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Review on Damped-Sogi Based Control Algorithm for Solar PV Power Generating System

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Abstract- This Review deals with two stage solar PV power generating system with improved power quality in three-phase distribution system. This system not only feeds the power to the grid but it also provides the load compensation, power factor correction and harmonics elimination. For this, a double stage system is used where first stage is a DC-DC boost converter, which performs the MPPT (Maximum Power Point Tracking). For extracting maximum power from the PV string, an incremental conductance based MPPT algorithm is used. Moreover, in second stage a voltage source converter (VSC) is utilized. For control of VSC, a damped-SOGI (Second Order Generalized Integrator) algorithm is proposed. By using damped-SOGI based control algorithm, fundamental active and reactive power components of load currents are extracted for estimating the reference grid currents. After comparing these reference grid currents with sensed grid currents, these produce the switching pulses for the grid tied VSC. A prototype of the proposed system is developed in the laboratory. Test results are shown to validate the design and control algorithm under steady state and dynamic conditions at linear and nonlinear loads.

Index Terms- Multilevel inverter, SIMO-SEPIC, solar PV, power quality.

I. INTRODUCTION

The attention is on renewable energy (RE) based power generation, which is expanding internationally at a rapid rate due to the rapid development of electrical energy consumption and the need for clean, free electricity for security of the environment. Among grid-integrated RE methods, photovoltaic (PV) solar energy systems are becoming more and more popular [1]. The key benefits of solar PV include their long lifespan, ease of installation, rooftop applications, availability of free and cheap energy, generation of clean energy, noiseless operation, lack of moving parts, and low maintenance requirements. The efficient power transfer from the solar PV to the distribution grid with is the modern.

The current research direction is towards efficient power transfer from solar PV to the power distribution grid. The connected to the grid solar inverters conserve space and money by avoiding large battery banks. A typical two-level (2L) inverter-based solar power conversion device (SECS) with a modified proportional-resonant (M-PR) controller functioning in both standalone and grid-connected modes is reported in [2].

The main benefits are the ease of switching and circuitry. In [3], the peak-peak current ripples in the multilayer inverter (MLI) and the 2L inverter are analysed and examined, and a few pulse width modulation, or PWM strategies for lowering the current ripples are also given. The lower switching stress of 2L restricts its use to low power. Additionally, the sophisticated filters and greater switching frequency decrease efficiency and cause electromagnetic interference (EMI) problems for communication and electricity lines that are closer by. Voltage source inverters (VSI) handle the grid-synchronization portion of SECS, and MLIs are introduced to address the drawbacks of 2L inverters.

II. CONVENTIONAL ENERGY SOURCES

Conventional energy sources are widely used for electric power generation, but they are not environment-friendly. Thus, a shift towards clean and renewable energy sources is observed. Renewable energy sources are soon to replace conventional energy sources in the area of electric power production due to their environment-friendly, free and clean nature. Solar, wind, tidal, biomass are some of the free sources of energy that are found to be cost-effective for long-term use. In the field of solar energy, several studies are being conducted to extract maximum power with reduced losses, for supporting the grid [1]. Nowadays, electric power generated from the emerging PV technology is made accessible to customers through grid integration.

PV array voltage forms the DC voltage input to the two-stage grid-integrated solar energy transfer system (SETS). A high gain DC-DC converter is required as a power interface between PV array and inverter for the two-stage SETS. The

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use of coupled inductors, switched capacitors or step-up transformers introduce high voltage gain in converters. The conventional boost converter has limitations for switching frequency, gain, duty ratio, etc. A magnetically modular coupled converter reported in [2] has a cascaded connection of boost converters with inductors magnetically coupled to each other. But, the use of coupled inductors has risks of electromagnetic interference (EMI) and increases size. A switched-capacitor based converter in [3] gives an appreciable gain of 30 but the use of a higher number of capacitors makes the system bulky.

To overcome the problems due to complexity, EMI issues, and reduced efficiency in conventional boost converters, the scope of quadratic converters is studied in [4]. A comparison between cascaded boost converter and conventional quadratic boost converter (QBC) concludes that the cascaded boost converter has better efficiency at the same operating conditions. Moreover, in terms of the number of components used, switching stress, frequency, and gain, the quadratic converter is a better option. A conventional QBC uses only one switch to obtain a gain of four, while some other QBC-derived topologies have additional features like lesser capacitor voltage stress, inductor current reduction , output voltage ripple reduction [5]-[6]. Some of the QBC-derived boost converters in [7], [8] are found to have a higher number of components and complexity. A modified QBC (MQBC) in [9] aiming for lesser output voltage ripple gives higher efficiency using less number of components. MQBC is found to have a lesser output voltage ripple, lesser voltage stress across the capacitor, and maximum efficiency of 95.8%. Duty ratio control of MQBC can be estimated by incremental conductance (INC) algorithm based maximum power point tracking (MPPT) technique [10]. It is simple to implement with less computational burden and control complexity while compared to advanced MPPT techniques.

III. PROBLEMS WITH EQUIPMENT SENSITIVITY

Since the need for solar and wind-powered clean energy systems has grown in the current distribution system, In this method [1], a model based on an adaptive filter is suggested for controlling a three-phase universal active power filter integrated DC Bus with solar PV panels. The magnitude of the load distortion's fundamental active component is extracted using two adaptive filters with zero crossing detection algorithms. It has become a big problem in [2] the low voltage distribution system network because of the fluctuation in voltage. Modern power electronics are increasingly becoming more advanced as semiconductor devices improve. The same goes for computer power supplies, variable frequency drives, switched mode power supplies, and server power supplies, for example. Energy-efficient electrical gadgets require non-linear current from the source even if they consume less power [3]. As a result, Voltage disturbances are more sensitive than before. Non-linear current influences distribution transformer and common point coupling. "The clean energy with the best power quality are not demand of the next future" has been made plain in[4] this post. It also decreased our reliance on energy derived from fossil fuels. Renewable energy sources are being linked with flexible AC transmission systems for unified power flow regulation, which could enhance the environment. Large PV farms and FACTS devices like UPFC are utilised in transmission systems to increase the stability of the electricity supply. Power Quality Issues Any variation in[5] voltage, current, or frequency has an impact on the power quality. Problems with equipment sensitivity that are frequently encountered are as follows:

- Power Surges
- Transients
- Frequency Variation
- Electrical Line Noise
- Brownouts or Blackouts
- Power System Faults
- Improper grounding

Among the main effects of these concerns is a rise in harmonics. End user equipment may be damaged as a result of the presence of harmonics. Heating of underground cables, insulation failure, reduced equipment life-span and increased losses are all a result of harmonics generated by these devices. Filters that minimise harmonics are the most effective way to improve power quality. The literature describes a variety of filter topologies, including active, passive, and hybrid. Parallel resonance is a difficulty with passive power filters, which are used [6] to filter out a specific harmonic. The Active Power Filter is another option. Series APF and shunt APF are two examples of different forms of APF. Because of its high cost, the shunt APF can only be employed in small systems. the negative-sequence voltage can be reduced by using a series APF as a harmonic isolator Hybrid Filter is a filter topology that combines APF with passive filtering.

IV. LITERATURE REVIWE

Atma Ram et al. [1] The distributed static compensators (DSTATCOM) are connected at the distribution end to enhance the quality of power. The performance of DSTATCOM needs to be improved for better utilization and more ancillary services. In this regard, an upgraded second-order generalized integrator (U-SOGI) based adaptive control structure is developed for DSTATCOM. The proposed control algorithm is much simpler than transformation based techniques because this structure consists of two integrator, three mathematical operators and a damping factor. This control algorithm is utilized to extract the fundamental active and reactive components from the distorted load current.

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Manoja Kumar Behera et al. [2] Photovoltaic (PV) sources are increasingly deployed as distributed generators in remote single-phase utility grids. Meanwhile, variable power demand and fluctuating PV power output pose a challenge to utility grid stability and consistent power supply. This article introduces a hydrogen/bromine (H2/Br2) redox flow battery (RFB) for a single-phase grid-integrated PV system. A unique spontaneous control scheme for a single-phase two-stage grid-connected PV-H2/Br2 RFB system is proposed using an orthogonal signal generator-anti-windup filtered second-order generalized integrator (OSG-AWFSOGI) and tilt integral derivative (TID) controller.

Rohit Kumar Jain et al. [3] In the last couple of decades, the integration of photovoltaic (PV) systems with the utility grid has gained significant attention due to its potential to harness renewable energy and contribute to sustainable power generation. However, the integration of the PV system into the grid leads to issues related to power quality and system stability under varying solar irradiation, dc offset, and distorted grid conditions. Therefore, this paper focus on the robust and efficient control of a single-phase, two-stage PV grid-tied system to improve power quality and stable system operation under abnormal grid conditions.

Nirmal Mukundan C.M et al. [4] Solar energy contributes a major share in sustainable energy-based electricity generation. The solar power transfer system (SPTS) has emerged to integrate solar energy into the distribution network. Moreover, the adverse effects and exhaustible nature of fossil fuels have made the control and design of the SPTS significant. This paper presents a novel grid integration control, named frequency adaptive generalized integral (FAGI) algorithm for a three-phase four-wire SPTS to compensate the reactive power, harmonics and DC offset demands of the sinks connected at the common point, and also eliminates the grid neutral current along with maximum PV array power injection to the grid. The narrow bandwidth bandpass filter property of the FAGI algorithm with adaptive corner frequency improves the fundamental component quality without compromising the response time at adverse operating conditions. The two-stage SPTS uses a DC–DC boost converter for peak power extraction. An enhanced incremental conductance (EIC) algorithm is utilized for its control, which gives simple and dynamic performance over other conventional maximum power point tracking techniques. The system control is developed to meet the load requirements, even at zero irradiance by importing the active power from the grid.

Christian Buzzio et al. [5] This paper presents a two-stage current-source DC-AC converter for grid-connected PV applications which is composed of an input step-up stage, followed by a step-down stage and an unfolding inverter. A decentralized control strategy of the DC-DC stage allows maximizing the renewable energy harvest using an Incremental Conductance MPPT algorithm and synthesizing an output current to be injected into the grid with low harmonic distortion. Double-loop PI controllers are used for the boost stage. The DC bus voltage of the buck stage is regulated using a PI controller, and an inner Proportional-Resonant (PR) controller tracks a sinusoidal reference. The PR controller proposed in this paper, includes a reduced number of resonant stages meeting the energy quality required by standards, which results in good stability margins. Finally, a SOGI-FLL algorithm synchronizes the inverter operation with the grid. Experimental results show an excellent dynamic response of the system, and the injected current complies with the IEEE Std. 1547–2018 specifications regarding harmonic content using a control law with a low computational burden.

Meghraj Morey et al. [6] The installed capacity of solar photovoltaic (PV) based generating power plants has increased significantly in the last couple of decades compared to the various renewable energy sources (VRES). As a result, the increased penetration of solar PV-based generating units leads to several issues related to power quality, system stability, and reliability. In view of these concerns, various international standards and grid codes have been amended to address such critical issues. Therefore, most solar PV-based generating units have undergone several changes in operational and control structure. Subsequently, varieties of solar PV configurations and control structures have been proposed by several researchers to augment the desired operational features. This paper presents a comprehensive review of various solar PV configurations, control strategies, and ancillary services with multifunctional features within this context.

Dinanath Prasad et al. [7] An adaptive control approach for a three-phase grid-interfaced solar photovoltaic system based on the new Neuro-Fuzzy Inference System with Rain Optimization Algorithm (ANROA) methodology is proposed and discussed in this manuscript. This method incorporates an Adaptive Neuro-fuzzy Inference System (ANFIS) with a Rain Optimization Algorithm (ROA). The ANFIS controller has excellent maximum tracking capability because it includes features of both neural and fuzzy techniques. The ROA technique is in charge of controlling the voltage source converter switching. Avoiding power quality problems including voltage fluctuations, harmonics, and flickers as well as unbalanced loads and reactive power usage is the major goal. Besides, the proposed method performs at zero voltage regulation and unity power factor modes.

Pragya Gawhade et al. [8] The contribution of solar photovoltaic (PV) in the electrical power sector is increasing expeditiously. Recent interest in the integration of solar PV into the grid raises concerns about the synchronization technique. Continuous research has successfully replaced the small stand-alone system with a grid-tied PV system. A grid-

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tied PV system is popular due to the abundance of solar light and advanced power electronics techniques. This paper helps to provide a basic conceptual framework to develop a superior grid-tied system. Synchronization is a crucial problem in grid-tied inverters operation and control research indicates that frequency, phase, and amplitude of voltage are the most crucial parameters that need to be measured and controlled for grid-tied application.

Vijayakumar Gali et al. [9] This article proposes a multifunctional control scheme to enhance the mode adaptive capability that prevents the collapse of microgrids subsequent to the failure of the utility grid and power generation units. The proposed control scheme allows photovoltaic, wind, and battery energy storage-based microgrids to operate impeccably during grid-connected and islanding modes. Static transfer switches are used to isolate and relink the microgrid to the utility on occurrence and clearing of faults. However, due to the presence of harmonics of variable frequencies in the utility grid, the mode transfer fails using conventional schemes. To the contrary, a novel harmonic frequency adaptive observer (HFAO) filter is proposed in this paper for accurate tracking of harmonic frequencies to exact fundamental components of signals under inadequate grid and nonlinear load conditions. The HFAO calculates frequencies and magnitudes of harmonics present in the signal accurately with reduced ripples, increases the robustness of quadrature-phase signal to sub-harmonics, and improves harmonic rejection property. All conceivable implications of the proposed controller are investigated under various conditions of load and microgrid operating modes using MATLAB®/Simulink® environment. Results from in-silico experiments confirm that compared to conventional control schemes, the proposed controller is more accurate in tracking harmonic frequency signals with respect to changes in grid distortions and loads.

Om Prakash Jaga et al. [10] This paper presents a grid-tied, solar energy conversion-battery energy storage system with an autonomous control method for critical load applications. In order to improve grid current dynamics and ensure that balance power is exchanged as an active power with utility, direct current management of voltage source converter utilises the least mean fourth method.

The intermittent nature of solar photovoltaic also affects dynamics and power quality of grid current. A potential solution to such a situation evolves by using a bidirectional, DC/DC converter, which interfaces the battery energy storage (BES) system with DC link. Dual-loop DC/DC converter control keeps the BES system charging and discharging current within pre-set limits and also simultaneously regulates DC link. State-of-charge control gets incorporated through a dual-loop control to prevent the BES system from overcharging/deep-discharging.

V. CONCULUSION AND FUTURE SCOPE

A discrete second order generalized integrator (DSOGI) based control is presented in this work for control of solar photovoltaic integrated unified power quality conditioner (SPV-UPQC). Two DSOGI based band-pass filters are used to extract fundamental positive sequence component (FPSC) of unbalanced grid voltages. The shunt compensator of SPVUPQC is controlled based on philosophy of drawing balanced positive sequence currents (BPSC) from the point of common coupling (PCC). The shunt compensator has the dual function of compensating for load power quality issues along with injecting power from solar photovoltaic (SPV) array. Sensitive loads are protected against grid voltage fluctuations such as voltage sags/swells etc with the help of the series compensator of SPVUPQC. A step-up DC-DC converter is used for coupling SPV array to the DC-bus of SPV-UPQC. A Maximum power point tracking (MPPT) algorithm generates appropriate duty cycle for the dc-dc converter so that the SPV array is operated at its peak power. The performance of DSOGI based SPVUPQC is simulated in Matlab-Simulink environment and tested under dynamic conditions of grid voltage disturbances, load disturbances and solar irradiation variation.

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