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A Survey on the Integration of Solar Photovoltaic Energy Conversion Systems into Commercial and Industrial Electrical Energy Usage

Abstract: - In this study, the main research hypotheses are the market for energy technologies and the contribution of innovation to solar energy. The solar photovoltaic (PV) energy industry is seeing incredible expansion. Global government policy has changed in response to technological breakthroughs that have cut down the cost of solar PV generating. The solar photovoltaic system is one of the more widely used solar energy systems. Examining pro-poor technological solutions is therefore necessary. This includes evaluating their environmental effect, field performance, consumer uptake, grid connections, and energy storage. The technological problems and difficulties with solar PV plant energy-generating components are examined in this research. Additionally, solar PV modelling is emphasized. Lastly, the report synthesizes the key studies in a coherent way to highlight the research gaps by analyzing them from the perspectives of fault analysis and the necessity of energy storage. Highly educated customers could be able to misunderstand the facts about electricity and solar energy. As a result, this article will offer insight into modern solar PV energy technology and energy management systems, facilitating interaction between industry, information, integration, and communication with society. Additionally, the use of technology for communication and information and its advantages in conjunction with the "Environmental Impact Assessment" will be discussed in detail.

Keywords: Solar Energy, PV System, Market Pricing, Technical Issues, Photovoltaic.

I. Introduction

The progress of technology and innovation depend on the perspective of Industrial Information Integration Engineering (IIIE). Li Da Xu and colleagues (2015) [1] and Li Da Xu et al. (2016) [2] distinguished the relationship between design concepts and ideas for IIIE. Chen (2016) also discussed and offered a comprehensive perspective on IIIE in another work [3]. Five linked tiers that cover the integration of engineering systems comprise the IIIE framework. Naturally occurring resources must be preserved through the flexible and reversible creation of new technologies. Socio-Economical-Technical-Environmental (SETE) components of sustainability are addressed in Figure 1 using an integrated and simplified approach. Establishing a systematic approach to the implementation of solar energy systems would provide a clear understanding amongst all stakeholders. New perspectives for sustainable development were examined by Pansera, M. et al. (2016) in their grassroots research [4]. All throughout the world, solar photovoltaic technology is becoming increasingly popular. Despite being a major player in the power industry, solar photovoltaic technology is still less widely accepted due to issues including high capital costs and poor power efficiency. Solar PV systems provide a lot of optimism in rural locations where grid access is quite expensive. On the other hand, solar photovoltaic (PV) systems are becoming more popular in metropolitan areas, where homeowners frequently install them to generate electricity. There are still technological and financial obstacles worldwide, despite the enormous technical potential and widespread availability of solar energy solutions. If obstacles related to technology and finances are not addressed, the increased energy output of solar photovoltaic systems will require ongoing expensive energy policies.

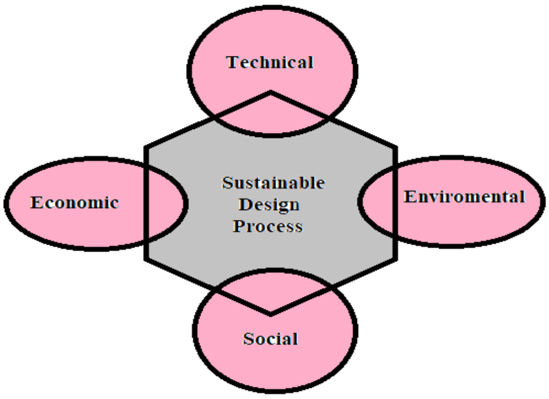

Fig.1. IntegratedmethodforSocio-Economical-TechnicalandEnvironmental

Seasonal changes, temperature variations, system losses, and battery/grid conditioning losses all have a significant impact on how much solar energy is transformed into electrical power and either sent into the common grid or stored in batteries.

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As a result of the aforementioned issues, new tactics are required to solve the difficulties. Power Conditioning Units (PCUs), PV module arrays, tracking devices, interconnection wire, surveillance control and Data Acquisition (SCADA), peak power point tracking (MPPT), and storage batteries are among the common parts of a solar PV system. To guarantee the optimum design and control for solar PV plants, the internal solar power plant's structure in addition to the grid need to be assessed. The importance of grid-connected PV system characterization was examined by Mohamed et al. [5]. Rathore, et al. [6] performed an extensive investigation through interviews regarding the potential and challenges faced by Indian solar energy entrepreneurs in many domains. The governmental, legal, and technological factors, according to around 63% of Indian solar energy providers, are the main obstacles to their operation. In addition, infrastructural constraints, according to 53% of developers, greatly increase their burden. In addition to the previously mentioned obstacles, 27% and 28% of developers perceive additional hurdles related to funding, accountability, and transparency. Figure 2 visually depicts each of the issues outlined above that Indian solar energy companies confront. Ideas for solar PV energy systems and its component parts have been developed by a variety of specialists. This presentation of the combined results will help to improve the solar PV power plant even more.

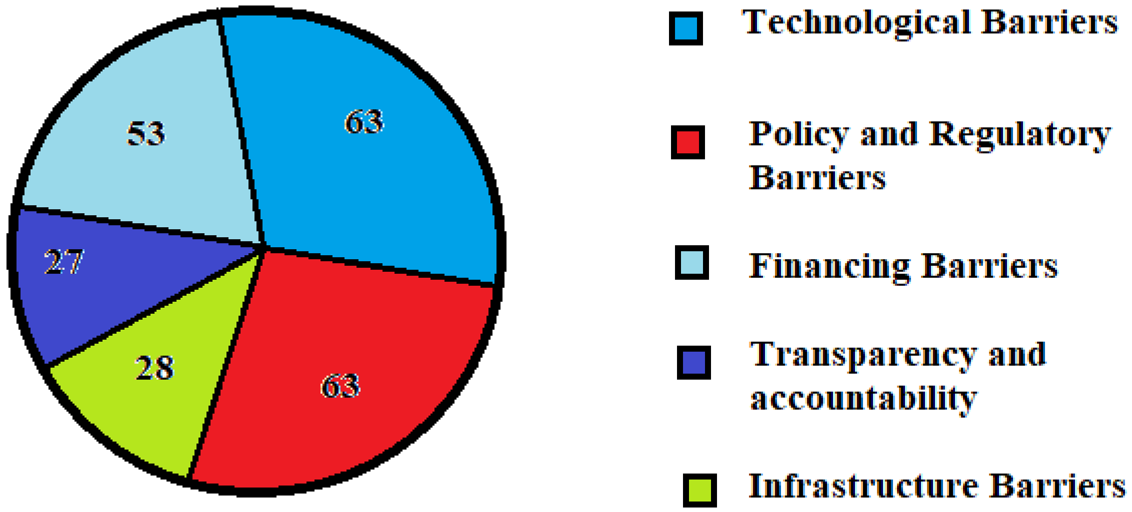

Fig.2. Solar energy developmental barriers ratings in India [6].

The goal of the research is to describe the components in terms of grid regulations and emphasize the importance of the solar PV system. Additionally, it will examine the specific requirements that satisfy the restrictions mentioned in the sources, particularly with regard to trial outcomes and technical malfunctions. The study also produces data by contrasting the Indian and international power markets, therefore redefining public attitudes regarding solar PV energy systems and increasing public knowledge and accessibility. Additionally, new information from the study may be utilized to back up new policy decisions about EIA. These decisions can be made in relation to market coordination, the problem of transitioning, and the elimination of obstacles to restructuring through the use of command-and-control methods.

2. SOLAR PROJECT EXECUTIONS OUTLINE

The development strategy for the photovoltaic system is comprehensive and serves as a significant messaging tool, informing all participants of the project's particular goals and the ways in which their roles are interconnected. In order to complete the execution duties, many teams are combined to generate desired results during various phases. Gantt charts may be utilized throughout project execution to provide effective coordination of generic procedures.

3. PRICING TREND OF SOLAR PV SYSTEM

Overall solar PV system costs have decreased by almost 70% over time. Prices changed in this way due to the high rate of use and energy consumption. Many variables affect how much a solar PV system costs. The thorough costing models for the Indian solar PV energy industry, spanning from 1kW to 1MW, were examined by Padmanathan et al. [7]. The performance of solar PV systems in the Indian market environment, stakeholder processes, and “Multiple Criteria Decision Making analysis” were also taken into consideration. The expansion of India's electrical industry between 1947 and 2017 was discussed by Jäger-Waldau [8].The “Central Electricity Authority”, Bridge to India, and Solar Mango have made significant contributions to the area of green power in terms of estimating examinations, changes in policy, market scenarios, technology transitions, obstacles, and the advantages, disadvantages, possibilities, and dangers (SWOT) framework [9–14].

Numerous academic publications have documented that the cost of solar photovoltaic modules is not constant, but rather varies on a weekly basis. This results from fluctuations in market pricing, demand, and ultimate end prices that are determined by mutual agreement, as well as a decrease in manufacturer module profit and the strain of entering a new market. Silver, the metal that makes up the conducting channel in solar cells, fluctuates in price during the production process[15,16]. The value of INR is further impacted by fluctuations in equity prices. An analysis was done to project the future pricing of cells based on the previously indicated sources of volatility. 2014 saw Chinese providers rule the whole solar business.In terms of solar module production, Chinese companies remain at the top of the list. Despite being the greatest market in the world, China does not allow vendors from other countries [16].

The data presented indicates a significant decline in the total cost of solar photovoltaic systems in recent years. Since the cost of inverters, modules, labor, installation, and the Balance-of-System (BOS) has decreased, significant market advancements are anticipated. Module prices are projected to drop from 260 Cents/Wp in 2009 to 30 Cents/Wp in 2018 at a maximum "Compound Annual Growth Rate" (CAGR) of 20%. The "National Renewable Energy Laboratory" source was used to calculate the global average because labor costs, taxes, and module costs differ from place to region. The price of the modules is the primary determinant of the solar PV system's cost, according to this conclusion (Ezysolare).Similarly; the cost fluctuations of PV solar systems and their constituent parts in the nation between 2012 and 2016.

4. PV SYSTEM

Electricity processing devices, several inverters, solar PV components, and electrical grid apparatus make up a grid-connected photovoltaic system. In comparison to standalone PV systems and off-grid battery storage systems, grid-connected PV systems are less expensive. A built-in battery option may be included in the off-grid and stand-alone photovoltaic system, which might increase system cost. Information on solar energy use is misinterpreted by even the most intelligent people. Consumers' ignorance of the distinctions between solar thermal and solar photovoltaic systems, as well as the varieties of these systems and their uses is a prime example [18].

According to a survey conducted by Eltawil et al. [5], grid-connected solar PV inverters outperformed other inverters in terms of performance. The survey also looked at the potential and technical difficulties with these systems. Less than 5% of all harmonic distortion (THD) was achieved with the help of high conversion efficiency and a power factor that exceeded 90% in broad working mode. Applications of grid-connected PV systems must include harmonic distortion demands islanding detection, and electrical interference. Power factor management, power output following, inverter current regulation, and other improved control and safety measures are all part of the control circuit. The likelihood of islanding rises with the usage of PV inverters with variable power factors at large adoption levels. In addition, PV inverters should be maintained at uniform power factor, according to the literature [5].

5. PV MODULE

PV modules produce power by using photons, which are light energy particles emitted by the sun. According to Standard Test Conditions (STC), a module's DC output power falls between 100 and 365 watts, which determine its rating. Different manufacturers in the market provide modules with varying physical dimensions and wattages, resulting in efficiency ranging from 14% to 17%. Only a small number of solar modules with efficiency levels higher than 22% are offered for sale [19, 20]. PV modules can be stacked in series, parallel, or a combination to suit the needs of the customer in a solar PV system. PV modules made of various materials are more efficient and come in a variety of sizes for the market. The majority of the modules make use of crystalline silicon cells or wafer-based thin film cells. Figure 3 shows the several layers that make up a solar PV module. There is a widespread misperception that solar modules are fragile since they are composed of glass. Solar modules, however, are resistant to wind loads (2400 PA) and snow loads (5400 PA).

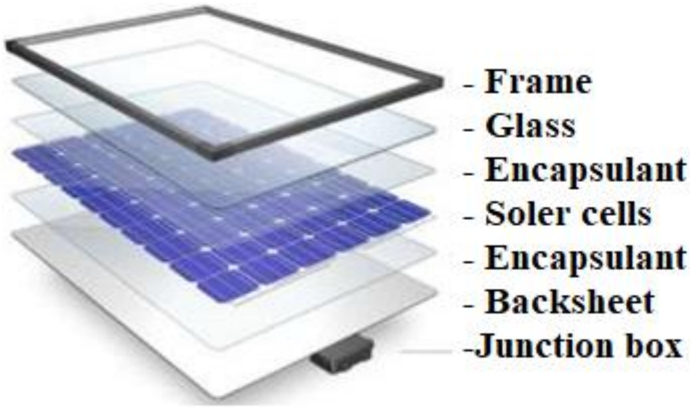

Fig.3 .layers of solar PV module

In order to determine the income and energy yields, Kinsey et al. [21] studied the PV module's spectrum response. Four modules—multicrystalline silicon, monocrystalline silicon, cadmium telluride, and copper indium gallium selenide—made of various materials were employed for this type of analysis at many locations around the United States. Research findings reveal that performance was evaluated using metrics including energy production, annual income, daily module charge density, hourly clear sky efficiency, and external quantum efficiency. When juxtaposed with different methods, the modules manufactured using cadmium telluride method performed better, according to the analysis of these criteria. This made room for the development of new technological modules for improved designs.

To make PV design simpler, Babu et al. [22] reduced the PV module to a two-diode type. MATLAB was utilized to run simulations that satisfied the real-world PV module parameters for multiple methods, including monocrystalline and multicrystalline. The two-diode approach was simpler to develop and required less energy than the single diode device. Different modules from several companies were used for the study, and the outcomes were consistent.

Several characteristics of the textured multicrystalline silicon wafer solar module were investigated by Peters et al. [23]. The modules were connected to the following: glass pane, encapsulation layer, and front surface encapsulation. The study came to the conclusion that imperfect internal quantum efficiency in solar cells is the cause of the current losses. The model known as the "spherical cap," which takes into account the roughness of the front surface of solar cells, served as the foundation for the study of the losses. The theoretical framework explains how light is trapped in the glass cover and absorbed in the Anti-Reflection (AR) film. The reflectance module, the external quantum efficiency (EQE) module, and a summary of present deficits all looked at all of the losses. The accuracy of the generated and observed signal quantum efficiency was more than 98%. Thus, it appears that the suggested model will improve the module's efficiency [23].

Ye, et al. [24] noted that although the system's operating costs were comparatively low, "PV module degradation" was one of the main disadvantages of PV systems. But because the PV module only lasts for 20 to 25 years, investors have to consider the upfront costs. When compared to other countries, the deterioration of PV modules was lower in tropical nations like Singapore. For the investigation in this case, 10 different types of solar PV modules composed of different materials were employed.

A variety of parameters, including Performance Ratio (PR), Open-Circuit Voltage (VOC), Short-Circuit Current (ISC), and Fill Factor (FF), were extracted using statistical decomposition techniques. For the deterioration study, the date for measurement from the Solar Energy Research Institute of Singapore (SERIS) Outdoor Module Testing (OMT) facility was utilized. It was discovered that the multicrystalline Si module degraded at a rate of about −1.0% year, while the monocrystalline Si module degraded at a rate of less than −0.8% annually. The modules including a-Si, micromorph Si, and CdTe demonstrated an approximate annual deterioration rate of −2%. The CIGS module detected a remarkable annual deterioration rate of about 6% [21].

Cutting-edge research focuses on improving PV component and system dependability, lowering the cost of solar cells, systems, and modules, and increasing solar cell conversion efficiency [25]. The different advancements in solar cell efficiency from 1975 to 2015 are detailed in Figure. The top three PV technologies of the future, including concentrated PVs, quantum dot PVs, and perovskite, were projected by Kalkman et al. [26] based on an analysis of the current PV technologies. In the next ten years, these are expected to be the most popular and innovative new photovoltaic technologies. To beat C-Si, though, would be a task as it keeps setting new benchmarks for increased efficiency. Likewise, there is no guarantee that these technologies will satisfy the growing demands, which will raise the ranks of PV capacity installed throughout the course of the ten years to come. In light of a field engineer survey carried out by Gateway to India [27]. The highest power prediction of a photovoltaic module was examined in a research by Moballegh et al. [28] utilizing a variety of modelling methodologies, “including Total Cross Tied” (TCT), “Series Parallel” (SP), and “Bridge Linked” (BP), on ten distinct shading zones. Mazumdar et al. constructed and examined a novel and intelligent PV module [29].This functions as the smart AC module and directly regulates the output AC voltage. It is composed of a DC-DC converter with a H bridge inverter running on feed forward control. These smart modules are the best choice for curved surfaces where temperature and insulation vary module to module and provide variable outputs. For increased dependability, film capacitors were used in place of the DC link electrolytic capacitors.

6. POWER ELECTRONIC CONFIGURATION

Power electronics and the uses for them are essential to solar PV systems. This section reviews power electronic circuits that are connected to photovoltaic systems and how they are affected. A solar power plant primarily uses power electronic setups including Maximum Power Point Tracking (MPPT), inverters, and power converters (DC–AC, AC–DC, and DC–DC). The requisite current and voltage are maintained with the aid of a DC-DC converter connecting two non-identical solar panels. When modified appropriately, a variety of non-isolated DC-DC converters can be employed, including Buck, Buck-boost, Boost, and CUK topologies.

Various inverter types were suggested by Strache et al. [30] for various sites. The optimal position with the highest efficiency was determined by testing and comparing various PV components, such as string inverters, micro inverters, and power optimizers, in various places such as PV plants, the top of vehicles, façade PV installations, and roof top PV installations. In order to identify the appropriate inverter for different sites, other types of Solar Cells (SC) were also tested, including triple junction concentrator PV (CPV), monocrystalline silicon (Mc-Si), and dye-sensitive solar cells (DSSC).

The authors Krithiga et al. (31) devised and examined a novel arrangement that leverages a multilayer boost converter and a line commutated inverter to optimize photovoltaic power output while circumventing the need for a separated maximum power point closed loop controller. By eliminating the need for a transformer in PV-grid linked systems, Li Zhang et al. [32] devised a novel inverter architecture. In comparison to the previous topologies of H5, and the Highly Efficient and Reliable Inverter Concept (HERIC), the new H6 topology was also shown to have lower power loss and device costs. The current that leaked was essentially identical, though. Sinusoidal PWM provided superior differential mode effectiveness in comparison to other PWM approaches, making this kind of inverter suitable for use in a single phase grid-connected photovoltaic installation.

A 250 kVA photovoltaic inverter using MOSFET and diodes was conceived and implemented by Sintamarean et al. [33]. The “Real Field Mission Profile Model” (RFMP), which was the component of the suggested design tool, was put into practice and evaluated for a year in two distinct locations, including Denmark and the USA. The study's findings included a description of the device's lifespan, electro thermal model, and PV model for both regions. PV inverters with great efficiency may be constructed using these data.

For PV system Maximum Power Point Tracking, a thermal camera was employed in a research by Hu et al. [34] to identify the solar module's healthy and defective regions. Clear photographs of the healthy and sick areas were obtained by the thermograph images that the thermal camera could provide. These data helped identify the problematic location and enable the implementation of Maximum Power Point Tracking.

According to a research by Zhou et al. [35], a PV balancer was used in place of the power converters. Two distinct irradiance zones were used in the design and verification of two architectures. The PV balancers were sometimes referred to as module embedded converters, as a PV balancer for the MPPT was built into every PV array module. The universal DC bus serves as the PV balancers' input in Configuration I. The front-end converter and input are shared by the PV equilibrium in Configuration II. The PV balancers in each module get a fairly low voltage from the front-end converter, which reduces the DC bus voltage. Every architecture has distinctive qualities. Architecture II is more cost-effective and efficient than Architecture I, although it has more intricate connections and is simpler and more modularized. To serve as a demonstration, fly back and buck-boost converters with an input voltage of 28 volts were attached to both topologies. It follows that a new approach to replacing power converters will result from the development of Module-Integrated Converters (MICs).

One of the key responsibilities of PV, according to Wang et al. [36], is tracking the maximum power point. Two approaches for tracking global maximum power point, known as Skip Judge Global MPPT (SSJ GMPPT) and Rapid Global MPPT (RGMPPT), were presented here. Based on partial shade circumstances, the findings demonstrated how quick and accurate these approaches were. The SSJ GMPPT technique was superior than the RGMPPT method in terms of accuracy and speed; it also had a faster searching speed. Boost converter and microcontroller were the two components of the 1 kW panel arrangements that were used for tracking.

The inverter, according to Zhou et al. [37], was a crucial component of the PV-based system. The most used inverter type in the majority of systems is the Z source, often known as the quasi-Z source inverter. There is a Double Frequency Ripple Energy (DFRE) issue with the Z source inverter. That can be removed, though, if the input voltage is altered or if the capacitance value is large. The usage of electrolytic capacitors is seen in some techniques. Unfortunately, the chemical utilized may evaporate with age, which may ultimately result in a decrease in capacitance. This article's method of buffering the DFRE used a new modulation technique and a change in the input voltage. A 1 kW system was created by employing this method.

To maximize solar energy collecting, Khan et al. [38] introduced Sub module-integrated converters (SubMics). A comparison between the SubMics model and a central inverter setup is made under a range of operational circumstances, including unequal temperature distribution and partial shadowing [38]. That being said, Sachin Jain et al. [39] created a novel inverter architecture that not only increased the PV array's output but also transformed the DC it produced into AC for grid feeding. The two DC to DC converters in the topology ran in the discontinuous-conduction mode (DCM). The suggested topology's MPPT was determined by using the Perturb and Observe and Hill Climbing approaches.

A system that may turn the solar panel output into AC for grid connection was proposed by Shen et al. [40]. A DC-DC converter, an AC-DC converter, a DC-AC converter, and a high frequency transformer made up the suggested PV generating system. In order to prevent current leakage and the corrosion of transparent conductive oxide in the photovoltaic arrays, the converter runs at a high frequency and has a grounded negative terminal. The suggested converter's output current has a THD of less than 5%.

Wu and colleagues (2019) reported that the PV system's DC side electromagnetic radiation was measured between 150 kHz and 30 MHz in frequency. The PV system will use a DC-DC converter to send its generated DC electricity to the grid. The PV power production system's power conversion process necessitates careful monitoring of electromagnetic radiation. A PV power generating system's noise output is influenced by the frame wire that is inserted in it. Apart from that, how the frame wire is laid out determines how loud it is. The radiation magnetic field is reduced at low frequencies because the frame wire is grounded along the DC cable's lines and attached to the edge of the PV panel. But when the frame wire is grounded perpendicularly and attached to the edge of the PV panel's frame, the radiation magnetic field rises at low frequencies.

Deceglie et al.'s Real Time Series Resistance Monitoring System (RTSR) [42] allowed for the monitoring of the PV system in the event that micro inverters or DC power optimizers failed. In addition, it offered early warning of some of the most prevalent reliability problems and fire hazards, such as ruptured solder joints, broken ribbons, and contact concerns in the junction or combiner box. The operational dataset of the device's voltage and current was utilized, in addition to the module temperature and irradiance, to determine the RTSR under operating load. In fact, since the expenses of in-person inspections are decreased, the PV system investors profited from the RTSR system.

The measuring of photovoltaic light is essential for the installation of energy-producing plants, as reported by Francisco D. Munoz et al. [43]. Therefore, an endogenous evaluation must be performed in order to examine the PV for intervention. This paper compares the data with the current deterministic planning approaches and suggests a probabilistic capacity growth model. A stochastic spare cushion strategy for scheduling is constructed based on the comparison, and the outcomes mirror the conduct of a more comprehensive bayesian model for various ranges of solar PV breaches.

Model Predictive Control (MPC) for Power Electronics and Drives is a particularly appealing application of Finite Control Set that is provided by Rodriguez et al. [44]. Additionally, the many uses of power converters with MPC are examined, covering the entire grid-connected PV system arrangement with MPPT.

7. CABLES

A solar wire connects the solar panels and other electrical parts of the PV system to produce power through solar energy sources. Weather and UV resistance are typically included into its construction. These cables are typically installed outside since they can withstand extreme temperatures.

String DC cables are used to link solar modules to each other as well as to string combiner boxes or array combiner boxes for the modules. The cables that are utilized to join modules are produced at factories. However, the cables needed for combiner box connections and string interconnections must be purchased. String DC cables have a 10 Ampere (A) current capacity, and to achieve this, a tiny cross section (2.5 to 10 sq mm) is enough. **Principal DC cables**: Main DC cables are used to link combiner boxes and inverters. They typically have a high current capacity of 200–600 A in utility-scale projects and need a greater cross section (95–400 sq mm) [27]. According to their respective percentages of the EPC cost, the DC cable, string DC cable, and main DC cable account for 2%, 30%, and 70%.The main DC cables consist of 90% aluminum and 10% copper, whereas the string DCCable is composed of 100% copper.

8. PARTIAL SHADING

Regular or scheduled shadowing often has an impact on the efficiency of solar photovoltaic systems, particularly when an obscure object or a cloudy sky prevents sunlight from reaching the solar panels. However, there are a number of techniques to reduce or prevent situations that might lower the reliability of PV systems. It happens frequently in solar PV systems that parts of the cells are shaded. PV characteristics become complicated with distinct peaks when partial shade occurs.

Zapata et al. (2015) deduced that a variety of factors, including seasonal fluctuations, soiling, panel lifespan, and partial shade, might lower the output power of photovoltaic panels. The buildup of dust particles or other "soiling" onto the panel and its impact on economics were the main topics of this study. Based on real-time data, the study deduced that panels with regular maintenance and cleanliness will have better output power than panels that are cleaned less frequently. When the program design was evaluated and put into practice in real time, the outcomes were far better than those of the usual system.

Numerous PV system layouts were examined in a study by Liu et al. [46] in order to gauge the effectiveness of the Building Integrated PVs (BPIV) system. The findings demonstrated that the combinations of the PV DC building module and AC module achieved good results from non-shadow zones and prevented electrical parameter mismatches. The studies were carried out using various irradiance and shade characteristics, including strong irradiance with minor shade, strong irradiance with severe shade, weak irradiance with little shade, and weak irradiance with severe shade.

Khoo et al. [47] state that in order to optimize PV utilization in the Singaporean environment, solar irradiance may be evaluated at different orientations and tilt angles. In order to determine the slanted irradiance, the aforementioned tests were carried out over a two-year period using 12 silicon sensors to quantify the overall horizontal radiation and dilute horizontal illumination using three sky models (Liu and Jordan, Klucher, and Perez et al.).The results suggested that a 10 degree slanted angle toward east produced the desired, favorable outcomes.

9. PERFORMANCE ANALYSIS

The economic review of a 3 MW solar PV plant located in Karnataka, in compliance with the International Electro technical Commission (IEC) Standard 617724, was covered by Padmavathi et al. in 2013.Analysis was done on the plant's 2011 data using normalized technical performance metrics. Estimates of losses were made for two years, including losses from grid failure and inverter failure. The daily and seasonal fluctuations in the PV plant production are monitored and presented every five minutes or so. It may be deduced that the PV module's efficiency ranges between 10.1% to 13.25%. The PV facility operates better than anticipated for a certain time frame, namely the months with favorable radiation from January to April. Inverter efficiency ranged from 96% to 110% from July to November, with February exhibiting the greatest system efficiency of 12.3%.

10. ENERGY STORAGE

Off-grid photovoltaic systems are built in situations where there is no grid or where batteries need to be deployed in order to store energy for consumption when needed. Blocking diodes are used in modules to stop batteries from draining at night. In addition, it aids in battery protection in the event of a short circuit and provides over-current protection for many strings when in use. The charger regulators regulate how much power the batteries can hold charge. The DC-DC conversion architecture is used in off-grid systems to control voltage regardless of variations in irradiance.

In this case, switch mode DC-DC converters are employed to match the fluctuating load to the DC output of the PV generator. It is possible to employ battery-based or grid-direct systems. The former is separated into two systems: an electric utility backup system and a stand-alone system. The former uses inverters to link the PV array to the grid. Jan von Appen et al. found that PV utilization was rising in their 2014 study, which was carried out throughout Germany. The market for storage systems is created by rising local demand, falling feed-in tariffs, and rising power prices.

Prior to this adjustment, either standalone or grid-connected PV systems would release their electricity to the grid or their utility. This was because there was an option to store any extra power generated throughout the day. The formulation of many ways to store generated power in batteries and manage local voltage problems in the storage was the main goal of this work. The tactics examined by the authors came to the conclusion that large batteries and low power factors actually resulted in lower voltage levels and that it was difficult to determine whether reactive power was supplied first or the battery was charged first. Growing self-consumption rules have eventually led to a rise in the storage sector [49].

Ghiassi-Farrokhfal et al. (2015) enumerated the elements that lead solar farm owners to make investments in their farms. Penalties, price fluctuations over time, storage, voltage fluctuations resulting from changes in solar radiation, power commitment level, and other considerations were among the issues mentioned. When compared to numerical and practical designs, the unique and optimized design for PV farms presented in this study produced results that were comparable. It should be mentioned that, in comparison to other demands, PV accounted for the bulk (96%) of the investment. In addition, compared to the PV panels' lifespan, the battery utilized to store the generated electricity had a limited lifespan. Simultaneously, the investment amount automatically grew as the storage lifespan increased.

"Battery swapping" was identified by Liu et al. [51] as a major problem with electric cars. Initiatives to build battery service stations did exist, but they ultimately failed for a variety of reasons. Liu and colleagues' work presented an innovative approach of charging an electric vehicle (EV) when it is combined with a photovoltaic (PV) grid system. Constant current charging was used to set up the battery charging process initially, and then constant voltage charging. These days, many people use continuous power boosting techniques. The grid-connected PV system, battery storage, metering system, and EV charging unit are some of the components of this technique. The tracking system continuously checked the battery level in EVs, and when 80% of the batteries were charged, it alerted the storage systems so that the charged battery would be replaced in the EV.

This approach made it possible to assess self-consumption rates and profitable activities in addition to just changing batteries. The wavelet neural network approach was employed by the authors to compute the battery switching even though there are other approaches for predicting the swapping of EV batteries.

11. SIMULATION STUDY OF POWER SYSTEM WITH SOLAR PV

A thorough modeling and simulation must be in place in order to optimize the PV cell, module, Power Conditioning Unit (PCU), and power systems network with solar plant activated, whether or not batteries are present. Similarly, other hybrid networks come together when they use several software environments to implement them. In addition to the aforementioned, return on investment (or ROI) forecasting was done using economic studies and improvement. The Ministry of New and Renewable Energy (MNRE), Government of India, and the Energy and Resources Institute (TERI) [52] collaborated to write a report regarding solar PV system parts and their IEC accreditation and standards in India. The seven simulation programs that are frequently used to develop solar PV systems—Solar Pro, PVsyst, Homer Pro, RETscreen, System Advisor Model (SAM), PV F-Chart, and pvPlanner—are thoroughly compared. In order to determine if the softwares for solar PV power system design and simulation are feasible, comparisons of these programs have been conducted, taking into account factors such as module and inverter information, price, historical weather data, and functionality [52].

Stimoniaris et al. [53] introduced a unique approach to PV storage management that preserved the pseudo state of charge without interfering with the inverter. The PV plant was managed by means of a remote control system for the actuations of PV strings, which improved the energy storage capacity. A 600-Ah-24-V battery bank with its own inverter, two 1.1 kW PV inverters, six linked PV panels, five loads of about 2600 W, and one 1 kWp wind generator with its own rectifier-charger comprised the configuration of a micro grid-based smart distributed system. The Special Control Unit (SCU), a unique gadget, was used to link the DC-AC inverters. The Voltage Transformer (VT), Current Transformer (CT), and one actuator-relay made up this SCU. It was always in connection with the micro grid-specific PC through cables and a data acquisition card. The control algorithm oversaw the administration of the voltage, frequency, and energy storage at all times. Improved outcomes were attained when this method was used since they matched the actual outcomes.

PV systems that are connected to the grid usually have a power circuit that consists of a full-bridge inverter and a DC-DC converter for converting DC to AC.A low pass filter reduces the Total Harmonic Distortion, which is often brought on by the inverter, to make sure the systems stay within allowable bounds. A feedback control circuit is utilized to manage the boost converter's output voltage. Owing to the constantly fluctuating output voltage of PV systems at the load side, a control circuit is necessary to maintain a steady output voltage.

"Load balancing" is a crucial problem in distribution systems, particularly for three-phase systems, according to Weckx et al. [54].It is difficult to load balance at each step as, from the perspective of the client, the load is not properly separated. In this study, a six-leg charger or inverter is used as a swappable source of three-phase units for a distribution network that is feeding three-phase loads like PV or EV units. This inverter may be used in conjunction with a common DC-bus as three separate single-phase inverters. Not to mention, when electricity is taken from a phase with lower loading and pumped into a phase with the greatest loading, the grid conditions might be enhanced. The application may be used to enhance grid conditions.

Wei Du et al. [55] developed and built a 100 kW innovative voltage source PV inverter for the Consortium for Electric Reliability Technology Solutions (CERTS) Microgrid. Voltage source photovoltaic inverters faced several difficulties, including load transients, monitoring maximum power under light loads that caused DCbus oscillation, and DCbus voltage collapse. Droop control can help with the aforementioned difficulties. Two islanding situations were evaluated using the PSCAD simulation: one included the micro grid exporting electricity, and the other had the micro grid acquiring power (each at 100 kW) from two sources, such as the PV micro source and the CERTS micro grid.

The relevance of producing non-conventional electricity was emphasized in a research by Mentesidi et al. [56] in Mediterranean nations by combining three elements: photovoltaic (PV), windmills, and concentrated solar power (CSR). Thermal solar wind, thermal solar hydro, and thermal solar were the three power plant combinations that were tested in this scenario. Many characteristics, including frequency, three-phase fault, and system voltage stability, were assessed and projected for these innovative integrated power plants in recent years. According to the findings, the solar, CSR, and wind combined model will perform the best. A comparable research by Wandhare et al.[57] assessed integrated PV and wind energy systems and found that they produced results with high efficiency. This experiment made use of a 250 kVA rotor side converter and a 340 kVA grid. Both the software and hardware models showed comparable outcomes, indicating that this integration approach actually decreased the separate inverter source for the PV grid. Despite the availability of several methodologies, the authors choose to utilize Sinusoidal Pulse Width Modulation (SPWM) technology for the converters. Additionally, they employed PID and Proportional Integral (PI) controllers because of their broad bandwidth and little steady state error. The integrated approach that this study suggested was shown to be a viable way to maximize the benefits of renewable energy sources like solar and wind energy.

A new control approach was presented by Xiao et al. [58], yielding a voltage profile that was noticeably superior to the developed approach of primary voltage control (PVC) and secondary voltage control. Online Supervisory Voltage Control (OSVC) can assist enhance the voltage since Wide Area Management System (WAMS) is there. PV systems are now constructed with grid-voltage standards in mind. PVC is not as good at controlling grid voltage as LDSVC (LineDrop Secondary Voltage Control), which performs 7% better.

Households worldwide choose photovoltaic (PV) systems because of rising power rates and concerns about the long-term supply of renewable energy, according to Han et al. [59]. Even if PV systems are becoming more and more common, the inefficiency of the energy extraction from nature is caused by environmental factors and system neglect. This article suggested a monitoring system for residence-based PV systems that is substantially less expensive and easier to operate. In this system, the PLC served as both a master and a slave, and the connection between the master and slave PLCs was made possible by the PV system's current DC supply.

The ground control station and a controlling unit, which included an image processing unit, a decision support system, and a database storage system, supported the Unmanned Aerial Vehicle (UAV) equipped with an infrared visual camera.

The setup of sources of clean energy, such as photovoltaic cells, small wind turbines, and energy storage systems, has been increasing among residents, according to Li et al. [61]. This is because non-renewable energy supplies are becoming more scarce and the cost of installation is decreasing. Even though these systems are easy to build, there are ownership as well as distribution issues with the electricity that is produced. From the viewpoint of residential structures, a new aggregator service is presented in this article. This innovative aggregator service was contrasted with various conventional invoicing models, including time of use, flat charge, higher performance attainment, and real-time pricing. This aggregator has intelligent remote monitoring with Zigbee-enabled control devices.

According to a research by Liu et al. [62], a cascaded modular multilevel converter may be used to manage the active and reactive power in PV system output before integrating with the grid, allowing for the control of large-scale grid-connected PV systems. Two 3 MW, 12 kV PV systems were used to test this method of PV system control. The PSIM simulation platform and MATLAB are used to conduct the simulation. The authors employed a cascaded multi-level inverter and a current-fed dual active bridge DC-DC converter while implementing the above-discussed approach [63]. This technique made use of high-voltage, high-frequency SiC power devices, each of which had a switching frequency value of 5 kHz. The PV inverter used phase-shift carrier-based pulse-width modulation (PWM) control to provide an output voltage with nine levels[64,65].

12. FAULT DIAGNOSIS

A PV system's manual inspection will be quite expensive because there are many parts. The novel technique for detecting voltage and current is the most efficient among them. The traditional current and voltage sensing technique was unable to differentiate between the environmental elements causing the capacity of power generation to diminish. A new technique that can precisely determine the site of a cell array defect is desperately needed for the safe and dependable operation of solar PV generation systems as well as for the increase of power production efficiency. The authors of this paper suggested a failure diagnosis method for PV systems based on chaotic signal synchronization. The precise fault state and location can be ascertained using the suggested system. By integrating the system with the ZigBee wireless network module and embedding it, the suggested fault diagnostic can be used in the future.

According to a study by Plat one et al. [67], a neural network-based model was created in order to identify a PV problem. The panel's temperature and irradiance level were examined in order to determine the AC power generated. After taking the findings every ten minutes, they were averaged over an hour. Even though the results were only tested for 10 minutes, they were 90% correct. By comparing the PV's efficiency under standard test conditions—1000 W/m2 of solar irradiation and a temperature of 25 °C for the PV module—to the ideal achievement, the efficiency ratio was determined.

13. INFORMATION AND COMMUNICATION TECHNOLOGIES

Over the previous ten years, electrical networks have remained traditional and unmodified. Even if wind and solar energy systems provide a sizable quantity of electrical energy, an intricate electrical network is still necessary for a smart grid. The development of a smart grid makes use of intelligent machinery, apparatus, parts, and components. To measure each change, it is necessary to keep an eye on the smart grid's performance and behavior. The evolution of the electrical network is guaranteed by the smart grid in terms of automation, scalability, quality-of-service, security, and economics. It is imperative that all recorded data and current data are transmitted inside the new grid architecture. With regard to the smart grid, communication technology (ICT) are essential, especially when it comes to renewable energy. The smart grid was defined by Gungor et al. [68] using ICT principles for the energy framework in an end-to-end system. Güngör et al. [69]

discussed smart grid criteria in relation to every facet of the smart grid's renovation. The discussion of smart grid standards in Güngör et al. [69] took into account capacity restrictions, equipment failures, distant sensing, timely gathering, and natural disasters.

These are vital for guaranteeing proactive, accurate, and timely diagnosis of potential smart grid faults.For safe, smooth, and effective power distribution, these kinds of optical sensor systems are essential and financially rewarding. Demand Side Management (DSM) was covered by Palensky, et al. [70]. This study included an analysis of the current spectacle outlines in this field and was carried out using many DSM methodologies. By utilizing the Internet of Things (IoT) for protective operations, Soham Adhya et al. (2016) have accelerated real-time remote monitoring and supervisory control and data acquisition (SCADA) of all elements of solar PV plants [71].

14. ENVIRONMENTAL IMPACT OF SOLAR PV SYSTEM

Albert Einstein once said, "Energy can only be transferred or changed from one form to another. It cannot be created or destroyed." This idea can also be used to the solar energy conversion process with solar photovoltaic systems. A solar photovoltaic system might include one module or millions of modules, depending on the size of the system. Individual and project developers have installed and integrated millions of modules worldwide. Large landscapes are needed for solar energy PV project farms and parks, even if the systems have positive social consequences and should not be overlooked.Two notable effects are the development of trash from solar modules and the environment. Despite the fact that the modules have a lifespan of twenty to thirty years or more, the industry has not given much attention to what will happen to the garbage when they become obsolete. In the present economic downturn for the photovoltaic sector, recycling end-of-life PV modules is not a particularly popular issue. Studies on solar PV modules that are nearing the end of their useful lives have been started by the International Renewable Energy Agency (IRENA) and the International Energy Agency Photovoltaic Power Systems (IEA-PVPS) [72].

15. INTERPRETATIONS AND RECOMMENDATIONS

Studies on the growth of solar PV energy allow us to draw the following conclusions:

1. Concepts broaden understanding of sustainability and go further into the subject.

2. The grid-connected photovoltaic systems' optimization for financial sustainability.
3. Reclosing, other interconnection problems, and grid disturbances cause inverter failures to occur substantially more frequently.
4. The passive techniques for identifying the islanding state often look at the parameters—such as voltage and frequency—and/or their properties. These techniques stop the inverter from converting electricity when there is a sufficient deviation from the typical set circumstances. The island that intentionally makes alterations or disruptions in the linked circuit is identified using active approaches. Typically, these techniques track the reaction to ascertain whether or not the utility grid is connected using its steady frequency, voltage, and impedance. 5. More research is needed to determine the impacts of harmonics while operating several photovoltaic systems.
6. It is not advised to utilize PV inverters with a variable power factor; instead, it is strongly recommended that they function at unity power. This is due to the possibility that, at high penetration levels, it may outweigh the balanced circumstances and so increase the risk of islanding. 7. The need for novel regulatory ideas to be researched and developed is growing in order to be integrated into controllers, inverters, and specialized voltage conditioner technologies that are integrated with power systems. Voltage control will then be possible to reduce flicker and voltage fluctuations brought on by variations in local photovoltaic.
8. More complex control and communication ideas must be created in order to be combined with solar energy grid integration systems and enable improved system management. This will enable accurate and sophisticated micro grid operation that optimizes efficiency, power quality, and dependability. 9. The identification of inverter-tied storage systems is necessary to integrate them with distributed PV generation to enable intentional landing (micro grids) and system optimization functions (ancillary services), thereby improving the competitiveness of distributed generation from an economic standpoint. 10. Balanced circumstances are extremely unlikely to occur in PV systems installed at low, medium, and high penetration levels. The likelihood of both the balanced circumstances being at the power network and the power network disconnecting simultaneously is zero.
11. It follows that islanding is not a technological impediment to the widespread installation of PV systems in residential areas.
12. Improvements to commercial and new PV technologies' deployed energy output, power conversion efficiency, service longevity, and manufacturability are becoming more and more important. 13. Reliable software for predicting solar radiation, data monitoring, performance ratio (PR) results, investment and return analysis, modeling, and loss analysis should be the main focus of future research.
14. To investigate cutting-edge and ideal tracking systems and structural designs for solar power plants of all kinds, including ground-mounted, roof-mounted, and Building Integrated PVs (BIPV) systems.
15. Good battery storage that is less expensive than lithium-ion batteries is required.
16. Emergence of new application-focused needs, such as the demand for the development of solar PV panel products for electrical vehicles.

17. The primary ICT difficulties facing DSM are covered in this review.
18. Future advancements pertaining to solar energy in the domains of micro grid and smart grid must be concentrated.
19. Research advancements have to be pursued in multidisciplinary “domains including Social”, “Technological, and Economic, Environmental”, and Political subjects.

16. CONCLUSION

From a technology standpoint, the current study has emphasized the following developing areas for solar PV energy systems:

i. IIIE Concepts for integrating solar PV energy.

ii. One of the top priorities for development is raising the efficiency of solar PV cells and modules.

iii. Updated solar PV models enable precise evaluation of the electricity produced and its effect on the grid.

iv. The power produced under partial shadowing is influenced by the PV modules' connecting topologies.

v. Another important field of study is power electronics, which clarifies components like inverters, maximum power point trackers, and DC-DC converters.

vi. Better fault diagnosis methods enable defects in PV arrays to be located

vii. Modeling and experimental validation have identified the regions where a solar PV system's efficiency has to be increased.

viii. The importance of energy management systems, smart grids, and ICT.

ix. Energy storage is increasingly being used in solar photovoltaic systems.

In the context of global wellness, the article also provided insights on research gaps and opportunities for future enhancement.

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