Implementation of incremental conductance algorithm and Distributed Sparse Control to grid integrated Solar PV generation system

Srikara KrishnaT[1], Revathi D[2]

[1]*PG Student, Department of EEE, Kakinada Institute of Science and Technology-2, Kakinada, Andhra Pradesh India.*

[2]*Associate Professor, Department of EEE, Kakinada Institute of Science and Technology-2, Kakinada, Andhra Pradesh India.*

Corresponding Author: srikar.thuraga1@gmail.com

Abstract: This paper deals with a multipurpose Distributed Sparse control approach for a one stage solar photovoltaic (PV) energy generation system. This single stage solar photovoltaic (PV) energy generation system is interfaced here to the three phase grid at varying solar irradiance and compensating the load tied at point of common interconnection. The proposed performs multitasks. It feeds the generated solar PV power to the local three phase grid. It reduces the harmonics of loads and furnished a balanced currents of local three-phase grid. Additionally, for extracting more maximum power from the PV source, the incremental conductance scheme is utilized here. The tracking performance and efficiency of incremental conductance technique, are also examined here at rapid changing climatic conditions to show behavior of incremental conductance scheme. The DS control approach is capable to estimate required fundamental component to find out reference grid currents. The proposed control approach is validated on a MATLAB Simulink.

Key Words— *SPEGS, MPPT, ADS*

I. Introduction

Power grid-connected three phase inverters plays an important role in integrating different types of renewable energy resources into the distribution networks or power grids for controlling the active and real power, while simultaneously improving the power quality [1]-[3]. However, since the distribution power networks or micro-grid for energy source integration are typically very weak and suffer from insufficient voltage quality at the end load points or unstable point of common coupling (PCC) voltage when the power grid operated in an islanded mode, non-ideal grid conditions (e.g., voltage/current harmonics, amplitude/ frequency/ phase angle variation) caused by external load/fault disturbances may adversely affect the power grid injected current quality and the stability of power inverter control [4], [5]. Moreover, depending on the grid configuration, the grid impedance, which is mainly determined by low power transformers and long distributed lines, varies over a wide range, especially in the weak grids [6], [7].

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It should be noted that when the power grid for the grid integration changes the mode of operation from grid-connected mode to islanded mode, the PCC voltage is maintained via other grid-forming units, while the grid impedance will be affected significantly [8].

The tracking performance and efficiency of incremental conductance technique, are also examined here at rapid changing climatic conditions to show behavior of incremental conductance scheme. The DS control approach is capable to estimate required fundamental component to find out reference grid currents. The proposed control approach is validated on a Simulink MATLAB-2019a.

II. Control Technique

The control of proposed system, consists of two sub-controls namely MPPT control (in Fig.1) and DSC algorithm (in Fig.2), which are described below.

A. MPPT Algorithm:

There are various MPPT methods reported in [8]. The incremental conductance algorithm is used in this work for harnessing maximum power from SPEGS [9]. The MPPT initially needs to take two points of solar panel voltage and solar array current and generates reference DC link voltage Vdc*.

B. *Distributed Sparse Based VSC control:*

Fig. 2 provides the block of control for proposed system. Following variables are sensed for implementation of proposed control approach, which are grid currents, solar PV voltage and current, load current and a point of interconnection voltages. The amplitude of PCI voltage is obtained as,

$$V_t = \sqrt{\frac{2}{3}(v_{ga}^2 + v_{gb}^2 + v_{gc}^2)} \quad (1)$$

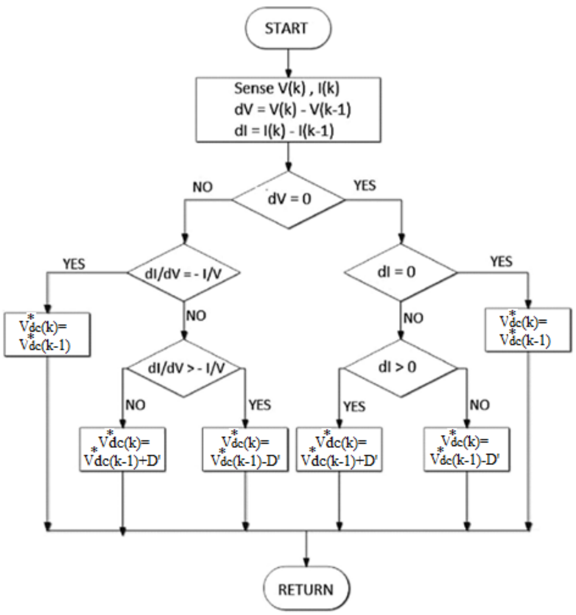


Fig.1. Incremental conductance algorithm

Where, the three phase voltages of the grid, are evaluated from the measured line voltages as,

$$v_{ga} = \frac{2v_{gab} + v_{gbc}}{3}; v_{gb} = \frac{-v_{gab} + v_{gbc}}{3}; v_{gc} = \frac{-v_{gab} - v_{gbc}}{3} \quad (2)$$

With the help of phase to neutral voltages, the in-phase unit templets are estimated as,

$$u_{pam} = \frac{v_{ga}}{V_t}; u_{pbm} = \frac{v_{gb}}{V_t}; u_{pcm} = \frac{v_{gc}}{V_t} \quad (3)$$

Due to this, the proposed system control performance in comparison with a local distributed adaptive filter, is improved. Therefore, for integrating a solar PV system into the power grid, a new control technique is proposed. The effectiveness of any control scheme is significantly influenced by co-operation that are allowed among the all nodes [21]. In this case, a typical network is assumed with m node technique. Here, the objective of every one, is to calculate the unspecified sparse vector D_{wpa0}. In this proposed scheme, as illustrated in Fig.2, every node m, cooperates with its neighbour-hood nodes. By this control technique approach, node m connects to its local estimate, $D_{Wpam(n)}$ with its nebiour hood estimations, {$D_{Wlm(n)}$, l belongs to Pm}, which is estimated as [21],

$$\lambda_{pam}(n) = \sum_{l \in p_m} \sigma_{lm} D_{Wlm} \quad (4)$$

In control scheme, the co-operation step helps combined information from nodes over the network into node m. This happens, because each node in Pm tends to have various neighbour-hood, as shown in Fig. 2. The error signal is obtained as [20, 21],

$$e_{pam}(n) = i_{La}(n) - \lambda_{pam}(n)^T u_{pam}(n) \quad (5)$$

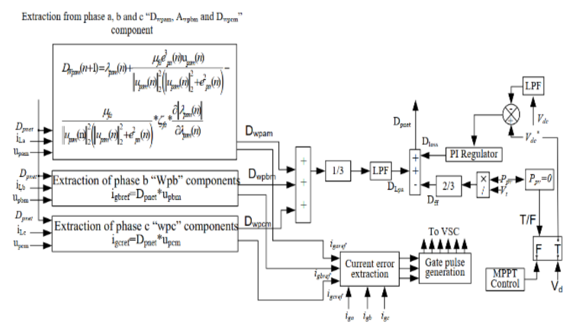


Fig.2. Block diagram for proposed control

Now, based on above obtained error signal and calculated estimation with cooperation factor λ_{pam} at node m, the fundamental component of load current of phase 'a' is estimated as [19],

$$D_{wpam}(n+1) = \lambda_{pam}(n) + \frac{\mu_{fa} e_{pa}^3(n) \mu_{pam}(n)}{\| \mu_{pam}(n) \|_2^2 \left(\| \mu_{pam}(n) \|_2^2 + e_{pa}^2(n) \right)} - \frac{\mu_{fa}}{\| \mu_{pam}(n) \|_2^2 \left(\| \mu_{pam}(n) \|_2^2 + e_{pa}^2(n) \right)} * \zeta_{fa} * \frac{\partial \| \lambda_{pam}(n) \|}{\partial \lambda_{pam}(n)} \quad (6)$$

Similarly, above equation applicable to remaining all the phases,

$$D_{wpam}(n+1) = \lambda_{pbm}(n) + \frac{\mu_{fa} e_{pb}^3(n) \mu_{pbm}(n)}{\| \mu_{pbm}(n) \|_2^2 \left(\| \mu_{pbm}(n) \|_2^2 + e_{pb}^2(n) \right)} - \frac{\mu_{fa}}{\| \mu_{pbm}(n) \|_2^2 \left(\| \mu_{pbm}(n) \|_2^2 + e_{pb}^2(n) \right)} * \zeta_{fb} * \frac{\partial \| \lambda_{pbm}(n) \|}{\partial \lambda_{pbm}(n)} \quad (7)$$

$$D_{wpcm}(n+1) = \lambda_{pcm}(n) + \frac{\mu_{fc} e_{pc}^3(n)\mu_{pcm}(n)}{\|\mu_{pcm}(n)\|_2^2\left(\|\mu_{pcm}(n)\|_2^2 + e_{pc}^2(n)\right)} - \frac{\mu_{fc}}{\|\mu_{pcm}(n)\|_2^2\left(\|\mu_{pcm}(n)\|_2^2 + e_{pc}^2(n)\right)} * \zeta_{fa} * \frac{\partial \|\lambda_{pcm}(n)\|}{\partial \lambda_{pcm}(n)} \quad (8)$$

By equating the sensed DC link voltage (V_{dc}) and estimated DC link voltage (V_{dc}*), a factor is obtained, called loss factor which is given to the PI controller to control the voltage between VSC and solar PV system to the defined value. The error is obtained as

$$V_{dc\_error}(n) = V_{dc}^*(n) - V_{dc}(n) \quad (9)$$

$$D_{loss}(n+1) = D_{loss}(n) + K_p\left\{V_{dcerror}(n+1) - V_{dcerror}(n)\right\} + K_I V_{dcerror}(n+1) \quad (10)$$

To enhance the dynamic performance of the PV system under varying climatic condition, a feed-forward term is estimated as,

$$D_{ff} = \frac{2P_{pv}}{3V_t} \quad (11)$$

Here, V_t is amplitude of PCI voltage estimated in (1). The active power component of utility grid (D_{Pnet}) is estimated as,

$$D_{pnet} = D_{Lpa} + D_{loss} - D_{ff} \quad (12)$$

Here, D_{Lpa} denotes the equivalent average load component of all three phase, which is calculated to perform load balancing and expressed as,

$$D_{Lpa} = \frac{(D_{wpam} + D_{wpbm} + D_{wpcm})}{3} \quad (13)$$

Moreover, the reference currents for local distribution

$$i_{garef} = D_{Lpa} * u_{pam}; i_{gbref} = D_{Lpb} * u_{pbm}; i_{gcref} = D_{Lpc} * u_{pcm} \quad (14)$$

An indirect current control approach with hysteresis controllers, is used to getting the switching pulses for VSC. Therefore, the current errors for hysteresis controller are calculated as,

$$i_{ga\_error} = i_{ga} - i_{garef}; i_{gb\_error} = i_{gb} - i_{gbref}; i_{gc\_error} = i_{gc} - i_{gcref} \quad (15)$$

III. Proposed System

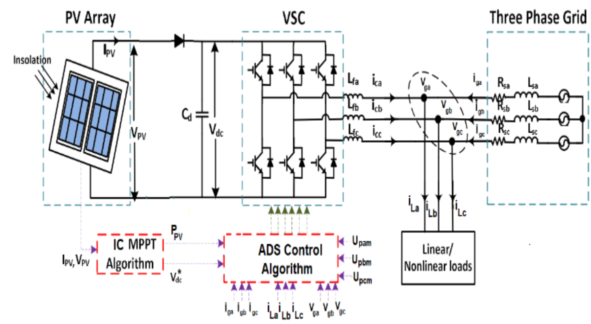


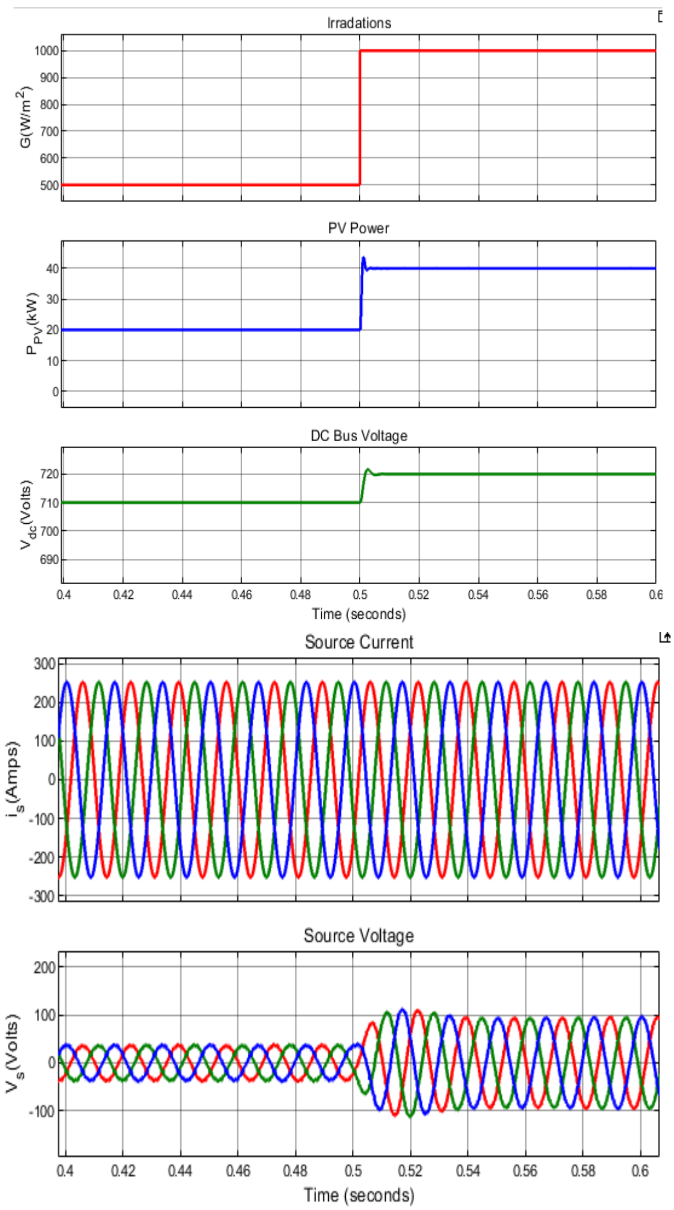
Fig.3. Block diagram of SPV-grid System

A multi-mode single stage SPEGS is depicted in Fig. 3. It consists of a single power converter, which is a voltage source converter (VSC) for exchange the power via MPPT as well as to feed the solar power from source to the three phase power grid and to assist it via facilitating some additional features like harmonics minimization, grid currents balancing and power factor improvement as a Distributed Static compensator without any additional device. Interfacing inductors are used between VSC and the distribution network to minimize the switching losses and subsequently, smoothens the distribution network currents. The difference between sensed *Vdc* and *Vdc* * increases the energy loss in DC link of VSC.

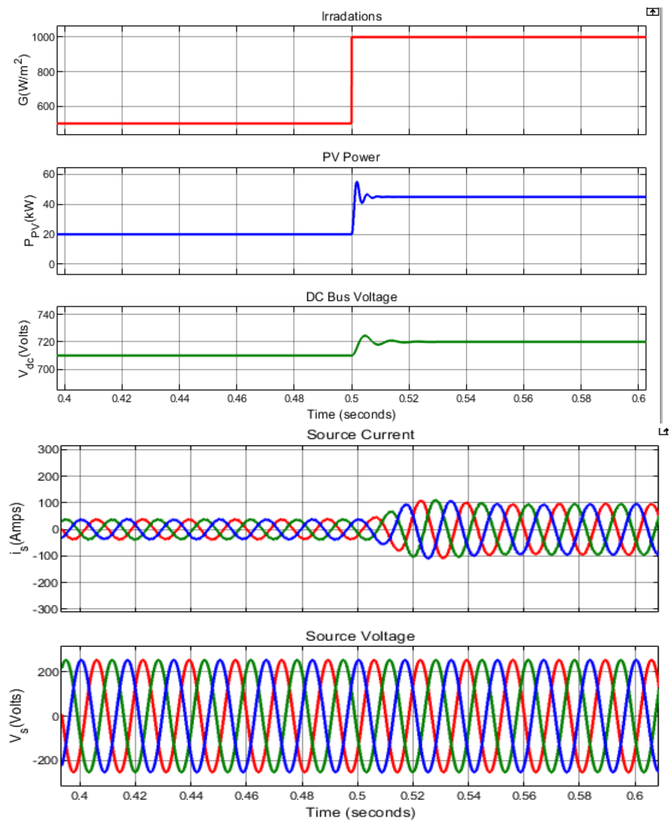
IV. Results And Discussion

The behaviour proposed control algorithm, is demonstrated in Fig. The increase in irradiance from 500 W/m2 to 1000 W/m2 at 0.5 s. The change in voltage between VSC and Solar PV system, is not perceived and hence, burden on Proportional Integral regulator is decreased. Furthermore, the variation in the utility currents (is) are not perceived at step variation at different solar irradiance. Nevertheless, the utility currents are increased as energy fed to the utility is increased. The oscillations in utility voltages (*vs*) are also not perceived at varying irradiance. Fig demonstrates the response of conventional algorithm with P&O algorithm. There is an overshoot and undershoot in DC link voltage, which puts the burden on proportional Integral regulator. The variations in the utility currents are also perceived at variation in solar irradiance, which increases the losses and tripping of VSC. An indirect current control approach with hysteresis controllers, is used to getting the switching pulses for VSC.

A. With P & O algorithm and DS control



B. With IC algorithm and DS control



The task of PI regulator is to reduce the voltage variation between the existing conditions of SPEGS and the actual state, which requires to reduce the voltage difference. The difference between sensed *Vdc* and *Vdc* * increases the energy loss in DC link of VSC. The variations in the utility currents are also perceived at variation in solar irradiance, which increases the losses and tripping of VSC.

V. CONCLUSION

This project presents the design of a distributed sparce based voltage source converter (VSC) control to integrate the SPVs to the grid while achieving robust current control under varying grid impedances and various grid voltage disturbances, such as harmonic pollution, magnitude (symmetrical/ asymmetrical) variations, and frequency, phase shift. Strong robustness and superior current tracking performance can be simultaneously ensured for external disturbance rejection and high-quality current injection. The smooth transient response can be ensured since the dynamic of the controller is fast. The stability of the proposed control is analyzed, and the effectiveness of the proposed control strategy is verified through simulation studies. Dynamic behavior of proposed control technique, has been observed better in comparison with existing control approaches. The proposed approach has worked well in all scenarios at unity power factor operation and resolves problems related to power quality of grid.

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