ADALINE LEAST MEAN SQUARE (ALMS) BASED MULTI-LEVEL INVERTER WITH PARTICLE SWARM OPTIMIZATION FOR PV SYSTEM

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Abstract.

This paper deals with a three-phase, four-wire multi-level inverter, based photovoltaic (PV) system with a lower total harmonic distortion (THD) to increase the system's stability and reliability. The active power filter plays a vital role in the compensation of power quality issues and maintaining the total harmonic distortion level within the IEEE-519 standards. The proposed method develops the active power filter with a voltage source converter (VSC) which is controlled by the Adaline-least mean square algorithm(ALMS) with the hysteresis current controller (HCC). The proposed method is compared with the recursive least mean algorithm (RLS) and found lower THD levels. The ALMS algorithm maintains the constant DC capacitor voltage level thereby compensating for the power quality issues under varying load conditions. The partial swarm optimization (PSO) MPPT technique is used to maintain constant and extract maximum power from the PV panels. The performance of the PSO-based multi-level inverter with the ALMS algorithm is developed and validated by using MATLAB/SIMULINK with reduced THD levels under unbalanced load conditions.

Keywords: PSO-MPPT, Adaline-based LMS, multi-level inverter, recursive least square, total harmonic distortion, power quality.

1. INTRODUCTION

The best source of energy that can be produced is the renewable energy source for clean and sustainable energy [1]. Power from natural sources such as solar, wind. The energy from the non-replenishing sources can be harvested and given to the power grids via an inverter that is connected to the grid. The energy produced by solar panels and other renewable forms of energy is DC in nature. The function of an inverter is to alter a DC input source voltage to a symmetrical AC output voltage in desired amplitude and frequency with a minimal amount of harmonics [2] However, inverters produce an alternative square wave at the output, thus increasing the THD of the waveform. The output generated from the inverter must a sinusoidal wave with a reduced amount of THD also output frequency should match with line frequency. The output sinusoidal with the lowest distortion is achieved in inverters by using high switching frequency along with various other Pulse Width Modulation (PMW) techniques [3,4]. There are many advancements in the development of the Multi-Level Inverter (MLI) to improve the power quality that most energy obtained can be effectively put to use. Deterioration of Power Quality, because of harmonics, happens in distribution systems and electric transmission due to the loads. These are generally caused by non-linear load usage. In the past few years the nearest solution we can obtain multi-level inverter-based APF which injects the compensating current into the power distributing system, improving power quality, can control and regulate electrical disturbances [5.-7] MLIs are used in large numbers in energy storage systems. Circuit topology, control techniques of MLI have been developed significantly in recent days. With MLI, the current harmonic compensation is effective for high power quality [8,9]. Various MLI configurations have been discussed in this area. In [10,11], the MLI they have minimized the number of switches that can be used. In [12.13] half-bridge cascaded multi-level inverter-based SAPF the authors presented providing the equal output voltage with a lower number of semiconductor switches in comparison with different MLI topologies that generate the same amount of output voltage. Among all MLI topologies, the [14] has implemented a hybrid multi-level inverter that generates the required output voltage from a combination of Level generation, polarity generation. Moreover, it provides a reduced number of component utilization in implementation by implementing alternate phase opposition disposition, carrier overlapping, and sinusoidal PWM techniques. In [15,16] the author is clear in working on a three-phase system using a multi-level inverter by supplying the compensating current to reduce TDH percentage below 5% as per IEEE for unbalanced load cases. However, the authors have used an artificial neural network [17], a recursive least square (RLS), A-LMS algorithms that are simple, robust, and linear in the computation are verified. A HILBAPF (H-bridge interleaved buck-type active power filter) [18] for linear and non-linear loads. This has been observed to be capable of balancing the capacitor voltages can exclude interfacing transformer.

In the proposed system the Adaline least mean square (ALMS) based multi-level inverter with particle swarm optimization MPPT algorithm for a PV system is developed. The ALMS algorithm is used to control the switching operation of the multi-level inverter to compensate for the power quality issues in the grid-connected PV system under nonlinear load conditions.

2. PROPOSED SYSTEM CONFIGURATION

The development of the proposed three-phase, four-wire module with optimum performance and lower THD level is shown in Fig.1(a). The system is a combination of a solar PV panel, DC-DC converter, a DC bus capacitor, interfacing inductors, and three-leg VSC. The PSO-MPPT technique is used to extract maximum PV power. The ALMS algorithm is used to maintain constant DC capacitor voltage and provides the functionality of an active power filter of harmonics elimination, and reactive power compensation. The model of the multi-level inverter is shown in Fig.1(b).

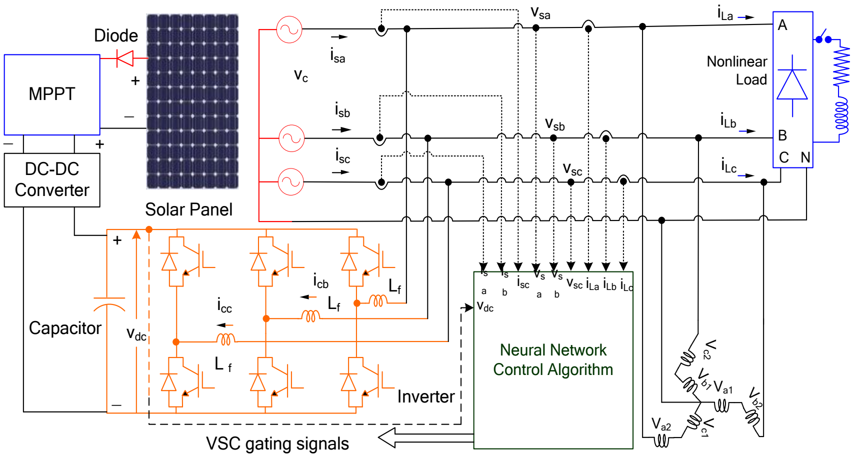

Fig.1(a) Proposed three-phase, four-wire PV system using ALMS algorithm

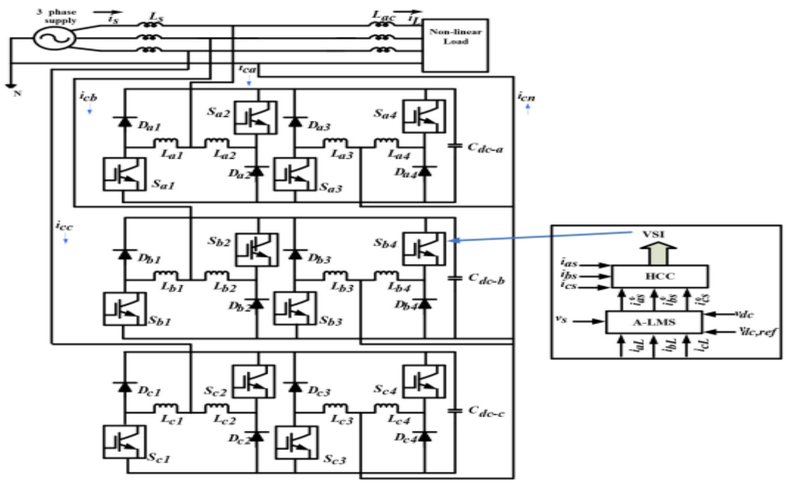

Fig.1(b) Multi-level inverter using ALMS algorithm

3. CONTROL ALGORITHMS

The fundamental source current is generated by injecting or absorbing the filter current by an active power filter which is in phase opposition with the harmonic components. The efficiency and reliability are improved by the control algorithms RLS and ALMS algorithms for multi-level voltage source converter (VSC), PSO-MPPT for PV panels.

Particle swarm optimization (PSO) MPPT technique:

The PSO-MPPT algorithm is used to extract the maximum power from the PV panels by updating the voltage and current values of the PV panels at different intervals of time. The PSO-MPPT is used to find the optimal solutions by increasing the speed of the tracking. The PSO-MPPT technique is shown in Fig.2.

RLS Algorithm

The recursive least mean square (RLS) algorithm is used to compensate for the reactive power and reduce the total harmonic distortion (THD) level in the system. Under the balanced load condition, the source active power is equal to the load active power and there is no current flow through the multi-level inverter. Under unbalanced load conditions, the DC capacitor voltage causes the power difference between source and load currents. To maintain a constant DC capacitor voltage, the RLS algorithm is used to control the voltage source converter (VSC) section as shown in Fig.3.

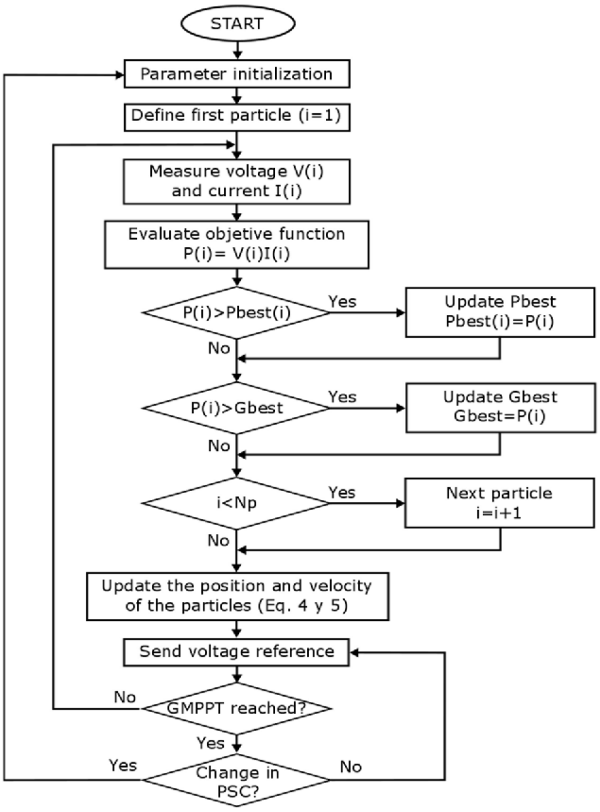

Fig.2 Particle swarm optimization MPPT technique

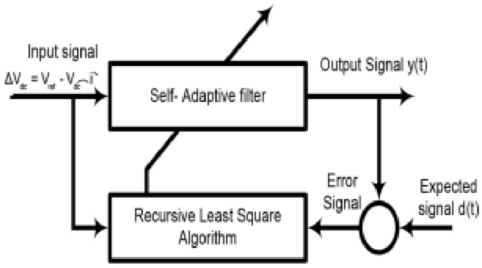

Fig.3 Recursive least mean square algorithm

The instantaneous current for each phase is given as

$$I_x(t) = I_{ax}(t) + I_{nx}(t) \quad (1)$$

Where $I_{ax}(t)$ Is the active current given as

$$I_{ax}(t) = A_x V_x(t) \quad (2)$$

The active parameter is given as

$$A_x = A_{ax} + A_{dc} \quad (3)$$

Where A_{dc} is given as

$$A_{dc} = P_{dc}(i)/V_x^2 \quad (4)$$

$$P_{dc}(i) = \left[\left(V_{ref} + V(i)\right)^2 - V_{ref}^2\right] * C/_2 \quad (5)$$

Adaline least mean square algorithm (ALMS):

This proposed ALMS algorithm as shown in Fig.4 is developed by combining two techniques, the Adaline and LMS algorithm. The weights in Adaline are updated using the LMS algorithm. The proposed algorithm is used to calculate the reference current components for the multi-level inverter and the convergence rate depends on the fixed step-size parameter.

The weight equation for active and reactive components are for single phase x at time t is given as

$$w_{Ax}(k+1) = w_{Ax}(t)+\mu e_x(t)u_{Ax}(t) \quad (6)$$

$$e_x(t)=\{i_x(k) - i^*_{AX}\} \quad (7)$$

$$w_{Qx}(k+1) = w_{Qx}(t)+\mu e_{Qx}(t)u_{Qx}(t) \quad (8)$$

$$e_{Qx}(t)=\{i_x(k) - i^*_{Qx}\} \quad (9)$$

Where e_x(t), is the error output of the reference current and load at phase x. and (μ) is the convergence factor which varies between 0.01 to 1.0. It is taken as 0.2 for the proposed multilevel ALMS system.

PI controller for active and reactive components is given as

$$w_{lA}(t)=w_{lA}(k\text{-}1) + k_{pA}\{v_{eA}(t) - v_{eA}(k\text{-}1)\} + k_{iA}v_{eA}(t) \quad (10)$$

Where $v_{eA}(t)=v^*_{refA}(t) - v_{DCA}(t)$ (11)

$$w_{lQ}(t)=w_{lQ}(k\text{-}1) + k_{pQ}\{v_{eQ}(t) - v_{eQ}(k\text{-}1)\} + k_{iQ}v_{eQ}(t) \quad (12)$$

Where $v_{eQ}(t)=v^*_{refQ}(t) - v_{DCQ}(t)$ (13)

The reference currents for active and reactive components for phase ‘x’ are estimated as

$$i^*_{xA} = w_{xA}(t)\, u_{xA}(t) \quad (14)$$

$$i^*_{xQ} = w_{xQ}(t)\, u_{xQ}(t) \quad (15)$$

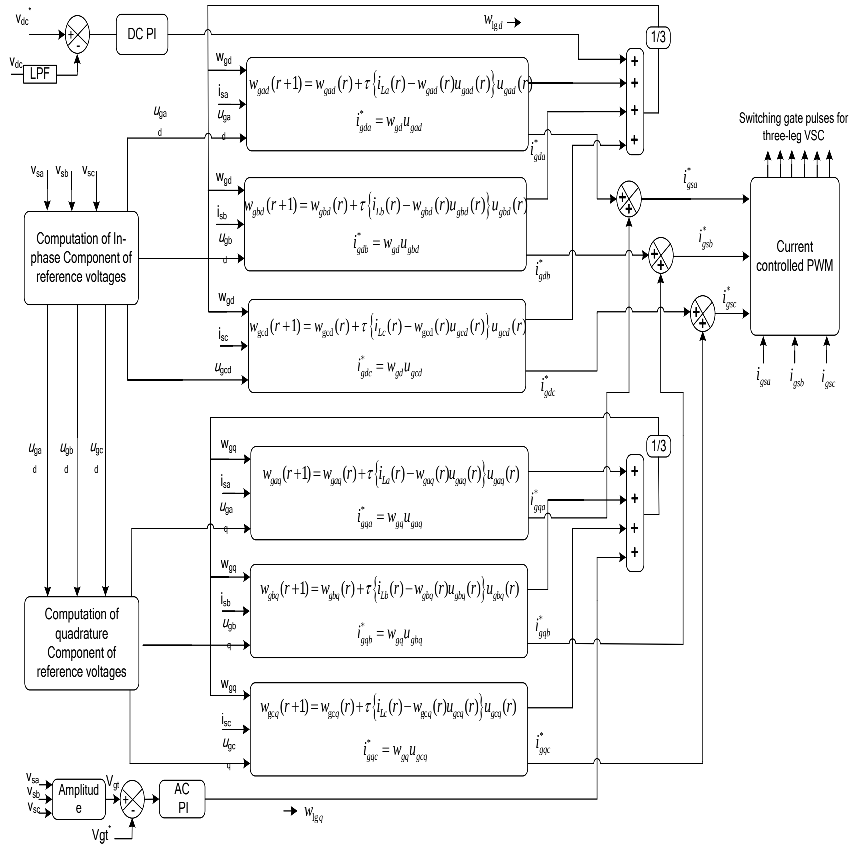

Fig.4 Adaline least mean square algorithm for three-phase multi-level inverter

4. RESULTS AND DISCUSSION

The Adaline least mean square based multi-level inverter PV system is developed and simulated in MATLAB/SIMULINK. The proposed system under balanced and varying load conditions with different control algorithms is analyzed with lower THD levels. The performance of the proposed model is analyzed with the recursive least square (RLS) and Adaline least mean square (ALMS) under varying load conditions. During nonlinear load conditions, the load current is distorted thereby increase in the THD level. The performance of the grid-connected single level inverter for the load current with the THD level of 38.97% under unbalanced load conditions and load current with the THD level of 28.53% is shown in Fig.5.

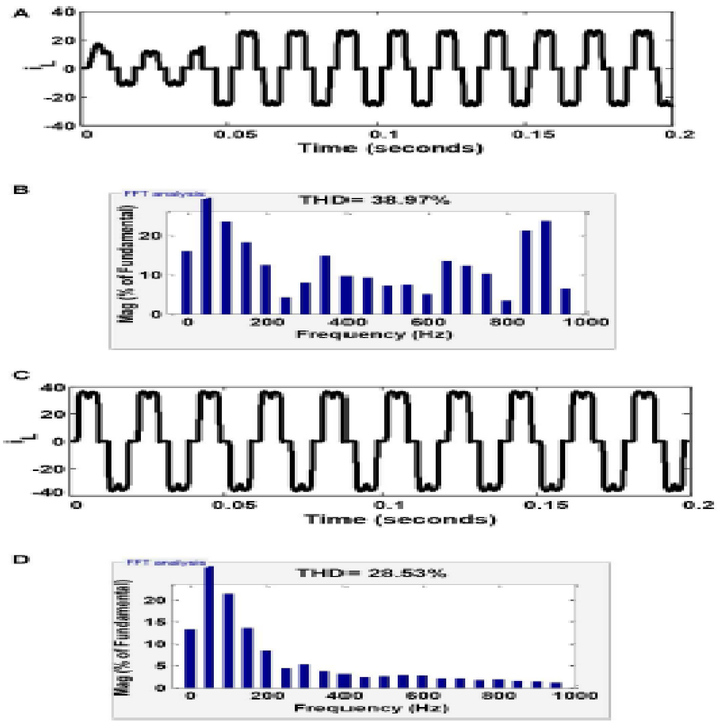

Fig.5 (A) Load current under unbalanced load conditions (B) THD level of load current under unbalanced load condition (C) Load current under balanced load conditions (D) THD level of load current under balanced load conditions

Balanced load condition

The performance of the multi-level inverter with recursive least mean square (RLS) algorithm is shown in Fig.5. The RLS algorithm is used for controlling the multi-level inverter thereby reducing the THD level. It is observed from Fig.6, that the THD level under balanced load conditions for the load current is reduced to 1.75%.

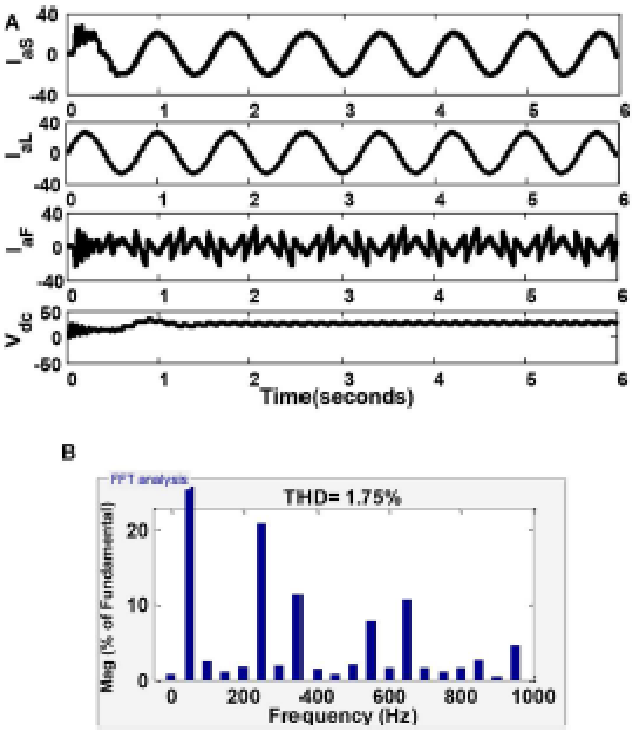

Fig.6 (A) Load current, source current, and V_{dc} (B) THD level

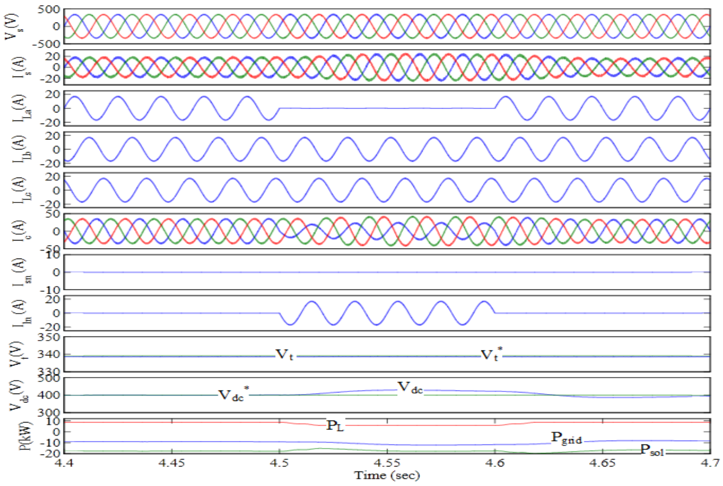

Fig.7 THD level for load current using ALMS multi-level inverter for linear loads

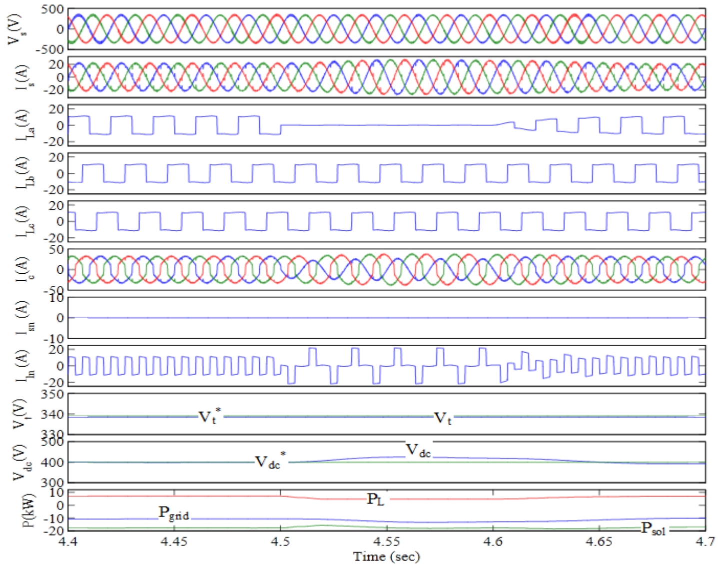

Fig.8 THD level for load current using ALMS multi-level inverter for non-linear loads

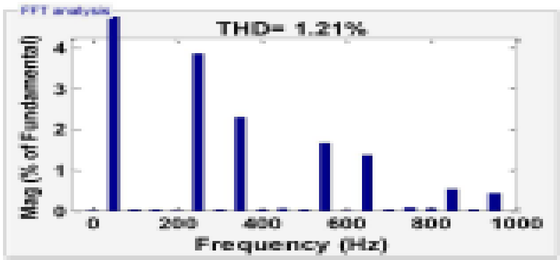

Fig.9, where the THD level is reduced to 1.21%,

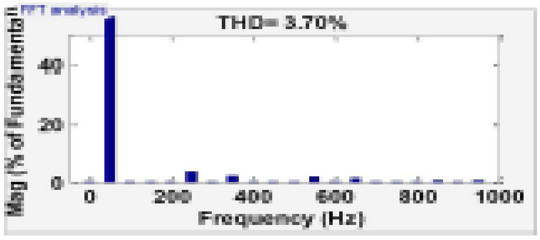

Fig.10 THD level for load current under nonlinear load conditions

The performance of the Adaline least mean square multi-level inverter under linear load conditions is shown in Fig.7, and the performance of the Adaline least mean square multi-level inverter under non-linear load conditions is shown in Fig.8. The performance of three-phase source current, load current, solar power, grid power, DC capacitor voltage are shown in Fig.7 and Fig.8. At time 4.5s, one of the phases is disconnected and the ALMS algorithm compensates for the fluctuations in the load current thereby maintaining constant DC voltage across the capacitor. The THD level for the load current using ALMS under linear loads is shown in Fig.9, where the THD level is reduced to 1.21%, and the THD level for load current under nonlinear load conditions is shown in Fig.10, where the THD level is reduced to 3.70%.

5. CONCLUSION

The proposed Adaline least mean square multi-level inverter with particle swarm optimization for PV system is implemented. The proposed system is compared with the conventional single level inverter and multi-level inverter with recursive least mean square (RLS) algorithm. The proposed ALMS algorithm has compensated for the power quality issues in the system under non-linear load conditions. The THD level of the three-phase multi-level inverter is reduced compared to the RLS multi-level inverter. The ALMS has maintained constant DC capacitor voltage under varying load conditions. The maximum solar power is extracted by the use of the particle swarm optimization-MPPT technique. The proposed model is developed and simulated in MATLAB/SIMULINK and found satisfactory results under varying load conditions.

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