A Review on Converter Topology and its Control on Solar Energy System

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Abstract: *The quantity of energy found in the sun is present as heat and radiation is called solar energy. Natural energy sources that make use of a range of constantly evolving and better technology include solar thermal energy, solar architecture, solar heating, molten salt power plants, and artificial photosynthesis. By running the PV generator at its MPP, the MPPT's job is to extract the most power possible. The PV generator, a battery, and a load profile (such a resistance or DC/DC motor) are all connected to this one. To get the most power possible out of the PV generator is the main objective of the MPPT technique. Solar Energy Systems are unquestionably helpful for the Power generation. Projects that are successfully completed will have a greater long-term value.*
Keywords: *Solar energy system, MPPT, PV Generator, Inverters, DG Converters.*

I. Introduction

India has experienced persistent energy poverty, and about a fifth of its citizens lack access to electricity. This also explains why India has some of the lowest per-capita electricity consumption in the world. Additionally, electricity is typically available only for a few hours during the day in many places. As a result, there is currently a sizable unmet demand for electricity due to its limited accessibility and availability. According to the "IESS – 2047[1] Tool" developed by Niti Aayog, Government of India (GOI), the Maximum Energy Security Pathway scenario predicts that India's electricity demand, which was 876 Terra Watt-hour (TWh) in 2012, could rise up to 5518 TWh by 2047 in the case of "Determined Effort" or default case scenario - the level of effort that is deemed most achievable by the implementation of current policies and programmes of the government might be alleviated to 3730 TWh by 2047 with heroic efforts to lower energy demand. On the supply side, India had 303118.21 MW of installed capacity as of June 30, 2016. (Ministry of Power, GOI).

India generates 62% of its energy from coal, followed by hydro, renewable energy, and gas. According to experts, coal will be the main primary energy source for power generation in India, but a report named "India Energy Outlook" published by the International Energy Agency (IEA), [2] suggests that by 2040, its share may fall to 41%. It is vital to examine the negative repercussions of coal use, which vary from pollution-related health risks to mining-related environmental degradations and human displacements [17]. Coal is a dirty fuel with the highest carbon emission coefficient. Indian coal-based thermal power facilities are some of the least efficient ones in the world, according to a report by the Centre for Science and Environment (CSE)[3]. The survey also noted that, despite rising electricity demand, power plant performance is far below industry guidelines, placing strain on priceless natural resources like water and land. Despite being clean and perfect for addressing India's peak demand, gas and hydropower did not make much progress. The absence of domestic gas supply, the wait for environmental permits, cost overruns, and public protests against the development of large-scale hydroelectric projects are the main obstacles. According to IEA projections, gas and hydro will only contribute 11% and 10% of total electricity in 2040, down from their present levels of 8% and 14%, respectively. How to provide electricity at a reasonable price with environmental responsibility is one of the main difficulties that India will face.

Solar energy is the amount of energy present as heat and radiation. As shown in Fig.1.0, examples of natural sources of energy that make use of a variety of constantly evolving and bettering technology include solar thermal energy, solar architecture, solar heating, molten salt power plants, and artificial photosynthesis. Solar energy is a particularly attractive energy source because of the vast amount that is available. 30% (about) of solar energy is reflected back to space, with the remaining 70% being absorbed by the clouds, ocean, and land masses. [18]

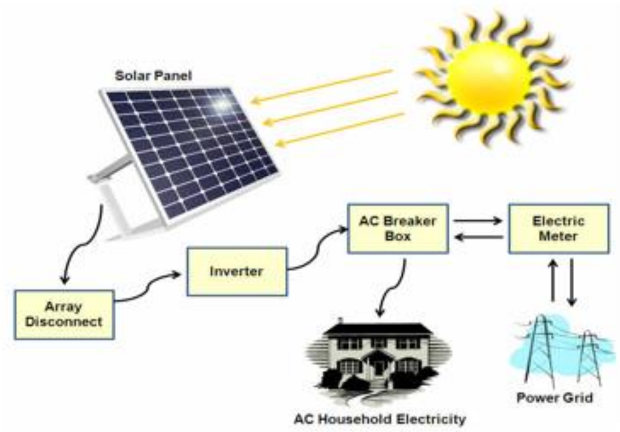

Figure 1. Solar Power System [18]

II. Inverters

In essence, an inverter converts a DC input into AC by rapidly switching the direction of the DC input back and forth promptly. As a result, an AC output is produced from a DC input. A clean, repeating sine wave that fluctuates in voltage and can be injected into the power grid can also be created using filters and other electronics. The sine wave is a shape or pattern that the voltage takes over time and is the type of power that the grid may use without causing harm to electrical equipment that is designed to function at specific frequencies and voltages. There is a trend for U.S. commercial-scale PV system (ranging from 50 kW to 250 kW) to do away with isolation transformers in order to boost efficiency, alleviate size and weight. To solve the issues in the commercial scale transformer less PV system, [1] (T. Zhao et. al., 2015) reviews the two key technologies, including transformer less inverter topologies and leakage current issue. In addition to the voltage restriction, elevated grid voltage causes an increase in power flow on the MV/LV transformers because distributed inverters throughout the network start absorbing additional reactive power to lower the grid voltage. The estimation of the hot spot temperature during this time can be used to determine the transformer's maximum load level [2] (Demirok et al., 2011). High hot spot temperatures cause the thermal insulation of the oil and windings to rapidly degrade over time. In actuality, the transformer is limited to the maximum permitted hot spot temperature defined by the transformer manufacturer. For the simplicity, 100% transformer loading will be considered as the maximum limit.
A (Bush & Wang, 2009) [3] has suggested a new PV inverter topology to address the low frequency ripple that frequently occurs in single-phase systems. It has been suggested to use the modulation and control algorithm. The modulation approach developed for the single-phase application may be expanded upon and applied to a three-phase CSI system that operates under unbalanced operating conditions. The numerical simulation results derived from a comprehensive SaberTM model have been used to verify the modulation and control methods. [4] (W. Liu, 2014) describes a grid-tie solar inverter with a series voltage compensator for alleviating the high-voltage DC-link capacitance. The compensator provides an AC voltage to counteract the voltage ripple on the DC link and draws energy from the DC link to maintain the voltage on the DC side. The compensator can be implemented using low-voltage devices since it handles small ripple voltage on the DC link and reactive power, and as a result, its volt-amp rating is low. The architecture enables replacing commonly used electrolytic capacitors with alternatives that have a longer lifespan, like power film capacitors, or extending the system lifetime even if there is a substantial alleviation in the capacitance of electrolytic capacitors due to aging. The required energy storage of the DC link is formed by a reduced value of the DC-link capacitor and the compensator. [5](Kabalcı, 2020) presents a detailed review on single- phase grid-connected solar inverters in terms of their improvements in circuit topologies and control methods. Even though there are many reviews have been proposed in the current literature, this study provides a differentiating approach by focusing on novel circuit topologies and control methods of string and micro inverters.

III. Literature Review

(T. Zhao, 2015) [1] Transformer less solar inverters are becoming more and more popular as their efficiency has been increased to an impressive 99% in residential and small commercial applications (less than 20 kW). These inverters are also becoming more and more popular on medium and large commercial scales (50–250 kW). However, there are new obstacles and issues for the commercial scale photovoltaic system to eliminate the isolation transformers and attain the competitive efficiency due to the changes in inverter power ratings, grid voltages, and standard requirements. In this article, the state-of-the-art PV inverter technologies used on U.S. commercial scale are reviewed and evaluated, and future directions for commercial scale transformer less solar inverters are suggested.
(E. Demirok et al., 2011) [2] The major goal of this study is to use solar inverters with reactive power regulation capabilities to boost the penetration level of photovoltaic (PV) power generation in low-voltage (LV) networks. This work offers a new reactive power control strategy that is based on sensitivity analysis after outlining the shortcomings of conventional reactive power strategies that are already required by some grid codes. According to the sensitivity analysis, placing the solar inverter at the end of a feeder makes a given quantity of reactive electricity more useful for maintaining grid voltage. The grid voltage support can be achieved with less overall reactive power consumption if a location-dependent power factor set value is assigned to each inverter based on this fundamental knowledge. The suggested method combines two droop functions that are inherited from the standard cos φ(P) and Q(U) strategies in order to prevent unnecessary reactive power absorption from the grid during admissible voltage range or to increase reactive power contribution from the inverters that are closest to the transformer during grid overvoltage condition. Modeling and simulating a genuine suburban LV network enables performance comparison in terms of grid losses and voltage variation with various reactive power techniques.
(C. R. Bush and B. Wang et al., 2009) [3] For single-phase photovoltaic (PV) applications, a new current source converter topology is presented in this study. The key differences between the proposed topology and existing PV inverter technology are that: a) it eliminates the low frequency (double of line frequency) ripple that is typical of single-phase inverters; b) it allows for significantly smaller passive components to achieve the required stiffness; and c) it easily achieves improved maximum-power-point-tracking performance thanks to the tightened current ripple even with reduced-size passive components. This study describes the suggested topology and its underlying working principle, supported by numerical verifications.
(W. Liu et al., 2014) [4] For lowering the high-voltage dc-link capacitance, a grid-tie solar inverter with a series voltage compensator is presented. The compensator provides an ac voltage to counteract the voltage ripple on the dc link and draws energy from the dc link to maintain the voltage on its dc side. The compensator can be used with low-voltage devices since it handles little ripple voltage on the dc link and reactive power, and as a result, its volt-amp rating is low. The architecture enables replacing commonly used electrolytic capacitors with alternatives that have a longer lifespan, like power film capacitors, or extending the system lifetime even if there is a significant reduction in the capacitance of electrolytic capacitors due to aging. The required energy storage of the dc link is formed by a reduced value of the dc-

link capacitor and the compensator. The total system's static and dynamic characteristics, as well as the control strategy, will be thoroughly mathematically analysed. There will be a streamlined design process provided for the compensator. An experimental 2-kW, 220-V, 50-Hz device has been constructed and tested. The experimental findings are favourably compared with the theoretical predictions. Last but not least, the cost of installing the dc link's electrolytic capacitor and compensator is compared.

(E. Kabalcı et al., 2019) [5] Due to the widespread usage of dispersed generation and renewable energy sources, there is a growing interest in integrating solar power into utility grids. Grid-connected solar inverters, which are the main equipment connecting solar power plants with utilities, are essential in this scenario. The microgrid restrictions promoted the usage of single-phase inverters in home power plants and grid connectivity even though three-phase inverters were the industry standard in large photovoltaic (PV) power plant applications. The advancement in circuit topologies and control strategies for single-phase grid-connected solar inverters is thoroughly reviewed in this research. Despite the fact that numerous reviews have been proposed in the current literature, this work takes a unique approach by concentrating on novel circuit topologies and control methods of string and micro inverters. The single and multi-stage solar inverters are reviewed in terms of emerging DC-DC converter and unfolding inverter topologies while the novel control methods of both stages have been surveyed in a comprehensive manner. The isolated and transformerless circuit topologies have been investigated by reviewing experimental and commercial devices. The soft computing, evolutionary and swarm intelligence based algorithms have been summarized in MPPT methods section while current injection and grid-connection control methods of unfolding inverters stage have been presented with and without PLL architecture. There are many papers have been compared and listed in each section to provide further outcomes which is followed by a summarizing discussion section and conclusion.

(K. Zeb et al., 2018) [6] With advancements in power electronics technology and growing environmental concerns, the use of photovoltaic (PV) technology in distributed generation systems is receiving more attention. Solar photovoltaic (PV) technology is essential for harnessing solar energy for the production of electricity. The use of solar PV is growing exponentially due to its clean, pollution-free, abundant, and inexhaustible nature. In grid-connected PV systems, the inverter's design and operation need to be carefully considered in order to achieve high efficiency for a variety of power topologies. Low total harmonic distortion of the currents injected into the grid, maximum power point tracking, high efficiency, and controlled power injected into the grid are requirements for the grid-connected inverter. The performance of the inverters connected to the grid depends mainly on the control scheme applied. In this review, the global status of the PV market, classification of the PV system, configurations of the grid-connected PV inverter, classification of various inverter types, and topologies are discussed, described and presented in a schematic manner. A concise summary of the control methods for single- and three-phase inverters has also been presented. In addition, various controllers applied to grid-tied inverter are thoroughly reviewed and compared. Finally, the criteria for the selection of inverters and the future trends are comprehensively presented.

(M. J. E. Alamet. al., 2015) [7] This paper proposes a multi-purpose VAr control strategy for solar PV inverters for voltage support in distribution networks. The suggested approach can be used in a variety of PV power generation scenarios. For voltage support, the inverters will typically operate in a dynamic VAr compensation mode (including low PV and no PV periods). The suggested solution will use a droop characteristic approach to manage the PV inverters to absorb VAr for voltage rise mitigation during the middle of the day when PV has excess power. By controlling the ramp-rate of the inverter VAr output, the method will alleviate voltage fluctuations while passing clouds.A dynamic model of the proposed PV inverter control has been developed to analyze its performance in terms of fast VAr control and voltage support under various PV generation conditions. The results of the analysis performed on an Australian distribution system show that the proposed VAr control strategy can mitigate voltage rise, and improve the voltage profile despite potential vast changes in the sun irradiation during passing cloud and also in the absence of PV output during the evening.

(Chatterjee and K. B. Mohanty et. al., 2018) [8] The emphasis today is shifting to the incorporation of small and medium-sized power plants powered by renewable energy sources into the electrical grid. Solar energy is the renewable energy source that is expanding the fastest, and photovoltaic facilities are connected to the distribution system using a single phase voltage source inverter. Stringent control requirements apply to the grid integrated inverter. To reduce the harmonics in the current injected into the grid and manage the power exchange between the plant and the grid, a current controller is used. The current control methods used for a single phase grid-tied photovoltaic inverter are reviewed in this work. Through simulation and experimental findings, a performance comparison of the current control approaches is also offered.

IV. Control Strategies

By injecting sinusoidal current into the grid, the DC to AC inverter helps in power factor regulation. Grid side inverters (GSI) are used to efficiently convert the DC energy generated by solar PV into AC power and feed it into the electrical grid (Zeb et al., 2018)[6]. The designing of a fast and accurate control system ensures the grid side inverter's proper operation. Therefore, one of the most significant components of the grid-connected PV system is the control of GSI. The PV control system is divided into two primary sub-classifications:

(a) MPP control module: The maximum power extraction from the PV module or input RE source is performed by the MPP control.

(b) Inverter control module: ensures (a) a proper grid synchronization and high quality of the injected power, (b) control of the active and reactive power delivered to the grid, and (c) the control of DC-link voltage.

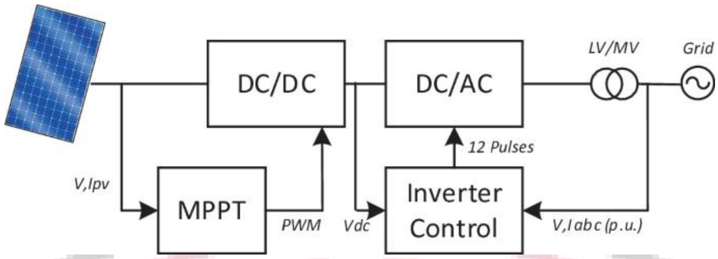

Figure 2 Architecture of solar system in grid connected configuration

A multi-purpose VAr control strategy for solar PV inverters for voltage support in distribution networks is suggested in (Alam et al., 2015) [7]. The suggested approach can be used in a variety of PV power generation scenarios. For voltage support, the inverters will typically operate in a dynamic VAr compensation mode (including low PV and no PV periods). The suggested solution will use a droop characteristic approach to manage the PV inverters to absorb VAr for voltage rise mitigation during the middle of the day when PV has surplus power. A overview of the current control strategies used for a single phase grid-tied photovoltaic inverter is included in (Chatterjee & Mohanty, 2018) [8]. It may be said that, when compared to other schemes, the MPCC scheme exhibits the best steady state performance. Effective harmonic mitigation is also accomplished by lowering the output current's THD value. The DBCC and PRCC exhibit perfect sinusoidal reference current tracking during steady state. The CHC and PICC strategies have a greater steady state current tracking error. Contrasted to other techniques, PRCC has a slow transient response. [9] (Teymour et al. 2014) have suggested a unique topology for a three-level NPC voltage source inverter that can incorporate both battery storage and renewable energy on the dc side of the inverter. The results demonstrate that the suggested system can regulate ac-side current as well as battery charging and discharging currents at several solar irradiation levels. The proposed topology to control both PV and battery storage in supplying power to the ac grid has been validated by trials utilising a prototype constructed in the lab. [10] (H. Liu et al., 2022) investigated the independent solar power system (ISPS), including the maximum power point tracking (MPPT) and the full-bridge inverter (FBI) management technologies for converting DC (direct current) to AC (alternating current). In this study, the proposed optimized FBI control strategy to the ISPS was integrated with the perturb and observe (P&O) algorithm based on the output voltage control strategy. The frequency and duty duty cycle of the suggested variable frequency and variable duty cycle (VFVDC) optimized FBI control approach could be changed. The sinusoidal pulse width modulation (SPWM) was contrasted with the proposed VFVDC control strategy. The operating frequency of FBI was 10 kHz when the output voltage was low. The proposed control strategy had a low harmonic level, was reliable and efficient, and could therefore be employed to meet actual electrical demands. A novel adaptive current harmonic control strategy for use in multifunctional single-phase solar inverters is proposed in (Xavier et al., 2015)[11] . The tactic is based on a brand-new way to find harmonic load currents. The harmonic current detection method can detect the load harmonic current at higher amplitudes and is frequency adaptable. This technique uses two phase-locked loops connected in cascade association a second order generalised integrator (SOGI-PLL). The detected frequency is used as feedback by the proportional resonant controller.

V. Ai Based Control Strategy

The PV generator will run at its MPP, and the MPPT's job is to extract the most power possible. The PV generator, a battery, and a load profile (such a resistance or DC/DC motor) are all connected to this one. The primary goal of this MPPT technique is to obtain the most power possible out of the PV generator. According to (Subramanian & Murugcsan, 2012) [12], the primary elements used in fuzzy logic-based MPPT controllers are fuzzification, rule-based, inference, and defuzzification. Maintaining the voltage and frequency within the predetermined ranges while switching between the grid-connected and islanded modes of operation is one of the difficulties faced by distributed generators (DGs) with inverter technology.[13] (El-ebiary et al., 2022) proposed strategy which is based on a deep learning neural network (DL-ANN) Proportional-Integral- Derivative (PID) controller to regulate the terminal voltage of the DG interface system. The suggested method for reducing grid harmonics incorporates a feed-forward loop by regulating the DG inverter to feed the harmonics components of non-linear loads without going beyond its capacity. For the suggested multi-level inverter, [14] (Qayyum et al., 2022) provided a thorough comparison of the SRF and AI-based control techniques. In order to alleviate the difference in inaccuracy between the target and reference voltages, ML-FFNN was used to anticipate non-linearities. A generalised model is created using the stochastic gradient descent optimisation algorithm after selecting the best weights and biases to optimise network performance. For gradient computation, the back- propagation approach is used to enhance the proposed model's overall performance. [15](Bakeer et al., 2022) offers a model-free control strategy on the basis of artificial neural networks (ANNs), for mitigating the effects of parameter mismatching while having a little negative impact on the inverter's performance. This method includes two related stages. First, MPC is used as an expert to control the studied converter in order to provide a dataset, while, in the second stage, the obtained dataset is utilized to train the proposed ANN. Simulation results reveal that ANN-based control strategy performs better with respect to the THD under most conditions. [16](Control & Networks, 2022)

VI. Applications Of Solar Energy System

The PV array (which includes the PV panels and support structures) and the balance-of-system (BOS) components are the two sections of a photovoltaic system (which include storage batteries, Charge controllers, inverters a, and wirings). A. Solar Energy's Basic Components Solar panels, charge controllers, batteries, and power inverters are the four main components of a solar power system [18]

a) Solar panels

Individual solar cells are combined to make a solar module, and several solar modules are joined to form a solar array. For maximum power output, they can be connected in series, parallel, or series-parallel combinations.

b) Charge Controllers

Charge controllers are used to keeping batteries from being overcharged by limiting high voltage, which might harm them. Pulse Width Modulation (PWM) is used in the cheapest charge controllers for the house, whereas Maximum Power Point Tracking (MPPT) is used in the best charge controllers.

c) Batteries

Deep Cycle Batteries are required for electricity storage, although more specialized batteries, such as Tubular Batteries, are gaining appeal for bigger uses such as household power.

d) Power Inverters

The PV panel generates Direct Current (often 12V, 24V, or 48V), which is subsequently converted to Alternating Current (AC) (AC).

Although Fig. 3.0 demonstrates that a DC load can be connected to the charge controller and battery storage system, a circuit breaker must be installed between the charge controller and the battery storage system to prevent excess current from flowing to the battery in the event of a short circuit. Which can be duplicated at all required locations.

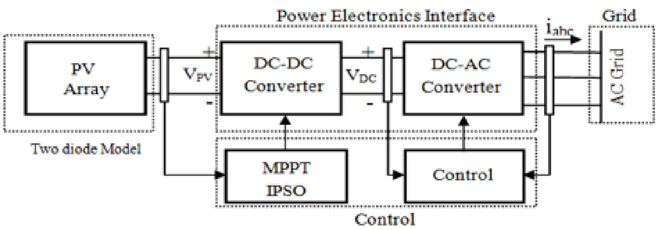

Figure 3 Block diagram of Photovoltaic System [18]

VII. Types Of Inverters For Solar System

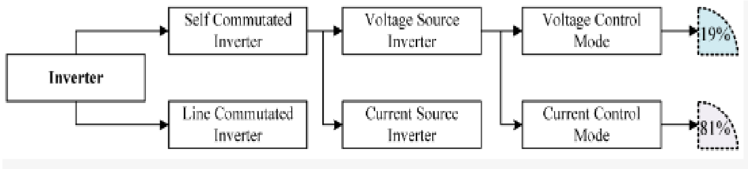

Figure 4 Classification of inverters (19)

1. Line-Commutated Inverters

The commutation process in a line-commutated inverter (LCI) is carried out by the utility grid's parameters, i.e., the polarity of the AC voltage is reversed and the flow of negative current (or zero current) starts the commutation process. The commutating thyristors, which are semi-controller devices, are typically used by the LCI as power switching devices. The device's gate terminal controls turn-on, but turn-off cannot be managed using the same mechanism because turn-off is dependent on line current or grid voltage. Therefore, an external circuitry is added to the semi-controlled devices to regulate the turn-off procedure as well, in the event that a forced commutation is required. For instance, the half-bridge LCI converter adds an anti-parallel diode for enabling the process of forced commutation. [20]

2. Self-Commutated Inverter

The fully controlled power electronic converter is called a Self-Commutated Inverter (SCI). The power switching devices' ability to turn on and off is controlled by the potential at the gate terminal. It is possible to permit a regulated transfer of current from one switching device to another. MOSFET and IGBT are among the components utilized in the SCI. IGBTs are employed for applications requiring low-frequency ranges of 20 kHz and medium to high power levels surpassing 100 kW. On the other side, MOSFETs are used for high frequencies typically between 20 and 800 kHz and low powers under 20 kW. Using the Pulse Width Modulation (PWM) switching technology, the output voltage waveform is generated, and the SCI is controlled. High switching frequencies are necessary for grid-connected inverter applications in order to alleviate the output current and voltage harmonics, as well as the output filter's size and weight [46]. The SCI regulates both the output current and voltage waveform of the inverter because it is a fully controlled power electronic converter. Additionally, it alleviates current harmonics, boosts grid power factor, and is extremely robust to utility grid disturbances. Nowadays, SCI is preferred over LCI for grid-connected PV systems due to the advancement made to the control system for SCI and in addition, due to the evolution of advance switching devices similar to that of the power IGBTs and MOSFETs. The SCI can further be divided in to voltage source converters and current source converters.[20]

2.1. Voltage Source Inverter

Because the DC voltage source is on the converter's input side in a voltage source inverter (VSI), the polarity of the input voltage is maintained. But the direction of average power flow through the inverter depends on the polarity of the input DC current. You can get an AC voltage waveform with a variable width and constant amplitude at the output side. To control the current flow from the inverter to the utility grid, a tie-line inductor is employed in addition to the VSI. Additionally, a large capacitor that resembles a voltage source is connected in parallel to the input DC side of the VSI. The Voltage Control Mode (VCM) and the Current Control Mode are the two operating modes for the VSI (CCM). There is no control over the line currents in VCM because the PCC voltage is the primary controlling variable. In contrast, line currents are given in a controlled manner in CCM. For standalone or off-grid PV systems, the VCM is advised since maintaining the PCC voltage magnitude, frequency, and phase is crucial for standalone power networks. Although both VCM and CCM can be utilized for a grid-connected PV system, CCM is the more popular option. The reason for using CCM is that the stiff electrical grid dictates the PCC voltage, thus controlling the currents for delivering the produced PV power is more reliable and safer than the VCM method with no control on currents. In case of grid disturbances, the transient current suppression is possible with CCM and a high-power factor can be acquired by simple control structure that is why inverters with the CCM are extensively utilized in grid-connected PV systems. Thus, the preferred inverter for a grid-connected PV system is the VSI operated in current control mode.

2.2. Current Source Inverter

In Current Source Inverter (CSI), the input side of the inverter is connected to a DC current source and hence, the polarity of the input current remains the same. The polarity of the input DC voltage, however, determines the direction of average power flow through the inverter. An AC current waveform of a variable width and a constant amplitude can be obtained at the output side. As opposed to VSI, a large inductor that upholds the stability of the current is attached in series to the input side of the CSI.

3. Inverters based on number of power processing stages [20]

The inverters based on the power processing stages are classified into two main types, which are the single stage inverters and the multiple stage inverters

4. Transformer and transformer less inverters [20]

According to the literature now in use, another classification of inverters is based on the presence or absence of the transformer. In other words, this classification may include single or multiple power stages, although the transformer serves as the primary basis for categorization in this instance. Transformer-based grid-connected PV inverter topologies are often divided into two categories: transformer-based topologies and transformer less topologies. Inverters use line-frequency transformers to provide a galvanic isolation between the utility grid and the photovoltaic panel. The isolation transformer aids in solving the issue of DC current injection into the utility grid from a PV system. Since, line frequency transformers are heavy in weight and bulky in size increasing in this way the overall cost of PV system, so therefore the line-frequency transformer are considered as the problematic component of the inverter. An alternative solution to this is to utilize the high-frequency transformer embedded in the inverter or DC/DC converter, which reduces the size and weight of the system, and thus decreases the overall cost.

5. Multilevel inverters [20]

Modern grid-connected PV systems are less expensive overall because of advancements made to grid-connected inverter technologies. Multilevel Grid-connected inverters provide many advantages over simple two-level inverters. The output terminal of the multilevel inverters produces an AC voltage that is made up of numerous staircase voltage levels. The multilevel inverter's staircase sinusoidal waveform closely resembles a actual, pure sinusoidal wave and has minimal overall harmonic distortion. As a result, the harmonic distortion is minimal and the filter requirement is minimised. Due to the modular design of PV arrays, it is simple to produce different DC voltage levels; consequently, multilevel topologies are primarily appropriate for PV systems. Since 1975, the idea of the multilevel converter has been presented and three-level converter initiated the term of multilevel.

For high-power needs, multilevel inverters (MLIs) have been introduced as a novel technology. Big motors, FACTS, devices that improve power quality, and renewable energy (RE) converters are just a few of the several applications that MLIs have been widely used in [21]. They generally use different direct current sources to produce the staircase voltage waveform. Electric motor efficiency in high-power applications is increased by the usage of MLIs [22]. In high and medium power industrial applications as EVs, ship propulsion drives, rolling mills, paper manufacturing, and metal forming, MLIs have recently become a significant alternative [23], [24]. Over conventional two-level inverters, MLIs have various intrinsic advantages, including as lower voltage stress, lower device ratings, and higher-quality transmitted power [25]. The bulk of critical sectors continue to use the classical MLI topologies; nonetheless, because of their numerous applications, cascaded MLIs are an important power converter [26]. For grid-connected systems, the cascaded MLIs are particularly concerned with lowering switch counts, THD, and DC supplies as well as making the network cost-effective. In today's infrastructures still in development, the RE is a crucial objective [27]. DC voltage, which is inherently unstable, is provided by RES. This RES's variable output causes to issues with power quality and network stability. Due to the standard three level inverter's numerous drawbacks, high/medium power applications require high-power components. Harmonics make up the waveforms of the output voltage. Additionally, it has large switching losses, which reduces system effectiveness. The MLIs are the prime choice in several industrial settings, as MLI more robust, low power losses, minimize the harmonics with Grid integration SPV required to address these issues. MLI with grid integration PV is regarded state-of-the-art technology and has been used in a variety of applications that minimize the level of harmonics [28]. Companies must cut inverter prices by roughly 20% within 5 years as a result of recent revisions in German subsidy schemes. In order to do this, new inverter designs have been created that combine the benefits of a string inverter's higher energy yield and a central inverter's more affordable price. Individual PV strings are connected to lower power DC to DC converters. The energy production from each PV string is separately optimized by its own MPP tracker.

The “Cascaded H-Bridge Multilevel Inverters” (CHBMLIs) are most widely used inverters for high-power medium voltage converters and AC drives [29], [30], [31]. It is made up of many H-bridge power cells which are generally linked in cascaded mode to provide medium voltage (MV) functioning with minimal harmonic distortion [29]. The usage of similar power cells results in a modular construction, which enables significant cost savings

VIII. ADVANTAGES AND DISADVANTAGES OF SOLAR ENERGY SYSTEM [32]

The sun emits energy across a broad range of electromagnetic wavelengths. The strength of the different wavelengths in the solar spectrum varies. Visible, Infrared, and Ultraviolet Radiation Photovoltaic cells primarily use visible radiation. The distribution of colours in light is significant because the various colours that reflect off of a photovoltaic cell will lead it to produce different quantities of current. The relative power levels in the various solar spectrum wavelengths are shown in Figure 5. Crystalline silicon and various other materials can generate electricity with the help of infrared radiation. However, in most situations, visible solar spectrum is more significant than infrared energy. The benefits and drawbacks of PV solar energy are as follows:

Advantages of Solar Energy System:[32]

- Environmentally friendly
- zero noise as well as no moving parts
- No emissions
- No use of fuels and water
- Minimal maintenance requirements
- Long lifetime, up to 30 years
- Electricity is generated wherever there is light, solar or artificial
- PV operates even in cloudy weather conditions
- Modular or “custom-made” energy, can be designed for any application from watch to a multi-megawatt power plant.

Disadvantages of Solar Energy System:

- PV cannot operate without light
- High initial costs that overshadow the low maintenance costs and lack of fuel costs
- Large area needed for large scale applications.

IX. Future Scope

India's solar sector could reach billions of dollars in value during the following ten years. Solar potential is sufficiently present, and the surrounding conditions are rapidly improving. Localization, project execution, and funding are essential. Indian solar projects that are successful will have a low cost base as their foundation. Procurement effectiveness will be necessary when projects and participants grow in number. The downstream solar market will be dominated by local companies. The downstream side, which comprises project development, installation, and distribution, is expected to be dominated by local, or at least well-localized, firms in the initial years. This contrasts with the upstream industry's (solar modules') worldwide nature. Given sufficient time to fine-tune their business models, global players entering India for the first time will be able to prosper. Entering and learning the ropes early will be important for both local and global players. While some players have already begun preparing, most have yet to place a bet on solar, given the uncertainties within the sector. Success in solar energy will require a long-term commitment and a sound understanding of local dynamics.

X. Conclusion

We have shed light on the solar route for producing power in this study. To accomplish the stated goal, natural resources like photovoltaic cells are helpful. Energy is produced by solar energy systems using inverters such as line-commutated inverters, self-commutated inverters (voltage source inverters and current sources), and inverters based on the number of power processing stages, transformer and transformer less inverters, and multilevel inverters. They are incredibly helpful for the production of electricity. Projects that are successfully completed will have a greater long-term value.

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