

MAXIMUM POWER POINT TRACKING OF PV SYSTEM BY EMPLOYING CONTROLLER WITH OPTIMIZATION TECHNIQUES

Ph.D. Thesis

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**MAXIMUM POWER POINT TRACKING OF PV
SYSTEM BY EMPLOYING CONTROLLER WITH
OPTIMIZATION TECHNIQUES**

A Thesis submitted in partial fulfillment of the requirement for the award of the degree

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In

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By

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Under the Guidance & Supervision

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CANDIDATE’S DECLARATION

I hereby declare that the work which is being presented in this thesis entitled **“Maximum Power Point Tracking of PV system by employing controller with optimization techniques”** in partial fulfillment of the requirements for the award of *the Degree of Doctor of Philosophy*, submitted in the Department of Electrical Engineering of National Institute of Technology, Jamshedpur in an authentic record of my own carrier out, under the supervision of **Dr. U. K. Sinha**, Associate Professor, Department of Electrical Engineering, National Institute of Technology, Jamshedpur.

The thesis contains my own work and has not been submitted elsewhere to any other University or Institute for the award of any degree or diploma.

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CERTIFICATE

This is to certify that work, which is presented in this thesis entitled “**Maximum Power Point Tracking of PV system by employing controller with optimization techniques**” in partial fulfillment of the requirements for the award of *the Degree of Doctor of Philosophy*, submitted in the Department of Electrical Engineering of National Institute of Technology, Jamshedpur has been carried out, under my supervision. The thesis contains candidate’s own *bona-fide* work carried out by the candidate and that the thesis does not contain any work, which has been previously submitted for the award of any degree/diploma/certificate anywhere else.

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Signature of Internal Examiner

Signature of External Examiner

DEDICATED

TO

PARENTS WITH RESPECT AND LOVE

Dearest, Father Mr. P Surya Narayana, & Mother Mrs. P Aruna Kumari

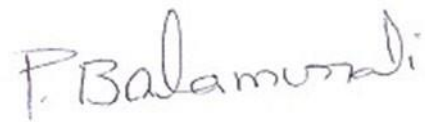
May their World be filled with blessings, happiness, loves and peaceful

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ABSTRACT

Nowadays, for the well-being of nations, power sector is a crucial constituent of organization. Additionally, it is critical for economic growth. The most diversified sector in India is the power sector. The interest for electrical energy is developing at a quick pace in India. In India the power generation sources mostly form conventional type of generations and also increasing demand in the non-conventional type of generations. The energy sources like hydro, coal, and oil are restricted and diminishing because of which, renewable energy assets will appear assume a critical part later on. Harnessing the power form, the renewable energy sources are the challenging task and it requires more complex methodologies. This work concentrates on the issues of the grid connected PV systems. The power output for the PV module is not constant always it varies according to the ambient temperature and the irradiation.

Due to the low performance of the solar PV module make the researchers to work on control topologies of grid connected PV system. In the methodologies of grid connected PV system, “maximum power point tracking (MPPT)” is an extreme factor to consider that is taken into account. As is the power output for the PV module is not constant always it varies according to the ambient temperature and the irradiation, it is necessary to extract maximum power with the help of MPPT controller.

In this work, Grey Wolf Optimization (GWO) based Incremental Conductance MPPT technique employed for grid tied PV system. The proposed technique is compared with the PSO based Incremental Conductance MPPT technique and shows that the proposed technique is reliable.

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NOTATIONS

Symbol	Description
I_{VP}	Total cell current
I_0	Diode saturation current
I_{SC}	Short Circuit Current
η	Boltzmann constant
I_d	Diode Current
V	Solar cell output voltage
R_S	Solar cell series resistance
R_p	Parallel Resistance
I_{R_p}	Current through R_p
V_T	Thermal voltage
U	Particle velocity
C_1, C_2	Acceleration coefficients
D	Particle position
$rand_1()$	Pseudo random number
X_i	Position of grey wolf
X_p	Position of the prey
lb	Local best
gb	Global best
k	Iteration number

CHAPTER – 1

1. INTRODUCTION

Current years have really revealed unparalleled advancement of renewable resource circumstance, where no matter the worldwide financial issue the area has really taken care of it. The toughness of the area versus all probabilities shows that renewable resource is definitely the future and also will absolutely play a significant task in facilitating a tidy, additionally lasting as well as safe power economic climate. The ability is certainly large as well as the promptly broadening economic climates are developed to change the economic crisis right into a chance for greener advancement. For the market to expand significantly to accomplish globe power needs, it is vital for the Governments of Federal to provide assistance in making renewables establish you back inexpensive as contrasted with numerous other power resources and also developments [5].

The world's power supply is substantially based upon nonrenewable fuel sources. It is estimated that by 2030, 80% of key power mix will certainly be controlled by nonrenewable fuel sources, where in oil will absolutely remain to be the leading gas in addition to requirement for coal will absolutely climb up much more than that of any kind of sort of various other gas in outright terms. In such a scenario, the awareness that these resources of power will certainly not last completely as well as additionally are also adding to eco-friendly issues is what has in fact made renewables a long lasting as well as successful choice. This has actually in addition led the government governments around the world, along with markets, thinking seriously regarding alternative sources of power, the demand for which was more verified by the 1973 oil deduction in addition to oil price shock of 2008, paired with the ever-elevating oil prices [44-49].

Current researches highlight that present worldwide patterns in power supply in addition to intake are patently unsustainable-- ecologically, monetarily as well as socially. It in addition took place to consist of that the circumstance can be transformed if the supply of relied on in addition to affordable power is safeguarded as well as likewise a fast remodeling is made to a low-carbon, effective in addition to ecologically benign system of power supply.

Presently, even more than ever before, countries throughout the globe completely recognize the need to market huge spread fostering of renewable resource right into their nation's power sources, with the intent of marketing regular monetary development, social improvement as well as likewise ecological stewardship. It is furthermore presumed that with boosting array, study, array and also advancement, the rate of renewable energy advancements will definitely condense; making them spending plan additionally able as well as pleasant to make a significant settlement to electric power generation, house heating, cooling down as well as likewise transport. Quotes highlight that renewable energy might add a minimum of half of all the electrical power in each of the large economic situations by 2050; additionally in countries where power requirement is significantly high. What's even more, renewable energy not simply has the ability to provide numerous people with accessibility to electrical energy; renewable energy gadgets producing and also setup is extremely work comprehensive, consequently including not simply to enhanced living issues, nevertheless additionally causing reduced hardship. Renewables Global Standing Record (2009 upgrade) by REN21 in addition duplicates that the renewable resource market provides a vital program for growth that can advertise monetary recovery as well as additionally job manufacturing without the worry of raising carbon discharges.[50]-[55]

In current times, there has really been an increasing acknowledgment concerning the global warming in addition to the harmful impacts that the exhausts of carbon have. This created a greater demand for likewise lasting as well as clean power resources like: wind, sea, sunlight, biomass and so on. The wind power has in fact experienced the best development in the previous 10 years. This is due to the fact that wind power is a pollution-free resource, has an infinite capacity as well as in addition due to its progressively affordable cost.

1.1 Renewable Energy Scenario in India

The Ministry of New as well as Renewable Energy (MNRE) is the nodal Ministry at the government degree for all issues associating with renewable as well as brand-new energy. The Ministry has actually been assisting in the execution of broad-spectrum programs consisting of utilizing renewable power, renewable resource to backwoods for food preparation, lights as well as objective power, use renewable resource in city, industrial and also commercial applications as well as growth of alternating gas and also applications.

For many years, renewable resource market in India has actually become a substantial gamer in the grid linked power generation capability. It sustains the federal government schedule of lasting development, while, becoming an essential component of the service to satisfy the country's energy demands and also a vital gamer for energy accessibility. It has actually been recognized that renewable resource needs to play a much deeper duty in accomplishing energy protection in the years in advance as well as be an essential component of the energy preparation procedure.[56]-[60].

There has actually been a noticeable influence of renewable resource in the Indian energy situation throughout the last 5 years. Renewable resource industry landscape in India has, throughout the last couple of years, experienced significant modifications in the plan structure with increased and also enthusiastic strategies to enhance the payment of solar power. There is an understanding that renewable resource can currently play a considerable function, as additionally, there is a self-confidence in the modern technologies and also capability to do so. Expanding the extent of the Jawaharlal Nehru National Solar Mission represents both, as well as certainly envelops the vision as well as passion for the future. This transformational modification is, possibly, the emphasize of the last 5 years of tasks under the Mission. Furthermore, the introducing of Renewable Energy Certificate (REC) device aids in the production of a Pan-India renewable resource market. The various other substantial success are intro of solar details acquisition responsibilities; introducing of enhanced cook-stoves efforts; starting worked with r & d

tasks in solar PV and also thermal; 2nd generation biofuels, hydrogen energy and also gas cells, and so on.

Core chauffeurs for advancement and release of renewable as well as brand- new energy in India have actually been:

a. Energy safety: At existing around 69.5 percent of India's power generation capability is based upon coal. Additionally, India's enhancing dependency on imported oil, is bring about imports of around 33 percent of India's overall energy demands.

b. Electricity scarcities: Despite rise in set up capability by greater than 113 times in 65 years, India is still not in a setting to satisfy its height power need along with energy need. The peak power deficiency throughout fiscal year 2001-02 was 12.2 percent, around 9252 MW, nevertheless, at the end of Financial Year 2014-15, the peak power shortage reduced to the order of 2.4 percent. As an after effects of this scenario, intended and also un-planned procedures were taken on by the federal government and also energies to connect this demand-supply space.

c. Energy Access: India encounters an obstacle to make certain accessibility of contemporary and also trusted kinds of energy for all its people. Practically 85 percent of country families depend upon strong gas for their cooking requirements as well as just 55 percent of all country homes have accessibility to electrical energy. Also with this reduced gain access to, a lot of country homes deal with concerns with top quality as well as uniformity of energy supply. Absence of country lights is resulting in massive use kerosene. This use requires to be decreased, as it causes boosted aids and also import dependancy, as well as ensuing stress on fx gets.

d. Climate adjustment: India has actually taken a volunteer dedication of lowering discharge strength of its GDP by 33-35 percent from 2005 degrees by 2030. In the lately ended 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) held at Paris, France, India devoted to attain regarding 40 percent advancing electrical power set up ability from non-fossil gas based energy sources

by 2030 with the aid of transfer of modern technology and also affordable global money consisting of from Green Climate Fund (GCF) [61]-[65].

It has actually been recognized that renewable energy has to play a much deeper duty in attaining energy safety in the years in advance as well as be an essential component of the energy preparation procedure.

There has actually been a noticeable effect of renewable energy in the Indian energy circumstance throughout the last 5 years. Renewable energy market landscape in India has, throughout the last couple of years, experienced incredible adjustments in the plan structure with increased and also enthusiastic strategies to raise the payment of solar energy. In enhancement, the establishing of Renewable Energy Certificate (REC) device aids in the development of a Pan-India renewable energy market. India cumulative Installed Power Capacity Mix is show in Fig: 1.1

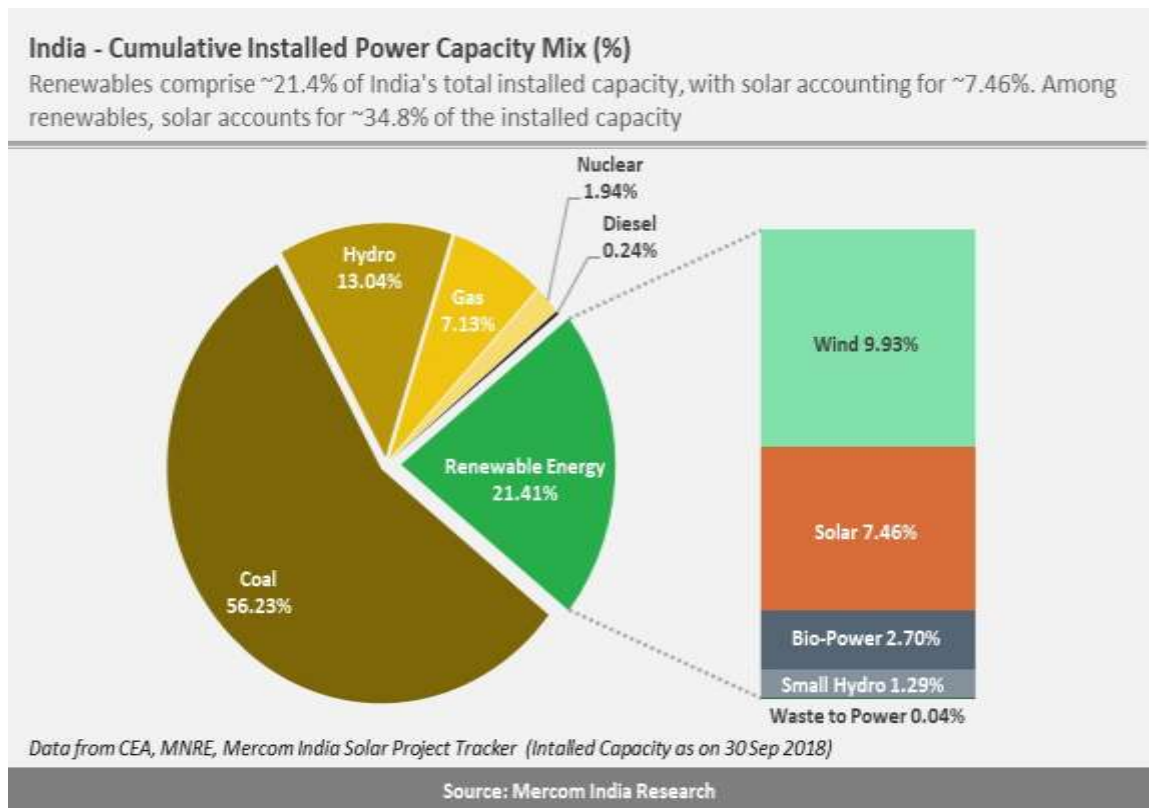


Fig: 1.1 Installed Capacity of Power in India in Percentage

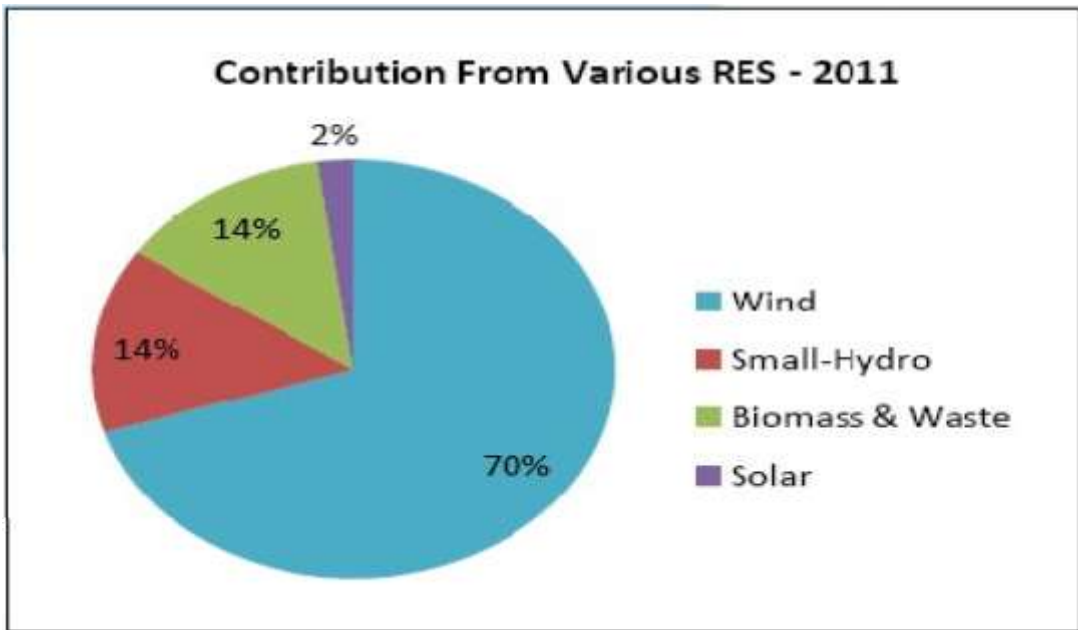


Fig: 1.2 RES contribution in India

1.2 Present Solar Power Situation in India

India has actually an approximated renewable resource capacity of regarding 900 GW from readily exploitable sources viz. Wind: 102 GW (at 80 meter pole elevation); Small Hydro : 20 GW; Bio-energy : 25 GW; and also 750 GW solar energy, thinking 3% marsh is offered. The Ministry had actually occupied a brand-new campaign for application of wind source evaluation in exposed/ brand-new locations with a purpose to examine the reasonable capacity at 100 m degree in 500 brand-new terminals throughout the nation under the National Clean Energy Fund (NCEF). The modified wind energy capacity in the nation theorized at 80 meter elevation has actually been located to be 102,788 MW. National Institute of Wind Energy has actually utilized sophisticated modeling methods and also changed the price quote the wind power possibility at 100 meter at 302 GW. Quotes of overseas wind energy possible suggest prospective in Tamil Nadu and also Gujarat. Wind energy generators of system dimensions in between 250kW and also 2.50 MW have actually been released throughout the nation. On top of that, there exists considerable capacity from decentralized dispersed applications for conference warm water demand for household, commercial and also industrial field with solar power as well

as additionally for conference food preparation energy requires in the backwoods via biogas. Table 1.1 gives information on state sensible renewable resource capacity in the nation.

Renewable resource has a wonderful possible to introduce global energy gain access to. In a decentralized or standalone setting, renewable resource is an ideal, sensible and also scalable remedy for supplying power to un-electrified or power lacking towns and also communities. Around 1.1 million families are making use of solar power to satisfy their illumination energy requirements and also nearly comparable varieties of the houses fulfill their food preparation energy requires from biogas plants. Solar Photovoltaic (PV) power systems are being made use of for a range of applications such as country electrification, train signaling, microwave repeaters, TELEVISION transmission and also function as well as for offering power to surround stations. Over 10,000 unattainable as well as remote communities as well as towns have actually been given with fundamental electrical power solutions with dispersed renewable power systems [66]-[70].

A huge residential production base has actually been developed in the nation for renewable resource systems as well as items. Business purchasing, these innovations are qualified for monetary rewards, tax obligation vacations and also devaluation allocation in addition to the advantageous returns for the power fed right into the grid. Better, the federal government is urging international capitalists to establish renewable power tasks with 100 percent international straight financial investment. The Indian Renewable Energy Program has actually gotten large acknowledgment worldwide in the current years. Several nations have actually evinced rate of interest together with India for promo of renewable as well as brand-new energy. India has significant experience and also experience in advertising renewable resource, both grid off-grid/stand-alone and also interactive applications for conference electric energy requirements. India has actually been communicating with a number of established and also establishing nations for teamwork in renewable and also brand-new energy market. Multilateral as well as reciprocal teamwork structures have actually been developed with 44 nations.

1.2.1 Installed Capability

The total Installed capacity of India is Shown in the Table 1.1.

Table 1: State Wise Installation

S.NO	STATE	MW
1	Andhra Pradesh	38440
2	Arunachal Pradesh	8650
3	Assam	13760
4	Bihar	11200
5	Chhattisgarh	18270
6	Goa	880
7	Gujarat	35770
8	Haryana	4560
9	Himachal Pradesh	33840
10	Jammu & Kashmir	111050
11	Jharkhand	18180
12	Karnataka	24700
13	Kerala	6110
14	Madhya Pradesh	61660
15	Maharashtra	64320
16	Manipur	10630
17	Meghalaya	5860
18	Mizoram	9090
19	Nagaland	7290
20	Orissa	25780
21	Punjab	2810
22	Rajasthan	142310
23	Sikkim	4940
24	Tamil Nadu	17670
25	Telangana	20410
26	Tripura	2080
27	Uttar Pradesh	22830
28	Uttarakhand	16800
29	West Bengal	6260
30	Andaman & Nicobar	0
31	Chandigarh	0
32	Dadra & Nagar Haveli	0
33	Daman & Diu	0
34	Delhi	2050
35	Lakshadweep	0
36	Puducherry	0
37	Others	790
	Total	748990

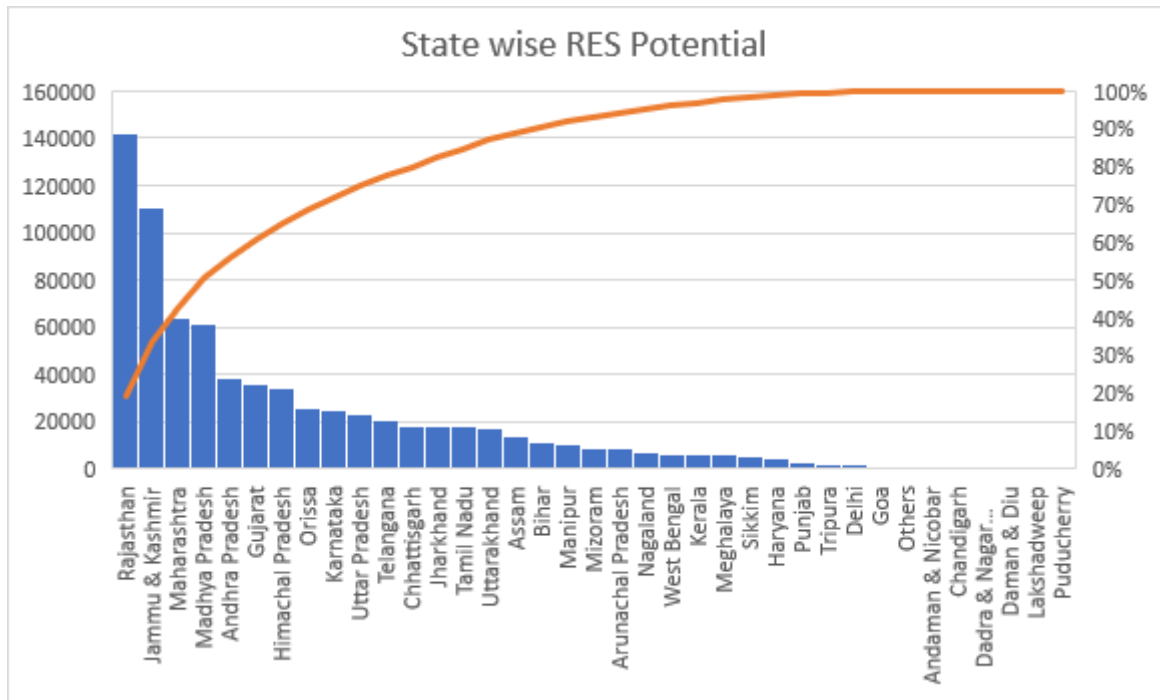


Fig: 1.3 State Wise RES Potential

1.2.2 Challenges and Opportunities:

Renewable resource (RE) resource possessions will certainly think a vital component later. India is performing at high speed in the direction of a lot more Renewable, fast growth of 17% with a basic mix of Renewable source of power restriction was seen from 2014 to 2017(EREP, 2017). The basic presented limitation of RE is broadened to 60.98 GW with a deal of 18.37% tidy energy in India. India has actually presented greater than 5.5 GW of PV based energy year-to-date, with a basic consolidated facilities going across 15 GW till day having fast growth of 56% from 2014 to 2017. Without criterion for Q2 2017, a high diminishment in PV based tax obligations was viewed that pertained to 2.50 (\$ 0.038)/kWh, making solar power more economical than various other (lasting source of power, 2017). "In 2009 India Government moved Jawaharlal Nehru National Solar Mission (JNNSM). The goal was to start Grid connected Solar Projects of 100 GW by 2022."(Marcum India 2018). The significant drawback of sunshine based vigor is its efficiency which will certainly remain in the range of 14 - 18% on conventional problems (financially used panel in India). Out of 100% lighting externally of photovoltaic panel around 30% of beam of lights mirrored back due to the covering product existing externally

a PV panel, used for panel safety and security from the eco-friendly corruption. Around 15% of the illuminations are needed for excitation of electrons which affects the electrons to relocate from valence band to transmission band and also beats the vigor opening. One more ~ 25% of sunlight powered light is thermal losses. A solar battery offers much better implementation under normal temperature level in contrast to in warm ambience, panels are ranked at 25 °C and also finest efficiency can be accomplished at this temperature level. For every level upwards press in temperature level upon 25 °C the reaction of the panel minimized regarding 0.25% for amorphous cells and also as pertains to 0.4-0.5% for crystalline cells. Ultimately, on cozy summer season days in India, panel temperature level might easily attain a minimum of 80 °c. This result in 25% much less power return when contrasted with what it is reviewed at 25 °C, which lowers its general performance. The efficiency of PV panel mainly trusts the product used for PV cell, the innovation of PV cell, strength of the sunlight or solar irradiation, panel temperature level, color, life time, positioning and so on. The Proposed bibliography researches consider facilities as well as assesses in between different kind of advancements made use of to boost the efficiency of PV panels as well as more suggestions for implementation of the most effective innovative technology. Varied type of solar based cells taking into account the product or their synopsis framework available in the here and now market which is cleared up in Figure 1 (Left). Out of these, poly-crystalline and also mono-crystalline silicone panels cover 90% of the Indian solar based market

Out of 100% lighting on the surface area of solar panel around 30% of light beams mirrored back since of the covering product existing on the surface area of a PV panel, made use of for panel protection from the eco-friendly corruption. For each level upwards press in temperature level upon 25 °C the feedback of the panel decreased concerning 0.25% for amorphous cells and also as pertains to 0.4-0.5% for crystalline cells. Out of these, poly-crystalline as well as mono-crystalline silicone panels cover 90% of the Indian solar based market [71]-[75].

1.3 Proposed System

In this work, GWO based MPPT algorithm for Grid linked PV system are established as well as contrasted under different conditions i.e. under various irradiance, and temperature conditions. Finally the proposed system is compared with PSO based MPPT Algorithm form the results it shows that proposed system shows the best performance.

Details of different parts of industrialized system is as follows:

1.3.1 Solar Module

Solar component contains Photo Voltaic cells made of semiconductor material that can produce and generate electrical power when brightened by sunshine. Solar PV component taken into consideration for analysis of proposed GWO based MPPT algorithm for Grid connected PV system.

1.3.2 Boost Converter

The Voltage generated for the solar module is not constant. Hence, we require a mechanism to maintain the voltage constant. This can be achieved by the Boost converter. The boost converter operates based up on the signal from the MPPT Controller.

1.3.3 Inverter

Inverter is also called as grid connected PV Inverter. The output of the boost converter is given to the PV inverter. Inverter Converts the DC to AC supply and helps in synchronizing the PV power to the Utility Grid.

This work presents a Novel Grey Wolf Optimization based Incremental Conductance Maximum Power Point Tracking (MPPT) technique employed for grid tied PV system. The Proposed Technique is Compared with the PSO based Incremental Conductance Maximum Power Point Tracking (MPPT) technique and exabits that the proposed technique is reliable

1.4 LITERATURE REVIEW

The renewable resource sources have actually boosted considerably as a result of fossil gas as well as ecological problems raised expense. Combination of renewable resource sources to energy grid depends upon the range of power generation. Big range power generations are linked to transmission systems whereas little range dispersed power generation is linked to circulation systems. There are specific difficulties in the combination of both kinds of systems straight. This paper provides a testimonial on grid Integration as well as power high quality problems related to the combination of renewable resource systems in to grid and also Role of power digital gadgets and also Flexible A/C Transmission Systems pertaining to these Issues. When there are voltage or existing variants existing in the power distribution, the economic situation of any kind of country withstands with huge tragedies. Failing or missing out on of procedure of customer materials due to any type of deviation/disturbances received the voltage, existing and also regularity from the common ranking is dealt with as a power high quality (PQ). In comprehensive amounts of energy sources, transmission tons, lines and also transformers receive the interconnected power networks, broadening sources of disruptions take place continuously which triggers PQ problems basically. Direct exposures to all-natural disruptions like lightning strikes are not enduring such systems. System equipment break down; COMPUTER information loss as well as memory breakdown of delicate tons, as an example, COMPUTER, programmable reasoning controller controls, safety as well as communicating devices and also unpredictable procedure of digital controls are triggered due to PQ concerns. To ensure greater degree of high quality supply, for instance, Un disturbed power supply (UPS) as well as stabilizers to maintain these concerns, customers will certainly buy on-site tools although that these are pricey. In the direction of financial circulation of the energy the relevance of power high quality is shown up [76]-[80]. Grid connected issues, as an example, harmonics, flicker, voltage dip/swell, voltage policy, lots unbalancing as well as variances in stage in addition to regularity are misstated due to lasting energy combination as well as wise transmission systems, well equipped with present control materials, increment the uses of nonlinear as well as online changed tools in circulation systems. With the goal of boosting provided power high quality in

latest twenty years a couple of strong state electronic/power-electronic gadgets have actually been produced, pondered as well as recommended to the international scholastic team. As demands, the dependability as well as high quality of power that is communicated to customers is updated by the FACTS based power digital controllers for circulation systems, particularly customized power gadgets.

K. Chandrasekaran et al. (2005) [1] In this paper, a total substitute QPP (Power Quality Provider) system has actually been created by utilizing the PSCAD software application. The simulation outcomes have actually confirmed the voltage recovering capacity of an unique collection compensator or QPP which is based upon recommendation voltage tracking control approach. The QPP is vibrant and also rapid and also has the ability to execute a twin feature at the same time to recover the tons voltage at its ranked worth. By recommending QPP in the power system, it has the ability to boost the power high quality.

Sai Kiran Kumar et al.(2011) [2] This paper examines that D-STATCOM is developed by the mix of two-level VSC and also PWM-based control. Right here the voltage dimension is managed by PWM Controller.

Sandesh Jain et al.(2012) [3] This paper has actually provided the power top quality issues such as voltage dips, distortions, harmonics as well as swells. Settlement methods of custom-made power digital gadgets, DVR existed. The THD and also the quantity of unbalance in tons voltage are lowered with the application of DVR. The suggested system executes far better than the typical approaches in alleviating harmonics and also voltage droops.

ChanchalKatariya, G. Shriwastava (2014) [4] This paper resolves the modeling as well as evaluation of personalized power controllers, power electronic-based tools targeted at boosting the integrity and also high quality of power moves in reduced voltage circulation networks utilizing DSTATCOM. A brand-new PWM- based control plan has actually been recommended that just calls for voltage dimensions the procedure of the suggested control technique exists for D-STATCOM.

Muhammad Hamid et al.(2014) [5] This paper has actually offered an approach to enhance the power high quality of a PV plant making use of a generation side conditioner device operating in a feed-forward plan. The plan utilizes a power conditioner device, which is positioned parallel with the plant as well as operates in feed-forward setting and also acts to make up the PV plants outcome, existing distortion, to ensure that the overall existing circulations to the grid is sinusoidal.

Rajasekaran Dharmalingam et al.(2014) [6] In this paper, concurrent recommendation structure concept based control technique is executed to regulate the working of unified power top quality conditioner based upon present resource converter geography. The recommended UPQC-CSC style has exceptional efficiency for minimizing the power high quality issues. The collection converter can alleviating the voltage associated issues and also shunt converter can reducing the harmonics.

Martin Valtierra-Rodriguez et al.(2014) [7] In this paper, a brand-new twin neural-network-based method to identify and also identify mixed and also solitary PQ disruptions is suggested, being composed, on the one hand, of a flexible direct network for harmonic as well as inter harmonic evaluation that enables calculating the root-mean-square voltage as well as complete harmonic distortion indices. With these indices, it is feasible to discover and also categorize droops, swells, harmonics, and also failures inter harmonics. On the various other hands, a feed onward semantic network for pattern acknowledgment making use of the upright as well as straight pie charts of a specific voltage waveform can categorize spikes, notching, flicker, as well as oscillatory transients. When they show up at the same time, the mix of the abovementioned neural networks enables the discovery and also classification of all the above mentioned disruptions also.

Sung-Wook Kang; Kyeong-Hwa Kim (2015) [8], this paper provides a SMHC (Sliding Mode Harmonic Compensation) plan to boost the power top quality of a Grid linked Inverter, when the grid is contaminated by indirect tons in DG system.

Jiefeng Hu et al.(2015) [9] In this job, a efficient as well as straightforward MPDPC (Model Predictive Direct Power Control) approach incorporated with power settlement system is suggested for DFIGs under out of balance grid voltage problems. The primary payments of this job are the first, a MPDPC technique for DFIGs is suggested. Second, a power settlement plan is created to include with the MPDPC approach so regarding boost the power top quality of the stator currents infused right into the grid.

Raj Kumar et al.(2015) [10] This paper manages a customized strategy for the acknowledgment of solitary phase and also numerous PQ (Power Quality) disruptions. A formula based upon ST (Stockwell's-Transform) as well as ANN (Artificial Neural Network) based classifier as well as a regulation based choice tree is suggested in this job. Solitary phase and also multistage disruptions have actually been efficiently identified with the S change based ANN classifier as well as regulation based choice tree. PQ disruptions have actually quickly been spotted and also local as regularity, amplitude and also time details of the PQ signals which is quickly gotten with S-transform.

D.Amoozegar (2016) [11], this paper provides approach for the enhancement of power top quality with the Fuzzy reasoning Control based DSTATCOM. That convention PI control based DSTATCOM will certainly include taken care of criteria. Because of the repaired criteria it reveals the unsuitable as the framework of the existing power system is nonlinear. The writer suggests the Fuzzy-PI controller based DSTATCOM which is made use of for the sufficient efficiency throughout the vibrant instances as well as Enhanced efficiency in Non-Linear Structure.

Soumya Mishra, PravatKumar(2016) [12] This paper offers a brand-new optimization formula (JAYA optimization) to discover the gains of PI controller as well as filter criteria for PV-DSTATCOM. In viewpoint of examining the competence of this brand-new JAYA maximized PV-DSTATCOM, its efficiency is compared to (Grenade Explosion Method) GEM as well as (Teaching Learning Based Optimized) TLBO based PV DSTATCOM. From the gotten outcomes, it is located that JAYA enhanced PV-DSTATCOMassembles faster than the TLBO and also GEM maximized ones.

Quentin Tabart et al. (2017) [13] In this paper, a 2nd order moving setting controller is suggested for the power circulation control of a HESS, making use of a Four Leg Three Level Neutral Point Clamped (4-Leg 3LNPC) inverter as the only user interface in between the RES/HESS as well as the mini grid. A three-dimensional area vector inflection and also a series decay based Air Conditioner side control enables the inverter to operate in out of balance tons problems while keeping a well-balanced Air Conditioner voltage at the point of typical combining.

Sanjay Kumar et al. (2017) [14] This paper recommends An enhanced Phase-Locked Loop (EPLL) based control formula for a double-stage solar photovoltaic (PV) grid-interfaced power-generating system exists in this short article. It is additionally minimizes power high quality (PQ) issues in a three-phase, four-wire circulation system under variable solar strength. The recommended boosted EPLL -based synchronization technique is applied to fulfill grid needs such as PQ enhancement, distortion-free signals under variable solar strength, as well as lots unbalancing. The recommended boosted EPLL-based synchronization method is made use of to do numerous features, consisting of boosted PQ, removal of maximum power from a provided score of solar PV variety, as well as feeding the removed solar PV power right into the circulation system.

S. Choudhury et al. (2018) [15], this paper offers method for maximum choice of subscription feature in the blurry reasoning with the assistance of the customized Seeker Optimization Approach (SOA). This brand-new approach chooses the optimal subscription features for the unclear reasoning as well as likewise to calculate the PI Controller gain worth. The efficiency of the recommended approach is validated in nonlinear instances as well as ended that the suggested control technique is the best.

Thierry A. Meynard Henri Foch et.al [16] suggested a standard multi cell voltage-source inverter (VSI). In his assumption these converters has actually expanded from an eye-catching principle to a reasonable commercial alternative for the future. In this paper, the

major features, such as harmonic termination as well as, particularly, open-loop all-natural voltage equilibrium have actually been researched as well as the certain expertise called for to utilize this idea for high power applications has actually been created. Much more advancements in the area of high-bandwidth control might still be prepared for, yet a vast array of applications might currently utilize this geography as well as high power could not be the only area.

Gui-Jia Su et. al [17] recommended Multilevel voltage-source inverters based upon the diode secured stage legs, flying-capacitor stage legs, or plunged H-bridges for changing both degree inverters with collection link of buttons or transformer-coupled several two-level inverters in tool as well as high-voltage degree applications such as electric motor drives as well as fixed VAR compensators. The recommended MLDCI inverters can get rid of about half the variety of buttons, their entrance motorists, securing diodes, and also capacitors compared to their existing MLI equivalents. Regardless of a greater complete VA score of the buttons, the brand-new MLDCI inverters can still set you back much less because of the financial savings from the removed gateway chauffeurs as well as from less setting up actions due to the significantly decreased variety of parts, which likewise causes a smaller sized dimension as well as quantity. The expense financial savings is better boosted with the suggested diode-clamped as well as the flying-capacitor inverters as a result of the considerable decrease in the overall VA ranking of the securing diodes and also in the complete voltage score of the voltage-splitting capacitors or the securing capacitors [80]-[83].

Gerardo Ceglia et. al [18] has actually made an unique multi degree converters in 2 various approaches specifically the geography consists of an H-bridge phase with a supporting bidirectional button, considerably minimizing the power circuit intricacy, and also a modulator as well as shooting control circuit created utilizing an area programmable gateway selection (FPGA) programmable circuit, to streamline the modulator circuit layout and also execution. These 2 ideas are made use of in the style of the five-level bridge converter provided listed below. When contrasted with the five-level converters, the brand-new converter geography made use of in the power phase provides a vital

renovation in terms of reduced element matter as well as minimized format intricacy. The contract in between the substitute outcomes as well as the information extracted from the speculative circuit program plainly that: The brand-new multilevel geography with the bidirectional complementary button functions as anticipated, producing the needed five level result utilizing just 5 power buttons, as well as just one facility faucet given by 2 capacitors; This geography can be run at extremely high inflection regularities (procedure at 200 KHz has actually existed), creating a spick-and-span result range. The integrated use these 2 modern technologies might bring about the layout of multilevel converters at a price affordable keeping that of common two-level converters.

A. Nami, F. Zare, et. al [19] has actually contrasted in between the un equivalent in proportion as well as unbalanced setup of Multi degree inverters. This paper carried out an unequal DC web link voltage arrangement. In this technique among the capacitors' voltages is constricted at two times the degree of capacitors throughout procedure. Unbalanced DC web link plan is used as there is an adjacency in between all outcome voltage degrees that indicates various voltage degrees are available with simply one button modification. Utilizing unbalanced plan, 9 various voltage degrees can be created on stage voltage which is 2 voltage degrees much more with the same variety of changing gadgets, in contrast with the traditional four-level inverters. This will certainly bring about the decrease of high and also reduced harmonic material of outcome voltage.

Yu Liu as well as Hoon Hong, et. al [20] developed a real-time formula for decreasing THD in multilevel inverters with unequal or differing voltage actions under stairs inflection. This paper has actually recommended a formula whereby the changing angles are determined in genuine time for multilevel inverters with unequal or differing voltage actions under the stairs inflection. With the recommended formula, the voltage THD is reduced, which is verified by the strenuous mathematical derivation. A brand-new expression of THD exists to streamline the derivation substantially. The computational intricacy is assessed to reveal that the computer time is tiny sufficient that usual microprocessors or DSPs can manage it conveniently in genuine time. Therefore, the reduction of the voltage THD as well as the actual time computing capability make the

suggested formula eye-catching in multilevel inverters with unequal or differing voltage actions. Speculative outcomes confirm the efficiency of the formula.

H. Taghizadeh and also M. TarafdarHagh, et. al [21] recommended a PSO optimization method for Cascaded Multi degree inverter about careful harmonic technique to lessen the harmonic material in the MLI result. The PSO has actually been recommended to resolve the SHE trouble with unequal dc sources in H-bridge plunged multilevel inverters. When the resultant technique gets to the constraint of modern algebra software application devices, the recommended approach has the ability to locate the optimal changing angles in a basic fashion. The simulation as well as speculative outcomes are attended to an 11-level plunged H-bridge inverter to confirm the precision of the computational outcomes [84]-[87].

AyoubKavousi, et.al [22] provided a unique technique in getting rid of the chosen harmonics in the plunged H-bridge MLI. The Bee formula is an optimization formula based upon the all-natural foraging habits of honeybees to locate the ideal service. This formula offers optimum changing angles in running the converter. In this paper, removal of low order harmonics making use of SHEPWM approach is explored. Bachelor's Degree is related to resolve the formulas. Simulation outcomes reveal precision and also capability of Bachelor's Degree for merging purposes. Options have near likelihood to obtain worldwide minimum for 1, 2, 5, and also 10 times runs and also this chance is greater than the very same runs for GA. To confirm Bachelor's Degree services, speculative outcomes are provided which confirm the precision of the suggested technique.

Javad Ebrahimi, et. al [23] recommended an unique multi degree inverter with decreased variety of power electronic devices elements called as Multi Level Module (MLM). This layout is based upon DC web link voltage stabilizing circuits which makes use of the capacitors instead of thyristor buttons. The recommended geography expands the layout versatility and also the opportunities to maximize the converter for different purposes. It has actually been revealed that the framework, containing MLMs with 2 buttons has the

minimal variety of buttons for a provided variety of voltage degrees. The recommended geography has actually been compared to various other geography. It has actually been revealed that the recommended geography gives 125 degrees on the result voltage with an optimal of 400 V, utilizing 24 IGBTs and also the obstructing voltage of 604.5 V on bidirectional buttons. The various other geography, generates 161 voltage degrees utilizing 28 IGBTs and also an obstructing voltage of 1000 V. The recommended geography not just has reduced buttons and also elements in contrast with various other one, yet additionally its complete bridge converters run in the reduced voltage.

Arpan Hota et. al [24] has actually recommended a system is acquired by plunging the degree generation get rid of the stage series generation component. Better, it can be run at any type of needed degree relying on the setup of the degree generation component. Therefore, for greater degree procedure additional elements are needed at the degree generation component just. Number of parts needed for the recommended MLI is reduced than the traditional 3- ϕ MLI geographies for greater degree procedure. The popular attributes of the suggested MLI are as complies with: 1) The suggested MLI arrangement is constructed by plunging LGP as well as PSGP. 2) For greater degree procedure just switches over needed go to the BUs just which lives in the LGP. This lowers the need of additional gadgets contrasted to standard geographies. 3) Also, each dc voltage resource in today MLI geography is just as shared by all the stages. Therefore, any kind of possibility of inter-phase crookedness is stayed clear of.

Sze Sing Lee, et.al [25] executed a Hybrid Cascaded Multi degree inverter (HCMLI) and also contrasted the efficiency and also style with CHBMLI. His style utilizes a different degree designer component (sub-module), which provides 4-levels of procedure as well as it is after that linked to a complete bridge converter to make it as crossbreed design (CHBMLI). The geography is extremely portable with lowered button matter. Modularity is accomplished by plunging the suggested sub-module. The sub-module is exceptional contrasted to the typically made use of half-bridge sub-module as it shows decrease in the number of carrying out buttons for all voltage degrees as well as it needs much less separated supply for entrance motorists.

Sarika D Patil, et. al [26], suggested an unique method for changing optimization of plunged H-bridge Multi degree inverter. This paper defines among the approach of PSO called ant swarm optimization method for running the buttons of CHBMLI. This paper generally focused on removing the reduced order harmonics like 5th as well as 7th order harmonics. The greater order harmonics are not removed by the suggested approach as well as can be get rid of by filters. The THD is minimized to really reduced worth as well as keep according to the IEEE 519 requirement.

Mahmoud Babaei as well as Hassan Rastegar, et. al [27], suggested ACO strategy for removing the harmonics in the CHBMLI. This paper totally focused on establishing as well as evaluating the ACO formula. Even more the formula is related to 7-level CHBMLI as well as the outcome is evaluated for the harmonic material. The SHEPWM method is made use for seven-level inverter, the maximum changing angles are fined by using ACO right into the relevant unbiased feature.

SourabhKundu, et. al [28], in his paper offered 5 various optimization methods (GA, BEE, PSO, BSA, as well as DSA) for learning the optimal offline changing angle. Additionally, a relative research study has actually been accomplished based upon the opportunity of acquiring worldwide minima as well as ranking of merging. PSO is a widely known formula made use of in the harmonic trouble associated with SHEPWM method, so ACO is compared to PSO in the harmonic trouble and also results reveal the performance of ACO as well as greater merging price relative to PSO.

P.Vishnuvardhan Reddy, et. al [29], created a 5-level multilevel inverter based SHE PWM method called as Phase Opposition Disposition method. A brand-new 5 degree inverter geography utilizing POD method is made as well as the exact same is carried out, which can generating 5 degree result with much less part matter. When contrasted to standard Cascaded H bridge multi degree inverter, no of dc supply sources utilized in suggested multi degree inverter are much less. At reduced changing regularity (50Hz) Switches are activated. Changing losses are virtually minimal.

Marif Daula Siddique, et. al [30], suggested a brand-new single-phase multilevel inverter geography. The recommended geography makes use of lower button matter. The recommended geography has the ability to create 13 degrees at the result making use of just 3 DC voltage sources in the unbalanced modus operandi, which is much better contrasted to a few other geographies. Essential regularity changing method for the generation of entrance pulses is reviewed. The simulation causes both modules operandi are contrasted. The unbalanced modus operandi offers boosted outcomes because of a greater variety of degrees at the result.

J. Jayachandran et. al. [31], in this paper writer recommended One cycle control formula based semantic network control geography will certainly raises the toughness and also makes the control topology easy by decreasing the convention procedure of determining the recommendation existing signals. There by there is no demand of having the voltage as well as present sensing units.

P. Chittora et. al [32], suggests an unique technique for D-STATCOM with the assistance of Neural networks i.e. man-made semantic network formula with Chebyshev useful growth approach (CHANN). Usually, this kind of settlement is utilized for the shunt. The suggested unique approach is usage complete in offering the control signals to the compensator. In this paper the semantic networks are educated with the live information embed in all situations. An equipment model is established with the assistance of DSPACE 1104. The awareness of the DSTATCOM is compared to the various techniques and also lastly wrapped up that the recommended technique is the most effective technique.

D. Amoozegar et. al [33], has actually provided technique for the renovation of power top quality with the Fuzzy reasoning Control based DSTATCOM. That convention PI control based DSTATCOM will certainly include repaired specifications. As a result of the repaired criteria it reveals the unsuitable as the framework of the present power system is nonlinear. The writer recommends the Fuzzy-PI controller based DSTATCOM which is utilized for the adequate efficiency throughout the vibrant instances as well as Enhanced efficiency in Non-Linear Structure.

H. Tolabi et. al [34] suggests a most recent method for DSTATCOM which functions under nonlinear as well as vibrant situations partial responses linearizing (PFL) controller. In this writer mostly recommends a unique crossbreed unclear collection as well as galaxy- based search formula made use of for the specification evaluation in PFL controller. The whole suggested system efficiency is utilized for the power high quality improvement. In this paper writer did not point out concerning the expense evaluation of the suggested system.

S. Choudhury et. al [35] has actually provided technique for maximum choice of subscription feature in the blurry reasoning with the assistance of the changed Seeker Optimization Approach (SOA). This brand-new approach chooses the optimal subscription features for the unclear reasoning as well as likewise to calculate the PI Controller gain worth. The efficiency of the recommended approach is confirmed in nonlinear instances and also wrapped up that the suggested control approach is the most effective one.

Y. Chen et. al [36] has actually provided technique for the renovation of power high quality with the flexible "Passivity Based Control (PBC) of plunged multilevel converter-based DSTATCOM". In this paper, writer uses the attaching transformer in between converter as well as the grid. The result line of the converter is linked to the primary of the transformer windings as well as thus flexi control of result voltage. The suggested "Passivity Based Control (PBC) of plunged multilevel converter-based DSTATCOM" produces the referral signals for the converter additionally a flexible method is made use of for the criterion evaluation lastly writer evaluated the incorporated converter with the both constant state and also vibrant state efficiencies and also a prototype is likewise created to boost the responsive power settlement.

R. Jayaraman et. al [37] recommends the "Implementation of differential formula of the single-phase source-load system-based control formula for three-phase DSTATCOM". The recommended "Implementation of differential formula of the single-phase source-load system-based control formula for three-phase DSTATCOM" boosts the power top

quality problems like out of balance tons, present harmonics and also responsive power. The responsive as well as energetic control signals are produced with the recommended approach. The writer directs the benefits like "Immune to sound, not affected from DC element that might exist in lots existing, and also being much less influenced from regularity discrepancies" as well as the model is create with the aid of FPGA to examine the suggested technique.

R. Agarwal et. al [38] suggests "SPV-DSTATCOM (Solar Photovoltaic- Distributed Static Compensator) system making use of a LLMF (Leaky Least Mean Fourth) control formula". Energetic power demand for the lots is provided by the SPV Generating System as well as likewise it provides the excess power to the grid. Power top quality improvements like Harmonics, responsive power settlement, tons harmonizing, power variable adjustment, can be sustained by the DSTATCOM. Also this DSTATCOM is made use of as a DC to Air Conditioning converter. The control signals are realised by the "(Leaky Least Mean Fourth) control formula". The whole system is substitute in MATLAB additionally model is created. The recommended "SPV-DSTATCOM (Solar Photovoltaic- Distributed Static Compensator) system making use of a LLMF (Leaky Least Mean Fourth) control formula" reveals its mark in accomplishing the fast reaction at vibrant problems.

E. Lei et al. [39], "Novel incorporated framework for a cascaded circulation fixed compensator (D-STATCOM) as well as circulation transformer for medium-voltage responsive power settlement". The Voltage anxiety in between the converter as well as grid is lowered by the circulation transformer. The recommended control method is utilized in accomplishing the responsive power payment. A reduced model is created and also the simulation is additionally provided for the suggested design. The outcomes reveal the significant efficiency of the recommended "Novel incorporated framework for a cascaded circulation fixed compensator (D-STATCOM) and also circulation transformer for medium-voltage responsive power settlement" technique.

A. Gupta et al. [40] suggests the "Optimal positioning of D-STATCOM in mesh circulation systems making use of level of sensitivity techniques". In this paper writer offer 4 techniques "(i) Optimal D-STATCOM positioning based upon the brand-new voltage level of sensitivity index in mesh circulation system, (ii) optimum D-STATCOM dimension decision for seasonal tons with tons development circumstance, (iii) contrast of D-STATCOM positioning as well as dimension decision with the existing level of sensitivity approaches, as well as (iv) effect of ideal D-STATCOM positioning on voltage security margin improvement". All these methods are made use of for system to come to be affordable by price effective, improved power top quality by boosted voltage security as well as responsive power control.

E. Shoubaki et. al [41] provided " μ -STATCOM gadget as a dispersed option to user interface with DER's". Writer describes the reduced voltage trouble in the circulation systems. To conquer these reduced voltage issues recommended approach i.e. μ -STATCOM tool is linked at the fallen leave end side of circulation system. The whole suggested system is substitute too model is created. The suggested " μ -STATCOM tool as a dispersed remedy to user interface with DER's" is examined for both PV system as well as Battery system. The outcomes validate the performance of the " μ -STATCOM gadget as a dispersed option to user interface with DER's".

Deepak C. Bhonsle et. al [42] suggests the "Performance assessment of composite filter (CF) for power top quality renovation of EAF circulation network". The composite filter is made use of for the improvement of harmonics as well as voltage flicker. "The composite filter is including a shunt LC passive filter gotten in touch with a reduced ranked voltage resource PWM converter-based collection energetic power-filter (SAPF)". The recommended approach is realized with MATLAB Simulink. Recommended

"Performance examination of composite filter (CF) for power top quality enhancement of EAF circulation network" provides the great efficiency.

N. Al-Emadi et. al. [43] suggests "Five degree plunged converter for Distribution Static Compensator (DSTATCOM) carrying out an unique inflection formula". The suggested Methodology consists of "harmonic reduction as well as a PI controller with stage change inflection for responsive power control" the suggested method is compared to the standard area vector control formula approach. The contrast researches reveal the efficient ness of the five degree plunged converter for Distribution Static Compensator (DSTATCOM) applying a unique inflection formula".

1.5 Research Gaps:

- Integrating renewable energy sources to grid is challenging task. It requires complex methodologies.
- Harnessing energy form the renewable energy sources depends on atmospheric conditions.
- We cannot harness energy form the renewable energy sources continuously.
- As so many methodologies are developed for the grid connected renewable energy sources, they are showing the unsatisfactory performance at the atmospheric changes.
- This is the reason why we are not completely depending on the renewable energy sources.

1.6 Research Objectives:

- To obtain solutions for the renewal of India's power sector to accommodate demand.
- To overcome the fossil fuel scarcity as they are not abundantly available in nature.
- To Apply Renewable energy technology as the enabling technology for sustainable development.
- To improve optimal MPPT controller for grid connected RES.

- To Power Quality in the Grid Connected PV Systems
- To Improve Stability of the MPPT Controller..

1.7 Research Methodology:

This paper presents a Novel Grey Wolf Optimization based Incremental Conductance Maximum Power Point Tracking (MPPT) technique employed for grid tied PV system. The Proposed Technique is Compared with the PSO based Incremental Conductance Maximum Power Point Tracking (MPPT) technique and exhibit that the proposed technique is reliable. In the Incremental Conductance Integral regulator is used to improve the stability. The gain value of the Integral regulator is tuned by the Grey Wolf Optimization. The Fitness or objective of the GWO is the output of the Integral Regulator. Based on the output of the Integral Regulator the GWO gives the optimal value of the gain. With optimal gain the stability of the MPPT increases. The proposed GWO is compared with PSO. The oscillations in the grid current are completely minimized in the GWO based IC MPPT method.

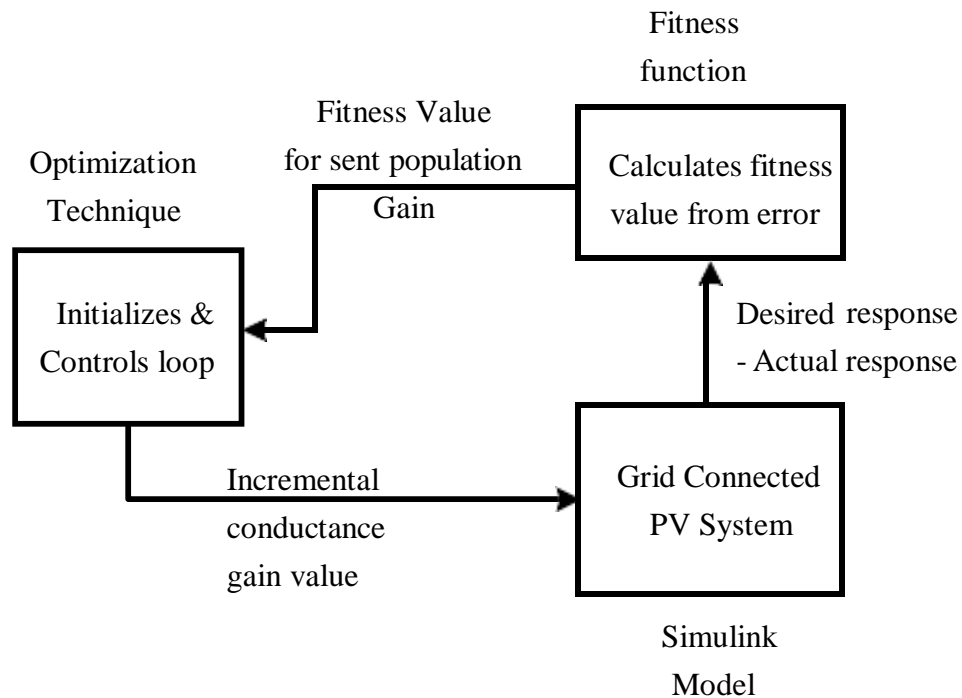


Fig: 1.4 Flow Diagram for the proposed methodology

1.8 ORGANIZATION OF THE THESIS

Chapter 1 includes brief introduction of renewable energy scenario and present solar power situation in India. Based on previous work a corresponding literature survey included here. Literature survey provided some important research gap insights which motivated us to work on the objectives postulated in this chapter.

Chapter 2 deal with the grid connected PV systems. It consist PV module, Boost converter, Voltage source inverter. In various engineering problems for small percentage improvement in output will result in large scale savings. For this purpose, optimization techniques required which are cost effective and useful. Optimization techniques categorized into conventional and Meta heuristic algorithms. Basic conventional algorithms for maximum power tracking are discussed and boost converter operation also presented here.

Chapter 3 discusses about mathematical modeling of INVERTER.

Chapter 4 deals with the Meta heuristic algorithms employed through this work.

Chapter 5 discusses about the implementation of proposed methods and its results under various conditions.

Chapter 6 Conclusion and Future scope.

CHAPTER – 2

2.0 GRID CONNECTED PV SYSTEMS

Among the significant issues in the power market is the daily raising power need however the absence of adequate sources to satisfy the power need utilizing the traditional power resources. Need has actually enhanced for eco-friendly resources of power to be used in addition to standard systems to fulfill the power need. Eco-friendly resources like wind power and also solar power are the prime power resources which are being made use of hereof. The constant use nonrenewable fuel sources has actually created the nonrenewable fuel source down payment to be lowered as well as has actually substantially influenced the setting diminishing the biosphere and also cumulatively including in international warming.

Solar power is perfectly offered that has actually made it feasible to gather it as well as use it correctly. Solar power can be a standalone creating system or can be a grid attached producing device depending upon the schedule of a grid close by. Hence it can be made use of to power backwoods where the schedule of grids is really reduced. An additional benefit of making use of solar power is the mobile procedure whenever any place needed.

In order to take on today power situation, one needs to establish an effective fashion in which power needs to be removed from the inbound solar radiation. The power conversion devices have actually been considerably lowered in dimension in the previous couple of years. The advancement in power electronic devices and also product scientific research has actually aided designers to find up effective however extremely little systems to stand up to the high-power need. The drawback of these systems is the enhanced power thickness. Fad has actually embedded in for using multi-input converter devices that can properly manage the voltage changes. Due to high manufacturing price as well as the reduced performance of these systems they can barely contend in the affordable markets as a prime power generation resource [88]-[92].

The continuous rise in the growth of the solar batteries making modern technology would most definitely make making use of these innovations feasible on a broader basis than what the situation is currently. Making use of the latest power control devices called

the Maximum Power Point Tracking (MPPT) formulas has actually caused the rise in the

effectiveness of procedure of the solar components and also therefore works in the area of usage of sustainable resources of power

2.1 Photovoltaic (PV) Cell

Photovoltaic (PV) is the conversion of light right into electrical energy making use of semiconducting products that display the photovoltaic impact, a sensation researched in electrochemistry, physics, as well as photochemistry.

A photovoltaic system uses photovoltaic panels, each making up a variety of solar batteries, which create electric power. PV setups might be ground-mounted, roof installed or wall surface installed. The place might be dealt with, or make use of a solar tracker to comply with the sunlight throughout the skies [93].

Solar PV has certain benefits as an energy resource: as soon as set up, its procedure creates no greenhouse and also no contamination gas discharges, it reveals easy scalability in regard of power requirements and also silicon has huge schedule in the Earth's crust.

2.1.1 Photovoltaic Generator Working Principle

A photovoltaic system, likewise PV system or solar energy system, is a power system made to provide functional solar energy through photovoltaic. It contains a plan of numerous parts, consisting of photovoltaic panels to transform and also soak up sunshine right into power, a solar inverter to alter the electrical existing from DC to Air Conditioner, in addition to installing, cabling, and also various other electric devices to establish a functioning system. It might additionally make use of a solar radar to enhance the system's total efficiency and also consist of an incorporated battery remedy, as costs for storage space tools are anticipated to decrease. Purely talking, a solar selection just incorporates the set of photovoltaic panels, the noticeable component of the PV system, as well as does not consist of all the various other equipment, commonly summed up as balance of system (BOS). PV systems transform light straight right into power and also should not be puzzled with various other modern technologies, such as focused solar power or solar thermal, made use of for home heating and also air conditioning.

A grid-connected solar (PV) system moves the solar power successfully which is formerly transformed right into electric power from to the energy grid. From the useful point of view a PV system can be separated right into 2 elements, the solar energy debt collector

along with in addition the power conversion system. The solar power debt collector include a variety of PV components that videotape the solar irradiance in addition to adjustment it right into electric power; this element of PV systems can be referred as 'solar generator'

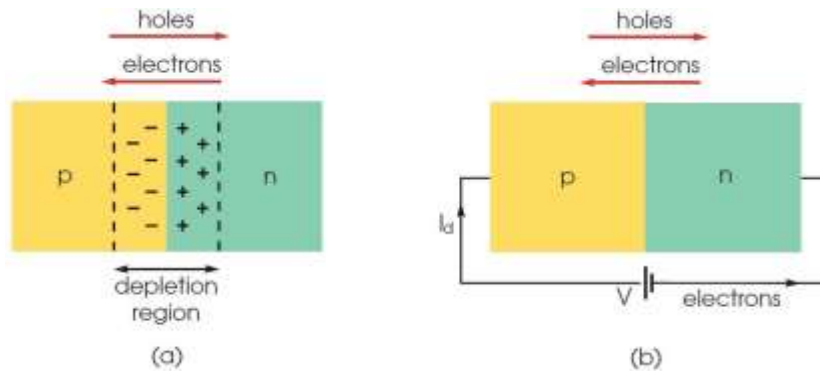


Fig: 2.1 Solar Cell construction (Lynn, P. A., 2010)

2.1.2 Photovoltaic Cell Model

As discussed earlier when PV cell is not brightened it is not an energetic device; it works as a diode, i.e. a p-n joint. In this state cell do not develops a present or a voltage. This present is called diode present or dark present when cell is connected to an exterior appropriately large supply than the cell voltage it produces an existing I_D .

A PV cell is usually stood for by an electric equal one-diode layout, as revealed Fig. 2.2 listed here.

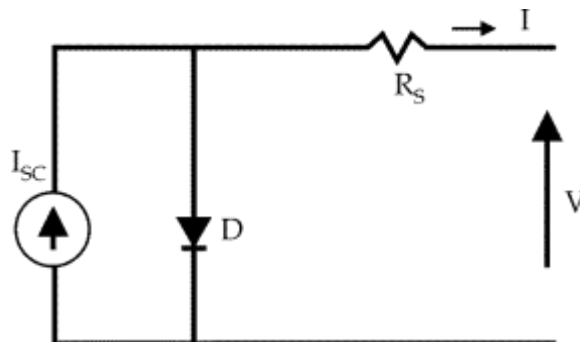


Fig: 2.2 Equivalent circuit of PV cell

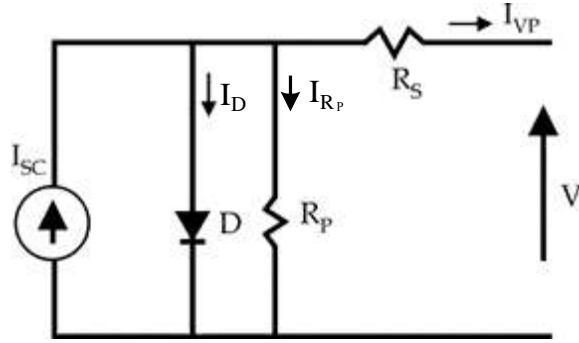


Figure 2.3 Equivalent circuit of Solar cell with R_s and R_p

A PV cell version can be considered as a present resource and additionally an upside-down diode affixed in alongside it. The model has its own series and also similar resistance. Collection resistance (R_s) is because of barrier throughout circulation of electrons from n to p junction as well as the same resistance (R_p) is considered as a result of cell leakage present. By thinking of the reasonable scenario, the worth of R_p is big which of R_s is really small, therefore these resistances taxicab be disregarded to improve the analysis.

Applying KCL to the equivalent circuit in Fig: 2.3 yields

$$I_{VP} = I_{SC} - I_D - I_{R_p} \quad (2.1.1)$$

Where, I_{VP} is total current from PV cell, I_{SC} is short circuit current, I_D is diode current I_{R_p} is the current through the R_p .

$$V_{R_p} = V + I_{VP} R_s \quad (2.1.2)$$

Where, V_{R_p} is open circuit voltage, V is voltage across the cell.

$$I_{R_p} = \frac{V_{R_p}}{R_p} = \frac{V + I_{VP} R_s}{R_p} \quad (2.1.3)$$

The current from the PV cell is given as follows

$$I_{VP} = I_{SC} - I_0 \left[e^{\frac{V + I_{VP} R_s}{nV_T}} - 1 \right] - \frac{V + I_{VP} R_s}{R_p} \quad (2.1.4)$$

Where I_0 is the diode saturation current, V_T is thermal voltage, n is the Boltzmann constant .

2.1.3 PV Cell Maximum Power Point

Common PV cell current-voltage characteristic curves are shown in Fig. 2.4. When PV cell voltage is equivalent to V_{oc} or cell current amounts to I_{sc} the power generated is no, as can be seen from the number. V_{oc} is the PV cell voltage when the output current of the cell is absolutely no, i.e. $I_{pv} = 0$ and also the shunt resistance R_p is overlooked. The short circuit existing I_{sc} is the existing at $V = 0$ and additionally is offered over formulas.

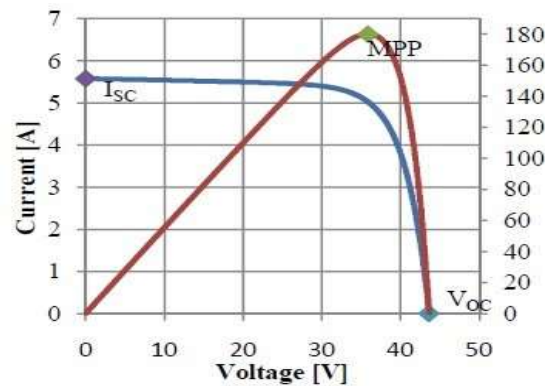


Fig: 2.4 Important Points in the characteristic curves of a solar panel

2.1.4 Fill Factor of PV Cell

“Fill factor may refer to: Fill factor (solar cell), the ratio of maximum obtainable power to the product of the open-circuit voltage and short-circuit current”.

2.1.5 Effect of Temperature and Irradiance on PV cell characteristics

Shielding effect of sunlight powered panel is a significant concern in India. Most of the time the solar panel are not established at genuine tallness or setting which might create fractional shielding on a couple of cells inside the component or collection as a result of next-door neighbor frameworks, relocating feathery animals, hazes, any type of nearby trees branches, the darkness of the adjoining panel. Shielding of PV cells will certainly affect the implementation of sunlight oriented panel along these lines reducing its basic performance. The shaded cells set about as the lot in the panel as well as they obtain the power from un-shaded cells regulate produced that makes the diminishment of

accumulated power. One more concern is shaded cells will certainly develop much less existing or no existing nevertheless un-shaded component will certainly provide normal existing as a result of which there will certainly be an assortment in the here and now that generates the issue locations. Hotspots in the panel will certainly construct the cell temperature level as well as can hurt the cell. Examination of shielding effects by different designers is shown in this field.

Mamun Mama et al., 2017, approximated the shielding effect under different lighting degrees expanding from 300 to 800W/m². The exploratory configuration is displayed in Figure 3 (left) where, 90 OSRAM halogen beads are made use of for providing variable light and also the component surface area was shaded by 0, 25, 50, and also 75%. For each and every growth in 10% shielding area, return power will certainly reduce by 12.41 W as well as electric efficiency will certainly lower by 2.3%. The temperature level range as a result of the shielding influence was very little however instead there is a minor decrease in the purposeful temperature level (0.87 ° C decrease for each 10% growth). A 500 W/m² light as well as under no shading: control return: 27.15 W & performance: 9.93%. For 80% shading: the power return: 1.35 W and also performance: 0.24%. The accumulated power return and also effectiveness of the component decrease by 25.8 W i.e. 95.02% as well as 9.69%, i.e. 97.58%. Patel H. et al., 2008, concentrate on a simulation and also showing utilizing MATLAB which can consider the implementation of photovoltaic panel high qualities under partial shielding problem. This recreation can furthermore be used as a gadget to analyze the shielding effect for different instances on PV panels. One more crucial element that the developer focuses about is to understand that exactly how collection or parallel PV component might affect the P_{max} (maximum power) under shielding problems. With the help of this showing the designer shows concerning the I-- V and also P-- V qualities of a PV panel which has substantial variety of parallel as well as collection cells under partial shielding problem. It was observed that at 10% shielding the return vigor decreased by 42.5. Tripathi A.K. et al., 2017, virtually described the result of shielding on collection as well as parallel cells on a couple of areas of the panel as displayed in Figure 3(right). For 50% shading of a singular cell, the power return was lowered to 25.71% as well as 50% shading of panel motivates 70.27% reduction in panel power outcome, for collection link 16.54% as well

as for identical link 6.03% diminishment in outcome power. In this paper maker facilities around 4 distinct effects with 3 varied ranking panels (2.5 W, 5W, 20W). 1) Effect of shielding on result power with 20W panel, 2) Effect of shielding on outcome power for solitary cell with 20W panel, 3) Effect of shielding top quality on result power collection and also identical mix of 3 similar 2.5 W panel in this influence electric criteria are approximated (I, V, P under shielding and also non-shading problems for 108 Ω , 50 Ω as well as 70 Ω consistent tons, 4) Effect of shielding on temperature level comparison on un shaded area with 5W panel. 4 shielding influences are approximated at 0%, 25%, fifty percent and also 75% shading. From the 3rd examination it was reasoned that identical blends of panel are much more effective under shielding problems after that collection blends. Johansson et al.,2004, tried out the shielding effect on amorphous silicon as well as crystalline silicon photovoltaic panels as well as in addition facility around hotspot collection slim movie (a-Si) cells which do not framework issue locations as like the c-Si cells nevertheless a-Si different at the affiliation to the adjoining cell and also enters to change tendency. The light provided by sunlight-oriented examination system at the Center for Renewable Energy Systems Technology (CREST), shows that for a-Si cells when extra variety of cells remains in collection then control misery decreased yet has a danger of cell damage also at 30% shading. Rezaei et al., 2017, taken a look at concerning Module Integrated Converters (MIC) to overcome the concern of shielding effect in PV range. Increase converters are used as MIC. To reduce the structure expense B4 inverter is used which is 3 stage as well as 4 button inverters. With the help of recreation as well as exploratory assessment midway shielding influences are made it through. The panel are related to the lift converter in an input means with MPPT (maximum power point tracking) and also PWM (plus size inflection) generator. At any type of there is the shielding on any type of panel the voltage will certainly obtain stopped by that panel as well as this went down voltage is identified by MPPT and also will certainly make the job of the lift converter to broaden the voltage degree by PWM generator. Complete structure reliably remains secure and also a constant power will certainly be sent out to this inverter and also the inverter infuses power right into grid without any kind of disruption. Shielding of PV cells will certainly affect the implementation of sunlight oriented panel along these lines reducing its basic performance. With the help of this showing the

developer illustrates regarding the I-- V and also P-- V characteristics of a PV panel which has significant number of parallel as well as collection cells under partial shading problem. 1) Effect of shading on outcome power with 20W panel, 2) Effect of shading on result power for solitary cell with 20W panel, 3) Effect of shading high quality on result power collection and also identical mix of 3 similar 2.5 W panel in this influence electric specifications are approximated (I, V, P under shading as well as non-shading problems for 50Ω, 108Ω and also 70Ω consistent tons, 4) Effect of shading on temperature level comparison on un shaded place with 5W panel. Johansson et al.,2004, explored the shading influence on amorphous silicon and also crystalline silicon solar panels as well as moreover facility around hotspot collection slim movie (a-Si) cells which do not structure trouble locations as very same as the c-Si cells nonetheless a-Si different at the affiliation to the adjoining cell and also obtains in to switch over tendency. The light provided by sunlight oriented examination system at the Center for Renewable Energy Systems Technology (CREST), shows that for a-Si cells when a lot more number of cells is in collection at that point control tragedy reduced yet has a danger of cell injury also at 30% shading.

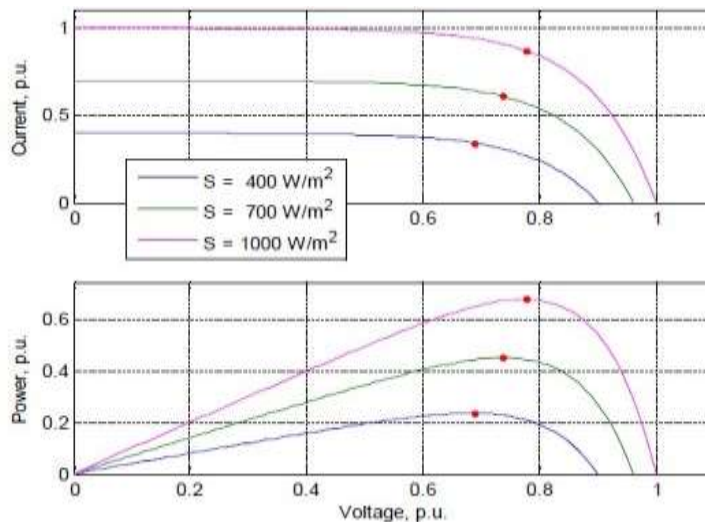


Fig: 2.5 V-I and V-P curves at constant temperature (25°C) and three different insolation values

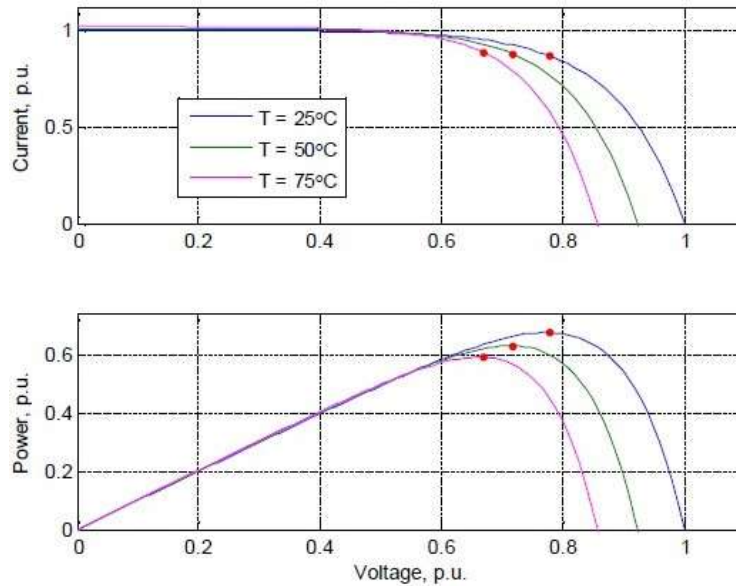


Fig: 2.6 V-I and V-P curves at constant irradiation (1 kW/m²) and three different temperatures

The above graphs shows the characteristics of PV modules for different irradiances .

2.2 Maximum Power Point Tracking Techniques

Maximum power point tracking is a strategy utilized typically with wind generators as well as photovoltaic (PV) planetary systems to make the most of power removal under all problems. Solar power is primarily covered, the concept uses typically to sources with variable power: for instance, optical power transmission and also thermo photo-Voltaic.

PV planetary systems exist in various setups when it come to their partnership to inverter systems, outside grids, battery financial institutions, or various other electric lots [3] Despite the supreme location of the solar energy, however, the main trouble dealt with by MPPT is that the effectiveness of power transfer from the solar battery depends upon both the quantity of sunshine dropping on the photovoltaic panels and also the electric qualities of the lots. As the quantity of sunshine differs, the tons quality that provides the highest possible power transfer effectiveness adjustments, to make sure that the performance of the system is enhanced when the tons particular adjustments to maintain the power transfer at highest possible effectiveness.[94]-[96]

This tons attribute is called the maximum power point as well as MPPT is the procedure of locating this point as well as maintaining the tons particular there. Electric

circuits can be created to existing approximate tons to the solar batteries and after that transform the voltage, existing, or regularity to match various other gadgets or systems, as well as MPPT resolves the trouble of selecting the very best lots to be provided to the cells so as to get one of the most functional power out. Solar battery have a complicated connection in between temperature level as well as overall resistance that creates a non-linear result performance which can be assessed based upon the I-V contour. [4] It is the function of the MPPT system to example the outcome of the PV cells and also use the correct resistance (lots) to get maximum power for any type of offered ecological problems. [6] MPPT gadgets are normally incorporated right into an electrical power converter system that supplies voltage or existing conversion, filtering system, and also law for driving numerous tons, consisting of power electric motors, grids, or batteries Solar inverters transform the DC power to A/C power as well as might include MPPT: such inverters example the outcome power (I-V contour) from the solar components and also use the correct resistance (lots) so regarding acquires maximum power. The power at the MPP (P_{mpp}) is the item of the MPP voltage (V_{mpp}) and also MPP existing (I_{mpp}).

2.2.3 Hill-climbing methods.

Both P&O in addition to furthermore In Cond solutions are based upon the "hill-climbing" idea, that includes relocating the treatment aspect of the PV option in the guidelines in which power rises. Hill-climbing strategies are among the most popular MPPT methods as an end result of their simplicity of application in addition to extraordinary performance when the irradiation is continuous (Sera, D. et al., 2006). The benefits of both strategies are the simplicity as well as lowered computational power they call for. The downsides are furthermore well known: oscillations around the MPP in addition to they can obtain shed along with track the MPP in the incorrect directions throughout swiftly changing weather condition (Femia, N. et al., 2004).

2.2.3.1 Perturb and Observe

P&O formula remains in enhancement called "hill-climbing", nonetheless both names specify the exact same formula depending upon specifically simply exactly how it is carried out. Hill-climbing consists of a perturbation on the commitment cycle of the

power converter in addition to P&O a perturbation in the operating voltage of the DC internet link in between the PV choice along with the power converter (Esrām, T. et al., 2007). When it comes to the Hill-climbing, worrying the task cycle of the power converter indicates personalizing the voltage of the DC net link in between the PV selection along with the power converter, so both names define the similar method.

In this strategy, the indication of the last perturbation along with the indicator of the last increment in the power is used to pick what the sticking to perturbation needs to be. As can be seen in Fig. 2.7, left wing of the MPP incrementing the voltage boosts the power whereas on the ideal decrementing the voltage raises the power.

It is essential to track the MPP in any kind of issues to ensure that the optimum easily offered power is gotten from the PV panel. The procedure of PV system at ideal power variable is completed by utilizing various MPPT remedies as talked about in following area.

As cleared up in the previous location, the trusted therapy of a PV system is feasible if the system carries out at Maximum Power Point on V-I, V-P premium quality. Hill-climbing involves a perturbation on the job cycle of the power converter as well as also P&O a perturbation in the operating voltage of the DC web link in between the PV choice as well as likewise the power converter (Esrām, T. et al., 2007). In the scenarios of the Hill-climbing, bothering the duty cycle of the power converter advises tailoring the voltage of the DC web link in between the PV selection together with the power converter, so both names describe the exact identical method.

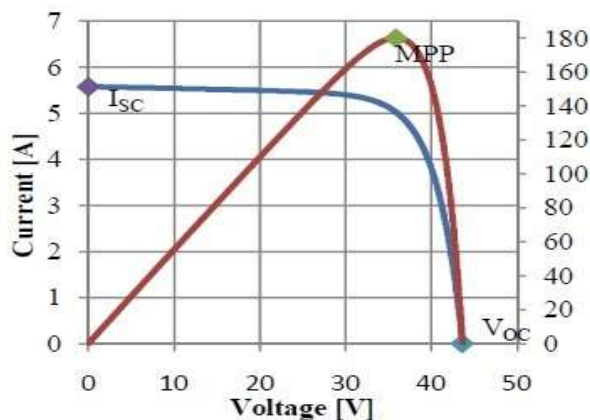


Fig 2.7 PV Panel Characteristic Curves

The circulation format of the P&O formula is presented in Fig. 2.8. The "worry and also observe" formula begins by observing the PV option existing in addition to voltage. The power is after that recognized along with contrasted to its previous worth saved in memory. In circumstances it has really remained to be the identical, the option voltage ought to stay as it is, nonetheless in circumstance it has in fact improved in addition to the variety voltage has actually in truth enhanced, afterwards the range voltage need to increase additionally by "v" to evaluate if the new power is more than the previous one. The operating variable is therefore on the left side of the operating as well as the mpp variable is relocating upwards. If the power has in truth raised however the voltage has really reduced, after that the selection voltage require to be lowered by "v" where the operating factor gets on the ideal side of the MPP with the element moving upwards.

In conditions the power has really reduced as well as additionally the voltage has in fact enhanced, after that the operating variable hops on the right of the MPP in addition to moving downwards, thus the option voltage should certainly be lowered by "v". If both power along with also voltage have really lowered, after that the operating aspect hops on the left side of the MPP in addition to moving downwards, consequently the choice voltage require to be improved by "v". "v" is an action voltage that is either consisted of or deducted from the selection voltage to reach the MPP The measurement of the activity "v" can be decreased to a little worth to guarantee that the MPP is ideal estimated.

On the different various other hand, lowering the measurement of "v" will definitely make the merging price slower along with for that reason even more time is asked for to reach the MPP.

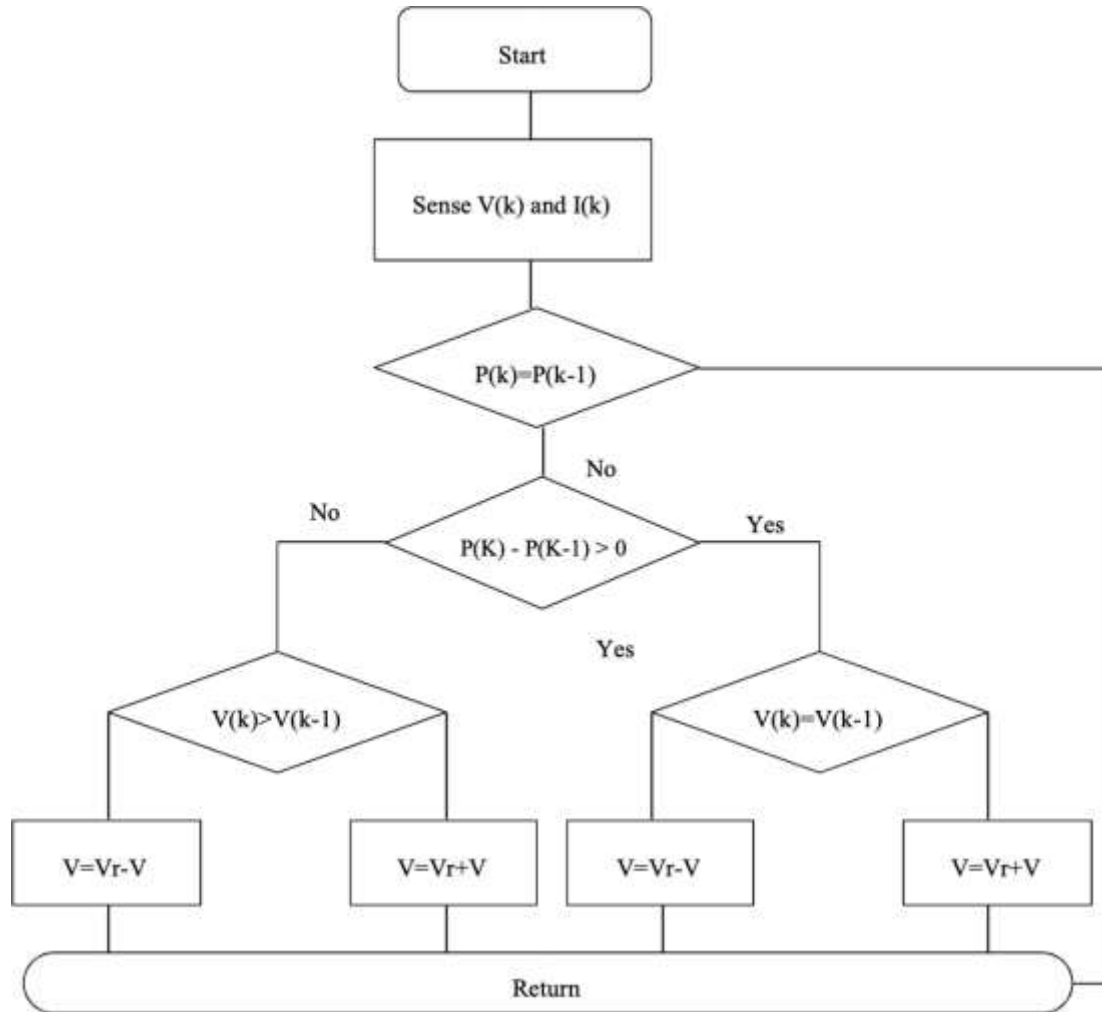


Fig: 2.8 Flowchart of the P&O Algorithm

2.2.3.2 Incremental Conductance

Step-by-step conductance (incCond) formula was suggested by Hussein, Muta, Hoshino, as well as likewise Osakada of Saga University, Japan, in 1992. The significant focus of this formula was to take care of the issue of the P&O formula under rapidly changing weather (Hussein, K. H. et al., 1995).

“The slope of the contour power vs. voltage (existing) of the PV part is definitely no at the MPP, positive (damaging) left wing of it and also unfavorable (favorable) on the right, as can be seen in Fig. 2.9

- $\Delta V/\Delta P = 0$ ($\Delta I/\Delta P = 0$) at the MPP
- $\Delta V/\Delta P > 0$ ($\Delta I/\Delta P < 0$) on the left of MPP

- $\Delta V/\Delta P < 0$ ($\Delta I/\Delta P > 0$) on the right of MPP

In this formula the change in the MPP voltage can be determined by contrasting the increment of the power vs. the increment of the voltage (existing) in between 2 consecutives examples. Fig. 2.9 reveals the Incremental Conductance formula (Jain, S. et al., 2007)”.

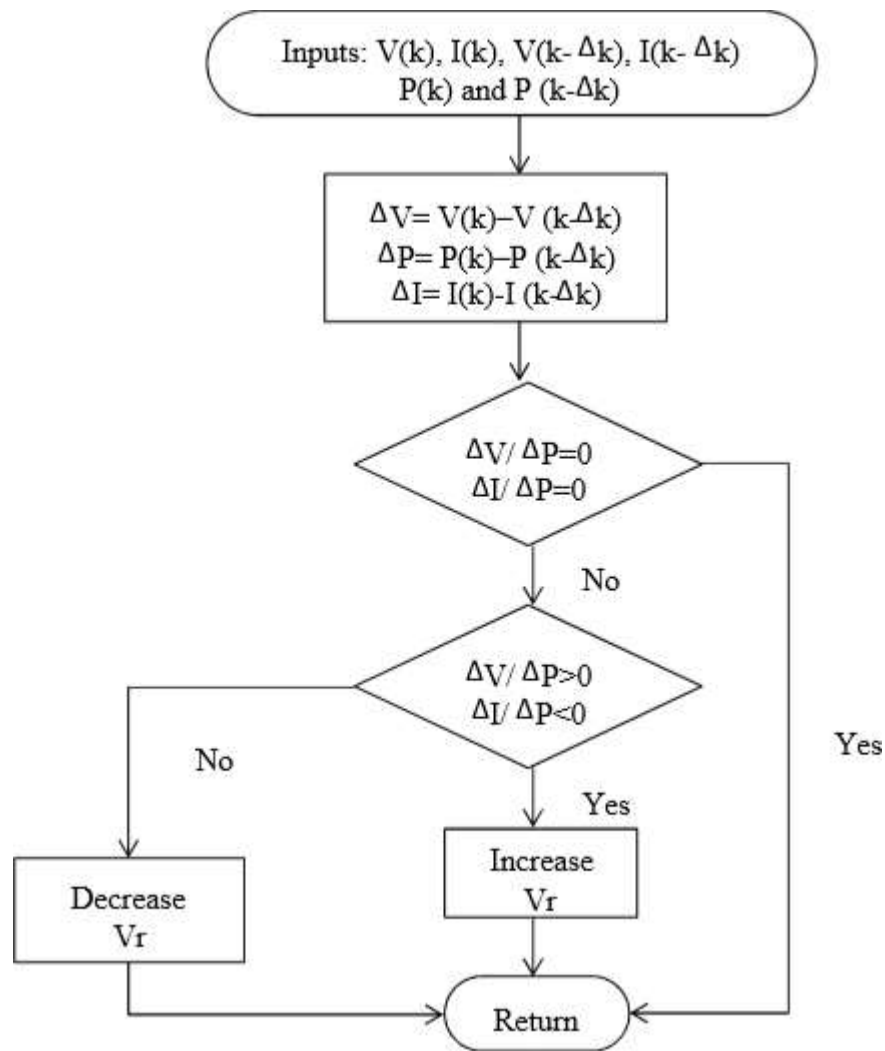


Fig: 2.9 Flowchart of Incremental Conductance Algorithm

In instance of over gone over Hill Climbing approaches particularly P&O as well as likewise InCond, the measurement of increment in reference voltage picks exactly how quick the MPP is obtained to., if this increment action dimension is bigger MPP will

absolutely be reached quicker. With bigger activity measurement the outcome power oscillates to much level.

2.3 BOOST CONVERTER

Increase converter tips up the input voltage size to a necessary result voltage size without using a transformer. The primary elements of an increase converter are an inductor, a diode and also a high regularity button. These in a co-ordinated fashion supply power to the lots at a voltage higher than the input voltage size. The control approach hinges on the control of the task cycle of the button which creates the voltage modification.

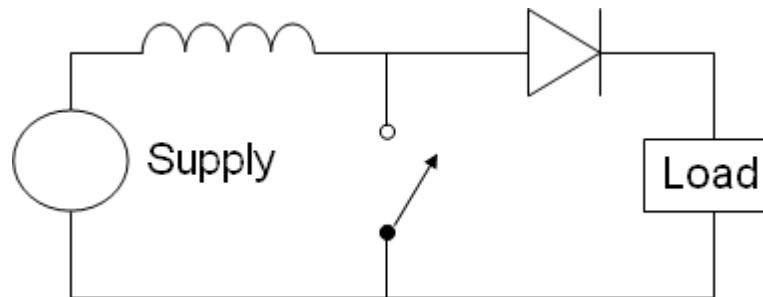


Fig: 2.10 Boost converter

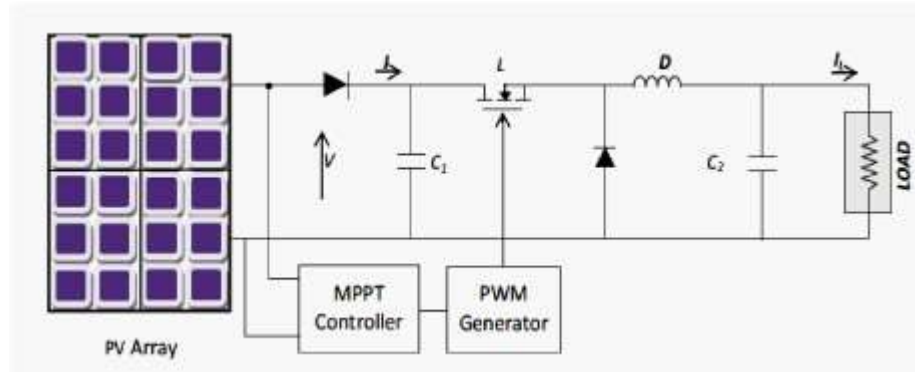


Fig: 2.11 A PV system with a DC-DC buck converter

2.3.1 Modes of Operation

There are two modus operandi of an increase converter. Those are based upon the closing as well as opening of the button. When the button is shut; this is recognized as the billing setting of procedure, the very first setting is. When the button is open; this is understood as the discharging setting of procedure [12].

2.3.2 Charging Mode

In this modus operandi; the button is shut and also the inductor is billed by the resource via the button. The billing current is rapid in nature however, for simplexes is presumed to be linearly differing [11] The diode limits the circulation of present from the resource to the tons and also the need of the lots is fulfilled by the discharging of the capacitor.

2.3.3 Discharging Mode

In this modus operandi; the button is open as well as the diode is ahead prejudiced [11] The inductor currently releases as well as along with the resource bills the capacitor and also fulfills the tons needs. The tons present variant is extremely tiny and also in most cases is presumed consistent throughout the procedure.

2.3.4 Waveforms

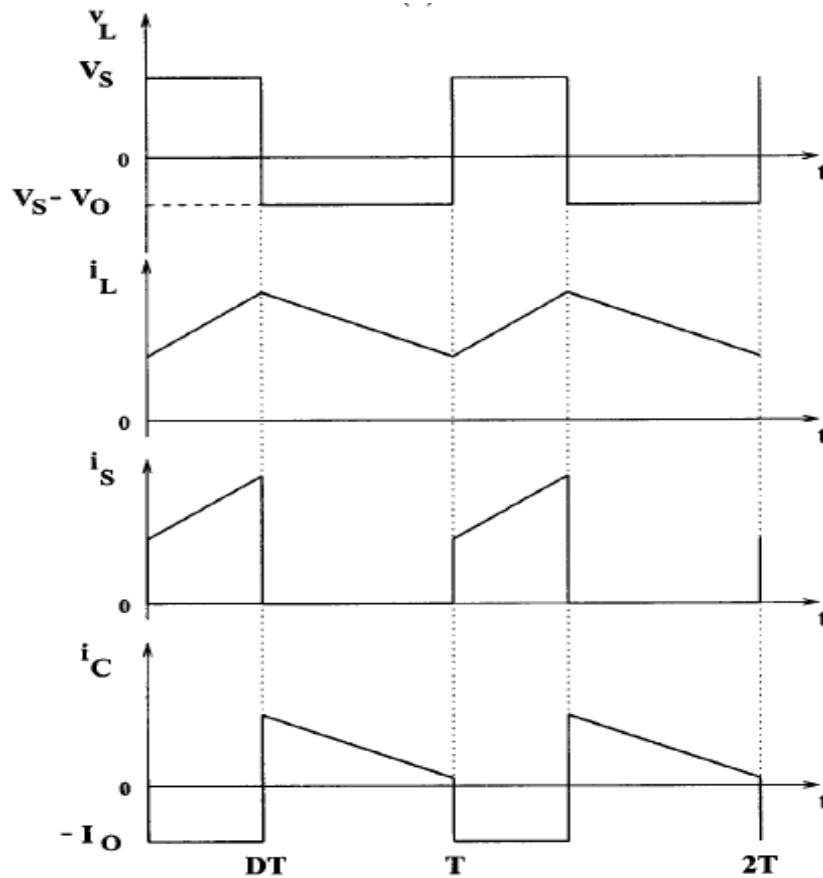


Fig: 2.12 Waveforms of boost converter

2.3.5 Operating principle

The vital concept that drives the increase converter is the propensity of an inductor to stand up to adjustments in existing. When being billed it functions as a tons as well as soaks up power (rather like a resistor), when being released, it serves as a power resource (rather like a battery). The voltage it creates throughout the discharge stage is associated with the price of adjustment of present, as well as not to the initial billing voltage, hence enabling various input and also result voltages.

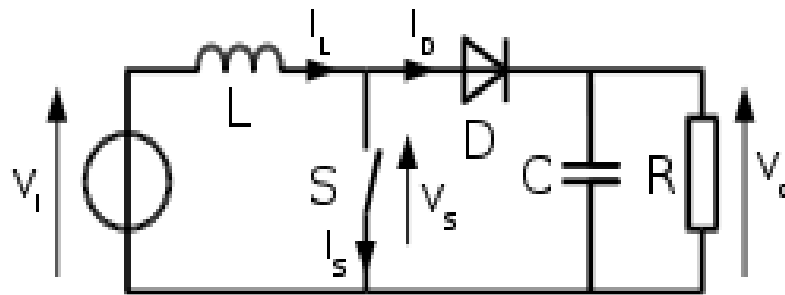


Fig: 2.13 Boost converter schematic

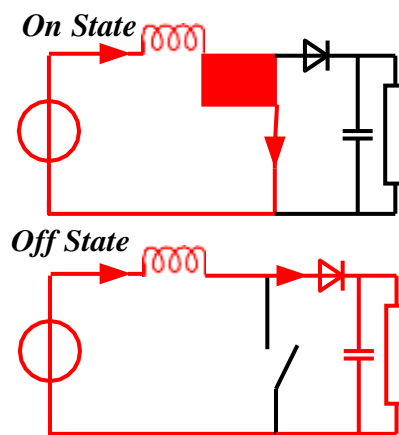


Fig: 2.14 Two configurations of a boost converter, depending on the state of the switch S.

The fundamental concept of a Boost converter contains 2 unique states (see numbers):

- In the On-state, the button S (see number) is shut, causing a boost in the inductor current;
- In the Off-state, the button is open and also the only course used to inductor present is via the fly back diode D, the capacitor C as well as the lots R. This lead to moving the power collected throughout the On-state right into the capacitor.

The input current coincides as the inductor existing as can be seen in number. It is not alternate as in the dollar converter and also the demands on the input filter are un-winded contrasted to a dollar converter.

2.4 **Inverter:**

The Photovoltaic panels generates electrical energy in the DC form but most of the house hold appliances and other components of major power system operates with alternating current of energy so there is a requirement of device for conversion one mode of electrical energy to the other. This function is performed by inverter through the bidirectional power electronic switches. The switching of these devices are performed through gate driven pulses. These pulse are generated in accordance to the control circuit commands. The controller for grid connected PV based inverter has to perform various functions to meet the standard requirements of power supply.

These are the sine wave generated through inverter should have same frequency as the main grid. So the control circuit require trace the frequency and phase angle of the grid. This is performed by the Phase locked loop control (PLL) circuit which takes the input three phase voltage and compares the signal with Voltage Controlled Oscillator (VCO). The error signal obtained by subtracting signal of VCO and normalized grid voltage is passed through a controller that changes voltage across the VCO to change its frequency and phase of the generated. When the error obtained is null, the frequency and phase generated by PLL is equal to that of grid phase and frequency. The phase value from the PLL is utilized in rotating reference frame to convert the AC reference voltage and current signals into DQ components [11] to make the reference signal generation feasible through PI controllers.

To generate required magnitude of voltage from inverter, required reference voltage signals are generated through control scheme and are modulated using Pulse Width Modulation (PWM) that produces gate pulse for switching the devices. In this work the reference voltage signals are generated through external control, where real and reactive

power required to supply is provided to control circuit. From these values I_{dref} , I_{qref} are calculated. The I_d and I_q values calculated from measured current are subtracted from I_{dref} , I_{qref} . The error signals obtained from these differences are passed into the PI controllers which generates the reference voltage signals V_d and V_q . These reference voltage signals are again transformed into the three phase domain using inverse parks transform and phase angle from PLL. Thus obtained reference voltage signals are modulated using PWM and are used for switching power electronic switches.

CHAPTER – 3

3.0 GRID CONNECTED PV INVERTER

The basic line flow diagram of a Grid Connected PV Inverter is shown in the fig: 3.1, in the following figure V_a , V_b , V_c are the Line voltages, i_a , i_b , i_c are the Line currents. R and L are the Resistance and Inductance together called as impedance Z of the line. e_a , e_b , e_c are the voltages at the Inverter. In this work three phase two level inverter is considered. It consists of S_1 to S_6 total six switches. IGBT's are considered as the switches for the inverter as IGBT's are the fully controlled switches.

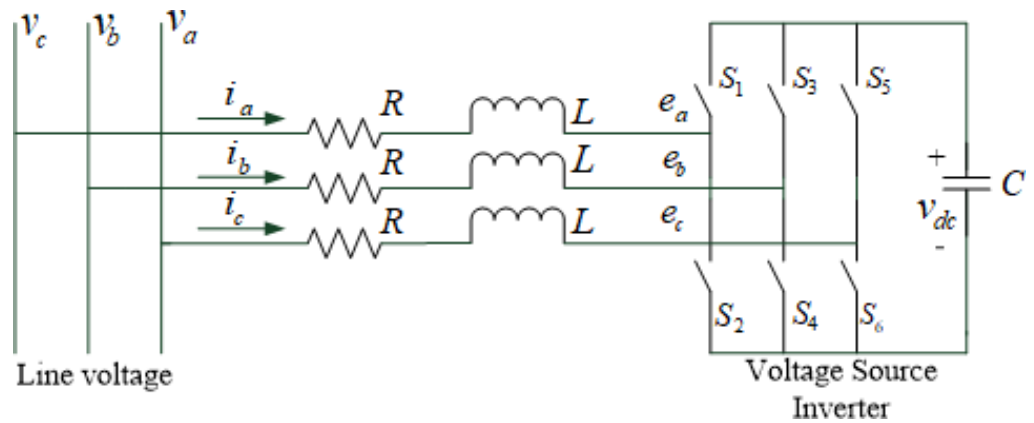


Fig: 3.1 Equivalent circuit of INVERTER

The Inverter can be controlled by controlling the switches S_1 to S_6 . Based on the controlling of the Switches S_1 to S_6 quality control can be achieved.

Control of Grid Connected PV Inverter.

The proposed Grid connected PV system consists of a PV Source, Utility, grid, Non-Linear load, PV Inverter. For a PI controller of the Grid connected PV Inverter, the output mainly depends on the gain values. The gain values of a PI controller are tuned by using trial and error method.. The entire system is simulated in MATLAB/Simulink Environment.

The Intelligence for a Grid connected PV inverter is made with the help of Control technique. The Control techniques consists of three parts

1. External control
2. Intermediate control
3. Internal Control

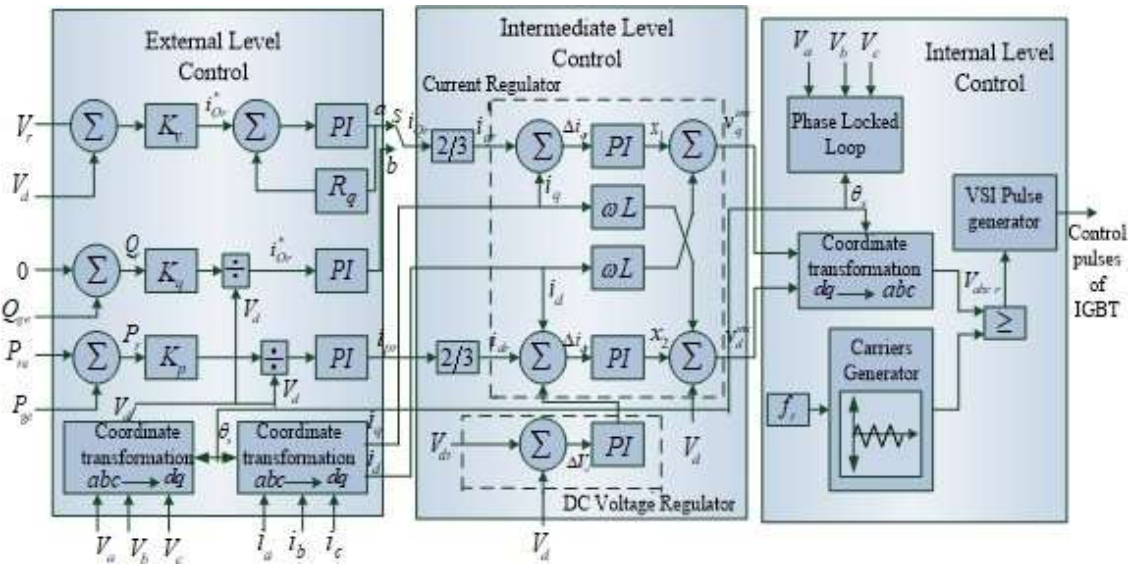


Fig: 3.2 Control Scheme of Grid Connected INVERTER

The fig: 3.2 shows the control scheme of grid connected Inverter. In the External control V_{abc} and I_{abc} are transformed to V_{dq} and I_{dq} with the help of parks transformation. In the Intermediate control the transformed quantities are compared. Final in the internal controller the controls signals for the switches S1 to S6 are generated

CHAPTER – 4

4.0 OPTIMIZATION METHODS

4.1 PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) is a populace based stochastic optimization method created by Dr. Eberhart and also Dr. Kennedy in 1995, influenced by social habits of bird gathering or fish education. [30] PSO shares lots of resemblances with transformative calculation strategies such as Genetic Algorithms (GA). The system is booted up with a populace of arbitrary options as well as look for optima by upgrading generations. Unlike GA, PSO has no advancement drivers such as crossover and also anomaly. In PSO, the prospective services, called fragments, fly via the trouble area by complying with the present optimal fragments.

In previous numerous years, PSO has actually been efficiently used in lots of research study and also application locations. It is shown that PSO improves lead to a much faster, more affordable means compared to various other approaches. [31] Contrasted to GA, the benefits of PSO are that PSO is very easy to execute as well as there are couple of specifications to change. One variation, with small variants, functions well in a variety of applications. Particle swarm optimization has actually been utilized for methods that can be utilized throughout a vast array of applications, along with for certain applications concentrated on a particular demand. PSO has actually been efficiently used in locations like, feature optimization, synthetic semantic network training, unclear system control, as well as various other locations where GA can be used.

$$U_i^{k+1} = U_i^k + C_1 \text{rand}_1() (lb_i - D_i^k) + C_2 \text{rand}_2() (gb - D_i^k) \quad (4.1.1)$$

Where U_i^{k+1} the velocity is update for i^{th} particle in $k+1^{\text{th}}$ iteration, C_1 and C_2 are acceleration coefficients for local best lb_i and global best g_b , $\text{rand}_1()$ and $\text{rand}_2()$ are pseudo random number generators.

$$D_i^{k+1} = D_i^k + U_i^k \quad (4.1.2)$$

Where D_i is the position update for i^{th} particle in $k+1^{\text{th}}$ iteration.

4.2 The pseudo code of the procedure is as follows:

```
For each particle
  Initialize particle
End
Do
  For each particle
  Calculate fitness value
  If the fitness value is better than the best fitness value (pbest) in history
    set current value as the new pbest
  End
  Choose the particle with the best fitness value of all the particles as the gbest
  For each particle
  Calculate particle velocity
  Update particle position
  End
While maximum iterations or minimum error criteria is not attained.
```

The input and output for the Pseudo code are the MPPT output and integrated regulator gain respectively.

4.3 PSO based MPPT Controller:

- 4.3.1 In the Incremental Conductance MPPT method the Error i.e. $dI/dV + I/V$ has to be minimized.
- 4.3.2 To minimize that error the work proposes an integral regulator which reduced the Error.
- 4.3.3 The gain value of the integral regulator is estimated with the help of PSO optimization.
- 4.3.4 First the proposed system which is developed in the MATLAB/SIMULINK is simulated and the error of the MPPT which to be minimized is given as the objective function of PSO algorithm.

4.3.5 The PSO algorithm estimates the optimum gain value of integral regulator for the corresponding minimum error.

4.3.6 Thus, the gain value of integral regulator is estimated optimally.

4.4 Grey Wolf Optimization (GWO):

The GWO algorithm mimics the leadership hierarchy and hunting mechanism of grey wolves in nature. Four types of grey wolves such as alpha, beta, delta, and omega are employed. In addition to the social hierarchy of grey wolf's pack hunting is another appealing societal action of grey wolves. The main segments of GWO are encircling, hunting and attacking the prey.

The above grey wolf based preying are modelled through following equations

$$A_i^d = 2a(k)(\text{rand}()) - a(k) \quad (4.4.1)$$

Where, $a(k) = 2 - \frac{2k}{\text{max imum iteration}}$, k is the current iteration, $\text{rand}()$ is the pseudo

random number.

$$C_i^d = 2\text{rand}_1()\text{rand}_2() \quad (4.4.2)$$

Where, $\text{rand}_2()$ is pseudo random generator.

$$X_{i,p}^d(k+1) = X_p^d(k) - A_i^d | C_i^d X_p^d(k) - X_i^d(k) | \quad (4.4.3)$$

Where, X_i is position of the grey wolf, X_p^d is the position of prey. p can be represented by $p = \alpha, \beta, \delta, \omega$. α is the first best solution, β and δ are second and third best solutions and ω represents remaining solution.

The grey wolf position is updated as following equation

$$X_i^d(k+1) = \frac{X_{i,\alpha}^d(k+1) + X_{i,\beta}^d(k+1) + X_{i,\delta}^d(k+1)}{3} \quad (4.4.4)$$

The grey wolf based optimization for the proposed system is illustrated through the flow diagram shown in Fig: 4.1

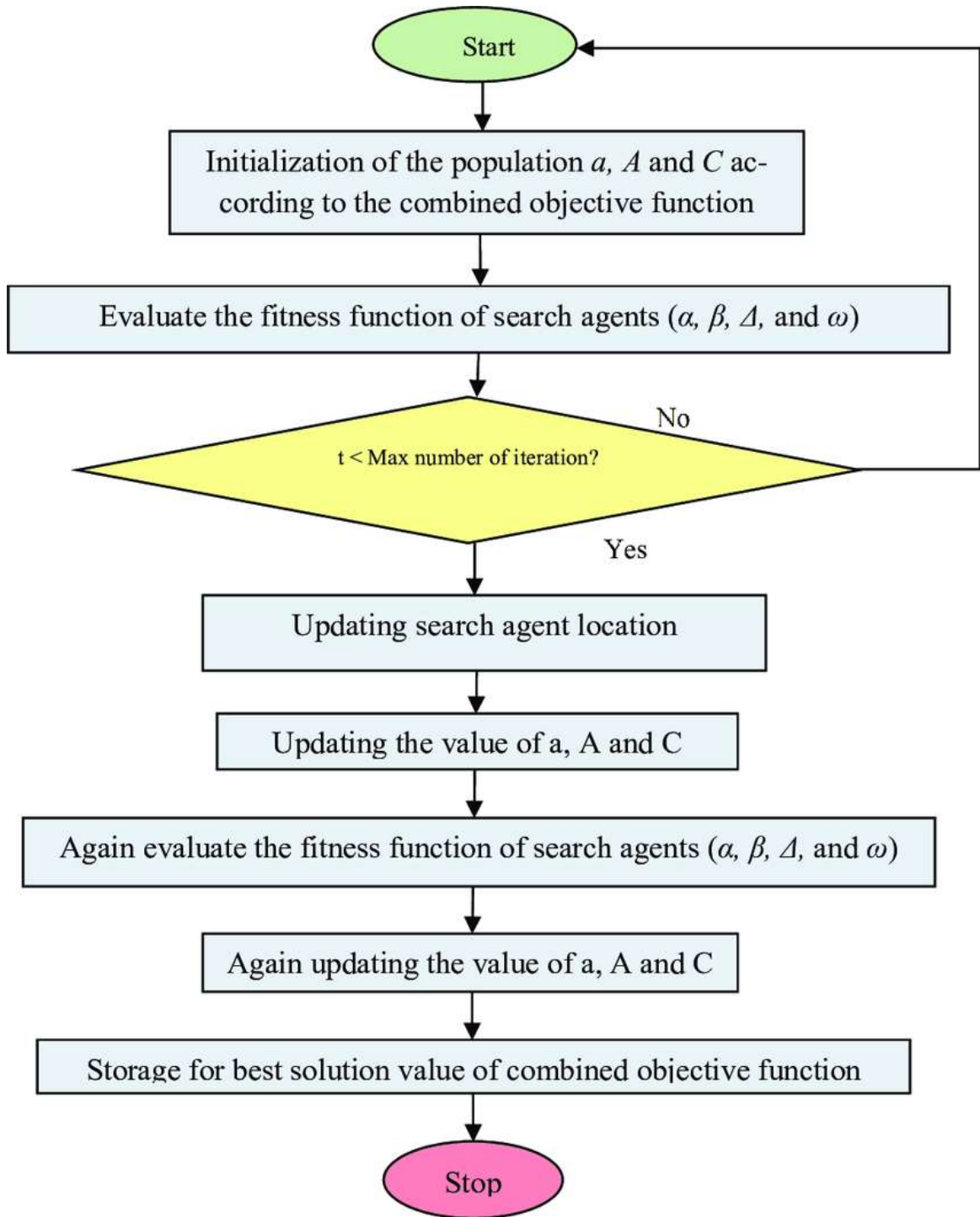


Fig: 4.1 Flow diagram of the Grey wolf optimization algorithm

4.5 The pseudo code of the GWO algorithm:

Initialize the grey wolf population X_i ($i = 1, 2, \dots, n$)
Initialize a , A , and C
Calculate the fitness of each search agent
 X_α =the best search agent
 X_β =the second-best search agent X_δ =the third best search agent
***while** ($t < \text{Max number of iterations}$) **for** each search agent*
Update the position of the current search agent
end for
Update a , A , and C
Calculate the fitness of all search agents Update X_α , X_β , and X_δ
$t=t+1$
***end while** return X_α*

4.6 GWO (Proposed method) based MPPT Controller:

- 4.6.1 In the Incremental Conductance MPPT method the Error $i.e. dI/dV + I/V$ has to be minimized
- 4.6.2 To minimize that error the work proposes a Integral Regulator which reduced the Error.
- 4.6.3 The gain value of the Integral Regulator is estimated with the help of GWO optimization.
- 4.6.4 First the proposed system which is developed in the MATLAB/SIMULINK is simulated and the error of the MPPT which to be minimized is given as the objective function of GWO Algorithm.
- 4.6.5 The GWO Algorithm estimates the optimum gain value of integral regulator for the corresponding minimum error.
- 4.6.6 Thus, the gain value of Integral Regulator is estimated optimally

CHAPTER – 5

5 SIMULATION RESULTS

5.1 Grid Connected PV System:

In this work 100 KW PV grid system is simulated in the MATLAB in this model Grey wolf Optimization method is employed for Incremental Conductance MPPT Technique and compared with the PSO MPPT and Conventional MPPT techniques. The Block Diagram is shown below.

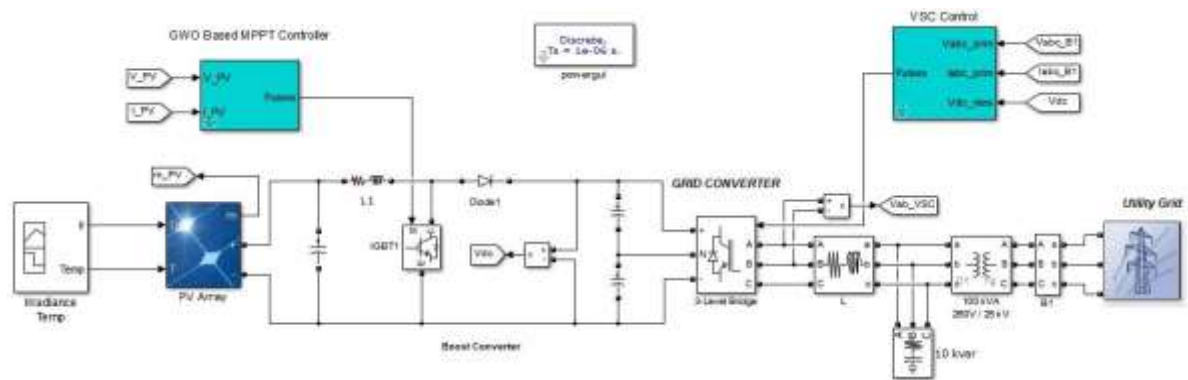


Fig: 5.1 Proposed Model of GWO IC based grid connected PV System

In this model a 100 KW PV module is connected to 5 KHz 500 V Boost converter which boosts the PV Module Voltage to 500 V irrespective of changes it maintains the constant 500 V. The boost converter is connected to the Grid tied Converter. In this model 3 level 500 V Voltage Source Converter is considered as a Grid converter. The Grid converter receives the constant 500 V DC voltage for the boost converter. The Grid converter is connected to the Utility Grid through 100 KVA Transformer. In the PV module the maximum power is traced with the help of Grey Wolf Optimization (GWO) based Incremental Conductance Technique for the optimal tracking of the Maximum power.

5.2 Results and Discussion:

The proposed model is tested with Three methods with different cases. The Three different methods are shown below.

1. Incremental Conductance MPPT for Grid Tied PV System.
2. PSO based Incremental Conductance MPPT for Grid Tied PV System.

3. GWO based Incremental Conductance MPPT for Grid Tied PV System.

5.3 Incremental Conductance MPPT for Grid Tied PV System:

The Incremental Conductance MPPT method is tested in four cases they are

Case: 1 Variable Irradiance and Variable Temperature

Case: 2 Constant Irradiance and Variable Temperature

Case: 3 Variable Irradiance and Constant Temperature

Case: 4 Constant Irradiance and Constant Temperature

Case: 1 Variable Irradiance and Variable Temperature

In the case 1 the maximum power is harnessed with Incremental conductance method. In this method the following results are obtained.

The following figure shows the Variable Irradiance, Variable Temperature. Mean Power, Mean Voltage, Duty cycle. In the Mean Power, Mean Voltage and duty cycle oscillations exist. At 1000 W/m^2 , 25 deg the Maximum power is 100.7 KW and in this condition the output voltage of the PV module is 273.5 V . At 250 W/m^2 , 25 deg the Maximum power is 24.4 KW and in this condition the output voltage of the PV module is 265.1 V . At 1000 W/m^2 , 50 deg the Maximum power is 92.9 KW and in this condition the output voltage of the PV module is 250.2 V .

Even though the variable cases are considered with the help of the Incremental conductance MPPT method the constant voltage is achieved

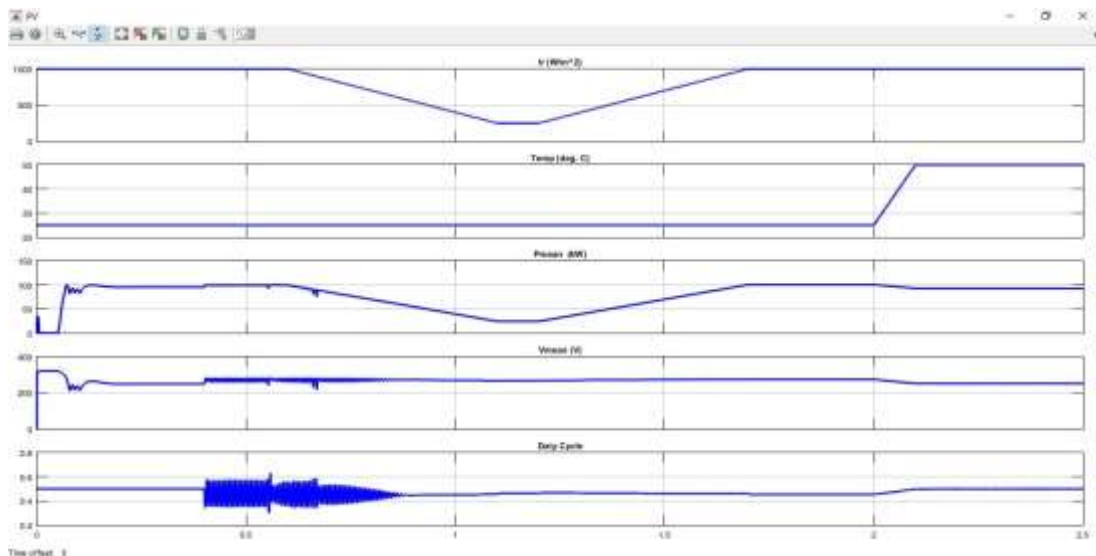


Fig: 5.2 Variable Irradiance, Variable Temperature. Mean Power, Mean Voltage, Duty

cycle of proposed model

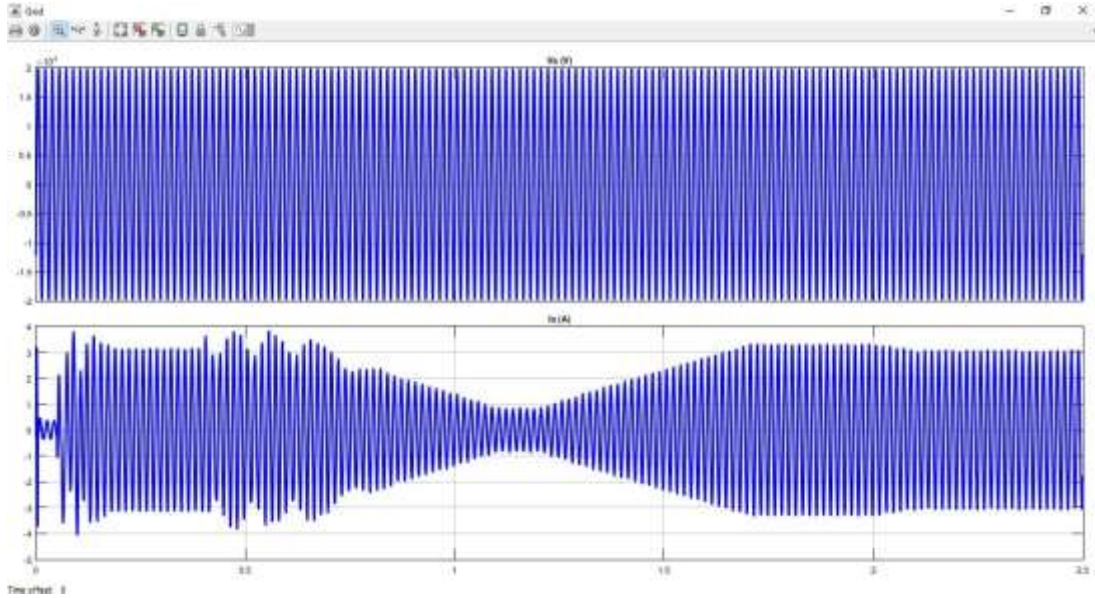


Fig: 5.3 Grid Voltage and Grid Current for the proposed model

The above figure shows that grid voltage is constant even though the variable Irradiance and Variable Temperature. In this method still, oscillation exist in the grid current even after MPPT method employed.

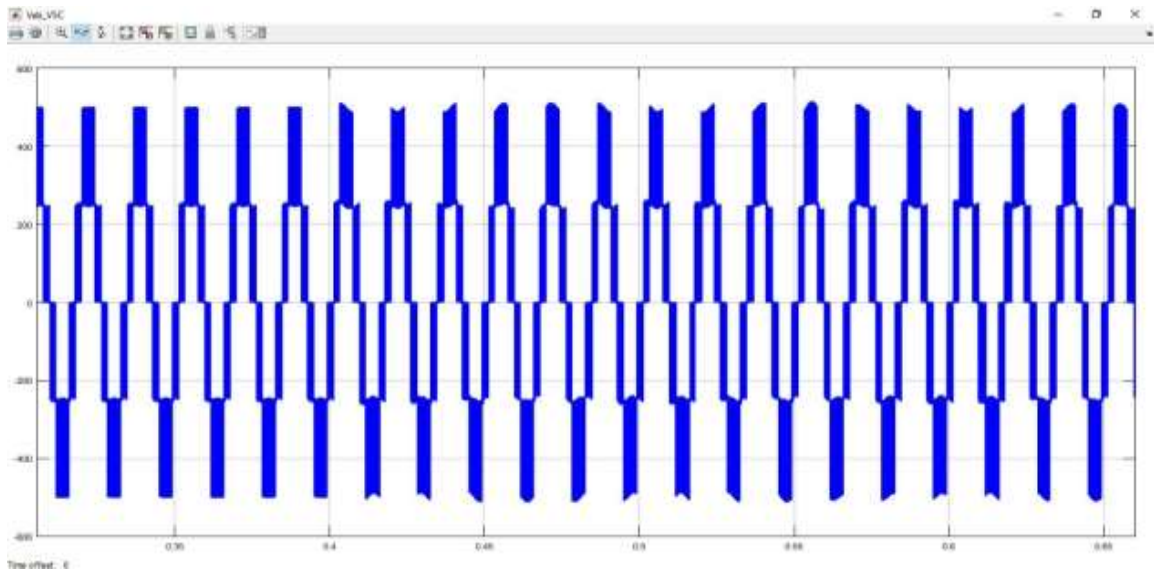


Fig: 5.4 Grid Converter Output Voltage

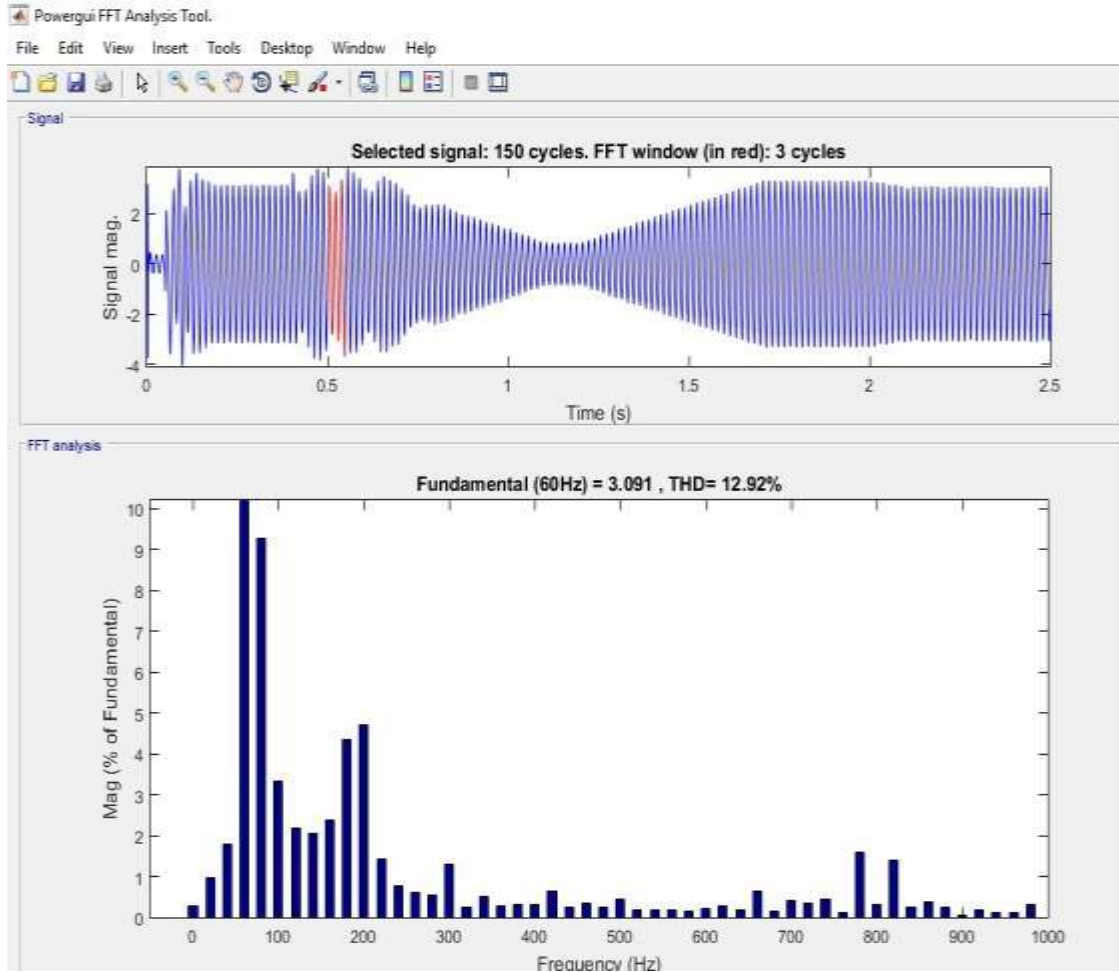


Fig: 5.5 THD analysis of Incremental Conductance MPPT Method.

The THD in this case is 12.92%.

Case: 2 Constant Irradiance and Variable Temperature

In the case 2 the maximum power is harnessed with Incremental conductance method. In this method the following results are obtained with constant Irradiance and Variable Temperature.

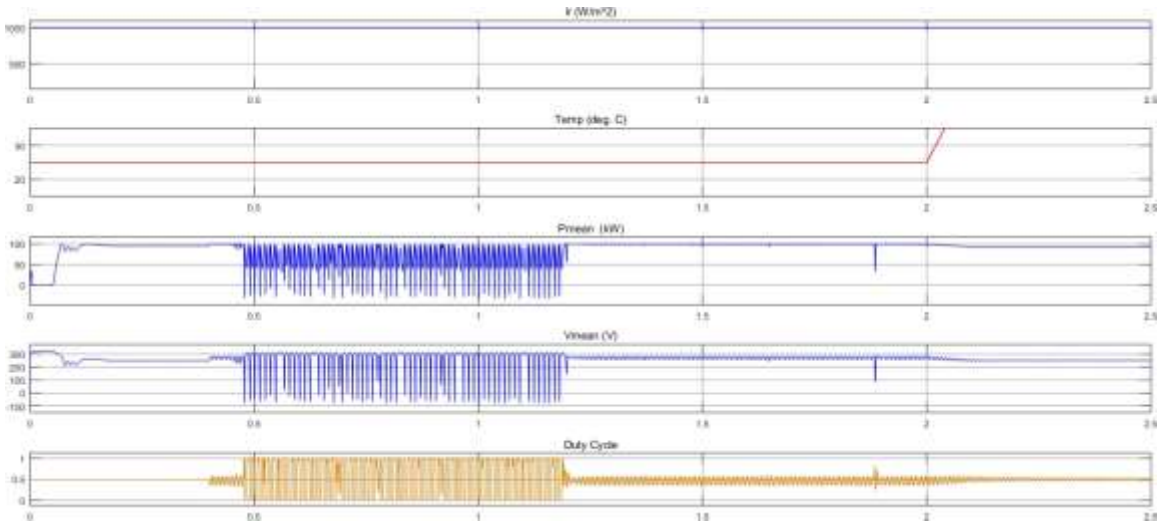


Fig: 5.6 Constant Irradiance, Variable Temperature. Mean Power, Mean Voltage, Duty cycle of proposed model

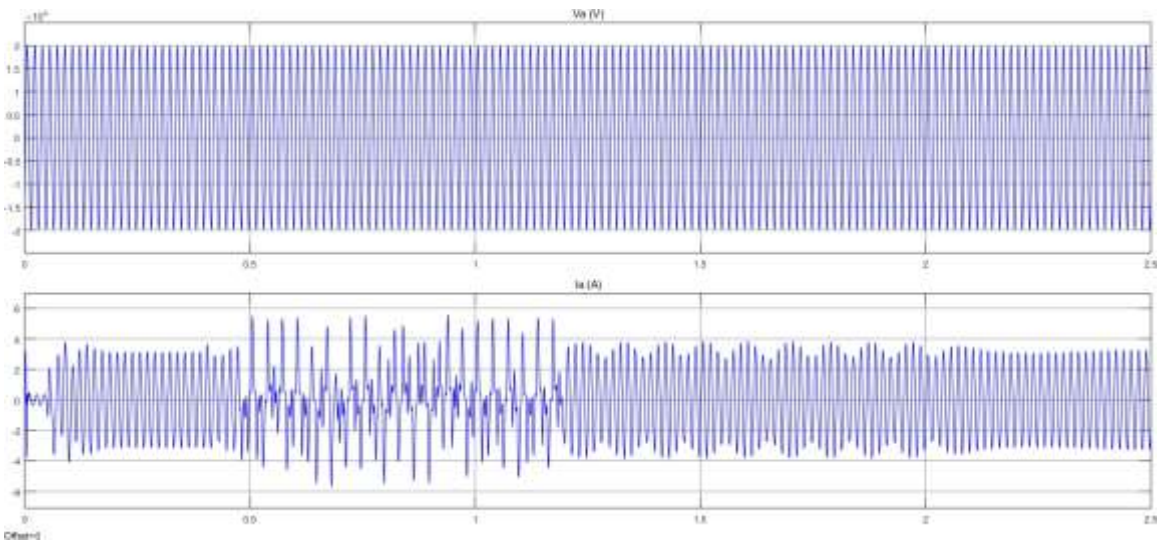


Fig: 5.7 Grid Voltage and Grid Current for the proposed model

The above figure shows that grid voltage is constant even though the Constant Irradiance and Variable Temperature. In this method still, oscillation exist in the grid current even after MPPT method employed.

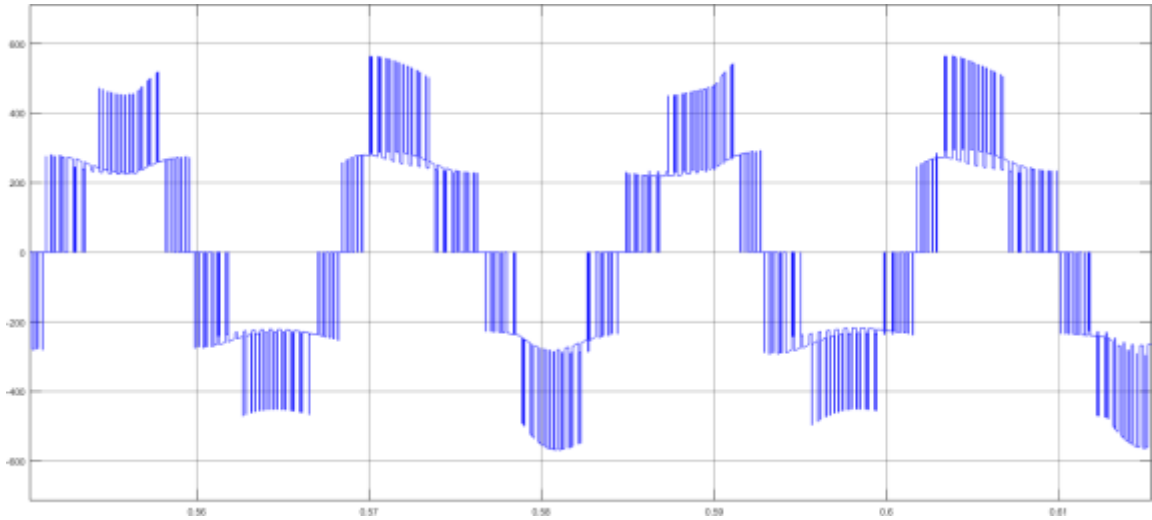


Fig: 5.8 Grid Converter Output Voltage

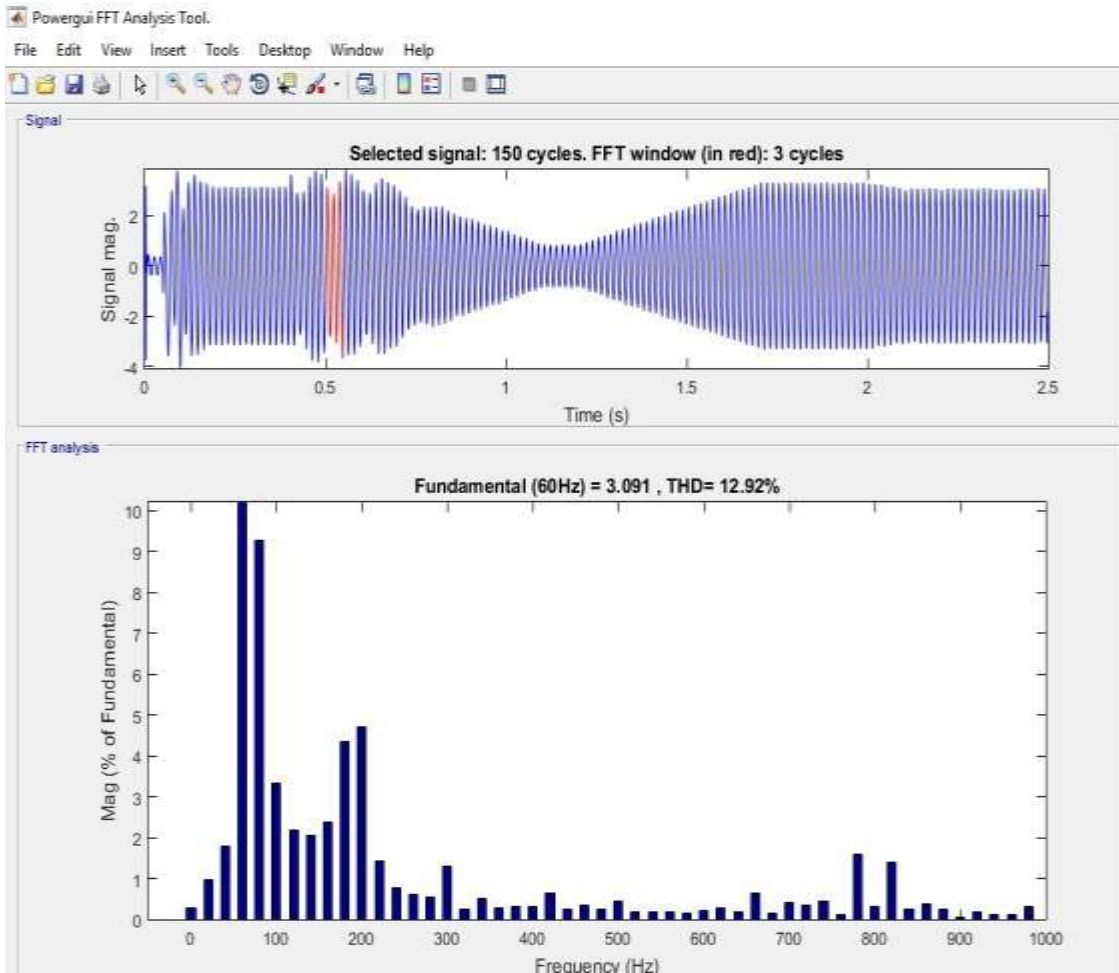


Fig: 5.9THD analysis of Incremental Conductance MPPT Method.

Case: 3 Variable Irradiance and Constant Temperature

In the case 2 the maximum power is harnessed with Incremental conductance method. In this method the following results are obtained with constant Irradiance and Variable Temperature.

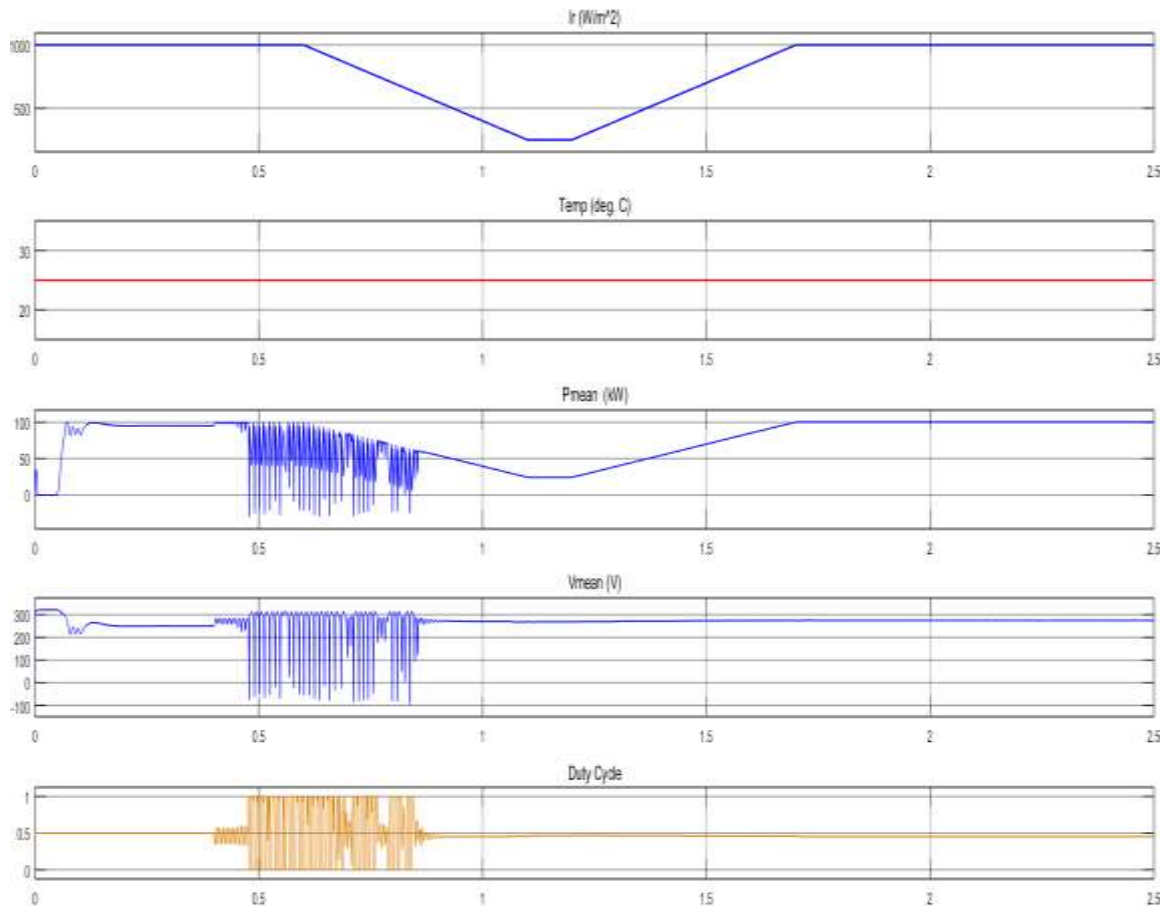


Fig: 5.10 Variable Irradiance, Constant Temperature. Mean Power, Mean Voltage, Duty cycle of proposed model

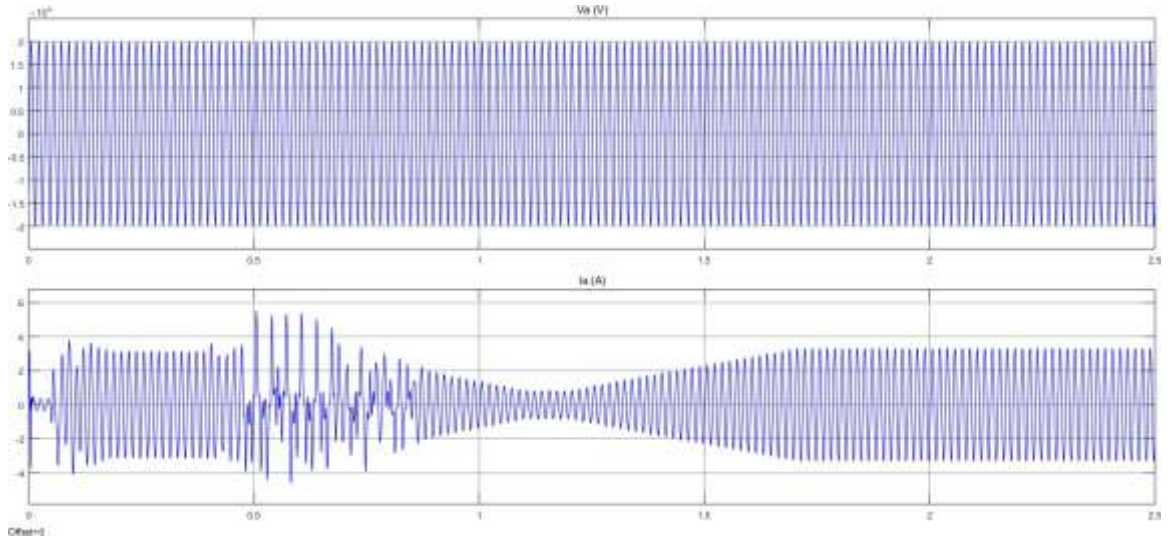


Fig: 5.11 Grid Voltage and Grid Current for the proposed model

The above figure shows that grid voltage is constant even though the Variable Irradiance and Constant Temperature. In this method still, oscillation exist in the grid current even after MPPT method employed.

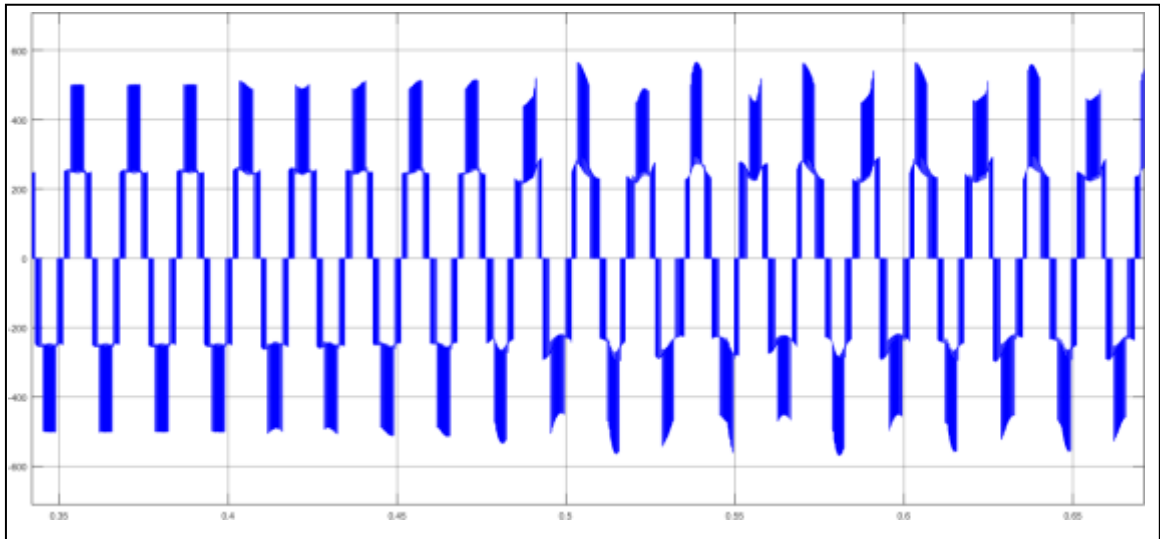


Fig: 5.12 Grid Converter Output Voltage

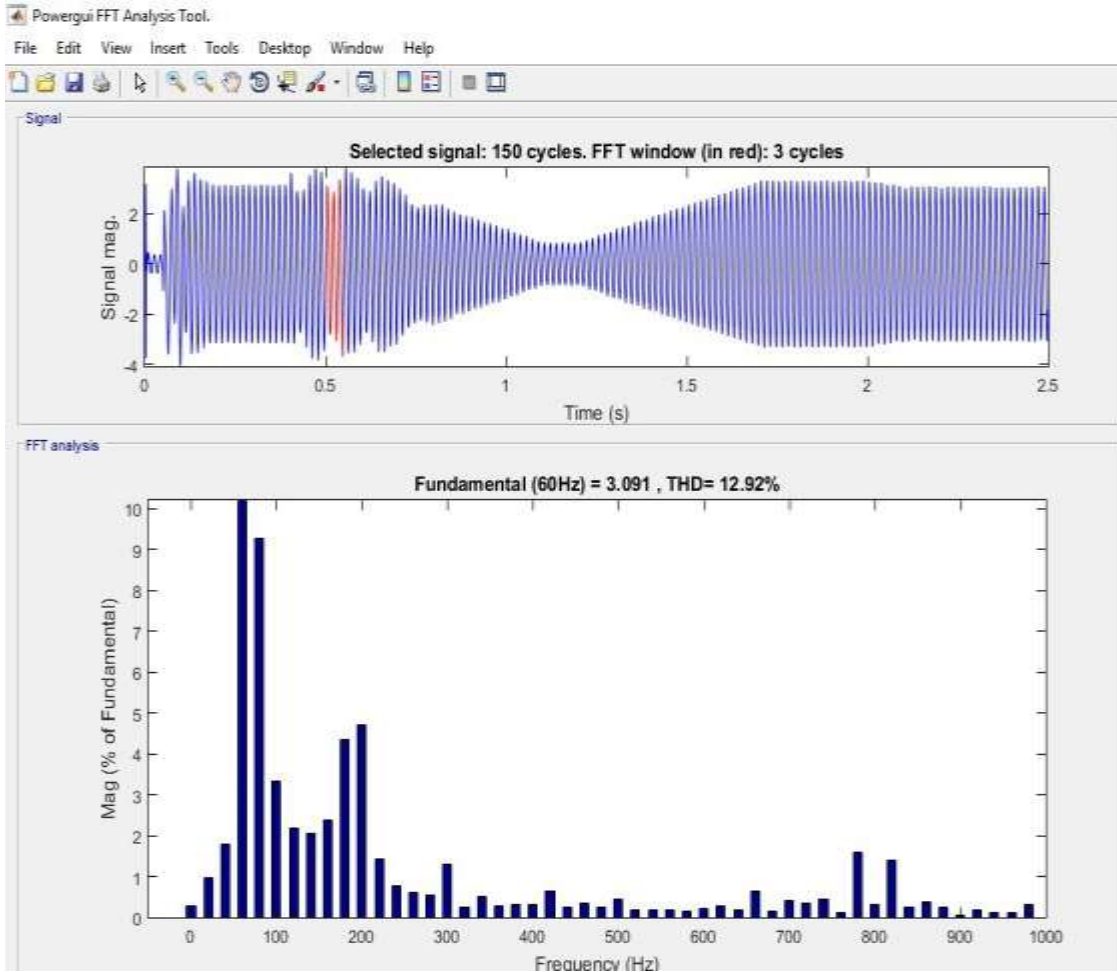


Fig: 5.13 THD analysis of Incremental Conductance MPPT Method.

Case: 4 Constant Irradiance and Constant Temperature

In the case 4 the maximum power is harnessed with Incremental conductance method. In this method the following results are obtained with constant Irradiance and Constant Temperature.

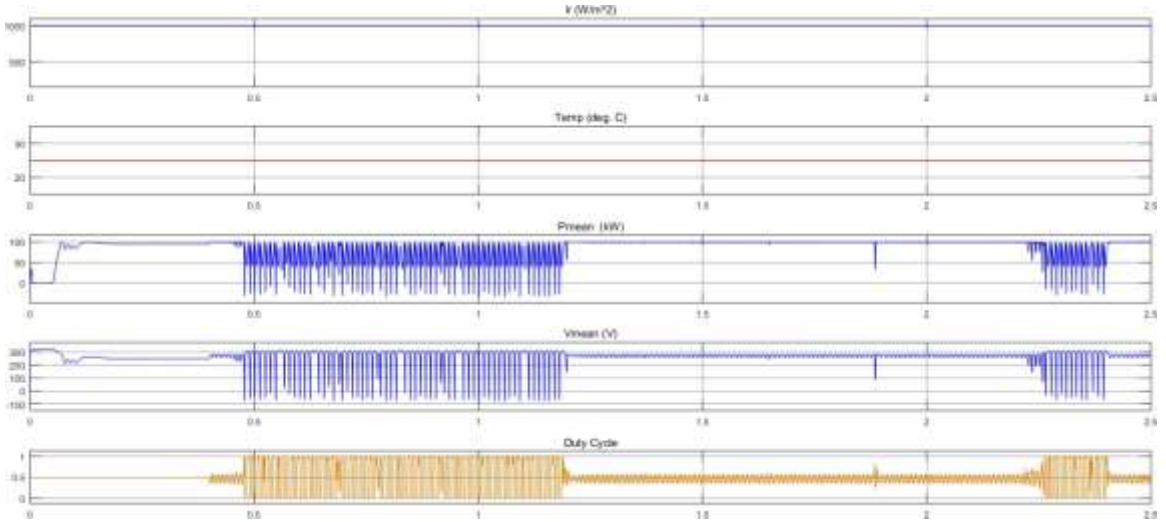


Fig: 5.14 Constant Irradiance, Constant Temperature. Mean Power, Mean Voltage, Duty cycle of proposed model

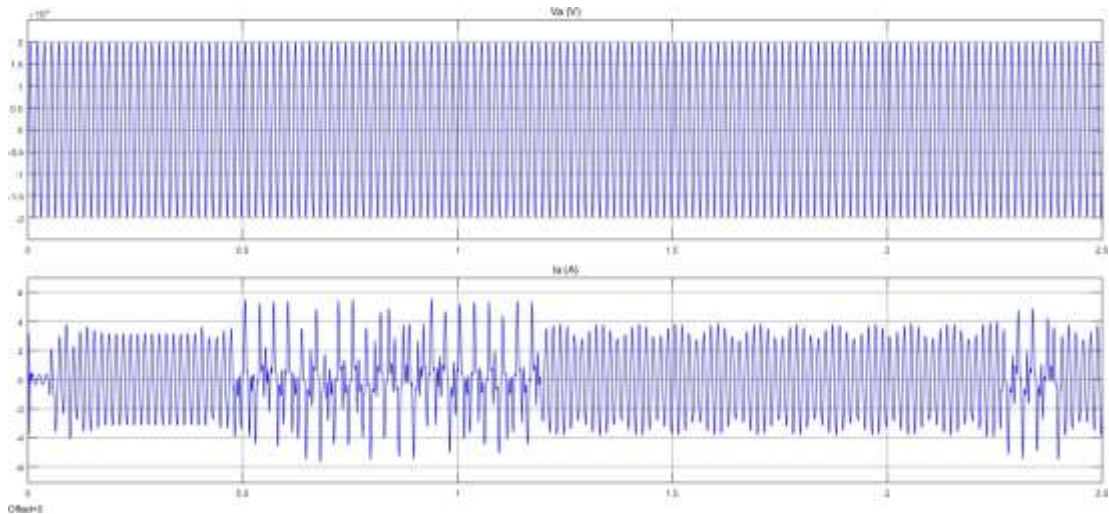


Fig: 5.15 Grid Voltage and Grid Current for the proposed model

The above figure shows that grid voltage is constant even though the Constant Irradiance and Constant Temperature. In this method still, oscillation exist in the grid current even after MPPT method employed.

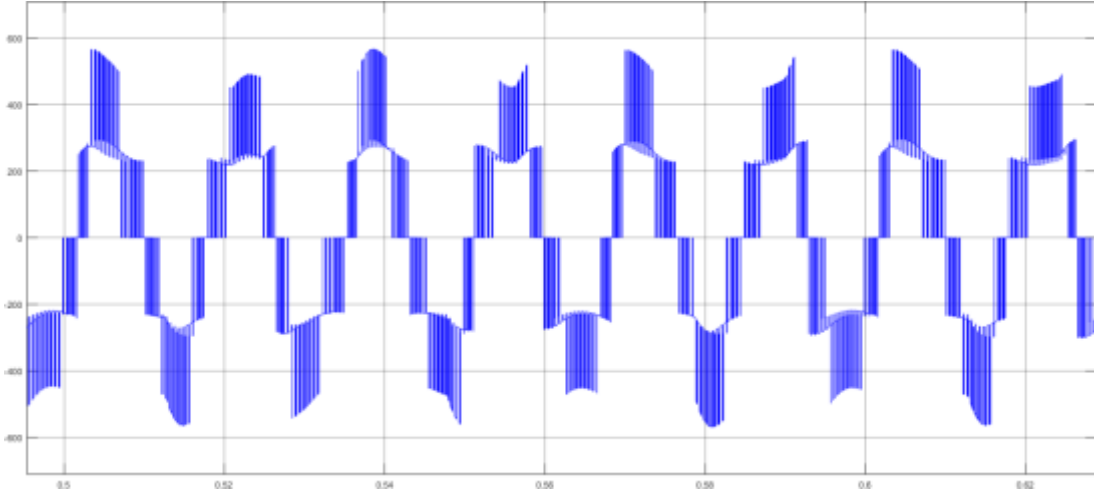


Fig: 5.16 Grid Converter Output Voltage

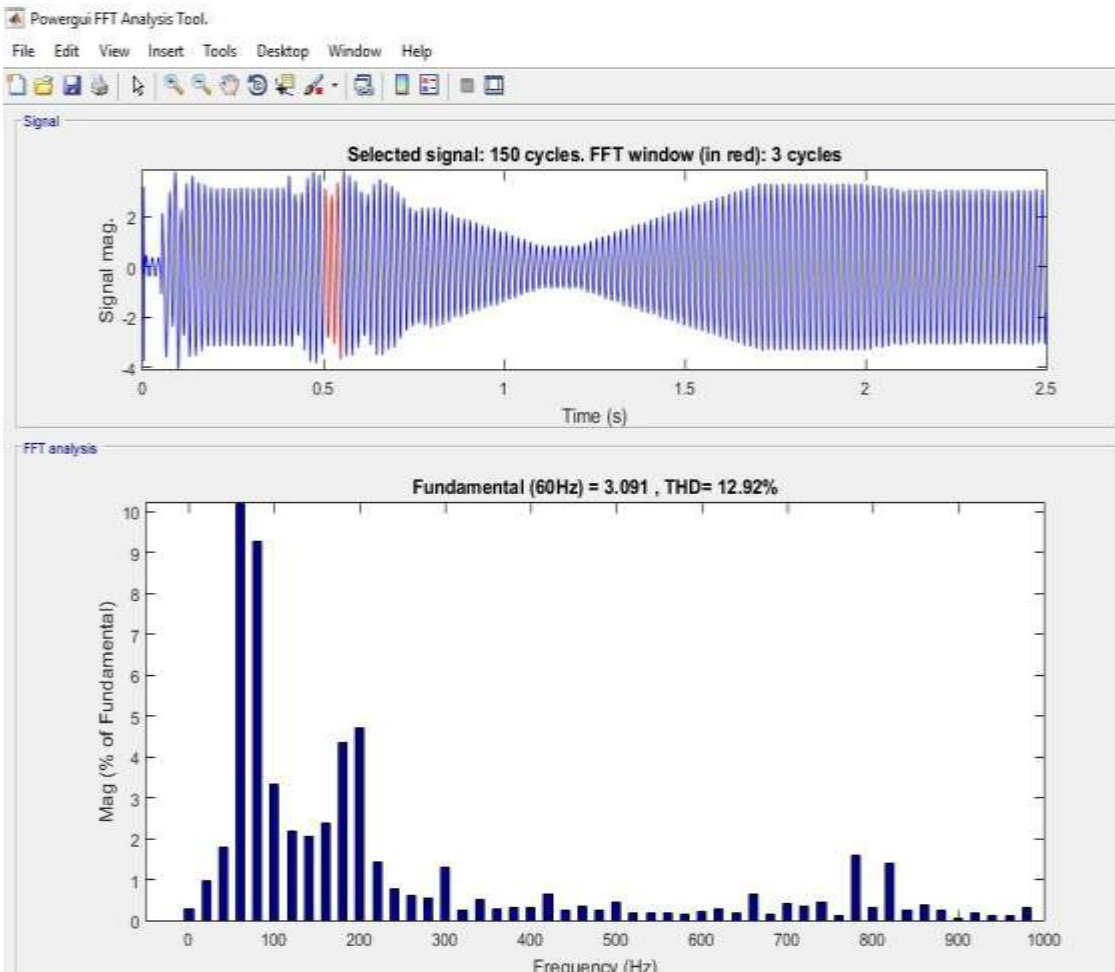


Fig: 5.17 THD analysis of Incremental Conductance MPPT Method

5.4 PSO based Incremental Conductance MPPT for Grid Tied PV System:

The PSO based Incremental Conductance MPPT method is tested in four cases they are

Case: 1 Variable Irradiance and Variable Temperature

Case: 2 Constant Irradiance and Variable Temperature

Case: 3 Variable Irradiance and Constant Temperature

Case: 4 Constant Irradiance and Constant Temperature

Case: 1 Variable Irradiance and Variable Temperature

In the case 1 the maximum power is harnessed with PSO based Incremental conductance method. In this method the following results are obtained.

The following figure shows the Variable Irradiance, Variable Temperature, Mean Power, Mean Voltage, Duty cycle. In the Mean Power, Mean Voltage and duty cycle oscillations exist. At 1000 W/m^2 , 25 deg the Maximum power is 100.7 KW and in this condition the output voltage of the PV module is 273.5 V . At 250 W/m^2 , 25 deg the Maximum power is 24.4 KW and in this condition the output voltage of the PV module is 265.1 V . At 1000 W/m^2 , 50 deg the Maximum power is 92.9 KW and in this condition the output voltage of the PV module is 250.2 V .

Even though the variable cases are considered with the help of the PSO based Incremental conductance MPPT method the constant voltage is achieved

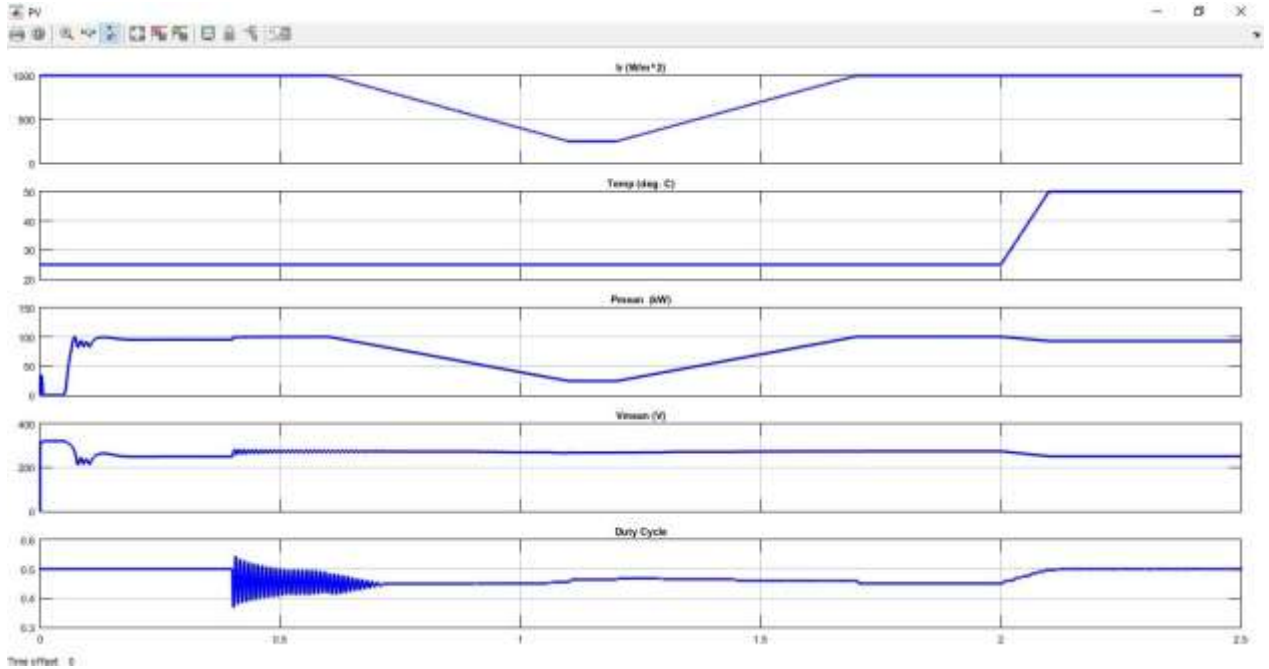


Fig: 5.18 Variable Irradiance, Variable Temperature. Mean Power, Mean Voltage, Duty cycle of proposed model

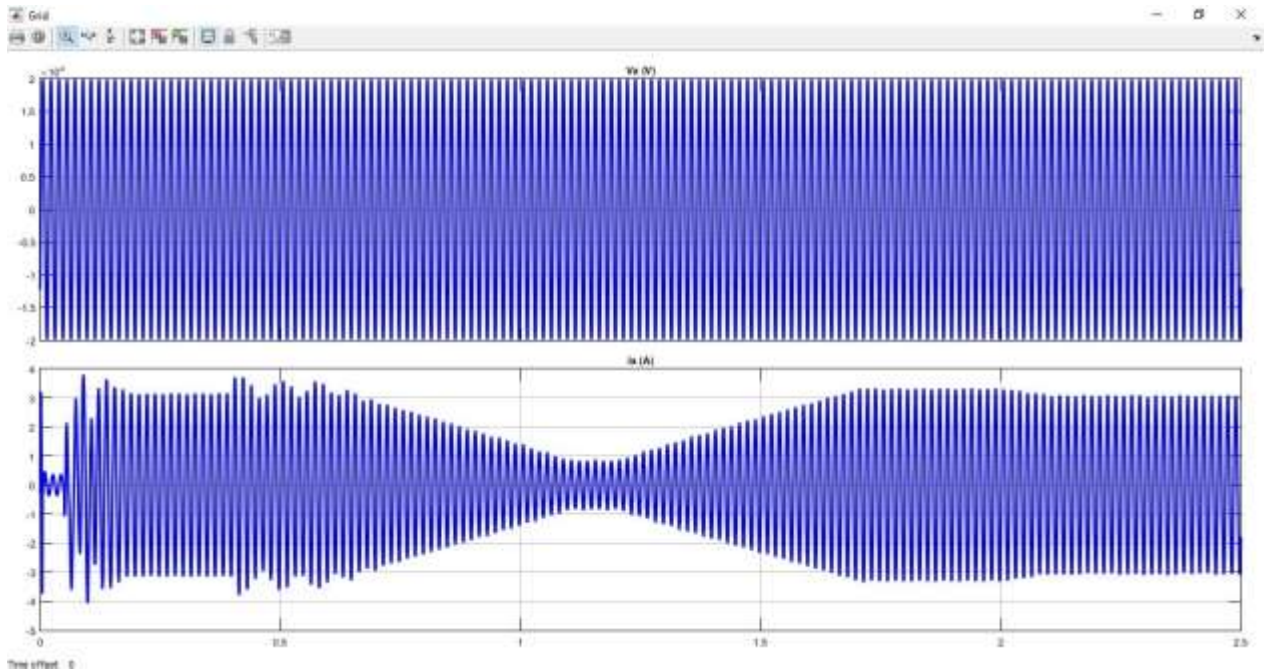


Fig: 5.19 Grid Voltage and Grid Current for the proposed model

The above figure shows that grid voltage is constant even though the variable Irradiance and Variable Temperature. In this method still, oscillation exist in the grid current even after MPPT method employed but better than the previous case.

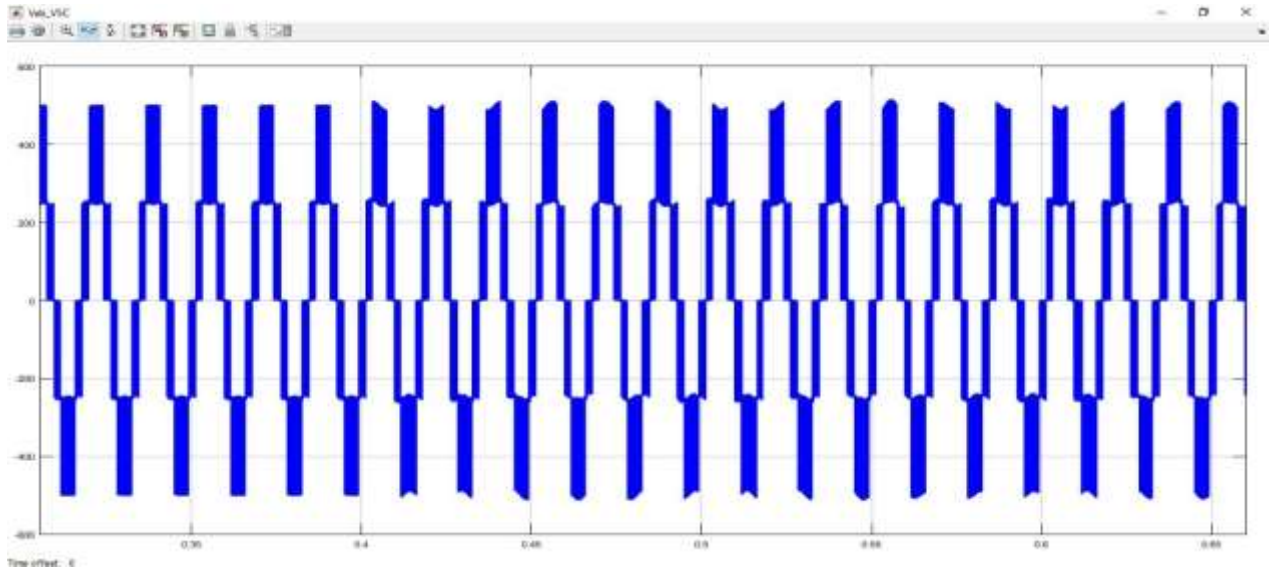


Fig: 5.20 Grid Converter Output Voltage

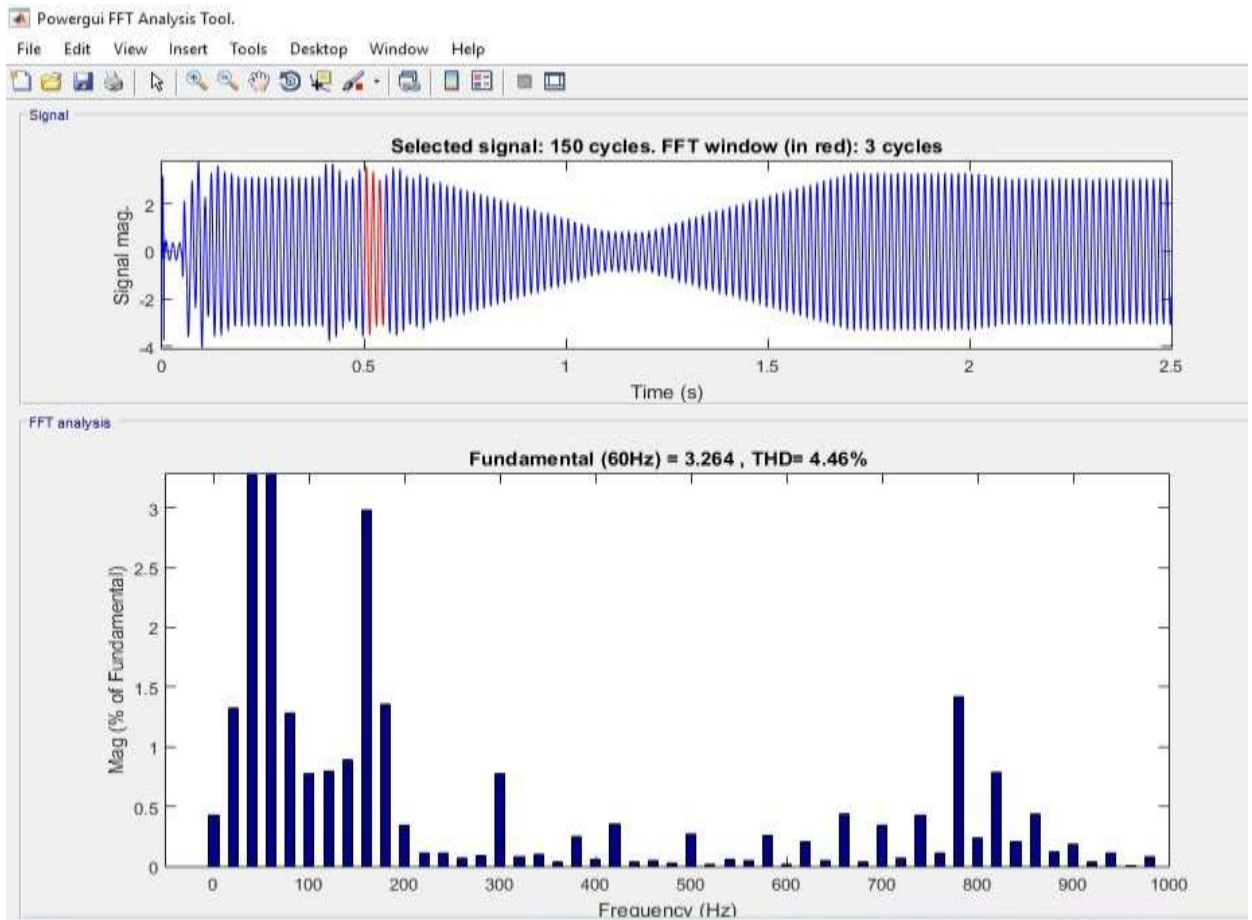


Fig: 5.21 THD analysis of PSO based Incremental Conductance MPPT Method.

The THD in this case is 4.46%.

Case: 2 Constant Irradiance and Variable Temperature

In the case 2 the maximum power is harnessed with PSO based Incremental conductance method. In this method the following results are obtained with constant Irradiance and Variable Temperature.

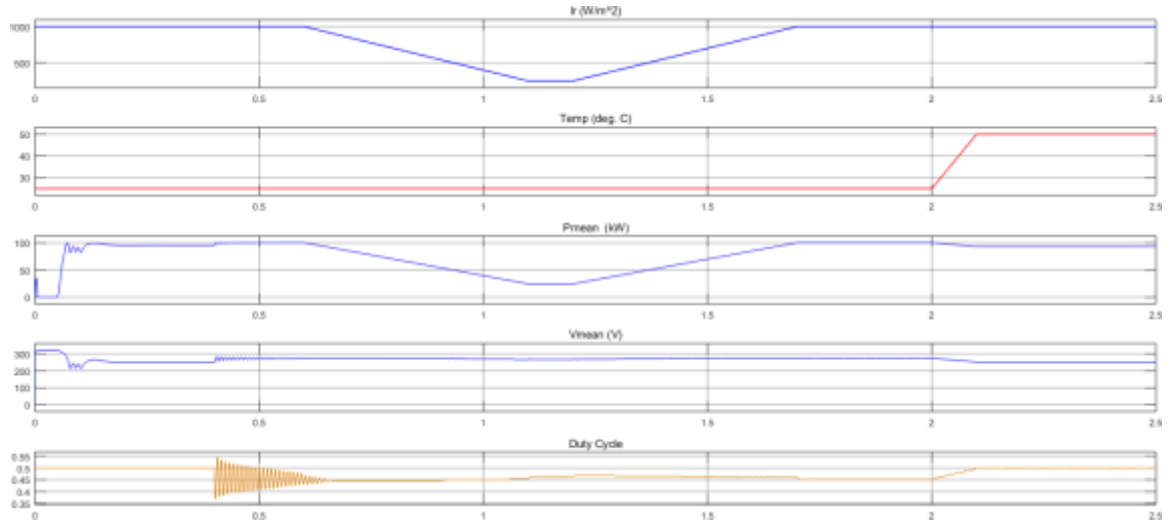


Fig: 5.22 Constant Irradiance, Variable Temperature. Mean Power, Mean Voltage, Duty cycle of proposed model

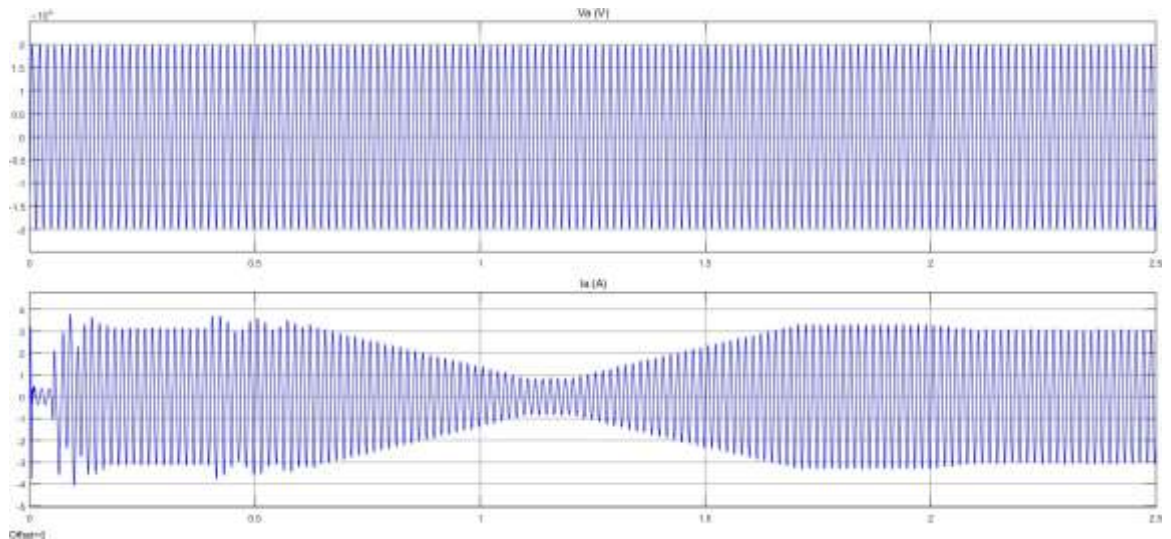


Fig: 5.23 Grid Voltage and Grid Current for the proposed mode

The above figure shows that grid voltage is constant even though the Constant Irradiance and Variable Temperature. In this method still, oscillation exist in the grid current even after MPPT method employed but better than the previous case.

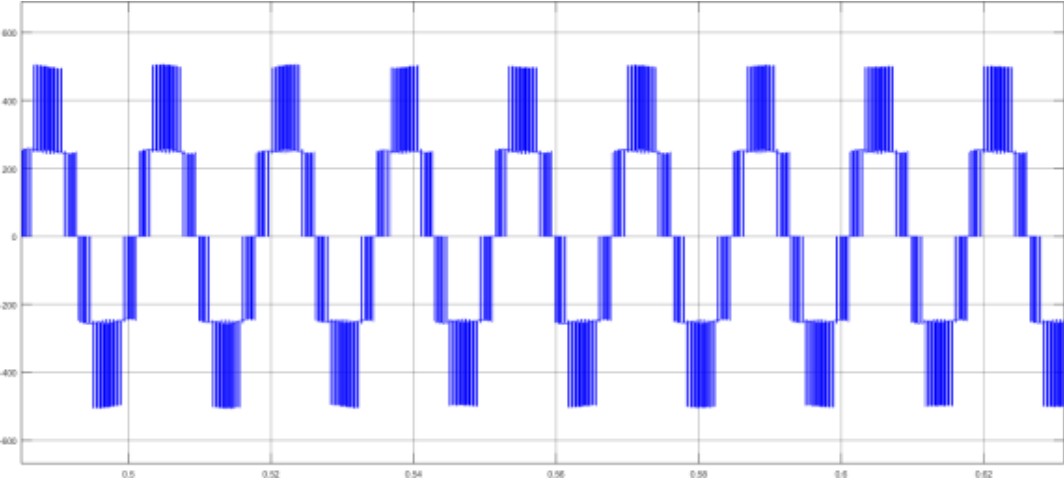


Fig: 5.24 Grid Converter Output Voltage

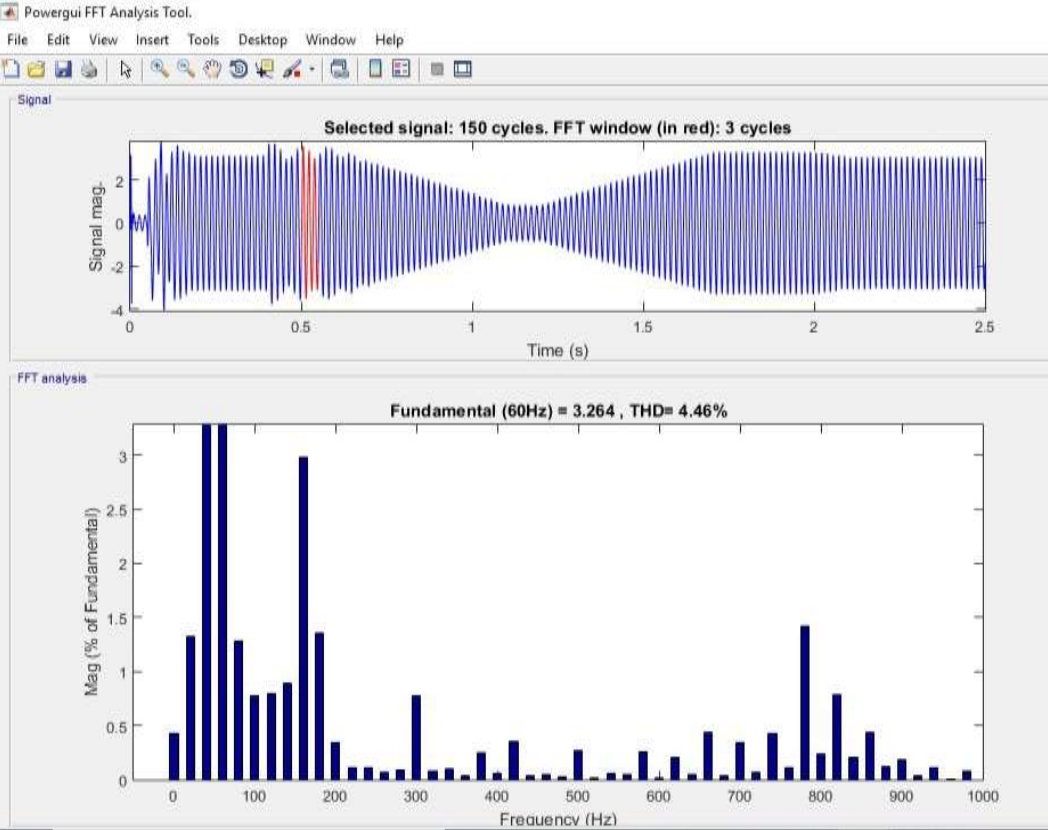


Fig: 5.25 THD analysis of Incremental Conductance MPPT Method.

Case: 3 Variable Irradiance and Constant Temperature

In the case 3 the maximum power is harnessed with PSO based Incremental conductance method. In this method the following results are obtained with constant Irradiance and Variable Temperature.

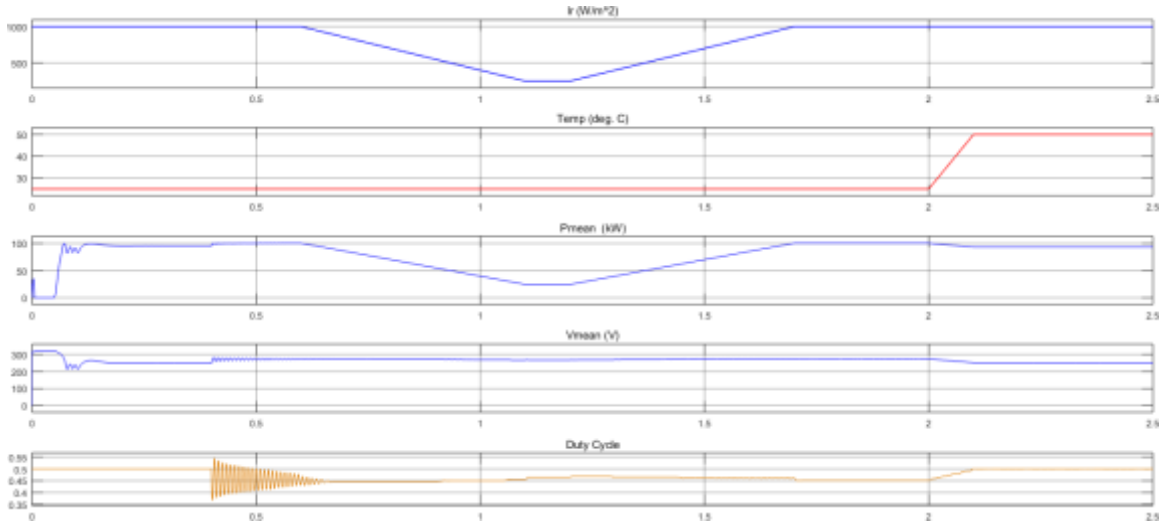


Fig: 5.26 Variable Irradiance, Constant Temperature. Mean Power, Mean Voltage, Duty cycle of proposed model

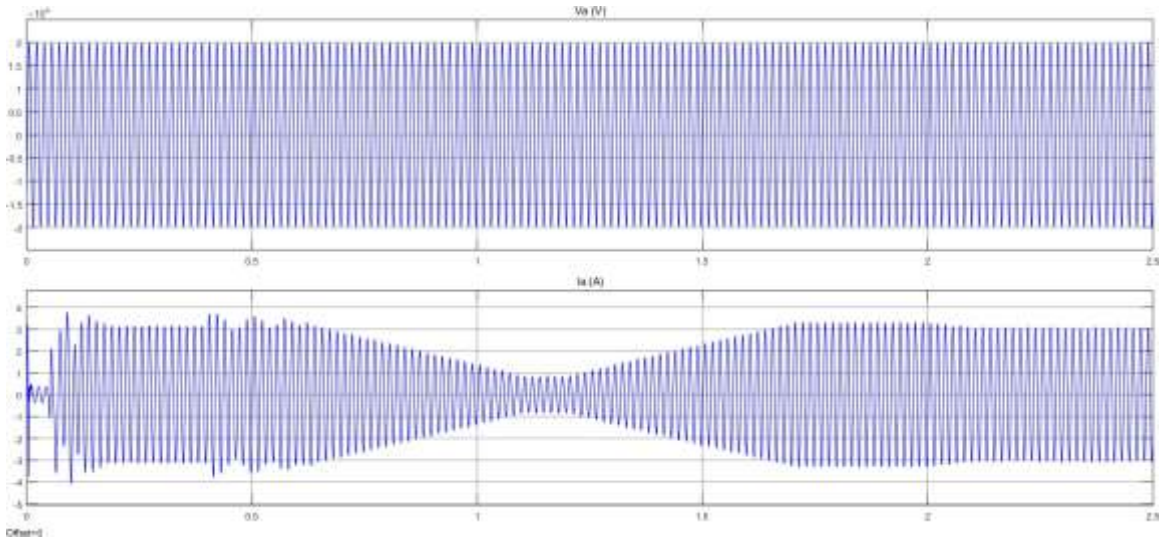


Fig: 5.27 Grid Voltage and Grid Current for the proposed model

The above figure shows that grid voltage is constant even though the variable Irradiance and Constant Temperature. In this method still, oscillation exist in the grid current even after MPPT method employed but better than the previous case.

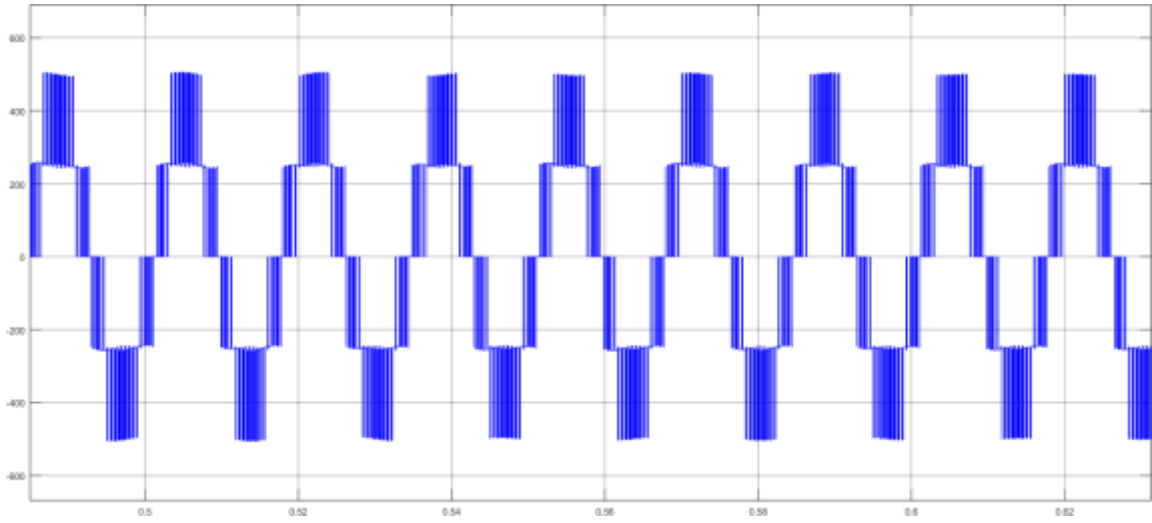


Fig: 5.28 Grid Converter Output Voltage

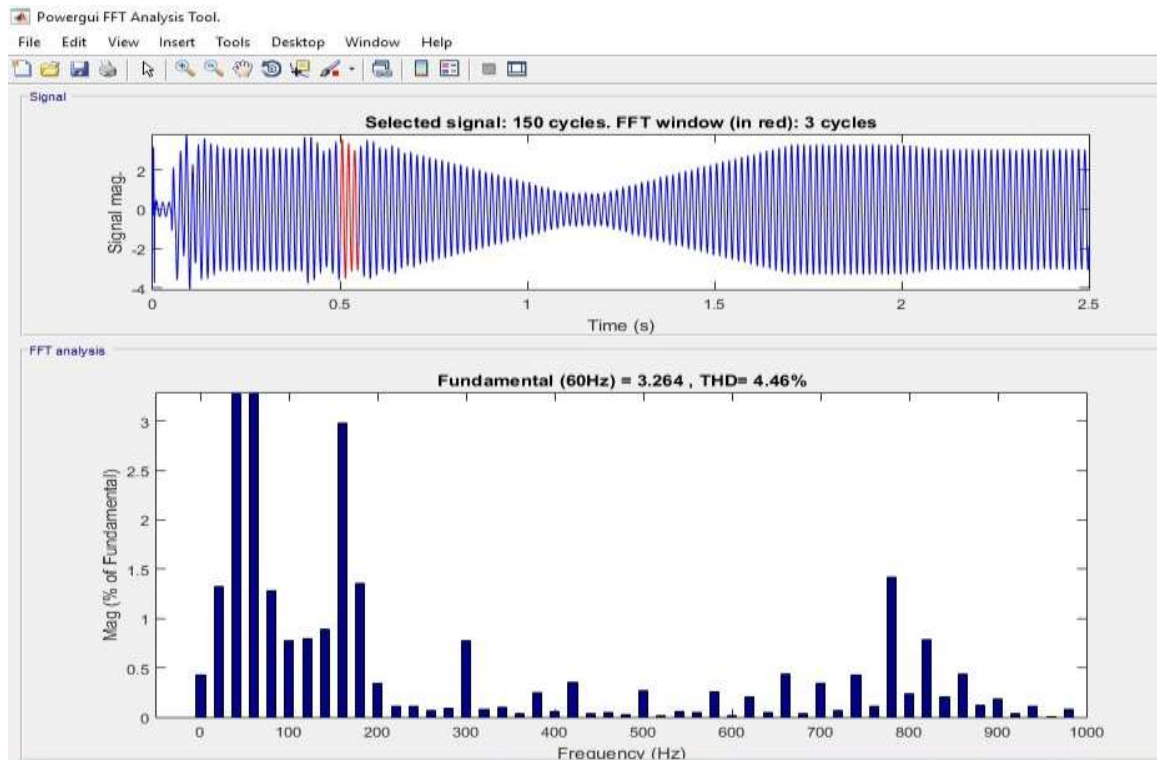


Fig: 5.29 THD analysis of PSO based Incremental Conductance MPPT Method.

Case: 4 Constant Irradiance and Constant Temperature

In the case 4 the maximum power is harnessed with PSO based Incremental conductance method. In this method the following results are obtained with constant Irradiance and Constant Temperature.

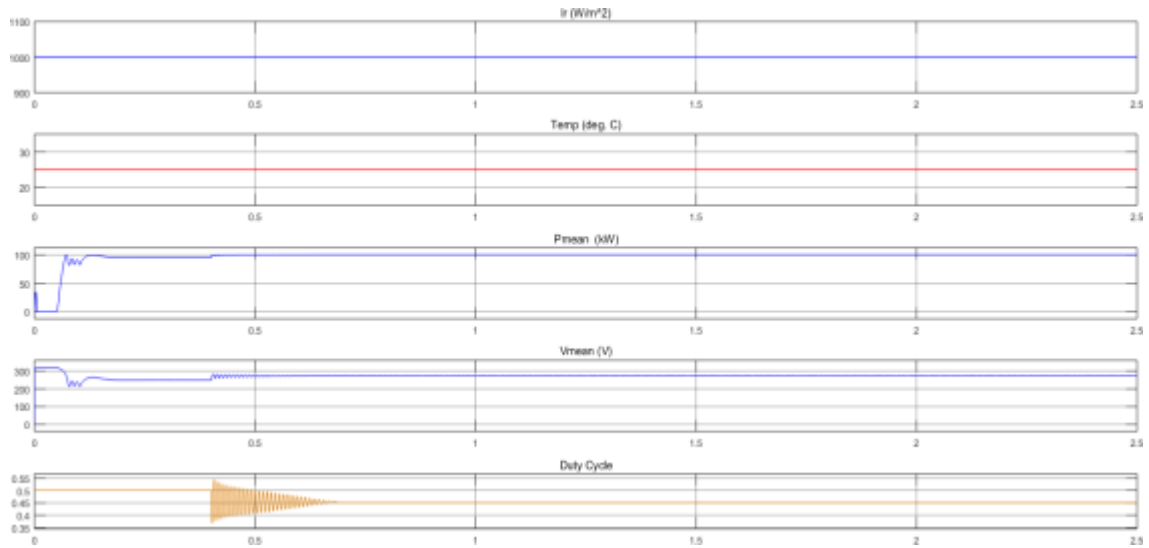


Fig: 5.30 Constant Irradiance, Constant Temperature. Mean Power, Mean Voltage, Duty cycle of proposed model

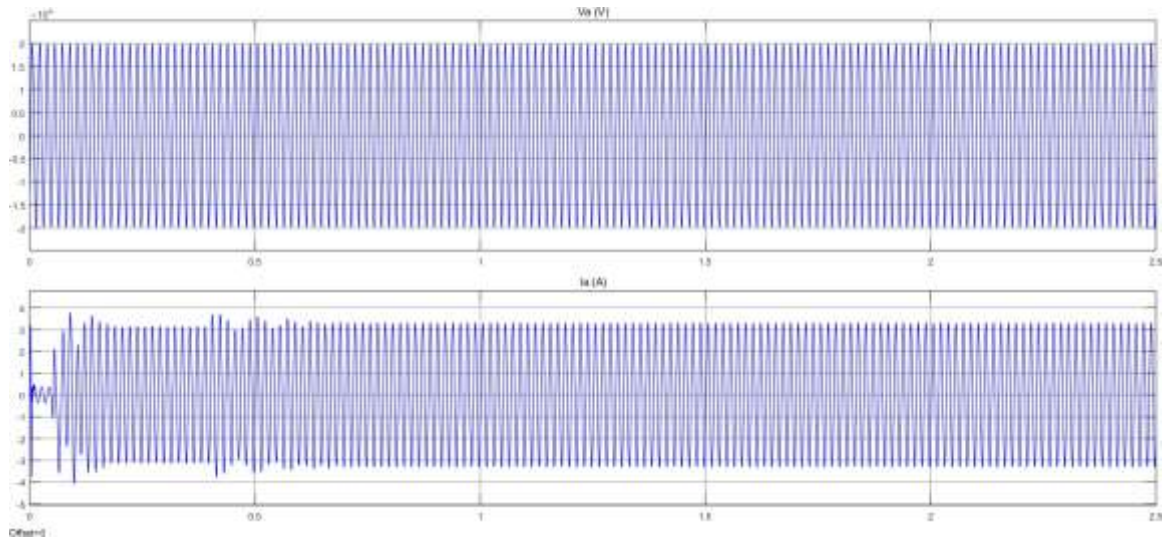


Fig: 5.31 Grid Voltage and Grid Current for the proposed model

The above figure shows that grid voltage is constant even though the Constant Irradiance and Constant Temperature. In this method still, oscillation exist in the grid current even after MPPT method employed but better than the previous case.

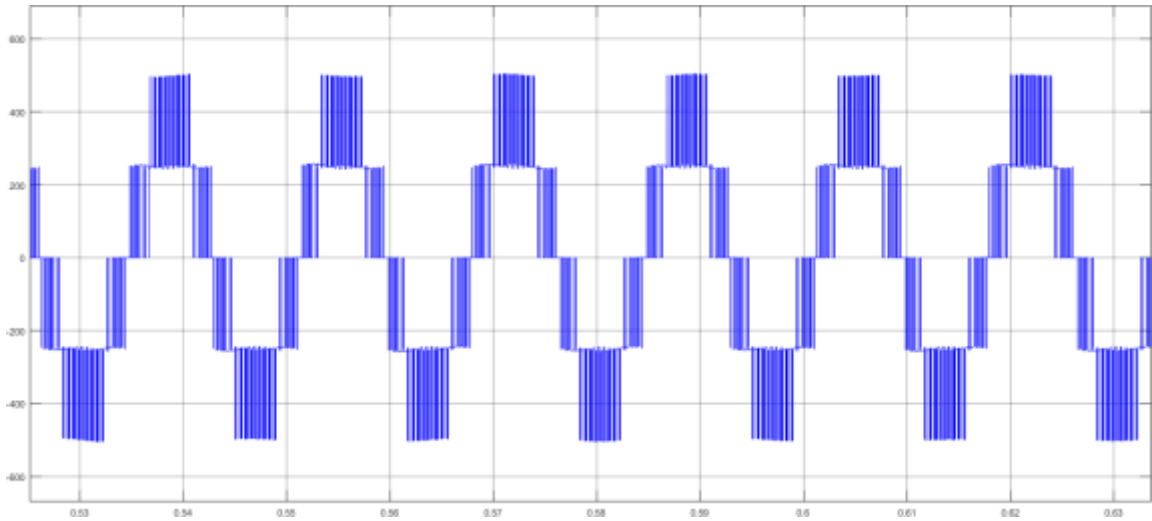


Fig: 5.32 Grid Converter Output Voltage

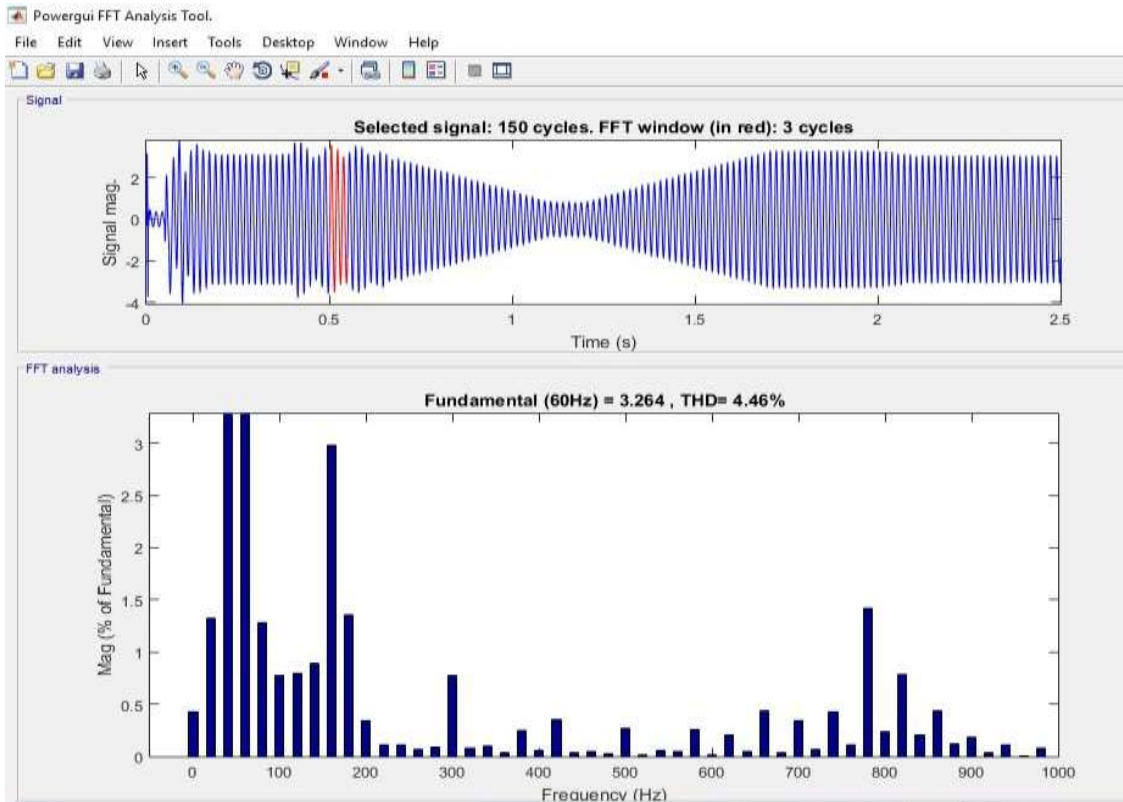


Fig: 5.33 THD analysis of PSO based Incremental Conductance MPPT Method

5.5 GWO (Proposed method) based Incremental Conductance MPPT for Grid Tied PV System:

The GWO based Incremental Conductance MPPT method is tested in four cases they are

Case: 1 Variable Irradiance and Variable Temperature

Case: 2 Constant Irradiance and Variable Temperature

Case: 3 Variable Irradiance and Constant Temperature

Case: 4 Constant Irradiance and Constant Temperature

Case: 1 Variable Irradiance and Variable Temperature

In the case 1 the maximum power is harnessed with Grey Wolf Optimized (GWO) based Incremental conductance method. In this method the following results are obtained.

The following figure shows the Variable Irradiance, Variable Temperature. Mean Power, Mean Voltage, Duty cycle. In the Mean Power, Mean Voltage and duty cycle oscillations exits. At 1000 W/m^2 , 25 deg the Maximum power is 100.7 KW and in this condition the output voltage of the PV module is 273.5 V. At 250 W/m^2 , 25 deg the Maximum power is 24.4 KW and in this condition the output voltage of the PV module is 265.1 V. At 1000 W/m^2 , 50 deg the Maximum power is 92.9 KW and in this condition the output voltage of the PV module is 250.2 V.

Even though the variable cases are considered with the help of the GWO based Incremental conductance MPPT method the constant voltage is achieved

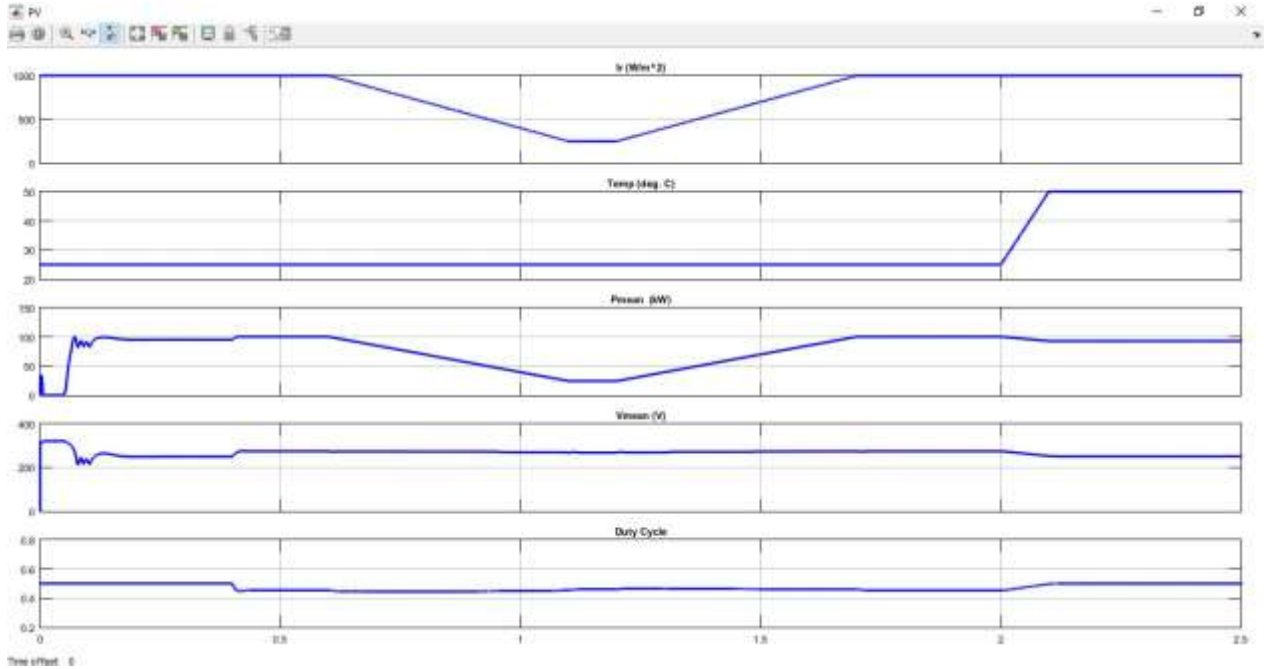


Fig: 5.34 Variable Irradiance, Variable Temperature. Mean Power, Mean Voltage, Duty cycle of proposed model

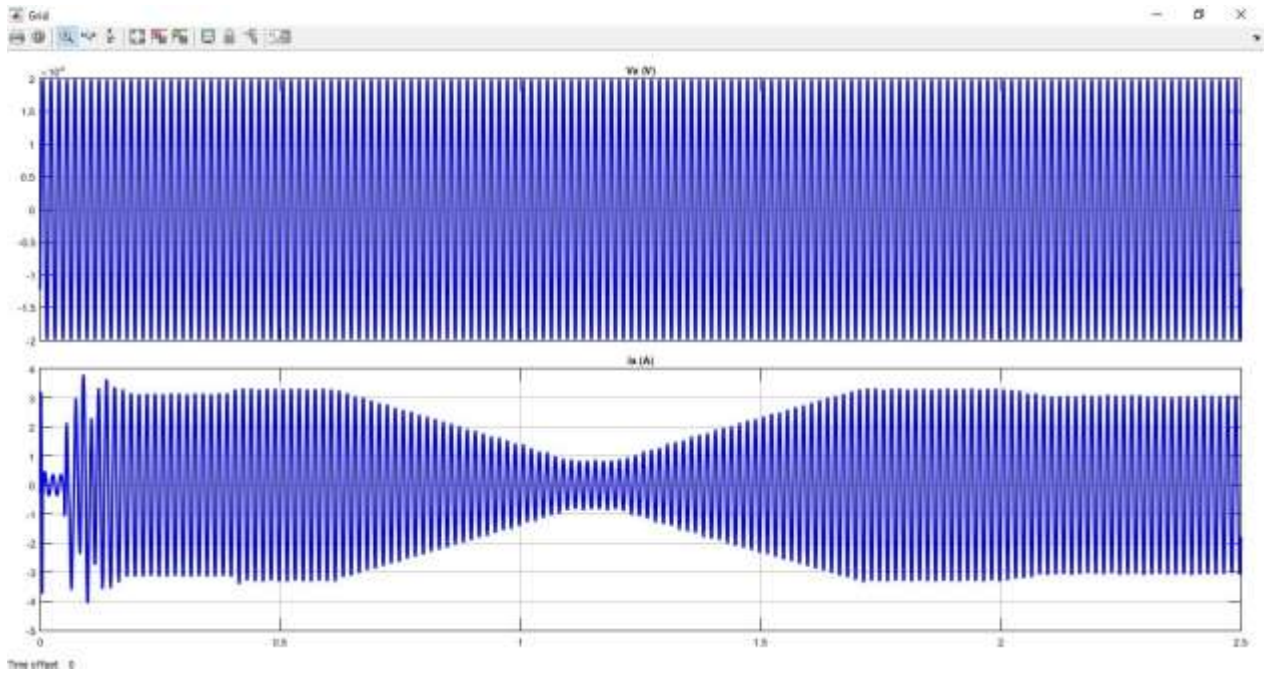


Fig: 5.35 Grid Voltage and Grid Current for the proposed model

The above figure shows that grid voltage is constant even though the variable Irradiance and Variable Temperature. In this method oscillations are damped in the grid current with Grey Wolf Optimized (GWO) based Incremental conductance method.

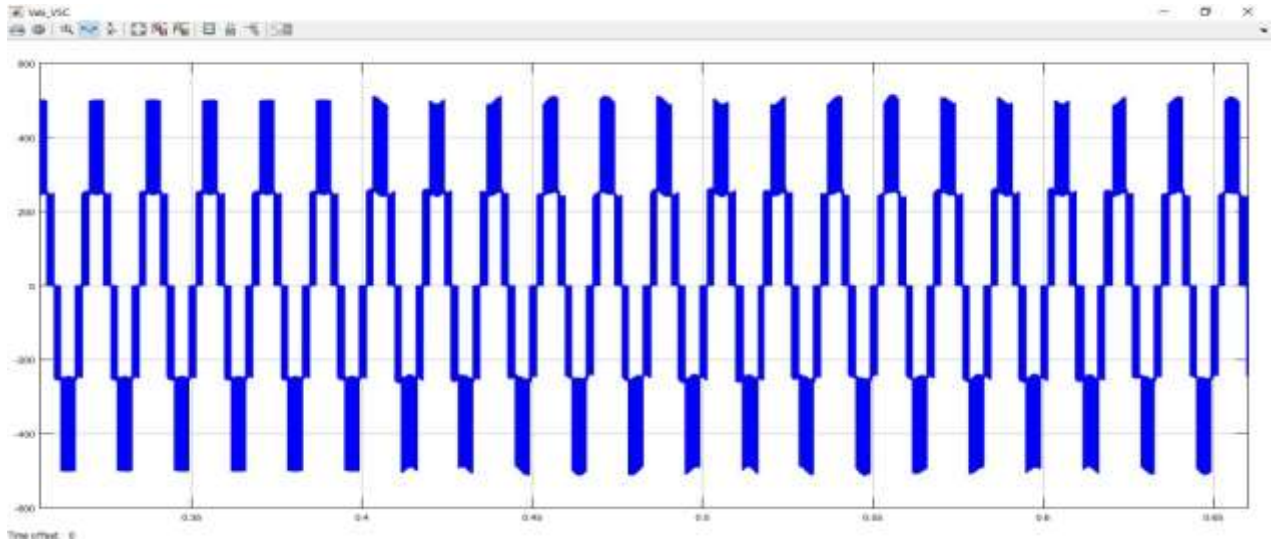


Fig: 5.36 Grid Converter Output Voltage

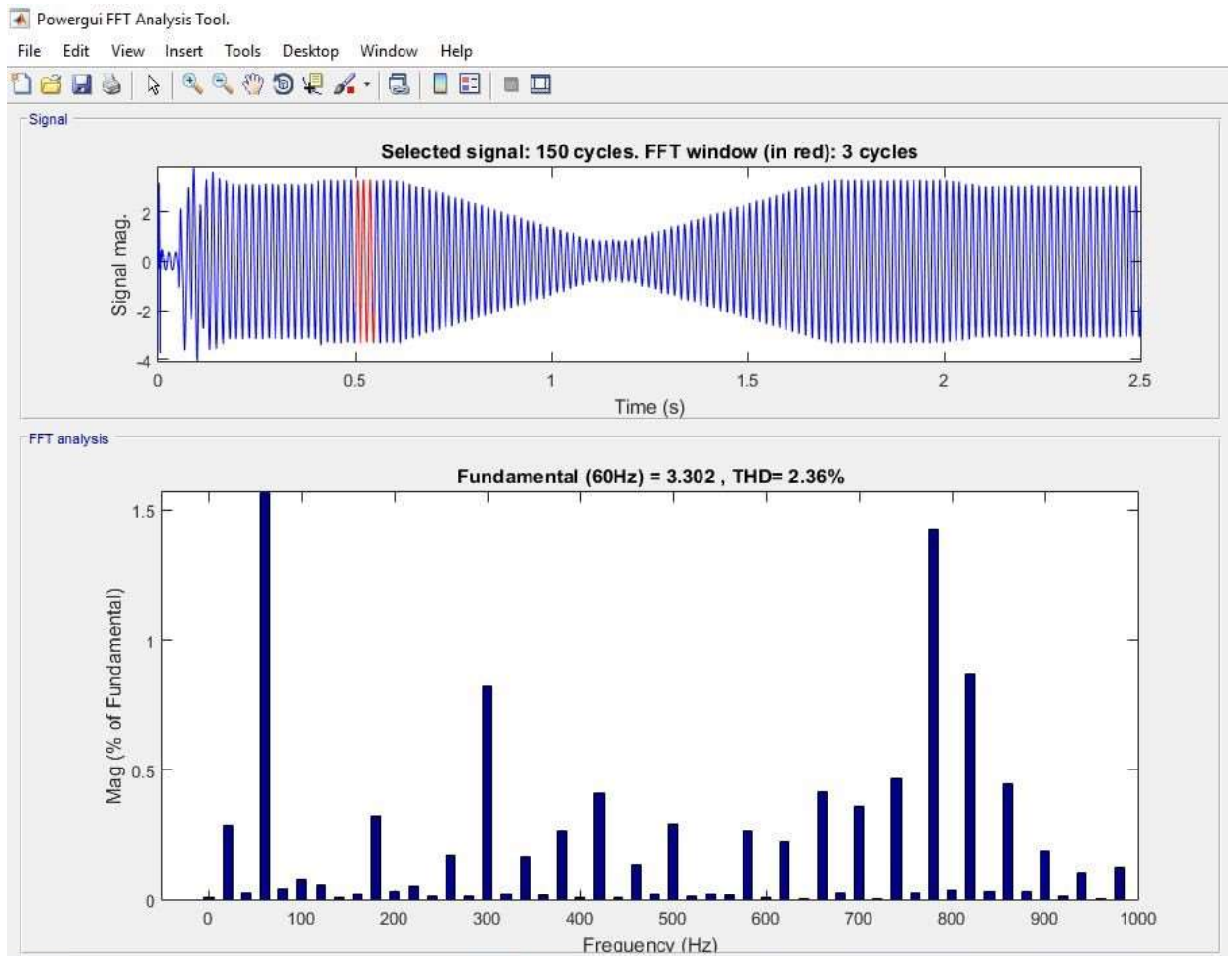


Fig: 5.37 THD analysis of GWO based Incremental Conductance MPPT Method.

The THD in this case is 2.36%.

Case: 2 Constant Irradiance and Variable Temperature

In the case 2 the maximum power is harnessed with GWO based Incremental conductance method. In this method the following results are obtained with constant Irradiance and Variable Temperature.

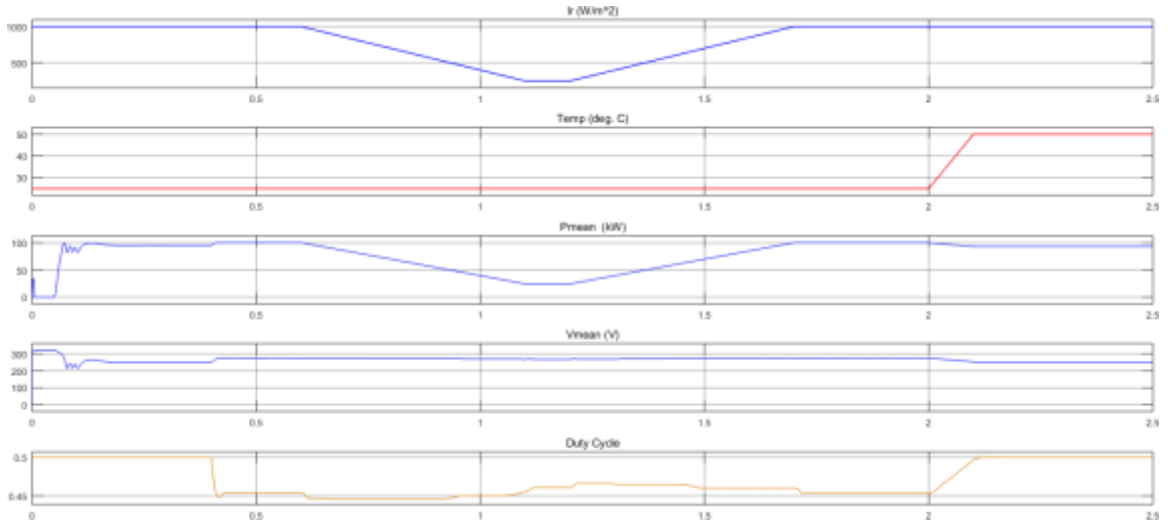


Fig: 5.38 Constant Irradiance, Variable Temperature. Mean Power, Mean Voltage, Duty cycle of proposed model

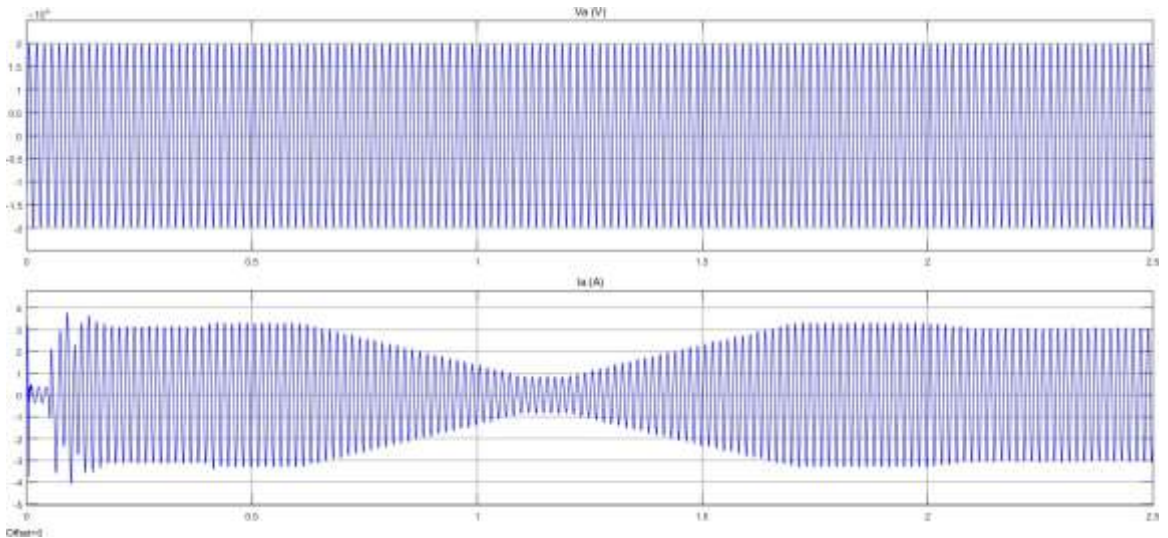


Fig: 5.39 Grid Voltage and Grid Current for the proposed model

The above figure shows that grid voltage is constant even though the Constant Irradiance and Variable Temperature. In this method oscillations are damped in the grid current with Grey Wolf Optimized (GWO) based Incremental conductance method.

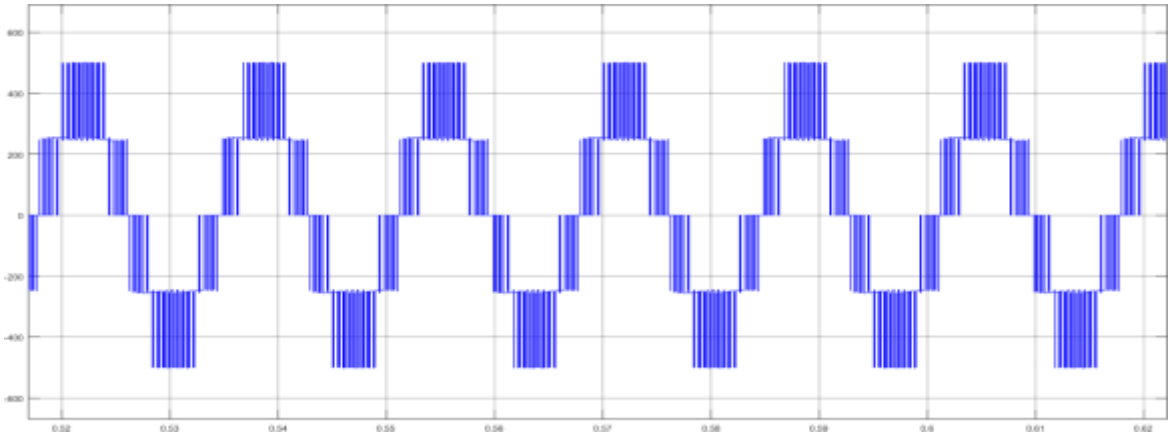


Fig: 5.40 Grid Converter Output Voltage

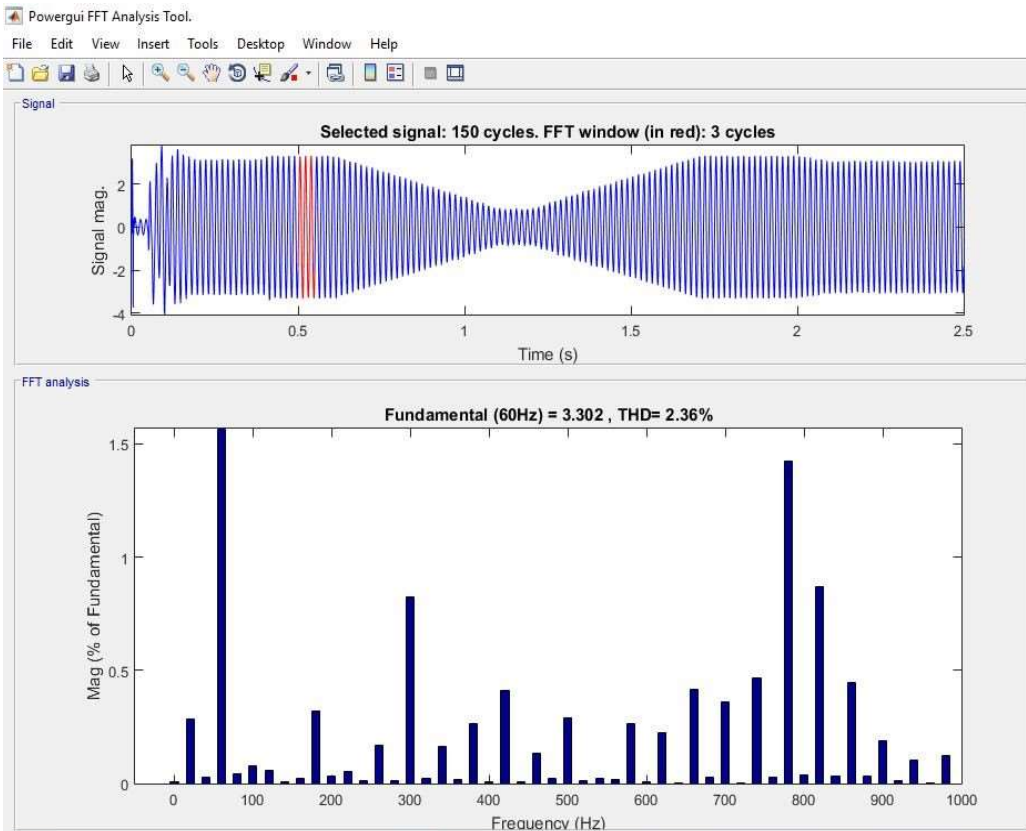


Fig: 5.41 THD analysis of GWO based Incremental Conductance MPPT Method.

Case: 3 Variable Irradiance and Constant Temperature

In the case 3 the maximum power is harnessed with GWO based Incremental conductance method. In this method the following results are obtained with Variable Irradiance and Constant Temperature.

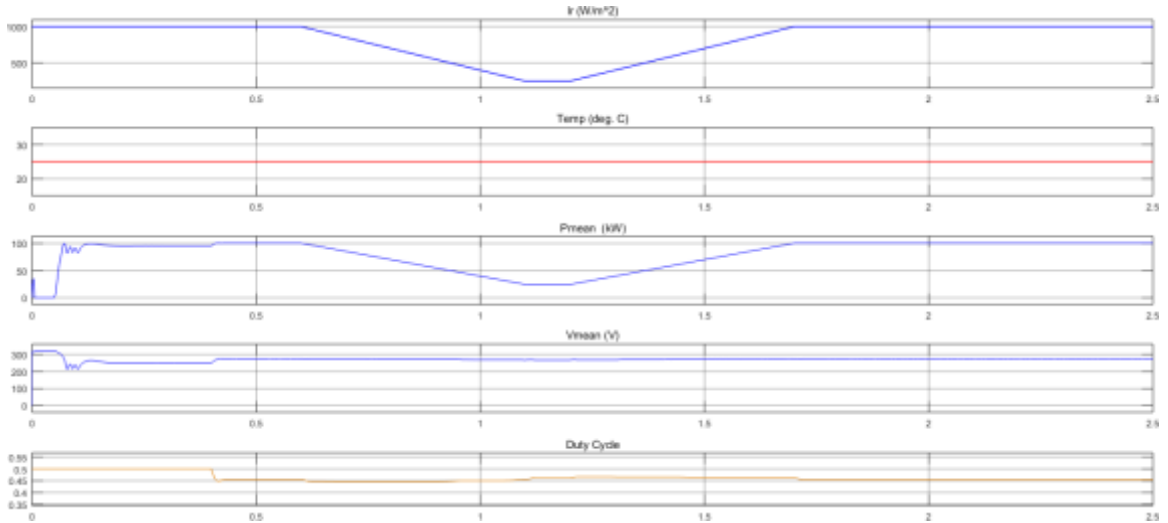


Fig: 5.42 Variable Irradiance, Constant Temperature. Mean Power, Mean Voltage, Duty cycle of proposed model

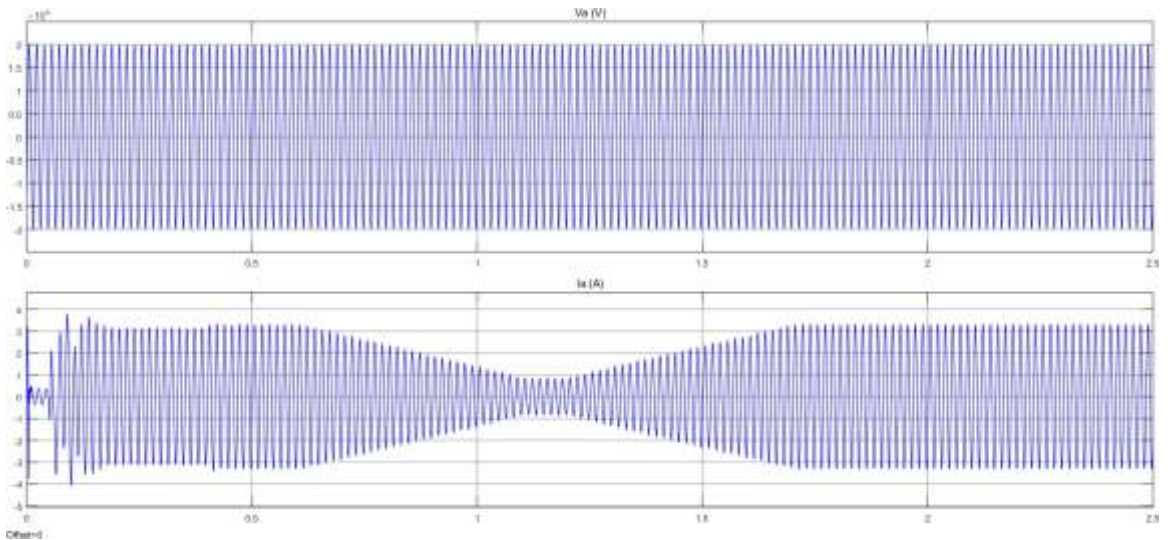


Fig: 5.43 Grid Voltage and Grid Current for the proposed model

The above figure shows that grid voltage is constant even though the variable Irradiance and Constant Temperature. In this method oscillations are damped in the grid current with Grey Wolf Optimized (GWO) based Incremental conductance method.

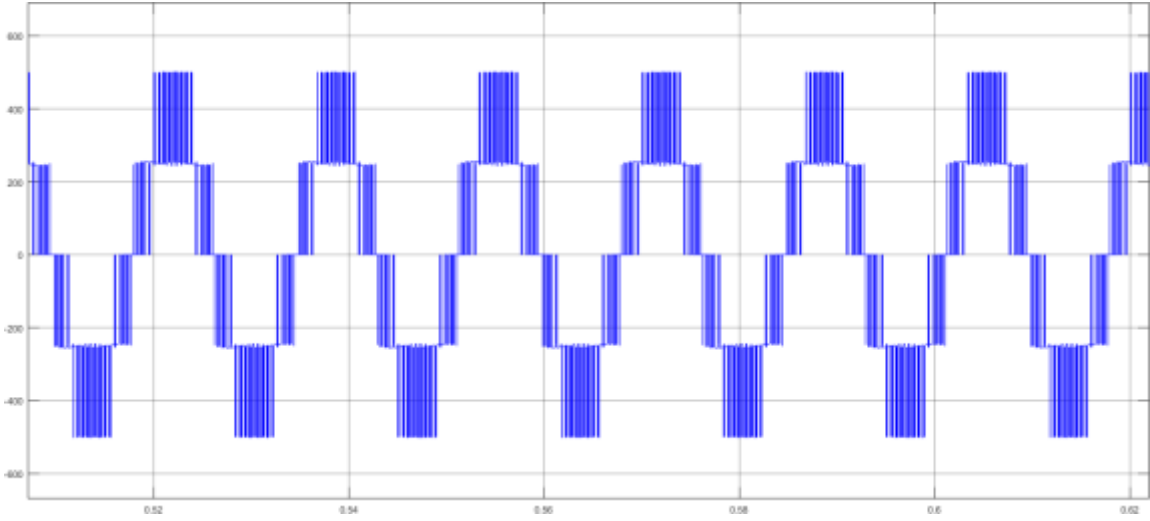


Fig: 5.44 Grid Converter Output Voltage

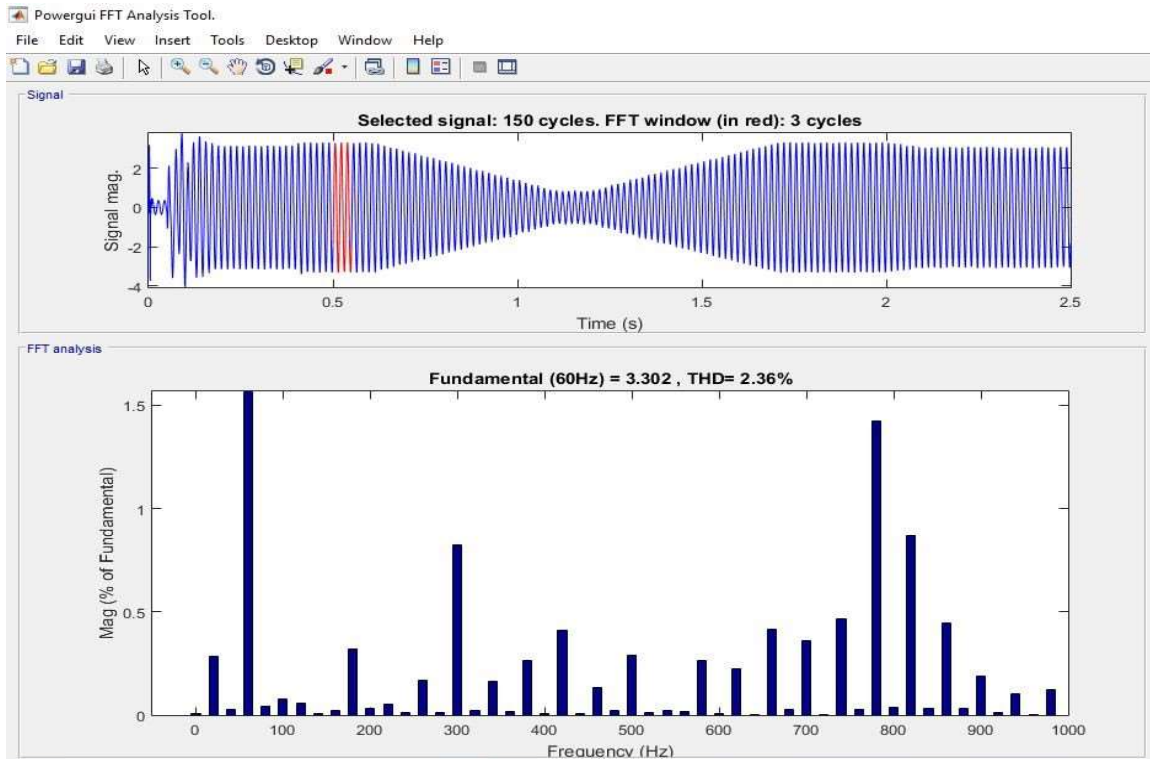


Fig: 5.45 THD analysis of GWO based Incremental Conductance MPPT Method.

Case: 4 Constant Irradiance and Constant Temperature

In the case 4 the maximum power is harnessed with GWO based Incremental conductance method. In this method the following results are obtained with constant Irradiance and Constant Temperature.

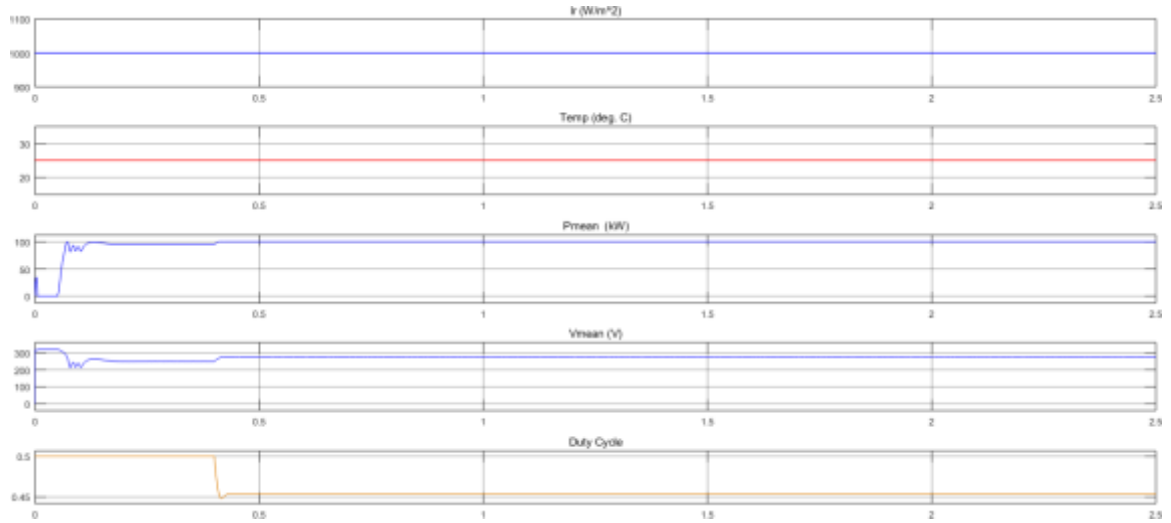


Fig: 5.46 Constant Irradiance, Constant Temperature. Mean Power, Mean Voltage, Duty cycle of proposed model

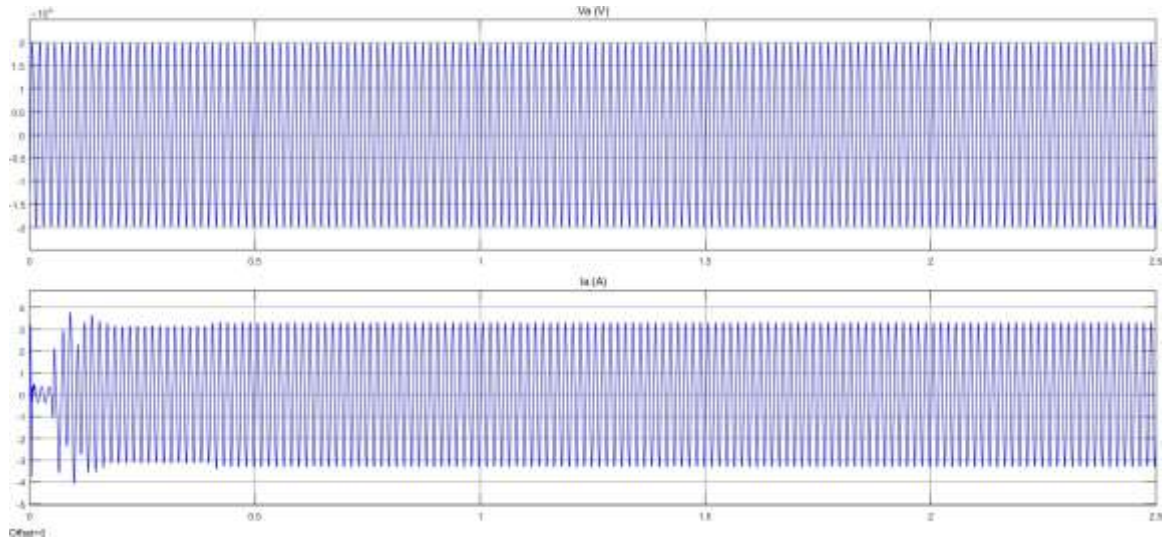


Fig: 5.47 Grid Voltage and Grid Current for the proposed model

The above figure shows that grid voltage is constant even though the Constant Irradiance and Constant Temperature. In this method oscillations are damped in the grid current with Grey Wolf Optimized (GWO) based Incremental conductance method.

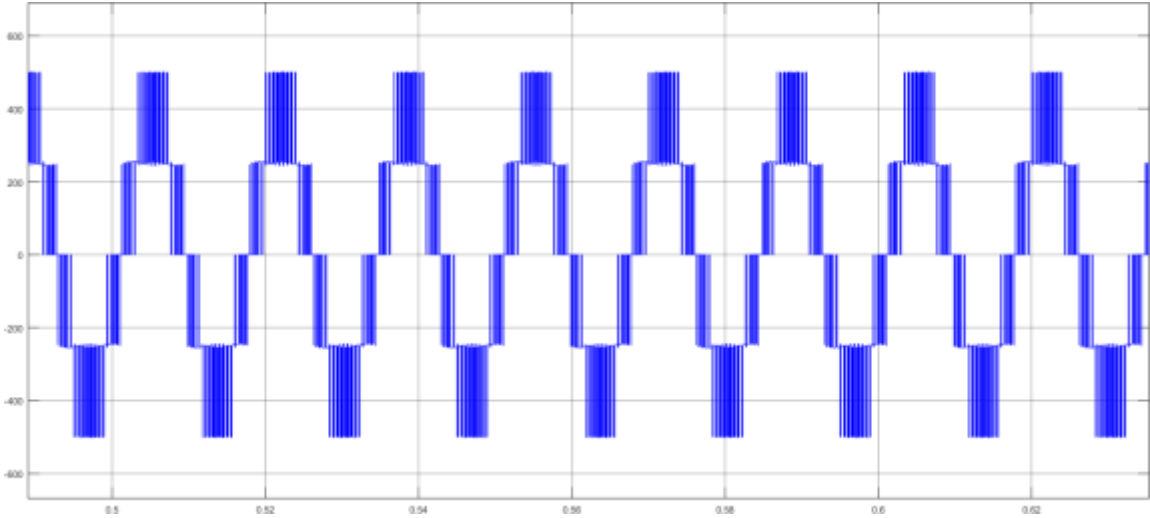


Fig: 5.48 Grid Converter Output Voltage

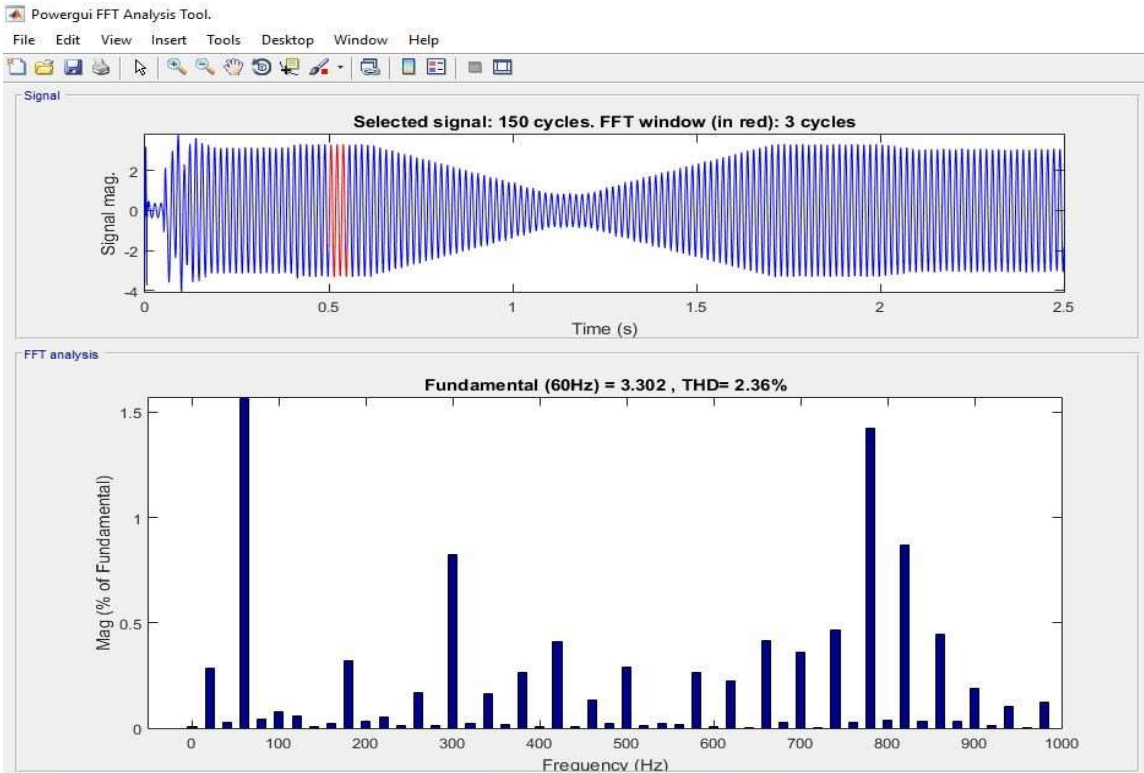


Fig: 5.49 THD analysis of GWO based Incremental Conductance MPPT Method

Table 2 Comparison

Case	Mode	THD
1	Incremental Conductance MPPT for Grid Tied PV System	12.92 %
2	PSO based Incremental Conductance MPPT for Grid Tied PV System	4.46 %
3	Proposed Scheme (GWO Based Incremental Conductance MPPT for Grid Tied PV System)	2.36%

From the above comparison it is clear that a mark reduction in THD from 12.92 % to 2.36% is observed and oscillations are clearly damped out with the proposed Grey Wolf Optimized (GWO) based Incremental conductance method. This validates the effectiveness of the Proposed GWO algorithm.

CHAPTER – 6

6 CONCLUSION&FUTURE SCOPE:

6.1 Conclusion

This work presents Grey Wolf Optimization based Incremental Conductance MPPT technique employed for grid tied PV system. The Proposed Technique is Compared with the PSO based Incremental Conductance MPPT technique and the simulation results shows that proposed method shows the better performance by the reduction of THD from 12.92 % to 2.36% and oscillations are clearly damped out. Form the results we can confine that the proposed GWO based Incremental Conductance MPPT technique is reliable. This research gives the optimal GWO based MPPT controller for the stability improvement. This work is carried out in the Standard Test conditions.

6.2 Future work

- 4.6.7 In the future, there is a scope for redesigning the MPPT controller with the Artificial Intelligent techniques.
- 4.6.8 In the future, the optimal MPPT techniques can be implemented with practical test conditions
- 4.6.9 Designing of intelligent controllers for the grid connected PV inverters.
- 4.6.10 Latest PV pannels Bi-facial PV Pannels can be tested under Practical Test conditions.

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INTERNATIONAL CONFERENCE

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