Comparative Study of the Three-Phase Grid-Connected Inverter Sharing Unbalanced Three-Phase and/or Single-Phase systems

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Abstract—Unbalance in a three-phase system is created due to single-phase loads and distributed single-phase renewable energy sources connected to the same system. This unbalance can be compensated locally at the point of common coupling using a three-phase four-wire grid-tied inverter. This paper presents a comparative study of three-phase four-wire inverter topologies to compensate for positive, negative, and zero sequence components of the current injected into the grid. The function of the inverter is to inject power to the grid and additional active power compensation (APC) to support unbalance, load reactive power, and load neutral current. Performance analysis and control of these topologies are being compared to evaluate utilization of dc link, size, control, and ease of implementation. A quantitative comparison of the topologies is provided to illustrate the advantages and disadvantages of the analyzed systems. The control algorithm has been presented to regulate the active and reactive power in each phase independently during both grid-connected and islanded modes. The analysis of three-phase 480-V 50-kV·A system based on three H-bridge inverter is presented with simulation and experimental results. The experimental results validate the ability of the inverter to provide four-quadrant control of each phase independently.

Index Terms—Active power compensation (APC), grid-tied inverter, microgrid, renewable energy sources, three-phase four-wire inverter.

I. INTRODUCTION

In a microgrid, integration of renewable energy sources is growing with the introduction of the net metering system where individual domestic/commercial users are able to generate electric power to supply to the grid. These distributed power generators could be either lower power single-phase or medium-power three-phase systems. Added to this, single-phase loads/sources in the microgrid can result in unbalance in the three-phase system leading to inefficiencies and voltage unbalance in the utility distribution grid. This phase unbalance could result in lower order torque pulsations in electro-mechanical systems such as generators leading to increased mechanical losses and could affect the stability of the system. Another problem is that the balanced three-phase generators must be designed for the maximum of any one of the three phases. This results in oversizing of the generation system. Unbalanced power also creates additional \( F_R \) losses and the current flow in the neutral wire.

Three-phase four-wire power conversion topologies have been proposed in the literature to address the aforementioned problems. Fig. 1 shows the block diagram of a typical system where a three-phase four-wire medium-power grid-tied inverter is used to compensate for the unbalance created by the local one-phase or three-phase subsystems of smaller power level consisting of household loads and renewable energy sources like renewable energy sources photovoltaic (PV) and wind. This inverter can be realized to perform the following functionalities:

1) inject power generated from the PV to the grid;
2) supply power to the local loads in islanded mode regulating the voltage and frequency;
3) active power compensation (APC) to compensate for the unbalance in the local loads or sources to ensure that the balanced power is delivered or drawn from the grid at the point of common coupling (PCC);
4) store energy in the battery bank and return it to grid during peak demand;
5) supply necessary reactive power to the grid; and
6) shunt active power filter (APF) to compensate local nonlinear loads.

By providing direct interfacing with an energy storage element and a renewable energy source, this architecture is capable of providing consistent output to the grid despite fluctuations in the renewable energy generation.

This paper focuses on comparison of three-phase four-wire inverter topologies and their control strategies considering the aforementioned features. The topologies that are investigated in this paper are as follows: 1) capacitor midpoint three-phase
inverter; 2) four-leg inverter; and 3) three single-phase H-bridge inverter.

A 480-V/50-kV·A three single-phase H-bridge inverter is built and tested to experimentally demonstrate the compensation of unbalances in a three-phase system. A control strategy is presented to control each phase independently to compensate for the unbalance in the three-phase system. The simulation and experimental results are also presented.

II. COMPARISON OF TOPOLOGIES

Several three-phase four-wire inverter topologies have been proposed in the literature. Objective of these inverters have been active power filtering injecting harmonic current to compensate nonlinear loads with only capacitor at the dc link [1]. Topologies of four-wire inverters for supplying unbalanced loads have been proposed and evaluated in various papers. However, this paper focuses on three-phase four-wire inverters for compensating unbalance in the grid due to single-phase loads as well as sources with multifunctioning capability. Since active and reactive power can be in any direction in each phase, zero-sequence current could be very high. Maximum current through the neutral could be as high as three times the phase current. This is possible when the three currents are in phase with each other while supplying active power in one of the phases and drawing both active and reactive power from the remaining two phases. The inverter for this application should be capable of handling higher unbalance in the current as compared to an inverter supplying unbalanced load and has to operate in the following modes.

1) Power Injection to the grid: In this mode, depending on the status of the energy storage system and local loads, if the power generated is in excess of local requirement, then surplus power is injected to the grid. During the peak load condition, it is also possible to deliver power from either renewable sources or the energy storage system.

2) Power is drawn from the grid: In this mode of operation, power is being drawn from the grid to either supply local loads and/or to store energy in the battery bank. The inverter operates as an active rectifier to transfer power from the grid to the dc link. The stored energy in the battery is used during the peak shaving operation.

3) APC: Single-phase loads/sources connected to the three-phase system cause unbalance. This can be compensated by supplying the unbalanced current from the three-phase four-wire inverter to make sure the phase and neutral currents injected to the grid \( i_{ag}, i_{bg}, i_{cg}, \) and \( i_{n} \) are balanced. The inverter has to supply unequal power in each phase, which is possible by controlling the three-phases independently.

4) Reactive power injection: In addition to active power injection, this inverter can also be utilized to inject reactive power to the grid to support voltage regulation. The inverter needs to supply the required reactive power by the local loads and also to deliver necessary reactive power to the grid.

5) Islanded mode: During abnormal situations such as deviation in the grid voltage or frequency, PCC is disconnected from the grid isolating local loads [2]–[4]. The three-phase inverter has to be operated to regulate the voltage and frequency of the local loads supplying necessary active and reactive power demand from the local loads.

In this paper, three topologies of the three-phase four-wire inverter are presented for comparison: 1) capacitor midpoint topology; 2) four-leg inverter topology; and 3) three H-bridge inverter topology.

A. Capacitor Midpoint Topology

Capacitor midpoint topology, shown in Fig. 2, is the simplest topology with least number of switches. In this topology, the neutral is connected to the midpoint of the split dc-link capacitors. This is equivalent to half-bridge configuration having very low dc-link utilization [5], [6]. Minimum dc-link voltage required is about 2.8 times the output phase voltage. Capacitance required at the link depends on the current through the neutral wire. Relation between capacitors midpoint voltage, \( V_{m} \) and neutral current \( i_{ni} \) is given by

\[
V_{m}(t) = \frac{1}{2C_{dc}} \int_{0}^{t} i_{ni}(\tau) d\tau + \frac{V_{dc}}{2}.
\]

For neutral current, \( i_{ni} = I_{N} \cdot \sin(\omega t) \), the dc-link capacitance value to limit the midpoint voltage fluctuation to \( \Delta V_{dc} \) is

\[
C_{dc} = \frac{\Delta V_{dc}}{\Delta i_{N}}.
\]

These two capacitors need to carry neutral current of lower order harmonics, like fundamental line frequency. Hence, the size of this capacitor has to be large and rated for higher voltage. Power devices need to be rated for higher voltage due to higher dc-link voltage, however current ratings are uniform and equal to line current. Total peak switching device power (SDP) is calculated as

\[
SDP_{peak} = \sum_{k=1}^{n} V_{sw,m} \cdot I_{peak_{sw,m}}
\]

Where \( V_{sw,m} \) is the maximum voltage stress on a device and \( I_{peak_{sw,m}} \) is the peak current through that device “m.” This switching power is calculated for all the “n” devices.

Devices can be controlled using space vector modulation or 3-D space vector modulation as discussed in [5]. The midpoint topology typically utilizes a sine-triangle pulse-width modulation (PWM) method. Control of the midpoint topology typically involves utilization of a balancing mechanism to regulate the voltage of the midpoint. This control is in addition to the required capacitance for minimizing ripple voltage. To balance the
voltage at the capacitor midpoint, typically the zero-sequence current is controlled. A third proportional-integral controller in addition to the $d$ and $q$ controllers is placed that regulates the capacitor midpoint voltage [7]. Given that the neutral current is specified by the loads, and not the phase controllers, controlling the zero-sequence current may be infeasible for the proposed application.

### B. Four-Leg Inverter Topology

In this topology, neutral is connected to an additional fourth switch pole as shown in Fig. 3. This gives additional degree of freedom (DOF) to control at the cost of additional pair of switches and gate driver circuits [8]–[13]. Unlike capacitor midpoint topology, the dc-link capacitor is not carrying high current and lower order harmonics. Only higher order switching currents are flowing through the link capacitor and low frequency is given by the input dc source or from the dc–dc converter connected to the inverter. Hence, capacitor of lower value can be used. There is an improvement in dc-link utilization by 15% and components of lower voltage rating can be used. Switches connecting to three phases (A, B, C) need to carry line currents, whereas the fourth leg (neutral) is rated to carry three times the phase current. Hence, switches of unequal current stresses are used that increases the peak SDP and complexity of implementation.

Per-phase control of the four-leg converter can be implemented by combining multiple standard techniques. Similar to three-phase balanced inverters, $dq0$ controller can be used to provide a dc control element for a linear controller [14]. The output of the $dq0$ controller can then be cascaded utilizing the $4 \times 4$, or quad, matrix transformation and 3-D space vector modulation to maximize the dc bus utilization [15], [16].

The quad matrix transformation converts the 3-DOF output-voltage space vector of the inverter into the 4-DOF leg-modulation space provided by the four phase-leg topology. This transformation is functionally equivalent to the Park transformation, but for four-leg inverters. The quad transformation allows a four-leg inverter to be modulated to produce arbitrary output phase voltages [16].

A hybrid version of the two techniques has also been developed where the fourth leg is tied to the capacitor midpoint through an inductor [17]. The fourth leg is used as an active balancing mechanism for the two halves of the link capacitor. The neutral voltage, relative to the dc-link voltage, may be regulated as the fourth phase leg resembles a buck converter.

### C. Three H-Bridge Inverter Topology

This type of power converter consists of three single-phase H-bridges to interface with the individual output phases, which are coupled to the utility grid with an isolation transformer as shown in Fig. 4. This topology has been proposed for four-wire active power filtering [12], [18], [19], however, the aforementioned functionalities are not being considered for the design and control discussed in this paper. A modified version of the three H-bridge topology is also used as a method of dynamic voltage restoration [20], [21].

Compared to topologies like capacitor midpoint and four switch poles where switches are rated unequally, this topology allows for all switches to have uniform ratings. In addition, it has advantages like lower dc-link voltage requirement for a given output voltage, which is half as compared to a capacitor midpoint inverter. Hence, a lower voltage rated capacitor, which needs to withstand only high-frequency switching currents can be used. Although higher number of devices are required in this power converter, the total peak SDP is still lower or of the same order as compared to other aforementioned topologies. The output voltage obtained is equivalent to the three-level inverter resulting in better harmonic profile and reduced requirement for passive filters. Higher reliability can be achieved since each phase is independent and during a fault in any one phase, the other two phases can still source power to the grid. Major disadvantage of this topology is the need for isolation transformer(s), which may not be an issue in case of requirement of isolation for safety and to meet the regulations. This inverter can be controlled similar to a three-phase PWM, 3-D space vector or $dq0$ or independent control of each phase.

Fig. 5 shows the overall control block diagram for a three-phase four-wire inverter in grid-connected mode during operation in modes 1–4, as mentioned in Section II. Based on the system configuration, reference for the active power is obtained either from the dc-link voltage controller or from the grid condition. Based on the grid requirement, reference for the reactive power $Q_{ref}$ is given to the current calculation block. Active
power is divided among the phases and reactive powers for individual phases are set depending on the desired functionality of the inverter. \( P_{a, \text{ref}} \) and \( Q_{a, \text{ref}} \) indicate the reference for the active and reactive power transferred to the phase-A of the grid. Current references for the three-phase grid current are calculated as

\[
I_{bg, \text{ref}} = \sqrt{\left( P_{a, \text{ref}}^2 + Q_{a, \text{ref}}^2 \right)} \cdot \frac{2}{V_{gd}} \cdot \sin \left( \theta + \tan^{-1} \left( -\frac{Q_{a, \text{ref}}}{P_{a, \text{ref}}} \right) \right) \quad (3)
\]

\[
I_{bg, \text{ref}} = \sqrt{\left( P_{b, \text{ref}}^2 + Q_{b, \text{ref}}^2 \right)} \cdot \frac{2}{V_{gd}} \cdot \sin \left( \theta - \frac{2\pi}{3} + \tan^{-1} \left( -\frac{Q_{b, \text{ref}}}{P_{b, \text{ref}}} \right) \right) \quad (4)
\]

\[
I_{cq, \text{ref}} = \sqrt{\left( P_{c, \text{ref}}^2 + Q_{c, \text{ref}}^2 \right)} \cdot \frac{2}{V_{gd}} \cdot \sin \left( \theta + \frac{2\pi}{3} + \tan^{-1} \left( -\frac{Q_{c, \text{ref}}}{P_{c, \text{ref}}} \right) \right) \quad (5)
\]

Where \( V_{gd} \) and \( \theta \) represent \( d \)-axis component of the grid voltage and the phase angle, respectively, which are obtained from phase-locked loop (PLL) [22]–[25]. \( i_{a, L} \), \( i_{b, L} \), and \( i_{c, L} \) represents the current requirement from the local loads connected to the corresponding phase. A cascaded delayed-signal-cancellation PLL structure is used to mitigate the effects of unbalance and harmonics in the grid voltage [24], [25]. References for the current from the inverter, \( i_{a, \text{ref}} \), \( i_{b, \text{ref}} \), and \( i_{c, \text{ref}} \) are obtained by combining the grid current and current through local loads. Individual proportional resonant (PR) [26], [27] controllers are used to regulate the inverter currents to generate gate signals for the power devices in the three H-bridge inverters. It is also possible to implement by transforming to \( d-q-0 \) or \( d-\beta-0 \) reference frame to regulate inverter currents. PWM signals are generated from the voltage references depending on the type of the converter topology using known suitable techniques.

Depending on the type of system, dc-link voltage of the inverter is regulated. If the dc side is connected to only renewable energy sources through a dc–dc converter operating in maximum power point tracking (MPPT), then the dc-link voltage is regulated by the inverter control providing \( V_{ref} \) that needs to be injected to the grid. Alternatively, if there is energy storage/sink connected to the link, then \( P_{ref} \) can be chosen based on the grid requirement to either inject or draw power. During this type of operation, dc-link voltage is regulated by the dc–dc converter connected to the energy storage. If this inverter needs to be operated also as an APF, then it has to deliver harmonic currents to compensate for the nonlinear loads connected locally. In that case, the hysteresis current controller can be used instead of the PR controller to accommodate the harmonics.

Fig. 6 shows the block diagram of the controller during islanded mode of operation. In this mode, the objective of the controller is to manage the inverter to establish a stable voltage and frequency for the local loads without any supply from the grid. Reference for voltage \( V_{ref} \) and frequency \( F_{ref} \) are used to calculate the three-phase balanced voltages \( V_{af, \text{ref}}, V_{bf, \text{ref}}, \) and \( V_{cf, \text{ref}} \). Three ac controllers are used to regulate the three-phase output voltage by generating reference for three-phase current from the inverter. For smooth transition from grid connected to islanded mode, initial value for the voltage angle \( \theta \) is taken from the PLL to avoid large change in the reference voltage.

### III. Comparison Summary

Table I summarizes comparison between the three topologies for the following specifications: three-phase line–line voltage, \( V_{c} = 480 \text{ V} \); switching frequency = 20 kHz; and total output power = 50 kV·A giving each individual phase power 16.7 kV·A. DC-link capacitance is calculated to limit the ripple to 1% of the link voltage. Energy storage requirement in the dc-link capacitance (\( 1/2CV^2 \)) is calculated that gives a measure of size and weight of the link capacitance. Estimate of size of switches can be obtained by comparing total peak SDP of the three topologies.

The capacitor midpoint topology requires the highest working voltage of 775 V for the dc link. The root mean square (RMS) current through the link capacitor is also the highest, because the link capacitor must carry the full neutral current. Electrolytic capacitor is the component with least mean time between failures in an inverter. Since, a link capacitor in this topology has more stress compared to other two topologies; reliability of capacitor midpoint topology is lower. While this topology has the fewest number of switches, the link capacitor requires 50 times higher energy storage than the next closest topology.
The four-leg inverter does not require as high a working voltage as the capacitor midpoint topology, nor as much link capacitance. This topology has two additional switching devices, but these switches must be of a higher rating to handle the worst-case scenario. This topology has the largest SDP and as such requires switching devices with a higher rating than the other topologies.

The three H-bridge topology has the lowest working voltage of all the topologies investigated. This topology also has the lowest current stresses on the link capacitor. The SDP of this topology is similar to that of the capacitor midpoint topology. Due to the required isolation transformers, this topology does suffer a weight and volume penalty.

Fig. 7 shows the estimated efficiency for the three topologies when an unbalance of $I_N/I_P = 2.7$ exists. When the phase currents are balanced, the efficiencies are comparable as given in Table I. As the unbalance increases, the capacitor midpoint and three H-bridge topologies stay similar, but the four-leg topology drops off markedly. The drop in the efficiency of four-leg topology is due to the neutral current leading to the insulated gate bipolar transistor losses in the fourth leg.

### IV. Simulation and Experimental Results

For the validation of the grid-connected configuration, the system shown in Fig. 8 is considered. The following specifications are used for the simulation and the experimental proto-
Fig. 9. Simulation results: Phase voltages, three-phase currents, neutral current, and power reference for phase-A.

Fig. 10. Simulation results: Three-phase inverter currents, neutral current, and voltages during transition from islanded mode to grid-connected mode.

Fig. 11. Simulation results: Three-phase inverter currents and voltages during transition from grid-connected mode to islanded mode.

during step change in active and reactive power. References for active and reactive power in phase-B and phase-C are given as 10 kW, 10 kVAR and 10 kW, 0 kVAR, respectively. Phase-A is supplying 5 kW to the grid initially and increased to 15 kW at \( t = 0.04 \) s, which is reflected in its peak value with current being in phase with the phase voltage, \( V_{af} \). Reactive power in phase-A is changed to 5 kVAR at \( t = 0.06 \) s resulting in current lagging the phase voltage as shown in Fig. 9. This shows that the power flow in each phase can be controlled independently supporting the zero-sequence current.

Simulation result for the grid synchronization is shown in Fig. 10, where the inverter is connected to the grid at \( t = 0.04 \) s. Initially, the inverter is supplying three-phase power of 11.5 kW to the local loads with fixed voltage and frequency. At \( t = 0.04 \) s, the inverter is connected to the grid and starts injecting additional power of 10 kW in each phases delivering total power of 41.5 kW from the dc link. Oscillations in the voltage across filter capacitors, \( V_{af}, V_{bf}, \) and \( V_{cf} \) are observed due to inclusion of an inductance between filter capacitor and the grid. Similarly, disconnection from the grid is shown in Fig. 11. The inverter is transferring the power to the grid initially with unbalanced currents in each phase, and then, goes to islanded mode at \( t = 0.04 \) s supplying power only to local load maintaining stable voltage. Fig. 11 also validates the operation of the controller in the presence of unbalanced grid voltages of \( V_{an} = 277 \) V, \( V_{bn} = 249.3 \) V, and \( V_{cn} = 290.9 \) V. Balanced phase voltages can be observed when the inverter transits to islanded mode.

For the experimental validation of the three H-bridge topology, the system shown in Fig. 8 is implemented. DC input from either PV or a battery is boosted using a bidirectional interleaved boost converter to feed the dc link of the grid-tied inverter. Photograph of experimental prototype of the three H-bridge topology is shown in Fig. 12, which consists of PP100B120 H-Bridge modules from Powerex; a TMS320F28335 DSP control card; an LC filter, and three single-phase transformers of turns ratio 1.73:1 connected in a Y configuration at the secondary. The three-phase resistor bank is used to emulate the local load.
Experimental results for the three H-bridge topology are presented in Figs. 13–21. The dc-link voltage of 450 V has been used to inject power to the three-phase grid. Fig. 13 shows the inverter operating in a balanced mode where all three phases are injecting the same current. The inverter is outputting 13 kW (4.3 kW per phase) to the grid. Current waveforms at the output of the inverter have been shown; however, the grid currents are 1.73 times higher than the inverter currents due to isolation transformers. The voltage of phase-A is channel 3 (magenta).

In Fig. 14, the capability of the proposed inverter to deliver unequal power in individual phases has been demonstrated. The inverter in each phase is injecting active power of different magnitudes to the grid. Current waveforms at the output of the inverter have been shown; however, the grid currents are 1.73 times higher than the inverter currents due to isolation transformers. The voltage of phase-A is channel 3 (magenta).

In Fig. 15, the inverter injecting power onto only two of the three phases of the grid. The controller has been set to inject 20 A rms into phase-A, 0 A into phase-B, and 12 A rms into phase-C. The inverter is outputting 4.3 kW in each phase injecting 4.3 kW, 4.3 kVAR (leading), and 4.3 kW, respectively. The control of the inverter has the ability to specify the real and reactive power independently, as shown in (3), and as such the inverter can produce four-quadrant currents on each phase independently.

Fig. 16 shows that power can be supplied from the grid on one phase (phase-B) and injected back to the other phases (A and C). The current references for this example are 20 A rms for phase-A, −10 A rms for phase-B, and 12 A rms for phase-C. In this case, the inverter is not supplying all of the power injected into phases A and C from phase-B. Excess power is being supplied from a dc source.

Fig. 17 demonstrates the inverter’s ability to inject the reactive power independently onto a single phase. The inverter is supplying 20 A rms into all three phases. The inverter is injecting 4.3 kW into both phases A and C, and 4.3 kVAR (leading) into phase-B. The control of the inverter has the ability to specify the real and reactive power independently, as shown in (3), and as such the inverter can produce four-quadrant currents on each phase independently.

Fig. 18 illustrates another configuration of injecting reactive power onto the grid. The inverter is again injecting 20 A rms of the current on each phase. While current in phases A and B are in the phase with their respective voltages, phase-C has been adjusted 120° out of phase with its voltage so that it is in phase with phase-A. Note that the Amps per div of channel 1 (phase-C current) have been adjusted to see the overlapping currents. In the case that all three phases are aligned in time would produce the worst-case neutral current where $I_N$ is the sum of all three phase currents. Performance of the inverter for another unbalanced condition has been demonstrated in Fig. 19. Currents in
Fig. 18. Experimental results: Grid voltage, $V_{ag}$ (Ch3: 200 V/div), inverter currents (Ch4, Ch2 [scale 20 A/div] and Ch1 [scale: 50 A/div]) supplying 20 Arms in each phase where phase-A current is in phase with phase-C current.

Fig. 19. Grid voltage, $V_{ag}$ (Ch3: 200 V/div), inverter currents (Ch4, Ch1, and Ch2 [scale 20 A/div]) supplying 20A rms in each phase where current in phase-B and phase-C are shifted by 45° and −45°, respectively, with their respective phase voltages.

Fig. 20. Experimental results: Grid voltage, $V_{ag}$ (Ch3: 200 V/div), inverter currents (Ch4, Ch1, and Ch2 [scale 10 A/div]) during grid synchronization. Phase-B and phase-C are 45° and −45°, respectively, with respect to their respective phase voltages with the equal current of 20 $A_{rms}$ in all the three phases resulting in neutral current of around 1.5 times the phase current, i.e., 30 $A_{rms}$. Waveforms from Figs. 12 to 19 validate the performance of the inverter for unbalanced conditions to operate at four quadrants of active and reactive power flow. Current magnitude and phase angle in each phase can be controlled independently to inject/compensate active and reactive power in the grid.

Dynamic performance of the inverter during transition from islanded mode to grid connection is shown in Fig. 20. Initially, the inverter is feeding the local resistive loads regulating voltage and frequency. The inverter output is synchronized with the grid voltage smoothly and starts injecting power to the grid in addition to the local load. As per IEEE1547 (5.1.2) standards, before closing the contactor that parallels the inverter with the grid, phase angle, frequency, and voltage difference have to be within the specified limit. This limit is 20°, 0.3 Hz, and 10 V respectively, for power rating of 0–500 kV·A. The feedback from the grid voltage is used to make sure contactor is closed only when the phase angle is within 20° as shown in the figure. Similarly, transient condition has been demonstrated in Fig. 21 where inverter disconnects from the grid and transition to islanded mode of operation supplying power to the local load without interruption.

V. CONCLUSION

This paper presents a comparative study of three-phase, four-wire inverter topologies to compensate positive, negative, and zero-sequence components of the current injected to grid. For this study, a medium-size power inverter is used to inject power to the grid and APC to compensate for unbalance, load reactive power, and load neutral current in the local PCC. Performance analysis and control of these topologies are being compared to evaluate the utilization of dc link, size, efficiency, and ease of implementation.

The performance of a CSDC PLL structure combined with PR controllers verifies the ability of the control system to control individual phase currents when connected to a grid with unbalanced voltages. Use of PR controllers to regulate islanded mode voltage is also verified.

A 480-V/50-kV·A three H-bridge inverter is constructed and examined. Experimental results are presented to demonstrate the operation of the developed converter and to validate the proposed control algorithms. It is demonstrated that full four-quadrant control could be achieved for each phase independent of the operation of the other two phases. With the improved algorithm, it is also possible to achieve functionalities of shunt APF to compensate local nonlinear loads.

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REFERENCES


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