Power Quality Improvement Using Dvr for Compensating Extreme Sag and Swell

S.Silambarasan,S.Kaviya,V.Manisha
Assistant Professor Dept. of EEE,
Student, Dept. of EEE, Idhaya Engineering College of Women,
China Salem, Kallakurichi, India

Abstract- In today's power system, power quality is a critical topic having several impacts on customers and utilities. In the current electric power system, the integration of renewable energy sources, smart grid technologies, and significant usage of power electronics equipment has generated a slew of issues. The sensitive equipment might be damaged by harmonics, voltage sag, and swell. These devices are vulnerable to Interference with other elements of the system resulting in input voltage changes. As a result, in the contemporary period, Power quality is becoming more important as the number of sensitive and costly electronic devices grows. To overcome the challenges of non-standard voltage, the Dynamic Voltage restorer (DVR) device has been extensively utilized to keep the load voltage stable. To have a dynamic and fast response of the DVR a modified instantaneous reactive power (PQ) theory is proposed to control DVR under extreme transient voltage circumstances. The proposed technique is based on the extraction of the positive sequence component of grid voltage and the negative sequence component of load current for generating a voltage reference signal. The power system network with the proposed PQ control scheme is investigated and assessed under various scenarios to compensate for severe balanced, unbalanced (voltage sags and swells), and load change. MATLAB/Simulink is used to verify the mathematical models of the conventional PQ and proposed PQ control system for DVR. The complete system is implemented experimentally using a space 1104 based laboratory system to validate the presented control scheme. The simulation and experimental results are correlated, demonstrating the efficacy of the suggested modified PQ control technique.
KEYWORD: S Instantaneous reactive power (PQ) theory, dynamic voltage restorer (DVR), balanced and unbalanced load, voltage sag, voltage swell, load change.

I.INTRODUCTION

Power quality is a criterion of a pure and regularized power supply in terms of load. Many factors, including sensitive, non-linear loads, the integration of distributed generation (DG), and advancements in power electronics equipment affect the power quality of the grid [1], [2]. Electrical power quality has massive consideration in the electrical distribution system. The major source of concern is power quality issues of the large load, open circuit faults. This issue will lead to insulation breakdown, overheating of electrical equipment, and damage to electronic equipment. Essay Et Al. State that Voltage sag is a serious power quality issue that plays havoc on sensitive loads in the distribution system [9]. To compensate for power quality issues, power electronics-based devices like power filters, unified power flow controller (UPFC), static compensator (STATCOM), distribution static compensator (DSTATCOM), and dynamic voltage restorer (DVR) are used [10], [11]. DVR requires a complex control mechanism to safeguard important distribution system loads from power quality issues [12]. DVR is used on distribution feeders to safeguard load. Problems caused by voltage sags and swells. DVR is linked in series with the load, and a battery energy storage system (BESS) is coupled with a transformer and inverter, which adjust the active and reactive power requirements for voltage sags and voltage swells [13]. For voltage stability, the DVR injects voltage into the distribution system, which is connected to the system through the transformer [14]. DVR is a FACTS device that adjusts for disturbances caused by loads such as voltage sags, swells, and voltage harmonics. In normal settings, DVR injects voltages in series with the transmission lines and injects a modest amount of voltage. When a disturbance occurs, however, DVR calculates the voltages needed to safeguard the load using sinusoidal pulse width modulation (SPWM) [15]. The voltages are then fed back into the system to keep the condition stable. DVR either absorbs or delivers active or reactive power in the steady-state, but when a disturbance occurs, DVR either delivers or absorbs active or reactive power from the dc-link. Martiningsih et al. have advocated installing a DVR in a PT DSS power plant, where the DVR functions as a compensator and is linked in series with the distribution line. The suggested PI-based DVR is capable of recovering power quality constraints [16], [17]. Estimably et al. developed a DVR-based technique for reducing voltage sag using DVR to improve the quality of power systems. To deterioration in electrical equipment performance. The findings show that DVR properly compensates for sag/swell and implements suitable voltage adjustment

[18]. To alleviate symmetrical and asymmetrical sags and swells, J. Han et al. presented a unique DVR with a power electronic transformer (PET) [19]. The findings show that the unique design efficiently alleviates the symmetrical and asymmetrical problems The DVR control strategy can protect the load from power quality issues related to voltage [5]. To have proper control, a perfect reference generation technique must be implemented. Various approaches for reference generation have been suggested, including, Clark's and Park's transformations, Pharos parameter and, Symmetrical components, Instantaneous real and reactive power [20]. Park's transformation is a mathematical transformation approach used to simplify the analysis of three-phase circuits is direct–quadrature–zero (dq0) in electrical engineering. The application of the dq0 transform on three-phase circuits reduces the three AC values to two DC quantities [8], [21]. The inverse transform is used to reconstruct the real three phase AC results using simplified computations on these imaginary DC variables. It is often used to ease the study of three-phase synchronous machines as well as calculations for three-phase inverter control [22]. When applied to three phase voltages and currents, the dq0 transform is The Phase Locked Loop (PLL) must create a signal with the same fundamental frequency and phase angle as the reference signal generation for the two approaches Clarke and Park's transformation [23]. The Pharos parameter or Phase Locked Loop (PLL) is a control system that attempts to create an output signal whose phase is allied to the phase of the input ''reference'' signal. It is an electrical circuit that consists of a phase detector and a variable frequency oscillator [24]. This circuit checks the phase of the input signal to the phase of the signal obtained from its output, then changes the frequency of its output signal to maintain the phases in synchronism [25]. The ''Generalized Theory of Instantaneous Active and Reactive Power, ''or ''Theory of Instantaneous Power,'' or simply ''PQ Theory System with a neutral wire was briefly mentioned in the original development of the theory, which was intended for three-phase, three-wire systems [7], [26], [27]. Afterward, it was expanded to three-phase four-wire systems (systems having phases a, b, and c, in addition to a neutral wire) After performing an algebraic translation (Clarke transformation) of the three-phase voltages and currents in the abs coordinates to the αβ coordinates, the PQ theory instantaneous power components are calculated [6], [28], [29]. In this article, an improved PQ method is proposed for the generation of reference signals in terms of the positive sequence component of the grid voltage and the negative sequence component of load current. The appearance of load current negative sequence component arises due to power quality issues such as voltage sag, swell, load change, harmonic effect, balance, and unbalanced load [30]. The main advantage of the modified technique is the non-utilization of phase-locked loop and low-pass filters, because of which the disadvantages of phase shifting and insufficient compensation are eliminated. Comparison analysis between the performances of traditional and proposed PQ methods is presented through different scenarios of power quality issues. The proposed method is superior in detecting and compensating the power quality issues. The paper is organized in the sections as followed. Section II provides a discussion on dynamic voltage restorer (DVR). Section III describes the proposed PQ algorithm. The experimental setup is described in Section IV. The result illustration, as well as a discussion, is presented in section V. The performance of the proposed DVR control system is summarized in Section VI.

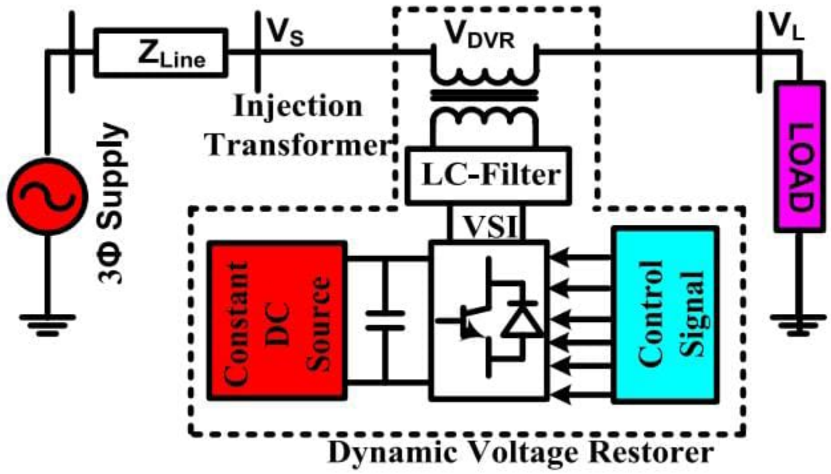


FIGURE 1. Single line diagram of power network with DVR.

II. PHILOSOPHY DYNAMIC VOLTAGE RESTORER (DVR)

Injection of compensation voltage with the precise magnitude and frequency is required to restore the load side voltage to the proper amplitude and waveform. The system may inject up to 50% of the normal voltage for a brief period of time (up to 0.1 seconds). Most voltage sags, on the other hand, are much below 50%. Dynamic voltage restoration or control is the term used to describe this (DVR) [31]. A dynamic voltage restorer (DVR) is described as the regulating device [12], [16], [32]. End-users who are experiencing power quality problems may benefit from DVRs [33]. Figure 1 depicts a simple DVR power system circuit with a control circuit to inject compensated voltage and maintain the voltage at the correct level. DVRs are often mounted on a crucial feeder, delivering active power through DC energy storage while internally generating the requisite reactive power [34], [35]. In restoring the load side voltage to the required level, a compensating voltage of the required magnitude and frequency must be injected [36]–[39]. The system can inject up to 50% of the rated voltage, but only for a brief period (up to 0.1 seconds). Normally voltage sags, are far smaller than 50%. A dynamic voltage restorer (DVR) is the regulating device. DVRs may be useful for end-users who are prone to undesirable power quality issues [40]. DVRs are often mounted on the main feeder, delivering active power through DC energy storage and generating the requisite reactive power internally [30], [41].

A.DVR OPERATING MODES

A DVR’s switching states are classified into three categories based on operating states: protective, standby, and voltage compensation [42]. In the protective state, if the load current exceeds the allowable value owing to a short circuit or a significant overcurrent current, the DVR will be disconnected from the grid [43]. The inverter shorts the secondary winding of the injection transformer. In the standby state, allowing full load current to flow through the primary winding. In this operation mode, the DVR will not inject any correction voltage into the power grid. In the voltage compensation state.

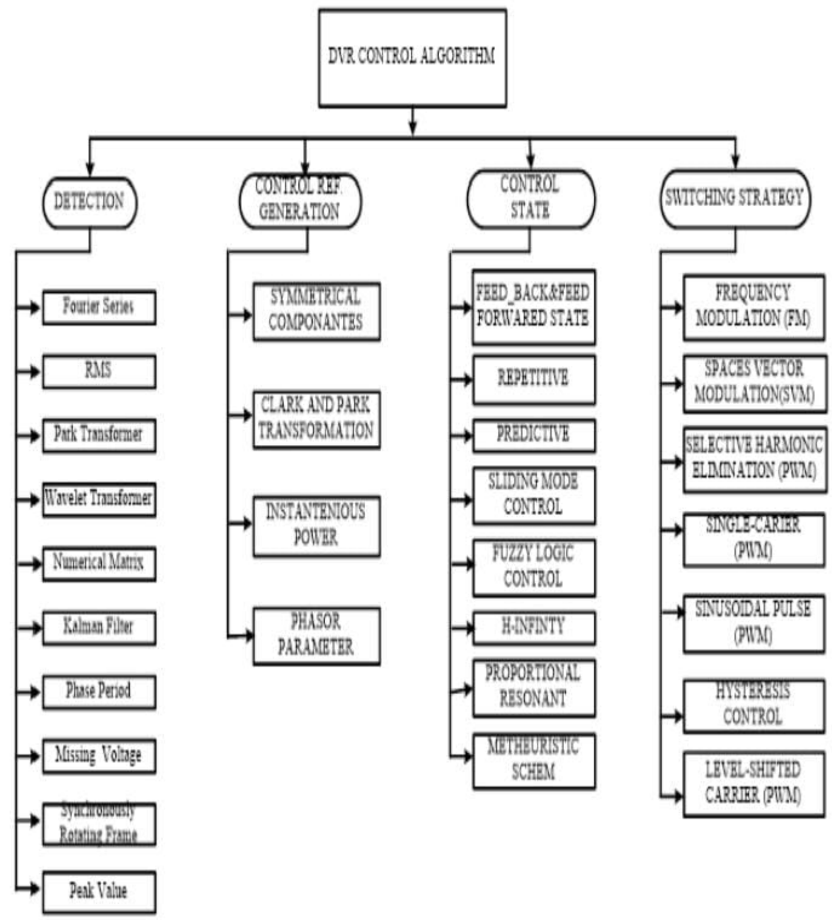


FIGURE 2. Flow chart for control strategies of DVR.

the DVR injects the appropriate compensatory voltage via injection transformer to the grid [44]. This mode of operation begins when a load voltage disturbance is detected and terminates when the voltage returns to normal operating conditions.

B.CONTROL STRATEGIES AND ALGORITHMS OF DVR

The detection of voltage disturbances is the major emphasis of the DVR's control system. Specifically, with sensitive loads, the detecting system should be fast enough to identify the voltage disturbance accurately for the assessment of DVR performance [20], [45]. As shown in Figure 2, various methods for voltage disturbance detection have been proposed, including RMS, Peak Value, DFT, Fourier Transform (FT), Wavelet Transform (WT), Windowed Fast FT (WFFT), ABC to DQ axis transformation, KF, Phase-Locked Loop (PLL), and SRF [28], [46]. The benefits and drawbacks of the most serious voltage disturbance detection techniques are provided.

C. PROPOSED SYSTEM DESCRIPTION

The proposed configuration shown in Figure 3 includes a supply (grid) voltage with grid impedance, a three-phase load, an injection transformer, and the DVR system. The DVR system comprises a Voltage Source Inverter (VSI) powered by a DC power source with a dc link capacitor and a harmonic passive filter. A three-phase balanced, and unbalanced load is considered in this system [16], [47], [48].

the DVR injects the appropriate compensatory voltage via injection transformer to the grid [44]. This mode of operation begins when a load voltage disturbance is detected and terminates when the voltage returns to normal operating conditions.

the DVR injects the appropriate compensatory voltage via injection transformer to the grid [44]. This mode of operation begins when a load voltage disturbance is detected and terminates when the voltage returns to normal operating conditions.

Detection Method	Benefits	Weaknesses
Peak Value [42]	0.25 cycle delay in identifying sags/swells.	Pass over noise, difficult to extract phase angle
Discrete Fourier [43]	Sags/swells recognition, harmonic distortion	Requires stationary signal, high Calculations (one cycle for perfect sag/swell value and phase data),
Root Mean Square[6]	Identifies start-/end- of sags/swells, simple, fast	Fails to detect the frequency, harmonic, and phase angle
Fast Fourier Transformation [44]	Quicker than DFT, identifies phase angle shifts, harmonic distortion, precision	Requires stationary signal, integer sample numbers
Phase Locked Loop[24]	Sags/swells recognition, phase angle	Requires time delay upward half-cycle, difficult to control
Synchronously Rotating Frame [49]	Fit for three-phase Very short time for detection	incompatible for single-phase systems, fails to Identify the imbalance of sags/swells voltage
Wavelet Transform[50]	Ease of use time and frequency data	Requires accurate choice of wavelet model, need a delay associated to wavelet models
Kalman Filter [29]	Ideal recognition of voltage sags/swells, solid for working with linear structures	Requests enhanced KF for non-linear structures

III. INSTANTANEOUS REACTIVE POWER CONTROL TECHNIQUE

Generalized Theory of the Instantaneous Reactive Power in Three-Phase Circuits,'' also known as ''Theory of Instantaneous Real Power and Imaginary Power,'' or ''Theory of Instantaneous Active Power and Reactive Power,'' or ''Theory of Instantaneous Power,'' or simply ''PQ Theory,'' was proposed by Acai et al. in 1983 for the control of active filters in three-phase power systems. The idea was first formulated for three-phase, three-wire systems, with a brief mention of neutral wire systems. Later, it was expanded to include three-phase four-wire systems (phases a, b, c, and neutral wire) [6], [29].

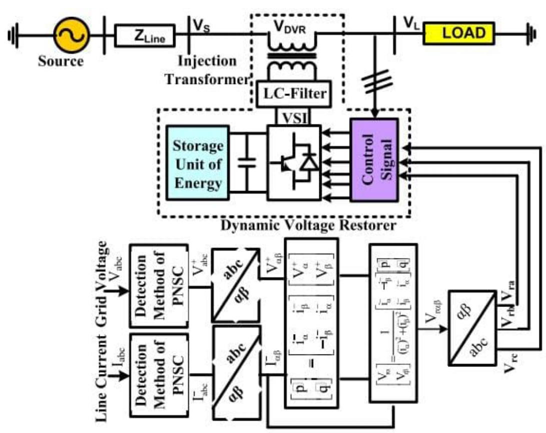


FIGURE 3. Proposed system configuration

PQ THEORY

PQ theory is a time-domain representation of instantaneous power. This theory is based on Clarke's Transformation. The voltage and current are transformed from abs coordinates to αβ0 coordinates. This method consists of a real matrix that transforms three-phase voltages and currents into the αβ0 stationary reference frames [5], [50]. With the help of Clarke's transformation, the voltages and current can be related in terms of abs and αβ0 as follows.

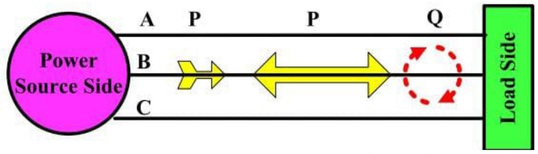


FIGURE 4. Power components of PQ scheme

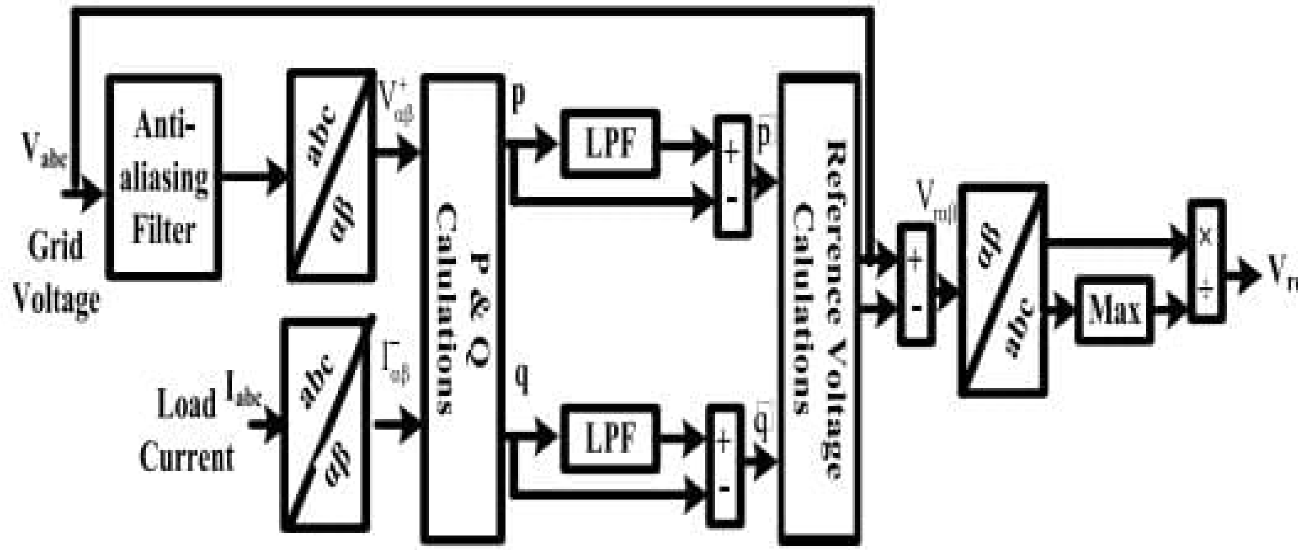


FIGURE 5. Traditional PQ method

As PQ control technique is intrinsically a 38 system, used in with or without a neutral line and balanced or unbalanced. it can be implemented in both steady-state and transient state conditions. It concedes two control strategies, one constant instantaneous power and another is sinusoidal supply current [5], [21]. The power components of the PQ scheme.

B. THE TRADITIONAL PQ CONTROL TECHNIQUE.

s the control model for generating Verve using Traditional PQ. Where the three-phase voltage and Load current are measured. The three-phase grid voltage is sensed and processed through an antialiasing filter and then αβ positive components of grid voltage (V + αβ) is obtained as given in equation (1). Simultaneously the load current is measured and αβ negative component of load current I − αβ is obtained as shown in equation (2). Both the components are processed to calculate the real (P) and reactive power (Q) using equations (5) and (6), later P, and Q are processed through a low pass filter for the generation of real and reactive power in αβ components where with reference voltage calculation block and inverse Clark's transformation the voltage reference Vref is generated.

s the control model for generating Verve using Traditional PQ. Where the three-phase voltage and Load current are measured. The three-phase grid voltage is sensed and processed through an antialiasing filter and then αβ positive components of grid voltage (V + αβ) is obtained as given in equation (1). Simultaneously the load current is measured and αβ negative component of load current I − αβ is obtained as shown in equation (2). Both the components are processed to calculate the real (P) and reactive power (Q) using equations (5) and (6), later P, and Q are processed through a low pass filter for the generation of real and reactive power in αβ components where with reference voltage calculation block and inverse Clark's transformation the voltage reference Vref is generated.

C. THE MODIFIED PQ TECHNIQUE

This improved method refers to the generation of a reference signal for compensating the power quality issues. This reference depends on the grid voltage and negative sequence component of load current. Power quality concerns like voltage sag, swell, load change, harmonic impact, balance, and unbalanced load induces the load current negative sequence component. To obtain the compensation, there are two issues firstly the magnitude of the compensation, and secondly the phase of the reference signal which is locked with the grid voltage. For the magnitude of the compensation power.

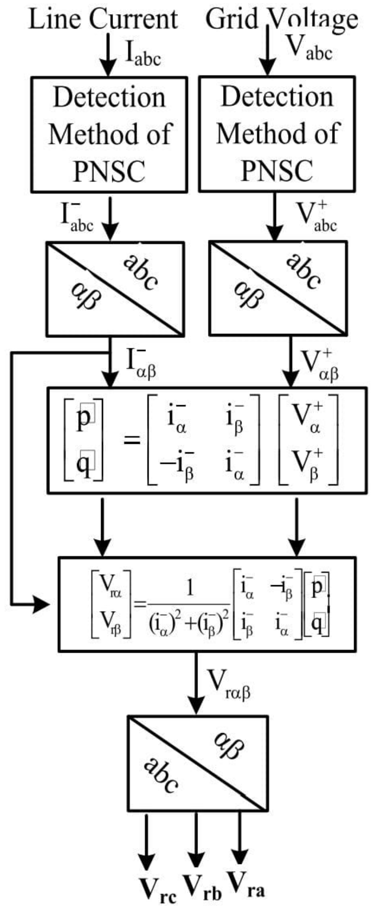


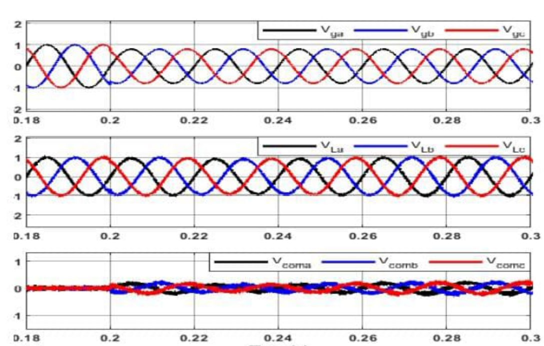
FIGURE 6. Block diagram of the modified PQ method.

D. HYSTERSIS VOLTAGE CONTROL

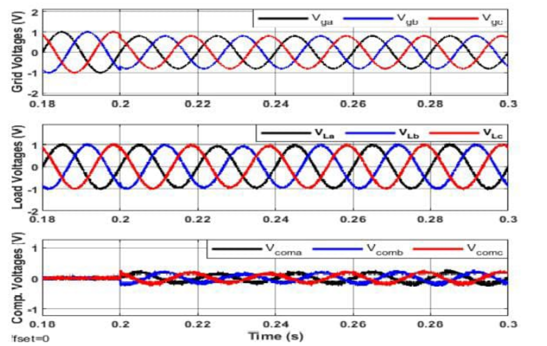
The switching signals for the voltage source inverter are generated using a hysteresis voltage controller. The load voltage references are compared with the measured load voltages. The error signals are then processed through the hysteresis band. This scheme can be seen in Figure 7. A hysteresis voltage controller has the benefits of effective dynamic response, superior precision, cheap cost, and ease of implementation, the hysteresis controller is favored over standard controllers such as PWM and SVPWM [51]. The hysteresis control.

E. PARAMETERS OF THE SYSTEM UNDER TEST

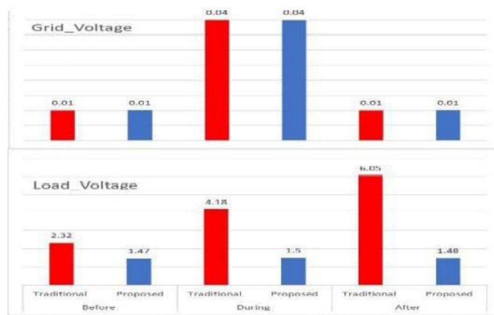
F. POSITIVE SEQUENCE COMPONENTS CALCULATIONS



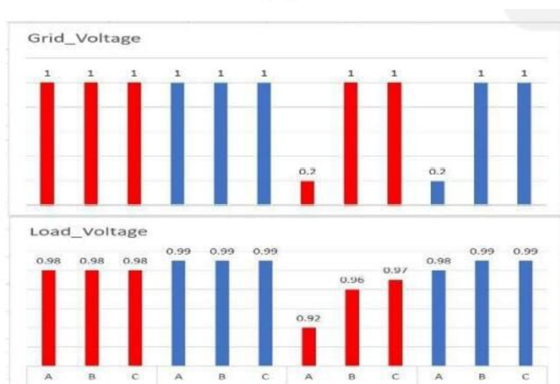
(A)



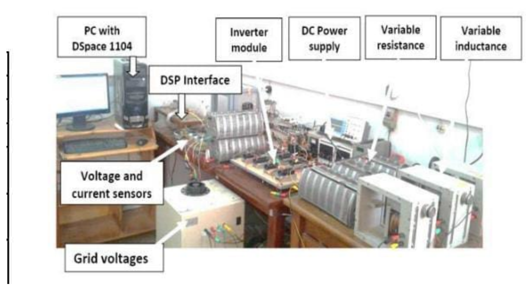
(B)



(C)



(D)



Experimental setup

Wherever V1 (t) is the positive sequence component in time domain interpretation of the 3-phase grid voltages, Tα1 and Tα2 are the time phase angle shift of the symmetrical component. Wherever, Tα1= t +tph − tα1 and Tα2= t + tph + tα2. Figure 7c shows the removal of grid voltage negative sequence component.

IV. EXPERIMENTAL SETU

The experimental setup for the proposed DVR system is shown in Figure 8. It is comprised of two circuits: one for the power and the other for control. The full experimental circuit consists of a three-phase AC voltage source, a transformer, VSI powered by a DC power source, and a 1kVA load. The control circuit is based on the digital signal processing type space (DS1104) to execute the proposed system, which was employed using Mat lab/Simulink. LV25-P voltage transducer circuit is used to measure the supply and load voltages. LA25 current sensor circuits are used to sense the load currents. Measured signals are scaled down to 10V before being given as inputs to the DS1104 board to fulfil the control board's requirements. The system parameters are presented in Table.

The experimental setup for the proposed DVR system is shown in Figure 8. It is comprised of two circuits: one for the power and the other for control. The full experimental circuit consists of a three-phase AC voltage source, a transformer, VSI powered by a DC power source, and a 1kVA load. The control circuit is based on the digital signal processing type space (DS1104) to execute the proposed system, which was employed using Mat lab/Simulink. LV25-P voltage transducer circuit is used to measure the supply and load voltages. LA25 current sensor circuits are used to sense the load currents. Measured signals are scaled down to 10V before being given as inputs to the DS1104 board to fulfil the control board's requirements. The system parameters are presented in Table

V. RESULTS AND DISCUSSION

To verify the proposed modified PQ control system for reference generation the complete system model is implemented in two different ways. Firstly, MATLAB simulation of the system based on ‘‘mathematical equations 1 to 16’’ is implemented and secondly experimental setup using ‘‘DSPACE DS1104 control board’’. Different scenarios of severe power quality conditions are extracted to verify and validate the efficacy of the proposed PQ scheme. The different scenarios of balanced, unbalanced, (sag and swell) and load reduction are considered and discussed in this section.

OUTPUT

VI. CONCLUSION

This paper delivered a method for compensating voltage disturbances while using the DVR. The proposed approach improves the quality of load voltages by protecting them against grid voltage abnormalities. The proposed DVR control approach is based on a modified version of PQ theory that employs a detection method for the positive and negative sequence components. The detection technique is carried out in the time domain. The efficiency of the proposed approach is assessed using extensive simulations in MATLAB/Simulink and experiments under several special disturbance scenarios: severe unbalanced sag and swell, load change, and voltage harmonics. The proposed method has shown capability in improving the voltage quality as well as the voltage profile. The results have emphasized the applicability of the proposed DVR compensation method. To sum up, the following advantages summarize the performance of the proposed system:

- Less computational effort.
- Faster response.
- Balanced load voltages under severe unbalanced voltage sag and swell.
- Effective harmonic cancelation.

• Less transient oscillation in the fundamental frequency

REFERENCES

[1] S. A. Mohammed, A. G. Cerrada, A. M. M. Abdel-Rahim, and B. Hasanin, ‘‘Dynamic voltage restorer (DVR) system for compensation of voltage sags, state-of-the-art review,’’ Int. J. Compute. Eng. Res., vol. 3, no. 1, pp. 2250–3005, 2013.

[2] N. Hosseinzadeh, A. Aziz, A. Mahmud, A. Gargoom, and M. Rabbani, ‘‘Voltage stability of power systems with renewable-energy inverter-based generators: A review,’’ Electronics, vol. 10, no. 2, pp. 1–27, Jan. 2021, doe: 10.3390/electronics10020115.

[3] Y. Jani, S. Savaliya, V. Solanki, and A. Mahavidyalaya, ‘‘A review on dynamic voltage restorer (DVR) to improve power quality,’’ Int. J. Eng. Sci. Res. Technol., vol. 3, no. 2, pp. 1–5, 2014.

[4] S. Jothibasu and M. K. Mishra, ‘‘A control scheme for storage less DVR based on characterization of voltage sags,’’ IEEE Trans. Power Del., vol. 29, no. 5, pp. 2261–2269, Oct. 2014, doi: 10.1109/TPWRD.2014.2316598. [6] F. K. de Araujo Lima, J. M. Guerrero, F. L. Tofoli, C. G. C. Branco, and J. L. Dantas, ‘‘Fast and accurate voltage sag detection algorithm,’’ Int. J. Electra. Power Energy Syst., vol. 135, Feb. 2022, Art. no. 107516, doi: 10.1016/j.ijepes.2021.107516

[5] S. F. Al-Gahtani, A. B. Barnawi, H. Z. Azazi, S. M. Arshad, J. K. Bhutto, H. M. Majahar, and E. Z. M. Salem, ‘‘A new technique implemented in synchronous reference frame for DVR control under severe sag and swell conditions,’’ IEEE Access, vol. 10, pp. 25565–25579, 2022, doi: 10.1109/ACCESS.2022.3151919.

[6] S. Shreya and K. S. R. Anjaneyulu, ‘‘SRF controlled DVR for compensation of balanced and unbalanced voltage disturbances,’’ Int. J. Electra. Eng. Technol., vol. 7, no. 3, pp. 73–92, 2016.

[7] E. A. Al-Amar, A. Al-Haq, A. Iqbal, M. Jalal, and A. Anjum, ‘‘SRF based versatile control technique for DVR to mitigate voltage sag problem in distribution system,’’ Aim Shams Eng. J., vol. 11, no. 1, pp. 99–108, Mar. 2020, doi: 10.1016/j.asej.2019.09.001.

[8] S. Nawaz, N. Jhajharia, and T. Manganic, ‘‘Reduction of distribution losses by combined effect of feeder reconfiguration and optimal capacitor placement,’’ Int. J. Recent Res. Rev., vol. 2, pp. 30–38, Jun. 2012.

[9] R. O. Benazir and N. S. Cetin, ‘‘Comprehensive overview of optimizing PV-DG allocation in power system and solar energy resource potential assessments,’’ Energy Rep., vol. 6, pp. 173–208, Nov. 2020, doi: 10.1016/j.egyr.2019.12.010.

[10] M. Farhadi-Kangarlu, E. Babaei, and F. Blaabjerg, ‘‘A comprehensive review of dynamic voltage restorers,’’ Int. J. Electra. Power Energy Syst., vol. 92, pp. 136–155, Nov. 2017, doi: 10.1016/j.ijepes.2017. 04.013.

[11] C. Zhan, ‘‘Dynamic voltage restorer with battery energy storage for voltage dip mitigation,’’ in Proc. 8th Int. Conf. Power Electron. Variable Speed Drives, 2000, pp. 360–365, doi: 10.1049/cp: 20000273.

[12] G. S. Chawda, A. G. Shaik, O. P. Mahela, S. Padmanaban, and J. B. Holm-Nielsen, ‘‘Comprehensive review of distributed facts control algorithms for power quality enhancement in utility grid with renewable energy penetration,’’ IEEE Access, vol. 8, pp. 107614–107634, 2020, doi: 10.1109/ACCESS.2020.3000931.

[13] T. Bhattacharjee, M. Jamil, and A. Jana, ‘‘Design of SPWM based three phase inverter model,’’ in Proc. Technol. Smart-City Energy Secur. Power (ICSESP), Mar. 2018, pp. 1–6, doi: 10.1109/ICSESP.2018. 8376696.

[14] N. Abas, S. Dilshad, A. Khalid, M. S. Saleem, and N. Khan, ‘‘Power quality improvement using dynamic voltage restorer,’’ IEEE Access, vol. 8, pp. 164325–164339, 2020, doi: 10.1109/ACCESS.2020. 3022477.

[15] J. Afonso, C. Couto, and J. Martins, ‘‘Active filters with control based on the P-Q theory,’’ IEEE Ind. Electron. Soc. Newslett., vol. 47, no. 3, pp. 5–10, Sep. 2000. [Online]. Available: http://hdl.handle.net/1822/1921

[16] J. Han, X. Kong, P. Li, Z. Zhang, and X. Yin, ‘‘A novel low voltage ride through strategy for cascaded power electronic transformer,’’ Protection Control Modern Power Syst., vol. 4, no. 1, pp. 1–12, Dec. 2019, doi: 10.1186/s41601-019-0137-1. [20] A. H. Soomro, A. S. Larik, M. A. Mahar, A. A. Sahito, A. M. Soomro, and G. S. Kaolin, ‘‘Dynamic voltage restorer—A comprehensive review,’’ Energy Rep., vol. 7, pp. 6786–6805, Nov. 2021, doe: 10.1016/j.egyr.2021.09.004.

[17] C.Nagarajan and M.Madheswaran - ‘Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter’ - Journal of ELECTRICAL ENGINEERING, Vol.63 (6), pp.365-372, Dec.2012.

[18] C.Nagarajan and M.Madheswaran - ‘Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis’- Springer, Electrical Engineering, Vol.93 (3), pp.167-178, September 2011.

[19] C.Nagarajan and M.Madheswaran - ‘Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques’- Taylor & Francis, Electric Power Components and Systems, Vol.39 (8), pp.780-793, May 2011.

[20] Nagarajan and M.Madheswaran - ‘Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis’- Iranian Journal of Electrical & Electronic Engineering, Vol.8 (3), pp.259-267, September 2012.

[21] G.Neelakrishnan, K.Anandhakumar, A.Prathap, S.Prakash “Performance Estimation of cascaded h-bridge MLI for HEV using SVPWM” Surah Punj Journal for Multidisciplinary Research, 2021, Volume 11, Issue 4, pp:750-756

[22] G.Neelakrishnan, S.N.Pruthika, P.T.Shalini, S.Soniya, “Performance Investigation of T-Source Inverter fed with Solar Cell” Surah Punj Journal for Multidisciplinary Research, 2021, Volume 11, Issue 4, pp:744-749

[23] G.Neelakrishnan, P.Iraianbu, T.Abishek, G.Rajesh, S.Vignesh, “IOT Based Monitoring in Agricultural” International Journal of Innovative Research in Science, Engineering and Technology, March 2020, Volume 9, Issue 3, pp:814-819