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Optimal Integrator Control Algorithm Design for Single-Stage Grid-Connected Solar Array System

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Abstract: In order to enhance the power quality of the distribution system while taking into account variations in solar irradiation and unbalanced grid circumstances, this research offers an optimum integrator control method for a three-phase single-stage grid linked solar array system. To obtain the greatest power from a solar array under various climatic circumstances, the P&O based maximum power point tracking (MPPT) approach is applied. The suggested control method further enhances load stabilisation, harmonic mitigation unit power factor operation, and reactive power mitigation. Under fluctuating solar irradiance, the optimum integrator control technique lowers voltage fluctuation in the DC link voltage and provides DC offset rejection in the Voltage Source Converter (VSC) input voltage. The primary objective of this suggested control strategy is to extract a positive sequence of per unit phase voltage values and to operate in weak grid and unbalanced grid voltage conditions. The MATLAB findings illustrate how the system responds to both steady-state and dynamic conditions, such as imbalanced loads and variations in solar irradiation. The THD of the source current and voltage as specified in IEEE 519 standards are attained, according to an analysis of the data.

Keywords: Solar array system, D-STATCOM, Optimal integrator algorithm, PID controller, Distribution network, Power quality.

I. INTRODUCTION

The limitation of traditional power sources of coal, gasoline, oil, hydro and nuclear fuel urgently required alternative energy sources. So, there is a need to identify the other methods for balancing the supply and demand without resorting to coal and gas fueled generators. The government is aiming towards new policies that encourage and support green energy projects [1]. The idea is to implement a solar grid interfacing network, which dispenses the energy storage unit effectively. The LMF has a lower stable performance that brings low accuracy to obtain the amplitude of the fundamental component. If the error in the LMF control equation is less than unit, the control algorithm takes an excessive amount

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of time to converge into real value with the existing dynamic load differences. The SOGI algorithm has low DC offset rejecting capability which reduces the device efficiency. The SRF has a strong calculation algorithm load and low dynamic performance due to the Low-Pass Filters. The Second-order harmonic term is predominant in the d-axis currents under unbalanced load-side network, which results in deficiency in the steady state performance by keeping the cutting frequency low. The Integrator based control scheme develops oscillations in the inverter input voltage (or) DC link voltage of and currents as change in solar irradiance [8]- [11]. The structure of single stage solar PV power conversion [12]-[13] more efficient than the double stage conversion due to reduce the conversion stages, losses and complexity of the control algorithm.

This paper mainly focuses on improving the load stabilization, unity power factor correction, harmonic mitigation and reactive power compensation, reduction of oscillations in the inverter input voltage wave forms (dc link voltage) under sudden change of solar irradiance.

II. DESIGN OF PROPOSED CONFIGURATION

The model consists of a D-STATCOM connecting to 3 phase system feeding 3 phase loads can be of a lagging power factor or a non-linear in nature or combination of above. Figure.1 shows 33 kW grid connected single stage solar array system for power quality improvement in utility distribution system.

The output of solar array system was connected to 3-phase within. In order to implement the solar array system effectively, several techniques are defined for acquiring full bridge VSC (Inverter) through dc link capacitance (Cdc). In AC side of Inverter, inductors (maximum energy in the solar photovoltaic array, using MPPT algorithm [2]-[3]. These techniques are framed to explain the performance comparison, convergence rate, sensing variables, installation and power quality. Researcher's objective like conservation of the given electrical network power quality was highlighted by the use of non-linear loads in energy transfer such as electrical traction, health care facilities, lighting and non-conventional networks. These loads will generate more harmonics within the given distribution networks and cause conversion of power failure.

The Least Mean Fourth (LMF) [5], Model Reference Adaptive Control [6], Synchronous Reference Frame (SRF) [7], SOGI-FLL control algorithm [9] and Generalised Integrator (GI) based control algorithm are analysed Lt) are used to minimize ripples in currents. The ripple filters (series connection of Rf and Ct) are tied parallel to the loads to a common connection point and it can be used to filter out the high frequency voltage switching noise at PCC. MPPT algorithm is employed to generate peak power in various temperatures and Irradiance. The solar photovoltaic modules are designed with peak

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capacity of 33kW, and it was connected to a AC utility distribution system with ratings of 415V, 50 HZ, 3- phase system. The design procedure of proposed configuration has explained [14].

III. DESIGN OF PROPOSED CONTROL ALGORITHM

Fgure.2 displays Optimal Integrator control scheme of Inverter (VSC) switching operation and it is involving the MPPT algorithm, extracting fundamental component of load current, PID controller design and inverter pulse generation. The P&O technique is used to generate maximum power from solar PV arrays at different temperatures and irradiance. The solar feed forward concept and PID tuning were added to the control algorithm that contributes to reducing the oscillation of DC link voltage and grid currents under variability in development solar power. This control scheme is used to derive the positive sequence of per phase voltages and also to obtain balanced operation of given network and to perform even under unbalanced grid voltages. The VSC switching algorithm involves the solar array feed forward element, inverter loss term and estimating the magnitude of fundamental component of nonlinear load current element. The error of grid reference currents and source currents are connected to Hysteresis current control (HCC) to develop the switching pulses in D-STATCOM. These pulses are produced based on error signal of HCC.

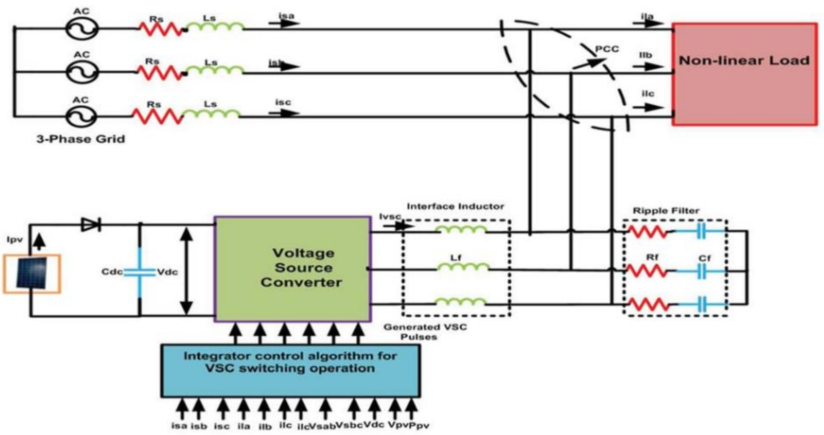

Fig. 1. Block diagram 3-phase single stage grid connected solar array system

IV. SIMULATION AND RESULTS

The MATLAB Simulink software uses a simscope tool box to simulate 3-phase grid connected solar array system. The Optimal Integrator controller described here is designed.

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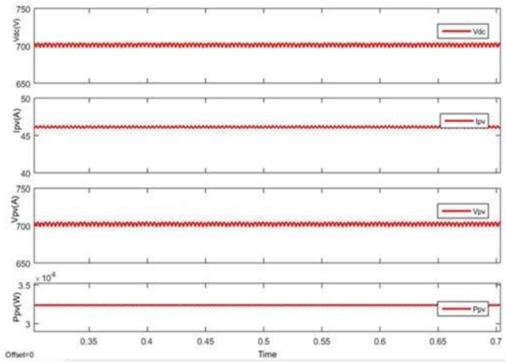

Fig. 2 Simulation results of load unbalancing condition V_{dc}, Ispv, andV_{spv}

V. Proposed system behavior under variation of solar irradiance

Proposed system behaviour under variation of solar irradiance from 500 W/m^2 to 1000W/m^2 was shown in figure 3, 4 and 5. Figure.6 shows the dynamics of inverter with PID controller was shown in figure7. The output of D- STATCOM current (I_{vsc}) was more compared to source current, that shows the power supplied from solar PV array to grid connected loads through D-STATCOM. The loads current was unchanged and therefore the real power DC link voltage (Vdc), MPPT reference voltage (V_{dcref}) provided in the given network was improved, It provides a significant rise in source or supply current with no solar array feed-forward component and inverter loss component I_{occ}. Solar array power and solar array feed- forward element (I_{caff}) are increased together with solar array current, due to a varying solar irradiance.

The power delivered to grid has been improved due to rising the solar irradiance at 0.5 s. The effective implementation of the perturb & observe method the MPPT tracking voltage (V_{dcref}), is constant during the variable irradiance and it shows in figure 3. Solar array current (I_{cpv}) and solar power (P_{cpv}) raised as solar irradiance has been varied from 500 W/m^2 to 1000 W/m^2. When sudden increasing of the solar irradiance at 0.5 s, the oscillations was developed in both inverter input voltage (DC link voltage) and source current (I_{cabc}) wave forms and it can be controlled by PID controller. The proper tuning of PID controller parameters the fluctuations in the inverter input voltage was reduced and it is shown in figure 3. The dynamics of G, I_{spv}, V_{spv}, P_{spv}, V_{sabc}, I_{sabc}, I_l, I_{vsc} using optimal integrator algorithm fluctuations and it is shown in figure 7.

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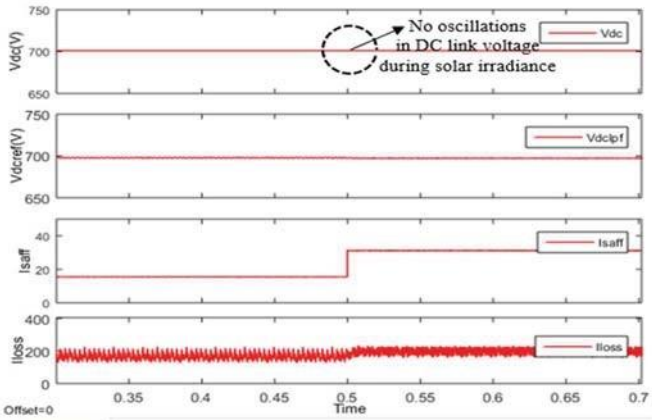

Fig. 3 Simulation results of V_{dc}, V_{dcret}, I_{satt}, and I*l*oss at variable solar insolation

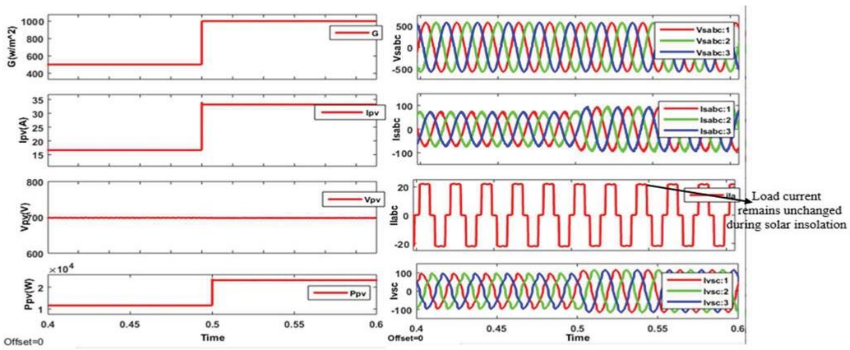

Fig.4 Simulink results of optimal integrator control algorithm with PID controller under non-linear load condition

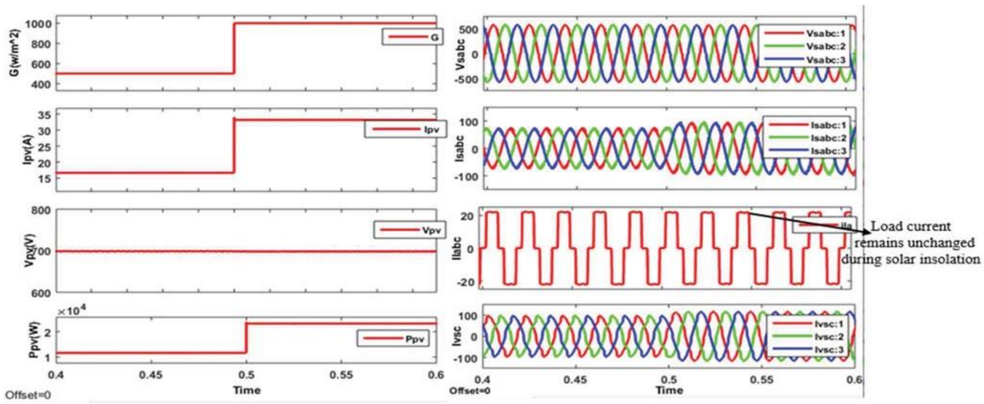

Fig.5 Bar graphs of the harmonic order of supply voltage (V_{sabc}) and source current (I_{sabc}) under variation of solar irradiance

From the figure 8 explains that the bar graphs of the magnitude of harmonic order of source supply voltage (V_{cabc}) and source current (I_{cabc}). It gives the THD of a source (grid supply) voltage and current under variation of solar irradiance. The total harmonic distortions of $Vcabc$ are 1.63% and its

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fundamental value is 572.2 V. The THD of $Icabc$ is 1.54% and its fundamental value is 91.81 A. Using this algorithm, the higher order frequency harmonics such as5th,7th,11th,13th has been eliminated in the grid voltage and current. This bar graph results show that the harmonic content (or) total harmonic distortion of voltage and current have reached according to the IEEE 519 standard limits [15]. Thus, the implemented Optimal Integrator algorithm was well-suited for grid connected solar array systems.

VI. CONCLUSION

For modelling and concurrent execution of the single-stage, grid-connected solar power conversion, the best integrator control method was utilised. The basic component of load currents has been derived using an optimal integrator and the FLL. With the help of this new control system, it was possible to increase the efficiency of the distribution network in a number of ways, including load balancing, power factor improvement, and harmonic reduction. Utilising the optimum integrator technique with a PID controller, it was successfully proved that solar insolation conditions reduced the oscillation in DC-link voltage and source current. Results from Simulink have demonstrated effective performance in both dynamic and steady state responses, such as imbalanced loads and variations in solar irradiation. Grid currents and voltages' THD conforms with the requirements of IEEE 519.

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