

3-Ø, TWO-STAGE, GRID-INTERFACED SOLAR PV ENERGY CONVERSION SYSTEM WITH ADAPTIVE CONTROL BASED ON APPROXIMATE MULTIPLIERS

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Abstract

In this work, a unique adaptive algorithm is successfully designed, controlled, and verified. For the grid voltage source converter (VSC) system, the suggested approximate multiplier least mean square (AM-LMS) management method effectively mitigates power disturbances without compromising power quality (PQ). Additionally, the VSC control method adds multipliers to the finite impulse response (FIR) filter and updates the coefficients of the circuitry to reduce the complexity of the LMS. Since it is more economical and reliable than other grid sides, the AC side is used. On the DC side, a bidirectional DC-DC converter and a photovoltaic (PV) array form the insular micro grid for which the VSC management is intended. On the DC side, a bidirectional DC-DC converter and a photovoltaic (PV) array form the insular micro grid for which the VSC management is intended the efficacy and validation of the suggested controller are guaranteed by the experiment findings. These results are considered satisfactory, with enhanced dynamic and steady state functionality and overall harmonic distortion of grid currents that meets the IEEE-519 standard resolution.

Keywords: Approximation Multiplier Least Mean Square (AM-LMS); PV (Photovoltaic); Power Quality

Introduction

The world's energy consumption is projected to grow steadily in the coming years as energy demand from electric cars, commercial, residential, and industrial loads continues to rise. As a key component of integrated energy generation, interconnected solar energy is gaining a new prototype for providing reliable and high-quality electric power. Moreover, distributed generation (DG) from renewable energy sources (RES), including solar, wind, and hydropower, is sporadic

in nature (Patel *et al.*, 2018). One of the renewable energy sources (RES), photovoltaic (PV) generation system is growing rapidly in recent years due to its important role in addressing the world's energy shortage and environmental issues. Furthermore, according to reports from the International Energy Agency (IEA), We know that by 2047, PV generation will become the most important source of low-carbon electricity generation not only in India but across the world,

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When about 40% of total electricity generation will come from renewable energy sources (Zhang *et al.*, 2018) and (El-Shimy *et al.*, 2018). Additionally, we know that solar photovoltaic array is intermittent in nature; so the maximum power point (MPP) of the array is tracked using this method, INC (incremental conductivity) approach, which we use to get more power. which emphasizes excellent efficiency in the presence of heavy and variable meteorological conditions (Beniwal *et al.*, 2018). Moreover, battery energy storage provides proactive power balancing within the micro grid due to non-dispatch able generation and load demand changes over time. As a result, excess energy is retained during load dispatch and released from peak load hours. Critically important services include load shifting, supporting dynamic local loads, and use in performing instantaneous frequency leveling, and reducing support from fossil fuel based generation. The presence of the dominant second order harmonic component. As a result, by using a boost converter DC-DC converter in the suggested system we not only control the operating mode but also maximize the power output of the solar array. In addition, Along with the amount and direction of active electric current, the DC bus's voltage is also demonstrated, the converter eliminates the second order harmonic of the current (García *et al.*, 2016) and (Philip *et al.*, 2014). Additionally, a streamlined single-stage PV array is shown, unlike a two-stage system where the VSC is used for AC conversion and the first converter performs the MPPT, thereby increasing the power in the system. On the other hand, hydropower generation in combination with PV arrays is becoming more popular because PV arrays are not available at night. Waste water from each house from a specific area of the city can be fed into the common sewage canal and stored in a small reservoir located in a remote area of the city to settle the liquid wastes before water management. Additionally, a small head dam can be built on the reservoir, and the treated water can be used to power a pico-hydro turbine generator before flowing into the mainstream. As a result, the possibility of river contamination is reduced (Liu *et al.*, 2018). For pico-hydro applications, self-excited induction generators (SEIG) are suggested in (Liu *et al.*, 2008) and (Ansel *et al.*, 2006). The primary goal of island mode of micro grid is to produce a suitable power distribution while maintaining the frequency and voltage stability of the system. The reference currents for the VSC are generated using advanced phase locked loop (PLL) based approach, Clark and Park transformation and conventional controllers based on PQ theory. Nevertheless, the primary drawbacks of these

traditional controllers are their lack of adaptive performance or their dependence on the loop gain coefficient for functioning. As a consequence, many adaptive control methods have been developed for real-time applications. The Least Mean Squares (LMS) algorithm, first presented by Widrow and Hoff (Karthikeyan and Gupta, 2017), is the most commonly used approach.

A popular algorithm for filtering and recognition of systems when developing is adaptive filtering. It is straightforward, requires less computation, and is simple to implement in terms of hardware. Nevertheless, there is a conflict between the low error of the classic LMS algorithm and its convergence speed in steady state (Ibrahim *et al.*, 2015). For improved filtering competence, the gradient of the weight coefficients must be changed, as well as the non-linear connection that exists between the step factor and the error signal. Furthermore, the LMS method generates so-called gradient noise because it is applied in an approximate manner. Next, the coefficients of the FIR segmentation based adaptive filter (AMLMS) are estimated. Meanwhile, multiplication is the most commonly used operation in an adaptive LMS filter, and multipliers provide some of the most energy-hungry digital blocks. The least significant column of the multiplicative partial product matrix is eliminated, and a compensation term is applied to minimize the resulting error approximation (Kong, 2018). Numerical consistency, acceptable convergence error, and computational simplicity are provided by the LMS method. Furthermore, due to the inherent stability of the FIR filter and the ability of the LMS algorithm to change its coefficients, an adaptive filter based on LMS is usually built using this filter (Malarvili *et al.*, 2022). The following goals are to be achieved by applying three-phase free system of PV array and three-phase balanced, unbalanced non-linear loads. Since the solar PV array is directly connected to the VSC's DC bus, a boost converter and the related losses during switching are not required (Ksiazek *et al.*, 2017) and (Kewat *et al.*, 2018).

Boost DC-DC Converter Specifications: The Boost DC-DC converter is designed with the following specifications: an input voltage range of 595-680 V DC, an output voltage of 700 V DC, and a switching frequency of 10 kHz. The converter uses an IGBT-based switching device with appropriate snubber circuitry to ensure reliable operation under varying load conditions. A current-mode control strategy is implemented to regulate the output voltage and maintain peak power point tracking (PPPT) efficiency from the PV array. Moreover, the inductor value is selected as 3 mH (Sayin *et al.*, 2014).

Inverter Specifications: The inverter used in the system is a three-phase, IGBT-based voltage source converter (VSC) with an output voltage of 415 V AC, 50 Hz and input DC bus voltage of 700 V. therefore, the IGBT of the inverter are selected as per the DC blocking voltage requirement. The input DC bus capacitor is selected as 5000 μ F. It is equipped with a hysteresis-based pulse width modulation (PWM) technique. The inverter is responsible for converting the DC power from the Boost converter to AC power and injecting it into the grid. The control algorithm implemented in the inverter ensures load balancing, harmonic mitigation, and power factor correction at the point of common coupling (PCC).

The VSC's DC bus has a direct relationship to the solar PV array, eliminating the need for a boost converter and the related losses associated with switches. In the proposed micro grid, the VSC feeds the nonlinear load and provides load balancing, harmonic suppression and voltage regulation. The system's VSC improves power quality (Kalla *et al.*, 2017; Niu and Chen, 2018). As a result, the voltage and current of the hydro generator reduces the THD (Total Harmonic Distortion) to below the acceptable limits of the IEEE-519 standard (Yazdani *et al.*, 2008).

Structure of Proposed system

Figure 1 shows the power circuit of a typical standalone system consisting of a three-phase, PV array, and self-supporting DC link voltage (V_{DC}) and current-controlled VSC as the primary components of the entire power circuit. It is basically a fixed energy source and provides it when there is a power shortage. Interfacing inductors are used to connect the VSC in a shunt configuration, which feeds a nonlinear load and provides voltage control, harmonic elimination, and load balancing. Additionally, high frequency ripples are removed

from the source currents by employing interface inductors, while the auxiliary components of the system passive filters R_f and C_f are employed to reduce high frequency ripples from the PCC voltage.

Control Algorithm

Whenever supplying nonlinear loads, a strong control is required with regards to load balancing, voltage and frequency regulation, and harmonic suppression. As seen in Figure 1, the control method is divided into two sections one for the voltage source converter and the other for the boost converter DC-DC converter control. Approximate multipliers, an advanced form of LMS and a well-known tool for micro grid filtering, are the foundation of the VSC control method.

VSC Control

Current research on VSC control algorithms has focused on enhancing convergence, robustness, and computational complexity. In addition, a variety of control techniques have been applied by investigators to improve LMS performance. Due to its inherent stability, a standard LMS-based adaptive filter is usually combined with an FIR filter, whose coefficients can be reconstructed using the LMS method, as seen in Figure 2. shows a comparison of AM-LMS and LMS. Thus, the aim of this study. Accordingly, this study aims to develop a new filtering method in which the matrix and multiplicative column partial product are discarded and an additional term is used for compensation to reduce the errors. Input into the Adaptive LMS Filter is provided as follows:

$$W_{La}(n) = [i_{La}(n), i_{La}(n-1), i_{La}(n-M+1)] \quad (1)$$

Every moment, the result may be written as

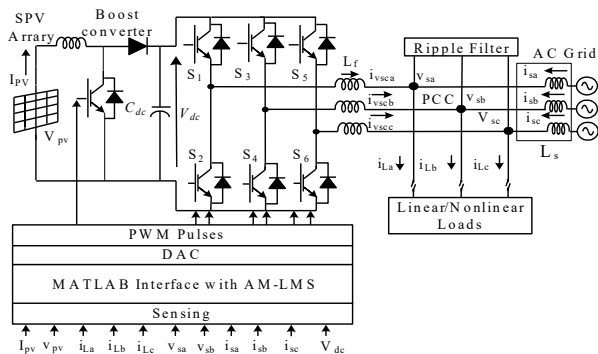


Figure 1. Proposed system configuration

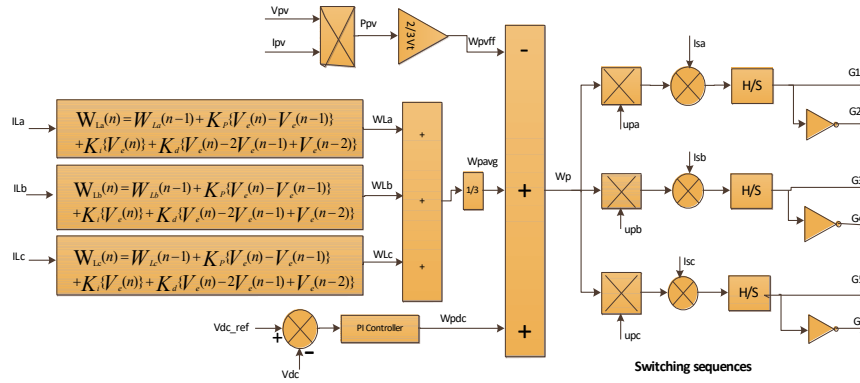


Figure 2. The proposed AM-LMS VSC control algorithm

$$W_{La}(n) = \sum_{k=0}^{M-1} w_k(n) i_{La}(n-k) \quad (2)$$

The weights are a function of the time instant n , which sets it apart from the non-adaptive FIR filter. As a result, the error signal $e_a(n)$ of the adaptive LMS filter is given as,

$$e_a(n) = i_{La}(n) - u_{pa}(n) W_{La}(n) \quad (3)$$

The LMS algorithm uses the error $e_a(n)$ to calculate the updated version of the filter tap weights $w_{pa}(n)$ in the following manner:

$$W_{La}(n-1) = W_{La}(n) - \mu e(n) i_{La}(n-k) \quad (4)$$

$$W_{Lb}(n-1) = W_{Lb}(n) - \mu e(n) i_{Lb}(n-k) \quad (5)$$

$$W_{Lc}(n-1) = W_{Lc}(n) - \mu e(n) i_{Lc}(n-k) \quad (6)$$

The algorithm's error and convergence speed are balanced. By the step size, denoted by μ . The LMS uses this estimate to approximate $\mu e(n) i_{La}(n-k)$ on the gradient. Low register counts are also observed, as well as fast convergence. Furthermore, to apply to the related hardware multiplication process, the step size μ is considered as a power of two.

Thus we see that, from the three phase load current component (W_{La} , W_{Lb}), the load value of the original active component can be calculated as,

$$V_t = \sqrt{\frac{2(v_{sa}^2 + v_{sb}^2 + v_{sc}^2)}{3}} \quad (7)$$

As $v_{sca} = -v_{sab} + v_{sbc}$ thus by sensing the two line voltage phase voltage

$$v_{sa} = \frac{(2v_{sab} + v_{sbc})}{3}, \quad v_{sb} = \frac{(-v_{sab} + v_{sbc})}{3}, \quad v_{sc} = \frac{(-v_{sab} + 2v_{sbc})}{3} \quad (8)$$

The in phase and quadrature unit template are assessed follows

$$u_{pa} = \frac{(v_{sab} - v_{sca})}{3v_t}, \quad u_{pb} = \frac{(v_{sbc} - v_{sab})}{3v_t}, \quad u_{pc} = \frac{(v_{sca} - v_{sbc})}{3v_t} \quad (9)$$

The extraction of weight values is comparable to the basic reactive components of three-phase load current (w_{pa}). The weight component for each phase of the active load is denoted by W_{pav} . The average power load weight component is determined individually for each phase and is provided in the form W_{pb} , W_{pc} . Additionally; Proportional-integral (PI) controllers provide regulation on the AC side respectively. The estimated voltage at terminal, or V_t amplitude, is In order to generate a frequency error for frequency regulation, the frequency reference is linked to the frequency measured. The frequency inaccuracy is shown as (w_{pav}) is then subtracted from frequency output controller (w_{pdc}) then approximating the net fundamental weight is given

$$W_{La}(n) = W_{La}(n-1) + K_p \{V_e(n) - V_e(n-1)\} + K_i \{V_e(n)\} + K_d \{V_e(n) - 2V_e(n-1) + V_e(n-2)\} \quad (10)$$

Where

$$V_e(n) = V_{dc}^* - V_{dc} \quad (11)$$

Where V_{dc}^* is the three-phase reference voltage Magnitude at the PCC and V_t is the AC supply voltage magnitude at the PCC. Additionally, the terminal weight voltage controller output (W_{pc}) is subtracted from the reactive fundamental Load average output (W_{pav}), yielding the net fundamental Weight is estimated as

$$w_p = w_{pdc} + w_{pav} - w_{pvff} \quad (12)$$

Consequently, these errors in current signals (i_{sa} , i_{sb} , and i_{sc}) are assigned to the hysteresis current controller for the formation of gating signals of IGBT's of VSC. Where the W_{pav} is the reactive load weight component per phase is evaluated as,

$$W_{pav} = \frac{W_{La} + W_{Lb} + W_{Lc}}{3} \quad (13)$$

Therefore, the quadrature pattern reference currents and phase currents are defined in the sequence given in the equation below,

$$\dot{i}_a^* = w_{pnet} \times u_{pa} \cdot \dot{i}_b^* = w_{pnt} \times u_{pb} \cdot \dot{i}_c^* = w_{pnet} \times u_{pc},$$

The total reference currents (i_a^* , i_b^* , i_c^*) are estimated as, Hence, for generation of gating signal of IGBT of VSC, these errors in the current signal (i_{sa} , i_{sb} , i_{sc}) are set to the hysteresis current controller. The measured current is, which is

obtained through a DC-link PI controller. The PWM pulse for the converter is created by evaluating the PI controller output (duty cycle) using a saw tooth signal.

Simulation Results

Using the Simscape Software, the AM-LMS control of the GPV system is modeled and simulated for verification in a MATLAB/Simulink environment. The solar PV array is rated at 40kW. The appendix includes a report on specific modeling parameters. Figure 3. Present simulation results that highlight the Characteristics of reactive power compensation, adaptive DC bus voltage variation and grid current balancing, as well as dynamic performance for different test conditions, such as changes in solar irradiance, non-linear Load fluctuations, grid frequency and PCC voltage magnitude changes.

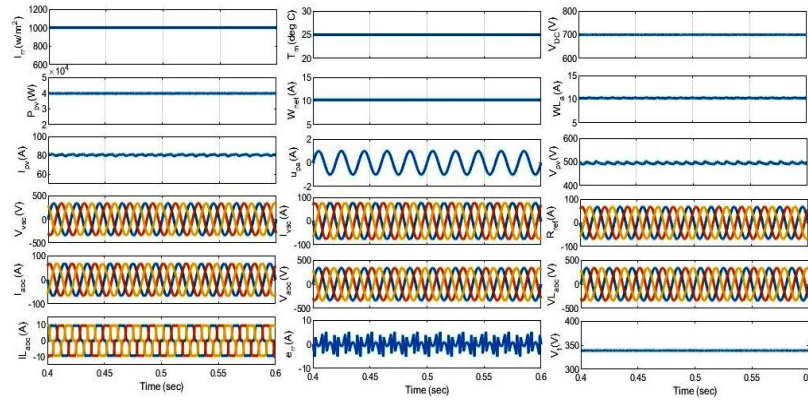


Figure 3. The propose Steady state condition under nonlinear load condition v_{sab} , i_{sa} , i_{sb} , v_{vsc} , i_{vsc} , P_{vsc} , v_{Lab} and i_{La} I_{pv} , V_{pv} , P_{pv}

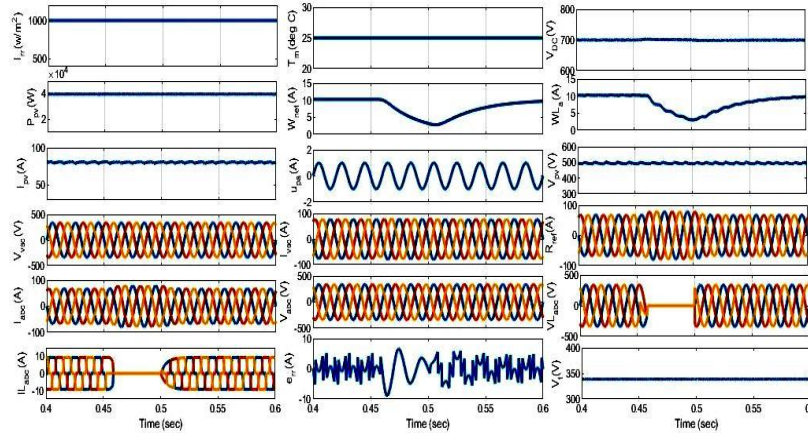


Figure 4. The proposed under Nonlinear Load Unbalance System

Accomplishment in the presence of nonlinear load imbalance

A three-phase nonlinear load (5kVA) supplied by the grid-PV system is connected to the PCC and is affected by the load imbalance. The Performance of the system is shown in Figure 4. The load imbalance is realized by disconnection of the phase “A” load which is shown in the figure below.

The simulation results of the system performance under various operating situations are presented in the following above sections.

Performance under Solar Insolation Variations

The system response at solar insolation change is presented in Figure 5. The change from 1000 W/m² to 550 W/m² is subjected at 0.4 s Within 2 ms, and then increased to 1000 W/m² within same time at 0.5 s. It makes sense for the PV array currents to drop because the load power consumption is the same. The PV feed forward term contributes for smooth and controlled dynamic performance even under rapid change in insolation.

Dynamic Performance of Microgrid The suggested control dynamic performance, load unbalancing, and the variation in insolation level are demonstrated here. Dynamic Performance of Microgrids in Response to Variations in Solar Insolation Level a. Performance of Sag and swell conditions Sag and swell conditions in electrical systems, including those involving solar PV (photovoltaic) arrays, refer to voltage variations that can occur on the electrical grid or within a power system. These conditions can Affect the performance of the PV system and connected equipment

Voltage Sag (Under voltage)

Voltage sag (also known as an under voltage or dip) is a short-term drop in voltage levels, typically lasting between milliseconds and a few

seconds. Voltage sags may occur due to a sudden increase in load (e.g., when large motors start), faults on the grid, or during poor weather conditions (like lightning strikes). Impact on PV Systems: The inverter may experience difficulties in maintaining the proper voltage and frequency, which can lead to disconnection from the grid. It may also trigger protective mechanisms to prevent equipment damage. Repeated sags could degrade the Efficiency and lifespan of sensitive electrical components.

Voltage Swell (Overvoltage)

A voltage swell is a short-duration increase in the voltage level, typically by 150% to 250% of the nominal voltage. Swells can result from a sudden decrease in the load on the system, faults in the power distribution network, or grid disturbances. Impact on PV Systems: Overvoltage can cause inverters and other equipment to shut down to protect them. It may lead to overheating of electrical components, insulation breakdown, and reduced system efficiency. Persistent swells can damage power electronics, degrade power quality, and affect the lifespan of components in the PV array.

Mitigation Strategies for PV Systems: Modern inverters come with protective mechanisms to disconnect in case of abnormal voltage conditions like sags and swells. Devices such as voltage stabilizers or automatic voltage regulators can help maintain steady voltage levels. Installing surge protection devices (SPDs) can help shield the system from voltage surges associated with swells. **Grid Monitoring:** Continuous monitoring of the grid conditions can provide insights into voltage fluctuations, allowing for better maintenance and fault response. Maintaining optimal voltage levels in solar PV systems is crucial for ensuring reliable energy generation and protecting the array and connected loads.

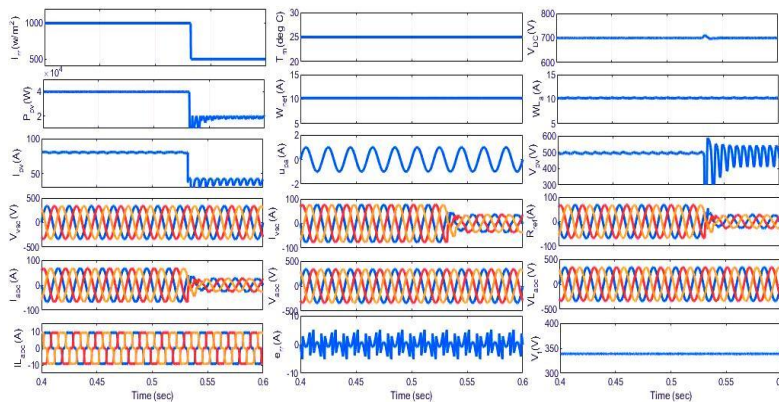


Figure 5. Under dynamic performance Vdc, i_{La} , v_{sab} & I_{pv} i_{sa} , P_{pv} , V_{vsc} , I_{vsc} under solar insolation change

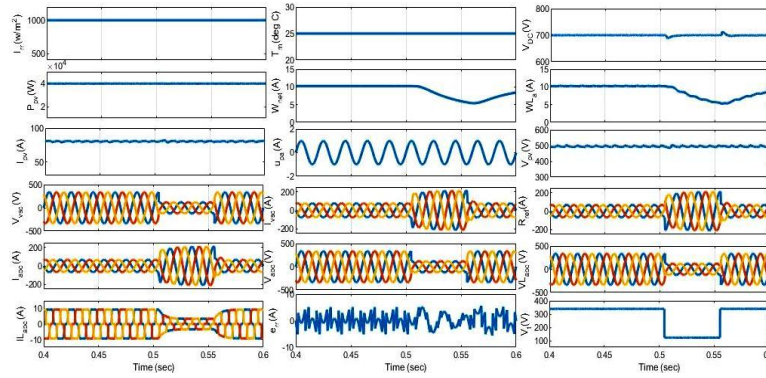


Figure 6. Under dynamic performance V_{dc} , I_b , v_{sab} , I_{pv} , i_{sa} , I_b , i_{vsca} & I_{pv} under voltage "Sag" and "swell" conditions

Test result

The idea that power output rises with solar insolation is supported by Figure 6. Since the load is fixed, any extra power generated is sent toward the grid, which enters load center mode. As a result, the load is unbalanced at a higher insolation level. The rise in insolation is also depicted in Figure 7(b), where the system's current and voltage remain the same, and the DC bus voltage is likewise kept constant. In a similar vein, the PV current drops in response to a step fall in insolation, as seen in Figure 6. Thus, the PV array's current decreases with a comparable slope. In order to maintain power homeostasis, the dynamic performance load balanced and unbalanced also reaches a condition inside the system. The load for every RES photovoltaic array is less than the power produced. Therefore, the controller maintains the power balance in the presence of dynamics including variations in sun intensity.

Performance under Solar Insolation Variations Adaptation to Real-Time Variations

Because of its intrinsic adaptability, the AM-LMS algorithm can handle the real-time fluctuations in solar insolation. The program may react to quick changes in the environment by dynamically modifying the adaptive multipliers. Adaptive multipliers allow for real-time adjustment of the filter coefficients in response to the discrepancy between the intended and actual system output. This guarantees that the system will continue to react to variations in solar irradiance levels. Selective precision: By modifying

the accuracy of the updates, the AM-LMS can decrease the number of multiplications at times when insolation variation is modest, increasing computing efficiency.

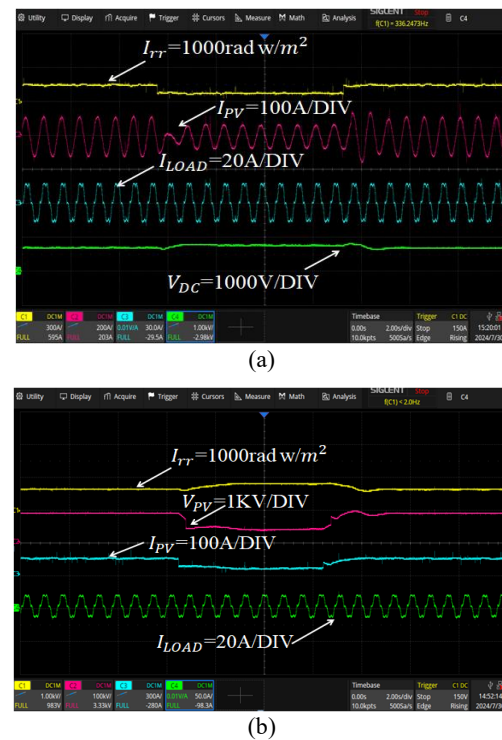
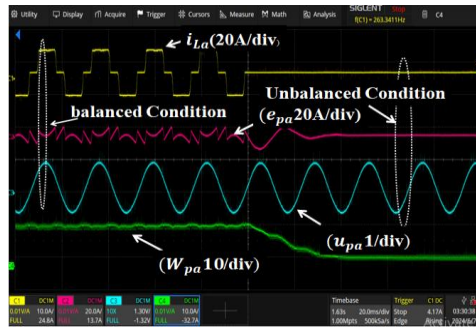
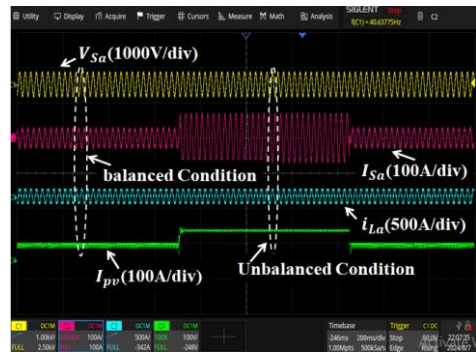


Figure 7. (a-b) Under dynamic performance V_{dc} , i_{La} , v_{sab} & I_{pv} , i_{sa} , P_{pv} , V_{vsc} , I_{vsc} under solar insolation change



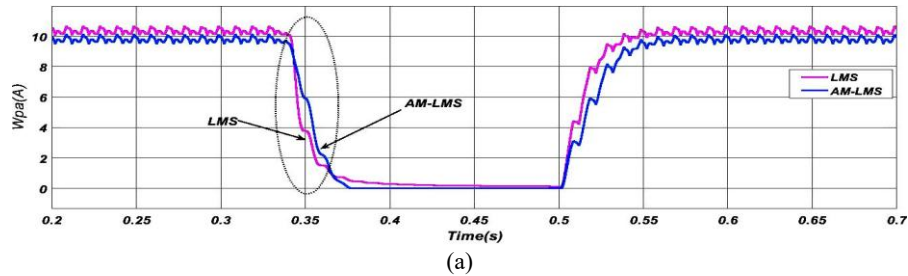
(a)



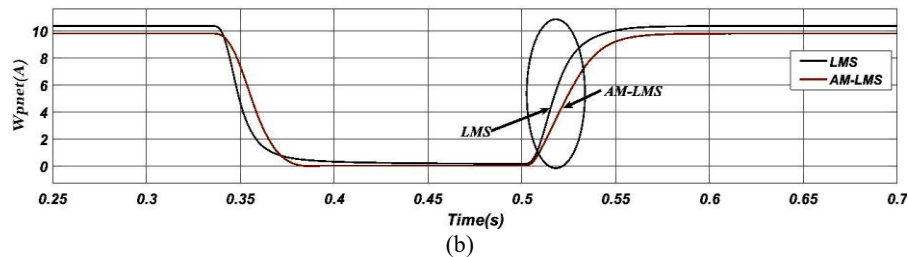
(b)

Figure 8. (a-b) the proposed under Nonlinear Load balance and Unbalance System

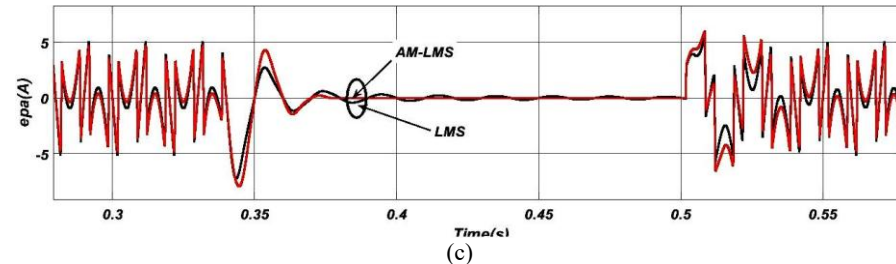
It's critical to evaluate how the grid functions under various load from Figure 8(a-b), generation, and grid voltage scenarios when examining the balanced and unbalanced states of a PV (photovoltaic) grid-connected system. An outline of how balanced and unbalanced situations affect the system and how power quality may be evaluated using THD (Total Harmonic Distortion) analysis is provided below. When the voltages and currents of the power system's three phases (assuming it is a three-phase system) are equal and the phase difference is 120 degrees, balanced circumstances are present. The system's power quality is at its best when everything is in harmony. There is symmetry in the distribution, generation, and loads of power. Removing and adding one load phase confirms the fluctuation in the currents (i_{sa} , i_{sb} , i_{sc}) responses to abrupt changes in load, as seen in Figure 8. The balances the rise and fall in load currents to maintain the scheme frequency and voltage while the source currents stay balanced and sinusoidal overall. When a single phase of the load is removed, the load current drops, and since the excess power is sent to the grid. The load current now rises when the load corresponding phase is reinserted in to these scheme. As a result, the extra power needed for load in order to keep the system necessary load



(a)



(b)



(c)

Figure 9. Analysis of Comparative Performance LMS or AM-LMS

Table 1. comparative performance of AM-LMS control algorithm

Algorithm/Method	Computational Complexity	Convergence Rate	Accuracy	Hardware Efficiency
LMS	High	Moderate	High	Low
NLMS	Moderate	Faster than LMS	High	Low to Moderate
RLS	Very High	Fast	Very High	Very Low
Sign-LMS	Low	Slow	Low	High
Sparse LMS	Low	Slow	Moderate	High
AM-LMS	Low	Moderate	High	Very High
PI Control (VSC)	Low	Fast	Moderate	Very High
Hysteresis Control (VSC)	Low	Fast	High	High
MPC (VSC)	High	Fast	Very High	Low

power balance. The source current does not fluctuate since is a fixed power supply. Further more is one offers a constant power in both dynamic load removal and inclusion scenarios. The As a result, when the load increases, the source voltages are balanced and steady with load change, as shown by Figure 8(a-b). When the load is suddenly removed, Intermediary Signals Weight extraction under unbalanced load conditions is shown in Figure 9(a-b-c) where it is evident that while MLMS and AMLMS have slower steady state errors, LMS has a much faster rate of convergence. Where as the MLMS and AMLMS have weight convergences of 8ms and 10ms, respectively. Nonetheless, the suggested control AMLMS has a very low steady state error, removing the conflict between error, stability, and convergence speed. Additionally, the convergence and error of the AMLMS and LMS with and without filters are displayed in Figure 9(a). The convergence and error performance in the absence of a filter.

Analysis of Comparative Performance

A range of LMS-based algorithms and other control techniques utilized in adaptive filtering and VSC control systems are compared below. The primary comparative metrics are: The amount of operations (mostly multiplications) needed for each iteration is referred to as computational complexity. Convergence rate, The speed at which the algorithm finds the best answer. Precision and accuracy, The capacity to reduce error in operations involving control and filtering. Efficiency of hardware and power: The algorithm's appropriateness for hardware implementation in terms of power consumption and resource utilization.

Summary

This paper presents the design and control of a three-phase VSC of PV using MA-LMS. Thru the purpose of limiting power dissipation in adaptive filters within the allowable convergence error, the approximation LMS adaptive filter-based VSC control is developed. Under varied insolation

conditions, an INC is implemented in the proposed microgrid to maximize the power extraction from the solar PV array. The PCC voltage and frequency have been successfully maintained under load changes to the integrated voltage source converter control technique. The suggested control strategy has also helped with load balancing, harmonic mitigation, and reactive power compensation variety of outputs, including the internal control signals of the control approach and all major power signals, have been validated under load unbalancing in order to demonstrate the viability of the proposed AMLMS in contrast to traditional control. The system's dynamic and steady state performances are deemed satisfactory, and the IEEE 519 allowable limit for source current and PCC voltage THD is met.

Appendix

Simulation System Parameters:

SPV array data: SPV module current $I_{sc} = 8.21A$, $V_{oc} = 32.9V$, $I_{mpp} = 7.61A$, $V_{mpp} = 26.3V$, Number of Series and parallel modules = 18 and 7, Boost Inductor = 5mH, Grid voltage = 415V, $f = 50Hz$, $L_s = 0.1mH/phase$, and $R_s = 0.02\Omega/phase$, $k_p = 0.65$, $k_i = 0.4$, $\mu_i = 0.0015$; Nonlinear load: $R_L = 55\Omega$, $L_L = 200mH$, Interfacing inductor $L_f = 3.5mH$, $f_s = 10kHz$, DC bus capacitor $C_{dc} = 4700\mu F$, Ripple filter: $R = 10\Omega$ and $C = 80\mu F$, $\delta = \pm 0.01$.

Experimental System Parameters:

$V_{oc} = 500V$, $I_{sc} = 16A$, DC bus capacitor (C_{dc}) = 2200 μF , $V_{dc} = V_{mpp} = 380V$, Interfacing inductor $L_f = 3.5mH$, Ripple Filter = 6 Ω and 12 μF , DC voltage Controller, $k_p = 0.6$, $k_i = 0.2$, Nonlinear Loads: diode bridge rectifier followed by 200mH, 60 Ω , $\omega = 314rad/s$.

Analysais of THD for Balance and Unbalanced PV-Grid SystemTotal

Total Harmonic Distortion analysis, or THD analysis, is what you appear to be talking about. In electrical engineering, this is frequently used to assess the harmonic distortion in signals, especially in audio Equipment and power systems.

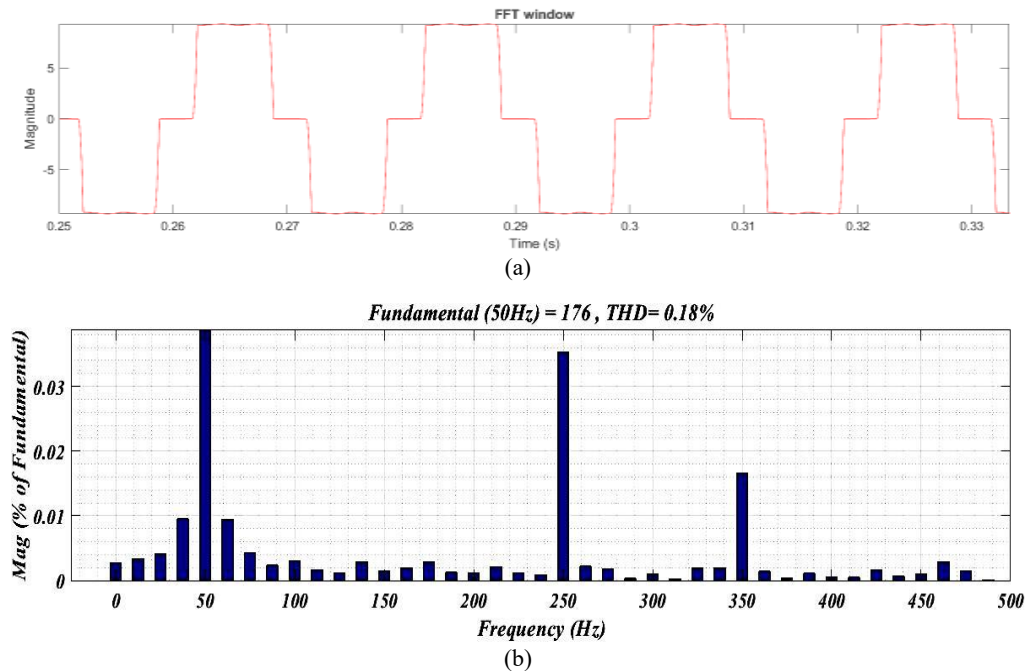


Figure 10. load current THD

The range of 0.25 to 0.2 seconds. In addition to applying linear load, the third occurred at 0.33 seconds. The findings demonstrate that the suggested approach was utilized in conjunction with pure sinusoidal waves of excellent quality in various algorithms, whereas the MA-LMS Based control method produced the best outcomes. The THD is shown in Figure 10.

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