

**An MVC-Based Adaptive Enhancement of Feed-Forward Controlled Unified
Power Quality Conditioner for Improved Dynamic Response Under Voltage Sag and
Swell**

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Abstract

In reaction to voltage sags and swells, this short suggests feed-forward control loops that speed up the corrected grid/input currents and dc-bus voltage of a three-phase universal power quality conditioner (UPQC). three-phase UPQC uses **feed-forward control** to achieve fast compensation during voltage sag and swell conditions. The series converter compensates load-voltage disturbances, while the parallel converter controls input current and maintains **DC-link voltage and power balance**. By keeping input currents and grid voltages in phase and properly adjusting current amplitude, the system reduces DC-bus transients and improves dynamic power-quality compensation. Simulation and experimental results demonstrate the

effectiveness of the proposed control strategy. Maximum Versoria Criterion (MVC)-based robust adaptive filter with feed-forward control to improve power-quality compensation. The MVC filter accurately extracts fundamental voltage and current components under noise, harmonics, and impulsive disturbances. The series converter compensates voltage sag and swell, while the shunt converter regulates source current, reactive power, harmonics, and DC-link power balance. The combined control strategy provides fast dynamic response, improved disturbance rejection, lower voltage/current THD, better power factor, reduced tracking error, and faster DC-link voltage recovery

compared with conventional UPQC control.

Index Terms: UPQC system, power quality events, and DC-bus dynamic improvement

1.Introduction:

A number of power quality (PQ) issues, such as harmonics, voltage distortion, sags, swells, reactive power, and load imbalance, have been brought on by the growing use of power-electronic equipment in recent years. Voltage and current correction are provided simultaneously by a Unified Power Quality Conditioner (UPQC), which is made up of shunt and series voltage source inverters linked by a shared DC bus. While the shunt inverter lowers current harmonics, reactive power, and load imbalance, the series inverter corrects voltage fluctuations. To enhance DC-bus voltage response and lessen voltage oscillations, sophisticated methods like adaptive control, sliding-mode control, and current feed-forward control are employed. Stable DC-bus voltage and better power quality are now more crucial due to the growing integration of microgrids powered by renewable energy[1]. For DC-side voltage regulation, a number of techniques have been studied, including PI control, compound control, fractional-

order control, repetitive control, and energy-storage-based strategies. DC-bus stability, however, may be impacted by energy coupling between the shunt and series converters. Optimized PI-controller parameters in an optical-storage-integrated UPQC can lower fluctuations, increase overall compensation performance, and improve DC voltage regulation. The suggested UPQC control strategy's efficacy can be verified using simulation data.

2.Existing system:

The existing system uses a **three-phase UPQC with conventional feed-forward control** to mitigate grid voltage sag and swell. The series converter compensates voltage disturbances, while the shunt converter regulates source current and the DC-link voltage[2]. Feed-forward control improves the transient response and active-power transfer. However, conventional filtering may perform poorly under harmonics, measurement noise, impulsive disturbances, and nonlinear loads, resulting in inaccurate reference extraction, higher tracking errors, and additional distortion in the compensated voltage and current[3].

2.1.Disadvantages:

1. **Sensitivity to noise and disturbances:** Conventional filtering

performance can degrade in the presence of measurement noise, harmonics, and impulsive disturbances[4].

2. Reference extraction errors:

Distorted voltage and current signals can cause inaccurate fundamental-component extraction and compensation references.

3. Higher transient fluctuations:

Sudden voltage sag and swell conditions can produce larger DC-link voltage fluctuations and transient errors.

4. Limited adaptability: Fixed control and filtering parameters may not perform equally well under changing grid and nonlinear-load conditions.

5. Reduced compensation accuracy: Filtering and tracking errors can result in residual voltage/current harmonics and slower or less accurate power-quality compensation.

3. Proposed system:

The proposed system introduces a Maximum Versoria Criterion-Based Robust Adaptive Filtering Algorithm into the existing feed-forward UPQC controller. The major objective is to improve the extraction of fundamental voltage and current components under distorted and noisy operating conditions[5]. The MVC adaptive filter processes the measured three-phase

voltages and currents before generating the compensation references. Unlike conventional mean-square-error-based adaptive filtering, the Maximum Versoria Criterion uses a bounded nonlinear similarity measure, making the adaptive process less sensitive to large impulsive errors.

3.1. Advantages:

1. Robust operation under impulsive noise: MVC reduces the influence of abnormal or high-amplitude error samples during adaptive filtering.

2. Improved fundamental-component extraction: The algorithm provides more accurate voltage and current reference components under distorted grid conditions.

3. Reduced harmonic distortion: More accurate reference generation improves compensation of source-current and load-voltage harmonics.

4. Faster transient recovery: The adaptive filter combined with feed-forward control enables faster response during sudden sag and swell events.

5. Improved DC-link stability: Accurate active-current reference generation reduces unnecessary DC-link voltage fluctuations during power exchange.

6. Better operation with nonlinear loads: The proposed filtering approach remains effective when the load

generates significant harmonic and distorted currents[6].

4. Project Objective :

The main objective of the proposed project is to develop a Maximum Versoria Criterion (MVC)-based robust adaptive filtering algorithm for accurate and reliable signal processing under noisy, distorted, and impulsive disturbance conditions. The MVC algorithm is designed to improve fundamental signal extraction, reduce the influence of large error samples, minimize filtering and tracking errors, and provide better convergence and robustness compared with conventional adaptive filtering techniques[7]. The proposed method aims to achieve improved noise rejection, lower error, faster adaptation, and stable performance for practical signal-processing applications.

4. Literature survey:

1. Li et al. (2023) developed a Recursive Constrained Maximum Versoria Criterion (RCMVC) algorithm for constrained adaptive filtering. The work extended MVC to situations where adaptive-filter coefficients must satisfy constraints, demonstrating the development of MVC toward more specialized adaptive-filtering applications.

2. Khalili et al. (2024) presented a detailed tracking analysis of MVC-based adaptive filters for non-stationary, Markov time-varying systems. The study derived steady-state excess mean-square-error expressions for both Gaussian and general non-Gaussian noise environments and validated the theoretical analysis through simulations[8]. This work is particularly relevant for applications where the underlying system changes with time.

3. Zhao et al. (2025) proposed a low-complexity recursive constrained MVC algorithm using weighting and dichotomous coordinate descent techniques. The study focused on reducing computational complexity while retaining the advantages of constrained MVC filtering, with simulations reporting improved performance compared with existing approaches.

4. To improve distribution-network voltage quality, Mei et al. (2024) introduced a UPQC-based method combined with a battery energy storage system (BESS). The suggested system uses energy storage to facilitate DC-bus voltage management and power compensation while addressing voltage disruptions[9]. The findings show how

UPQC and BESS can be combined to improve voltage quality and boost distribution networks' dynamic performance.

5. Implementation methodology:

5.1 Three-Phase Grid and Disturbance Generation: A three-phase AC grid is modeled as the input source of the UPQC. Voltage disturbances are intentionally introduced into the grid to evaluate the compensation capability of the system. A voltage sag is created by reducing the grid voltage amplitude for a specified time interval, whereas a swell is created by increasing the voltage amplitude. Additional harmonic components and measurement disturbances can be introduced to evaluate the robustness of the adaptive filtering algorithm.

$$v_{abc}(t) = V_m \sin(\omega t)$$

5.2 Voltage and Current Measurement: The three-phase grid voltages, source currents, load voltages, load currents, and DC-link voltage are measured continuously[11]. These measurements are supplied to the control algorithm.

5.3 MVC-Based Robust Adaptive Filtering: This is the main extension

introduced in the proposed work. The measured voltage/current signals are supplied to the Maximum Versoria Criterion-based adaptive filter[10]. The filter continuously updates its coefficients according to the error between the desired signal and estimated signal.

5.4 Fundamental Component and Reference Extraction: The filtered three-phase quantities are transformed from the abc reference frame to the stationary or synchronous reference frame. The Clarke transformation can be represented as

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}$$

5.5. Feed-Forward Voltage Sag/Swell Compensation: The feed-forward controller detects the difference between the desired load voltage and the measured supply voltage. The series compensation voltage can be represented as

$$V_{series}^* = V_{load}^* -$$

5.6. Shunt Converter Current Control: The shunt converter controls the source current so that the grid supplies the required active power while minimizing unwanted reactive and harmonic current components[12]. The desired source current can be represented as

$$i_s^* = I_m \sin(\theta)$$

5.7. DC-Link Voltage Control: The common DC-link capacitor provides the energy-storage interface between the series and shunt converters. The DC-link error is

$$e_{dc} = V_{dc}^* - V_{dc}$$

$$I_d^* = K_p e_{dc} + K_i \int e_{dc} dt$$

5.8. PWM Generation: The generated series and shunt converter references are compared with appropriate carrier signals to produce switching pulses for the power electronic switches[13].

5.9. Series Converter: The series converter is connected in series with the supply and load. Its primary function is to compensate voltage disturbances.

During sag:

$$V_{inj} > 0$$

and the converter injects the missing voltage.

During swell:

$$V_{inj} < 0$$

and the converter counteracts the excessive grid voltage.

5.9. Power Quality Measurement: The performance of the UPQC is evaluated using electrical quality indices such as:

Voltage THD	$THD_V = \frac{\sqrt{\sum_{n=2}^{\infty} V_n^2}}{V_1}$
Current THD	$THD_I = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{I_1}$
RMSE	$RMSE = \sqrt{\frac{1}{N} \sum_{n=1}^N e_n^2}$
Voltage Error	$ev = V_{ref} - V$

6. Phase-Angle Compensation:

Phase-angle correction regulates the phase difference between AC busses to control power flow[14]. Phase-angle control is provided by devices like PST, PAR, TCPAR, and UPFC. By combining series and shunt converters via a single DC link, UPFC improves power-system performance by controlling voltage, line impedance, and phase angle.

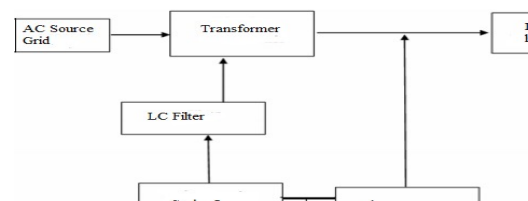


Fig.1. Single Phase UPQC

6.1. Voltage source inverter:

A DC-DC converter with Maximum Power Point Tracking (MPPT), which is frequently utilized in solar-powered generators, can be readily connected to the inverter. The inverter current must have a phase angle of less than 90°

from the grid voltage in order to supply energy to the grid. When the inverter voltage phase is ahead of the grid voltage phase, this is accomplished. A simplified schematic of the inverter's power unit [15]. The inverter uses pulse width modulation (PWM) to generate a sinusoidal voltage. The first harmonic of the current delivered to the grid is also determined by the filter at the grid connection point, which is often just an inductance.

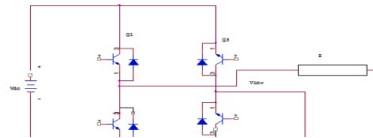


Fig. 2 Circuit of the inverter's power stage with connection to the grid

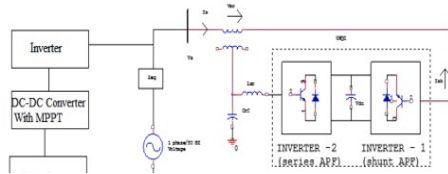


Fig. 3 Functional Diagram of proposed system

6.2 Microgrid:

A microgrid is a small electrical network that functions as an island or grid-connected controlled unit. To consistently provide local loads, it can combine distributed generation, renewable energy sources, and energy storage. For isolated locations where connecting to the main grid is challenging or expensive, standalone microgrids are helpful. Regulation of

voltage and frequency, protection, power sharing, and stability during islanded operation are important challenges.

6.3 Description of the UPQC Power System:

Two back-to-back voltage-source inverters coupled by a shared DC link make up the three-phase UPQC. Voltage disturbances like sags, swells, harmonics, and imbalance are compensated for by the series inverter[16], which is coupled via series transformers. The shunt inverter compensates for reactive power and current harmonics while controlling the DC-link voltage when linked in parallel with the load. In the UPQC-P architecture, power balance is maintained under voltage sag and swell circumstances by exchanging active power via the DC link. Both converters work together to provide better power quality and controlled load voltage.

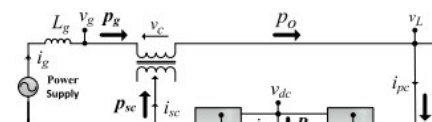
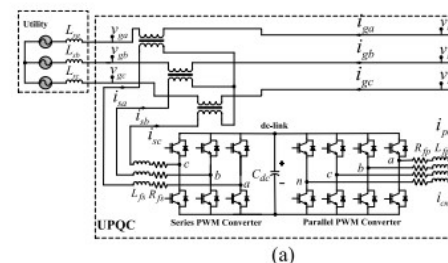


Fig.4. UPQC system: (a) Power circuit of the three-phase UPQC system; (b) UPQC active power flow.

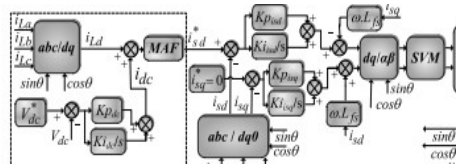


Fig.5. Control scheme for a generation of the series converter current references of the UPQC system.

7.1 Control Strategies of the UPQC System:

Series Inverter Control: Maintaining a steady, balanced, and sinusoidal load voltage at the rated magnitude and frequency—typically 230 V, 50 Hz for a single-phase system[17]is the primary goal of the series active power filter. The series inverter injects an appropriate compensating voltage through the transformer in response to supply disruptions like voltage sag, swell, harmonics, or switching of heavy loads. This enhances power quality and permits the load voltage to stay around its reference value.

7.2 Control Scheme for Shunt Inverter:

The necessary reference current is produced by the shunt inverter using a unit-vector control method. Its primary job is to balance reactive power and load current harmonics while keeping the DC-link voltage steady. The shunt

inverter increases power factor and guaranties balanced current operation by regulating the source current to be sinusoidal and synchronized with the supply voltage.

7.3 Control Strategy of UPQC:

Unit Vector Template Generation (UVTG) is used by the UPQC control technique to coordinate the shunt and series inverters. While the shunt inverter produces the reference current for DC-link voltage regulation and current compensation, the series inverter produces the necessary compensatory voltage to maintain a controlled load voltage. Their coordinated operation enhances overall power quality and effectively compensates for voltage and current disruptions.

7.4 Age of reference voltage signal for arrangement dynamic channel:

Supply voltage twisting was recognized, and an assessment for which two balanced unit vectors obliges the production of a single stage catapulted circle ($\sin\omega t$, $\cos\omega t$). The sinusoidal voltage using the ordinary apex stage formula with which the PCC yield from the

PLL ($V^* \sin\omega t$) is copied usi

$$[v^*] = v_{i,\dots}^* [l \sin\omega t]$$

As a result of the voltage variety of the non straight burden gave by PCC (VS), this voltage can be rotted into the total of fundamental (Vsf) and higher consonant fragments (Vsh) and experimentally conveyed as

$$V_s(\omega t) = V_{sf} + V_{sh}$$

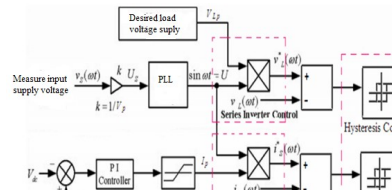


Fig.6.Circuit diagram of single phase UPQC with UVCT

7.5 Design and Implement PID Controllers

PID Controller: A PID controller uses proportional, integral, and derivative actions to control voltage, current, and other system variables. With appropriate gain calibration and feedback, it offers precise and reliable closed-loop control.

7.6. PWM: By altering the pulse duty cycle at a predetermined switching frequency, PWM regulates converter output. It is frequently utilized in power converters and inverters for precise and effective voltage and current management.

DESCRIPTION:

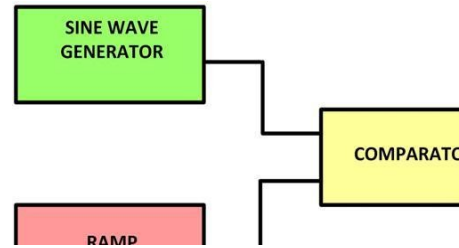


Fig.7. SPWM block diagram\

PWM controls the converter output by altering the duty cycle in accordance with the reference signal while maintaining a constant switching time. PWM creates switching signals for the shunt and series converters in UPQC to generate compensating current and voltage. Faster DC-link regulation enhances UPQC dynamic performance during voltage fluctuations and allows for faster reference generation. The scheme pertaining to the active power flow through the UPQC is shown in A. Power Balance Through the UPQC Fig. The power balance of the UPQC is therefore provided by the following statement based on this scheme:

$$P_g = P_L + P_{Lo}$$

Knowing that the respective grid, load, and loss instantaneous powers are defined by

$$p_g = v_{sd}i_{gd}; p_L = v_{Ld}i_{Ld};$$

And $p_{Loss} = v_{gd}i_{gd}$, where v_{gd}

and v_{Ld} are the respective grid and load voltages in the d-axis of the synchronous reference frame (SRF); i_{gd} and i_{Ld} are the SRF grid and load

currents; and i_{Loss} is the d-axis current associated with system losses. From (1), i_{Loss} can be found as:

$$i_{Loss} = i_{gd} - \frac{v_{Ld}}{v_{gd}} i_{Ld}$$

On the other hand, i_{gd} is given by:

$$i_{gd} = i_{Ld} + i_{cp_d} = i_{Ld} + (i_{bal} + i_{Loss}),$$

where i_{cp_d} is the synchronous direct axis current of the parallel converter; and i_{bal} is the current that flows through the parallel converter to ensure the energy balance in the system when there are differences in the voltage amplitude between the input (v_g) and output (v_L) of the UPQC. Thus, replacing (2) in (3), i_{bal} is obtained as:

$$i_{bal} = \left(1 - \frac{v_{gd}}{v_{Ld}}\right)$$

From equation (4), it can be seen that i_{bal} depends on the relationship between the grid and load voltage amplitudes. Since this relationship is equal to 1, i_{bal} will be equal to zero. B. Bus Control Modelling of the DC-Bus

The power that flows through the parallel converter (p_{pc}), associated with the energy balance in the system (p_{bal}) and the losses (p_{Loss}), is defined by:

$$p_{pc} = p_{bal} + p_{Loss} = v_{Ld}(i_{bal} + i_{Loss}) = p_{bus},$$

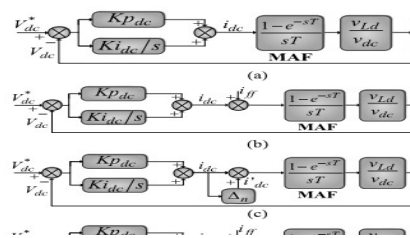
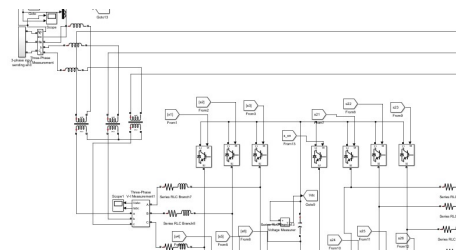


Fig.8. dc-bus voltage control model:

(a) conventional dc-bus model; (b) model incorporating FF current i_{dc} ; (c) model incorporating FF currents i_{dc} and i_{Loss}

8. RESULTS AND DISCUSSION:



Above fig.9. explains The Three-Phase UPQC in MATLAB/Simulink uses shunt and series converters connected by a common DC-link capacitor, as shown in Fig. 19. While the series converter injects compensating voltage through coupling transformers to reduce grid voltage swells and sags, the shunt converter balances current harmonics and controls the DC-link voltage. Fast active-power transfer and enhanced dynamic power-quality performance are made possible by synchronized IGBT gate pulses and feed-forward control.

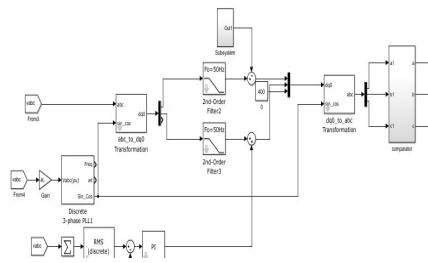


Fig.10. explains The SRF control circuit generates PWM switching pulses for the UPQC converter. Three-phase grid signals are synchronized using a Discrete 3-Phase PLL and transformed into (d)-(q) components using abc-to-dq0 transformation, followed by filtering. The RMS voltage is compared with the 415 V reference through a PI controller to adjust the (q)-axis component. The corrected signals are converted back to abc form and processed by the PWM generator to produce six gate pulses for the inverter switches.

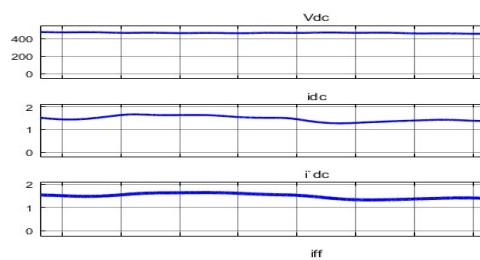


Fig.11. explains The plot shows the DC-bus control response over approximately 0.15–0.34 s. The DC-bus voltage remains stable near 450 V, while (i_{dc}) and (i'_{dc}) vary smoothly around 1.3–1.7 A. The feed-forward current (i_{ff}) increases from about 4.5

A to 6 A at 0.20 s and decreases after 0.30 s, demonstrating effective power-balance control during the disturbance.

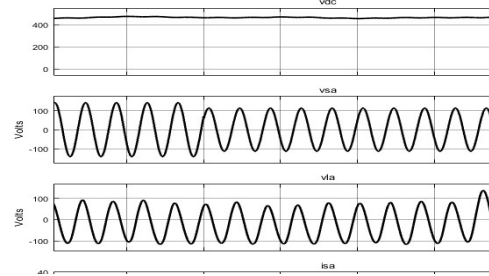


Fig.12.explains The plot shows the UPQC dynamic response from 0.10 to 0.46 s during a voltage sag. The DC-bus voltage remains stable near 450 V, while the source voltage drops from 150 V to about 110 V between 0.20 and 0.38 s. The UPQC maintains the load voltage at approximately 100 V peak, while the source current increases from 20 A to 35 A to maintain power balance, demonstrating effective sag compensation.

MVC

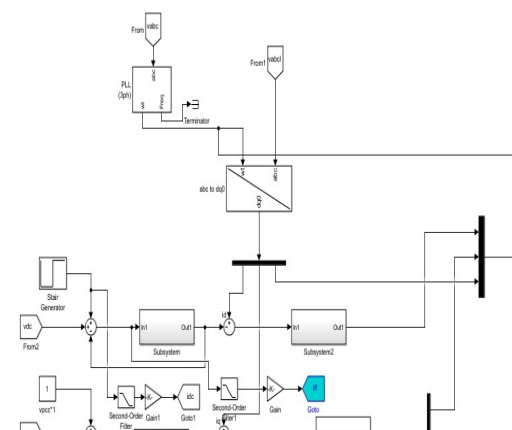


Fig.13. explains the feed-forward control circuit improves the dynamic response of the UPQC during grid

disturbances. A three-phase PLL provides synchronization [18], while abc-to-dq0 and dq0-to-abc transformations process the reference signals. Step generators, filters, summation blocks, and gain controllers calculate the required compensation signals, which are then supplied to the 2-Level PWM Generator to produce synchronized inverter gating pulses for rapid power balancing.

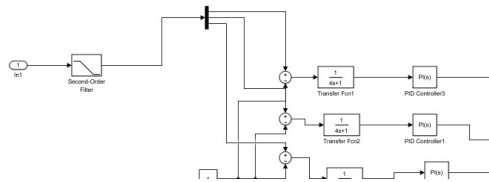


Fig.14. explains The subsystem filters the input signal using a Second-Order Filter to reduce noise and switching harmonics. The filtered signal is divided into three branches, where summation blocks generate error signals by comparing the tracking variables with reference values. Transfer functions and PID controllers regulate these errors, and the processed signals are recombined to produce the final synchronized control output[19].

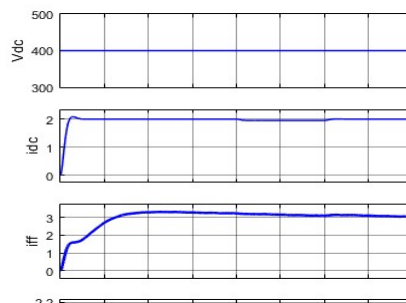


Fig.15. explains the plot shows the DC-bus initialization and transient response from 0 to 0.5 s. The DC-bus voltage remains stable at 400 V, while the actual and modified DC currents quickly settle near 2 A with a slight dip between 0.2 and 0.3 s. The feed-forward reference current rises to about 3.3 A at 0.12 s and gradually settles near 3 A, demonstrating stable control and effective transient response.

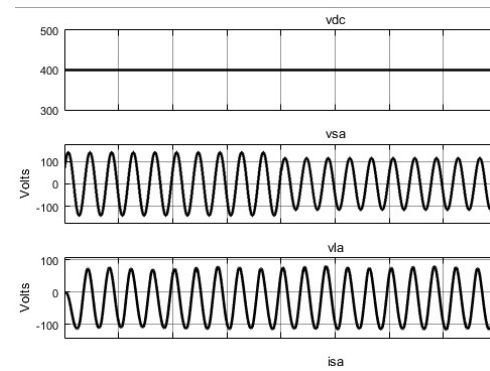


Fig.16 explains The plot shows the UPQC dynamic response from 0.12 to 0.48 s during a grid voltage sag. The DC-bus voltage remains stable near 500 V, while the source voltage drops to about 110 V and recovers to 150 V at 0.40 s. The series inverter maintains the load voltage at approximately 75 V peak, while the grid current increases to 20 A during the sag to support active-power balance[20].

TABLE III
DYNAMIC PERFORMANCE OF THE DC-BUS VOLTAGE

FFCLs	Without i_{gr} and i_{dc}	With i_{dc}	With i_{gr}	With i_{gr} at
Overshoot (%)	9.00	8.25	3.22	2.90
Undershoot (%)	10.82	6.42	1.85	1.75
Settling time (ms)	576	489	62.6	30.6

TABLE IV
DYNAMIC PERFORMANCE OF THE DC-BUS VOLTAGE with MVC

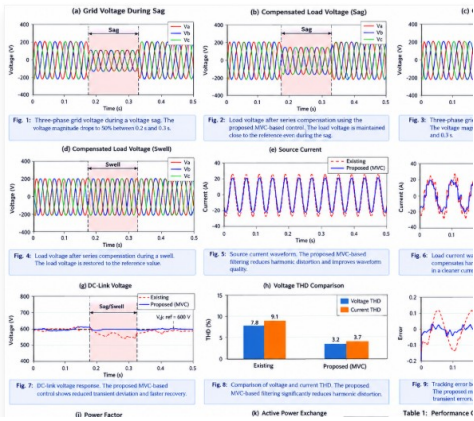
With MVC	Without i_{gr} and i_{dc}	With i_{dc}	With i_{gr}
Overshoot (%)	8.2	5.28	4.5

Fig.17.explains The Maximum Versoria Criterion (MVC) is an advanced signal processing cost function used in adaptive controllers and filters. The FFC shows a system operating near a higher DC voltage (~430 V) with relatively small current changes, while the MVC shows a 400 V DC voltage and substantially larger changes in i_{dc} , indicating a stronger transient/start-up response.

8.1. Voltage and Current THD: The THD results can be presented using a comparison graph between the conventional filtering method and the proposed MVC-based filtering method. Illustrative THD comparison[18] :Replace these illustrative values with the actual MATLAB/Simulink THD measurements before using the graph in the final report.



8.2. Overall Performance of MVC-Based Robust Adaptive Filtering System:



The simulation waveforms demonstrate the effectiveness of the proposed Maximum Versoria Criterion (MVC)-based robust adaptive filtering algorithm under different disturbance conditions. The grid-voltage waveform shows a clear reduction in voltage magnitude during the sag interval and an increase during the swell interval, while the compensated load-voltage waveform remains close to its reference due to accurate compensation. The MVC-based adaptive filter extracts the fundamental voltage and current components from distorted and noisy measurements, providing improved reference signals

for the controller[19]. The source-current waveform becomes more sinusoidal with reduced harmonic distortion, while the load-current waveform shows effective compensation of harmonic and reactive components[20]. The DC-link voltage remains close to its reference value with reduced transient deviation during power exchange, indicating improved power-balancing performance. The tracking-error waveform shows lower error with the MVC method, demonstrating improved reference tracking and adaptive filtering accuracy. The THD results indicate a reduction in voltage and current harmonic distortion, while the improved power factor demonstrates better source-current shaping. The active-power waveform confirms appropriate power exchange between the grid, converters, and load during sag and swell conditions. Overall, the results indicate that MVC-based adaptive filtering improves noise robustness, fundamental-component extraction, harmonic reduction, tracking accuracy, transient response, and system stability, making it more suitable for dynamic power-quality compensation under distorted and impulsive disturbance conditions.

9. Conclusion:

Suggested an algorithm called Maximum Versoria Criterion (MVC), grounded in the maximum Versoria criterion, and evaluated its resilience to non-Gaussian noise in acoustic echo cancellation settings. In recent times, the use of the MVC algorithm in system identification and channel equalization has also drawn significant attention. This short comparison was conducted between FFCLs and mvc to enhance the dynamic responses of the dc-bus voltage and the currents drawn from the utility grid during power quality events, including voltage sags and swells, when the UPQC is in operation. The acceleration of the mentioned dynamic responses was accomplished by directly influencing the computation of the series converter's current references, which governs the sinusoidal currents drawn from the grid. The first MVC (iff) was implemented by calculating the UPQC's power balance, while the second (idc) involved estimating the active power drawn from the grid to offset losses caused by grid voltage sags or swells. Both of them help enhance the performance of the UPQC during voltage sag or swell PQ events. The simulation results demonstrate that integrating the **Maximum Versoria Criterion-based robust adaptive**

filtering algorithm improves the signal-processing stage of the UPQC controller. The MVC algorithm provides more reliable fundamental-component extraction in the presence of noise, harmonics, and impulsive disturbances. This leads to improved voltage compensation during sag and swell events, cleaner source currents, lower tracking errors, and better DC-link regulation. The final quantitative performance should be reported using the **actual MATLAB/Simulink THD, RMSE, settling time, peak DC-link deviation, and power-factor measurements**, rather than assumed numerical values.

10. Future enhancement:

The proposed UPQC system can be further enhanced by integrating advanced intelligent control techniques such as fuzzy logic, neural networks, and reinforcement learning for faster and more accurate compensation. Renewable energy sources and battery energy storage systems (BESS) can be integrated to improve DC-link stability and support power management during severe voltage disturbances. Future work can also focus on adaptive control, reduced-switching-loss converters, real-time hardware implementation, and improved compensation of harmonics, voltage

sag, swell, and load disturbances. These developments can improve the reliability, efficiency, and dynamic performance of UPQC-based smart distribution systems.

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