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Review: Technology of Grid Connected Solar PV System

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***Abstract*— Traditional power systems are designed in large half to utilize large base load power plants, with restricted ability to speedily ramp output or prune output below an exact level. The increase in demand variability created by intermittent sources like photovoltaic (PV) presents new challenges to increase system flexibility. This paper aims to analysis and emphasize the importance of the grid-connected PV system regarding the intermittent nature of renewable generation, and thus the characterization of PV generation with relevancy grid code compliance. The investigation was conducted to critically review the literature on expected potential problems associated with high penetration levels and islanding bar methods of grid tied PV. In line with the survey, PV grid affiliation inverters have fairly good performance. They have high conversion efficiency and power issue extraordinary ninetieth for wide operative vary, whereas maintaining current harmonics Doctor of Theology but 5%.**

Numerous large-scale solar PV grid system project presently being commissioned, with loads of planned for the getting ready to future. Prices of every PV and balance of system element (BOS) unit decreasing that is in a position to lead to additional increase in use. The technical desires from the utility grid aspect have to be compelled to be glad to verify the protection of the PV installer and additionally the responsibility of the utility grid. Distinctive the technical desires for grid interconnection and backbone the interconnect problems like islanding detection, harmonic distortion desires and magnetic attraction interference unit so necessary issues for widespread application of PV systems. The feedback loop together provides ample control and protection functions like most power following, convertor current controller and power issue management. Responsibility, repairing and maintenance needs have to be compelled to be certified through the long operation of PV system. Additional reduction important , size and weight is required for loads of utilization of PV systems. Victimization PV inverters with a variable power issue at high penetration levels would possibly increase the number of balanced conditions and afterward increase the chance of islanding. It's powerfully steered that PV inverters have to be compelled to be operated at unity power issue.

Keywords—Solar PV grid connected system(SPVGC), Inverter

I. INTRODUCTION

Grid interconnection of PV power generation system has the advantage of more practical utilization of generated power. However, the technical needs from each the utility installation grid facet and also the PV system facet got to be glad to make sure the security of the PV installer and also the responsibility of the utility grid. Informative the technical needs for grid interconnection and resolution the issues like islanding detection, harmonic distortion needs and magnetism interference are so important problems for widespread application of PV systems [1]. Grid interconnection of PV systems is accomplished through the electrical converter, that convert dc power generated from PV modules to ac power used for standard power provide to electrical equipments. Electrical converter system is so important for grid connected PV systems. Grid affiliation associated extension prices are important factors for desegregation renewable energy sources-electricity (RES-E) generation technologies into an existing electricity network. Costs of each PV and genus BOS are decreasing following a trend of augmented production and improved technology. This explains the high quantity of subsidies for R&D and application of PVs in industrialized countries. The solar PV electrical power generation can play a very important role within the future energy provide in China. In step with the current arrange, total PV power installations can reach 350MW by 2010, 1.8 GW by 2020 and 600 GW by 2050.

According to forecasts created by the Chinese electrical power analysis Institute, renewable energy installations can account for half-hour of the whole electrical power installations in China by 2050, of that PV installations can account for five [2].

In fact, growing of PV for electricity generation is one among the best within the field of the renewable energies and this tendency is predicted to continue within the next years [3]. As a comprehensible consequence, associate increasing variety of recent PV elements and devices, primarily arrays and inverters, are coming near to the PV market [4]. The energy production of a grid-connected PV system depends on numerous factors. Among these we tend to distinguish the rated characteristics of the elements of the PV system, the installation configuration, the geographical sitting of the PV system, its encompassing objects, and defects that occur throughout its operation.

The need for PV arrays and inverters to be characterized has then become a lot of and a lot of vital side [5–9]. Thanks to the variable nature of the operational conditions in PV systems, the entire characterization of those parts is kind of a tough issue.

II. DIFFERENT TECHNOLOGY FOR GRID CONNECTED SOLAR PV SYSTEM

Maximizing performance of a grid-connected electrical phenomenon (PV)-fuel cell hybrid system by use of a two-

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loop controller is planned in [10]. One loop could be a neural network controller for optimum electric receptacle chase, that extracts most obtainable solar energy from PV arrays beneath varied conditions of isolation, temperature, and system load. A true reactive power controller (RRPC)s the alternative loop. The RRFT achieves the system's needs for real and reactive powers by dominant incoming fuel to cell stacks still as shift management signals to an influence learning system.

A neural network based mostly controller is adopted to stay track of most power points of the PV array as a result of its nonlinear I-V characteristics match well with a NN application. Take a look at simulations disclosed that the planned technique is ready to create the PV array accurately track the height power conditions even occasionally of apace dynamical isolation. A PI-type controller is planned for the electric cell powerhouse to satisfy the system's necessities for real and reactive powers. Satisfactory dynamic responses verify effectiveness of the developed management theme as is seen from the pc simulation results.

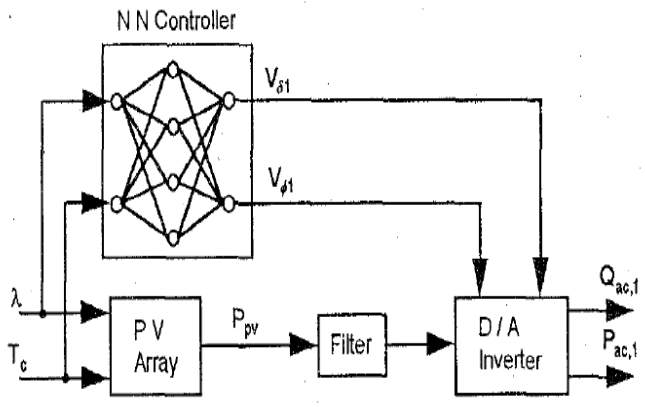

Fig.1. NN controller for MPPT of the photovoltaic power generator [11]

A novel multi-input electrical converter was planned [11] for the grid-connected hybrid PV/wind power grid so as to modify the ability system and scale back the value. The planned multi-input device consists of a buck/buck-boost amalgamated multi-input dc/dc converter and a full-bridge dc/ac electrical converter. The output power characteristics of the PV array and therefore the turbine area unit introduced. The perturbation and observation technique is employed to accomplish the most electrical outlet pursuit rule for input sources. The operational principle of the planned multi-input electrical converter is explained.

The feedback loop is accomplished by employing a digital signal processor and auxiliary analog circuits. For sensible applications, functions of soft-start logic gate protection area unit enforced.

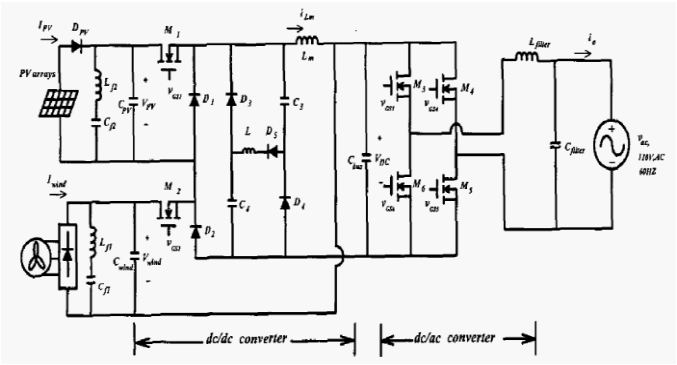

Fig.2. The schematic diagram of the proposed multi-input inverter [12]

A novel multi-input electrical converter for the grid-connected. Hybrid PV/Wind grid is projected. it's the subsequent advantages: I) power from the PV array or the turbine are often delivered to the utility grid separately or at the same time, 2) most electrical outlet following (MPPT) feature are often accomplished for each PV and wind energy, 3) an outsized vary of input voltage variation caused by totally different isolation and wind speed is appropriate, 4) power rating of the electrical converter are often reduced.

High performance, single-stage electrical converter topology was projected for grid connected PV systems [12]. The projected configuration can't solely boost the typically low photovoltaic (PV) array voltage, however may also convert the star dc power into top quality ac power for feeding into the grid, whereas following the most power from the PV array. Total harmonic distortion of this, fed into the grid, is restricted as per the IEEE-519 normal. The projected topology has many fascinating options like higher utilization of the PV array, higher potency, low price and compact size. Further, thanks to the terribly nature of the projected topology, the PV array seems as a floating supply to the grid, thereby enhancing the safety of the system. A survey of the present topologies, appropriate for single-stage, grid connected PV applications, is allotted and an in depth comparison with the projected topology is given. a whole steady-state analysis, together with the look procedure and expressions for peak device stresses, is enclosed. Necessary condition on the modulation index "M" for curved pulse breadth modulated management of the projected electrical converter topology has additionally been derived for discontinuous conductivity mode operation.

The projected configuration, operational in DCM, together with the traditional hill rising MPPT theme, is very sturdy is as a result of the operational voltage of the PV array can be controlled by varied M. Also, there's a matched relationship between M and therefore the average operational voltage of the PV array i.e., for every worth of M, the system settles all the way down to a stable average operational purpose. Thus, there's no chance of the system going in the tangency region for higher values of M.

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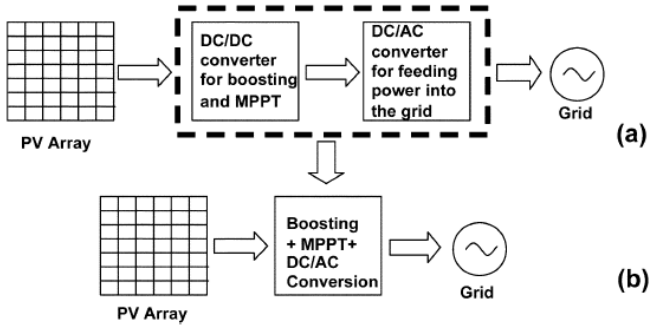

Fig.3. Grid connected PV system topologies: (a) conventional two-stage and (b) single-stage configuration [13]

A symbolic logic controller has been developed for interfacing PV array with utility grid through a 3 section line commutated electrical converter for the primary time [13]. The controller tracks and feeds most power to the utility grid. The linguistic variables are elect fitly to modulate the firing angle of the electrical converter for pursuit the most power. The simulink model of the planned theme using symbolic logic controller has been designed victimization MATLAB/PSB. A PIC microcontroller has been programmed for generation of firing pulses to the thyristors within the electrical converter. Experimental setup of the planned theme has been designed and therefore the results obtained on a PV array of fifty four V, twelve A rating square measure conferred. The comparison of experimental and simulation results shows terribly shut agreement between the 2 therefore corroborative the controller planned.

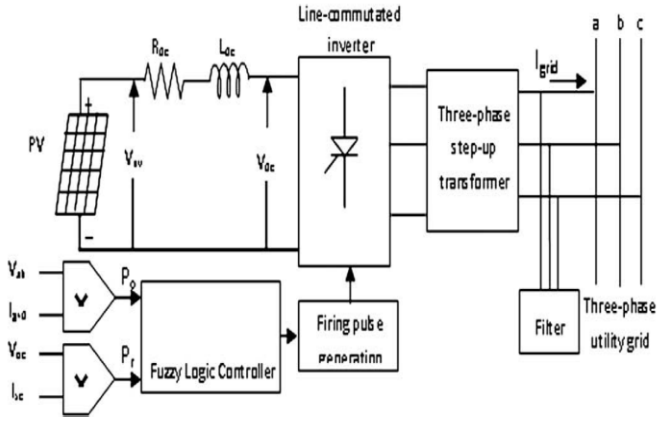

Fig.4. Basic PV system integrated with three-phase utility grid using fuzzy logic controller [14]

A simple power electronic controller for interfacing electrical phenomenon arrays with the three-phase grid through a line-commutated electrical converter and transformer has been developed. Simulation studies of the closed-loop system theme with mathematical logic controller are applied. The results obtained from the experimental investigation and simulation studies of the projected theme are compared and it's been found that the simulation results closely trust the by experimentation obtained results, so confirmatory the experimental power circuit and management circuits of the electrical converter. So, the mathematical logic management is an efficient tool to trace and extract most power to the grid. the employment of SCR convertor in electrical converter mode has resulted in simpler power circuit. Further, it's the advantage of lesser shift power loss over forced commutated electrical converter with self-commutating devices like IGBTs and power MOSFETs. However, thanks to the electrical converter utilized in the projected theme, sure harmonics are introduced within the grid current.

A three-phase condenser bank is unbroken across the grid to cut back the present harmonics evoked by the line-commutated electrical converter. This has improved the grid current wave and thence reduced harmonics within the three-phase grid current, thereby decreasing the doctorate. The harmonic spectrum for the grid current waveforms with and while not filter has been obtained to prove that the introduction of condenser filter across the grid has eliminated the lower order harmonics to a good extent, so transfer down the doctorate on the point of five-hitter. The doctorate obtained for the grid current wave (32.4%) is additionally closely matching with the analytical worth (31.08%) that more enhances the correctness of the controller. However, because of losses within the dc inductance and therefore the autotransformer interposed between the convertor and therefore the utility grid, the output power fed to the grid is somewhat less. This could be hyperbolic by choosing Associate in Nursing inductance with low losses and operative the electrical device at rated load condition that is feasible with higher capability of PV array. Once a fraction of a module is shaded, the panel voltage and therefore the panel current get reduced leading to decrease of most power from the array.

The impact of photovoltaic (PV) array size, orientation, inclination, load profile, electricity shopping for worth, feed-in tariffs, PV/inverter size quantitative relation ('sizing quantitative relation') and PV/inverter price ratio ('cost ratio') on the economic viability of a grid-connected PV system was investigated employing a valid TRNSYS simulation model [14]. The results showed that the aliquot load met directly by a PV system depends on matching between PV offer and building load profile, size quantitative relation and PV inclination. The gain of a grid connected PV system will increase if the PV system is sized to scale back excess PV voltage fed to the grid once the feed-in tariff is below electricity consumption for worth. The impact of feed-in tariffs on PV saving for selected European countries has been shown. The price of the PV electricity depends on size quantitative relation, PV and electrical converter lifetimes, cost ratio, PV inclination and money parameters. The impact of price quantitative relation on the optimum PV/inverter size quantitative relation is a smaller amount vital once the price quantitative relation lies among 7–11.

The magnitude relation of 'buy' to 'sell' costs and building electrical load profile square measure vital determinants for filler grid-connected PV. The profitableness of a grid-connected PV system is improved by minimizing excess PV electricity fed to the grid significantly once the worth for getting electricity is beyond for mercantilism. For time dependent utility tariffs, it's vital to match the PV electricity generation and building load profiles once filler grid-connected PV. Most PV contribution to the building load is achieved for a load profile that matches closely the PV

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system output profile. Considering the result of feed-in tariffs on PV savings for various countries, it had been found that the rise rate of PV saving with increase in PV size is higher at high feed-in tariff than low feed-in tariff. At high insolation locations the PV saving is a smaller amount suffering from outsized electrical converter. it had been found that at high insolation location the electrical converter performance is affected for the filler magnitude relation on top of one. Two whereas at low insolation the electrical converter performance improved for filler magnitude relation within the vary one.2–1.4. As PV saving depends on the extent of insolation obtainable still because the shopping for and mercantilism electricity costs, for low insolation locations high feed-in tariffs would encourage adoption of grid-connected PV.

A A grid-connected electrical phenomenon (PV) was planned for multistring power acquisition system with PV input current reduction management [15]. An improved maximum power point tracking (MPPT) methodology for the multistring convertor is usually recommended. The urged MPPT formula tracks the most wall plug despite the fact that measure errors exist. To scale back the PV current variation introduced by the electrical converter, a PV current variation reduction management is usually recommended. This PV current variation reduction management reduces the PV current variation while not extra parts. The low current variation reduces the filter size and improves the MPPT potency. All algorithms and controllers square measure enforced on a single-chip microcontroller. Experimental results obtained on a 3-kW example show high performance like a MPPT potency of ninety nine.7%, An nearly unity power issue, an influence potency of ninety six.7%, and a complete harmonic distortion of 2%.

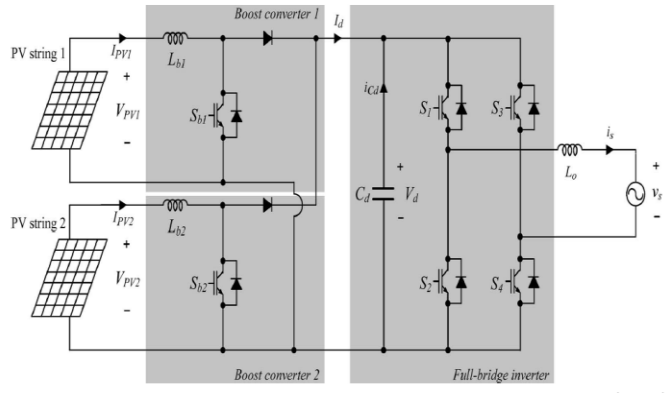

Fig.5. Multistring PV single-phase PCS [15]

The grid-connected multistring PCS with a PV current variation reduction management is projected. The advised MPPT controller as a changed P&O technique tracks MPP quicker and properly albeit activity errors exist. The PV current variation reduction controller is usually recommended to cut back the filter size and therefore the PV current variation and to extend the MPPT potency. The experimental results obtained on a 3-kW model show high performance of the projected technique. All algorithms and controllers are enforced on a single-chip microcontroller.

A single-phase five-level electrical phenomenon (PV) electrical converter topology was projected for grid-connected PV systems with a unique pulse width modulated (PWM) management theme [16]. Two reference signals similar to one another with an offset cherish the amplitude of the triangular carrier signal were wont to generate PWM signals for the switches. A digital proportional–integral current management algorithmic program is enforced in DSP TMS320F2812 to stay this injected into the grid curving and to possess high dynamic performance with quickly dynamical part conditions. The electrical converter offers abundant less total harmonic distortion and might operate at near-unity power issue. The projected system is verified through simulation and is enforced in a very model, and therefore the experimental results ar compared therewith with the traditional single-phase three-level grid-connected PWM electrical converter.

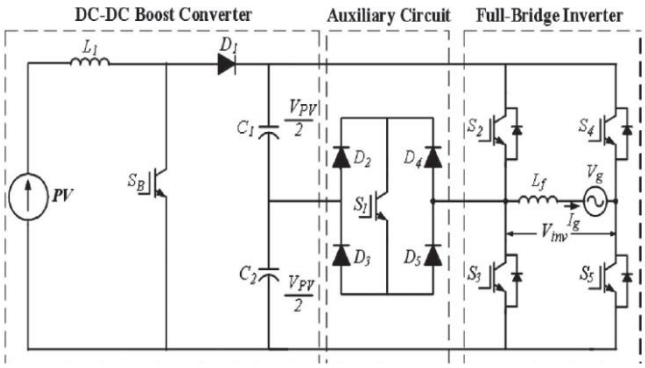

Fig.6. Single-phase five-level inverter topology [16]

A three-level Neutral purpose Clamped (NPC) voltage supply electrical converter was planned [17] for grid connected electrical phenomenon (PV) systems. The controlling technique used is that the Extended Direct Power management (EDPC), that may be a generic approach for Direct Power management (DPC) of structure inverters supported geometrical issues. most wall socket chase (MPPT) algorithms, that enable highest power conversion into the grid, are enclosed. These ways are capable of extracting most power from every of the freelance PV arrays connected to every DC link voltage level. The primary one may be a standard MPPT that outputs DC link voltage references to EDPC. The second relies on DPC conception. This new MPPT outputs power increment references to EDPC, so avoiding the utilization of a DC link transformer. The full system has been tested on a three-level NPC voltage supply electrical converter connected to the grid and results ensure the validity of the tactic.

Two separate PV arrays are connected to the grid by suggests that of a three-level NPC voltage supply electrical converter with associate degree inductive filter. This electrical converter has been controlled victimization Extended Direct Power management, a generic management methodology for structure inverters that permits direct management of active and reactive powers and middle purpose voltage management while not parameter standardization, showing a wonderful dynamic response.

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An optimum power management mechanism was projected for grid connected electrical phenomenon (PV) systems with storage [18]. The target is to assist intensive penetration of PV production into the grid by proposing peak shaving service at all-time low price. The structure of an influence supervisor supported associate degree optimum prognostic power programming rule is projected. Optimization is performed victimization Dynamic Programming and is compared with an easy ruled-based management. The quality of this study remains 1st within the thought of batteries ageing into the optimization method and second within the "day-ahead" approach of power management. Simulations and real conditions application square measure applied over one exemplary day. In simulation, it points out that peak shaving is realized with the lowest price, however particularly that power fluctuations on the grid square measure reduced that matches with the initial objective of serving to PV penetration into the grid. In real conditions, potency of the prognostic schedule depends on accuracy of the forecasts that ends up in future works regarding optimum reactive power management.

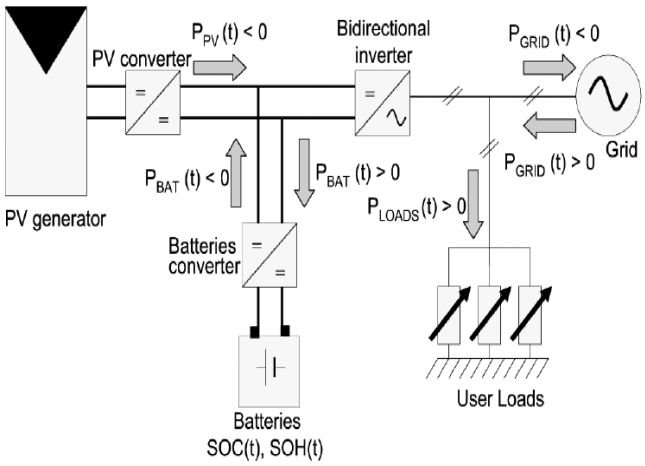

Fig.7. Power direction and sign convention in the system studied [18]

The objective was to perform peak shaving with the lower value for the owner of the system. The quality of the approach lies within the thought of the batteries' ageing into the day-ahead power management. The management developed helps integration of PV power into the grid as peak masses area unit well-shaven. Relying of the reactive management in real conditions, the facility fluctuation of the PV production is balanced to the facility changed with the grid or with the batteries. During this context, next and future works can wear down reactive management for real condition operations.

From the conclusion of this study, a unique reactive management are developed and compared in real condition operations. Specifically, AN optimum reactive management, developed from the refugee algorithmic program of the prognostic optimization stage, are projected. During this manner, the total of the works can achieved to a whole power management system that's reactive like optimum management is secured in keeping with the important conditions.

Increasing penetration of electrical phenomenon (PV) similarly as increasing peak load demand has resulted in poor voltage profile for a few residential distribution networks. This proposes coordinated use of PV and Battery Energy Storage (BES) to handle voltage rise and/or dip issues. The reactive capability of PV electrical converter combined with droop primarily based BES system is evaluated for rural and concrete eventualities (having totally different R/X ratios). Results show that reactive compensation from PV inverters alone is decent to keep up acceptable voltage profile in AN urban situation (low resistance feeder), whereas, coordinated PV and BES support is needed for the agricultural situation (high resistance feeder). Constant similarly as variable droop primarily based BES schemes area unit analyzed. The desired BES filler and associated value to keep up the appropriate voltage profile beneath each schemes is conferred [19]. Uncertainties in PV generation and cargo area unit thought of, with probabilistic estimation of PV generation and randomness in load modelling to characterize the effective utilization of BES. Actual PV generation knowledge and distribution system network knowledge is employed to verify the effectiveness of the projected methodology.

Advantage of variable droop primarily based energy storage is mentioned in terms of economic investment from customers and transient comparison of economic and technical blessings between BES and D-STATCOM (reactive power compensation device) is conferred. though only once investment in D-STATCOM is lower in comparison with total investment in BES, BES provides long run technical edges in terms of peak shaving.

Considering the intermittent characteristics of PV generation, probabilistic estimation is also performed. The probabilistic estimation of PV generation and randomness in load profiles are considered over a year (2012) to analyze the utilization of BES. Two distinct seasonal profiles (summer and winter) are considered.

In future low voltage grids, with multiple electrical converter interfaced sources connected, voltage regulation might become a necessary task. The potential exists for electrical converter interfaced sources to be deployed to control the voltage at the purpose of common coupling (PCC) of every electrical converter interfaced sources. The PCC voltage regulation is getable with electrical converter interfaced sources by dynamically dominant the quantity of reactive power injected to the facility distribution grid by individual systems. Within the current analysis, a closed-loop controller is planned to control the PCC voltage of a star electrical phenomenon (PV) system that's connected to a single-phase power distribution feeder (with R to X quantitative relation larger than 1). The plant model of the PCC voltage controller of the PV system springs considering each electrical phenomenon and resistance of the network to that the

PV system is connected [20]. Three completely different compensators are evaluated to spot an acceptable compensator for the closed-loop PCC voltage controller to control the PCC voltage at a given reference voltage. Simulation studies and experimental verification make sure that the theoretical approach taken to derive the management plant model of the PCC voltage controller is correct and therefore the procedure that's followed to style the controller is strong.

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The projected closed-loop controller for a PV system that's connected to the distribution grid is capable of control the purpose of common coupling (PCC) voltage of the PV system at a given reference voltage by dominant the number of reactive power injected to the grid by the PV system. So as to accurately regulate the PCC voltage at a given reference, an appropriate compensator ought to be enclosed within the controller. Among three totally different compensators that square measure evaluated within the study, the scaled measuring system is found because the most fitted compensator for control the PCC voltage of the PV system at a given reference voltage resulting in zero steady-state error. The derived plant model of the PCC voltage controller is correct since the dynamics of the designed PCC voltage controller square measure certain. The projected dynamic PCC voltage management theme will be wont to examine potential management interactions which will occur in multiple PV installations in a very low voltage distribution feeder.

A single-stage, three-phase grid connected solar photovoltaic (SPV) system was planned [21]. The planned system is twin purpose, because it not solely feeds extracted solar power into the grid however it conjointly helps in rising power quality within the distribution system. The bestowed system serves the aim of most point pursuit (MPPT), feeding SPV energy to the grid, harmonics mitigation of masses connected at purpose of common coupling (PCC) and equalization the grid currents. The SPV system uses a three-phase voltage supply convertor (VSC) for playing of these functions. Associate improved linear curving tracer (ILST)-based management formula is planned for management of VSC. Within the planned system, a variable dc link voltage is employed for MPPT. an on the spot compensation technique is employed incorporating changes in PV power for quick dynamic response. The SPV system is 1st simulated in MATLAB in conjunction with Simulink and sim-power system toolboxes, and simulated results area unit verified through an experiment. The planned SPV system and its management formula area unit enforced in a very three-phase distribution system for power quality improvement and improved utilization of VSC. the full harmonics distortions (THDs) of grid currents and PCC voltages area unit determined inside IEEE-929 and IEEE-519 standards.

The dc link voltage has been regulated to reference price employing a PI controller and projected control rule. The performance of projected single stage grid interfaced SPV system in conjunction with harmonics compensation, power issue correction, and grid currents equalization has been found satisfactory and meeting IEEE standards. Improvement in existing ALST rule has been projected in conjunction with modifications to include feature of alternative energy injection into the grid. Associate ILST-based management rule has been used for the basic current extraction in conjunction with fast compensation for PV power for quick dynamic response. The options of projected management rule are found easy to implement, quick convergence, and it needs terribly less procedure effort.

III. CONCLUSION

This paper presents a literature review of the recent developments and trends bearing on Grid Connected photovoltaic Systems (GCPVS). In countries with high penetration of Distributed Generation (DG) resources, GCPVS are shown to cause accidental stress on the electrical grid. A review of the prevailing and future standards that addresses the technical challenges related to the growing variety of GCPVS is bestowed. Maximum power point tracking (MPPT), solar following (ST) and also the use of rework less inverters will all result in high potency gains of electrical phenomenon (PV) systems whereas guaranteeing least interference with the grid. Inverters that support appurtenant services like reactive power management, frequency regulation and energy storage area unit important for mitigating the challenges caused by the growing adoption of GCPVS.

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