IJAREEIE

e-ISSN: 2278-8875
p-ISSN: 2320-3765

# International Journal of Advanced Research

## in Electrical, Electronics and Instrumentation Engineering

Volume 10, Issue 2, February 2021

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.122

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE)

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 10, Issue 2, February 2021||

DOI:10.15662/IJAREEIE.2021.1002015

# Implementation of Adaptive Distributed Sparse (ADS) Control Algorithm to Single Stage Grid Connected Solar PV System for DC-AC Conversion

**Ezekiel Nnamere Aneke[1], Ahuchaogu Nnamdi[2], Dr. Ngang B.N[2]**

Ph.D Student, Department of Electrical and Electronic Engineering, Enugu State University of Science and Technology, Agbani, Enugu PMB 01660 Nigeria[1]

Lecturer, Department of Electrical and Electronic Engineering, Abia State University , Uturu, Abia State, PMB 2000 Nigeria[2]

**ABSTRACT**: This paper deals with the implementation of adaptive distributed sparse (ADS) control algorithm to single stage grid connected -photo voltaic (SSG-PV) system for DC-AC power conversion with expected voltage and frequency levels along with same phase sequence of power grid. The proposed system is used to examine the ADS control algorithm with balanced linear and balanced non-linear loads. Additionally, single stage grid connected photo voltaic (SSGPV) system with ADS control provides active and reactive power balancing, harmonic compensation, VAR generation and quality of power. For extracting maximum power from solar system, the conventional traditional P and O algorithm is used. In the proposed system, single stage means one converter called Voltage source converter (VSC) enough for DC- AC conversions and tracking maximum power transfer from solar system. The performance of the proposed system is simulated on MATLAB/Simulink and achieved total harmonic distortion (THD) of voltage at point of common coupling (PCC) and grid currents within limits according to an IEEE 510 standards.

**KEYWORDS:** Power quality, ADS algorithm, Solar PV system, VSC, MATLAB

## I. INTRODUCTION

In recent time, renewable energy sources have experienced dramatic innovations and improvements in terms of both quality and quantity with increased pressure to overcome environmental problems and economic crisis from increased prices of non-renewable natural resources. Especially, grid-connected solar PV farms have been developed very quickly and the penetration of solar energy in the grid is rapidly increasing. Since solar power is randomly varying and it has to be captured over a wide area for stable and reliable operations. Grid connected solar PV generation has two topologies – single-stage (only one converter between grid and solar PV system) and two-stage (two converters, one is DC-DC converter and second one is VSC, between grid and solar PV system). In this paper, single – stage grid connected photo voltaic (SSG-PV) system is considered and ADS control algorithm implemented on this system for DC-AC power conversion.

In this paper, an ADS control algorithm implemented on SSG-PV system. The P and O control techniques generates a reference DC voltage $V_{dc}^{*}$ signal, which is used in ADS control algorithm to extract maximum power from the solar PV system at various irradiation conditions. The target of this paper is to make sure that the control algorithm is able to provide better power DC-AC conversion, load balancing and harmonics compensation.

## II. CONTROL ALGORITHMS OF PROPOSED SYSTEM

Control system of single stage grid connected photo voltaic system consists of two algorithms, one for extracting maximum power transfer from solar PV system, called traditional P and O algorithm and another algorithm is ADS control algorithm for DC-AC power conversion. Both algorithms play a vital role for generating desired gate pulses for VSC operation.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|
||Volume 10, Issue 2, February 2021||
DOI:10.15662/IJAREEIE.2021.1002015

A) Traditional P and O Algorithm:

**There are various MPPT techniques explained in [8]. The traditional P and O algorithm is used in this paper for extracting maximum power transfer from solar PV system [9]. Initially, the P and O MPPT needs to take solar array voltage point and solar array current point. From these two points algorithms generates reference DC link voltage $V_{dc}^{*}$.**

B) ADS algorithm:

The ADS algorithm schematic diagram shown in figure2. The algorithm needs the following data: solar PV voltage($V_{PV}$) and current($I_{PV}$) ; grid three phase currents $(i_{sa}, i_{sb}, i_{sc})$ ; load currents $(i_{la}, i_{lb}, i_{lc})$; voltages $(v_{ta}, v_{tb}, v_{tc})$ at PCC and voltage across the capacitor $V_{dc}$.

The voltage amplitude at PCC as,

$$|V_t| = \left(\frac{2}{3}\left(v_{sa}^2 + v_{sb}^2 + v_{sc}^2\right)\right)^{1/2} \tag{1}$$

Where, the above voltages are phase voltages which are obtained from measuring line voltages

$$v_{sa} = \frac{1}{3}(v_{sbc} + 2v_{sab}); v_{sb} = \frac{1}{3}(v_{sbc} - v_{sab}); v_{sc} = -\frac{1}{3}(2v_{sbc} + v_{sab}) \tag{2}$$

From equation (2), the in-phase unit templates are

$$z_{san} = \frac{v_{sa}}{V_t}; z_{sbn} = \frac{v_{sb}}{V_t}; z_{scn} = \frac{v_{sc}}{V_t} \tag{3}$$

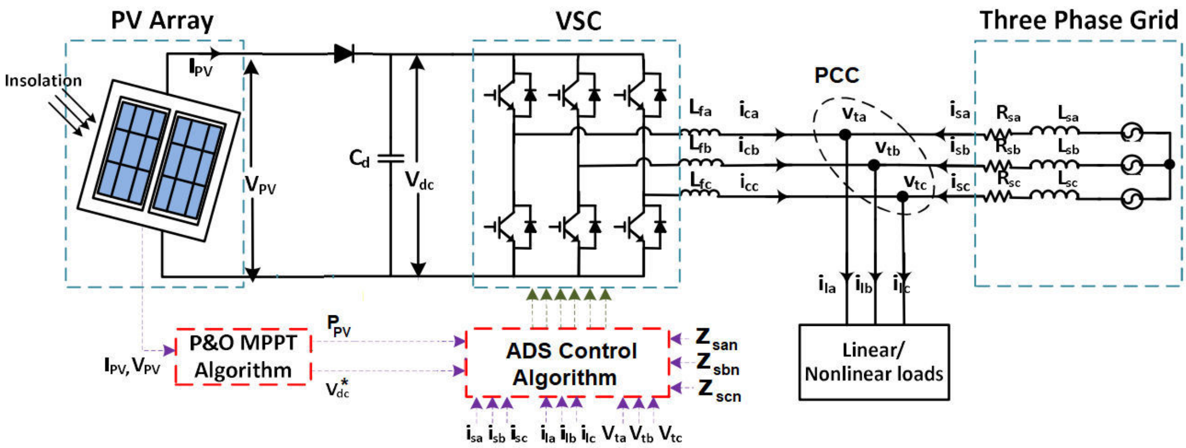



**Figure 1: Block diagram of SSG-PV system**

In this control system, a simple network considered with 'n' node technique. The main objective is to calculate unknown space vector $A_{usa}^{0}$.

The 'n' node adaptive technique as shown in figure3. In this, every node m, collaborate with neighbour nodes. In this technique, node n connects to its neighbour estimations $A_{usan}(m)$, this estimation is

$$\sigma_{san}(m) = \sum_{l \in s_n} \lambda_{\ln} A_{u\ln} \tag{4}$$

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 10, Issue 2, February 2021||

DOI:10.15662/IJAREEIE.2021.1002015

The error signal is

$$e_{san}(m) = i_{la}(m) - \sigma_{san}(m)^T z_{san}(m) \tag{5}$$

Phase 'a' load current estimated as

$$A_{usan}(m+1) = \sigma_{san}(m) + \frac{z_{xa} e_{sa}^3(m) z_{san}(m)}{\|z_{san}(m)\|_2^2 \left(\|z_{san}(m)\|_2^2 + e_{sa}^2(m)\right)} - \frac{z_{xa}}{\|z_{san}(m)\|_2^2 \left(\|z_{san}(m)\|_2^2 + e_{sa}^2(m)\right)} \times \xi_{xa} \times \frac{\partial \|\sigma_{san}(m)\|}{\partial \sigma_{san}(m)} \tag{6}$$

Similarly, on phase 'b' load current estimated as

$$A_{usbn}(m+1) = \sigma_{sbn}(m) + \frac{z_{xb} e_{sb}^3(m) z_{sbn}(m)}{\|z_{sbn}(m)\|_2^2 \left(\|z_{sbn}(m)\|_2^2 + e_{sb}^2(m)\right)} - \frac{z_{xb}}{\|z_{sbn}(m)\|_2^2 \left(\|z_{sbn}(m)\|_2^2 + e_{sb}^2(m)\right)} \times \xi_{xb} \times \frac{\partial \|\sigma_{sbn}(m)\|}{\partial \sigma_{sbn}(m)} \tag{7}$$

Similarly, on phase 'c' load current estimated as

$$A_{usan}(m+1) = \sigma_{scn}(m) + \frac{z_{xc} e_{sc}^3(m) z_{scn}(m)}{\|z_{scn}(m)\|_2^2 \left(\|z_{scn}(m)\|_2^2 + e_{sc}^2(m)\right)} - \frac{z_{xc}}{\|z_{scn}(m)\|_2^2 \left(\|z_{scn}(m)\|_2^2 + e_{sc}^2(m)\right)} \times \xi_{xc} \times \frac{\partial \|\sigma_{scn}(m)\|}{\partial \sigma_{scn}(m)} \tag{8}$$

A loss factor ($V_{error\_dc}$) obtained by equating estimated DC voltage ($V_{dc}^*$) and actual DC voltage ($V_{dc}$). To control DC voltage, the value $V_{error\_dc}$ is given to the proportional-Integral controller.

$$V_{error\_dc}(n) = V_{dc}^*(m) - V_{dc}(m) \tag{9}$$

The output of the PI controller is obtained as,

$$A_{loss}(m+1) = A_{loss}(m) + k_p\{V_{error\_dc}(m+1) - V_{error\_dc}(m)\} + k_I V_{error\_dc}(n+1) \tag{10}$$

Power grid real power component is estimated as

$$A_{snet} = A_{lsa} + A_{loss} - A_{xx} \tag{11}$$

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 10, Issue 2, February 2021||

DOI:10.15662/IJAREEIE.2021.1002015

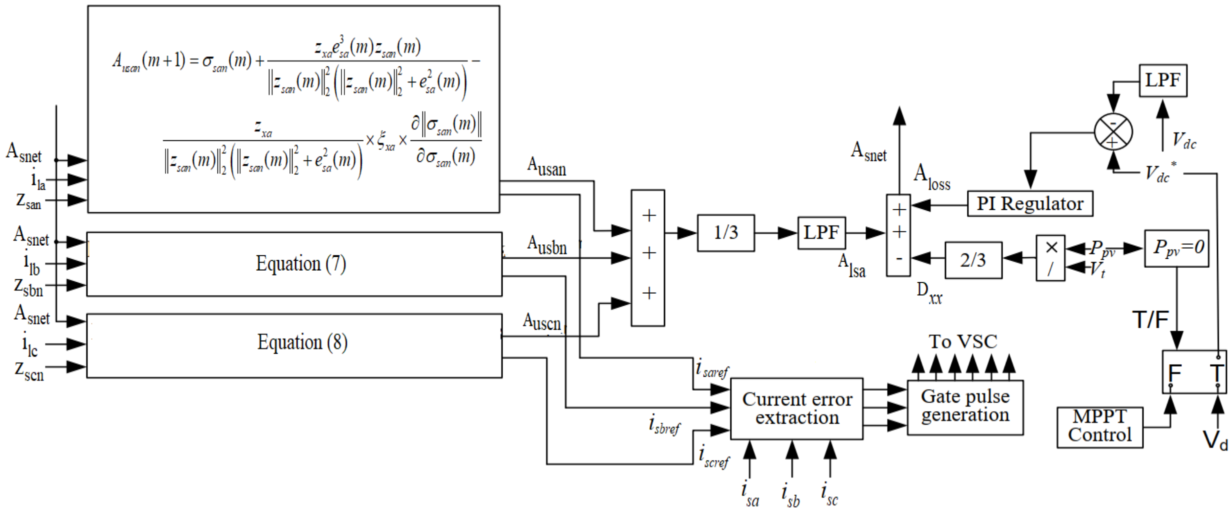



**Fig 2: ADS control architecture**

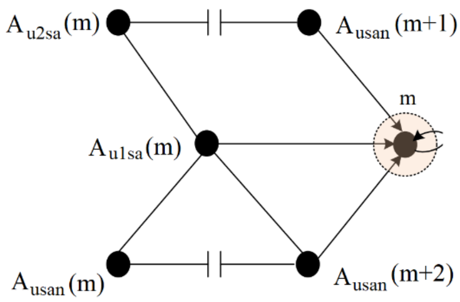


**Figure 3: Distributed sparse approach**

## III. RESULTS AND DISCUSSIONS

The proposed system along with P and O algorithm and ADS control is simulated using MATLAB 2019(a) Sim Power system tool box. The performance of the system was tested under all load conditions (linear and nonlinear).

**(i) Performance of proposed System under linear load condition**

**(a) balanced linear load**

**Figure4 shows the simulation results of the proposed SSGPV system with DS control under balanced linear load conditions. A three-phase inductive linear load of 16kW, 0.8 lagging power factor placed on SSGPV system. In figure 4 waveforms belongs to three phase grid voltages** $(v_{sa}, v_{sb}, v_{sc})$ **in volts;** three phase grid currents $(i_{sa}, i_{sb}, i_{sc})$ in amps; three phase VSC output voltages $(v_{ca}, v_{cb}, v_{cc})$ in volts; three phase VSC output currents $(i_{ca}, i_{cb}, i_{cc})$ in amps; **solar PV power $P_{PV}$ in watts; active power ($P_l$)in watts and reactive power($Q_l$) in VAR of the load ; three phase load voltages $(v_{la}, v_{lb}, v_{lc})$ in volts; three phase load currents $(i_{la}, i_{lb}, i_{lc})$ in amps ; Solar PV array voltage($V_{PV}$)in volts and current ($I_{PV}$)in amps; DC voltage ($V_{DC}$) in volts; active power ($P_{inv}$) in watts and reactive power($Q_{inv}$) in VARs of the inverter; active power ($P_s$) in watts and reactive power ($Q_s$) in VARs of the grid; All waveform in figure 4 observed under steady state and liner load conditions. An 16Kw+12Kvar resistive-inductive linear load is connected to the point of common coupling (PCC), the16Kw load demand power balances by grid and solar PV system with 6Kw and 10Kw respectively and 12 Kvar reactive supplies locally by VSC so reactive power generated by grid is Zero. Total harmonic distortion (THD) of voltage at point of common coupling (PCC) and grid currents within limits according to an IEEE 510 standards.**

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 10, Issue 2, February 2021||

DOI:10.15662/IJAREEIE.2021.1002015

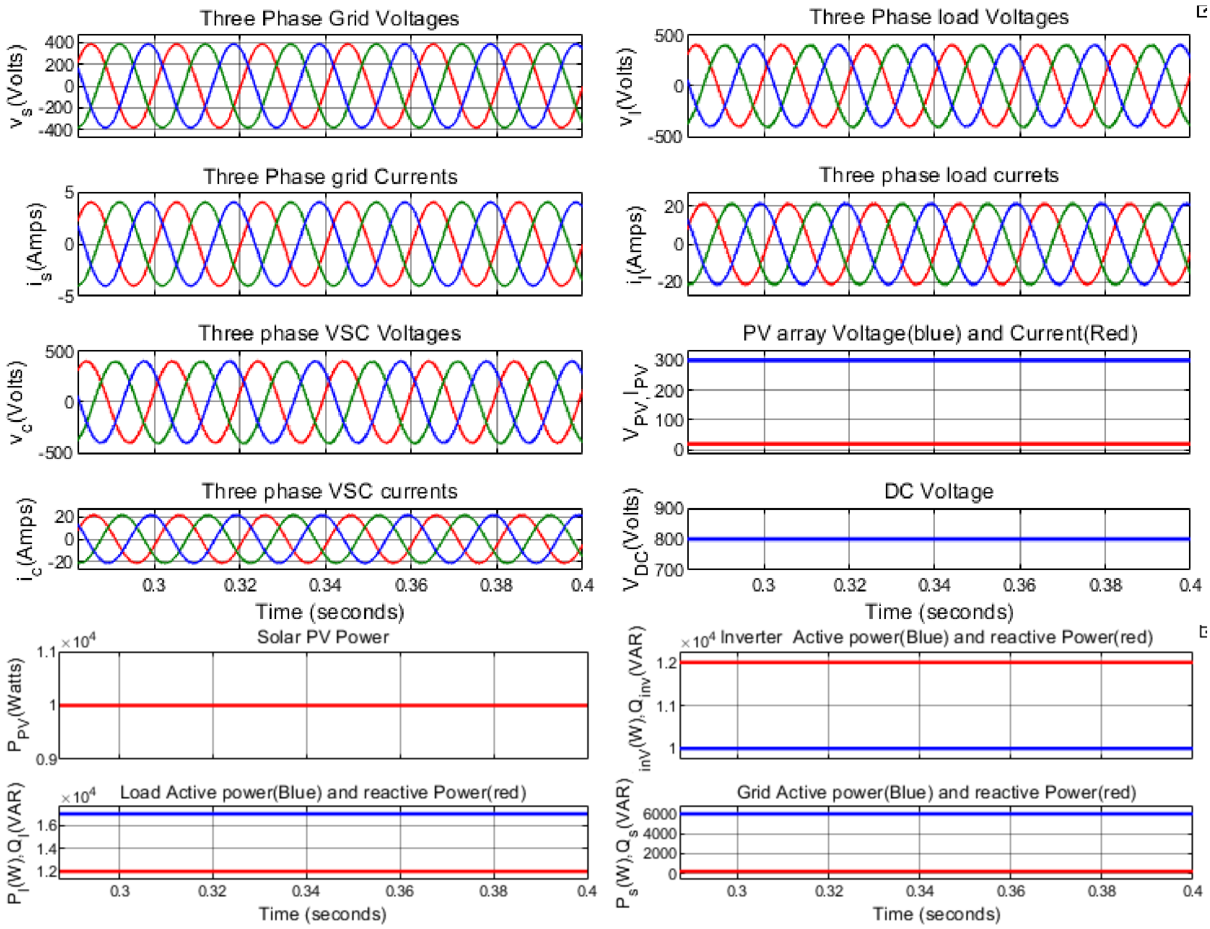



**Figure 4: Performance of SSG-PV system under balanced linear load condition**

**(ii)Performance of proposed System under linear load condition**

**(b) balanced non-linear load**

**Figure 5 shows the simulation results of the proposed SSGPV system with DS control under balanced non-linear load conditions. A three-phase inductive non- linear load of 11Ω and 0.7mH is placed on SSGPV system at t=5sec. In figure5 waveforms belongs to three phase grid voltages** $(v_{sa}, v_{sb}, v_{sc})$ **in** volts; three phase grid currents $(i_{sa}, i_{sb}, i_{sc})$ in amps; three phase VSC output currents $(i_{ca}, i_{cb}, i_{cc})$ in amps; **three phase load currents** $(i_{la}, i_{lb}, i_{lc})$ **in amps ; DC voltage ($V_{DC}$) in volts; Solar PV array voltage($V_{PV}$) in volts and current ($I_{PV}$) in amps; solar PV power $P_{PV}$ in watts; load active power ($P_l$) in watts and grid active power($P_s$) in Watts. All waveform in figure 5 observed under steady state and non-liner load conditions. A resistive-inductive linear load is connected to the point of common coupling (PCC), the load demand power balances by grid and solar PV system respectively and reactive supplies locally by VSC so reactive power generated by grid is Zero. According to IEEE standards the harmonic content levels on grid currents a voltage within permissible limits and also it was observed that Solar PV system was able to generates power smoothly. So, ADS control algorithm perfectly is suitable for SSGPV system under non-linear balanced load conditions. Total harmonic distortion (THD) of voltage at point of common coupling (PCC) and grid currents within limits according to an IEEE 510 standards.**

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 10, Issue 2, February 2021||

DOI:10.15662/IJAREEIE.2021.1002015

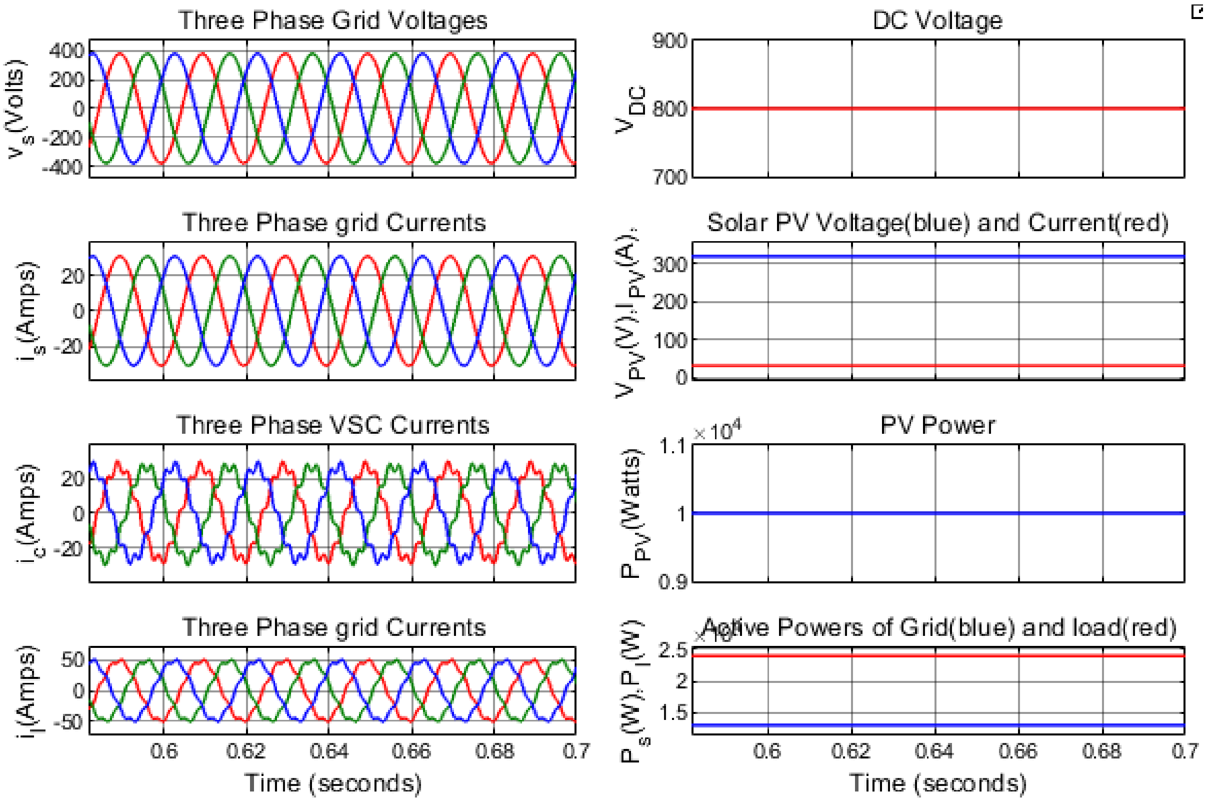



**Figure5: Performance of SSGPV system under balanced non-linear load condition**

TABLE 1: PERFORMANCE OF THE proposed SYSTEM IN TERMS OF THD

| **Parameter/load** | **% THD on Load current** | **% THD on grid current** | **% THD on VSC current** |
|---|---|---|---|
| Linear load | 3.27% | 2.43% | 1.89% |
| Non-linear load | 23.83% | 2.02% | 14.21% |

TABLE 1: PERFORMANCE OF THE proposed SYSTEM IN TERMS OF THD

| **Parameter/load** | **% THD on Load voltage** | **% THD on grid voltage** | **% THD on VSC voltage** |
|---|---|---|---|
| Linear load | 3.27% | 2.43% | 1.89% |
| Non-linear load | 23.83% | 2.02% | 14.21% |

## IV. CONCLUSION

The single stage solar PV system has been integrated to three-phase AC grid using ADS control algorithm for DC-AC power conversion **with expected voltage and frequency levels along with same phase sequence of power grid.** The SSGPV system supplies real power and reactive power to connected loads and also reduces the several power quality issues like current harmonics distortion, voltage harmonics distortion and load unbalancing under steady state conditions. ADS control with P and O based MPPT has been found easy to implement on proposed SSGPV. The performance of the system has been simulated in MATLAB/SIMULINK environment under balanced linear and nonlinear load conditions.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 10, Issue 2, February 2021||

DOI:10.15662/IJAREEIE.2021.1002015

## REFERENCES

[1] S. Kouro, J. I. Leon, D. Vinnikov, and L. G. Franquelo, "Grid-connected photovoltaic systems: an overview of recent research and emerging PV converter technology," IEEE Ind. Electron. Mag., vol. 9, no. 1, pp. 47-61, March 2015.

[2] B. Singh, S. Dwivedi, I. Hussain and A. K. Verma, "Grid integration of solar PV power generating system using QPLL based control algorithm," in Proc. 6th IEEE Power India Int. Conf., 5-7 Dec. 2014, pp. 1-6.

[3] S. Kumar, A. K. Verma, I. Hussain and B. Singh, "Performance of grid interfaced solar PV system under variable solar intensity," in Proc. IEEE 6th India Int. Conf. on Power Electronics, 8-10 Dec. 2014, pp. 1-6.

[4] B. Singh, S. Goel, A. Singhal, A. Garg and C. Jain, "Power quality enhancement of grid integrated solar PV system based on adaptive noise reduction control," in Proc. IEEE Power & Energy Society General Meeting,26-30 July 2015, pp.1-5.

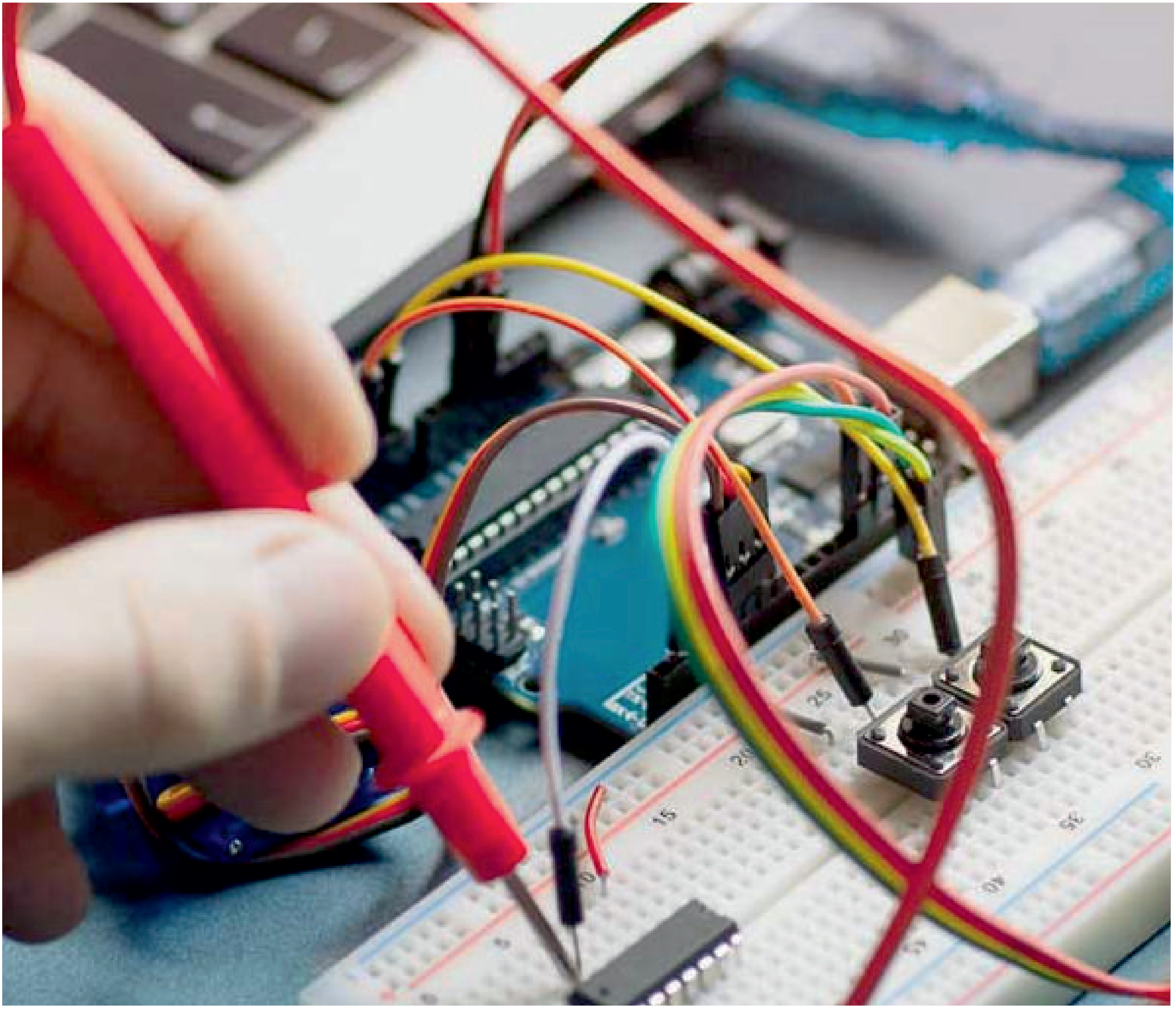
[5] A. K. Barnes, J. C. Balda and C. M. Stewart, "Selection of converter topologies for distributed energy resources," in Proc. IEEE 27th Ann. App. Pow. Electron. Conf. Exposi., 5-9 February 2012, pp. 1418-1423.

[6] Tsai-Fu Wu, Chih-Hao Chang, Li-Chiun Lin and Chia-Ling Kuo, "Power loss comparison of single-and two-stage grid-connected photovoltaic systems," IEEE Trans. on Energy Conv., vol. 26, no. 2, pp. 707-715, June 2011.

[7] M. A. G. de Brito, L. Galotto, L. P. Sampaio, G. A. Melo and C.A.Canesin, "Evaluation of the main MPPT techniques for photovoltaic applications," IEEE Trans. on Ind. Electron., vol. 60, no.3, pp.1156-1167, March 2013.

[8] B. Widrow, J. M. McCool, M. Larimore and C. R. Johnson, "Stationary and non-stationary learning characteristics of the LMS adaptive filter," Proc. of IEEE, vol.64, no.8, pp. 1151-1162, Aug. 1976.

[9] Bhim Singh, Ambrish Chandra and Kamal Al-Haddad, Po wer quality: problems and mitigation techniques, John Wiley & Sons Ltd., U.K, 2015.



INNO SPACE
SJIF Scientific Journal Impact Factor

Impact Factor:
7.122

INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

निस्केयर
NISCAIR

# International Journal of Advanced Research

## in Electrical, Electronics and Instrumentation Engineering