Comprehensive Analysis of Grid-Tied Photovoltaic Systems

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Abstract: *Grid-connected Photovoltaic (PV) system adoption is rising, and their dynamic behaviors and effects on the public grid are receiving a lot of attention. This essay discusses how power quality has always been a major issue because outages harm the power system significantly. The paper describes the power quality and the different power quality problems that arise when integrating a PV system with the grid. Power quality problems cause data loss, process interruptions, insulation breakdown, overheating, inefficiency, and shortened equipment service lives. This paper presents a thorough review.*
Keywords: ***Solar energy, PV System, Grid Connected PV System, micro-inverters***

I. Introduction

Fossil fuel use has caused a number of environmental issues, such as the greenhouse effect and global warming. This led to an era in which distributed generation (DG) systems based on renewable energy sources are used to meet the increased demand (RES). systems for distributing generators Basically, the use of renewable energy has gained popularity as a way to improve utility grid resilience, stability, and reliability. The decarbonization of the current grid makes extensive use of renewable energy sources. The government promotes the production of solar power among other renewable energy sources [1]. The main utility grid and the distribution generator typically operate simultaneously. DGs serve as a backup system for the primary grid during emergencies. PV systems are becoming more important due to the rapid advancement of technology.Solar PV's intermittent nature complicates controllability. As a result, PV systems need to operate within the grid system's standard for interconnection. There is a cap on the consumption of RES because of the unpredictability of renewable energy sources.

Distributed generation refers to the process of producing electricity using Renewable Energy Sources (RES) like solar, wind, and other sources (DG). Modern conventional power systems have entered a new era thanks to DGs. Solar energy is emerging as a promising option for a global response to the rising demand for electricity. A solar energy system is now a trustworthy source of energy due to the abundance of solar energy on earth and advancements in solar technology [2]. The fact that solar energy is green and clean, with very little carbon emissions compared to conventional sources of electricity production like thermal, is another benefit it has. They pollute the environment and have high carbon emissions. The system's overall performance is impacted, which causes the end users serious concern. Generally speaking, it shortens the lifespan and efficiency of the machinery and equipment.

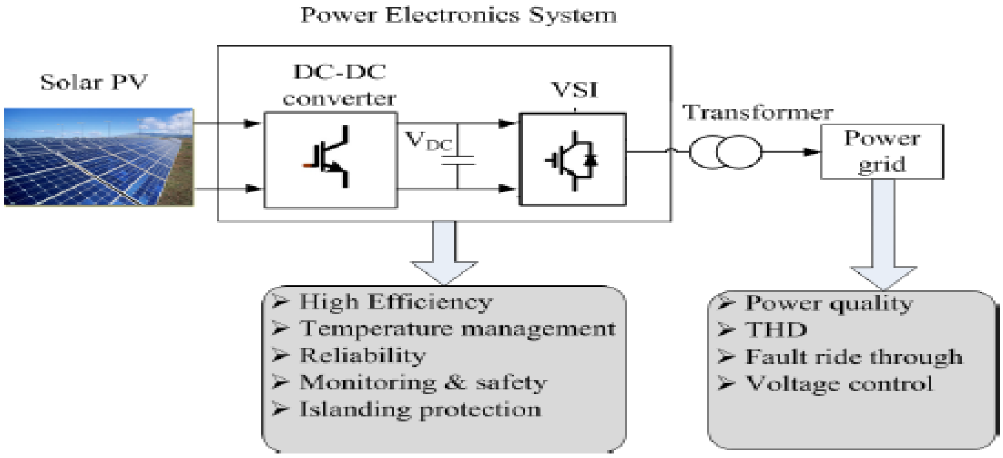

Figure 1 General Structure of Grid Connected PV Systems

In most cases, PV systems and microgrids supplying local loads are both connected to the local distribution system. Grid-tied PV systems can be investigated to carry out additional tasks, such as active filtering and/or reactive power compensation, in addition to energy production by implementing an appropriate control strategy. To put it another way, is capable of reducing a number of Power Quality (PQ) problems [3]. PV systems can carry out duties resembling those of traditional parallel active power filters (PAPF). When there is a sudden change in solar irradiation or when there are no solar insolations, the PV system can be used as a standard static compensator..PV converter controls the amount and direction of power flowing to the grid, so by adjusting the DC bus control loop through converters, conventional compensating strategies can be used..

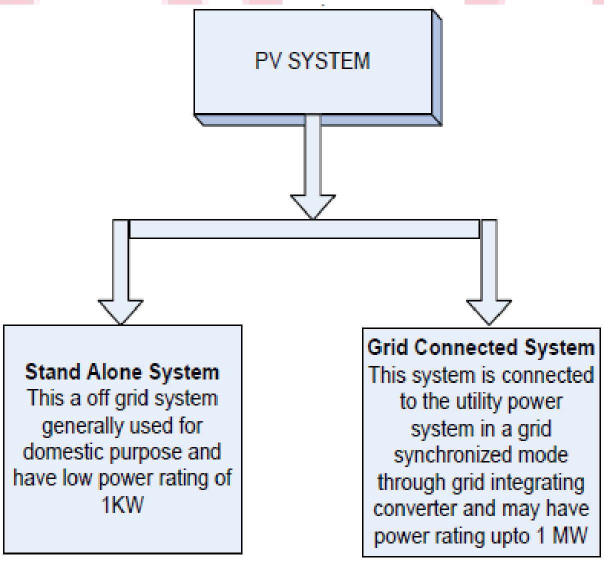

Figure 1 Classification of PV Systems

The solar energy system has undergone technical advancements that make it practical to use in many applications. Solar photovoltaic (PV) systems can be used for both small- and large-scale power generation. They are primarily used to convert solar energy into electrical energy. The cost of solar photovoltaic is decreasing because semiconductor technology is advancing. Additionally, the development of power electronics makes it possible to generate electricity with high efficiency and supply it directly to the grid. Because PV power is used more effectively and more energy is obtained, a grid connection is required. Eliminating the use of batteries is now cost-effective and requires less maintenance for PV systems connected to the grid [4].

II. GRID CONNECTED PV SYSTEMS

Solar cells or photovoltaic (PV) cells are devices that convert sunlight directly into electricity. The PV effect, also known as the PV effect, is the conversion of light energy (photons) to electricity (voltage), which gave rise to the name PV. Simple

grid-connected PV system illustration is shown in Figure 1. The various system parts are briefly described in Figure 3 below.
The main part of grid-connected PV systems are inverters. It is an electronic device that transforms DC power from solar panels into grid-compatible AC power. According to their architecture, there are three main inverter topologies: central inverter, string/multi-string inverter, and module integrated microinverter. For large-scale generation, central inverter topologies are typically preferred, and they have a centralized inverter and a common MPPT for PV arrays (series-parallel connection of PV modules). The topology of a string inverter is a scaled-down version of a central inverter; a string is formed by a number of modules connected in series, and an inverter is connected to that string. Where each string has a unique MPPT.The evolution of the string inverter into a multi-string topology, where each string has its own DC-DC converter and is connected to a single inverter, is followed by the development of the module integrated microinverter, where each PV module has its own inverter and individual MPPT.

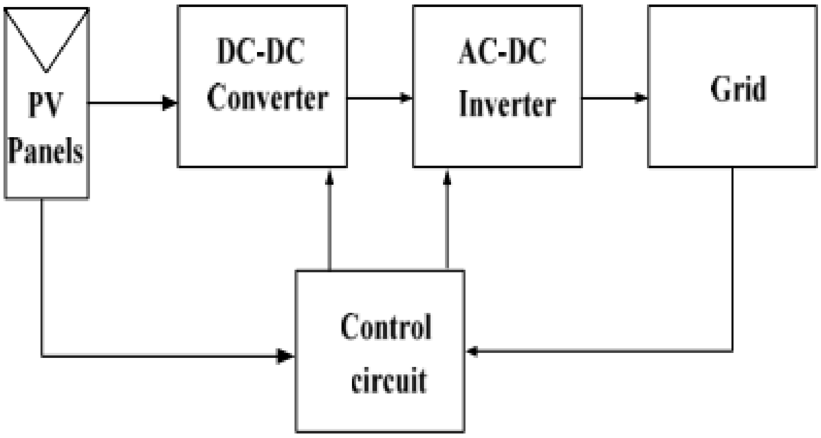

Figure 2 Block diagram of typical grid connected PV systems

A micro-grid is a local power supply system that combines renewable energy sources, energy storage technologies, local loads, communication technology, protection components, and the control center. A PV system that is connected to the utility grid by a power inverter allows photovoltaic panels or an array to run in parallel with the electrical utility grid..A standalone PV system stores solar energy using photovoltaic panels and deep cycle batteries, creating a fully independent solar power system. However, as long as there is sufficient solar radiation during the day to recharge the batteries for use at night, this type of solar system is functional. As they are typically used in remote and rural areas, stand-alone solar systems are self-contained fixed or portable solar PV systems that are not connected to any local utilities or the main electrical grid. This typically indicates that the electrical appliances are far from the closest fixed electrical supply or that it would be expensive to extend a power line from the local grid.
However, there are now significantly more solar-powered homes that are connected to the local electricity grid than there were previously. These PV systems that are connected to the local electrical grid network at night have solar panels that can meet all or a portion of their power requirements during the day. PV systems powered by solar energy can occasionally produce more electricity than is required or used, particularly during the long, hot summer months. In most grid-connected PV systems, the excess or extra electricity is either stored in batteries or fed back into the electrical grid network.
The most important factor when integrating a PV system with the grid is power quality. This is defined as the utility's ability to give customers steady, noise-free power. The electrical equipment and components used for power distribution would start to suffer from poor power quality as frequency variations would cause processes to occur in undesirable places. There are some challenges with regard to power quality when integrating a PV system into an existing power system.

III. LITERATURE REVIEW

Systems for generating electricity using renewable resources and connecting them to global grids. The grid's maintenance of power quality, grid integrity, and protection against islanding detection became urgent concerns as a result of the grid's extensive use of renewable energy sources. The adoption and current control methods for the inverter are two of the most crucial components of the renewable grid interconnection. While interconnecting to the grid, these current-controlled inverters must comply with international standards and grid requirements. [5] Provides a review of the various current control techniques that have been used in the market in accordance with industry best practices and technological advancements. Two categories, such as linear controller and non-linear controller, were discussed for various techniques and their control algorithms. The paper also discussed contemporary new control methods like artificial neural networks and fuzzy logic controllers. This paper also discussed performance analyses of various controller types to help readers better understand the system's characteristics. A test using MATLAB/SIMULINK was done to see how well the system worked.

For reactive power compensation and power quality enhancement in distribution systems, a traditional PI controller called a Distribution Static Compensator (DSTATCOM) is recommended. Five different methods of obtaining reference currents for a DSTATCOM are analyzed in [6].Performance of DSTATCOM is affected by the control algorithm for extracting reference current components. In addition to model predictive control (MPC), Sliding mode controller (SMC) based STATCOM, and ANFIS-LMS based control, asynchronous reference frame theory and a new Adaline-based algorithm are also employed. A three-phase distribution system's supply side voltage and currents become out of balance when non-linear loads are added, giving the system the appearance of being out of phase. The issue is resolved by rectifying a balanced three-phase supply using a DSTATCOM to bring the voltage and current into phase. The suggested conventional PI controller, DSTATCOM, will be put into practice in MATLAB using the SIMULINK model. Simulation and experimental results show how effective this method is at controlling DSTATCOM..

Due to their ability to convert electronic power for high power applications, multilevel inverters have grown and developed into a successful and mature technology. This paper's goal is to review various recently created three phase multilevel inverter topologies with various configurations and control strategies in order to employ fewer components and ultimately produce a technologically efficient design. Focuses the reader's attention on recent developments in the new topologies, their control strategies, modulation schemes, and operational issues to provide a comprehensive and synergistic in [7].

In three-phase grid-connected Photovoltaic (PV) systems, unbalanced grid voltage dips can result in unbalanced non-sinusoidal current injections, dc-link voltage oscillations, and active and/or reactive power oscillations with twice the grid fundamental frequency. The dc-link capacitor, one of the system's most fragile parts, can further deteriorate as a result of double grid frequency oscillations at the dc-link of conventional two-stage PV inverters. The solution to this issue may be effective converter controls. In those solutions, Current Reference Calculation (CRC) is one of the most significant issues that must be addressed for grid-connected converters to operate reliably in the presence of unbalanced grid faults. Consequently, [8] reviews the current CRC techniques and presents a new reference generation technique with up to 16 distinct modes. In this paper, problems that the two-stage three-phase converter encounters in each mode are also examined. Through simulations under unbalanced voltage dips, the performance of the CRC method is confirmed and contrasted to the state-of-the-art methods.

The world is turning to renewable energy sources in the face of rising energy demand and diminishing resources. Solar energy is the best renewable energy source currently available because of its many advantages over other renewable energy sources. When coupled with the grid, the photovoltaic (PV) system proves to be beneficial for contemporary society. Although integrating a sizable PV system with the grid raises a number of power quality issues. Poor or low power quality could result in losses in revenue and inconvenience for end users. The components of the power system overheat and begin functioning in undesirable places as a result of low power quality issues, which results in significant damage. Researchers examine the problems with the quality of the grid-connected photovoltaic system in [9].

[10] presents a thorough analysis of photovoltaic (PV) systems with an emphasis on PV inverters. There is currently no agreement that this technology will have a significant impact or be the first option for generating energy in the future for a number of reasons, the most significant of which is its inefficiency. In order to improve the efficiency, longevity, and cost of PV cells, modules, and power electronic devices, various materials are currently used and more materials are anticipated to be used.

For Egyptian Distribution Utilities, high levels of distributed (PV) generation on the electrical distribution system present both opportunities and challenges. By using solar inverters with reactive power control inconvertibility mandated by specific grid codes, this threshing aimed to increase the penetration level of PV power production in three-phase LV grids. The whole solar inverter could be cushioned using this method, which is based on the grid voltage profile for location-dependent PF set premium. The primary goal was to reduce needless Q absorption [11]. This approach combines the Q-(V) and active power droop function power factor strategies. Each inverter's efficiency is determined by comparing the output voltage recorded and controlling the quantity of Q. Therefore, an improvement in the voltage profile at a particular bus can lower overall losses, allow customers to consume power more efficiently, and boost system capacity by 4.5 percent.

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Localized renewable energy production is becoming more and more essential due to the need for a cleaner environment and the ongoing rise in energy needs. Because of the overload on the power plants' distribution grids caused by this constant increase in energy consumption, power availability, security, and quality have all suffered [12]. The Distributed Generation (DG) system is one of the ways to get around this. The benefit of using renewable energy sources for dg systems, such as solar, wind, or hydro, is that the power is generated nearby where it will be used.

In recent years, multi-functional voltage source inverters (VSIs) have drawn more attention due to their useful auxiliary services for enhancing power quality in independent microgrids. These VSIs can meet the required standards for power quality and stability in addition to achieving a proper control scheme in autonomous mode [13]. When compared to multiple devices with independent functionalities, these functionalities are combined into a single device, significantly increasing the cost-effectiveness of microgrids while lowering the investment and bulk. This paper provides a thorough review of control strategies for power quality improvement in autonomous microgrids using multi-functional VSIs. These VSIs are also thoroughly discussed, and comparisons are also given. Finally, several areas of future research for multi-functional VSIs are.

Renewable power generation systems (RPGSs) are constantly being developed, with Germany, China, Japan, Italy, and the USA being the countries that have made the most progress in each region. Power quality, safe operation, and islanding protection of RPGSs, among other things, are issues that are becoming more significant as a result of the growing number of RPGSs connected to the utility grid. The current control method, which must satisfy the criteria for grid interconnection in accordance with international standards and practices, is one of the most crucial components. For dependable and secure grid interconnection operations, the RPGS itself needs to be secure and extremely effective. [14] Provides an overview of the state-of-the-art of the most recent control techniques for the three-phase grid-interconnection of RPGSs.There was discussion of a number of current control architectures, their functions, as well as advantages and disadvantages. A review of the performance evaluation and comparison of various controllers was also conducted.

Grid-connected photovoltaic systems have become more popular recently thanks to their ease of use, dependability, and durability. Grid tie inverter (GTI) ranges are divided into small scale and large scale, which are measured in hundreds of megawatts. As a result, the grid's standard for interconnection has been raised, which has improved the cost, efficiency, and reliability of the power system. Additionally, the functionality of a grid-connected inverter is largely dependent on the robustness of the control strategy, even when operating in abnormal grid conditions like voltage and frequency deviation.The focus of [3] is on updating grid standard codes and regulations, as well as providing an overview of current control strategies. Briefly discussed is the structure of the phase locked loop (PLL) with grid synchronization methods for single phase and three phase. Investigations for fault ride through capabilities are carried out, along with a thorough analysis of islanding detection techniques and their various types.

Regarding power quality and safety concerns, galvanic isolation in grid-connected photovoltaic (PV) microinverters is a crucial feature. However, the efficiency of the isolated types of microinverters is reduced by high-frequency transformers and high switching losses. Recently, several isolated topologies to extend the lifespan and efficiency of PV converters were proposed. A thorough analysis of the most recent isolated topologies for PV microinverters can be found in [15]. In terms of the power processing stages, these topologies can be divided into two groups: single-stage microinverters and multi-stage microinverters. Different topologies are shown, contrasted, and examined with regard to power losses at various stages, control strategies, the location of the decoupling capacitor, and cost analysis. To get a clear picture of the framework for next-generation isolated PV microinverters, recommendations are given for improving the current topologies and choosing the appropriate control techniques.

IV. CONCLUSION

Grid-connected The adoption of photovoltaic (PV) systems is growing, and much attention is being paid to their dynamic behaviors and impacts on the public grid. This essay discusses how power quality has always been a significant issue because power outages seriously damage the power system. The power quality and various power quality issues that result from integrating a PV system with the grid are discussed in the paper. Data loss, process halts, insulation failure, excessive heat, inefficiency, and shortened equipment service lives are all consequences of poor power quality. This essay provides a thorough analysis.

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