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Calculations of the Effect of Photovoltaic Renewable Resources on the Power Generation Grid Continuity

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Abstract : In order to identify these challenges and investigate the potential for solutions, it was it is vital to research and evaluate how integrating renewable energy sources into the electrical power network would affect the system. This was done to be able to address the increasing need for electrical energy as well as the ongoing integration utilize electric power systems and renewable energy sources (RES). Additionally, as the need for affordable, clean energy, such as renewable sources, has grown globally, so too has its availability. This has had an influence on the efficiency, reliability, and performance of electrical distribution networks. This study evaluated the impact of PV sources on by observing and documenting the electric power grid energy losses from acting or responding sources, as well as the grid networks' voltage variations, which resulted from The use of renewable energy sources is being integrated. Several technological aspects linked A review of the voltage output's effectiveness and quality was done. MATLAB Simulation software was used to implement the simulation model in this study. The outcomes were contrasted with the IEEE 9-bus grid standard.

Keywords: 9-IEEE standard, MATLAB Simulink, electrical power, renewable energy.

1. Introduction

Research into utilizing a variety of renewable energy sources is being pushed by rising CO2 emissions and diminishing fossil fuel stocks. By 2050, the European Union wants to reduce CO2 emissions to 80% of what they were in 1990, which is an extremely ambitious goal [1]. Electrical power systems are increasingly using renewable energy sources to replace CO2 emitting sources [2]. Solar energy is becoming more widely used. Over 2240 GW of renewable energy might be produced globally in 2016. Renewable energy sources may become considerably more prevalent if technological costs continue to fall [3]. This was the key element driving investment in renewable energy sources, in addition to the environmental pollution concern [4]. The ability to fulfill local consumption demands is one of the numerous advantages of integrating all available power sources, which eliminates having to transfer electrical power and energy across long distances [5]. The decentralized generation of renewable energy has the effect of lowering the lines' pressure as well as some of the two types of energy losses inside the aforementioned power system. This thus lessens the likelihood of increasing safety in the main network by overloading electricity transmission and distribution cables. Additionally, the transmission system operator will be in charge of the case of a power outage in his network, therefore the decrease of losses will have some financial advantages [6].

Numerous academics have started to investigate and examine the examination of the results in the case that the electrical power distribution system integrates sources of renewable electricity [7]. The fundamental issue of where and how many dispersed energy sources should be used was addressed by the researchers [8]. The primary role may vary, but the main goals are to lower losses, boost efficiency, and enhance voltage conditions [9] An extremely helpful tool for learning the status of a power system is energy calculations. Under specific parameters for the load and output, the calculation's findings will give us a range of values for the voltage's voltage magnitude and phase and capacitance. We can obtain distinct and potential states of the primary network state since the system's properties for input and output are regarded as arbitrary variables. Following that, the ideal power quantity for each set of random input variable data will be determined. Every time the optimal power is calculated, the results are recorded. This procedure is continued until the interrupt condition of the method is met [10]. Networks of energy are impacted by the growth of distributed generating systems based on renewable energy. In addition, it is challenging to maintain the stability and balance of the system since RES cannot produce power continually, unlike traditional energy sources. As a result, several research on the effects of renewable energies are conducted in the literature, including:

It was investigated how producing wind energy will affect the Iberian electricity market. Historical data for the years 2008 to 2016 is presented in some of the forecasting analyses. These investigations have revealed that when wind energy output projections are inaccurate, very negative grid conditions occur [11].

The impact of the main electrical grid's integration with renewable energy sources up to 2050, the networks for electric electricity with in European Union will be evaluated for grid efficiency. utilizing the improvement of economic circumstances in various integration instances, was also evaluated [12].

a. Some scholars discussed the problems experienced and the lessons learnt from Brazil's experience integrating renewable energy sources into the main grid [13].
b. To analyze the effects of renewable energy on a wide scalability when used into a high voltage power transmission system, a simulation was done for the Australian grid electrical power distribution system model [14].
c. Costs of renewable energy sources and technical diversity, the addition of energy to Chile's electricity grid, Emissions of carbon dioxide, and energy consumption, are all studied [15].
d. The Waybill distribution function has been used to research and analyze how Electricity and production are impacted by wind farms. The findings of this approach were utilized to calculate the electrical grid lines' transmission capabilities [16].
e. It was investigated, examined, and assessed how Malaysia may use solar energy. In order to assess the potential, this study also supplied data on clean power intensity as well as the use of environmental assets in engineering [17].
f. In a research and examination of the significance of precise RES forecasting for power systems, it was determined that a control reserve was required due to the rising integration of RES [18].
g. It was shown how the electrical network will behave in the case of a failure as a result of the rise in distributed generating. He argued that following a certain error, the system should reestablish its equilibrium. Therefore, it is necessary to look into and evaluate all of these options for dispersed generating sources.
h. Breakdown and transmission using power generation in the event of any momentary electricity distribution software glitch were analyzed, and it was established the distinction among both the basic scenario and with or without DGs [19].

2. Scientific Method

To assess the effects of a PV energy source that is connected to the electrical grid, a few crucial technical factors in two scenarios will be researched and analyzed. In the first case, the system will be studied independently without connection with the photovoltaic source, but in the second situation, the availability of a sustainable solar form of energy will also be taken into consideration. There will be three categories used to group the technical elements. Power loss, voltage fluctuation, and load capacity will all be covered in the first unit.

Additionally, several technological aspects have been investigated and evaluated in two scenarios: this one is whenever the solar generator is not incorporated into the power supply, and the second is when it has. This paper presents the investigation and analysis of power losses, load capacity, and voltage fluctuation.

Significant thought has also gone into how the load on the nodes would be affected by the accompanying PV power supply. Then, the amount of solar radiation that is randomly released is gauged. It is crucial to comprehend and evaluate the influence of how the major power distribution system will operate and how well it will perform with the incorporation of photovoltaic panels in order to develop an appropriate model to compute the quantity solar frames' output effectiveness, etc.

2.1. The High Solar Concentration Factor

The solar radiation may be calculated and known for a set amount of time using the probability intensity function of the beta distribution, which has the following structure [20].

$$f(r) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} \left(\frac{r}{r_m}\right)^{\alpha-1} \left(1-\frac{r}{r_m}\right)^{\beta-1} \quad \text{-------------} \quad (1)$$

Where & denotes the characteristics of a Beta distribution, and what the Beta symbol is, and r & rm denote the immediate and greatest sunlight irradiance at a specific time interval. The mean and variance of sun irradiation over a period of time may be used to determine the following characteristics of the power generation radiation's Beta distribution [21]:

$$\alpha = \mu\left[\frac{\mu(1-\mu)}{\sigma^2} - 1\right] \quad \text{-------------------------} \quad (2)$$

$$\beta = (1-\mu)\left[\frac{\mu(1-\mu)}{\sigma^2} - 1\right] \quad \text{-----------} \quad (3)$$

The mean sun irradiation value was 3.034, the median value was 2.299, and the maximum value was 1.029 (kW/m2). These values are used to calculate the beta distribution parameters.

2.1.1 Loss parameters of active and reactive power

Losses in reactive power at active lPa ' technical details In basic scenarios without RES and RES scenarios, lPr compute the total power losses for both active and reactive. They are expressed mathematically in terms of formulae (4) and (5) [20]:

$$LPa = 1 - \frac{Re[Sy]}{Re[Soy]} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. \quad (4)$$

$$LPr = -\frac{Ie[Sy]}{Ie[Soy]} \quad \dots\dots\dots\dots\dots \; \dots\dots\dots\dots\dots\dots\dots\dots. \quad (5)$$

where;

Sγ ; Absence of solar energy results in a complete lack of active power.

Soγ : Absent a solar energy source, there is a complete loss of active power.

Once the parameters' values are (0 < LPa ,LPr < 1), Positive outcomes might be attained , with a bigger decrease in loss if the penetration of solar panels is reduced, Negative readings, however, indicate a rise in power losses.

2.1.2 Index of network voltage fluctuations (Vd)

A good power transmission is ensured by maintaining the voltage within the necessary range. The Grid Code specifies the maximum permissible voltage variations in great detail. The allowed variation is typically between 5% and 10% that of the nominal voltage. The sensitivity of a few loads and voltage. levels over the established limits varies. This value is significant in some circumstances, particularly with respect to motors whose starting torque is proportional to (V2), since the result of low voltages challenging to begin with sort both an engine excessive voltages hasten gadgets may be harmed by the insulation's deterioration.

The greatest deviation between busbars is indicated by the (Vd). In order for this system to operate optimally, a consistent profile voltage is often desired. As a result, positive voltage parameter values signify a consistent voltage profile, whereas negative values suggest a greater voltage variance. These formulae translate the index into mathematical terms [21]:

$$Vd = (Vomax - Vomin) - (Vmax - Vmin) \quad \dots\dots\dots\dots\dots. \quad (6)$$

Where :

V_{max} :. Maximum and voltage values in the system incorporating the solar source

$V_{min:}$. The system's minimum voltage when incorporating a solar source

Vomax :. Maximum system voltage absent a solar source

Vomin:. the system's lowest voltage while using no solar power

2.1.3 Index of the load level (LL**)**

This parameter describes the systems' transmission lines' degree of load. It may have an impact on the cost savings connected to the building of extra electrical power lines that are required as a result of the escalating system load. The index may be written mathematically as [21]:

$$LL = \max\left(\frac{SL_m^0}{SR_m}\right)_{m=1}^{NL} - \max\left(\frac{SL_m}{SR_m}\right)_{m=1}^{NL} \qquad \text{........} \qquad (7)$$

where:

SL^0_m & SL_m. : the feeder load for the solar-powered system

SR_m : is the maximum load that a feeder can carry, and NL is a measure of the system's overall feeder count. This indicator measures if incorporating solar power changes, the amount of load on the most congested transmission lines for the better or worse. Therefore, altering the load on the lines immediately impacts the system's capacity to handle future increases in demand. This indicator suggests obliquely the expenditures required for a new transmission capacitance.

2.1.4 Effects of parameter modifications on the properties of a PV module.

The I-V and P-V characteristics are displayed in Figures 1 and 2 for varied irradiations at a constant temperature of 25 °C. These graphs demonstrate that the module current is proportional to radiation whereas the open-circuit voltage very marginally alters with radiation. [22].

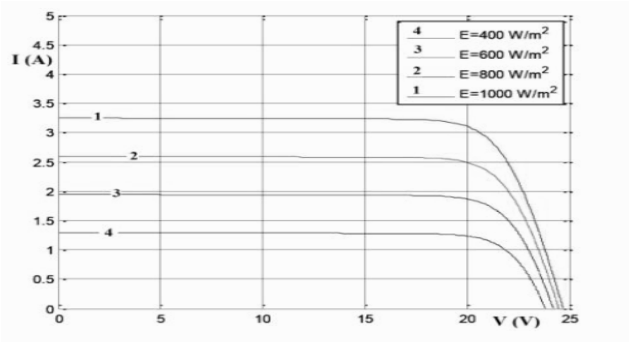

Figure 1: The outcome of the preservation on the I -V characteristic

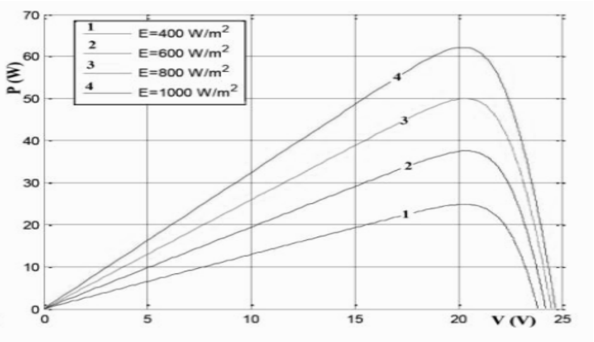

Figure 2: The effect of preservation on the P-V characteristic

The MPP rises from 24.85 for a 400 W/m2 irradiation to 62.2 for a 1000 W/m2 irradiation, as shown in Table 1's values of various MPP during irradiation variation. A rise in MPP is thus possible with increased irradiation.

Table 1: Different MPP values while the irradiation is changing

Irradiation (W/m^2)	400	600	800	1000
Power(W)	24.85	37.53	50	62.2

Another crucial element in PV module behavior is temperature. Figures 3 and 4 demonstrate that the open circuit voltage drops as the temperature rises [23].

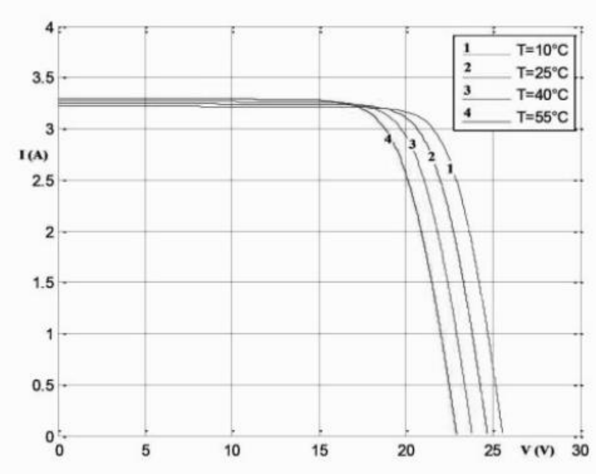

Figure 3: Depending on the temperature P-V characteristic

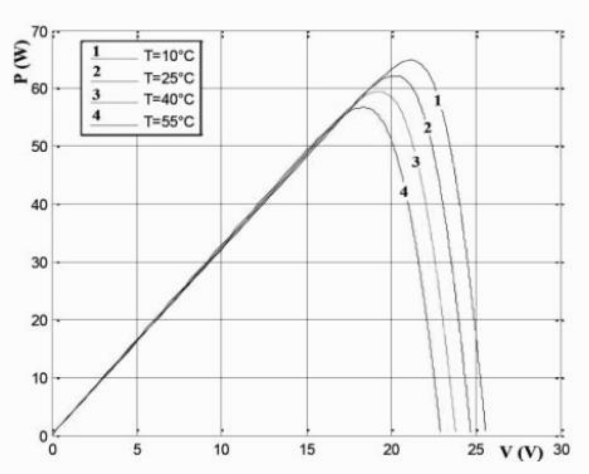

Figure 4: The result of raising the temperature. I -V characteristic

The values of various MPPs as a function of temperature are shown in Table 2; the MPP falls from 64.89 at 10°C to 56.72 at 55°C. Consequently, lowering the MPP is made possible by raising the temperature.

Table 2: Different MPP values as a function of temperature

Temperature (°C)	10	25	40	55
Power(W)	64.89	62.2	59.47	56.72

Additionally, as seen in Fig. 5, a solar panel's performance is highly influenced by the characteristics of the weight it is connected to; in fact, only a charge that flows through its particular MPP permits extraction of a powerful amount, also known as optimum resistance.

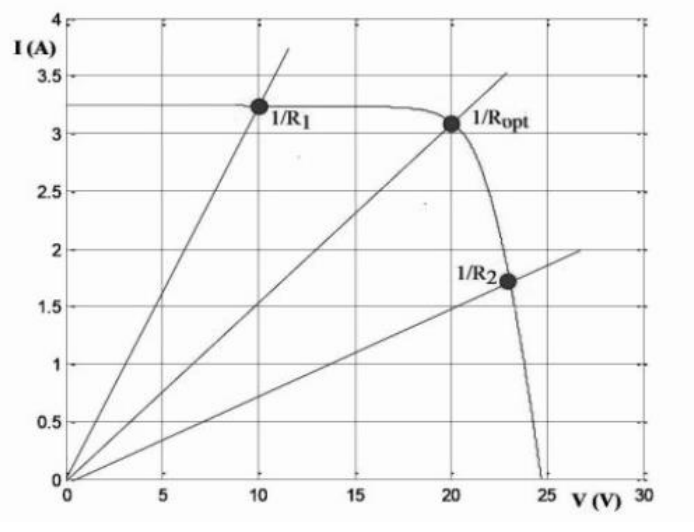

Figure 5: shows direct electrical connection between a solar cell and a resistive load.

According to the following connection, the value of the ideal resistance is determined:

$$R_{opt} = V_{opt} / I_{opt}$$

Figure 6 illustrates the properties of voltage and current (voltage current) in the presence of various resistances. Figure 7 shows the properties of voltage and capacity (current voltage) when various resistors are present.

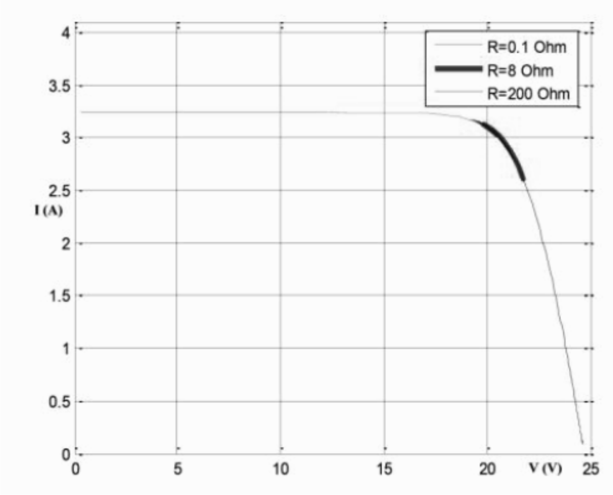

Figure 6: Current-voltage characteristics

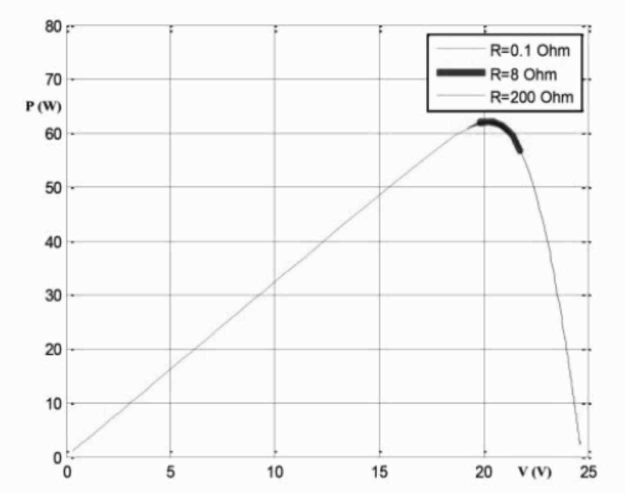

Figure 7: Power-voltage characteristics for various resistances for various resistances

The following relationship gives the value of the optimal resistance:

$$I_{opt} - R_{opt} – V_{opt}$$

The operating point of the PV system must change in order to optimize the amount of energy generated since under these circumstances the MPP of the PV array fluctuates continually. An MPPT approach is utilized to maintain the operating point of the PV module at its MPP.

2.2 Monitoring the Highest Possible Power Point (MPPT)

A maximum power point tracker (MPPT) is used to harvest and transmit the maximum possible power from the solar PV panel to the load, overcoming the aforementioned detrimental impacts on PV output power. Figure 8 illustrates the structure of the MPPT, which consists of a DC-DC converter and a control circuit with an MPP searching algorithm.

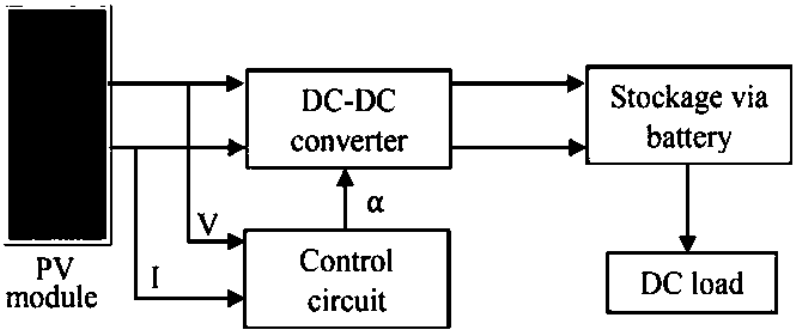

Figure 8: PV system configuration with MPPT.

2.2.1 DC-DC Converter

The coils in electronic power transformers are static energy that transfers electricity from one constant current source to another [24]. Their duty D D cycle identifies them. Lift coils, step-down helicopter boosters (boost), bottoms (buck), and the back-post helicopter are all options (Fig. 9).

The Buck-Boost converter, also known as a serial-parallel converter, translates DC & DC a voltage conversion from one to another. The magnitude and calculation of the direct current voltage, whether it is lower or higher but of opposite polarity [24].

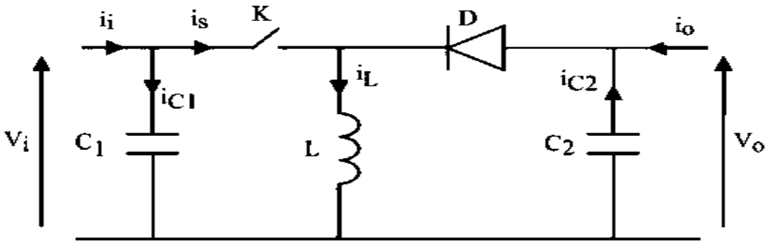

Figure 9: shows a Buck Boost converter.

The conversion ratio is calculated as follows:

$$M(\alpha) = Vs/V = -\alpha/(1-\alpha) \quad \ldots\ldots \quad 8$$

Conversion ratio versus duty cycle is shown in Fig 10.

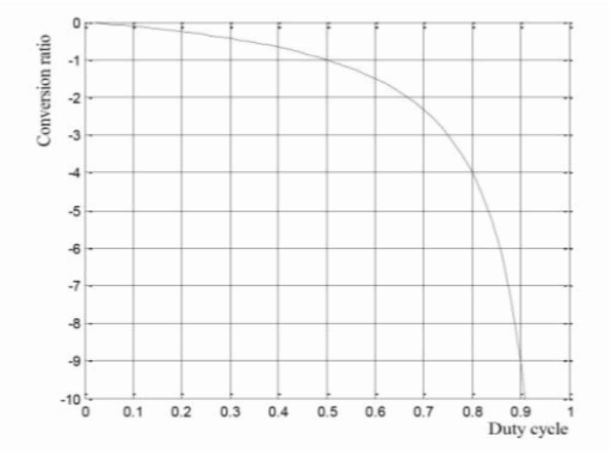

Figure 10: Change ratio versus load cycle

2.2.2 PV System Circuit Design

PV systems that are connected to the grid are generally composed of PV panels, an inverter that will convert DC power to AC power, a LC filter that filters the harmonics that the AC/DC system produces inverter and non-linear load, a current controller that blocks reverse current and prevents batteries from overcharging, a Maximum Power Point Trackers (MPPT), a Grid parameter detection Fig. 11 shows how to correctly operate an inverter linked to the grid and determine the health of the electrical grid.

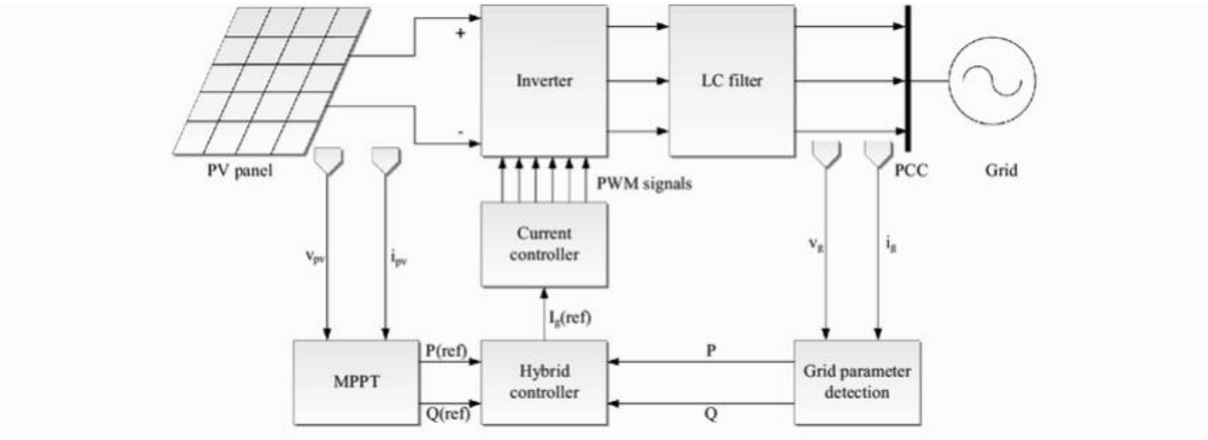

Figure 11: PV system circuit design. [25]

Regulation:

- Majority of the regulations governing electrical installations, including PV systems, are found in National Electrical Code (NEC).
- NEC is a widely accepted guideline for safe electrical installation practices that most American jurisdictions utilize as their main electrical code.
- Numerous NEC provisions, in particular Article 690, apply to the integration of a PV system with electricity.

2.2.3 Max DC Voltage

Integration of a PV system's electrical components is governed by a number of NEC requirements, most notably Article 690. This voltage determines the minimum voltage ratings, which must be lower than all DC-side system components' maximum voltage limitations (PV modules, inverter, charge controller, disconnects, and conductors). One- and two-family homes are limited to a maximum voltage of 600V for PV source and output circuits; commercial or utility-scale PV systems are permitted to use higher voltages, but they are subject to various regulations, notably those in NEC Article 490.

2.2.4 Max PV output current

The maximum PV source or output circuit voltage is calculated as follows:

$$V_{max} = V_{oc} * n_m * C_T \quad \ldots\ldots\ldots \quad 9$$

where,

V_{max} = Voc * n m * CT

V_{max} = maximum voltage of a PV system

V_{oc} = rated open-circuit voltage of the module at 25 °C

n_m = number of modules linked in sequence

C_T = adjustment factor for low-temperature voltage

2.2.5 Maximum PV circuit current

The maximum current for PV source circuits is equal to 125% of the total short-circuit current ratings of modules that are linked in parallel. The maximum current for a single series string of modules is just the short-circuit current of the module multiplied by 125%. The maximum currents of the parallel-connected source circuits are added to determine the maximum current for PV output circuits.

2.2.6 Maximum input current of an inverter

When a PV output circuit is linked directly to the inverter input of an interactive inverter, the inverter input circuit is identical to the PV output circuit and has the same maximum current. For battery-powered stand-alone systems, the battery voltage determines the inverter input current. This is how the maximum current is calculated:

$$I_{max} = \frac{P_{AC}}{V_{min} \times \eta_{inv}} \quad \ldots\ldots\ldots \quad 10$$

2.2.7 Inverter output current maximum

Due to the limited power of inverters, they do not use load calculations for sizing their AC output circuits; instead, they use the maximum inverter output. The inverter's maximum continuous output current rating is the same as the highest current that may be used in the output circuit.

3. Protection Of PV Circuits

For overcurrent protection fuses and/or circuit breakers are used. Each PV source circuit usually requires overcurrent protection. All ungrounded array conductors must include overcurrent protection. The conductors in each branch circuit (AC or DC) must be protected from overcurrent

4. Conclusions

Climate change and the rise in various gas emissions give renewable energy sources considerable advantages over traditional electrical sources. However, because of their unpredictable and intermittent character, The use of renewable power sources is being integrated into the current power system may be viewed as a complicated task. In order to prevent unfavorable circumstances that might impair the system, the influence of alternatives to fossil fuels on the electrical network distribution system has been examined in this study. The inquiry approach uses stochastic behavior to examine how renewable energy sources are used and valued in the electrical power system. Analysis has been done on the impact of solar power sources on electricity outages, voltage variation, and line load. According to the results, the utilization of renewable energy sources decreases both the load placed on electrical power lines and some active power losses. This conclusion is supported on the grounds that the integration of sun energy plants that locally utilize electrical power results in the unloading of the lines and subsequently lowers network losses. Another finding of this study is that the voltage level in the network might be affected differently by the renewable energy source. This is a direct result of the fact that network grids heavily rely on reactive assistance close to load centers.

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