Indian J.Sci.Res. 17(2): 39-43, 2018
ISSN: 0976-2876 (Print)
ISSN: 2250-0138(Online)

ADAPTIVE THREE LEVEL NPC MULTILEVEL GRID INTERFACED INVERTER WITH AANF FOR POWER QUALITY ADVANCEMENT

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***Abstract*—**This paper presents adaptive three level diode clamped multilevel grid interfaced inverter fed synchronization based dq-current control technique for Power quality improvement in Distribution Generation system. The act of a grid interfaced distributed generation (DG) systems are significantly exaggerated by impulsive power quality (PQ) events such as, balanced and unbalanced voltage sag/swell, frequency shift, phase jump and harmonic distortions in the service grid voltage due to undependable synchronization. An amplitude adaptive notch filter (AANF) is used for recognition of utility voltage phase angle due to its adaptable accuracy and amplitude flexibility. Three phase extension of single phase AANF is developed and its presentation is estimated under aforesaid PQ events. Vigorous behavior of three phase AANF improves the control performance of the interfacing inverter in introducing constant current into utility grid under Power Quality events. This technique also activates the interfacing inverter close to unity power factor mode. The effectiveness of the proposed control technique in integrating the DG system to the utility grid inspects through MATLAB simulation results.

Keywords: AANF, Distribution generation, Neutral point clamped inverter, power quality

I. Introduction

Now a days DG (distributed generation) resources are playing a prominent role in electrical networks. By applying these DG resources (e.g. wind power generation, solar energy, fuel cells, micro turbines and etc) in to power system many changes occurs such as change in operation and design of distribution network. The main advantages of DG technology are environmental aspects and the short period of construction leads in the development of DG technology. The important aspects to be considered while synchronizing the DG system to the distribution grid are practical, cost effective and flexible control strategies [1]. Power electronic devices are increasing in demand to achieve flexible distribution networks. An important issue in the control of distribution systems is reactive power compensation. Due to reactive current not only increases the distribution losses also reduces the power factor, causes heat losses in machines, also reduces the capability of active power which causes the variations in voltage amplitudes which may cause the changes in the electrical demand [2]. The main intention of the DG technology is to provide active power by using power electronic devices and the reactive power can be can be compensated by using the active power filters. This compensation of active and reactive power can be obtained by using the proper control techniques for interfacing circuits. The DG systems can connect to distribution grid in series or shunt type, but the main issue of control is reactive power, this can be achieved by shunt compensation. By shunt connected compensation the reactive current can be compensated. In this paper we propose a VSI (voltage source inverter) as an interfacing power electronic circuit. For better compensation of reactive power and to reduce the total harmonic distortion a three level NPC inverter is used for shunt connected DG system in to distribution grid. By using the multilevel inverters the harmonic distortion can be reduced enormously. Several control techniques have been proposed for NPC VSI. The simple and predictive current control SVPWM (space vector pulse width modulation) for shunt connected NPC VSI to three phase three wire distribution grid. The current control technique uses the proportional integral current control technique in stationary and synchronous reference frame. For the proposed SVPWM technique the currents voltages to be represented in stationary and synchronous reference form. The instantaneous angle θ can be obtained from PLL which is connected to PCC at load side of the distribution grid. This control technique provides fast dynamic response and reduces the overshoots [3].

In this paper, performance improvement of grid interfaced three-level diode clamped inverter DG system under various PQ disturbances such as balanced and unbalanced voltage sag/swell, frequency shift, phase jump and harmonics distortions is presented. Adaptive synchronization based dq-current control technique for three-level NPC grid interfaced inverter DG systems is proposed. Three phase extension of single phase AANF is developed for detection of utility voltage phase angle due to its adjustable accuracy and amplitude adaptability [4]–[6]. Adaptive nature of three phase AANF is verified under aforementioned PQ disturbances. The control circuit is designed such that DG will only inject active power and maintains power factor close to UPF. Performance of the proposed control technique in injecting the active power

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into the utility grid under aforementioned PQ disturbances is investigated through MATLAB simulation results.

II. Distribution Generation System with 3-Level NPC Inverter

The block diagram of three-level neutral point clamped inverter DG system used for performance authentication is as shown in Fig.1. The efficacy grid is modeled as a three phase programmable source with corresponding source resistance and inductance as Rs and Ls. In practice DG system is the interconnection of unusual renewable energy sources to the distribution grid. For effortlessness, here DC source is measured as DG power input for three-level NPC inverter. The coupling inductance Lc with resistance Rc represents the corresponding inductance of a passive filter and coupling transformer linked at PCC. The control circuit is intended such that DG will only inject active power and maintains power factor close to UPF. In order to accomplish UPF operation, reactive power reference value (Q_{ref}) is implicit zero.

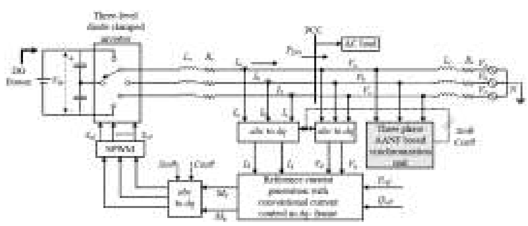


Fig. 1. Block diagram of three level diode clamped inverter interfaced DG system.

III. 3-Φ Amplitude Adaptive Notch Filter (AANF)

Adaptive and robust synchronization is very important in order to improve the performance of grid connected DG systems under various PQ-events. Here, three phase extension of AANF is developed for detection of utility voltage phase angle and generation of fundamental unit voltage reference signals. Single phase AANF is used because of its adaptability under adverse grid conditions [5], [6]. An input grid voltage signal is represented as,

$$V(t) = \sum_{i=1}^{n} A_i \sin\phi_i \quad where, \phi_i = \omega_i t + \varphi_i$$

Here, the frequencies ωi, and the phases ϕi, where, i = 1, 2, 3, ..., n, are unknown quanties. To estimate all these quantities an AANF structure proposed in [20] is represented as,

$$\begin{aligned} \ddot{x} + \theta^2 x &= \sqrt{2}\theta e(t) \\ \dot{\theta} &= -\gamma x \theta e(t) \\ e(t) &= V(t) - \dot{x} \\ \gamma &= \frac{\epsilon}{(1+A^2)(1+\mu\theta^2)} \end{aligned}$$

Where, θ represents frequency. Estimation accuracy of AANF depends on two real positive constants ζ and γ. For a fundamental frequency ω1, the periodic orbit of AANF is located at,

$$(\ O\ ) = \begin{pmatrix} x \\ \dot{x} \\ \theta \end{pmatrix} = \begin{pmatrix} \frac{-A_1}{\omega_1}\cos(\omega_1 t + \varphi_1) \\ A_1 \sin(\omega_1 t + \varphi_1) \\ \omega_1 \end{pmatrix}$$

Where, the element O gives the fundamental frequency ω1 of the periodic input signal. Here, ζ value is assumed as 1/√2 to achieve non-oscillatory response. Along with frequency detection, AANF is able extract an amplitude, fundamental component (x˙) and its 90o phase-shift component (−θx). This information is then useful for sequence component extraction in order to accurately detect utility voltage phase angle for control circuit design. For this, three identical AANF mathematical models described above are used to develop three phase AANF structure. A basic block diagram of the single phase AANF structure used to develop three phase AANF is as shown in Fig. 2. Three phase AANF structure is mathematically represented as,

$$\begin{aligned} \ddot{x}_n + \theta^2 x_n &= \sqrt{2}\theta e_n(t) \\ \dot{\theta} &= -\theta \sum_{n=a,b,c} \gamma_n x_n e_n(t) \\ e_n(t) &= V_n(t) - \dot{x}_n \\ \gamma_n &= \frac{\epsilon}{(1+A_n^2)(1+\mu\theta^2)} \end{aligned}$$

Where, n = a, b, c are three phases of sinusoidal input voltage signals. in (7) x˙n = An sin(ω0t + ϕn) and −θxn = An cos(ω0t+ϕn) are the fundamental and its 90o phase-shift component of the three phase input voltage respectively.

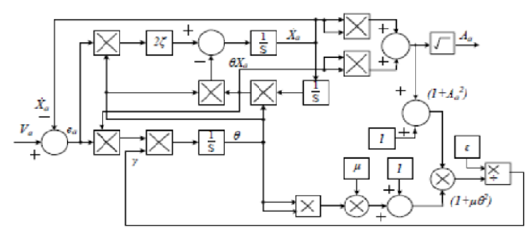


Fig. 2. Structural representation of amplitude adaptive notch filter (AANF).

IV. Control Circuit of 3-Level NPC Inverter

In the proposed control technique, three phase amplitude adaptive notch filter (AANF) is used as a synchronization unit for extraction of fundamental frequency and phase angle of the utility voltage signal. In the conventional current control technique proposed. A SRF-PLL is replaced by extended three phase AANF for performance improvement under various PQ-events. The schematic representation of inverter control circuit is as shown in Fig. 3. This control technique is designed to inject active power generated by DG systems into the utility grid and maintain UPF operation of interfacing inverter. Here, the extracted fundamental phase angle (θ) is used for estimation of sin(θ) and cos(θ) required for Park's transformation. In order to operate DG system inverter in UPF mode, reactive power reference value (Qref) is assumed zero. However, the selected active power reference value (Pref) represents the active power injection capacity of the DG. Assuming the steady state condition, the active and reactive power supplied by the DG in dq-frame is given as,

$$P_{ref} = \frac{3}{2}[V_d I_{d\_ref}]$$

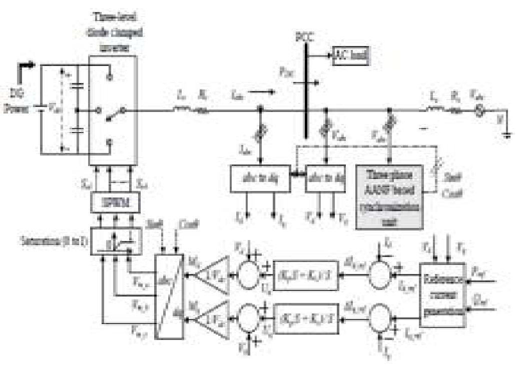


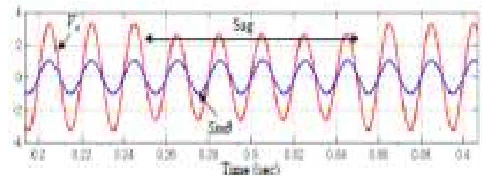
Fig. 3. Schematic diagram of three level inverter control circuit in dq-frame.

Here, for the simulation study, active power reference value (Pref) is taken as 5kW. However, as the reactive power reference value is set to zero (Qref = 0), Iq ref is always zero. The actual output DG currents in abc-frame (Iabc) are transformed into synchronously rotating dq-frame (Idq) using Park's transformation. These actual DG currents (Idq) are then subtracted from the reference DG currents (Idq ref) and the current error (ΔIdq ref) is regulated using PI-regulator. The outputs of the PI-regulator are then added with the PCC voltages in dq-frame (Vdq) to get the modulating signals (Mdq) required to drive interfacing inverter. Level shifted carrier based SPWM technique is used to generate gate pulses for three level diode clamped inverter.

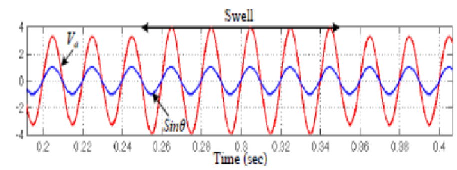
Table I The DG System Parameters

S.No	Parameter	Value
1	Nominal grid voltage	400
2	System frequency	50Hz
3	Coupling inductance	4.9mH
4	Dc link voltage	750v
5	Switching frequency	3150Hz

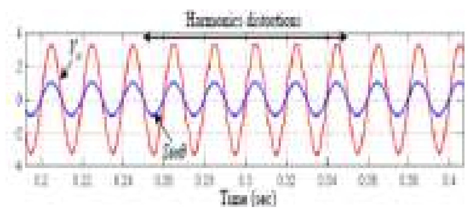
V. Simulation Results



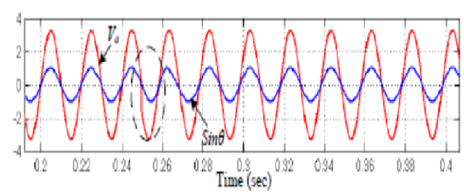
a) Unbalanced voltage sag



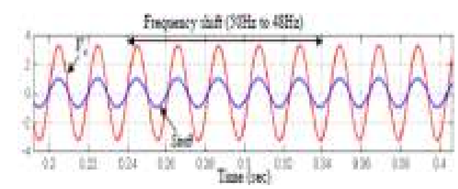
b) Unbalanced voltage swell



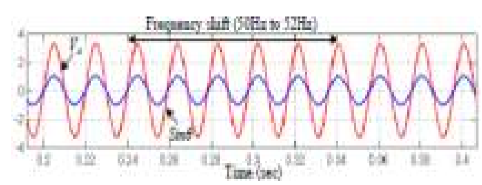
c) Harmonic distortion



d) Phase jump



e) Frequency shift from 50Hz to 48Hz



f) Frequency shift from 50Hz to 52Hz

Fig.4 . Simulation results of three phase AANF for phase angle detection under voltage sag, swell, harmonic distortion, phase jump and frequency shift

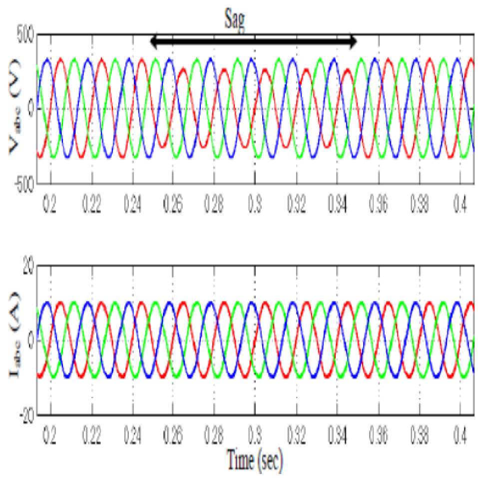


Fig.5 . Simulation results showing performance improvement in DG injected current under voltage sag: PCC voltage (Vabc) and DG current (Iabc).

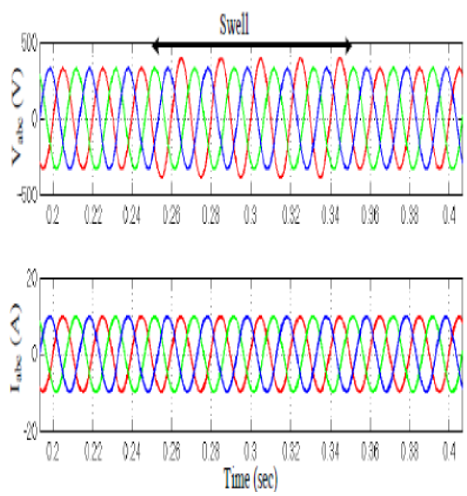


Fig.6 . Simulation results showing performance improvement in DG injected current under voltage swell: PCC voltage (Vabc) and DG current (Iabc).

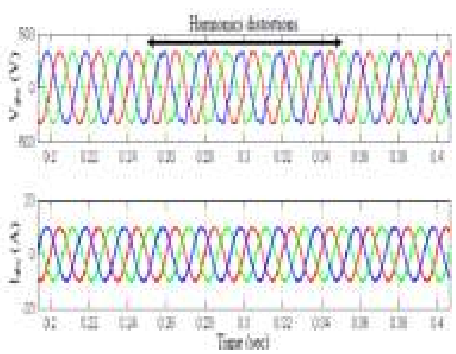


Fig.7 . Simulation results showing performance improvement in DG injected current under harmonic distortion: PCC voltage (Vabc) and DG current (Iabc).

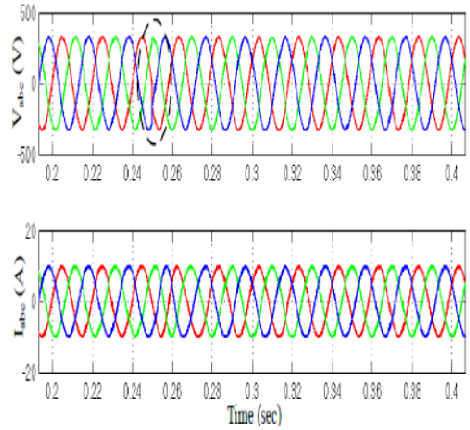


Fig.8 . Simulation results showing performance improvement in DG injected current under phase jump: PCC voltage (Vabc) and DG current (Iabc).

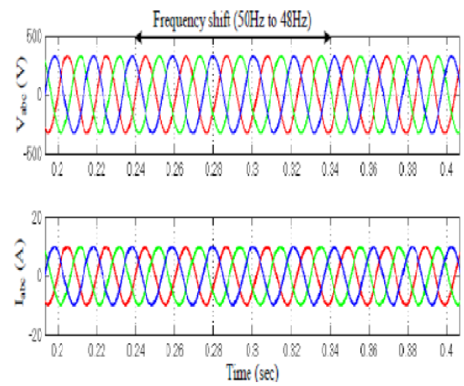


Fig.9 . Simulation results showing performance improvement in DG injected current under frequency shift 50Hz to 48 Hz: PCC voltage (Vabc) and DG current (Iabc).

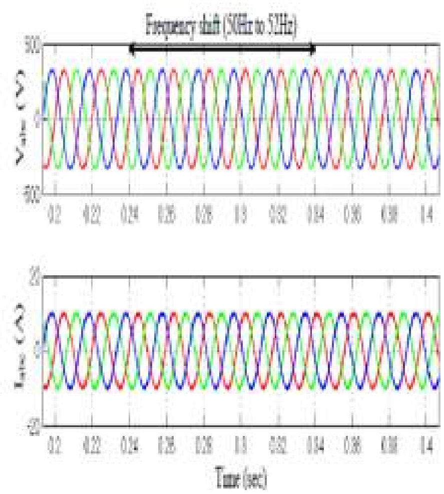


Fig.10 . Simulation results showing performance improvement in DG injected current under frequency shift 50Hz to 52 Hz: PCC voltage (Vabc) and DG current (Iabc).

Table II.THD Analysis Of DG Current Under Various PQ-Events

S.No	Power Quality-Event	Distribution generation current % of THD
1	Unbalanced voltage sag	2.14
2	Unbalanced voltage swell	2.14
3	Harmonic distortions	2.56
4	Phase jump	2.39
5	Frequency shift	2.35

V. Conclusion

Performance of the proposed DG system in introducing the active power into the grid under assorted power quality disturbances has been examined through MATLAB simulation results. Three phase extension of single phase amplitude adaptive notch filter (AANF) is extended to three phase system for detection of utility voltage phase angle and its performance and is evaluated under various power quality events. Three phase AANF based dq-current control technique for three-level NPC grid interfaced inverter DG systems is proposed. This control circuit operates DG in unity power factor mode by introducing only active power into the utility grid. Robust performance of three phase AANF improves the control concert of the DG system.

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