MODEL DESIGN OF PHOTOVOLTAIC POWER SYSTEM FOR THE OPTIMIZATION OF ELECTRIC TRANSMISSION IN BAGHDAD

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I certify that in my opinion the presented thesis that has been submitted by Aeshah Burhan ABBAS titled "MODEL DESIGN OF PHOTOVOLTAIC POWER SYSTEM FOR THE OPTIMIZATION OF ELECTRIC TRANSMISSION IN BAGHDAD" is fully adequate in scope and in quality as a thesis for the degree of Master of Science.

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Aeshah Burhan ABBAS

ABSTRACT

Master. Thesis

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Solar energy has become an area of investigation to improve efficiency in light of the rapid growth spurred by the sector's investments. Several factors influenced the increased need for electricity. These factors include rapid technological advances, the rising population, and the increased fuel cost. However, conventional electrical power is influenced significantly by alteration in solar irradiance and temperature, which in turn makes the electrical features non-linear and reduces the overall effectiveness. According to the world bank statistics, energy loss in Iraq was 51%, due to burglary, and illegal connection on main grid which is considered significantly high. To improve efficiency, scientists devised several methods for monitoring the maximum power point (MPP) and maximizing power output from solar panels under various situations. Most solar-powered systems incorporate maximum power point tracking (MPPT) technologies. This study used the method of Perturb and Observe (P&O) and Incremental Conductance (I&C) for the MPPT technology, and it is modelled in MATLAB/Simulink to optimize DC-DC boost converter duty cycle and power extraction. Simulated data could evaluate the photovoltaic system's efficiency under different irradiance conditions and variable temperature environments. The inverter converts over 99% of the power from the photovoltaic panels under typical and non-typical test conditions. The comparison between P&O and I&C illustrated that both techniques had the same power value. The I&C operates much closer to the Maximum power point than the P&O module. The reason is sensitivity to the sudden change in the irradiance. The I&C is not sensitive to the sudden change for the irradiance, while the application of P&O was sensitive to irradiation and temperature, and it showed a greater signal distortion than I&C method. Therefore, based on this study, we conclude that I&C is the most suitable module for the ever-changing climate in Iraq.

Key Word **:** Electric Transmission**,** MPPT, Optimization, Photovoltaic System, Solar energy.

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ÖZET

Yüksek Lisans Tezi

BAĞDAT'TA ELEKTRİK İLETİMİNİN OPTİMİZASYONU İÇİN FOTOVOLTAİK GÜÇ SİSTEMİNİN MODEL TASARIMI

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Güneş enerjisi, sektördeki yatırımların getirdiği hızlı büyüme ışığında verimliliği artırmak için bir araştırma alanı haline geldi. Elektrik ihtiyacının artmasında çeşitli faktörler etkili oldu. Bu faktörler arasında hızlı teknolojik gelişmeler, artan nüfus ve artan yakıt maliyeti sayılabilir. Bununla birlikte, geleneksel elektrik gücü, güneş ışıması ve sıcaklıktaki değişiklikten önemli ölçüde etkilenir, bu da elektriksel özellikleri doğrusal olmayan hale getirir ve genel etkinliği azaltır. Dünya bankası istatistiklerine göre, Irak'ta hırsızlık ve önemli ölçüde yüksek kabul edilen ana şebekeye kaçak bağlantı nedeniyle enerji kaybı %51 olmuştur. Verimliliği artırmak için bilim adamları, maksimum güç noktasını (MPP) izlemek ve çeşitli durumlarda güneş panellerinden güç çıkışını en üst düzeye çıkarmak için çeşitli yöntemler geliştirdiler. Güneş enerjili sistemlerin çoğu, maksimum güç noktası izleme (MPPT) teknolojilerini içerir. Bu çalışma, MPPT teknolojisi için Perturb and Observe (P&O) ve Artımlı İletkenlik (I&C) yöntemini kullandı ve DC-DC boost dönüştürücü görev döngüsünü ve güç çıkışını optimize etmek için MATLAB/Simulink'te modellendi. Simüle edilmiş veriler, farklı ışınım koşulları ve değişken sıcaklık ortamları altında fotovoltaik sistemin verimliliğini değerlendirebilir. Evirici, tipik ve tipik olmayan test koşullarında fotovoltaik panellerden gelen gücün %99'undan fazlasını dönüştürür. P&O ve I&C arasındaki karşılaştırma, her iki tekniğin de aynı güç değerine sahip olduğunu gösterdi. I&C, Maksimum güç noktasına P&O modülünden çok daha yakın çalışır. Nedeni ışınımdaki ani değişime karşı hassasiyettir. I&C, ışınımdaki ani değişime duyarlı değilken, P&O uygulaması ışınım ve sıcaklığa duyarlıydı ve I&C yönteminden daha büyük bir sinyal bozulması gösterdi. Bu nedenle, bu çalışmaya dayanarak, Irak'ta sürekli değişen iklim için en uygun modülün I&C olduğu sonucuna vardık.

Anahtar Sözcükler : Elektrik İletimi, MPPT, Optimizasyon, Fotovoltaik Sistem, Güneş enerjisi.

Bilim Kodu : 90513

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SYMBOLS AND ABBREVITIONS INDEX

SYMBOLS

ω_0 : Fundamental of the power frequency

P : Active power

Q : Reactive Power

R : Resistance load

L : Inductance

C : Capacitance

V : Voltage

I : Current

ABBREVITIONS

MOE : Ministry of electricity

IEA : International energy agency

kVA : Kilo volt ampere

kW : Kilo watt

I&C : Incremental Conductance

P&O : Perturb and Observe

GHGs : Green House Gases

THD : Total Harmonics Distortion

HFO : Heavy Fuel Oil

IEC : International Electrotechnical Commission

PV : Photovoltaic

PWM : Pulse Width Modulation

GW : Giga Watt

SVC : Static Var Compensator

MV	: Medium Voltage
LV	: Low Voltage
MPPT	: Maximum Power Point Tracing
MPP	: Maximum Power Point
GE	: General Electric
IGC	: Iraq Generation Capacity
FLC	: fuzzy logic control
PSO	: Particle Swarm Optimization
AVR	: Automatic Voltage Regulator
RES	: Renewable Energy Sources
RE	: Renewable Energy
UNEP	: United Nations Environmental Programme
MOSFET	: metal–oxide–semiconductor field-effect transistor
IGBT	: insulated-gate bipolar transistor
MCDM	: multiple-criteria decision-making
AHP	: analytic hierarchy process
GIS	: Geographical Information System
PVPS	: Photovoltaic Power Systems Program
MDP	: Main Distribution Panel

PART 1

INTRODUCTION

1.1. INTRODUCTION

The need for electricity is rising quickly due to industrialization and modernization. It is required to enhance the generation capacity to fulfil the increased demand for power. The world uses conventional energy sources based on fossil fuels to create electricity, but they have adverse environmental effects, such as increased pollution and climate change. Consequently, alternative power sources are utilized to meet the growing energy demand with minimal ecological impact [1]. Considering the limited availability of fossil fuels and their excellent environmental friendliness, Renewable Energy (RE) sources are gaining popularity nowadays [2]. Renewable Energy Sources (RES) provide electricity from renewable natural resources. These include solar, wind, biogas, geothermal, micro-hydro, and tidal energy. The primary benefits of renewable energy sources are that they are abundant, pollution-free, and unlimited. They may be utilized for water and air heating and power generation [3].

Solar cells made of semiconductors [4] are exposed to sunlight to generate electricity. The degree of solar radiation and the temperature are the two most essential factors in determining its price [5,6]. Therefore, its electrical characteristics are almost non-linear. The constant non-linearity of its electrical characteristics lowers a solar configuration's performance [7]. Numerous techniques have been created to track the MPP point regarding the maximum power that could be obtained with panels considering the changes in weather climates; this is referred to as (MPPT) [8]. This was done to combat the limited performance of the system and the impact of altering the intensity of temperature and radiation on them. One example of an algorithm designed for use in MPPT technology is the fuzzy logic control (FLC) algorithm, which is described as "powerful and simple" [9]. It showed less loss in tracking the

MPP point in various measurement conditions and compares simulation outcomes with the results of utilizing the techniques of conventional perturb and observe (P&O) [10].

1.2. RESEARCH BACKGROUND

Recent years have seen an increase in energy consumption in Iraq due to fast population expansion, industrialization, and improved living standards. The 1991 Gulf War destroyed about 90% of the generation and transmission facilities, and it has been impossible to fully restore the devastated systems since then [11]. Despite this, the government restored only 50% of the networks. The Iraqi electricity sector is still unable to create and supply adequate power in the post-war period (2003 to 2023) because of a loss of control regarding power transmission and supply. In other words, the power industry could not supply enough electricity to meet the needs of households, businesses, and industries. Since 2003, electricity demand has skyrocketed due to the failure to address this problem. Sabotage, theft, military measures, and corruption have all contributed to the escalation of the crisis. Iraq's power outage costs the country between $3 and $4 billion annually [12]. Economic growth is adversely affected by a lack of electricity supply, which in turn has a detrimental impact on the lives of citizens. Over 90% of Iraqi families supplement the public power supply with expensive private auto-generators, which are inadequate and rely on gasoline and diesel, according to multiple reports [13].

Furthermore, more than two-thirds of Iraqi homes rely on self-generators as their primary source of electricity. Approximately 60,000 to 85,000 individual units were in use, with needed capacity about 8,000 MW [14]. Electricity needs to be increased by 70% to meet demand after a slight power generation improvement [15]. Due to the expansion of the country's residential and industrial markets, Iraq's electrical consumption has increased. As a result of the decreased price of household equipment, particularly air conditioners and heaters in the summer and winter, energy production has fallen short of demand [13]. Due to these challenges, the rate of electrical unreliability in Iraq is rising.

In recent times, a growing number of developing nations have been exploring alternative sources of energy for the purpose of generating electricity. Among these alternatives, solar energy has emerged as the most widely adopted form of energy [16]. Solar energy is promising worldwide and contamination-free [17]. However, solar irradiance and temperature affect the utilization of energy [18]. Numerous initiatives developed models and techniques for greater advantage of solar energy [19]. Moreover, studies are adopting new methods and techniques for the optimal use of solar energy progressively.

1.3. PROBLEM STATEMENT

Because of the excessive need for electricity in Iraq, the electricity demand is escalating [20]. The government suffered from a lack of control over electric power usage [21]. This weakness extended to free consumption by the users. Iraq's energy problem is severe compared to its neighbors, owing to its limited dependence on natural resources, unstable political situation, and financial crisis. Moreover, Iraq is importing some of its electricity from neighboring countries [22]. Iran is a crucial supplier for Iraq's electrical industry. About 5% of Iraq's electricity in 2019 came from Iran, where 23% of the country's natural gas was used in electrical generation [23]. These obstacles have prompted the development of alternative energy sources to ensure a sustainable, secure, and cost-effective supply while simultaneously lowering greenhouse gases (GHGs) emissions. In this context, one of the most effective ways to accomplish these goals is for the country to strengthen its dependence on renewable resources [24] In Iraq, numerous studies discussed the theoretical implementation of Photovoltaic systems (PV) as a sustainable power alternatives for the individual use, but these studies witnessed a gap in applying PV power in the transmission system. According to Iraq's numerous financial obligations, the Iraqi government has realized it cannot handle all the financial responsibilities of the development of the electricity sector [25]. Consequently, the government of Iraq and united nations programs encouraged conducting reformation initiatives in the industry to promote electric sector [26]. These issues are the primary focal points of the Iraqi government. As such, the implementation of these modifications has the potential to enhance the financial efficacy and operational efficiency of the system. Aiming to involve and promote the private sector as an active participant in the electricity market should be vital to any reforms implemented. However, the implementation of these modifications in Iraq faces several issues. Some me of these issues are as follows:

1. The capabilities of the existing conventional power generation systems in Iraq are limited, and the power generation stations are insufficient. Moreover, the current components of the transmission and distribution networks in Iraq are overworked and they are inadequate systems that cannot keep up with the increasing power demand.
2. Most studies discussed the development of the PV system primarily for power distribution purposes. However, it is crucial to introduce upgraded methods in the power transmission network of Iraq. Iraq climate experienced aggressive weather conditions high temperature and variable irradiation.

1.4. OBJECTIVES AND AIM OF STUDY

The study aims to develop a system for generating and transmitting electric power in Iraq by introducing modern technologies and renewable energy sources of power.

The study's objectives considered embedding renewable energy and creating a model for the optimal use of electric power in Iraq. Therefore, these objectives are listed below:

1. Integrate renewable energy sources into the existing conventional power generation system.

2. Develop a model to compare different PV algorithms for the benefit of photovoltaic power in Iraq.

1.5. SCOPE OF THE STUDY

This study proposed an improved MPPT for a photovoltaic power system for Baghdad City in Iraq. The introduced model tested using P&O and I&C techniques. These techniques experienced variable temperature and irradiation in the area of the study for the optimal outcomes.

1.6. LIMITATION OF THE STUDY

This study discusses the development of electric power generation and transmission systems for government sectors, residential areas, hospitals, and schools, which are managed and operated by the Iraqi Ministry of Electricity, except for private-sector sites.

1.7. THESIS OVERVIEW

The thesis is structured into five chapters. The initial chapter serves as a preface and outlines the research background, problem, objectives, and methodology utilized in this study. Chapter two provides an overview of the existing literature pertaining to the subject matter. Chapter 3 presents an in-depth analysis of the research data and modeling purposes. Chapter 4 presents an analysis of the results of the simulation. The fifth section of the thesis provides a comprehensive summary of the primary conclusion and potential avenues for future research.

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PART 2

PHOTOVOLTAIC POWER SYSTEMS

2.1. INTRODUCTION

Photovoltaic (PV) power has expanded fast across the world's developed countries. As per the European Commission's "PV status report 2012," the growing need for PV systems is attributed to the passage of new rules encouraging its use [27]. Energy consumption has increased quickly, providing vital energy for transportation, homes, and factories. It was further improved with the advent of nuclear energy, which benefitted mankind by allowing for the operation of massive plants to generate power. However, this energy is still restricted in use due to its inherent dangers and high cost. The globe is rapidly transforming the way a renewable energy revolution. Renewable or sustainable power is derived from renewable resources (natural sources) such as light, wind, rainfall, tides, waves, and geothermal energy. Renewables have two primary advantages: the first is that they are naturally replenished relatively quickly, and the second is that they are an environmentally benign energy source that does not pollute the environment by generating hazardous gases. The globe relies on renewable energy sources for a variety of reasons. The first is that fossil fuel energy is rapidly depleting. According to a study, these resources will be depleted by the end of this century as a result of the alarms generated by global fossil fuel consumption [28]. The second significant issue is the environmental impact of non-renewable energy resources, which are highly polluting and destructive to the ecosystem.

However, renewable energy technologies continue to draw significantly more investment dollars than fossil fuel power plants. $310 billion was reported to have been committed to new renewable energy projects, compared to around $145 billion committed to fossil fuel-fired generation capacity, including nuclear power capacity [29]. There are two primary purposes why Iraq was selected for this study: there has been no PV energy plants access to the power system. Consequently, we can contrast the modelled power grid operations following the deployment of a Photovoltaic system to the existing state and assess the impact of the Photovoltaic system installation. Secondly, because Iraq's electric power system focuses on a single grid that serves all urban regions and the majority of rural areas, an effect study of the Photovoltaic system is straightforward.

2.2. IRAQ CURRENT CONDITION

Hydro, diesel, steam, and gas turbine facilities meet Iraq's energy needs. Figure 2.1 illustrate the operational capacity and energy production in Iraq for 2019. Clearly, the country depended on gas turbine and steam power plants. They account for around 61% and 28% of the installed capacity, respectively [30].

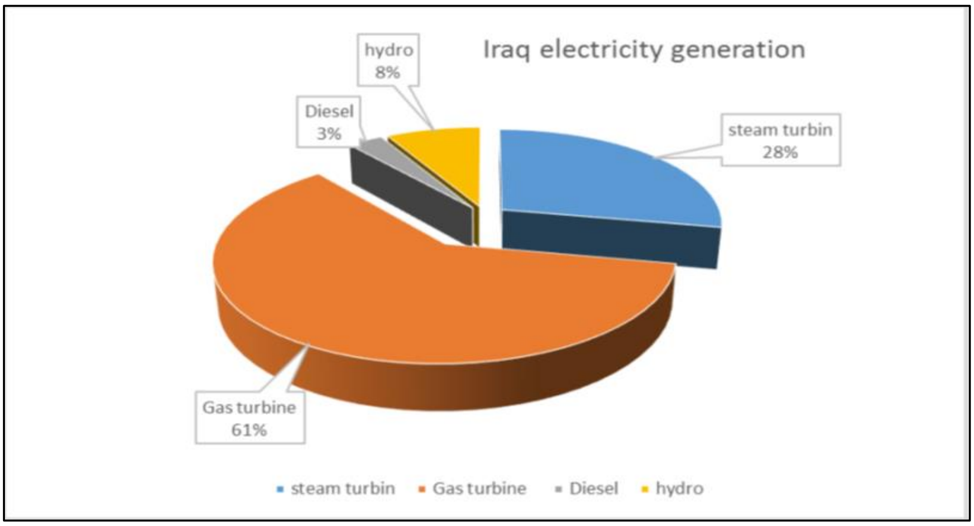

Figure 2.1. Electricity generation in Iraq

Iraq's grid system reached a maximum generation capacity was (19.3 GW) in 2019 and about (18.6 GW) in August 2020 [14]. Peak demand load of about (26 GW) in 2019, to an estimated peak demand of (~27 GW) in 2020. Nearly all (more than 97%) of Iraq’s electricity generation is from fossil and natural gas.

Table 2.1. Transmission and distribution in Iraq

Type	2015	2017	Plan for 2022
400 kV substations	29	52	82
400 kV overhead lines	5100 Km	6000 Km	9200 Km
132 kV substations	219	283	391
132 kV overhead lines	12600 Km	16000 Km	20000 Km

2.3. PHOTOVOLTAIC SYSTEM

Photovoltaics use sunlight to generate electricity in the form of AC power. To ensure decreased consumption and dependence on sources of energy that are not renewable, it is crucial to incorporate the generated electricity generated by alternating current into electrical power when a PV generation facility has been built [31]. Large-scale renewable energy from PV installations can be added to the power grid through solar-grid integration. Producing solar components, installing and operating the system, and other factors are all important to think about while employing this method [32]. Additionally, solar energy must be well integrated into the power grid, which must fully understand the transmission line's influence at various locations. Therefore, this study analyzes the existing solar-grid integration methodologies, the benefits and drawbacks of solar electricity systems attached to the network, reduction mechanisms for negative effects, ideal PV system placement within the network, protective cooperation, and energy factor.

2.4. PHOTOVOLTAIC CONFIGURATION

In most cases, a PV system will be composed of many cells that will be assembled into a module. From then, a PV panel is constructed from interconnected modules. The collective term for these panels is a photovoltaic array. The purpose of connecting these components in either series or parallel is to increase the PV system's output power. PV setups are categorized by their inverter connection type. There are primarily four configurations for connecting inverters: centralized, string, multi-string, and AC module [33].

2.4.1. Centralized PV Configuration

A single inverter connects all PV arrays in a centralized PV arrangement. Typically, a series array of PV panels is linked to the inverter, which is subsequently parallelly attached to the inverter; see Figure 2.2. Due to the series and parallel connection, a high voltage is produced, eliminating the necessity for a secondary amplification procedure with this configuration. The downsides of a centralized PV system include PV panel mismatch, poor performance and stability and maximum DC connection voltage, string diode losses, and the inability to use (MPPT) [33].

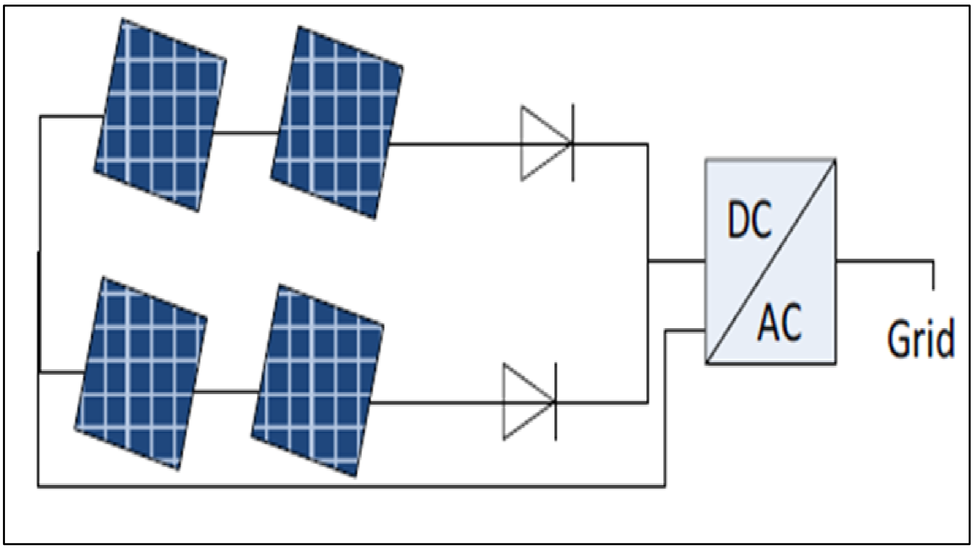

Figure 2.2. Centralized PV Configuration

2.4.2. Configuration of String

The string inverter depicted in Figure 2.3 is designed to counteract the drawbacks of centralized configurations. In the string structure, Photovoltaic modules are linked in series to an inverter, injecting the electricity produced into the network or the load. This arrangement can be made more efficient with the application of MPPT. Similar to the centralized module, diode loss does not arise. Due to the inverter's high voltage, (MOSFET) or (IGBT) can be utilized [33].

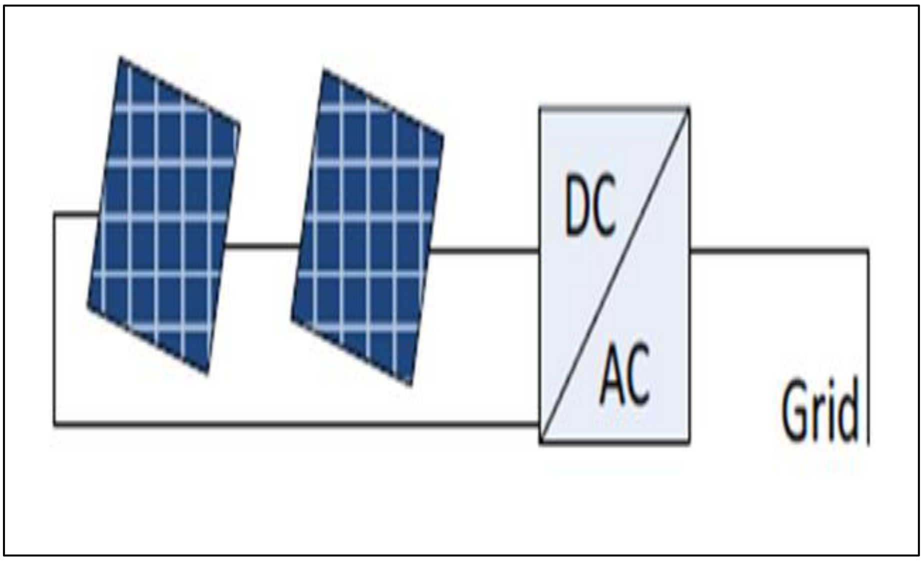

Figure 2.3: Configuration of String

2.4.3. Configuration of Multi-String

Figure 2.4 depicts a multi-string setup that is much more productive than the string setup but comes at a higher cost due to the MPPT's ability to be applied to each string. DC-DC converters make this possible, which has the added benefit of allowing you to join lines with varying power outputs and connecting types [33].

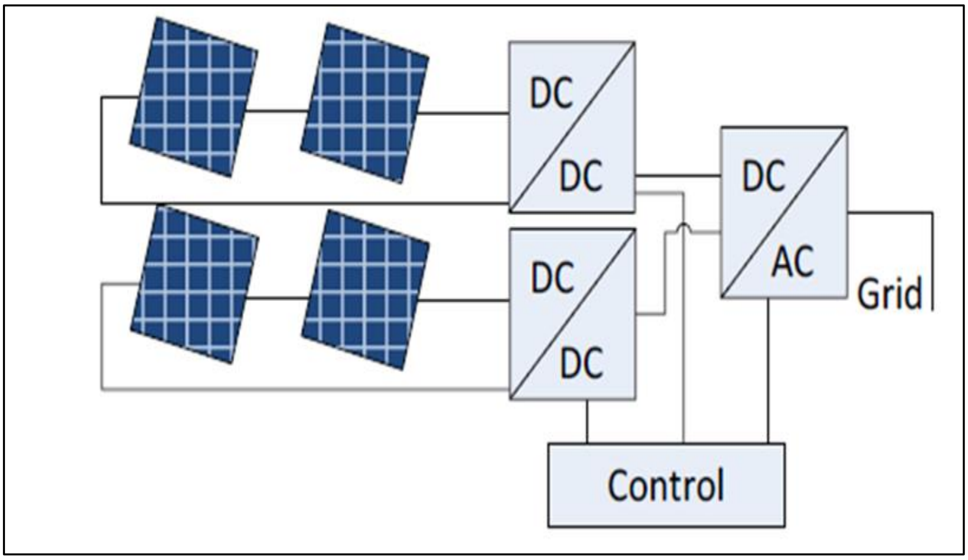

Figure 2.4: Configuration of Multi-string

2.4.4. Configuration of AC Module

The AC module, depicted in Figure 2.5, combines a photovoltaic cell (PV) and an inverter (inverter). Since each PV contains its own MPPT, the inefficiency caused by incompatibility between PVs, which plagued all preceding setups, is eliminated. The AC module's high price tag is understandable. Still, it's important to remember that incorporating it into a manufacturing plant at scale could lead to lower prices for the final product. This method is ideal when the PV cell or panel surface is vulnerable due to environmental factors, as it often is in domestic applications. This integrated module has a socket at its output that may be used to link to any device without needing a specialist or a person with technical proficiency [33].

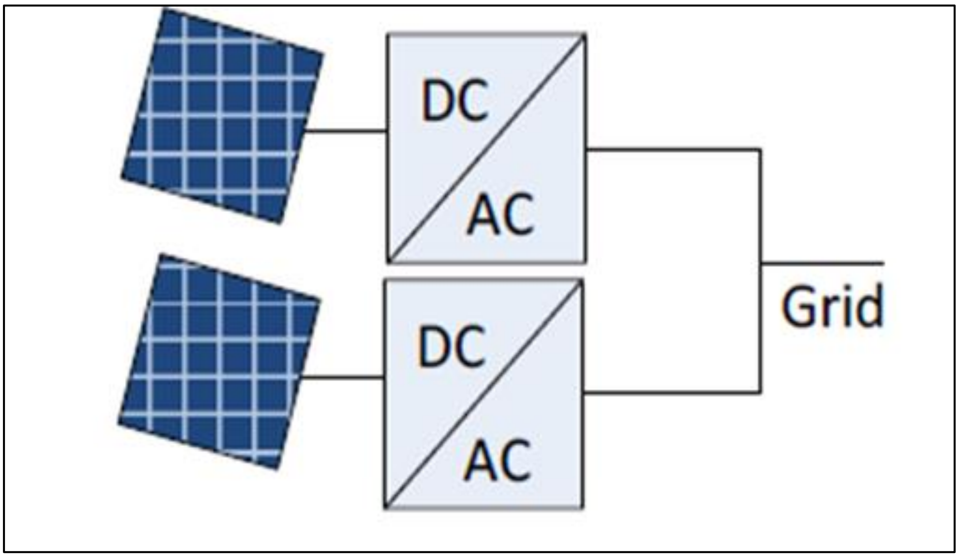

Figure 2.5: AC module configuration

2.5. PHOTOVOLTAIC PLANT COMPONENTS

Photovoltaic systems that link to the transmission grid are made up of numerous components, including an inverter, photovoltaic solar modules, meters, generator junction box, AC and DC cabling, and grid connection. Recent studies asserted that the yield of a solar system is mainly determined by the inverter's dependability and efficiency, as well as the photovoltaic module's quality, orientation, and connections

[34]. As with other forms of solar energy, an inverter is the most critical component of solar-grid systems. An inverter converts a direct current (DC) output to alternating current (AC), which the standard electrical equipment uses. Thus, inverters must maintain a consistent voltage and frequency regardless of the load and absorb or supply reactive power to reactive loads [32]. Additionally, inverters integrate solar and grid technologies to ensure maximum efficiency when power is fed into the transmission grid.

2.6. MAXIMUM POWER POINT (MPP)

Over the past years, there has been a significant increase in the utilization of renewable energy alternatives. One of these alternatives, photovoltaic energy, is cost-free and converts to electricity. The massive cost and poor conversion ratio of PV energy are two significant barriers to its application. A PV system's power generated is non-linear and dependent on temperature, irradiance, and weather. The electricity voltage (P-V) features of the PV are shown in Figure 2.6, which also clearly illustrates the non-linear relation between the voltage level and the power consumption. This figure also demonstrates that the PV only operates at one precise operational point, which results in optimal behaviour and maximum power output. To get the most power out of each PV array, (MPPT) was developed. The MPPT's use in the Photovoltaic system is depicted in Figure 2.6 [35].

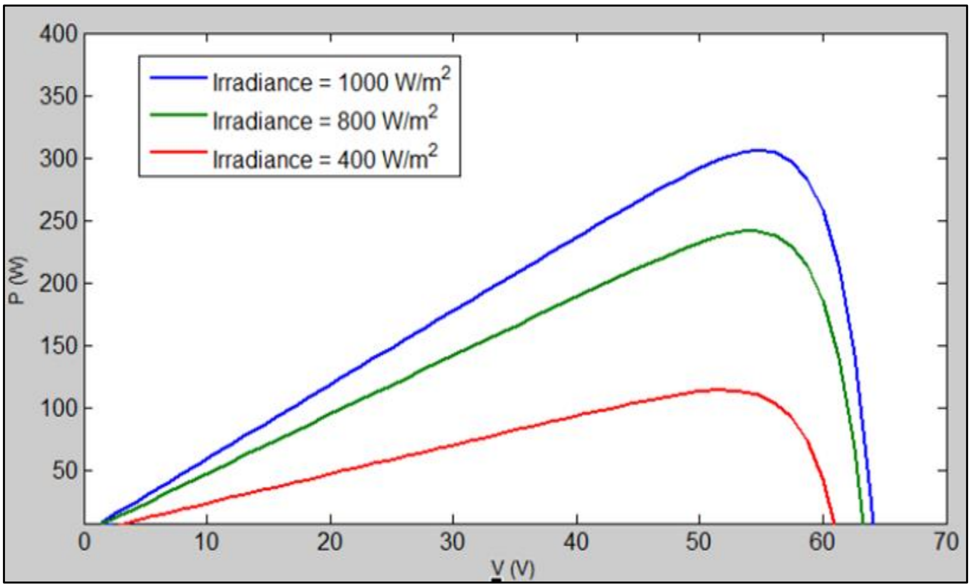

Figure 2.6: PV system features at varying irradiance

With its low energy conversion, MPPT has prompted researchers to investigate the (MPP) under various weather situations. The outcome of a photovoltaic panel varies with weather, which is self-explanatory. Figure 2.6 depicts a standard PV system's P–V features at various irradiation levels.

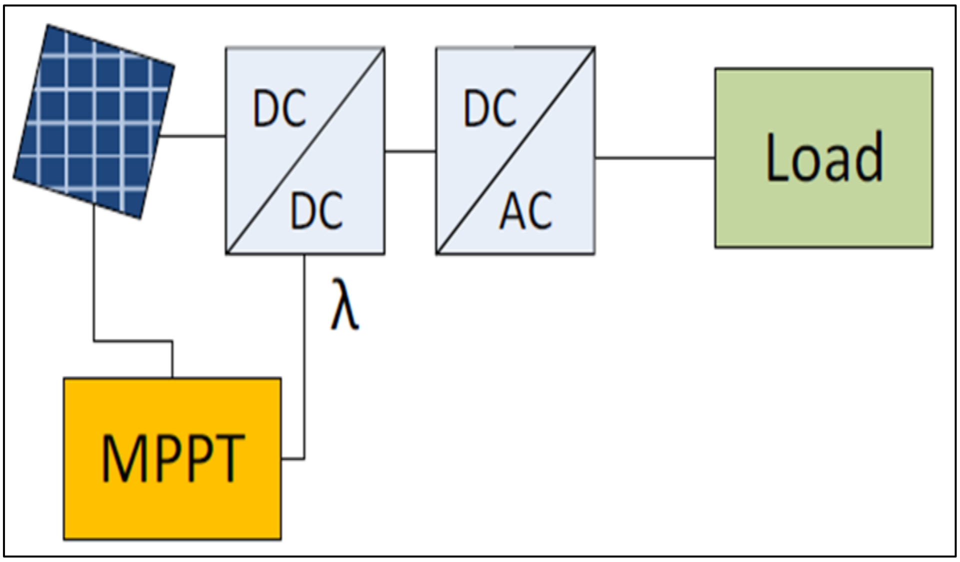

Figure 2.7: A schematic illustrating MPPT installation

Numerous techniques have been developed to monitor the MPP. These approaches can be categorized in various ways based on their complication, necessary observations, cost, and monitoring speed, among other things. Sometimes, the methodology employed might not be the most effective strategy for broad applications, whereas it might be the most effective technique for a particular application [36].

2.6.1. Perturb and Observe (P&O)

Most commonly, the (P&O) technique is utilized, which requires only the Voltages (V) and Current (I) to be measured [37]. By changing the voltage operating and computing the energy output at that point, the P&O algorithm can identify the MPP and compare it to the initial value. The tracking is heading in the right direction, and the perturbation process will proceed similarly if the new power value is more remarkable. Conversely, for example, if the power output at the operating point falls below the current voltage, the MPP will lag; therefore, the tracking mechanism must be inverted for the next disturbance [38]. The P&O procedure is depicted in Figure 2.8 [39].

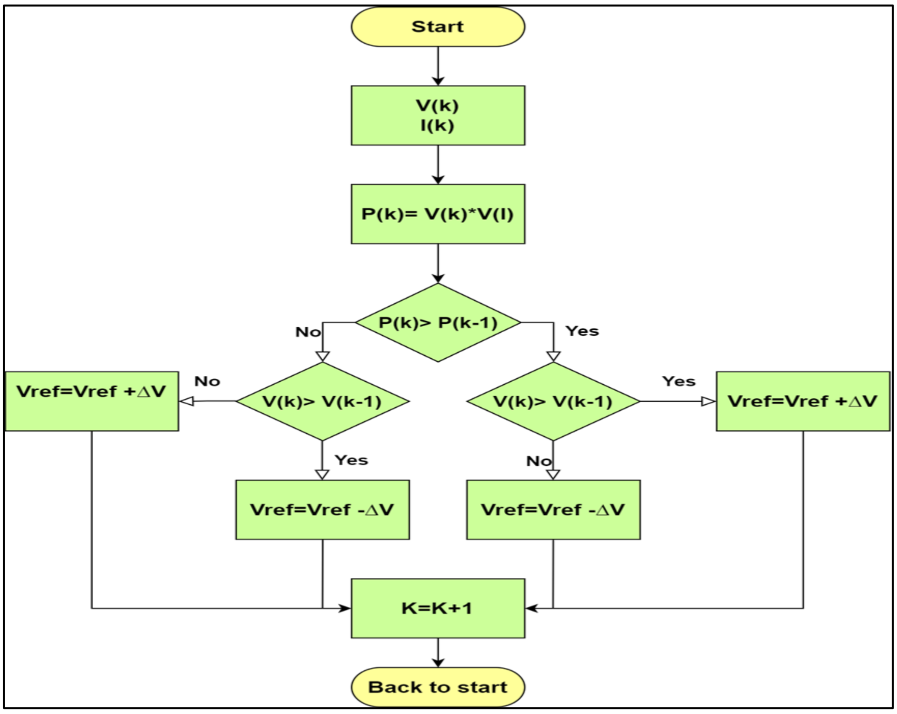

Figure 2.8: P&O algorithm

There are two main downsides to the perturb and observe strategy. At steady conditions, energy is wasted due to oscillation around the MPP [40]. However, minimizing energy losses due to fluctuation using a tiny perturbation value considerably slows the tracking progress. There are modified P&O strategies available to deal with the oscillation issue. In one study, researchers proposed a variable perturbation rate that would begin at a high value and gradually decline toward the MPP [41]. Two further investigations found evidence for varying values for the P&O-introduced perturbation [42]. The second drawback is the subpar tracking performance in unstable weather [43]. The algorithm cannot determine whether the increased output power is a result of the increased irradiation or the increased duty cycle.

2.6.2. Incremental Conductance

One of the most popular MPPT strategies is based on the observation that the PV system derivative relative to its voltage level is zero at the Maximum Power Point (MPP). It has been shown that the derivative is positives to the left of the MPP and negatives to the right [44,45], as given by:

$$\frac{dP}{dV} = 0, at\ MPP \tag{2.1}$$

$$\frac{dP}{dV} > 0, left\ of MPP \tag{2.2}$$

$$\frac{dP}{dV} < 0, right\ of\ MPP \tag{2.3}$$

Equation 2.4 can be used to simplify, solve, and apply Equations 2.1, 2.2, and 2.3.

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} = I + V\frac{\Delta I}{\Delta V} = 0 \tag{2.4}$$

If we start with Equation 2.4, we can rearrange Equations 2.1, 2.2, and 2.3 as follows:

$$\frac{\Delta I}{\Delta V} = -\frac{I}{V}\ , at\ MPP \tag{2.5}$$

$$\frac{\Delta I}{\Delta V} > -\frac{I}{V}\ , left\ 0fMPP \tag{2.6}$$

$$\frac{\Delta I}{\Delta V} < -\frac{I}{V}\ , right\ of\ MPP \tag{2.7}$$

Equations (2.5), (2.6) and (2.7), respectively, indicate that the incremental conductance can follow the MPP given the current and power of the PV at any given moment (2.7). The algorithm self-adjusts by determining the duty cycle of the power converter, which in turn regulates the array's voltage by raising or reducing it as necessary until the MPP is met. Upon delivery to the MPP, the tracking procedure terminates, and the array continues operating normally until a change in current is detected, which indicates that atmospheric conditions have shifted. Once the MPP is again reached, tracking begins again.

It is up to the user to set the increment size. While precise monitoring is possible with a smaller interval, it requires more time. However, a wider interval results in faster tracking, albeit at the expense of precision close to the MPP and the additional difficulty of oscillation[45]. It can be avoided by splitting the tracking process into two phases. The first tracking stage uses a unique approach to assign the MPP-related operation, whereas stage two is the same as in the first. Progressive conductance with smaller increments for precision at the MPP [46,47].

For the incremental conductance technique to work, you will need two sensors to simultaneously detect the voltage and current. A Digital Signal Processing (DSP) and microcontroller, which can store current and historical results and make the right call based on the methodology in Figure 2.9, can be used to implement this tracking approach [48].

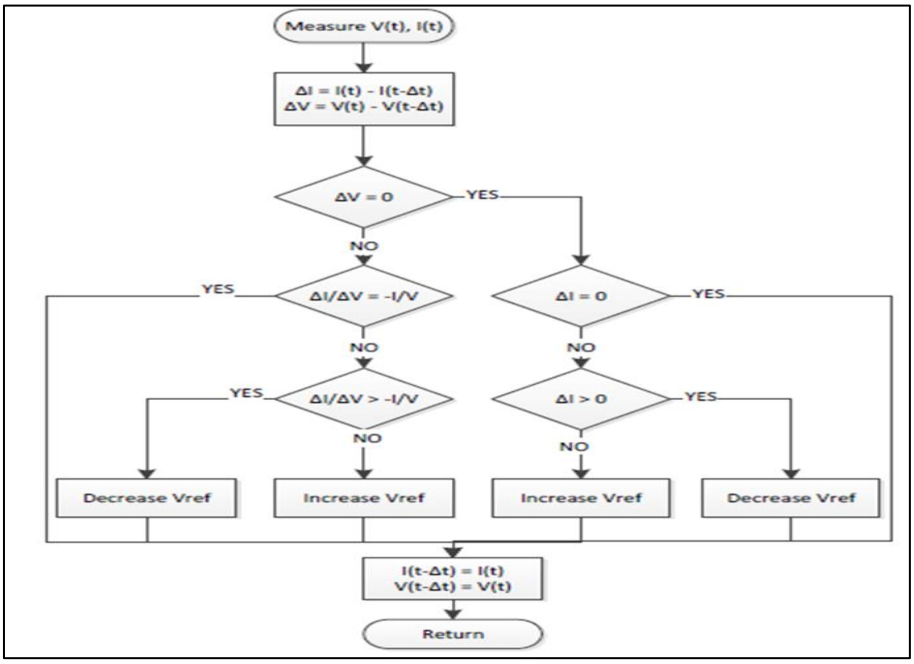

Figure 2.9: Incremental Conductance Algorithm Flow Diagram

2.6.3. Short-Circuit Currents in Fractions

It is based on the observation that the I_{mpp} and I_{sc} of PVs have a nearly linear connection, even when the weather is variable [49,50]. The following equation characterizes this connection:

$$I_{mpp} \approx K_1 I_{sc} \tag{2.8}$$

where K_1 is a value that can be set between 0.78 and 0.92 to accommodate different PV characteristics [45]. To keep the power flowing to the MPP regardless of the weather, an I_{sc}meter is used to shorten the Photovoltaic array's circuit as needed. Because of this, the system's total cost and number of moving parts increases, and power is lost every time the switch is used to short the circuit. Using the converter switch to determine I_{sc} , it is one method provided for getting around these problems [51]. Because (2.8) is approximate, the PV system will never function at the MPP, which is a drawback in addition to the higher upfront cost. By adjusting the rate of K_1according to the current weather circumstances, [52] came up with a strategy to increase the reliability of the I_{mpp} value. Despite the above-mentioned drawbacks, the fractional short-circuit current approach continues to be useful due to its simplicity and low cost of implementation [45].

2.6.4. Open-Circuit Voltage in Fractions

Whatever the weather, there is a nearly linear relationship between the PVs' V_{mpp} and V_{oc}. Due to this realization, a technique based on the fractional open-circuit voltage has emerged [49,50,53]. More specifically, the following formula describes the connection between V_{mpp} and V_{oc}:

$$V_{mpp} \approx K_2 V_{oc} \tag{2.9}$$

where K_2 is a value that differs based on the specifics of the PV and the ambient temperature and humidity. According to[45], K_2 is between 0.71 and 0.78, and the result is only between 0.7 and 0.8. [54].

The biggest problem with this method is the energy loss that occurs since electricity must be cut frequently to measure V_{oc} [54]. An option is to employ many Solar arrays of the same type and in the same environmental circumstances so that V_{oc}may be measured relative to a known value [49]. The approach also eliminates the need to measure V_{oc} because the voltage in the vicinity of the diode is typically 75% of that value [55]. When using the fractions open-circuit method, the V_{oc} is modified using equation (2.9), but since the V_{mpp} is only approximative; the maximum power point is rarely if ever, reached. However, this approach is appealing due to its ease of use and low cost.

2.6.5. Fuzzy Logic Technique

With the advent of microcontrollers in the Photovoltaic, fuzzy logic controllers entered the realm of PV technologies as a novel artificial intelligence Maximum Power Point Tracking (MPPT) technique [56]. This approach is helpful because it can handle non-linear equations and work with imperfect inputs. Error (E) and the percentage of error over time (E) are the relevant metrics for this technique. Yet the converter's control signal is modified at the output [56]. Fuzzification, rule-based database lookup, and defuzzification are the three phases of operation for the fuzzy logic approach. The inputs undergo fuzzification, which uses a membership function to transform numerical values into linguistic variables. The user can scale these factors across five distinct levels (as in Figure 2.10). They range from highly negative (-100) to extremely positive (+100), with 'zero' ('Z') in the middle. Several researchers have adapted a seven-level membership function (output and input) to improve accuracy [56].

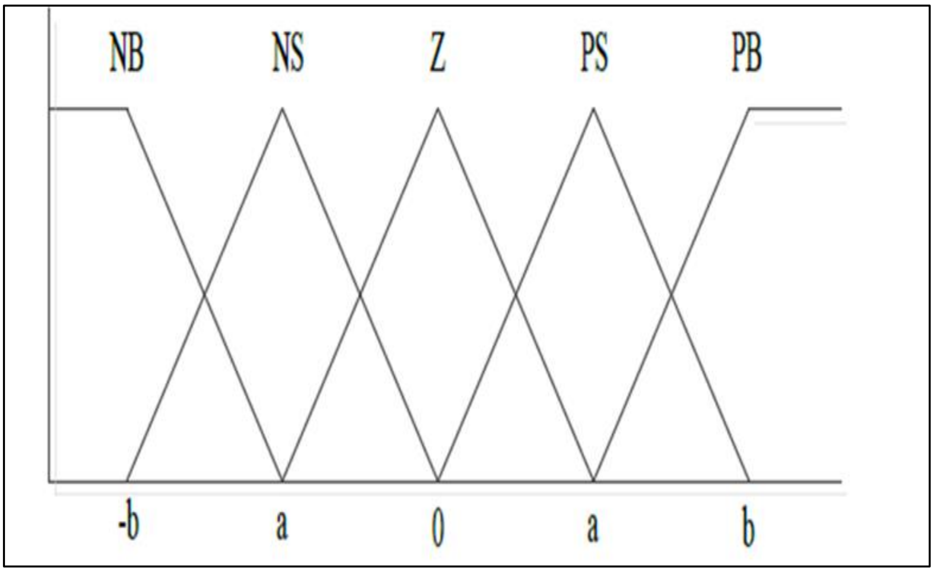

Figure 2.10: Fuzzy Logic Controller Membership Function

Following are altered formulae based on the observation that at MPP dp/dv = 0. [57]

$$E(n) = \frac{P(n)-P(n-1)}{V(n)-V(n-1)} \quad (2.10)$$

$$\Delta E(n) = E(n) - E(n-1) \quad (2.11)$$

After computation, E and ΔE are transformed into linguistic variables in the fuzzification phase. In this stage, necessary steps are executed according to a predetermined rule table (Table 2-2) [57]. The DC-DC converter's duty cycle is the controller's output.

Table 2.2: Fuzzy logic rule base

ΔE / E	**NB**	**NS**	**ZERO**	**PS**	**PB**
NB	ZERO	ZERO	NB	NB	NB
NS	ZERO	ZERO	NS	NS	NS
ZERO	NS	ZERO	ZERO	ZERO	PS
PS	PS	PS	PS	ZERO	ZERO
PB	PB	PB	PB	ZERO	ZERO

User expertise is required to validate the table that relies on rules and its membership feature. As shown in Figure 2.10, the final step, defuzzification, involves a transformation back to a numerical base for the output. Because of this output, the Photovoltaic is now required to operate at its MPP. An expert must build up the purpose of membership as well as the rule-base structure, which is a glaring drawback of the fuzzy logic paradigm. An adaptive fuzzy logic control system was suggested in [56]. According to an instructional process to routinely alter the Membership duty and the regulation basis table, it proved more effective than the standard approach. Experiments have shown that using two distinct membership functions improves tracking performance; hence, this issue was addressed later in the software [58].

2.6.6. Neural Network

Neural networks are a different artificially intelligent MPPT approach that significantly benefits from microcontrollers. Similar to fuzzy logic controllers, neural networks include three levels or strata: input, output, and hiding processing layers (see Figure 2.11) [45]. A user can customize the number of nodes present at each level of processing.

The PV's V and I, the temperatures, and whatever else the user desires can be selected as input variables. The output of this hidden stage, which considers these inputs is generally a duty cycle indication that adjusts the intensity of the power converter to match the MPP as closely as possible.

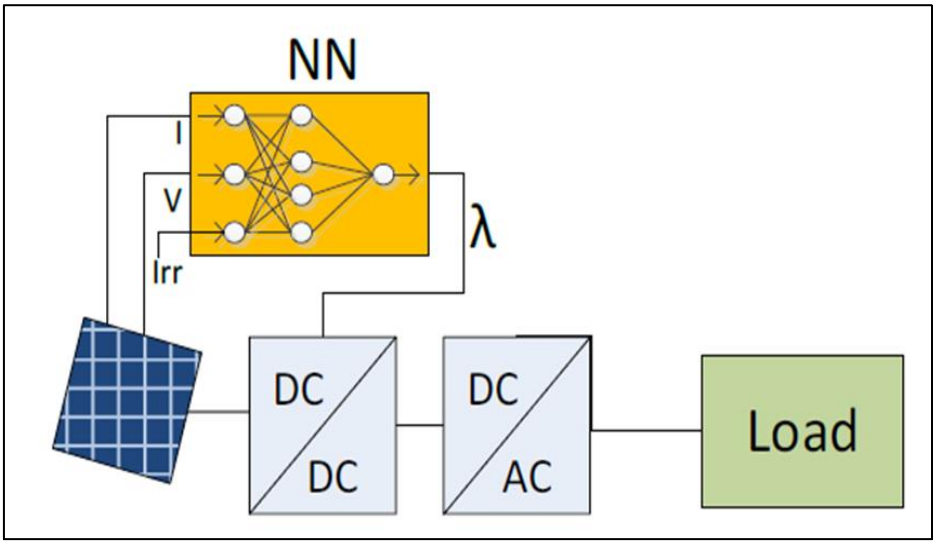

Figure 2.11: Neural network

The MPP is where the neural network approach is implemented, requiring extensive training for optimal performance. This training takes place over a long period, wherein the neural network databases is regularly updated with all PV data for months or even years. We acquire and document the input-output linkages. This training leads to an algorithm in the hidden units where each connection between the points is given a specific weight. Since every PV module is different, each module's neural network controllers need to be trained independently. In addition, weather and the Photovoltaic array's age are two variable factors that might alter the array's characteristics, necessitating periodic retraining of neural networks to ensure accurate monitoring [59–61].

2.6.7. Ripple Correlation Control (RCC)

Any PV module will often have a DC-DC power converter attached to it to follow the MPP and boost voltage. These switching pulses create current and voltage ripples in the array. It causes some distortion and ripple in the PV array's output power. This MPPT technique takes advantage of ripple by determining the differential of the PV time-varying power $\dot{p}$ with the PV time-varying current $\dot{i}$ or voltage $\dot{v}$ as a function of time t. The minimum power point (MPP) is found at a point where the power differential is equal to zero [62].

When the duty cycle is increased using a boost converter, the Photovoltaic current will increase while the voltage drops. Because of this, the obligation ratio is equal to the:

$$d(t) = -k_3 \int \dot{p}\,\dot{v}\ dt \qquad (2.12)$$

or

$$d(t) = -k_3 \int \dot{p}\,\dot{i}\ dt \qquad (2.13)$$

, where k3 is a positive value [45].

An analogue circuit experiment demonstrated rapid and precise RCC tracking despite varying atmospheric conditions. Also, Ripple Correlation Control (RCC) can be used with any PV because it is not dependent on the PV's specific features [62].

2.6.8. DC Link Capacitor Drop Control

As seen in Figure 2.12 [63], this technique can be applied to PVs wired in parallel with an AC line. If you want to calculate the boost converter duty cycle, you can do it as follows:

$$d = 1 - \frac{V}{V_{link}} \qquad (2.14)$$

V is the voltage at which the PV is functioning, and V_{link} is the voltage at which the capacitor is charged. This method optimized the duty cycle to produce more current from the Photovoltaic and increase the power delivery by holding the V_{link} Constant. This version of MPPT does not necessitate complex computations or calculations to function, unlike some of the others. Instead, analogue amplifiers and logic units can be used to accomplish the strategy with relative ease.

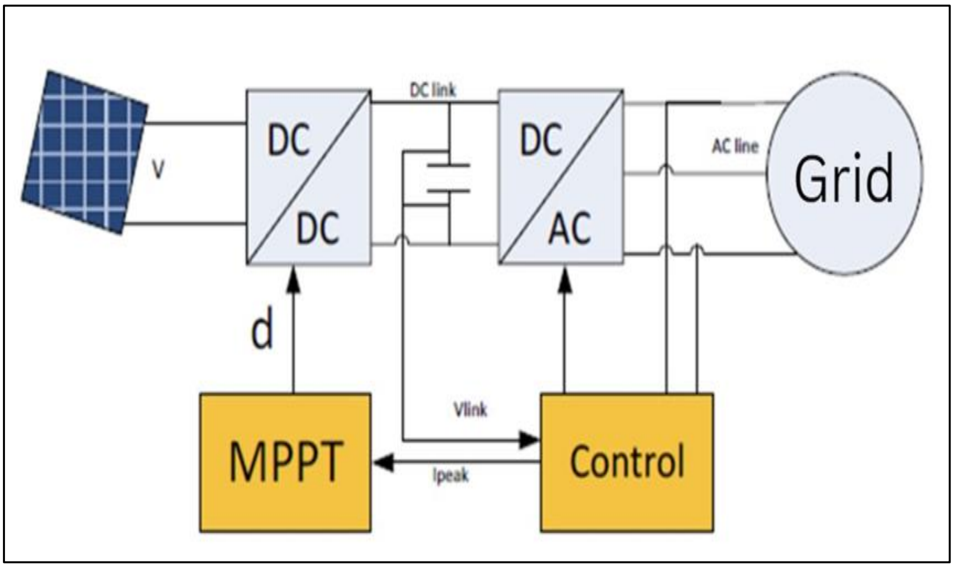

Figure 2.12. DC link capacitor drop control technique

2.6.9. Maximization Current Load

This maximum power point tracking (MPPT) technique is predicated on the idea that increasing the energy at the load would result in higher PV output. The load may be a resistive load, a voltage or current supply, or a combination of these. Until the PV reaches its maximum power point of operation, the charger must be maximized while the supply voltage, the battery, stays fixed. It's the same deal for current sources, except the output voltage must be regulated. This method can be applied to any load type and yields optimal results with a single sensor to optimize the PV's energy output. Operation with this method is typically performed close to the MPP but seldom strictly at the Maximum power point [64,65].

2.6.10. *dp/dv* Feedback Control

Since microcontrollers and Digital Signal Processor (DSPs) excel at handling complex calculations, this approach can derive easily dp/dv Gradient from the Photovoltaic features curve. In addition, Maximum PowerPoint Tracking (MPPT) can be accomplished by re-introducing the curve to the converter and using some form of control to force dp/dv to zero[66,67] . There are a variety of methods available for shaping the curve. A small number of cycles are calculated and saved in [67], and each has a different sign. The controller then optimizes the duty ratio in response to these indicators, instructing the converter to either raise or reduce its output until the MPP is met. To generate the dp/dv curve,[68] adopted a linearization-based strategy[66,69] developed a different method by digitally dividing P and V after collecting data to determine dp/dv. The average tracking time is 10 ms [68].

2.7. METHODS OF MPPT AND COMPARATIVE ANALYSIS

Table 2-3 summarises and compares the MPPT strategies covered in this section [70]. The comparison covers the MPPT's capacity to pinpoint the precise MPP, the necessity for periodic re-adjustment, the tracking speed, the technologies employed, the complexities level, and the variables detected.

Table 2.3. MPPT Approaches

MPPT Technique	Regular adjusting	Exact MPPT	Tracking speed	Analog or Digital	Sensed Variables	Complexity
Perturb and Observe	NO	YES	Differs	Both	V , I	Low
Incremental conductance	NO	YES	Differs	Digital	V , I	Medium
Fractional short-circuit current	YES	NO	Medium	Both	I	Medium
Fractional open-circuit current	YES	NO	Medium	Both	V	Low
Load current maximisation	NO	NO	Fast	Analog	V , I	Low

2.8. MODELS OF PHOTOVOLTAIC (PV) CONVERTERS

Researchers have been motivated by the increasing demand for PV panels and arrays as renewable technologies to enhance the system and improve its reliability, inexpensive, and highly efficient [71]. An option for improving operations would be to examine a complete PV system and optimize the effectiveness of each element.

The power generation of PV is impacted by weather [72]. Furthermore, the voltage level might be quite low whenever the supply consists of a single or a small number of Photovoltaic cells. Thus, the DC-DC converter is a crucial component of the Photovoltaic system setup, as it boosts and controls the voltage, reports the MPPT, and provides the highest level of maintained power [73].

Typically, the voltage is stepped either upwards or downwards through the converter by adjusting the switches' timing on and off. Moreover, this regulation can be carried out at a standard or high frequency. The ratios between Ton, whenever the converter's button is shut, and Toff, whenever the switch is opened, is referred to as the duty cycle of the converters. Hence, Equation 2.15 can compute the duty cycle [70].

$$D = \frac{T_{on}}{T_{off} + T_{on}} = \frac{T_{on}}{T} \tag{2.15}$$

In a perfect scenario, the power generated matches the input power; nevertheless, switching frequency causes energy losses in practice [74]. Within a Solar panel, three distinct kinds of energy converters are typically employed: buck converters, boost converters, and buck-boost converters [75].

2.9. TYPES OF PV SYSTEMS

Various PV designs can be used in Stand-alone and Grid-connected installations. It is clear that the utility grid availability is the primary distinction between these two basic types, as shown in Figure 2.13 [76]:

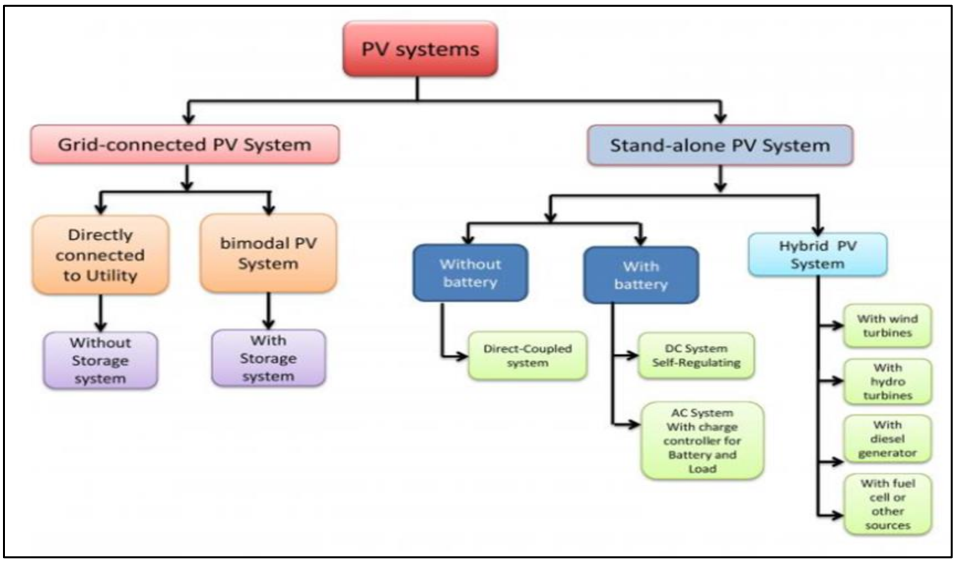

Figure 2.13. Types of PV systems

2.9.1. Stand- Alone PV System

As depicted in Figure 2.14 [76], all stand-alone, this method also referred to as "off-grid" without the power grid. We anticipated a suitable fit between demand and supply or, precisely, the relationship between the capacity of the solar power system and the needed load. The PV system, in this instance, can be referred to as a "Direct-Coupled PV System" when this match is executed flawlessly for a single load, and relatively few components are required without the requirement for storage technologies. A storage facility is required for a distinct type of stand-alone system in which surplus energy can be stored, and captured when the sun is not shining and used when it is unavailable. As we will discover later, this can be joined to AC loads directly or to DC loads via an increased power conditioning component known as an "Inverter."

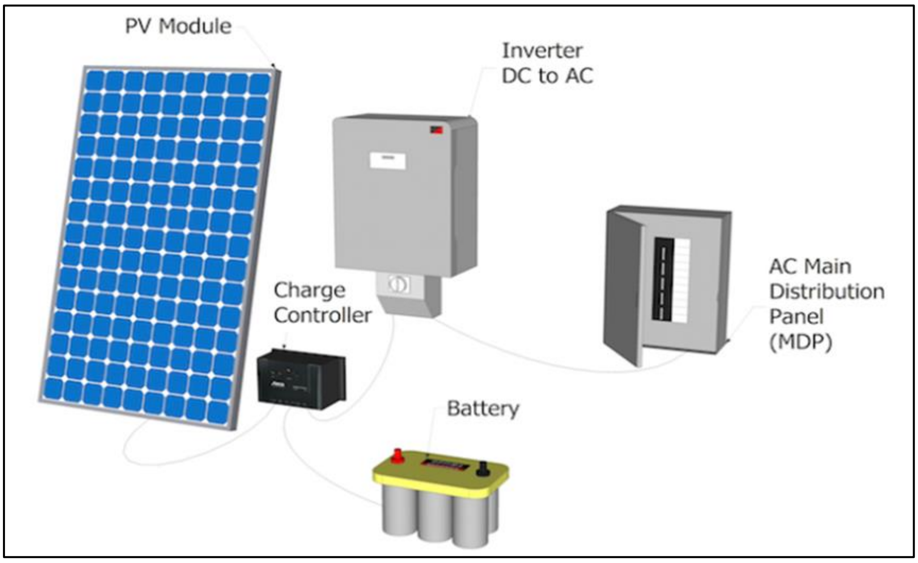

Figure 2.14. Stand-alone AC systems

The "Hybrid PV System," depicted in Figure 2.15 as another typical form of stand-alone structure, uses additional sources of energy in addition to the Photovoltaic system to power loads [76]. These power sources include fuel cells, diesel generators, hydro turbines, wind turbines, and hydro turbines. Hybrid PV systems can also use batteries to store energy.

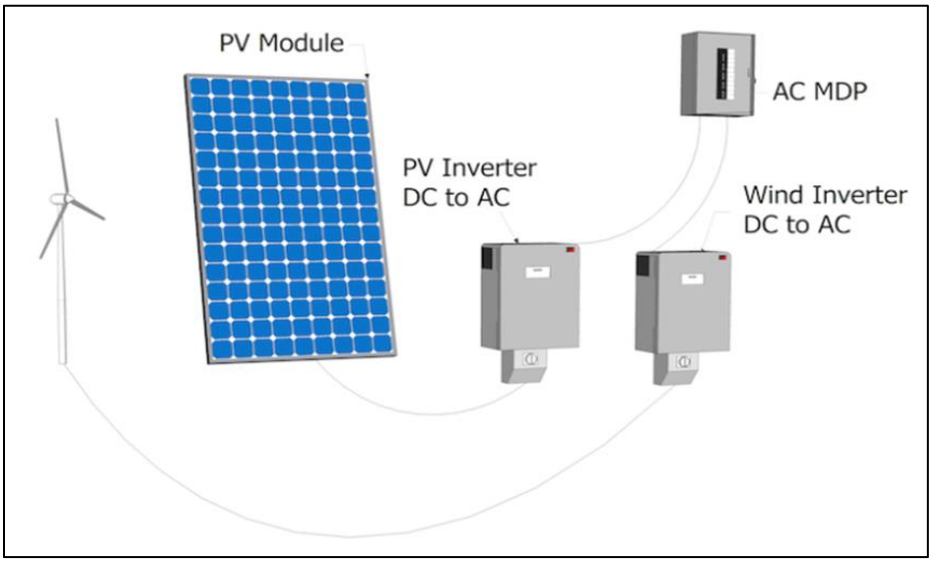

Figure 2.15. Hybrid systems

2.9.2. Grid-Connected System

This configuration is the norm for clients looking to cut their energy bills. Additionally, while the PV array is not generating any power, the utility network is still accessible. A "Utility-Interactive PV Technology or Grid-Tied PV System," as depicted in Figure 2.16 [76], is a PV array that has a direct link to the electrical network without a system for storing power. A "Bimodal PV Technology" or "Battery Support PV Technology" stores additional electricity in storage banks of batteries for future use, as depicted in Figure 2.17 [76].

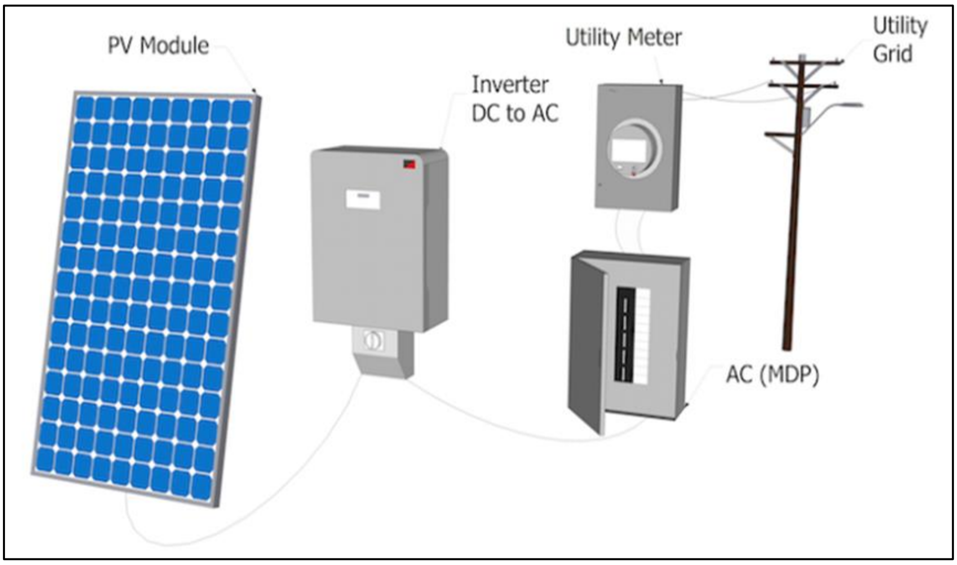

Figure 2.16. Interactive PV System

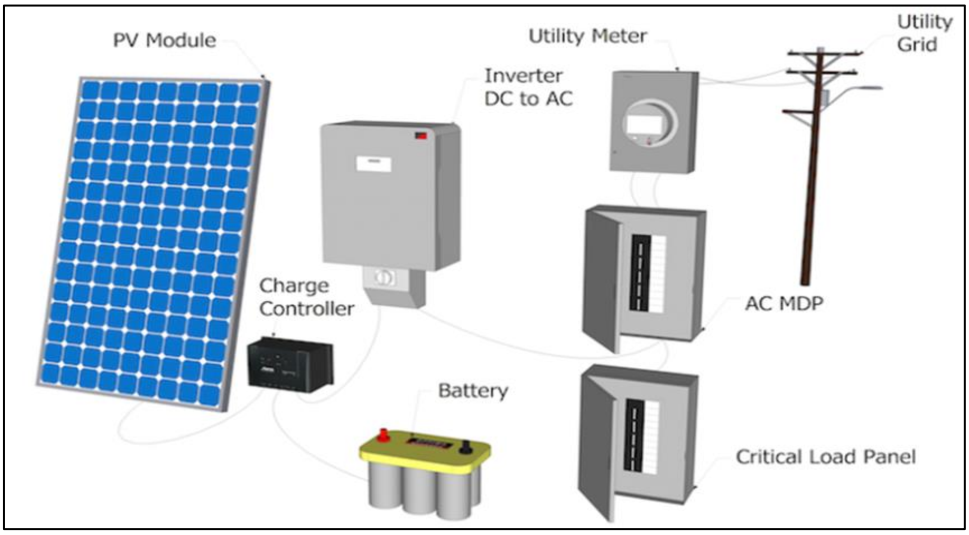

Figure 2.17. Bimodal PV System

2.10. STATE AND GLOBAL PROSPECTS FOR THE DEVELOPMENT OF SOLAR ENERGY

Global demand for primary energy has increased by an average of 1.8% per year since 2011, with large fluctuations across countries. Demand growth has primarily picked up in developing countries, while it has stalled or even declined in developed countries [77,78]. The most critical issues facing society in recent years are related to sustainable development and climate change. Due to limited fossil fuel resources and efforts to reduce global warming, governments are leading the transition to low-carbon energy systems. In this energy transition context, in academia and industry, there is an extensive research effort focused on improving efficiency and limiting the costs of renewable energy sources such as hydropower, wind, solar and biomass.

2.11. Overview of Global Solar Energy Markets

The market for solar energy surpassed 100 GW for the third consecutive time in 2019 [79]. The worldwide PV market has, in fact, been largely influenced by China's economic growth level for a number of years. From 102 GW in 2018 to 103 GW in 2019, the worldwide PV economy has grown to 114.9 GW, with around 30.1 GW expected to be deployed in China this year. This is an increase of over 43.4 GW in 2018 and 53.0 GW in 2017. The EU, which constructed roughly 16.0 GW annually in 2019, took second place behind China. The US comes in second with a larger market at 13.3 GW, then India, whose market size decreased marginally to 9.9 GW. With an expected 7 GW, Japan rounds out the top five, maintaining its level from 2018. The top five stayed the same from the previous year. In 2019 there were some changes in these nations: For the first time, Vietnam installed 4.8 GW, followed by a thriving Spanish sector at 4.4 GW, Australia installing the anticipated 3.7 GW, and Ukraine installing 3.5 GW. Germany saw growth in the European Union during the past year, installing about 3.9 GW, while the Netherlands has continued its massive installation program with 2.4 GW. Despite the decline in the Chinese market, Asia still holds a monopoly on the worldwide PV market. About 57% of the worldwide PV market in 2019 came from Asian markets, a considerable decline from levels in prior years.

The US market's fast growth was largely to blame for the market's modest growth in the Americas. (13.3 GW). With around 2.0 GW deployed in 2019, Brazil is the second market, and Mexico is third with approximately 1.0 GW deployed. Chile added 700 MW, a rise that is largely consistent, while Argentina installed roughly 500 MW, a record amount. Canada's market has a small installed capacity of around 200 MW, making it relatively small. America accounted for over 16% of the international PV market in 2019. After decades of market stagnation, the Spanish market in the European Union expanded by 4.4 GW; Germany moved into second place with 3.9 GW, an important gain for the third consecutive year. With 2.4 GW, the Netherlands saw a second large market development, and France was close behind with 0.9 GW. In 2019, Europe accounted for slightly more than 18% of the worldwide market for photovoltaic technologies. The biggest capacity utilization in recent years was erected by Israel, which added 1.1 GW.

There are around 2 GW of projects that have been launched in the country of Emirates. In Jordan, a number of projects totalling 600 MW were under development and were launched in 2019. Africa saw installations of 1 GW in South Africa, at least 1.7 GW in Egypt in 2019, and more than 200 MW of solar systems in Morocco before the end of 2019.

2.12. THE TOTAL INSTALLED CAPACITY OF SOLAR POWER PLANTS IN THE WORLD

Figure 2.18 depicts the overall capacity currently in place around the globe as of the year's end of 2019 [14]. The value shown is a minimum of 627 GW. In terms of total installed capacity, China (204.7 GW) is far ahead of the rest of the pack, which consists of the EU (131.3 GW), the United States (74.9 GW), Japan (63.1 GW), and India (42.8 GW). Australia achieved 14.6 GW while Korea achieved 11.2 GW in the Asia-Pacific area. In the EU, Germany has the most installed capacity with 49.2 GW, then comes Italy at 20.8% and the United Kingdom at 13.3%. The total of all other nations is less than 10 GW [13]. Solar power installations in IEA PVPS countries totalled 534.5 GW by the end of the year of 2019, the vast majority of which were grid-connected. In addition to IEA PVPS program participants, other major global markets represent a combined installed capacity of at least 92.1 GW at the end of 2019: India - at least 42.8 GW, Vietnam - 4.9 GW, Ukraine. from 4.8 GW, Taiwan with 4.1 GW or more: Several GW installed in Pakistan, Brazil, Egypt, UAE, Jordan, and Russia.

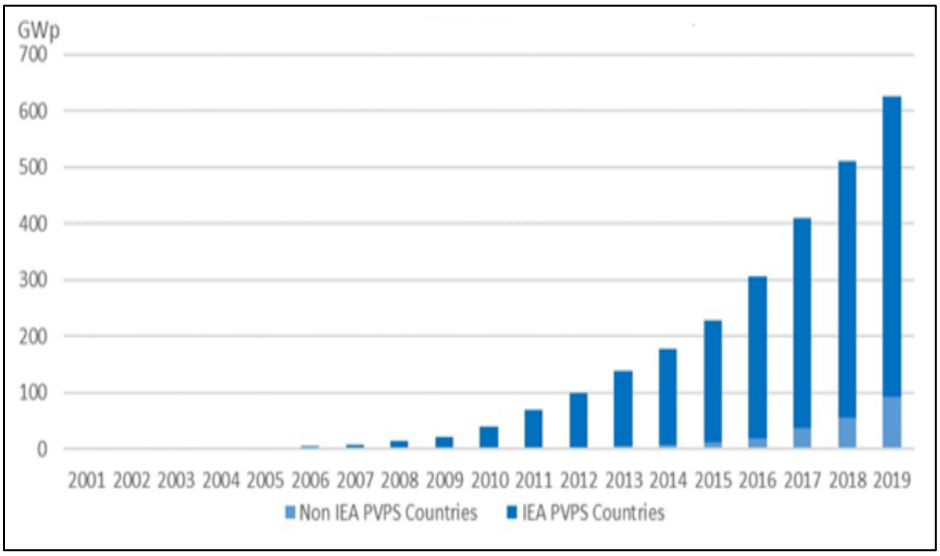

Figure 2.18. The global evolution of cumulative photovoltaic installations

Photovoltaic installations have been installed at various levels worldwide, but most calculate installations in MW rather than GW. Currently, 617.2 GW appears to be the minimum set by the end of 2019, with a solid confidence level in countries in the IEA PVPS and other significant markets. The combined capacity currently in operation is roughly 627 GW, with an extra 9.8 GW attributable to the residual areas.

2.13. WAYS TO IMPROVE THE ENERGY EFFICIENCY OF ELECTRICAL INSTALLATIONS WITH SOLAR ENERGY CONVERTERS

Top-level conversion solar energy can be achieved while realizing multiple system methods: implementation and application of systems MPPT maximum power point tracking for charge controllers' batteries, automatic continuous monitoring of the joint venture for sun and optimizing the design of the solar battery in order to achieve minimal heating of the photocells, since the increase in temperature leads to a decrease in the efficiency of the joint venture. Continuous Tracking SP behind the sun allows you to increase the energy efficiency of ASPP by 25-30%. However, the technical implementation of such a system is complex, as it must contain various mechanical devices and fixtures with electric drives of vertical and horizontal rotation with gearboxes, control units and photoelectric sensors. Production of solar electrical installations with automatic solar tracking is currently engaged in various Russian and foreign companies: NPO Astrophysics, DITRAS, FTI RAS im. A.F.Yoffe, MPEI, Celtek (Ukraine), Sun power (USA), Gin tech (China), Mo tech (Taiwan), Ying li Green Energy (China), Canadian solar (Canada), First Solar (USA), Titan tracker (Spain), SUNPOWERT20 TRACKER (USA), Merlin Power Systems (USA), and others [80,81].

2.14. SOLAR ASSESSMENT

The variety of released studies evaluating PV effectiveness in various locations has been growing consistently for more than a decade, reflecting the rising popularity of solar energy sources. Attempts have been made to predict the energy production of photovoltaic (PV) systems installed on the roofs and walls of buildings [82–84]. The evaluation of PV systems that are incorporated into buildings is beyond the scope of this document because it requires a large amount of data and computer resources. The second line of inquiry, which is more pertinent to our investigation, investigates the evaluation and selection of locations for large-scale, ground-mounted solar generating installations. These inquiries cover quite different geographic areas. While many studies include regional or global context, the vast majority focus on a single country or region [85]. [86] conducted a comprehensive assessment of Europe's solar energy potential without specifying specific production plants.

To our understanding, no worldwide assessment of this nature has been published, indicating a considerable research deficit. This highlights the significance of this finding to the solar sector worldwide. Typically, national and regional evaluations aim to discover or promote project opportunity areas (POA) for renewable power advancement. Following the concepts of (MCDM) [87,88] or an (AHP) [89,90], the standard procedure entails a geographical analysis of numerous geographic data sets using a (GIS) software. Quantity, quality, and suitability of accessible data sets for such studies vary by nation, study kind, and study region size. Regional studies enable the34eployent of more advanced approaches, typically involving data on local land-use rules, electricity system components, transmission systems, accessibility, and pricing. While the added complexity may improve the accuracy of the work, it also reduces the study’s replicability and comparability with other locations and nations where input data are inadequate or inaccessible. In addition to the data sources, the precise procedure settings produce a further variance in the findings (Any set of data is subjected to Boolean analysis vs fuzzy logic, as well as other variable weights, limits, and categories). In conclusion, each country/regional investigation may seek distinct objectives, siting requirements, and exclusion zones based on its regulatory systems.

SWERA is a United Nations Environmental Programme (UNEP) program that began in 2006 intending to provide high-quality information on renewable energy resources around the world, as well as the instruments required to put this data in ways that promote renewable energy regulations and initiatives. The program employs a variety of well-established data collection approaches, including satellite-derived information. This information can be used to create an approximate evaluation of wind and solar energy prospects using advanced computer simulations of atmospheric processes. For numerous global regions, high-definition modelling data are available. Figures 2.19,20 and 21 are maps from the Open Energy Info website [91]. They are created using the previously discussed data.

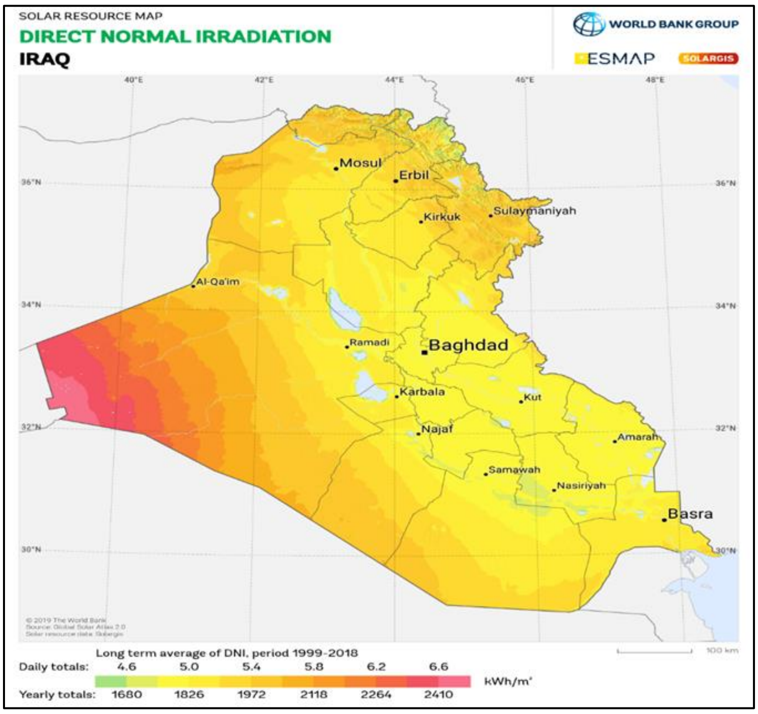

Figure 2.19. Direct normal irradiation map

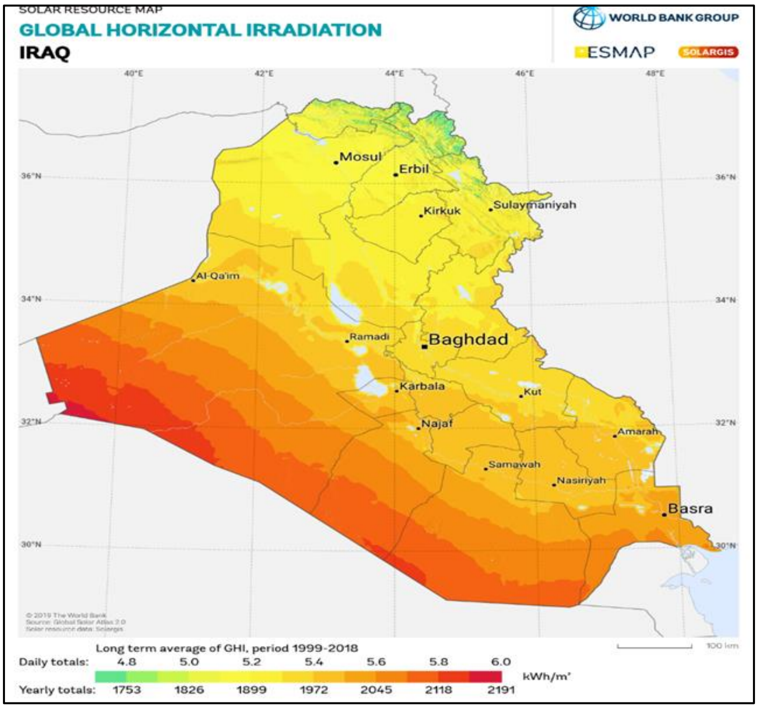

Figure 2.20. Global horizontal irradiation

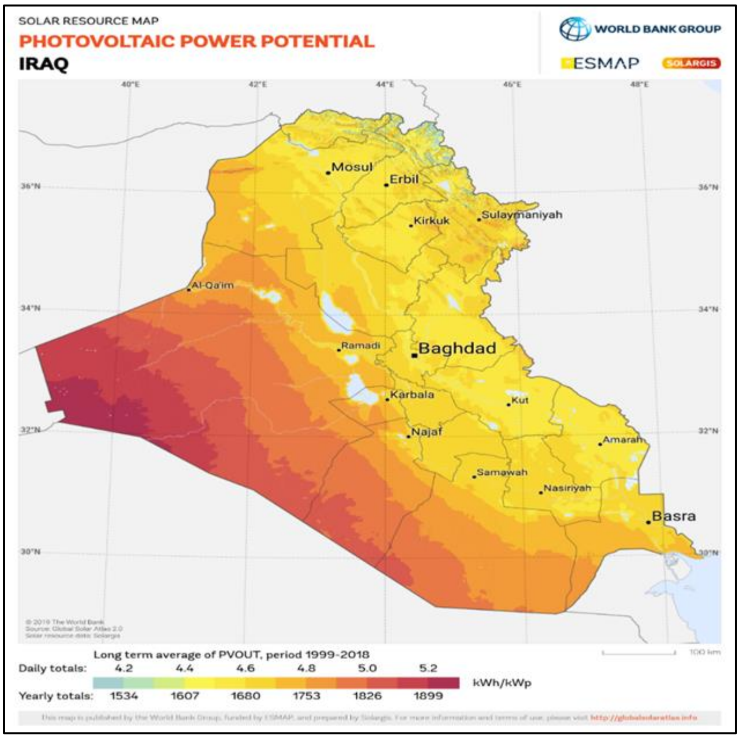

Figure 2.21. Photovoltaic power potential

2.15. EXISTING COMPARATIVE STUDIES BETWEEN MPP TECHNIQUES

Recent studies discussed the implementation of the best used algorithms for the development of photovoltaic panels.

In [92] discussed partial lighting affects PV systems and provides an upgraded Perturb and Observe (P&O) approach with a monitoring algorithm. The suggested algorithm increased the traditional P&O MPPT tracker efficiency at the partially shaded circumstances by over 16%. The system using traditional P&O, on the contrary, appears unsteady and generated a larger percentage of inaccuracy. Additionally, in both circumstances, the boost converter performance offered greater than 70%. Moreover, [93] this study highlights a reliable MPPT method based on modified perturb and observe (MPO). Relying on the voltage in the open circuit estimates technique, the revised MPO-MPPT technique's control plan divides the solar module/cell P-V curve into four operational parts.

In [94], the author explored how installing solar cells affected the end-of-line voltages and the loss of power that ensued when distribution infrastructures with radial configurations were used. The prospect of lowering losses, enhancing voltage, and boosting the assimilation of renewable energy by applying the Loop design approach was another assumption made by the study's author. Using changeable parameters and solar power capacity for each, seven alternative looping and radial situations were developed in the busbar. MATLAB was used as the basis of the contrast. The findings revealed that using radial rings in the loop minimizes the impact of excessive voltage and losses of power and increases the penetration of photovoltaic cells in the grid.

Employing two test processes with 132 and 32 node locations, the author in [95] developed the MPC of the LPC in detail for the condition of operation responses to both power and time output parameters from generators beneath secure circumstances and over several operating times. As power flow controls are crucial for balancing loading on feeders, the author came to the conclusion that LPC controls power flow to lessen the impact of greater penetration by distributed generators.

In [96] The authors developed an adaptive P&O algorithm for swiftly monitoring MPP that has lower constant state fluctuation than the traditional P&O MPPT algorithm. The effectiveness of the suggested approach is validated using computational and experimental data.

Other studies developed a Cuk converter for an intelligent P&O approach [97], this research overcomes P&O system limitations with fuzzy-based P&O. Voltage conversion oscillates. Better voltage converters can solve this problem. PV converters like Cuk are efficient. Cuk converters need higher duty cycles for greater efficiency and voltage conversion fluctuations.

Another study [98] proposed Linear Tangents of MPPT for P&O using Matlab simulations are used to validate the efficacy of the suggested approach and other conventional methods. The simulation results demonstrate that the suggested technique has superior precision, increased efficiency, minimal fluctuation, and enhanced steady-state and dynamical performance in comparison with conventional techniques.

[99] this study developed an approach that utilizes a (PV) module employing a single-diode structure for a solar cell and compares steady duty cycle, the standard (P & O) technique, and the suggested technique using a PI controller for obtaining the greatest amount of power from the PV array. Buck converters execute these strategies.

In this project [100], the authors entailed a the creation of module using P&O on the basis of using 200W PV sample and acid battery, the findings demonstrated improved performance and good efficiency compared to the traditional systems under insolation and temperature conditions. Other studies led the comparison of P&O and I&C for grid connection and concluded that P&O never achieve an exact value of voltage compared to I&C which made it faster [101].

In discussing the characteristics of P&O method, [102] studied the efficiency of P&O energy output at higher perturbation frequencies, while [103] studied the theoretical advancement of P&O through the ant colony optimization (ACO).

Other studies suggested automatic tuned P&O for the operation point [104], and adaptive P&O of boost dc-dc converter [105].These methods were the results of modernization of the MPPT and the P&O approach. Nevertheless, each method above had a limitation and drawbacks, because it was developed as a case study for a specific area. Therefore, the wide application of these methods required careful considerations.

In Iraq, few studies investigated the application of different techniques to reach higher MPPT performance and power generation. The authors [106] Studied FLC algorithm to obtain high efficiency of MPPT and power generation. Therefore, the findings revealed 96.41% of power efficiency under variable climate condition. Other studies [107] discussed in a comparison the traditional P&O and four meta-heuristic in terms of maximum power and MPPT efficiency. For the study cases, the results illustrated variable outcomes according to the weather conditions.

In addition, PV system based on the use of Artificial intelligence adopted schemes to deliver an improved system voltage by 3.5% compared to the basic P&O techniques [108]. To improve the PV module during the partial shade, this study [109] suggested using environmental effects and Hybrid systems ANN for the optimization of the system regarding conventional techniques. Other studies [110] tested different solar panels with different techniques for measuring power generation, voltage levels and currents. The study revealed a better performance of I&C technique in term of timing and rapid response.

2.16. SUMMARY

This chapter included an overview of the history of photovoltaics, the mathematical formalism, the current setup, and MPPT techniques. First, a brief overview of the origin and evolution of Photovoltaic panels was provided. The PV panel was then evaluated and mathematically constructed, subsequently examining the merits and drawbacks of the different PV systems. This section ended with a comparison table permitting a side-by-side assessment of the setups. In the final section of the chapter, MPPT was examined, including some explanation, function, and implementation algorithms. Flowcharts or diagrams are used to illustrate and justify each of the most effective methods. A comparative table summarizes the pertinent information regarding the MPPT methods.

PART 3

MODELING AND SIMULATION

3.1. INTRODUCTION

The use of solar systems increased due to the grave environmental risks posed by the utilization of fossil fuels and the limited availability of conventional fossil fuel energy sources. It is displayed in the renewable, wind, geothermal, etc. categories. Solar energy is a more significant energy source than conventional sources, which has devastating environmental effects. Photovoltaic (PV) energy is given greater consideration when using renewable energy sources due to its basic form, which consists of noiseless electric power and additional advantages over other energy sources. Photovoltaic systems are advantageous for various users due to their low cost and ease of operation, particularly in rural areas with high insolation and no access to an electric grid or load shedding issues.

3.2. SYSTEM BLOCK DIAGRAM

The system contains a PV module, a DC/DC converter that is controlled by a PWM signal, and an MPPT controller, which will take PV voltage and current as inputs to change the duty cycle of the PWM signal to make it possible to extract the highest power drawn likely from the PV module, inverter which convert DC to AC, VSC controller to generate the pulse signals for the inverter and a 132kV bus to connect with, and obviously some loads are connected. The general idea of the system is represented below in the block diagram, as shown in Figure 3.1

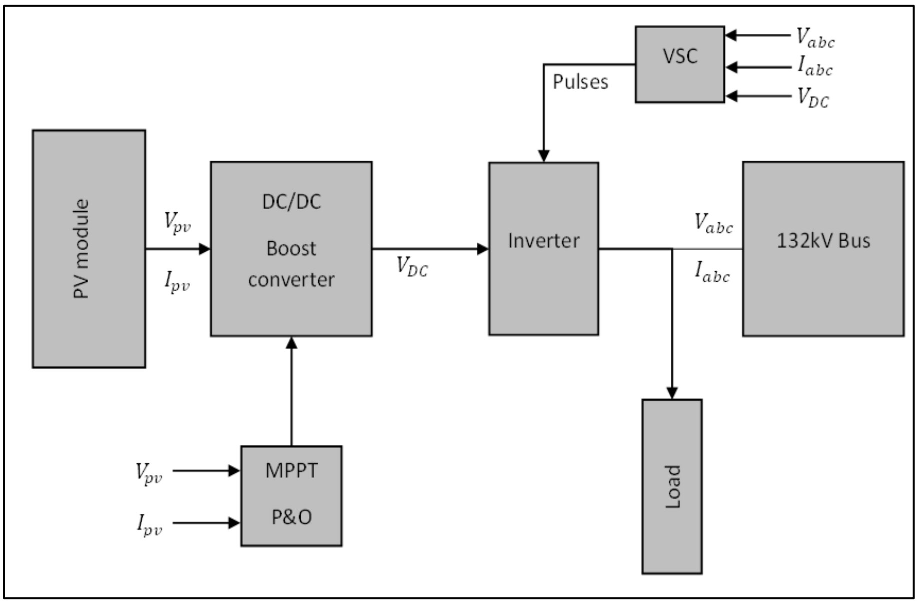

Figure 3.1. Block Diagram of the system

The parameters used in the block diagram were shown in the Table 3.1:

Table 3.4: system parameters

Parameter	**Value**
PV maximum power of module	305.2 W
PV short circuit current of module	5.96 A
PV open circuit voltage of module	64.2 V
PV maximum current of module	5.58 A
PV maximum voltage of module	54.7 V
Parallel strings of PV array	66
Series-connected module per sting	5
Inductance of boost converter	5 mH
Resistance of boost converter	0.005 Ω
Capacitance of boost converter	100 µF
Converter switching frequency	5 KHz
Reference voltage of DC link	500 V
Inductance of filter	0.5 mH
Resistance of filter	0.005 Ω
Grid voltage	132 KV
Grid frequency	50 Hz
Set up transformer	260 V / 132 KV

Considering the block diagram mentioned above, the description of each component of the system is shown:

3.3. PV MODULE

The PV module is initially a source of electricity, but its behaviour changes as the voltage on the module's terminal approach the open circuit voltage; as a result, the modelling is extremely complex due to this behaviour change. The circuit depicted in Figure 3.2 is the PV module's prototype [111].

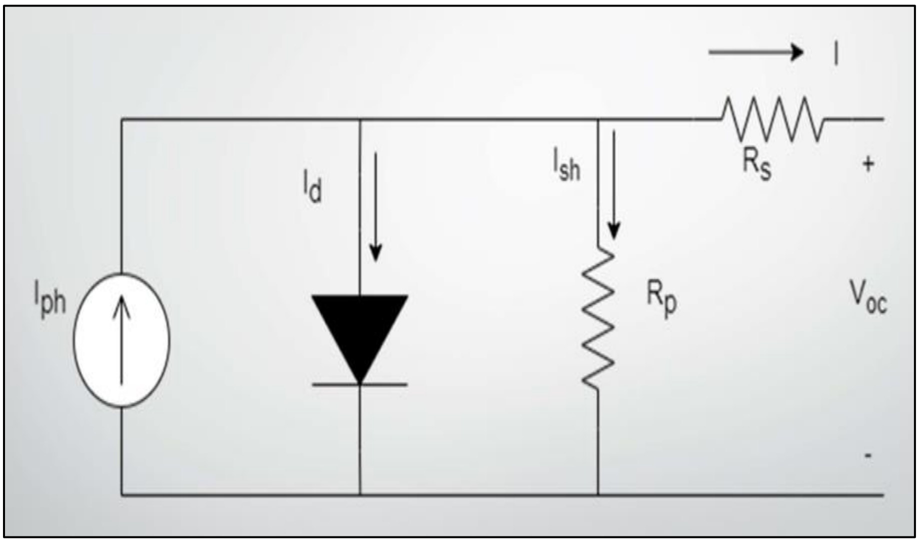

Figure 3.2. Circuit Model of the PV module

The mathematical equations obtained by analyzing the circuit are stated:

$$I = I_{ph} - (I_d + I_{sh}) \tag{3.1}$$

$$I_{ph} = (I_{scr} + k_i \Delta T)\frac{G}{G_c} \tag{3.2}$$

$$I_o = I_{rs}\left(\frac{T}{T_{ref}}\right)^3 \exp\left[\left(\frac{qE_{G_c}}{AK}\right)\left(\frac{\Delta T}{T_{ref}T}\right)\right] \tag{3.3}$$

$$I_{pv} = I_{ph} - I_o\left[\exp\left(\frac{q(V_{pv}+I_{pv}R_s)}{AKT}\right) - 1\right] - \frac{V_{pv}+I_{pv}R_s}{R_p} \tag{3.4}$$

Where:

I_{pv}: Current from lighting sources

R_p: Equivalent Parallel Resistance

V_t: Array thermal voltage (V)

I_o: reverse saturation current

R_s: Similarity in Series Resistance

N_{ser}: Cells in series

N_{par}: Parallel cells

Since the numerical representation of this model is an inherent function, as shown in equation (3.4), it is impossible to establish a direct relationship between terminal voltage and current. With the assistance of the program, the association can be found and analyzed the behavior by analyzing the graph of terminal voltage (V) versus Power (P) and terminal voltage (V) versus current (I). considering the constant parameters, the voltage and current depend on temperature and irradiance. The test condition for a PV module is 1000 W/m^2 irradiance and 25°C temperature. The PV and IV plot for this condition is in Figure 3.3.

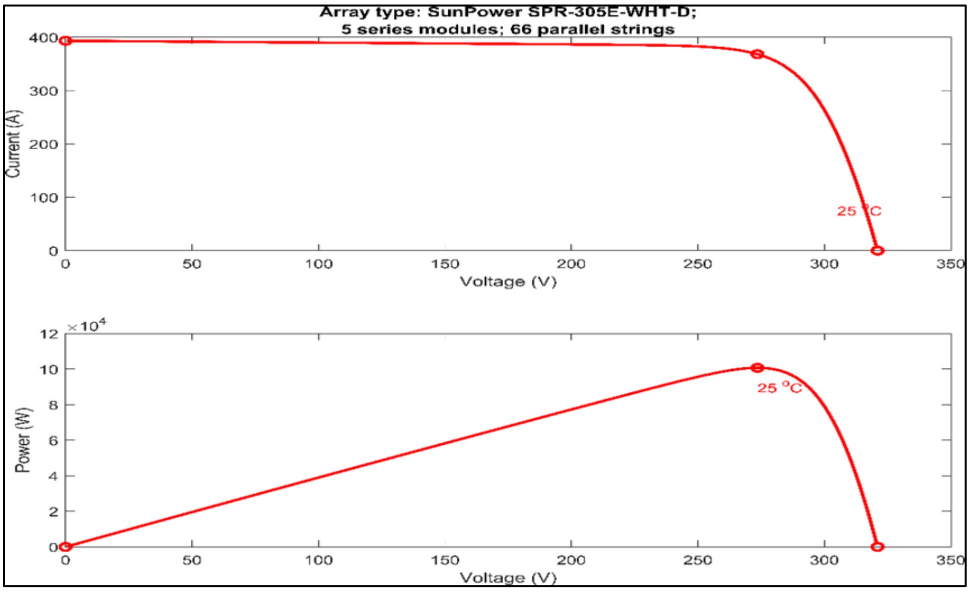

Figure 3.3. PV and IV at 25°C and 1000 W/m^2

Considering the IV plot, the current is constant for a wide voltage range, and P linearly increases with voltage in this region. Notice the peak power, which is the desired point of operation of the solar system. Keeping in mind that maximum power increases with the increase in irradiance. So, the higher the irradiance, the better for the system. It is visualized in Figure 3.4.

Considering the temperature, increasing the temperature decreases the maximum power. So, the higher temperature is not better for the system. $25°C$ is considered an ideal temperature for the operation. This phenomenon is visualized below in Figure 3.5.

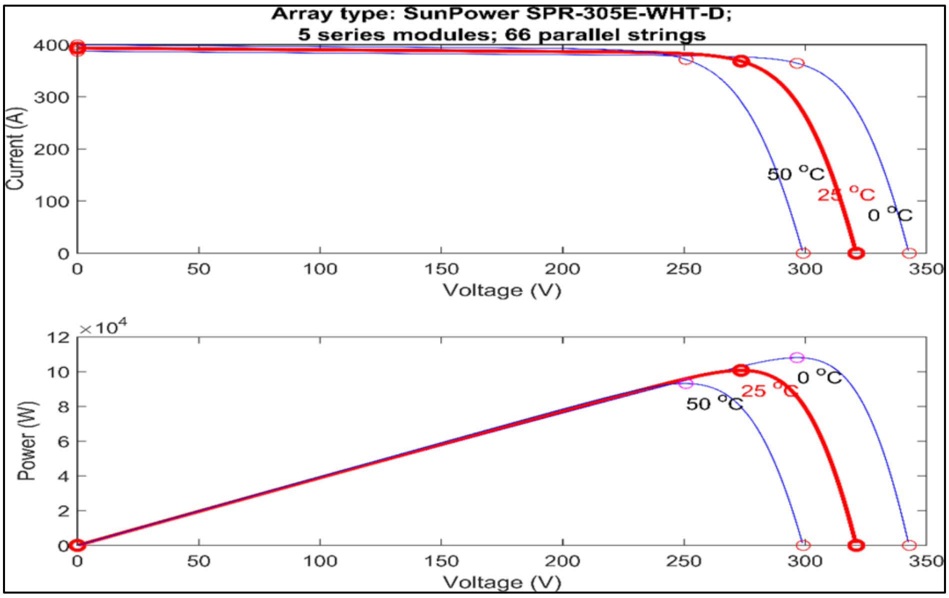

Figure 3.4. PV and IV plot for 1000 W/m^2 and different temperatures.

3.4. BOOST CONVERTER

The DC/DC boost converter boosts the voltage to be greater than the input voltage to control the power drawn from the PV module. The ratio at which the input voltage boost depends upon the duty cycle (D) of a square wave of a specific constant frequency used to drive the transistor in the boost converter circuit shown in Figure 3.6 [112].

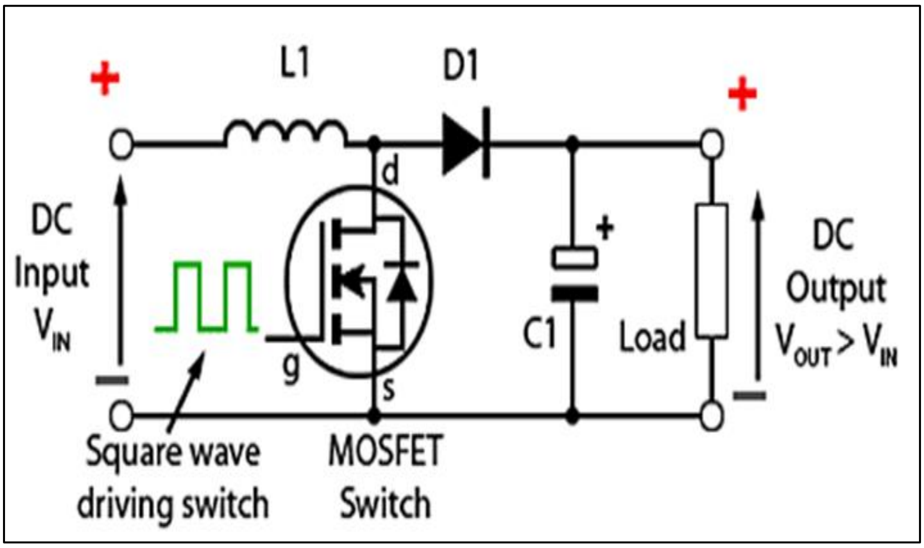

Figure 3.5. DC/DC boost converter circuit

MOSFET transistor is used as a switch driven by a square wave, the duty cycle (D) determining how much the input voltage will be boosted. Mathematically, it follows:

$$V_{out} = \frac{V_{in}}{1-D} \tag{3.5}$$

Here $D = 0$ and $D = 1$ represent the 0% duty cycle and 100% duty cycle, respectively. Designing the boost converter is to find the best possible values of the inductor and the capacitor and the frequency of the square wave. The higher the frequency, high will be losses in the circuit. So, the frequency considered should be the least possible to minimize the losses. This study employed equations 3.6 and 3.7 to obtain the inductor (L) and capacitor (C) values. The chosen frequency (f) of the square wave is $5kHz$, and the designed values of the L and C are about $5mH$ and $24mF$, respectively.

$$L = \frac{V_{in}\, D}{\Delta i_L\, f} \tag{3.6}$$

$$C = \frac{D}{R\,\frac{\Delta V_O}{V_O}\, f} \tag{3.7}$$

The voltage (V_{in}) at the maximum power point, in this case, is about $273\,V$ and the voltage (V_o) is boosted to about $500\,V$. So, the duty cycle of the square wave signal for deriving the transistor can be found as:

$$500 = \frac{273}{1-D} \qquad \rightarrow \qquad D = 0.454$$

So, the duty cycle of the square wave signal should be around 45.5% in the simulation.

3.5. MPPT CONTROLLER

In this setup, the MPPT controller acts as the central processing unit. The method for monitoring the P-V and I-V curves is implemented by this controller. The P&O method, often known as the climb-up-a-hill technique, was used in this project.

3.5.1. Perturb and Observe (P&O)

The P&O method is used most often to determine the PV array's voltages (V) and current (I) [37]. By adjusting the voltage at which the device operates and calculating what energy is generated at the moment, the energy consumption can be altered. The P&O algorithm can identify the MPP and compare it to the initial value. The algorithm is summarized in Figure 3.7 [113].

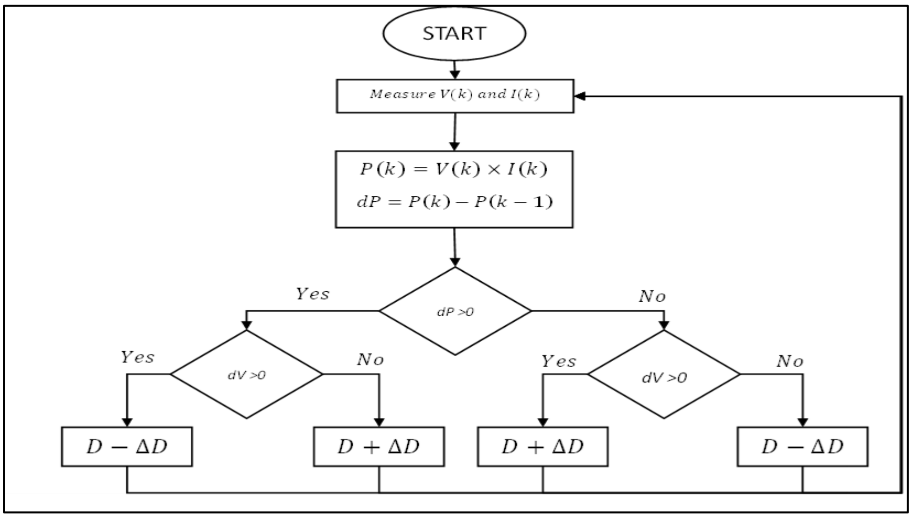

Figure 3.6. Flow chart of P&O Algorithm with Drift

D The PWM signal's duty cycle, which is utilized to gate the transistor signal in the Boost converter, is shown here. Two things need to be gauged in relation to the algorithm's flow. Initially, the terminal current and voltage are computed, along with the power obtained from the photovoltaic (PV) module. The numerical value for D will subsequently be increased or decreased based on the circumstances specified. The algorithm's focus on the PV curve and disregard for the IV curve is what matters most in this situation. With this approach, there is an issue known as drift. When there is an unexpected shift in radiation, the drift happens. It is hoped that the algorithm will always go closer to the maximum point. However, the algorithm moves a single step farther from the final point towards the voltage of an open circuit when there is a fast shift in irradiance. In Figure 3.8, drift occurrence is depicted [113].

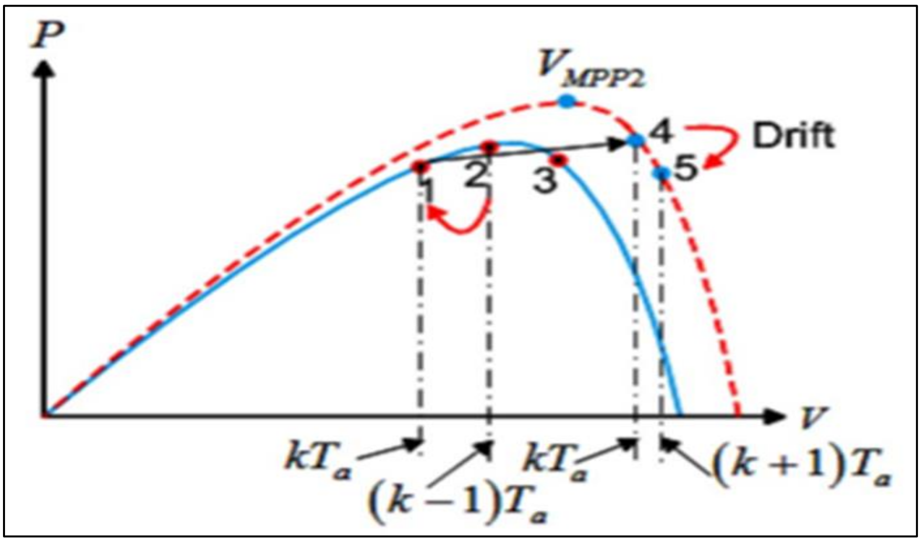

Figure 3.7. Drift occurrence

The condition responsible for the drift is shown in Figure 3.9 below. The drift occurs when there is a sudden change in the irradiance, which can happen in the morning when the sun rises.

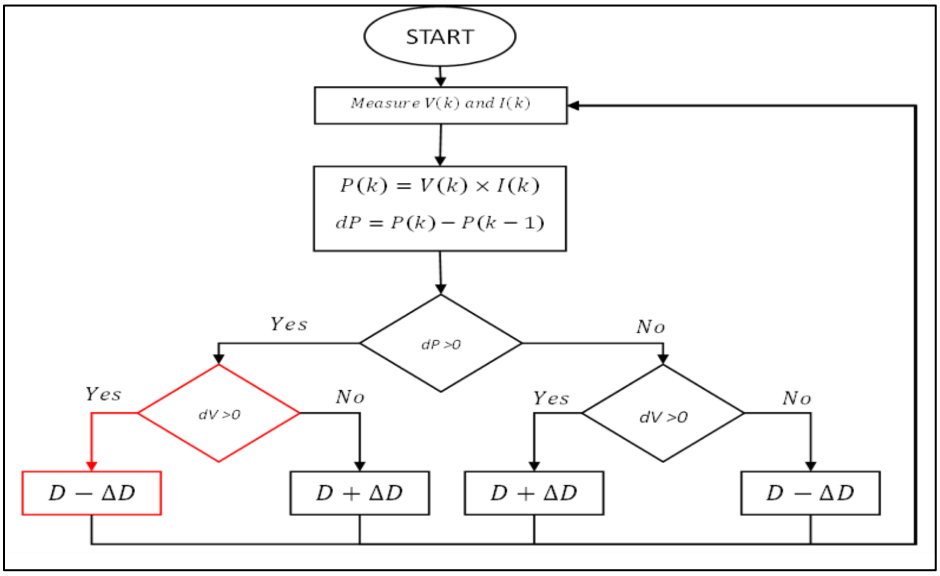

Figure 3.8. Condition responsible for the drift

The power is very sensitive to drift because the PV curve decreases very fast beyond the maximum point. If the drift occurs, then the power drop is very significant. So, we need to modify the algorithm to eliminate the drift phenomenon. The revised version of the P&O algorithm is shown in Figure 3.10 [113]:

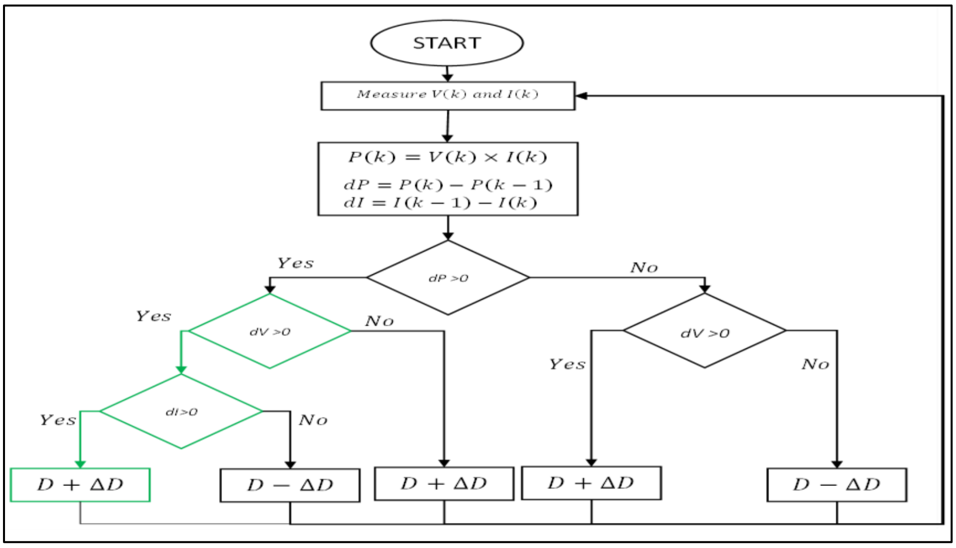

Figure 3.9. Modified P&O Algorithm

This algorithm counts the current curve to go ahead for the forward step, and no drift occurs anymore. The point-to-point working of this algorithm on the PV curve is summarized in Figure 3.11.

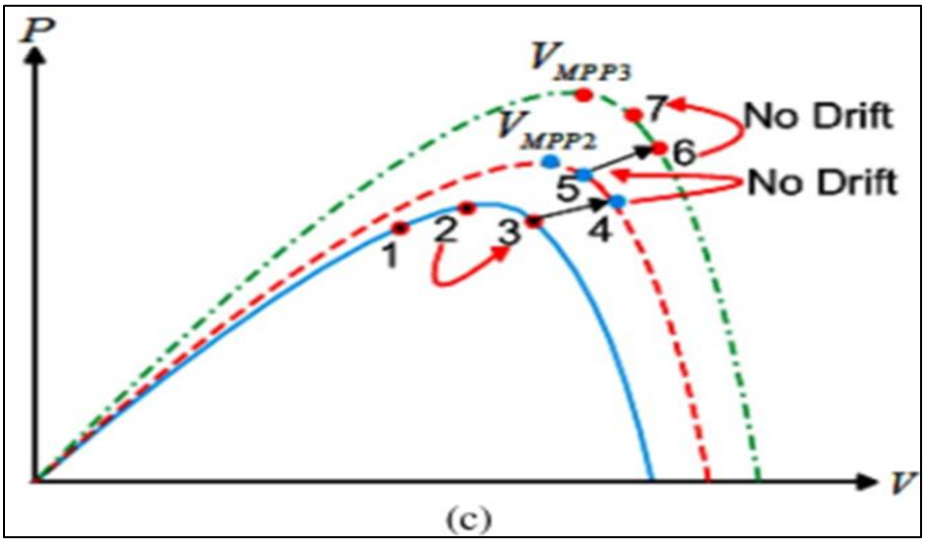

Figure 3.10. Drift free Algorithm Tracking

The drift-free modified P&O algorithm is implemented in the simulation. The MATLAB code for implementing the P&O algorithm is in Appendix 1.

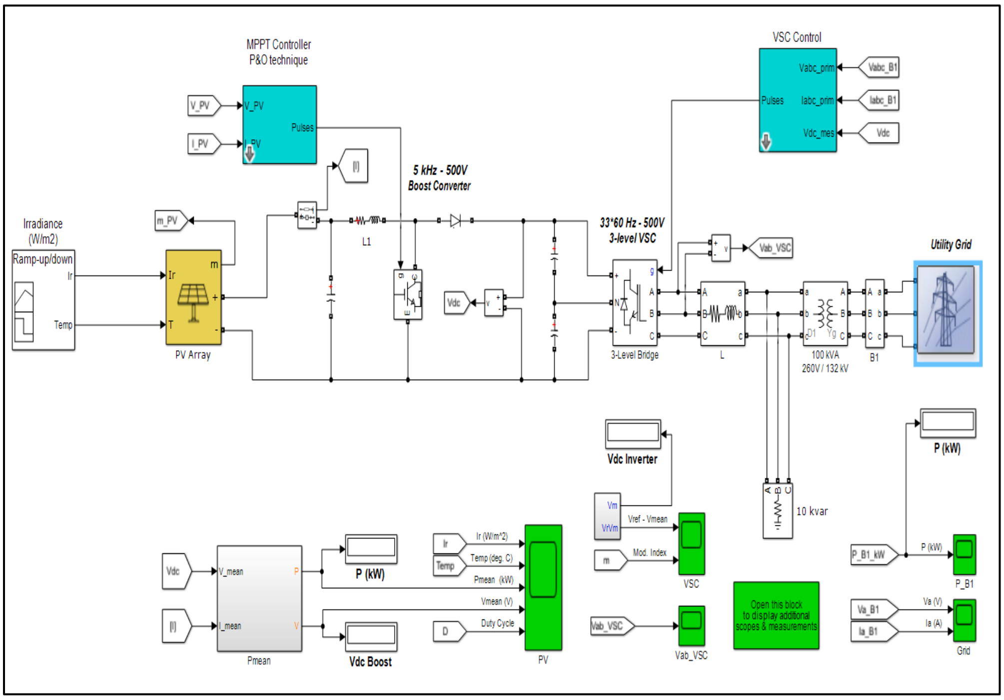

Figure 3.11. SIMULINK Block Diagram

3.5.2. Incremental Conductance

Incremental conductance is one of the good algorithms for tract the MPP on the PV curve. Conductance is the inverse of resistance. Mathematically,

$$\text{Conductance} = \frac{1}{\text{Resistance}} = \frac{\text{Current}}{\text{Voltage}}$$

The incremental conductance is named because the algorithm tracks the $\frac{\Delta I}{\Delta V}$ (Incremental conductance) to approach the MPP point. The incremental conductance uses the slope of the PV curve to reach the MPP. In the case of the MPPT algorithm, complex algorithms work much better than simple algorithms because complex algorithms incorporate multiple parameters. That is Incremental work better than the P&O algorithm because it contains instantaneous conductance $\frac{I}{V}$ and incremental conductance. The algorithm changes the square wave's duty cycle according to the following conditions. On the left side of the MPP, the value of the derivative is positive, while on the opposite side, it is negative [44,45], as given by:

$$P = IV \tag{3.9}$$

$$at\ mppt \qquad \frac{dp}{dv} = 0 \tag{3.10}$$

$$\frac{dp}{dv} = I + V\ \frac{dI}{dv} = I + V\frac{\Delta I}{\Delta V} = 0 \tag{3.11}$$

$$\frac{\Delta I}{\Delta V} = -\frac{I}{V} \quad at\ mppt \tag{3.12}$$

$$\frac{\Delta I}{\Delta V} > -\frac{I}{V} \quad ,left\ of\ mppt \tag{3.13}$$

$$\frac{\Delta I}{\Delta V} < -\frac{I}{V} \quad ,right\ of\ mppt \tag{3.14}$$

Equations (3.12), (3.13) and (3.14), which demonstrate how the incremental conductance can track the MPP, allow us to know the PV's instantaneous current and voltage values while contrasting them to the incremental conductance. (3.14). The algorithm selects the amount of array voltages by increasing or decreasing the duty cycle of the power converter to achieve the maximum power point. The entire procedure is consistent until an alteration in the current is detected, at which point the tracking method begins again and the set of instruments continues to be distributed at the MPP, a sign that changes in the environment have occurred, is detected. Once that happens, a new tracking cycle begins until the MPP is again reached. The basic working of the incremental conductance is shown in the Figure 3.13 [70].

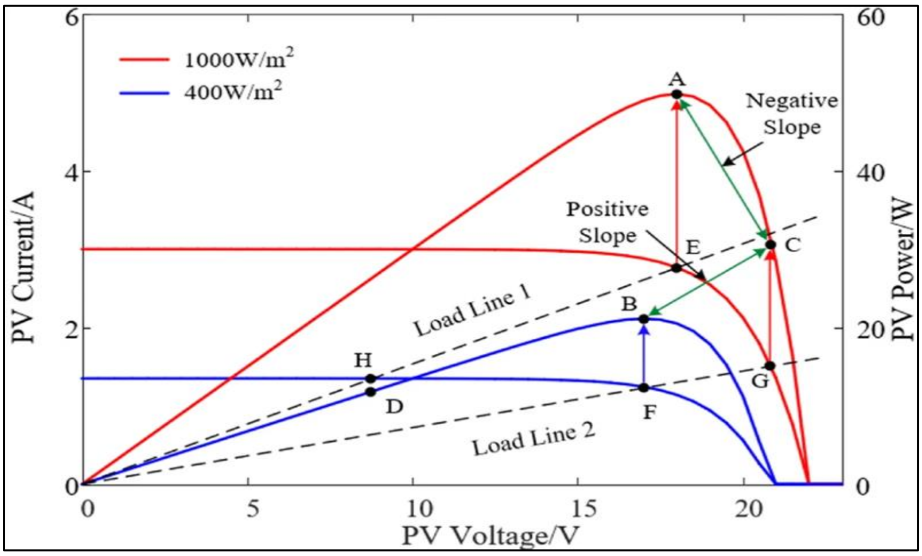

Figure 3.12. Incremental conductance working visualization.

The flowchart of the algorithm is shown in the Figure 3.14.

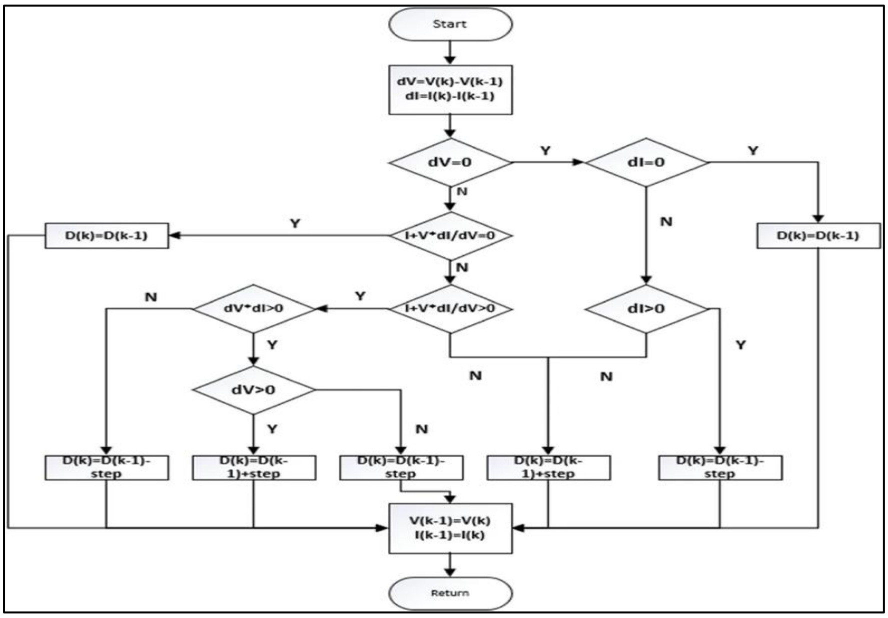

Figure 3.13. Incremental conductance Flowchart

The SIMULINK model for implementing the incremental conductance method is in the Figure 3.15.

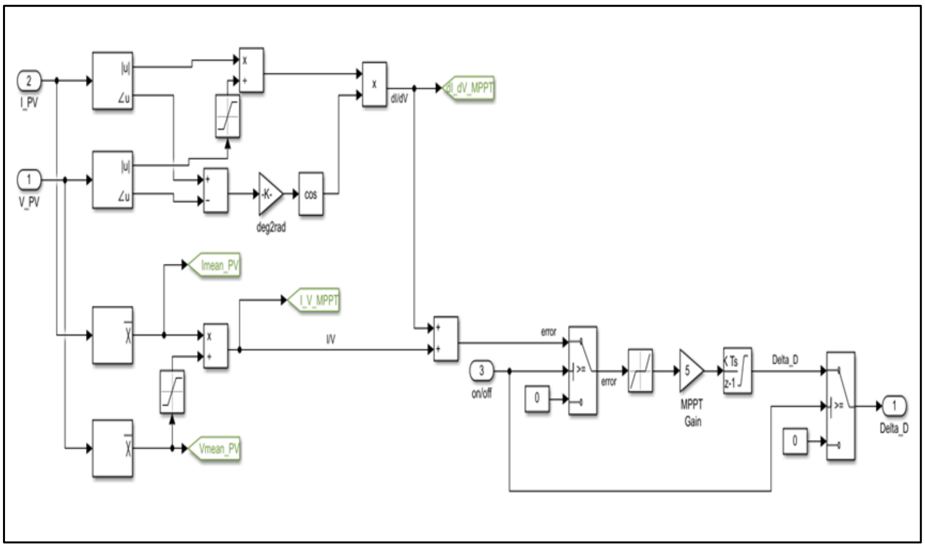

Figure 3.14. SIMULINK model of Incremental conductance

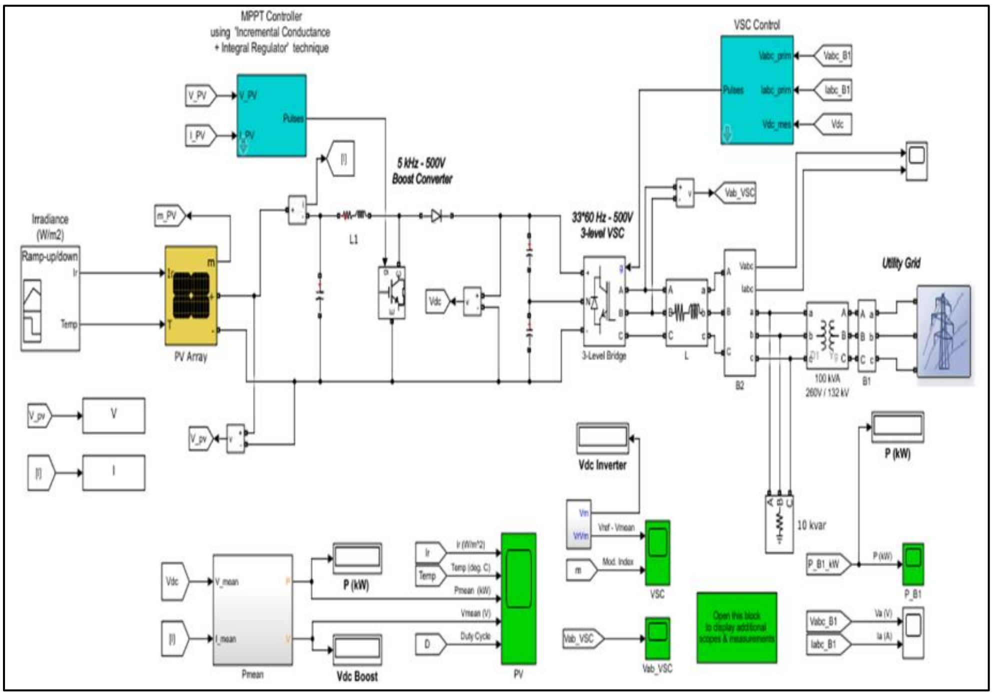

Figure 3.16. SIMULINK Block Diagram

3.6. INVERTER

The output voltage of the DC/DC boost converter is fed to the inverter to convert to 3-phase AC voltages to make it compatible to be connected with the 132kV grid. To get the 3-phase AC voltage, the transistors in the inverter circuit should be 6 and 6 square wave signals are required to derive the transistors. Out of 6 square waves, 3 square waves complement the other 3 square wave signals. The general circuit of the inverter is shown in the figure 3.17 [114].

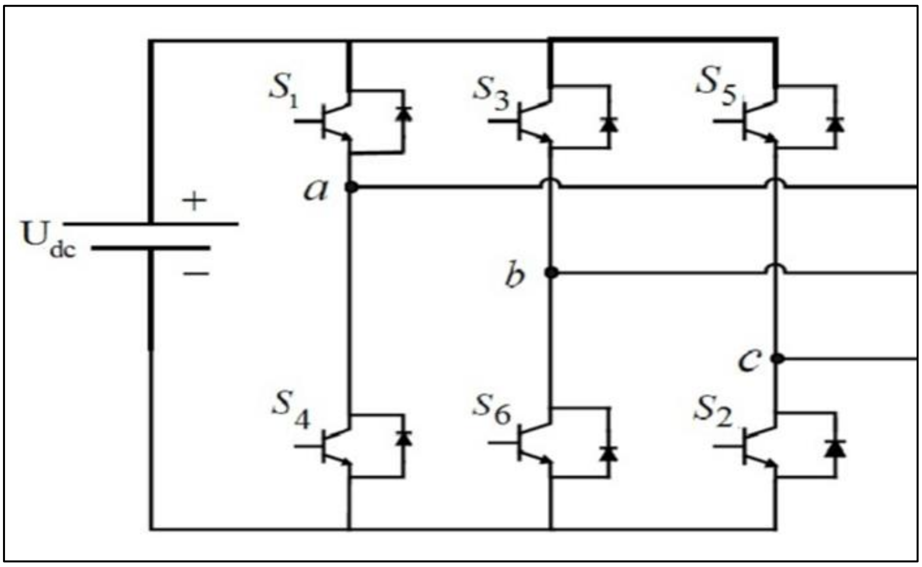

Figure 3.15. Inverter circuit

In the circuit, the output lines a, b, and c are the 3-phase AC lines, and the switches from S1 to S6 need to operate so that output is 3- a phase approximate sine wave of a specific frequency. Notice that transistors S1 and S2 are connected in the series. So, making it both "on" simultaneously will cause a short circuit. So, they should never be "on" at the same time switch S4 should complement switch S1 not to have a short course for even a sec. To get 6 square waves for deriving the transistors, the VSC controller is described below in detail. In general, three-phase sine signals of a small voltage and a triangular signal are required to generate 3 square signals and complement them to get the other three squares. So, in this case, the 132kV grid is connected. So, using the AC voltages and currents will be appropriate to create the triggering signals to make it sync precisely with the inverter voltages to make it compatible to connect to the grid.

3.7. VOLTAGE SOURCE CONVERTER (VSC) CONTROLLER

The input to the controller is 3-phase AC voltages and the current of the 132kV bus and DC voltage at the Boost converter's output. The general block diagram of the VSC controller is shown below [115]:

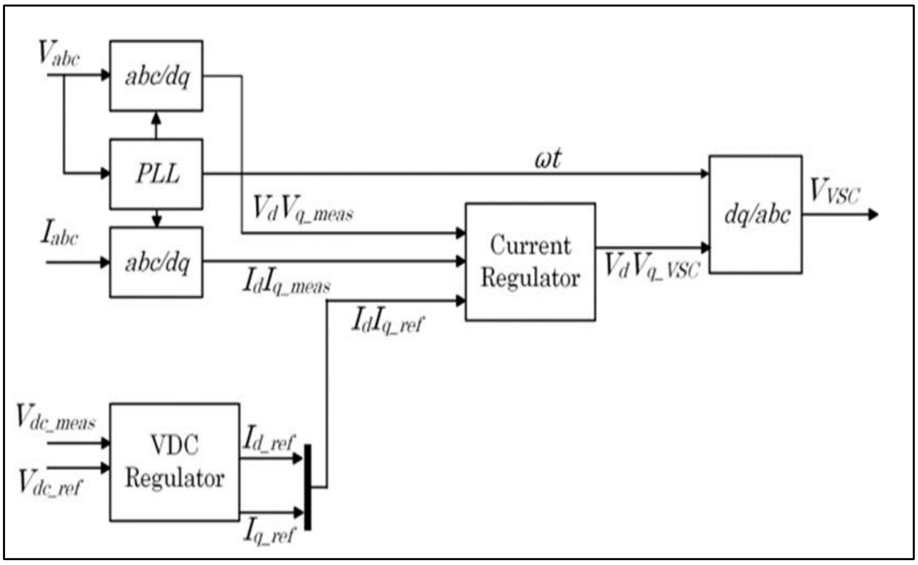

Figure 3.16. Block diagram of the VSC controller

The components of the VSC controllers are Phase Lock Loop (PLL), Voltages and current regulators, and abs-to-dq converter and vice versa. The SIMULINK block diagram for the VSC controller.

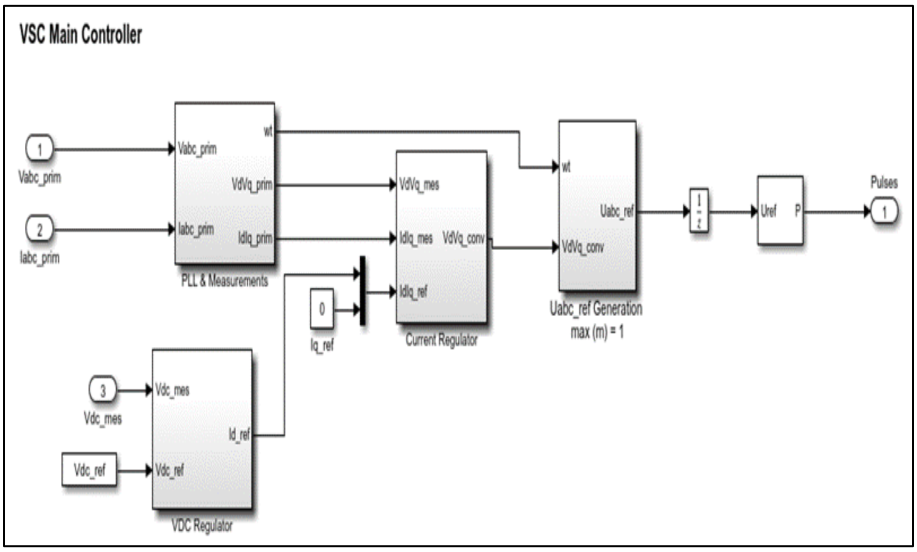

Figure 3.17. SIMULINK Block diagram of the VSC controller

3.8. 132KV GRID

The grid contains a 3-phase source, transmission lines and the load connected. The Simulink block diagram of the 132kV grid is shown below:

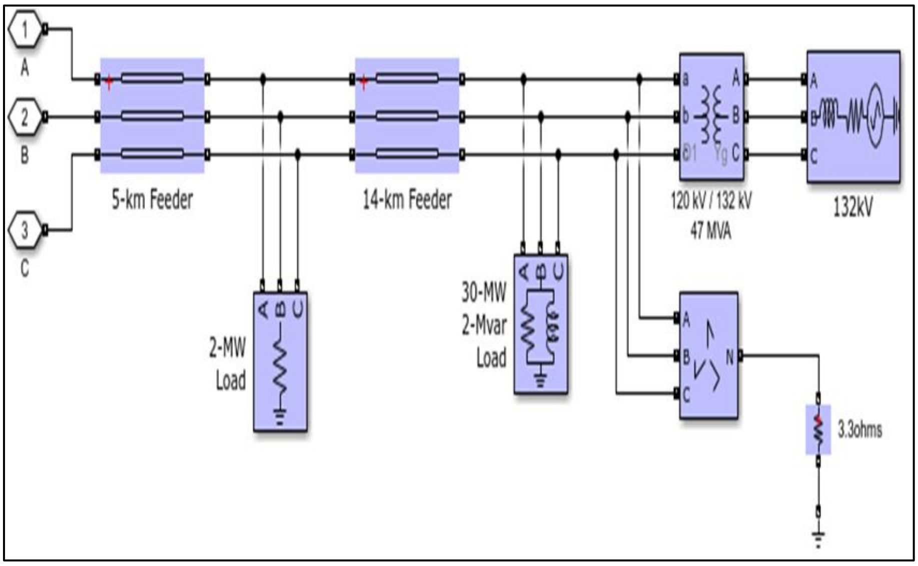

Figure 3.18. 132kV grid

PART 4

RESULTS AND ANALYSIS

4.1. INTRODUCTION

This chapter describes the researcher's developed model, the simulation study and the outcomes of several situations. These findings should demonstrate the configuration's significance and competitiveness quality. The researcher created solar panels to transform solar energy into electrical energy. It is a combination of solar photovoltaic module connections in series and parallel. Solar cells, produced by semiconductors, are used to design solar PV modules. Two MPPT approaches are presented in this work. Under the abovementioned circumstances, these strategies are employed to get the most power possible from the PV module.

4.2. ANALYSIS OF P&O

This study runs the SIMULINK model for about 3 seconds considering the Fixed step discrete simulation with a step size of a microsecond. Although the P&O method tracked the peak power, it is inaccurate, and the reaction is sluggish due to additional oscillations. The results obtained are discussed below in detail. Considering the P&O algorithm, the PV modules should operate on the maximum power point (MPP) to ensure the best possible usage of the PV module. It is analyzed by looking at the PV and IV curves representing the performance of the PV module. The PV and IV curves are below in the figures. The system was typically running at full power.

Additionally, the solar panel was extremely sensitive to changes in temperature and sunlight because it lost curve harmonics and affected the distorting characteristics of the line at voltages between 160 and 275 V. The highest possible power output is.

impacted by this distortion, which also decreases system reliability, as in Figure 4.1. This voltage variation affected the current distortions for the same reasons as in Figure 4.2.

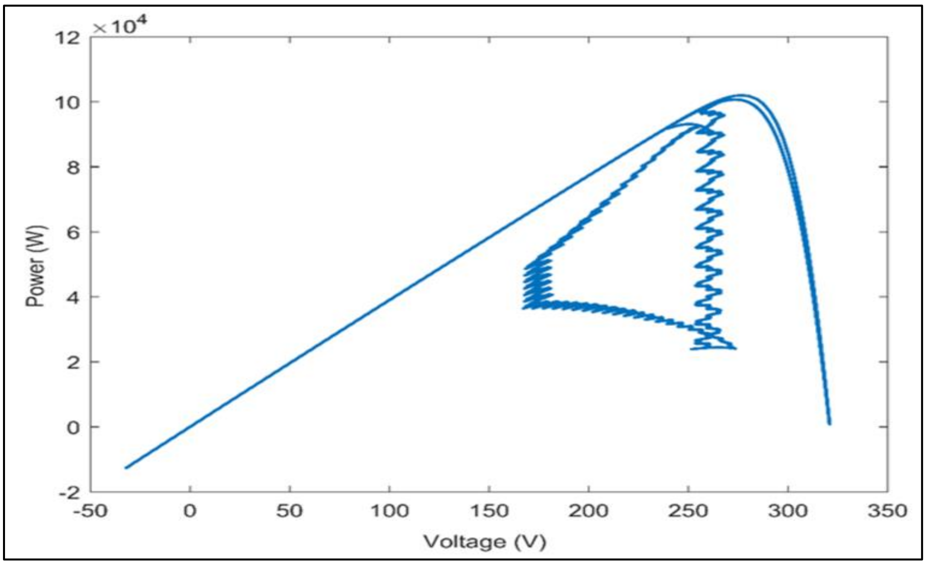

Figure 4.1. PV module output curve

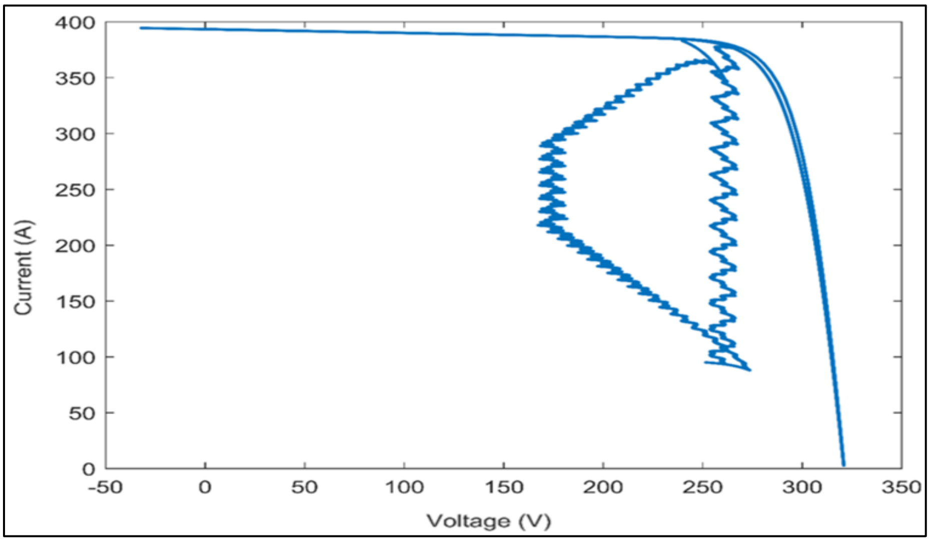

Figure 4.2. PV Module Intrinsic Value

Looking at PV and IV curves, the system is usually operating at the maximum power point. The distortion appears in the curves because of the changing irradiance and temperature set in the simulation setting. The P&O algorithm is one of the fundamental ways to access the MPP.

The irradiance and temperature profile for the 3-second simulation described in figure 4.3, and it was from (0-0.5) second, it showed high irradiation of (1000 w/m^2) and temperature is at 25˚C. Moreover, from (0.5-1) second, there is a drop in radiation until it reached 250 w/m^2 and temperature constant at 25˚C. The radiation rises from (1.5-2) second until it reached (1000 w/m^2) and become stable, and for temperature, it rises from (25-50˚C). We will see the change in irradiation and temperature of the simulation in the Figure 4.3.

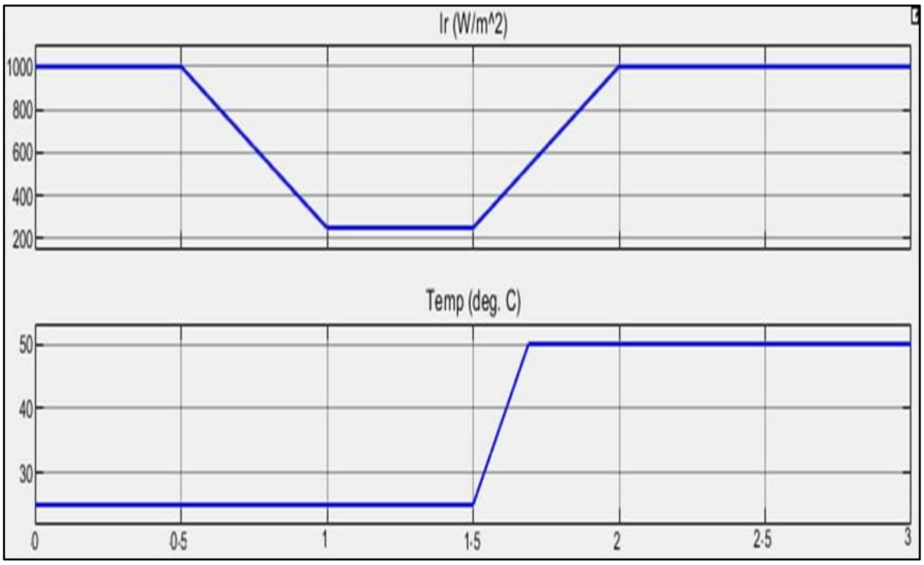

Figure 4.3: Irradiance and temperature profile for the system

The power delivered from the PV module to the load, the output voltage of the boost converter, and the duty cycle of the square drive of the transistor of the boost converter are shown in the Figure 4.4.

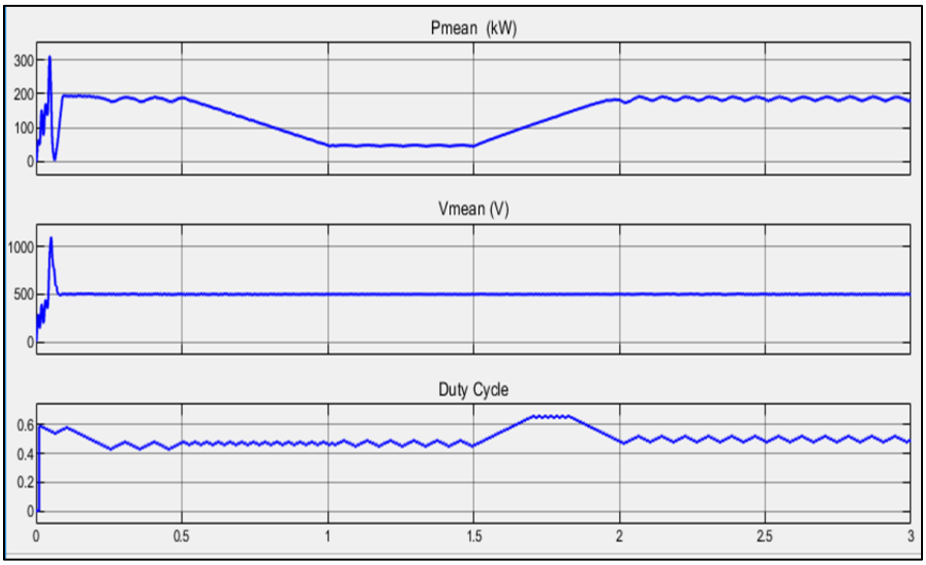

Figure 4.4. PV module Power, Boost voltage, and Duty cycle D

Notice that the duty cycle plot repeats when it becomes steady after irradiance or temperature changes. It shows that the system is moving slightly on the Maximum power point (MPP). One disadvantage of the P&O algorithm is that the system cannot reach the MPP. This slight repetitive movement on the MPP is seen in Figures above.

4.3. COMPARISON OF USING (P&O /I & C)

After running the SIMULINK model for about 3 seconds, considering the Fixed step discrete simulation with a step size of a microsecond, the results obtained are discussed below in detail. From the model, figures 4.5 and 4.6 show the differences between the P&O and I&C technique in terms of power and current change.

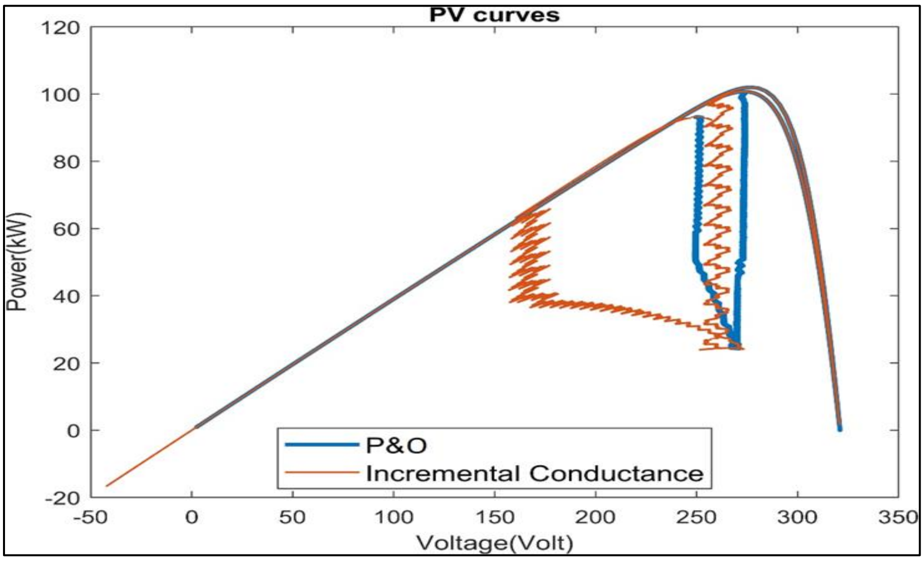

Figure 4.5. PV module output curve

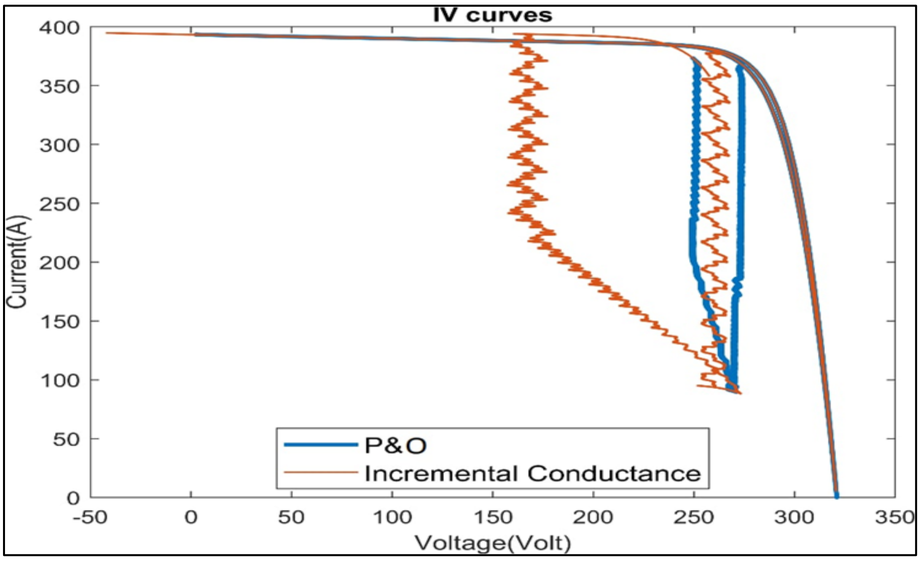

Figure 4.6. PV Module Intrinsic Value

Looking at PV and IV curves, the incremental conductance algorithm works better for both algorithms than the P&O algorithm. Notice the PV curve; the incremental conductance operates much closer to the Maximum power point than the P&O module. The reason is sensitivity to the sudden change in the irradiance. The I&C is not sensitive to the sudden change in the irradiance. The irradiance and temperature profile for the 3-second simulation is below in the Figure 4.7.

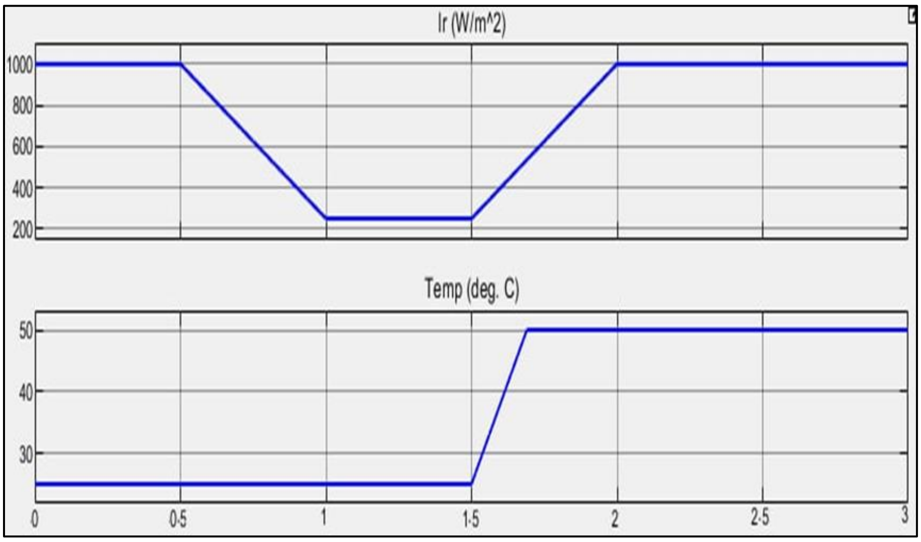

Figure 4.7. Irradiance and temperature profile for the system

The power delivered from the PV module to the load, the output voltage of the boost converter, and the square's duty cycle drive the boost converter's transistor for both algorithms are shown in the following Figure 4.8.

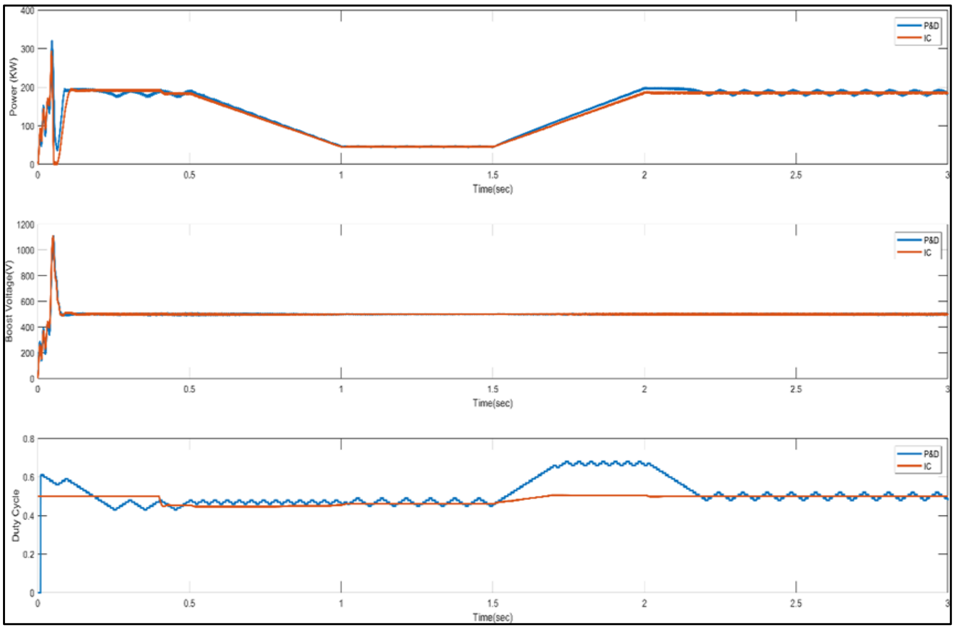

Figure 4.8. PV module Power, Boost voltage, and Duty cycle D

Notice that the power drawn from the PV module and boost converter is almost equal for both techniques from (0-0.5) second. The power drawn from the PV module is steadier and more stable in the incremental conductance than the P&O algorithm. A drop in power from (1- 1.5) second after that it rise again gradually from (1.5-2) second to become stable after that. Moreover, for the P&O algorithm, the duty cycle plot repeats itself when it becomes steady after irradiance or temperature changes. It shows that the system is moving slightly on the Maximum power point (MPP). One disadvantage of the P&O algorithm is that the system cannot become on the MPP. This slight repetitive movement on the MPP is seen in Figure 4.8. The duty cycle is steadier in incremental conductance than the P&O algorithm. The I&C operates much closer to the MPP than the P&O technique. The reason is sensitivity to the sudden change in the irradiance. The 3-phase voltage and current from the 132kV bus are shown in the following figures 4.9, 4.10, and 4.11.

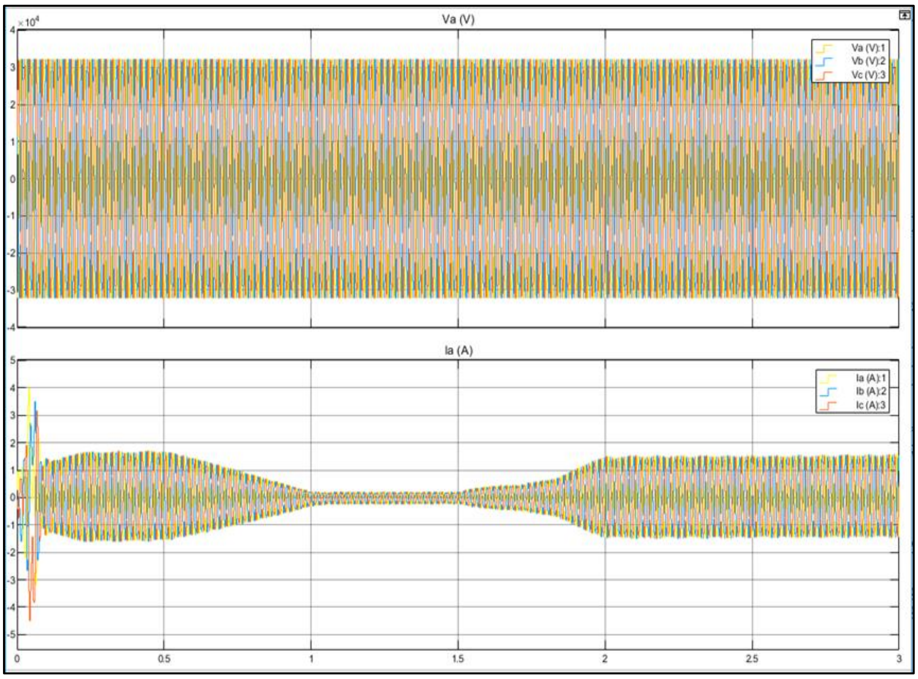

Figure 4.9. 3-phase voltage and currents of the 132kV bus

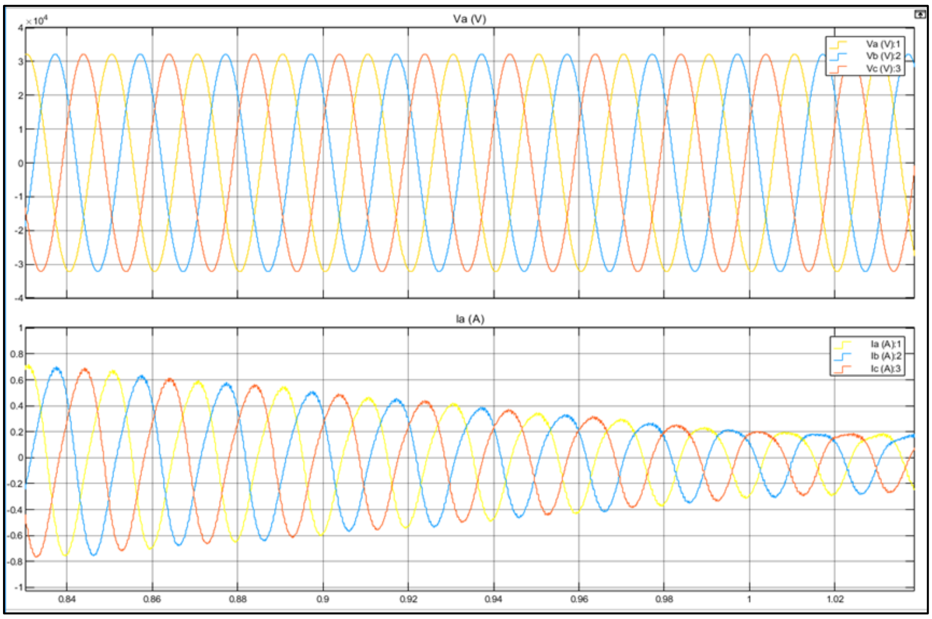

Figure 4.10. Zoom view of 3-phase voltage and currents of the 132kV bus

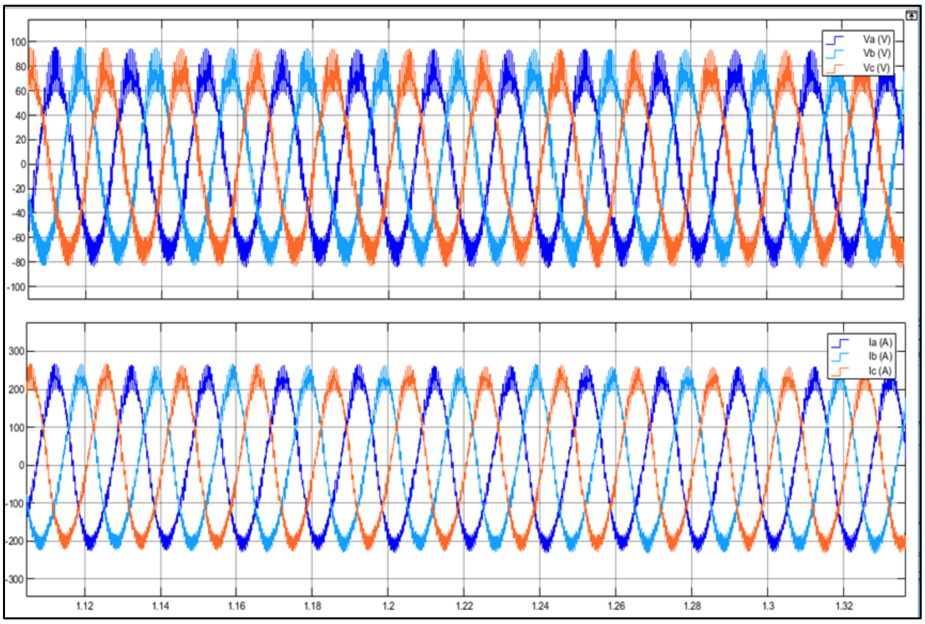

Figure 4.11. 3-phase voltage and current output of the inverter

The distortion in the voltage-current is because of the ripple voltage of the boost converter. Generally, the boost converter is not working like an ideal amplifier. There is some distortion in the output voltage, and a range is defined for 500V output, and voltage must be between 495V to 505V with $\pm 5V$ ripple voltage. The ripple voltage can be minimized by improving the boost converter design, but it could not be 0. So, this ripple voltage is responsible for the distortion in the 3-phase voltage and current output of the inverter. It is because of the harmonics involved, and the harmonics could be reduced by using a suitable filter (LC filter) to mask higher frequencies, especially the third harmonics (3*fundamental). Frequencies = 3 * 50 = 150 Hz

PART 5

CONCLUSION AND RECOMMENDATION

The study used MATLAB/Simulink to develop the system's suggested features. The researcher recreated various situations to validate the viability of each component and the system's efficiency. The outcomes of simulating multiple scenarios have been described, resulting in the following accomplishments: The Solar panel has been designed and analyzed, proving the developed model's reliability compared to produced models under different weather situations. The IC approach is superior to perturb and observe since it can identify the MPP utilizing fewer harmonics surrounding this value. In addition, it can execute the MPPT technique with greater precision than the P&O approach, which is proven even when the irradiation changes incredibly quickly. The researcher used a VSI inverter transmitted with an LC filter to reduce lower-order harmonics.

The primary objective of this study is to introduce the renewable energy in Iraq and to present an updated simulation model for a solar photovoltaic (PV) system that utilizes the (P&O) and (I&C) techniques for (MPPT). The MPP tracker is required to optimize its load in order to align with the highest possible output of electricity of the most electrically productive (PV) generator. The MPP of a PV module changed with the varied solar radiation and temperature and it tested to the weather condition of Iraq. In the simulation both P&O and I&C tested to obtain the maximum output power to grid. Firstly, the model used P&O algorithm which is one of the basic approaches to assess the maximum power point (MPP), and sometimes it is called a hill climb algorithm because the PV curve looks like a hill and peak point in the MPP. The disadvantages of the P&O algorithms are the drift because of the sudden change in the Irradiance, and the effectiveness of operation is not steady. This could be avoided by adding another loop to the algorithms or flow chart; this has led to better results. But its simplicity is the reason for some cons, such as sensitivity to a sudden change in Irradiance, and the point of operation is not steady and moving back and forth around the MPP; that is why the duty cycle D is periodic in the constant state. The power drawn from the PV module drops significantly after the MPP point. Furthermore, Incremental conductance incorporates the instantaneous approach to the MPP—complexity results in better performance. The incremental conductance is not sensitive to changes in the Irradiance, so the duty cycle is steady even when Irradiance changes. The simulation analysis emphasized on the credibility of the I&C to use rather than P&O. In comparison to previous studies, the inverter converts over 99% of the power from the photovoltaic panels under typical and non-typical test conditions which gave the ultimate efficiency of the proposed module. There is a need for additional research on a novel MPPT technique that could outperform different algorithms, such as fuzzy logic and Machine learning algorithms.

Furthermore, Incremental conductance incorporates the instantaneous approach to the MPP—complexity results in better performance. The incremental conductance is not sensitive to changes in the Irradiance, so the duty cycle is steady even when Irradiance changes. There is a need for additional research on a novel MPPT technique that could outperform different algorithms.

This study recommended using several options for the optimal operating system. Complex systems cannot function as intended without the use of control strategies. Model Predictive Control (MPC) is another popular method, as it is Adaptable Controller and Proportional-Integral-Derivative (PID) control. These methods achieve their intended results, see the extensive application, and come with various complications and flexibility. The output of a system under PID control is modified in response to a deviation from a predetermined value. MPC is employed in complex systems and predicts how the system will behave using a mathematical model. When dynamic or operational circumstances alter, adaptive control readjusts the system's settings to account for the shift. The recommendation is extended to Adopting the Artificial Intelligence for optimal outcomes of the PV system. The practical employment of the designed system and figuring out the real-time operation. Introduce improved P&O and I&C techniques, and fuzzy logic for the ultimate operation system.

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APPENDICES

```
function D  = PandD(V, I)
% MPPT controller based on the Perturb & Observe algorithm.
% Dp:
Dint = 0.6;
Dmax = 0.8;
Dmin = 0.2;
deltaD = 1/100;
persistent Vpre Ppre Dpre;
if isempty(Dpre)
Dpre = Dint;
Vpre=0;
Ppre=0;
end
P= V*I;
dV= V - Vpre;
dP= P - Ppre;
% if dP ~= 0
    if dP < 0
        if dV < 0
            D = Dpre - deltaD;
        else
        if dV > 0
            D = Dpre + deltaD;
        else
            D=Dpre;
        end
        end
    else
        if dV < 0
            D = Dpre + deltaD;
        else
        if dV > 0
            D = Dpre - deltaD;
        else
            D=Dpre;
        end
        end
    end
% else D=Dpre;
% end
if D >= Dmax || D<= Dmin
    D=Dpre;
end
Dpre=D;Vpre=V;Ppre=P;
```

RESUME

Her name is Aeshah Burhan Abbas ABDULKADER. Her primary and elementary education in Iraq. She completed his undergraduate studies at Middle Technical University in 2007 Baghdad - Iraq. Then she started her master’s degree in Department of electrical and Electronics Engineering at Karabuk University.