonlinear load responses on the AC side.

- To enhance the power output from the PV system by using MPPT algorithm specifically designed for driving the linear as well as non-linear loads on stand-alone systems.

- To make the system more efficient in dealing with DC loads at local level.

- To make the system responsive towards varying irradiation level in the environment and get regulated uninterrupted output from the system.

IV. PROPOSED METHODOLOGY

The model was developed in MALAB / SIMULINK environment. It is a high-level matrix / array language with control flow instructions, functions, data structures, input/output functions, and object-oriented programming. It has the following main features:

- High level language for scientific and technical informatics
- Desktop environment designed for iterative exploration, design, and troubleshooting
- Charts to visualize data and tools to create custom charts
- Applications for curve fitting, data classification, signal analysis, control system tuning and many other tasks
- Complementary toolkit for a wide variety of technical and scientific applications
- Tools for creating applications with custom user interfaces
- Royalty-free implementation options to share MATLAB programs with end users

An autonomous photovoltaic system is modeled, capable of supplying the load with variable responses including linear and non-linear load fluctuations. The battery storage system and PV were connected to the load via a DC bus powered by both sources and then converted to AC power to power the load. As shown in Figure 1, the basic architecture of the system was modeled to meet the requirements.

The modeling of the different parts of the system was discussed in more detail. The photovoltaic system modeled with MPPT technology for optimal operation. .

A PV energy conversion system consists of a PV module, a DC-DC device, an electrical converter and ideally an energy storage system (ESS). The photovoltaic module consists of photovoltaic cells connected in series and in parallel to generate the specified nominal power. In the system under consideration, the output of the DC sources is connected to a step-up DC / DC converter and the voltage of the intermediate circuit is regulated. The function of the intermediate circuit controller is to follow the voltage across the capacitor, compare it with the reference value and process the error value so that the steady-state error is zero.

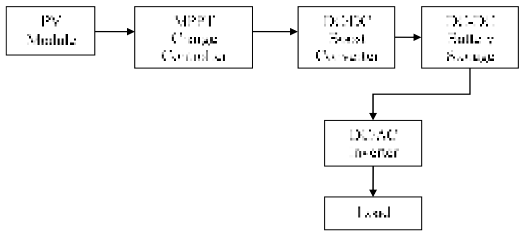

Fig. 1 Basic architecture of a PV system

Fig. 1 shows the Simulink diagram of the island's solar battery system. TATA Power solar system with 10 modules in series and 3 strings in parallel. Fig.1 shows the simple diagram of the solar system and its connection to independent domestic loads with converter with DC load battery, in parallel with single-phase inverter with AC load.

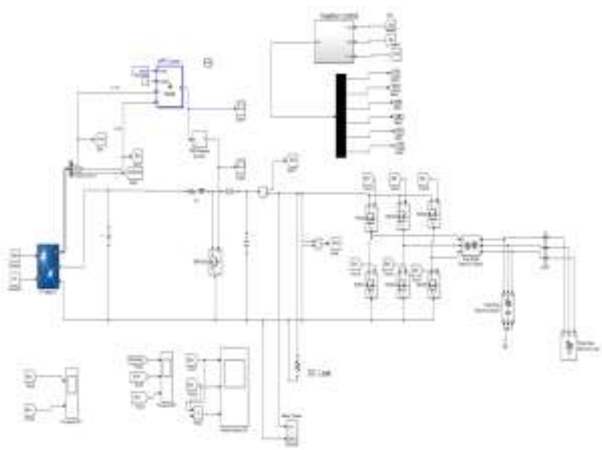

Fig. 2 Complete Simulink diagram of the proposed system

The operation of a single PV cell can be explained via electrical equivalent circuit as shown in Figure.2, PV cells have single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to V/I. A simple equivalent circuit of PV cell is shown in Fig. 6.

The MPPT algorithm has been employed in order to obtain the operation of solar module at maximum power continuously.

A cell series resistance (Rs) is connected in series with parallel combination of cell photocurrent (I_{ph}),exponential diode (D), and shunt resistance (R_{sh}) , I pv and Vpv are the cells current and voltage respectively. It can be expressed as

$$I_{pv} = I_{ph} - I_s\left(e^{q(V_{pv}+I_{pv}*R_s)/nKT} - 1\right) - (V_{pv} + I_{pv} * R_s)/R_{sh}$$

Where:

I_{ph} - Solar-induced current

I_S - Diode saturation current

q - Electron charge (l.6e^{-l9}C)

K - Boltzmann constant (l.38e^{-23}J/K)

n - Ideality factor (l~2)

T - Temperature ^{0}K

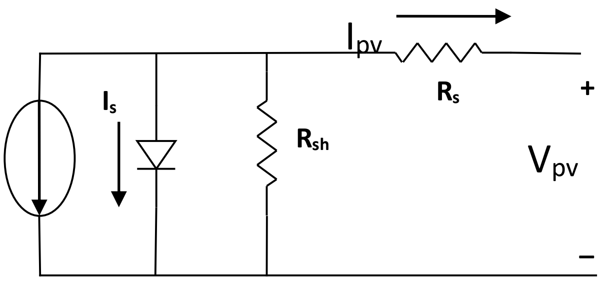

Fig. 3 Equivalent circuit of solar PV cell

The solar induced current of the solar PV cell depends on the solar irradiation level and the working temperature can be expressed as:

$$I_{ph} = I_{sc} - k_i(T_c - T_r) * \frac{I_r}{1000}$$

Where:

I_{SC} Short-circuit current of cell at STC

k_i Cell short-circuit current/temperature coefficient (A/K)

I_r Irradiance in w/m

T_C ,T_r Cell working and reference temperature at STC

A PV cell has an exponential relationship between current and voltage and the maximum power point (MPP) occur at the knee of the curve as shown in the Fig 4.

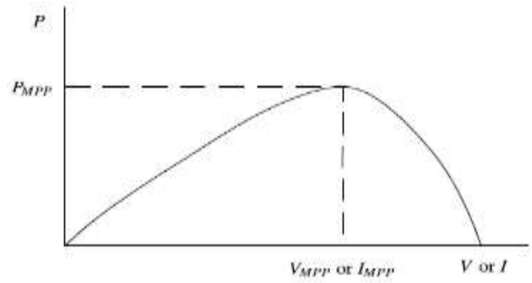

Fig. 4 Characteristic PV array power curve

The MPPT algorithm tracks the maximum power to power the DCMG system. The assumptions for the derivation of the model are that the ideal energy source can be represented by the behavior of the PVs. Furthermore, all converters operate in continuous conduction mode (CCM) and harmonics are also ignored.

Battery Storage systems.

The battery can switch from charge to discharge mode to maintain DC link power balance. When the energy storage device reaches its capacity limit, it maintains the power balance of the DC link by exchanging energy to / from the AC grid.

Table 1: Battery modeling parameters	
Nominal voltage (V)	120
Rated capacity (Ah)	200
Initial state-of-charge (%)	70
Battery response time (s)	0.01

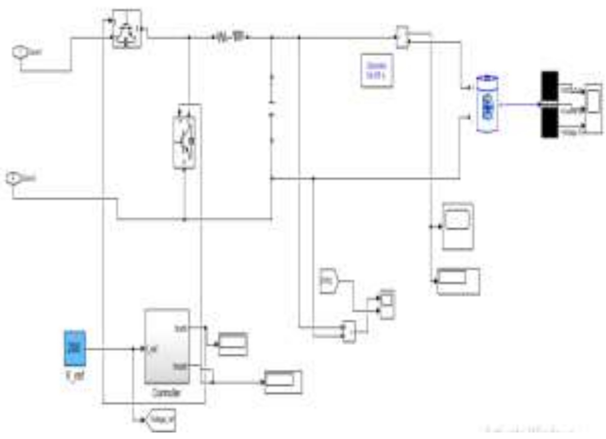

Fig. 5 Modeled Lithium-ion battery storage system

The battery energy storage performs charging and discharging with the difference between P_{pv} and P_{Load} . When P_{pv} is more than P_{Load} the power charged to surplus the storage unit. When the battery is completely charged, battery control unit stops charging and the excess power generated from this moment are delivered to AC grid. In battery modeling, I_{bat} and V_{bat} can be expressed as in (3) and (4), when the power consumption is P watt.

$$I_{bat} = \frac{V_{ocv} - \sqrt{V_{ocv}^2 - 4R_{bat}^{int}P}}{2R_{bat}^{int}}$$

$$I_{bat} = V_{ocv} - R_{bat}^{int} I_{bat}$$

Where;

$$V_{ocv} = f_1(SOC)$$

$$R_{bat}^{int} = \begin{cases} R_{ch} = f_2(SOC) - charging \\ R_{dls} = f_3(SOC) - discharging \end{cases}$$

$$I_{pv} = I_{ph} - I_s\left(e^{q(V_{pv}+I_{pv}*R_s)/nKT} - 1\right) - (V_{pv} + I_{pv} * R_s)/R_{sh}$$

$$SOC = SOC_{in} - \int \frac{\eta I_{bat}}{Q} dt$$

$$\eta = \begin{cases} \eta_{ch} = \dfrac{V_{ocv}}{V_{ocv} - I_{bat}R_{ch}} - charging \\ \eta_{ch} = \dfrac{V_{ocv} - I_{bat}R_{ch}}{V_{ocv}} - discharging \end{cases}$$

The control system of the battery has been shown figure. The mechanism uses two PI controllers in order to provide signals for its charging and discharging. The gain of the controllers is assumed to be Kp= 2, Ki= 120.

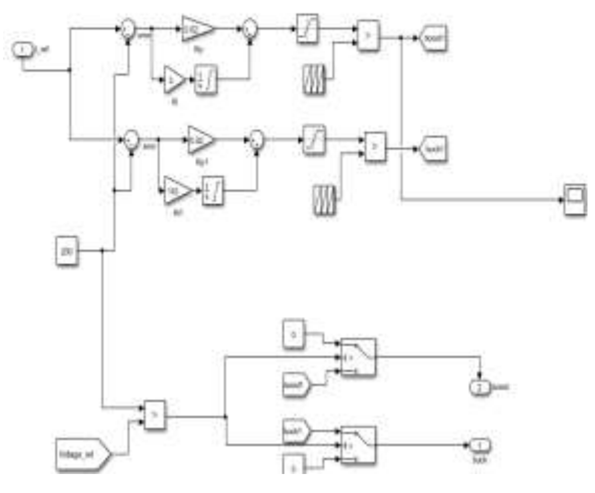

Fig. 6 Electrolyte battery controller

MPPT Design

Maximum power point monitoring (MPPT) is a technique used to derive the current maximum power from a photovoltaic system. The maximum power varies according to the solar irradiation, the ambient temperature and the temperature of the solar cells. The power obtained by the solar system depends primarily on geographic conditions, including the temperature and solar radiation available in selected locations. MPPT tries to achieve maximum performance based on the characteristics of the solar panels.

The maximum power depends on the availability of radiation and temperature. The MPPT algorithm is implemented on the DC-DC converter, e.g. B. on buck, boost and buck-boost converters. A boost converter is used in this project and the duty cycle of the converter is controlled by the MPPT algorithm. A generic PV module with MPPT system can be represented as shown in Fig.7.

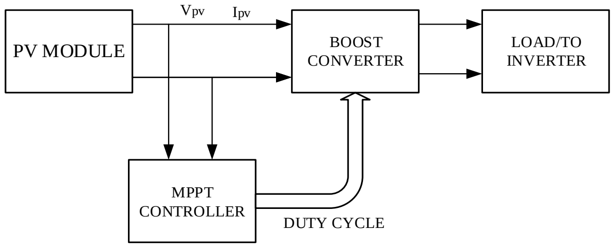

Fig. 7 Block diagram of MPPT

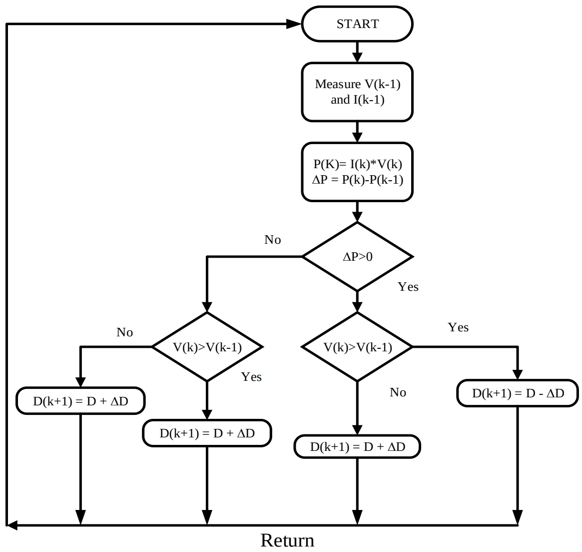

Fig. 8 Flow chart for Perturb and Observe (P&O) scheme.

There are several algorithms to extract the maximum power from photovoltaic panels, such as: B. Noise and observation (P&O), incremental conductance (IC) and fuzzy based MPPT. The choice of the appropriate technique depends on the goal of the problem, MPPT techniques depend on the application or areas of application.

Perturb & Observe is one of the most used MPPT schemes due to its simple and economical implementation. Usually this technique is used for low power applications such as B. for residential and commercial applications. In this method, the current duty point is determined based on the different voltage and power values, i.e.H. the current power and voltage value is compared with the previous values. By simply changing the duty cycle, the duty point is moved in the direction of the MPP. Disturbance and observation diagram in fig. 8.

DC-AC Converter/Inverter Modeling

An inverter is an electrical device that converts direct voltage into alternating voltage. In small inverters, devices such as rooftop solar panels, small micro-grids, home inverters, etc. Two types of inverters are used, e.g. B. single-phase and three-phase inverters. A three-phase inverter has three arms with two switches each, each of which operates at an electrical angle of 180°. The internal model of a three-phase inverter is shown in Fig.4.9.

The three phase inverter is equipped with Sine Wave Pulse Width Modulation (SPWM) and has been designed and simulated. The inverter control design depends on various parameters such as DC voltage, grid voltage, grid current, switching frequency, etc. Inverter control is complemented by a combination of two-stage pulse width modulated regulators. The grid voltage is measured by the unit of measurement of the voltage and this unit of measurement is placed on the connection bus of the inverter. After removing the harmonics, the voltage and current are measured. A stage wave, which is one or two stage depending on the operating mode of 180° and 120°, is converted into a pure sine wave. The proposed system is analyzed for linear and non-linear AC loads. Figure 4.9 shows the AC voltage and current for a 3 kW linear load with constant solar radiation.

Fig. 9 shows the voltage and current harmonics for a linear load, it can be seen from the figure that the voltage and current harmonics are within the range defined in the IEEE standard. The system is also analyzed with a non-linear load. A DC rectifier with ohmic load is simulated and analyzed. Figure 9 shows the charging current with a non-linear load. Figure 9 shows the harmonics of current and voltage for a non-linear load. The current harmonics are 30.3% of the fundamental current.

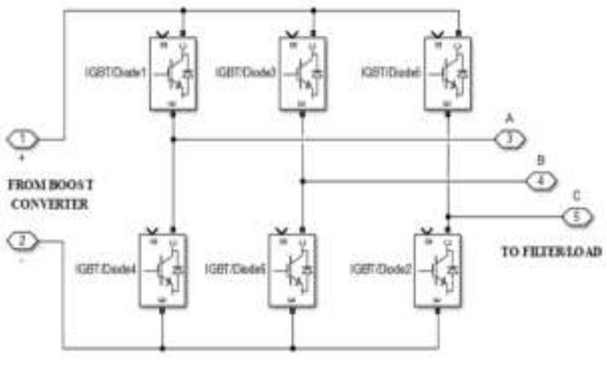

Fig. 9 Circuit diagram of three phase inverter.

V. RESULTS

In practical scenarios, the operating conditions of the photovoltaic module are not constant; it always changes. Understand the behavior of the photovoltaic module with temperature fluctuations and constant irradiation. Fig. 10 and fig.11 show the different peak values for each operational state when the PV module is exposed to a change in the temperature level, e.g. H. 45 ° C 25 ° C and 0 °C. As the operating temperature increases, there is an increase in Isc and a decrease in VOCs, but the output power decreases, which means that the decrease in voltage dominates over the increase in current. the V-I and P-V characteristics of the PV cell can be represented as in figures 3 to 6 for different solar radiations and temperatures.

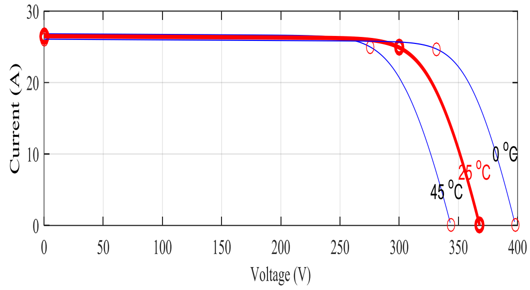

Fig. 10 I-V curve with variable ambient temperatures and constant irradiance.

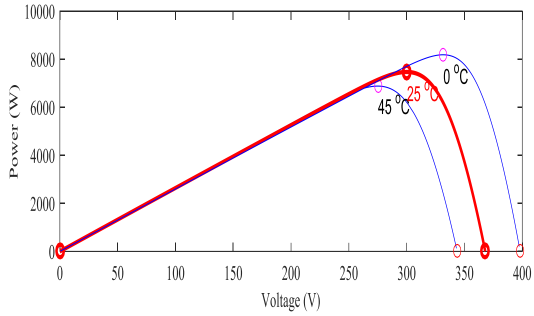

Fig. 11 P-V curve with variable ambient temperatures and constant irradiance.

The properties of the photovoltaic module are obtained at three different levels of solar irradiation of 1000, 500 and 200 W / m^2. It is clear from Fig. 12 and fig. 13 that the VOC and Isc change each time the PV module is exposed to fluctuations in solar radiation. The increase in irradiance causes an increase or decrease in the operating voltage and current. The increase in the operating voltage is considerable, while the operating current varies slightly, so the output power increases with increasing irradiation.

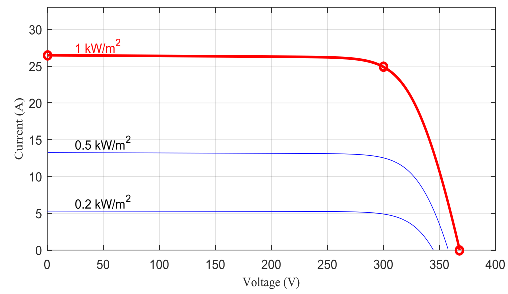

Fig. 12 I-V curve with different solar irradiations.

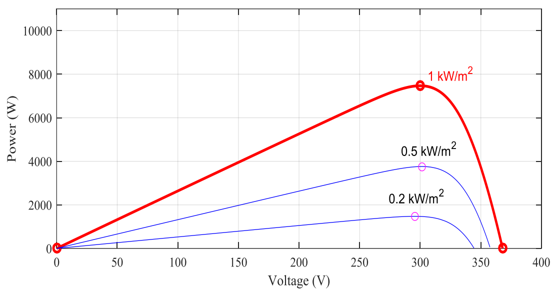

Fig. 13 P-V curves with different solar irradiations.

Fig. 13 shows output of the solar PV system for constant solar irradiance. The maximum solar irradiance is considered as 1000 w/m^2 . The output voltage of the solar PV system before boost converter is 150 V and 26 A as shown in Fig. 14.

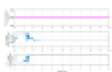

Fig. 14 PV solar output voltage and current with constant irradiance (1000 W/m2).

According to the maximum power transfer theorem, to obtain the maximum external power from a finite internal resistance source, the resistance of the load must be equal to the resistance of the source at its output terminals. To achieve the maximum power of the PV modules, the PV plant must be operated with the correct load setting, e.g. H. The load resistance must match the impedance of the photovoltaic module. An up converter is used to achieve the goal. The efficiency of photovoltaic energy production is very low compared to other renewable energy productions. To improve the efficiency of the photovoltaic system, the photovoltaic module must therefore be controlled in order to generate maximum power as the solar radiation and temperature vary. This function can be provided by the Maximum Power Point Monitoring (MPPT) method

The output variable of the boost converter is shown in Fig.15. The output voltage and current of the step-up converter are respectively 308V and 14A.

Fig. 15 Boost converter output voltage, current and power with constant irradiance

DC load of resistance 100 Ω is connected at output terminals of the boost converter. The voltage across DC load and current drawn by it for constant solar irradiance is shown in Fig. 16.

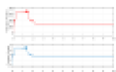

Fig. 16 DC load voltage and current with constant irradiance

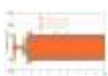

Fig. 17 AC load voltage at constant irradiation and linear load.

Fig. 18 AC load current at constant irradiation and linear load.

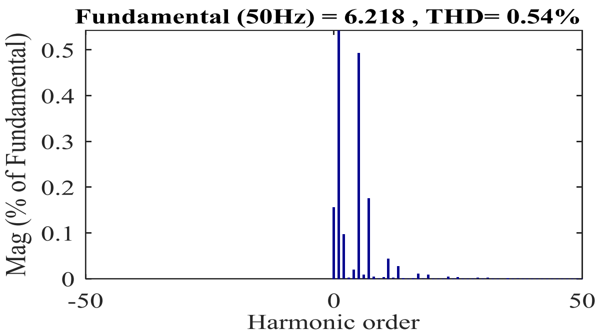

Fig. 19 Current harmonics for linear load

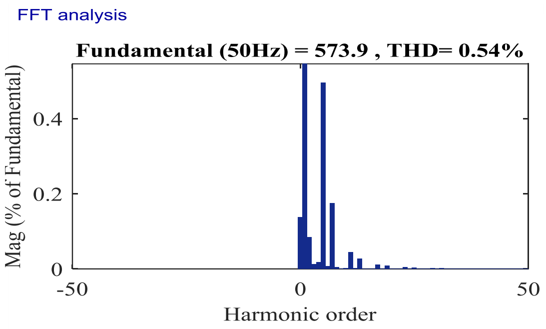

Fig. 20 Current harmonics for linear load

Fig. 21 AC load current at constant irradiation and linear load.

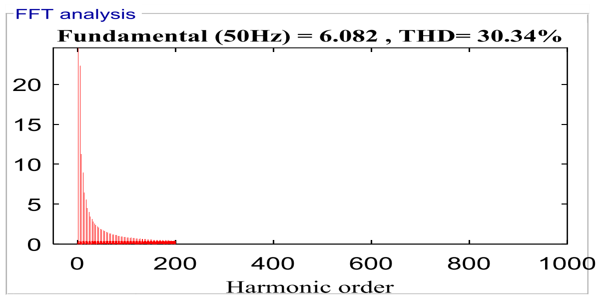

Fig. 22 Current harmonics for nonlinear load

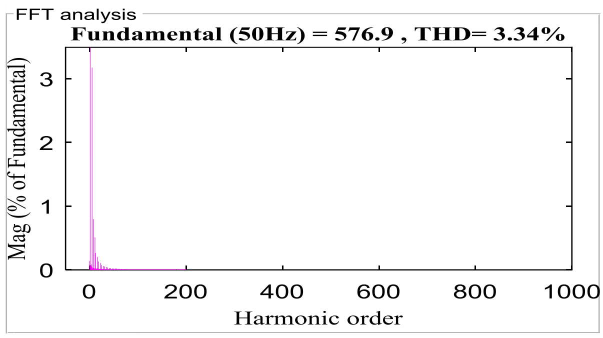

Fig. 23 Voltage harmonics for nonlinear load

Active and reactive power output of the inverter is shown in Fig 24.

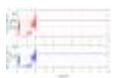

Fig. 24 Inverter active and reactive power output for constant irradiance

Simulation of solar PV with DC and AC Load under Variable Irradiation

Variation the PV array radiation from (400 to 1000 W/m^2) as shown in Fig. 25. Solar PV output voltage and current with variable solar irradiance is shown in Fig. 25 Fig. 26 shows boost converter output with variable solar irradiance. Voltage and current variation of the DC load with variable solar irradiance is shown in Fig. 25. AC output voltage and current variation with variable solar irradiance and linear load is shown in Fig 26.

Fig. 25 PV solar output voltage and current with variable irradiance

Fig. 26 Boost converter output voltage, current and power with variable irradiance

Fig. 27 DC load voltage and current for variable irradiance

Fig. 28 AC Load voltage and current at variable irradiance and linear load.

VI. CONCLUSION

Solar photovoltaic systems are being studied as the energy of the future and most of the research is aimed at this area. The thesis proposes an analysis of isolated systems in order to examine their performance without making them dependent on the network. The solar system design was performed in a MATLAB environment and the implemented module was exposed to variable irradiation to do justice to the practical influences on the solar panel.

The system examined the response to linear and non-linear loads during constant irradiation of 1000 wb / m2 and then modified them to a value between 1000 wb / m2 and 200 wb / m2. The harmonic content in the power line voltage increased to 3.34% with a non-linear load by 0.54% with a linear load.

The studied system demonstrated the performance of non-linear loads with linear loads even with variable irradiation input and integrates the efficiency of the autonomous system in driving various loads. The modeling used DC-DC converter and DC-AC converter technologies, as well as control of the battery conversion system to achieve the best results when charging.

VII. FUTURE SCOPE

The thesis has provided some contributions to the MPPT for autonomous photovoltaic systems when they receive uniform and irregular irradiation. However, MPPT is an accessible research area for further research to be done. The photovoltaic model was developed taking into account various assumptions, such as: the abandonment of the presence of bypass diodes in the solar modules. Bypass diodes play their role when a certain part of the panel is damaged or heavily shaded and therefore the I-V characteristic curve of the panel is different. Future work may take into account the effect of bypass diodes in uncertainty modeling, and PV models can also be developed using two diode models rather than single diodes.

In addition, the system must be further integrated into the network to examine its performance at the network terminal level.

REFERENCES

[1] Anis Ammous, Abdulrahman Alahdal “Optimization of an On-Grid Inverter for PV Applications Using Genetic Algorithms”, Volume 2020.

[2] Ronald Jackson, Shamsul Aizam Zulkifli “An Investigation on Active and Reactive Power Flow Control Based on Grid-tied Parallel Inverters”, AIP Conf. Proc. 2173, 020001-1–020001-10; https://doi.org/10.1063/1.5133916 Published by AIP Publishing. 978-0-7354-1920-9/$30.00

[3] Samet Biricik; Hasan Komurcugil; Malabika Basu “Photovoltaic supplied grid-tie three-phase inverter with active power injection and reactive harmonic current compensation capability”, Annual Conference of Industrial Electronics Society, 2017.

[4] B. Venkatasamy, L. Kalaivani “Performance Analysis of Grid- Tie Inverter for Reactive Power Injection Mode in Hybrid Wind Solar

Energy System", Proceedings of the 2nd International Conference on Trends in Electronics and Informatics (ICOEI 2018) IEEE Conference Record: # 42666; IEEE Xplore ISBN:978-1-5386-3570-4

[5] Leonardo P.Sampaio, Moacyr A.G.de Brito "Grid-tie three-phase inverter with active power injection and reactive power compensation", Renewable Energy, Volume 85, January 2016, Pages 854-864.

[6] Moacyr A. G. de Brito, Leonardo P. Sampaio "Grid-Tie Three-Phase Inverter With Active And Reactive Power Flow Control Capability", Eletrôn. Potên., Campo Grande, v. 19, n.4, p. 397-405, set./nov.2014.

[7] Anubrata Das, Ankul Gupta, "Adaptive Reactive Power Injection by Solar PV Inverter to Minimize Tap Changes and Line Losses", 978-1-4799-5141-3/14/$31.00 c 2016 IEEE.

[8] G. Uicich, S. Maestri, M. Benedetti, D. Carrica, "A Nonlinear Approach for Assessing Stability in Line Commutated Converters with an Integrating Controller", IEEE Transactions on Power Electronics, vol. 29, no. 1, pp. 339-346, January 2014.

[9] D. C. Martins, M. F. Schonardie, R. F. Coelho, L. Schmitz, "Active And Reactive Power Control In A Three-phase Grid-connected Pv Power System Using Dq0 Transformation", Eletrônica de Potência, vol. 18, no. 4, pp. 1180-1187, November 2014.

[10] Y. Zhou, W. Huang, P. Zhao, J. Zhao, "A Transformerless Grid-Connected Photovoltaic System Based on the Coupled Inductor Single-Stage Boost Three-Phase Inverter", IEEE Transactions on Power Electronics, vol. 29, no. 3, pp. 1041-1046, March 2014.