Power Quality Improvement Using UPQC

Patel Hardikkumar Kalpeshbhai
Sigma University, Vadodara, India

***Abstract*—Unified Power Quality Conditioner (UPQC) is an advanced system designed to address power quality issues in modern electrical networks. This thesis investigates the design, implementation, and simulation of UPQC to mitigate voltage and current disturbances, improve load balancing, and reduce Total Harmonic Distortion (THD). Through simulations, the thesis demonstrates the effectiveness of UPQC in enhancing power quality under varied operating conditions. Results highlight the system's ability to stabilize voltage, manage reactive power, and ensure compliance with power quality standards.**

I. INTRODUCTION

This chapter provides an overview of power quality challenges and the importance of solutions like UPQC. Power quality issues have become a significant concern in modern electrical distribution systems due to the increasing use of nonlinear loads, renewable energy sources, and sensitive electronic equipment. The Unified Power Quality Conditioner (UPQC) is a versatile and effective power electronic device designed to mitigate both voltage and current-related power quality issues simultaneously. This report provides an in-depth analysis of UPQC, its working principle, design considerations, and applications.

Power quality disturbances can severely affect industrial, commercial, and residential electrical systems. Some common issues include:

- Voltage Sags and Swells: Temporary reductions or increases in supply voltage.
- Harmonics: Distortion in voltage and current waveforms due to nonlinear loads.
- Reactive Power Demand: Leads to reduced system efficiency and power factor issues.
- Unbalanced Loads: Causes uneven power distribution in three-phase systems.
- Voltage Flicker: Periodic variations in supply voltage affecting sensitive equipment.

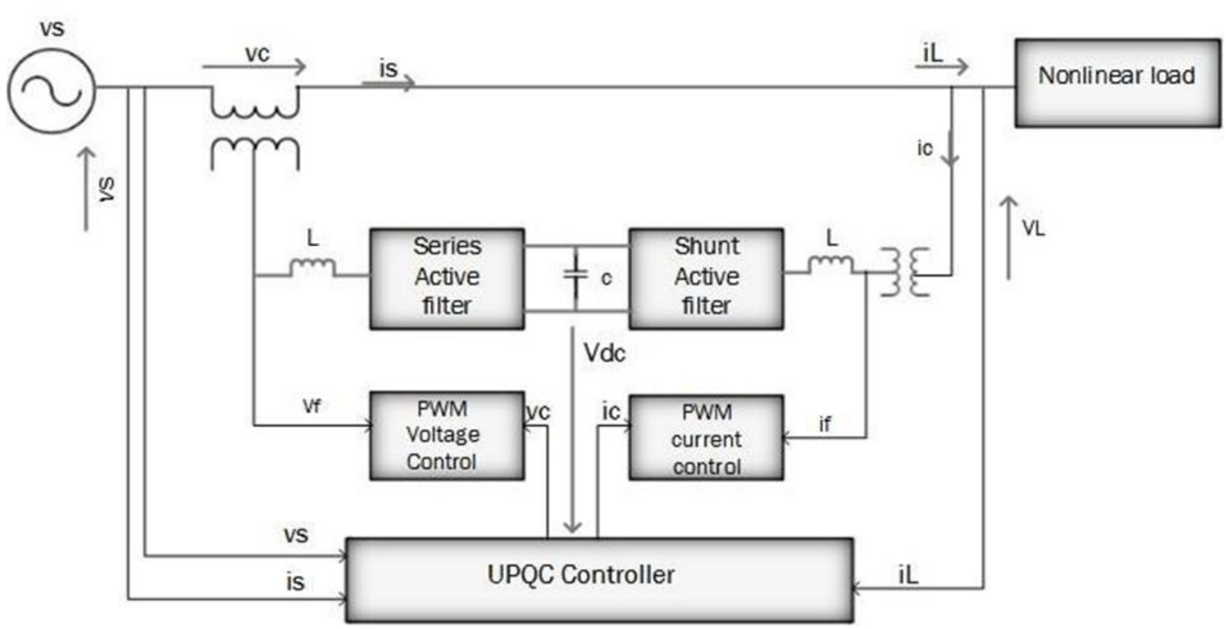


Fig.1.1 Block diagram of UPQC

UPQC is designed to simultaneously mitigate voltage and current quality issues, ensuring a stable and reliable power supply

Major Components for Making a UPQC:

1.1 Power Circuit Components

1. Power Electronic Converters (Inverters) –Two Voltage Source Inverters (VSI) (one for series APF, one for shunt APF). o Uses IGBTs or MOSFETs for high-speed switching.
2. DC-Link Energy Storage-A DC capacitor (or supercapacitor/battery) to provide the necessary energy exchange.
3. Series Transformer – Connects the series APF to the grid and injects voltage.
4. Inductors and Filters – Used in the Shunt APF to inject compensation currents smoothly.

1.2 Control and Sensing Components

1. Voltage Sensors – Measures supply and load voltages.
2. Current Sensors – Measures load and grid current.
3. Microcontroller/DSP (Digital Signal Processor)-Implements the control algorithms.
4. PWM Generator (Pulse Width Modulation) – Generates switching signals for VSI.

UPQC consists of two key components:

1.2.1 Series Active Power Filter (Series APF)

- Connected in series with the power supply through a series transformer.
- Compensates for voltage disturbances, including sags, swells, and harmonics.
- Operates as a voltage-controlled inverter.

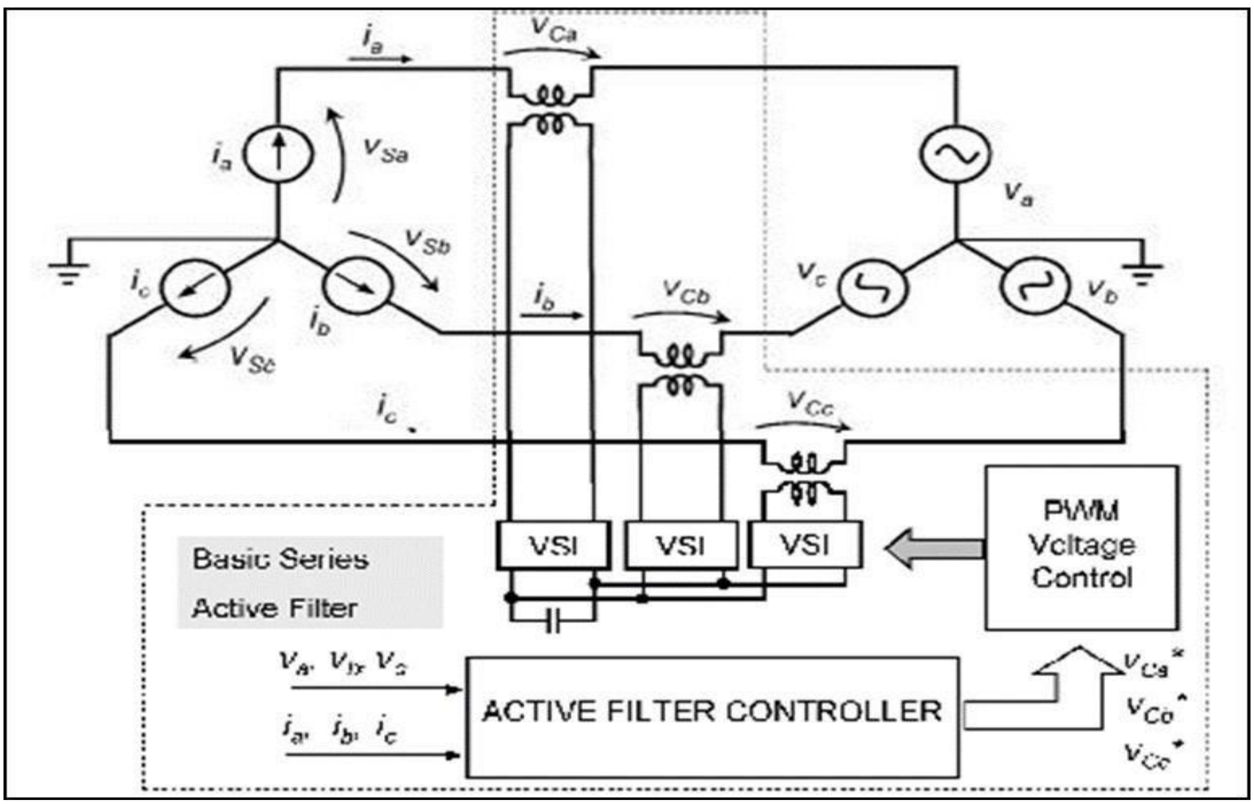


Fig.1.2 Series Active power filter

1.2.2 Shunt Active Power Filter (Shunt APF)

- Connected in parallel with the load.
- Injects compensating currents to eliminate current harmonics,
- balance loads, and improve power factor.
- Operates as a current-controlled inverter.

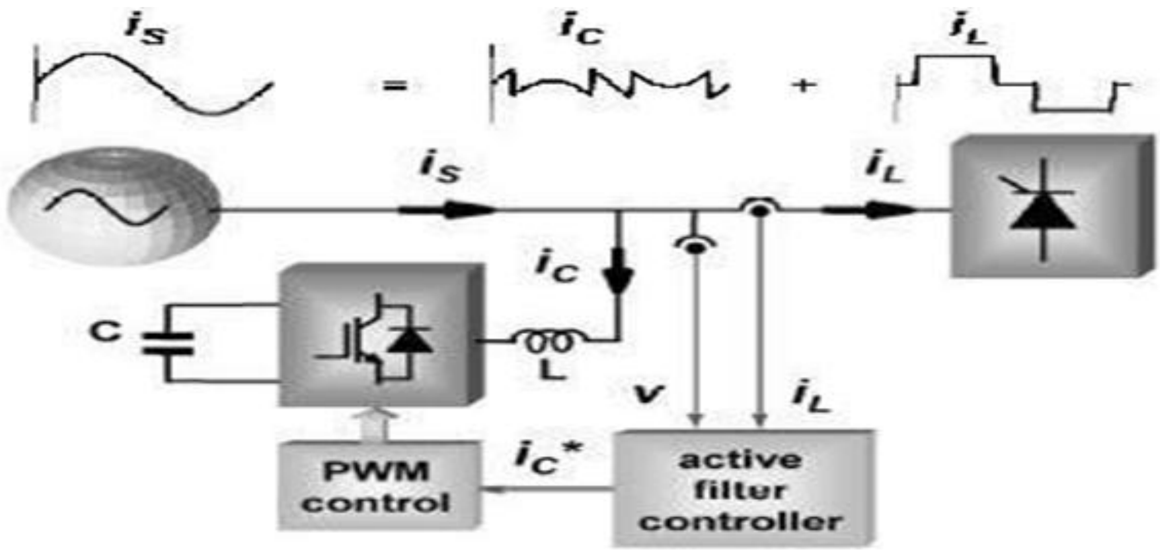


Fig.1.3 Shunt Active Power Filter

1.2.3 DC-Link Capacitor

- Acts as an energy storage element, facilitating energy exchange between Series and Shunt APFs.
- Ensures proper voltage regulation and compensation.

II. LITERATURE REVIEW

A review of research on UPQC and related technologies is presented in this chapter.

 Over the years, significant research has been conducted to improve the performance of UPQC systems. Key studies include:

1. Control Strategies for Series and Shunt Active Filters** by Mauricio Aredes et al. (2003):
   This work introduced robust synchronization techniques to enhance the performance of shunt active filters. In this paper series and shunt active filters were described. The fundamentals of the PQ theory was exploited & introduced into a minimization method, which together a robust synchronizing circuit allowed an improvement of a control strategy for shunt active filters encountered in the literature.
2. The Unified Power Quality Conditioner: Integration of Series- and Shunt-Active Filters** by Hideaki Fujita and Hirofumi Akagi (1998):
   This study analysed the flow of active and reactive power within UPQC systems and proposed efficient control strategies. This paper discusses the control strategy of the UPQC, with a focus on the flow of instantaneous active and reactive powers inside the UPQC. Theoretical comparison among three types of control methods for the series-active filter has clarified that the combination of current and voltage detecting methods is suitable for voltage flicker/imbalance elimination and harmonic compensation.
3. A Review of Active Filters for Power Quality Improvement** by Bhim Singh et al. (1999)
   This paper provided a comprehensive review of active filters, focusing on harmonic and reactive power compensation. Active filtering of electric power has now become a mature technology for harmonic and reactive power compensation in two wire (single phase), three-wire (three phase without neutral) and four-wire (three phase with neutral) ac power networks with nonlinear loads. This paper presents a comprehensive review of active filter(AF) configurations, control strategies, selection of components, other related economic and technical considerations and their selection for specific applications.
4. Enhancing Electric Power Quality Using UPQC by Vinod Khadkikar (2012)
   This work highlighted the practical implementation and challenges associated with UPQC in distribution systems. This paper presents a comprehensive review on the unified power quality conditioner (UPQC) to enhance

the electric power quality at distribution levels. UPQC in this context could be useful to compensate both voltage and current related power quality problems simultaneously. Different aspects of UPQC and up to date developments in this area of research have been briefly addressed.

5. Harmonic Mitigation Using Unified Power Quality Conditioners by M. Sharanya et al. (2014): The study demonstrated the effectiveness of UPQC in reducing harmonic distortions using advanced control schemes. The steady state and dynamic response of UPQC is enhanced due to its control method using DC voltage regulation, hysteresis controller for shunt active filter and PWM controller for series active filter. Simulation results shows that by using this control scheme the harmonic reduction is good, the source voltage and load current are compensated and also the DC voltage is well regulated.

III. METHODOLOGY, SIMULATION AND RESULTS

The methodology details the design and simulation process for the UPQC system.

UPQC operates by continuously monitoring and correcting power quality disturbances. The control system detects power quality issues and commands the Series and Shunt APFs to inject compensating voltage and current.

A. Series Active Power Filter (Series APF) - Voltage Compensation

- Detects voltage sags/swells and harmonic distortion.
- Generates compensating voltage and injects it through a series transformer.
- Maintains constant voltage at the load side.

B. Shunt Active Power Filter (Shunt APF) - Current Compensation

- Monitors current harmonics and reactive power demand.
- Injects compensating current to cancel harmonics and improve power factor.
- Balances unbalanced loads by redistributing current.

3.1 Simulation of Main Diagram Without UPQC

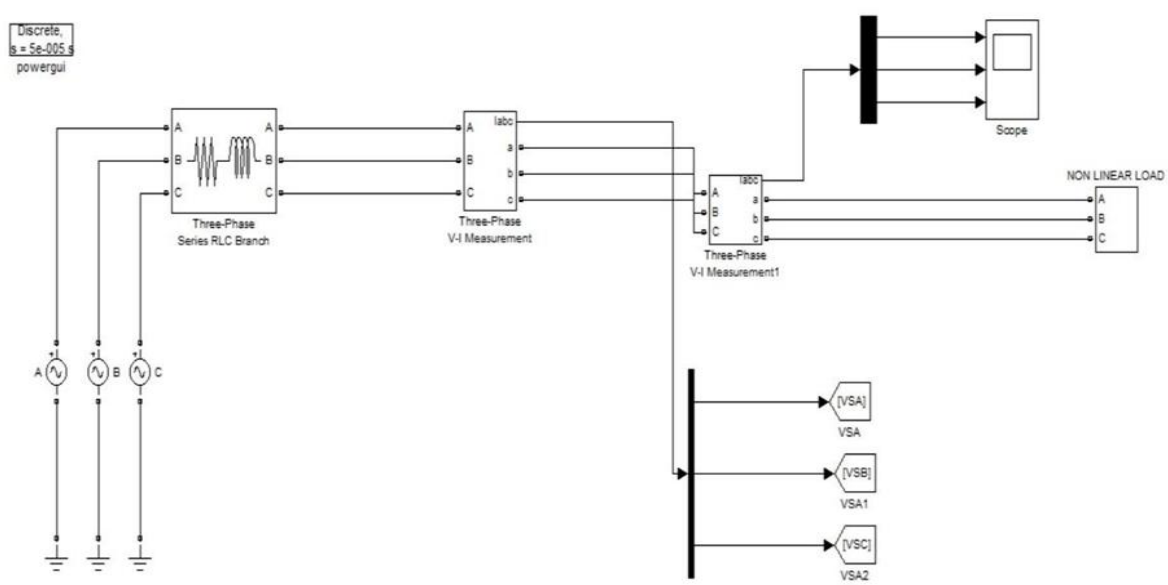


Fig.3.1 Simulation of Main Diagram Without UPQC

SR NO.	SYSTEM	SUBSYSTEM	PARAMETER	VALUE
1	SOURCE	SOURCE IMPEDANCE	RESISTANCE	1 OHM
			INDUCTANCE	248 mH
		SOURCE VOLTAGE	VOLTAGE	230 V (RMS)
2	3-φ SERIES TRANSFORMER (Y-Y)		RATING	100 KVA, 50 HZ
			PRIMARY	400 V
			SECONDARY	400 V

Table 1. Main Power diagram data

3.1.1 Subsystem of Non-Linear Load

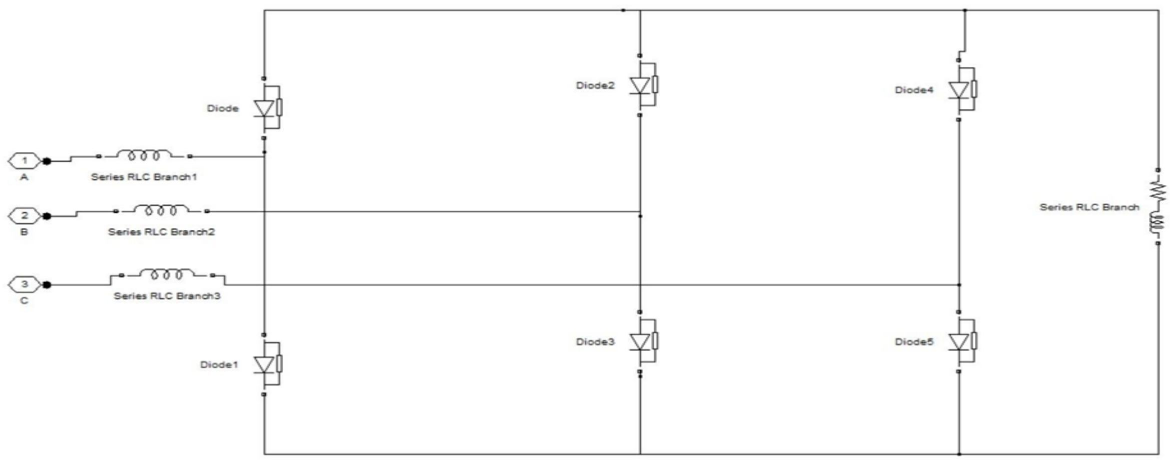


Fig 3.2 Non-Linear Load

SR NO.	SYSTEM	SUBSYSTEM	PARAMETER	VALUE
1	Load	Series RLC	RESISTANCE	20 OHM
			INDUCTANCE	5 mH
2	Input series RLC Branch 1,2&3		INDUCTANCE	0.5 mH

Table 2. Non linear load data

3.1.2 Simulation Result of Load Current without UPQC

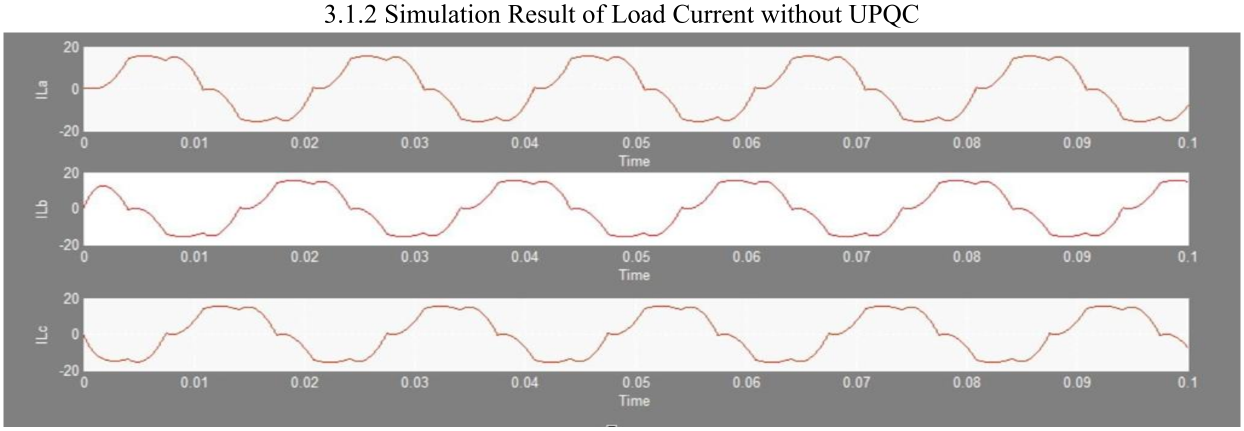
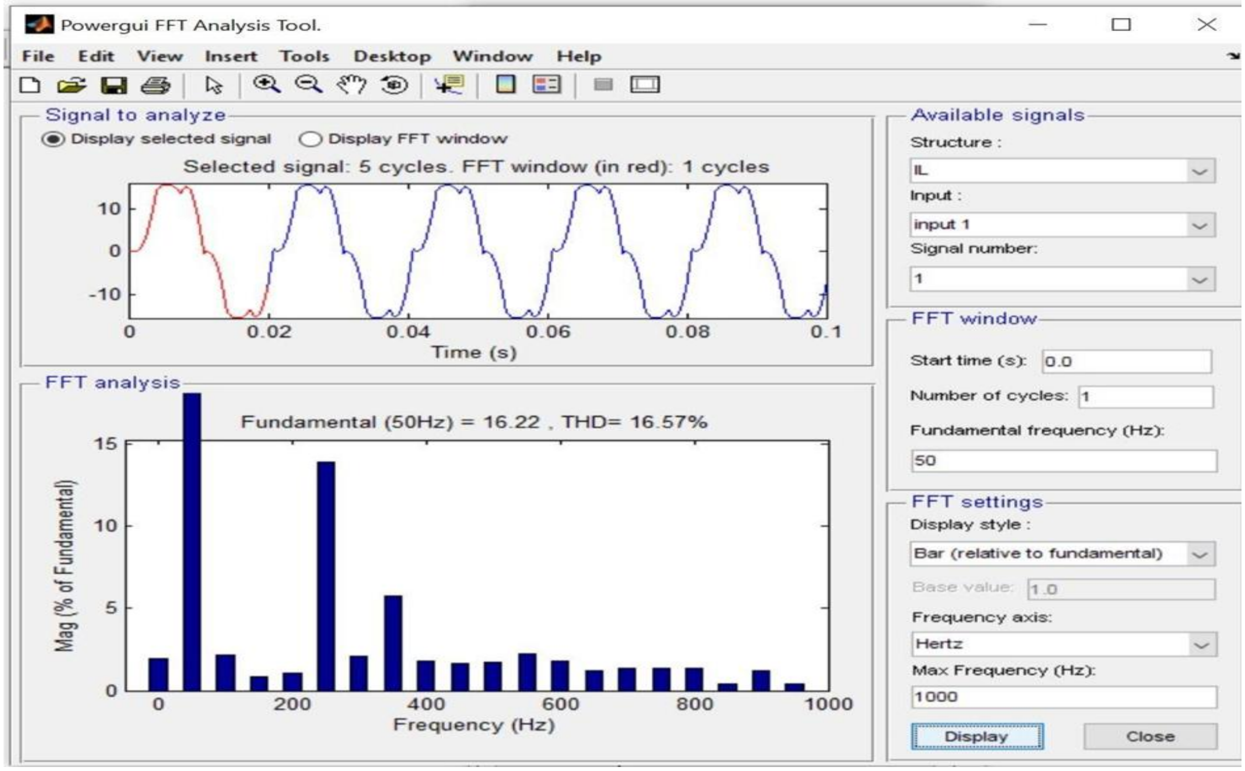


Fig.3.3 Simulation Result of Load Current without UPQC

Fig.3.4 THD OF LOAD CURRENT (WITHOUT UPQC)



3.2 Matlab Simulation of Shunt Active Power filter

Design of Phase locked loop design on MATLAB as given below:

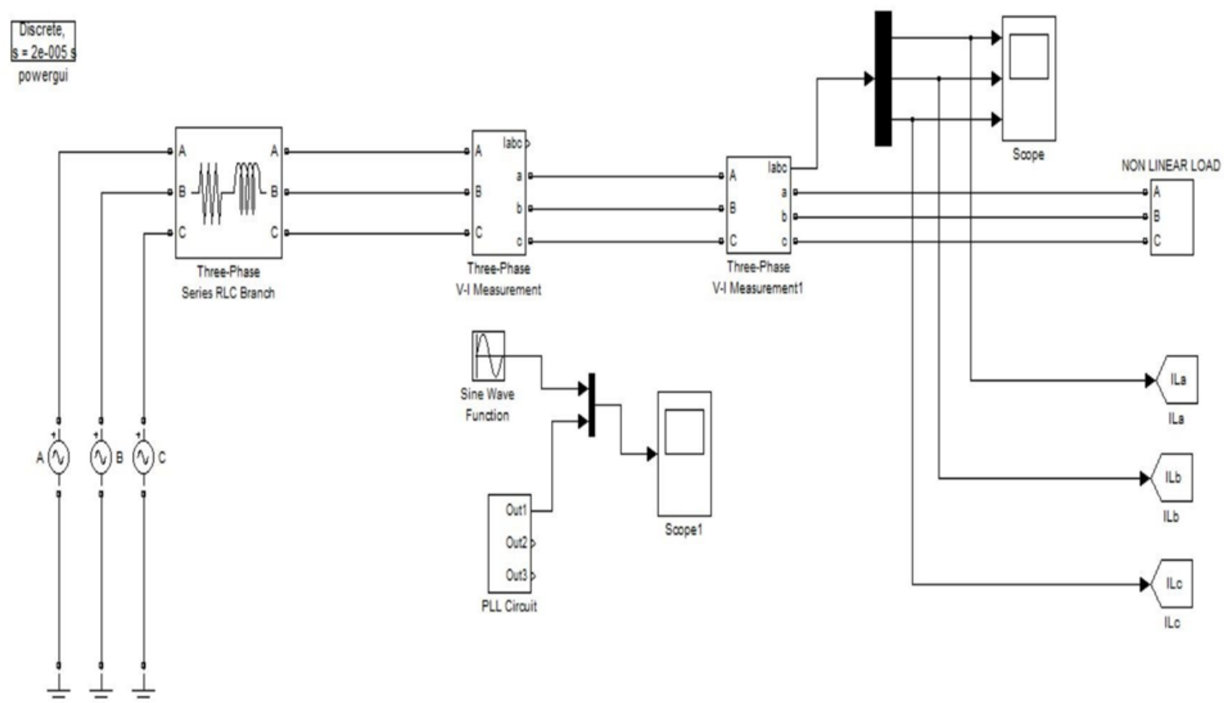


Fig 3.5 Phase Locked Loop Tuning Model

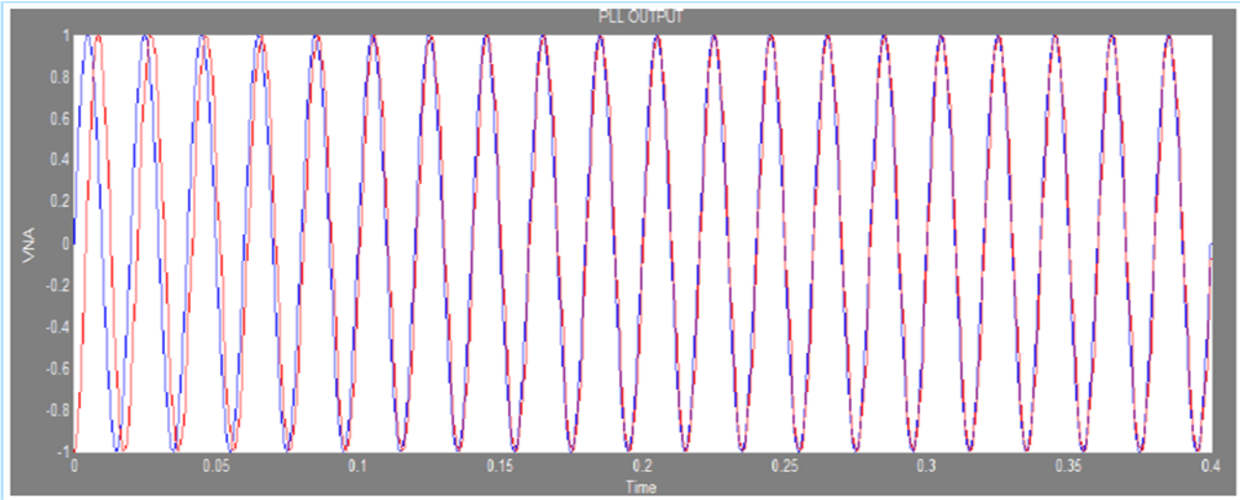
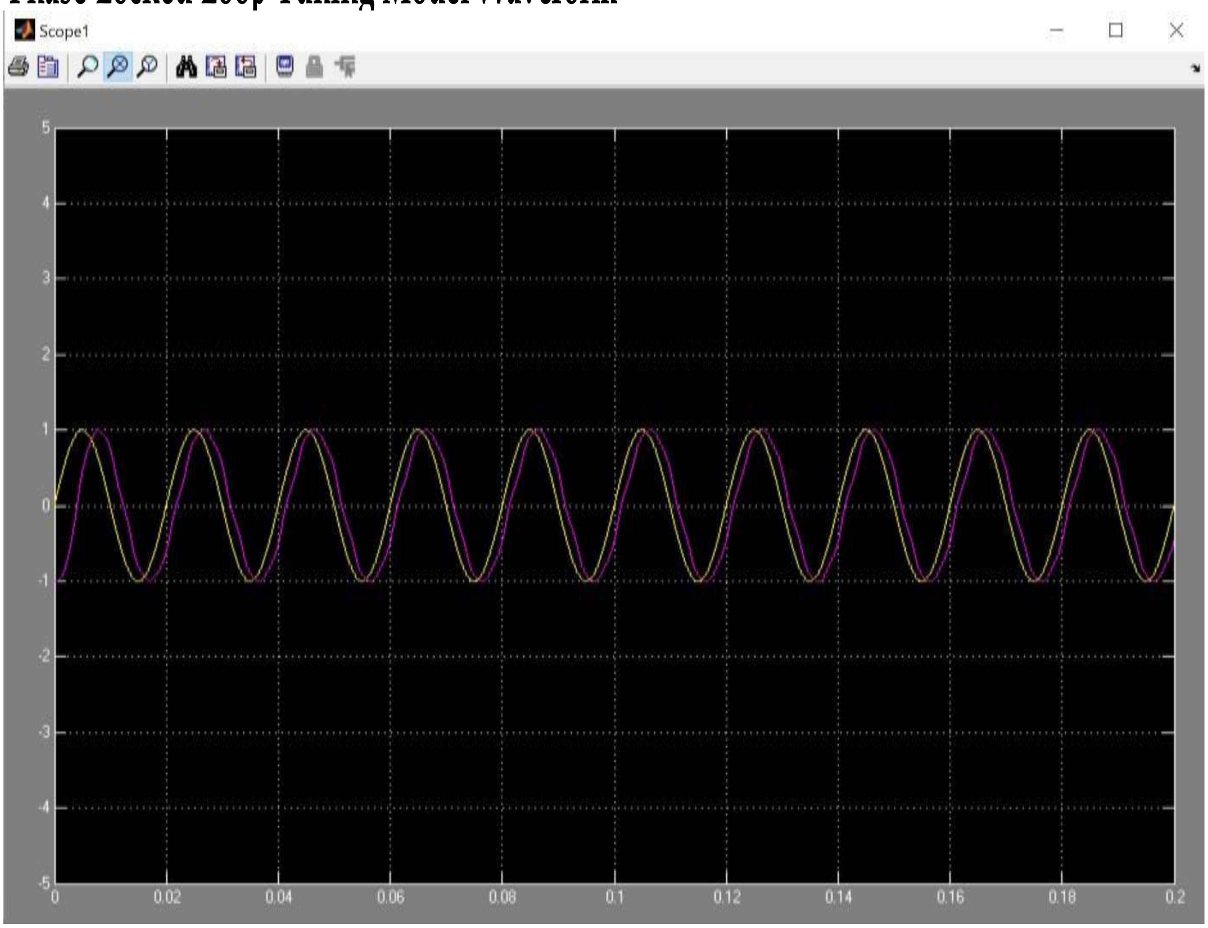


Fig.3.6 Phase Locked Loop Tuning Model Waveform

3.2.1 Control Strategy of Shunt Active Filter (sinusoidal current control strategy)

Phase Locked Loop Tuning Model Waveform



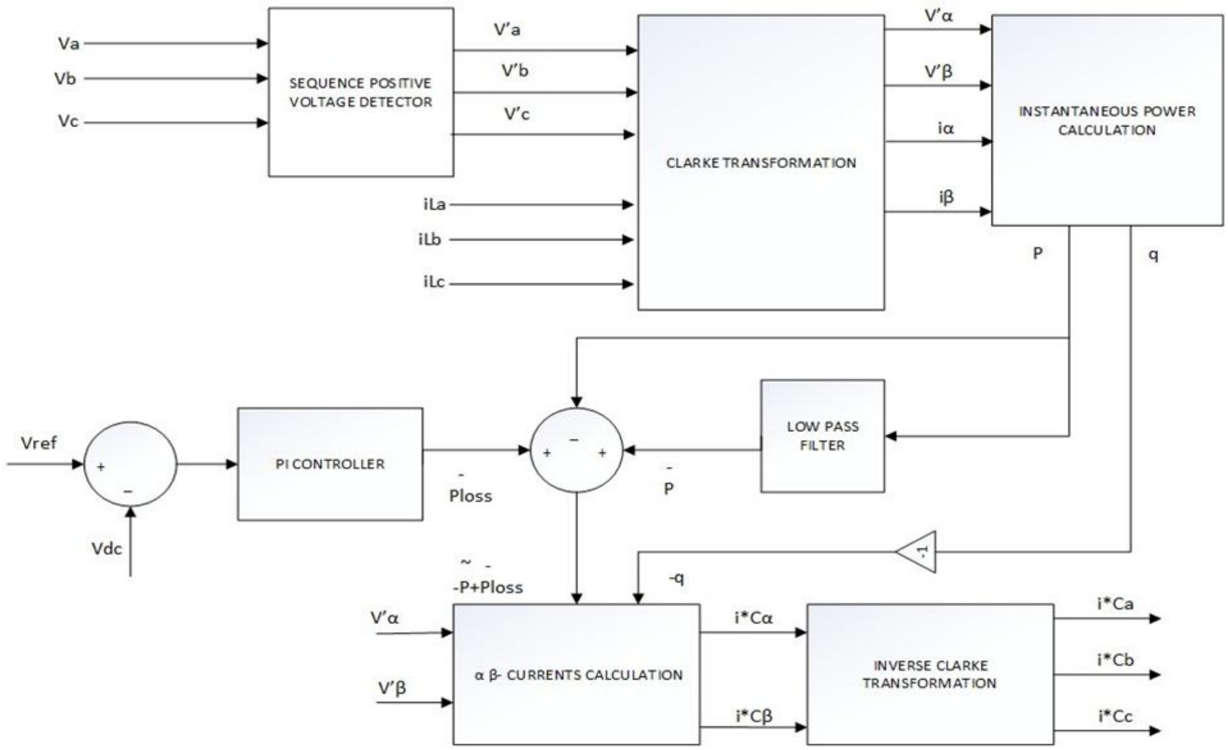


Fig.3.7 Control Strategy of Shunt Active Filter

The sinusoidal current control strategy for a shunt active filter (SAF) aims to compensate for harmonic currents and reactive power by injecting a sinusoidal current that cancels out the problematic components. This approach utilizes instantaneous p-q theory and a hysteresis controller to achieve precise current control, often complemented by sliding mode control for DC-link voltage regulation. The control system extracts the fundamental component of the source voltage and load current, then uses the instantaneous reactive power theory (IRPT) or pq theory to generate the reference current for the filter.

Here's a more detailed breakdown:

1. Pre-processing and Fundamental Component Extraction:

- The pre-processing step, often using a modified symmetrical sinusoidal integrator (MSSI), is crucial for extracting the fundamental positive-sequence component of the source voltage and load current.
- The MSSI helps reject harmonics and DC offsets, ensuring the control system operates on the desired fundamental frequency.
- This fundamental component is then used as input for the IRPT or pq theory for reference current generation.

2. Reference Current Generation using IRPT/p-q Theory:

- The IRPT or p-q theory mathematically separates the instantaneous power into real and reactive components.
- The reference current is then calculated based on the instantaneous reactive power (q) and a reference voltage to generate a sinusoidal current with a desired phase shift.
- This reference current is used to control the shunt active filter (SAF).

3. Current Control and DC-link Voltage Regulation:

- A hysteresis controller is used to regulate the shunt active filter's output current, ensuring it tracks the reference current closely.
- DC-link voltage fluctuations, especially with motor drive loads, are addressed using sliding mode control to maintain stable operation.

4. Simulation and Validation:

- Simulation software like MATLAB R2016a is used to validate the performance of the sinusoidal current control strategy in various scenarios, including non-linear loads and passive load conditions.

- Simulation results are used to evaluate the THD of voltage and current, confirming the filter's ability to mitigate harmonics and achieve desired power factor.

5. Key Components and Considerations:

- Phase-Locked Loop (PLL):

A PLL circuit is essential for synchronizing the filter's control system with the source voltage, ensuring correct phase alignment for accurate compensation. Clarke Transformation:

This transformation is sometimes used to convert the 3-phase signals into a 2-phase reference frame, simplifying the control process and enabling the separate compensation of positive and negative sequence current components.

 Switching Devices:

Power electronic devices like IGBTs (Insulated Gate Bipolar Transistors) or MOSFETs are used in the shunt active filter to switch the current, allowing for rapid response and efficient harmonic compensation

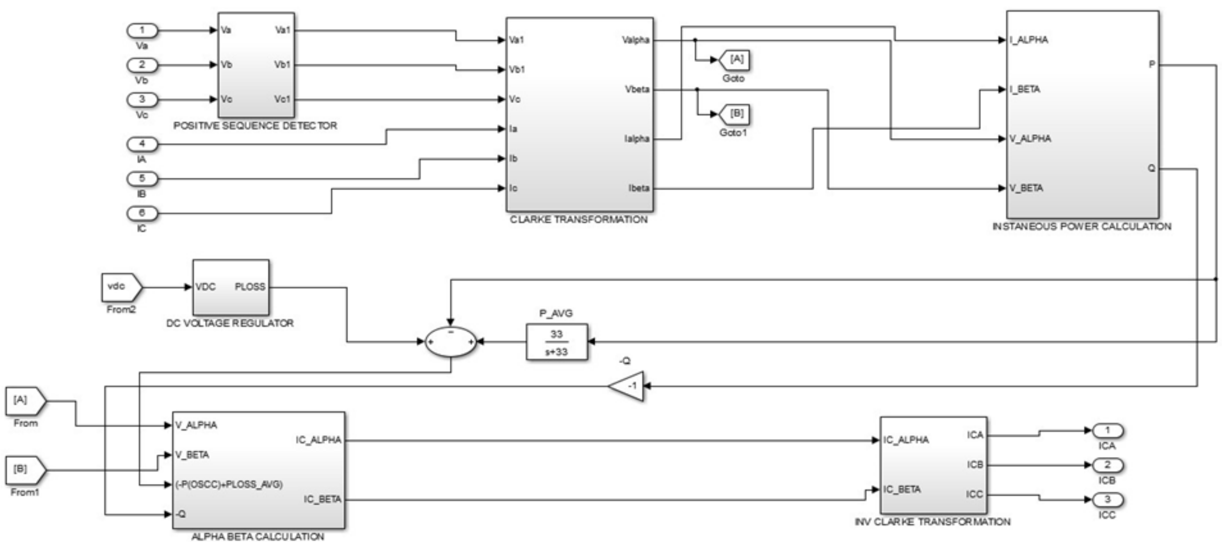


Fig 3.8 Simulation of active filter controller

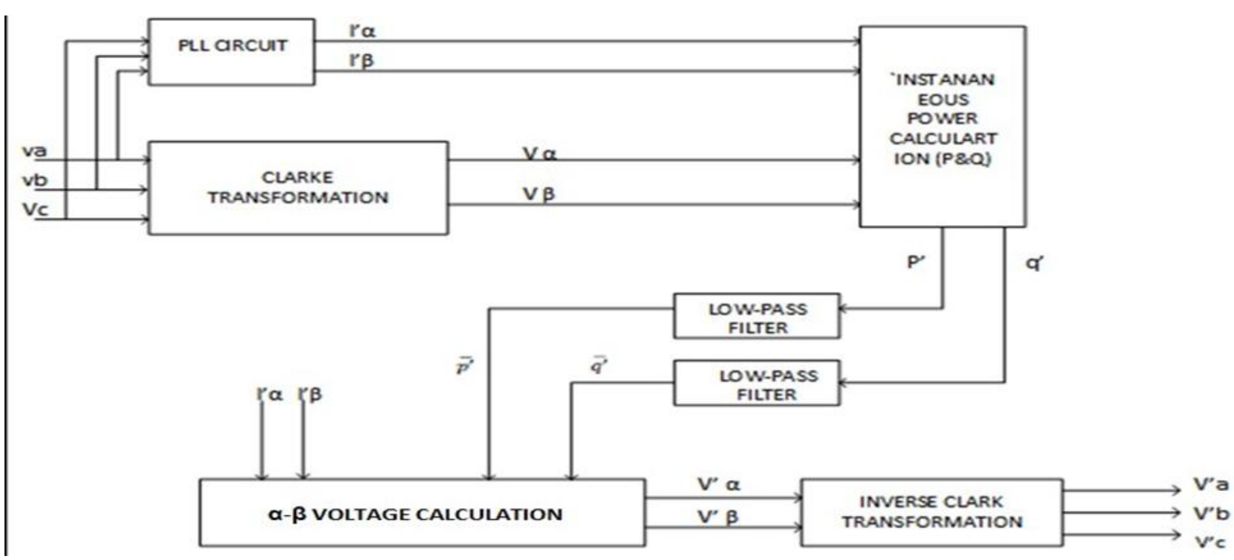


Fig.3.9 Positive-Sequence Voltage Detector

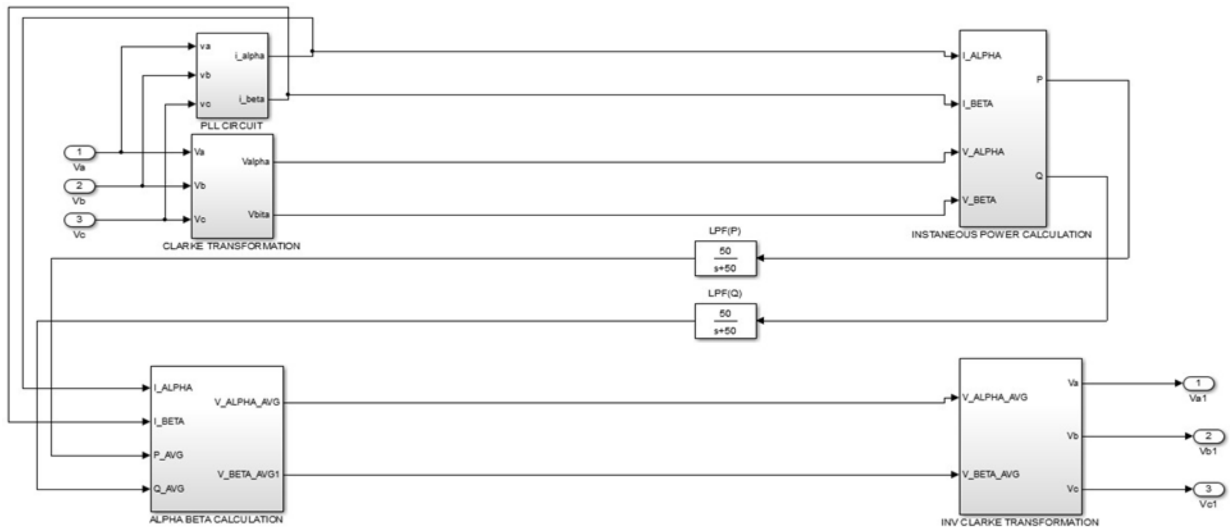


Fig.3.10 simulation of positive sequence voltage detector

- Simulating a positive sequence voltage detector involves modeling the device's behavior, typically using mathematical models and simulation software, to accurately detect and extract the positive sequence component of a three-phase voltage signal. This is crucial for power system analysis, control, and protection, especially when dealing with unbalanced grid conditions or faults.
- Simulation Methods and Tools:
- Mathematical Models:
- Positive sequence voltage detectors often employ mathematical models based on symmetrical components theory, which separates three-phase signals into positive, negative, and zero sequence components.
- Signal Processing:
- Simulating the signal processing steps, including filtering, Park transformation, and symmetrical component extraction, is crucial.
- Fault Scenarios:
- Simulations often include fault scenarios (e.g., short circuits, voltage sags) to assess the detector's performance under challenging conditions.
- Parameter Tuning:
- Simulations allow for fine-tuning of the detector's parameters, such as filter bandwidths or PLL gain settings, to optimize its performance.
- Performance Evaluation:
- The simulation results can be used to evaluate the detector's accuracy, speed, and robustness under various grid conditions.

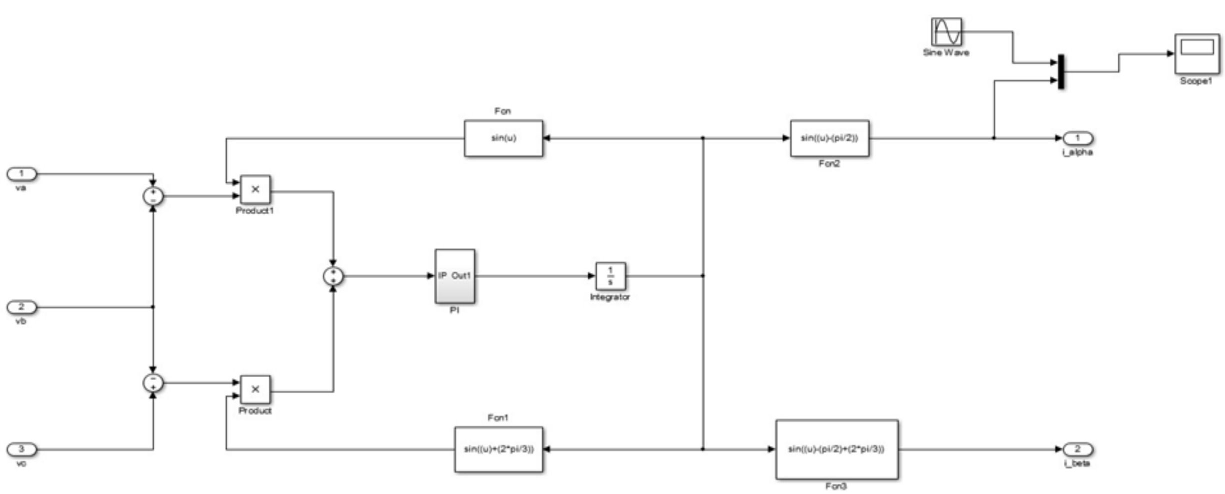


Fig.3.11 subsystem of PLL (shunt)

 Phase-Locked Loop (PLL) is a crucial component used to accurately track and synchronize with the grid voltage, ensuring efficient power quality correction. The PLL generates a reference signal that matches the grid's fundamental frequency and phase, which is then used by the UPQC to control the shunt and series active filters.

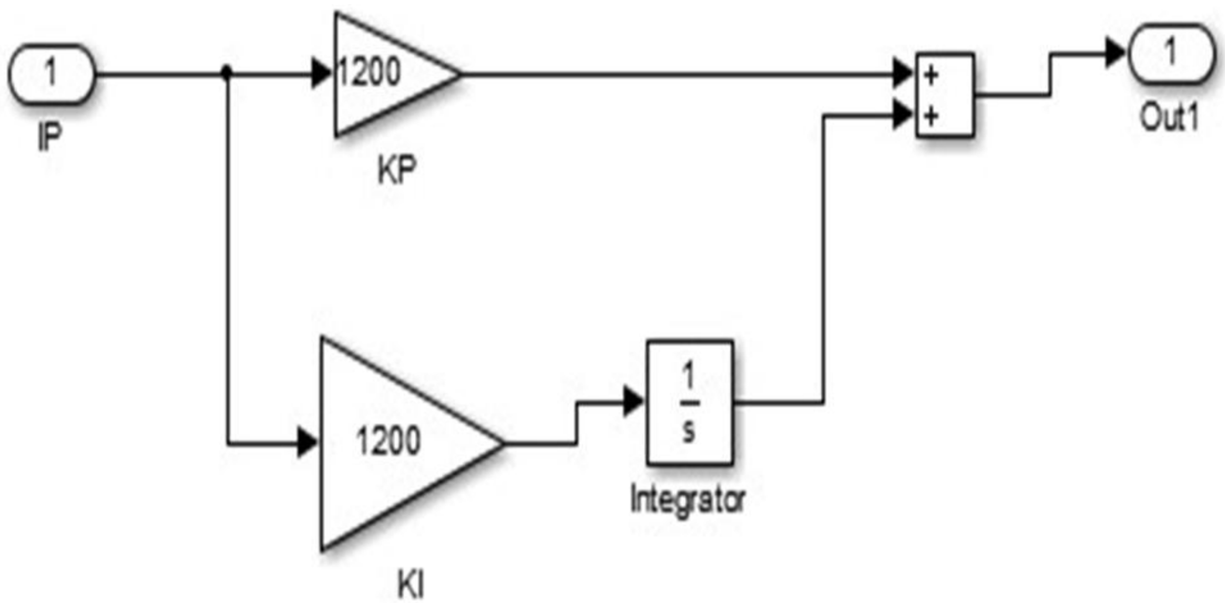


Fig.3.12 subsystem of PI Controller (shunt)

 In Unified Power Quality Conditioner (UPQC) systems, a PI (Proportional Integral) controller is commonly used to regulate the output of the UPQC and maintain desired power quality. The PI controller's proportional term provides a fast response to errors, while the integral term eliminates steady-state errors, ensuring accurate voltage and current control.

Subsystem of instantaneous power calculation (PSD)

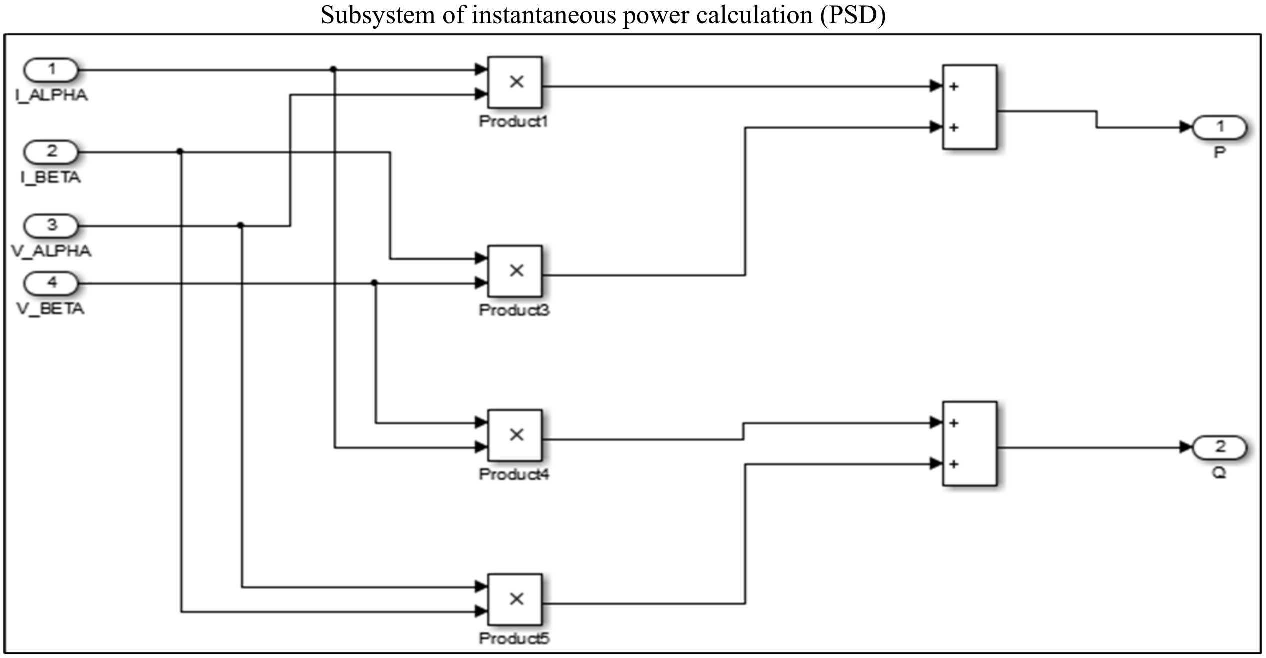


Fig.3.13 Subsystem of instantaneous power calculation

$$P = v_\alpha i_\alpha + v_\beta i_\beta$$
$$Q = v_\beta i_\alpha + v_\alpha i_\beta$$

Subsystem of clarke transformation (PSD)

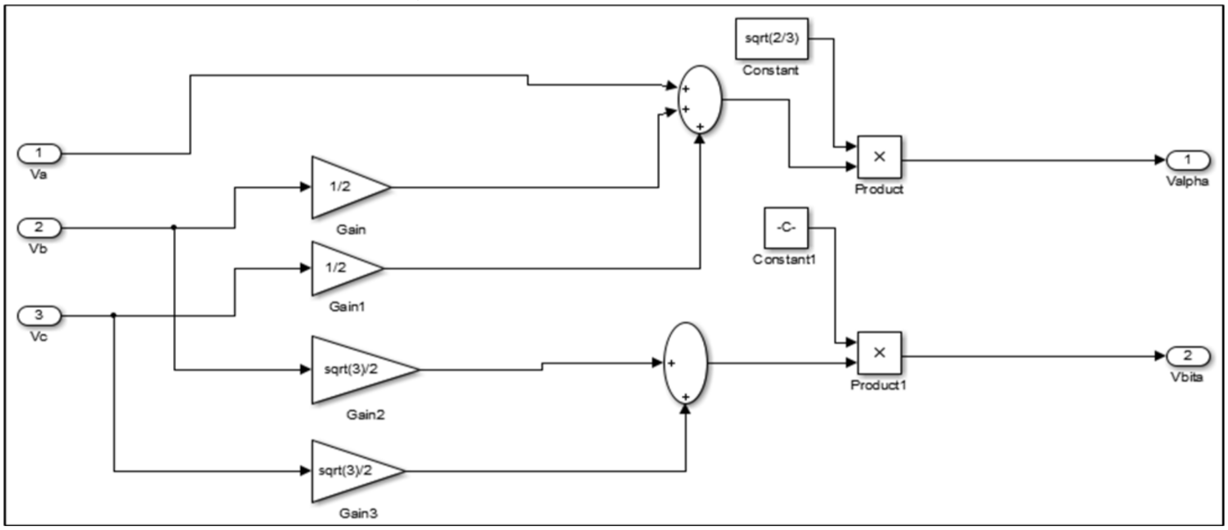


Fig.3.14 Subsystem of clarke transformation (PSD)

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\tfrac{2}{3}} \begin{bmatrix} 1 & \tfrac{1}{2} & \tfrac{1}{2} \\ 0 & \sqrt{3}/2 & \sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$
$$v_\alpha = \sqrt{\tfrac{2}{3}} \left(v_a + \tfrac{1}{2} v_b + \tfrac{1}{2} v_c \right)$$
$$v_\beta = \sqrt{\tfrac{2}{3}} \left(\sqrt{3}/2\, v_b + \sqrt{3}/2\, v_c \right)$$

Subsystem of α-β voltage calculation (PSD)

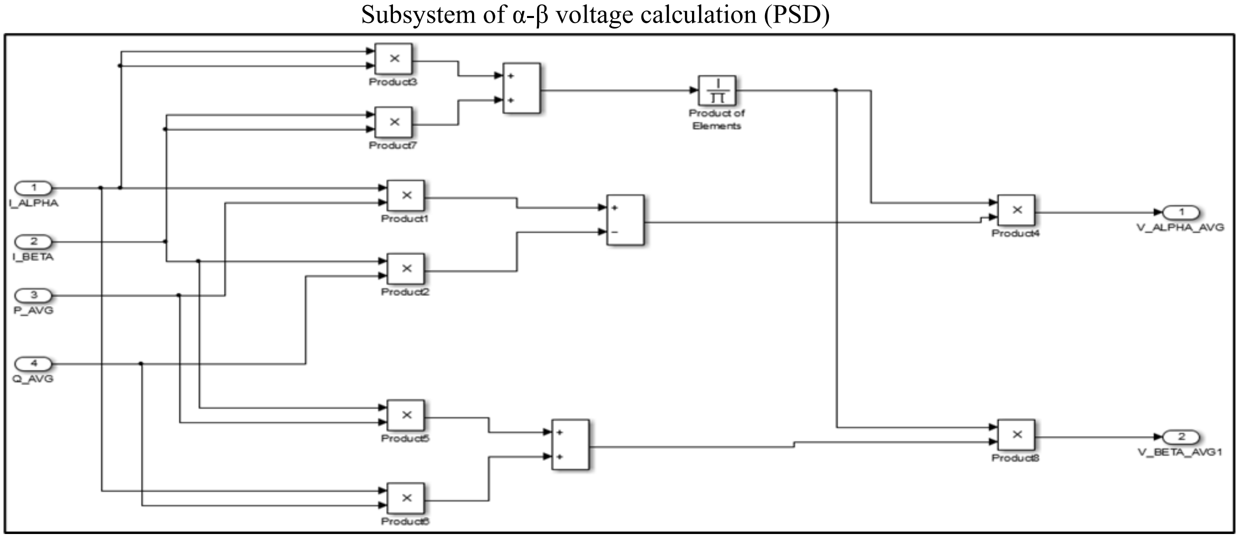


Fig.3.15 Subsystem of α-β voltage calculation (PSD)

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$$\begin{bmatrix}\bar{v}_\alpha \\ \bar{v}_\beta\end{bmatrix} = \frac{1}{i_\alpha^2+i_\beta^2}\begin{bmatrix} i_\alpha & -i_\beta \\ i_\beta & i_\alpha\end{bmatrix}\begin{bmatrix}\bar{P}\\ \bar{Q}\end{bmatrix}$$

$$\bar{v}_\alpha = \frac{1}{i_\alpha^2+i_\beta^2}\left[i_\alpha \bar{P} - i_\beta \bar{Q}\right]$$

$$\bar{v}_\beta = \frac{1}{i_\alpha^2+i_\beta^2}\left[i_\beta \bar{P} + i_\alpha \bar{Q}\right]$$

Subsystem of inverse clarke transformation (PSD)

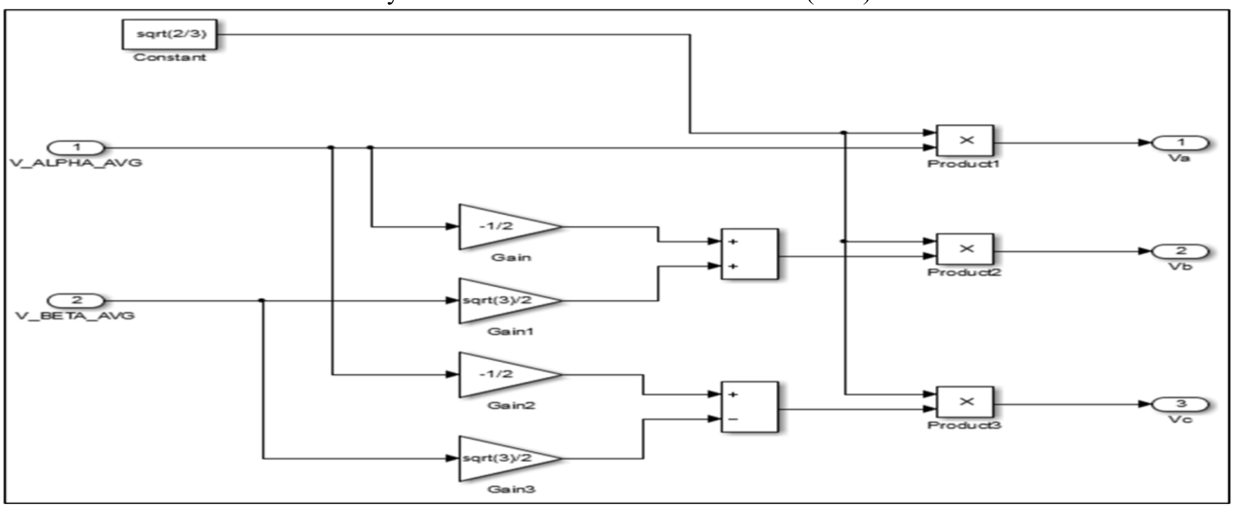


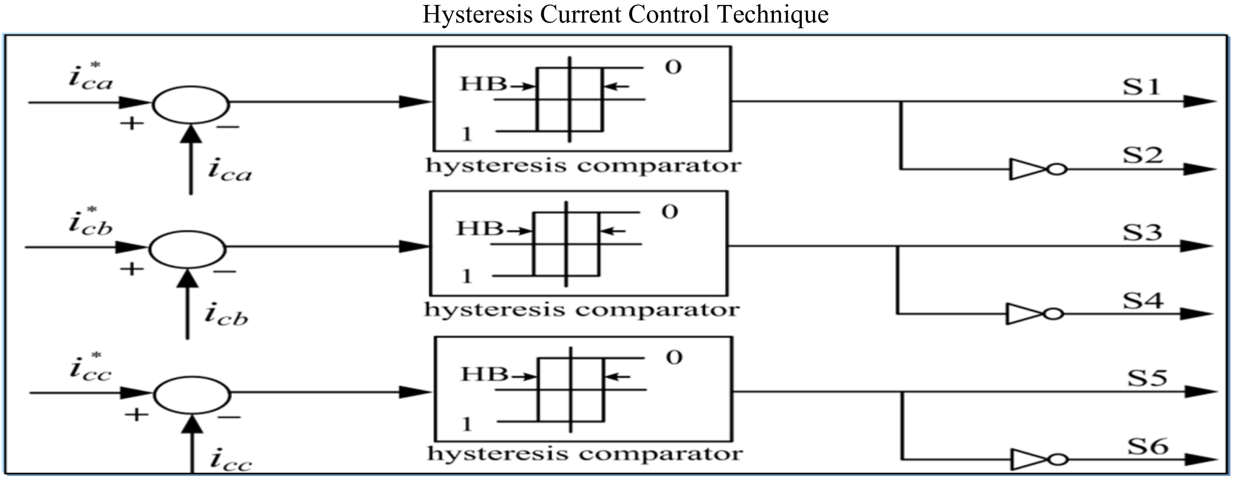
Fig.3.16 Subsystem of inverse clarke transformation (PSD)

$$\begin{bmatrix}v_a \\ v_b \\ v_c\end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \sqrt{3}/2 \\ -\frac{1}{2} & -\sqrt{3}/2\end{bmatrix}\begin{bmatrix}\bar{v}_\alpha\\ \bar{v}_\beta\end{bmatrix}$$

$$v_a = \sqrt{\frac{2}{3}}\,\bar{v}_\alpha \quad , \quad v_b = \sqrt{\frac{2}{3}}\left(-\frac{1}{2}\bar{v}_\alpha + \sqrt{3}/2\,\bar{v}_\beta\right)$$

$$v_c = \sqrt{\frac{2}{3}}\left(-\frac{1}{2}\bar{v}_\alpha - \sqrt{3}/2\,\bar{v}_\beta\right)$$

Hysteresis Current Control Technique



Hysteresis Current Control Technique is a popular method used in power electronics, especially in current-controlled inverters and motor drives. It's primarily applied for controlling the output current in voltage source inverters (VSIs) to match a reference current waveform, typically for applications like DC-AC inverters, AC motor drives, and active filters.
Hysteresis current control is a closed-loop feedback control technique where the actual current is forced to track a reference current within a specified hysteresis band.

- The method turns power semiconductor switches ON or OFF depending on whether the actual current deviates outside the hysteresis band.
- The switching decisions are made instantaneously without the need for complex computations.

A reference current signal (e.g., sinusoidal) is compared with the actual current.If the actual current goes above the upper limit of the hysteresis band:
The controller switches OFF the power device to reduce current.

If the current goes below the lower limit:
The controller switches ON the power device to increase current.
This keeps the current waveform within a bandwidth around the reference.

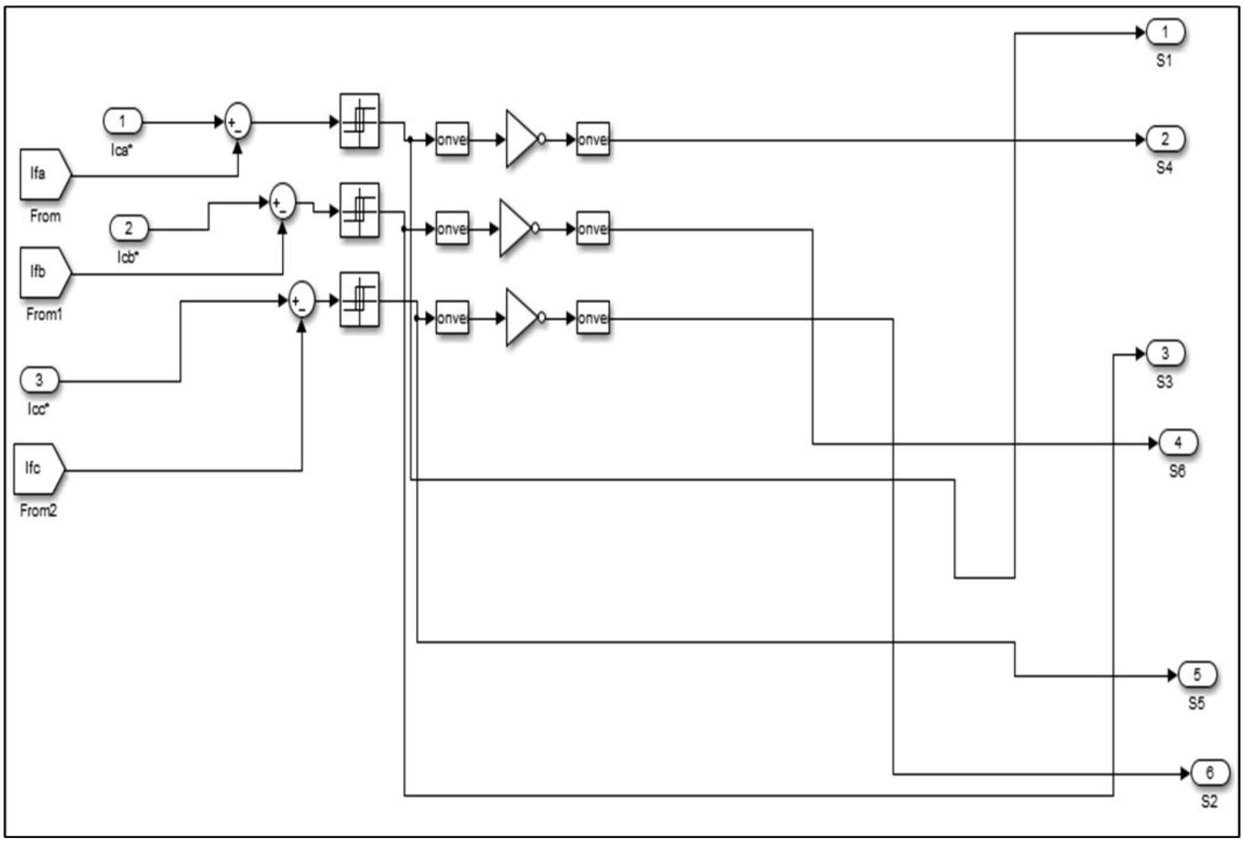


Fig.3.17 subsystem of hysteresis current controller

SR NO.	SYSTEM	SUBSYSTEM	PARAMETER	VALUE
1	HYSTERESIS CURRENT CONTROLLER	SWITCH ON POINT		0.1
		SWITCH OFF POINT		-0.1

Subsystem of shunt inverter

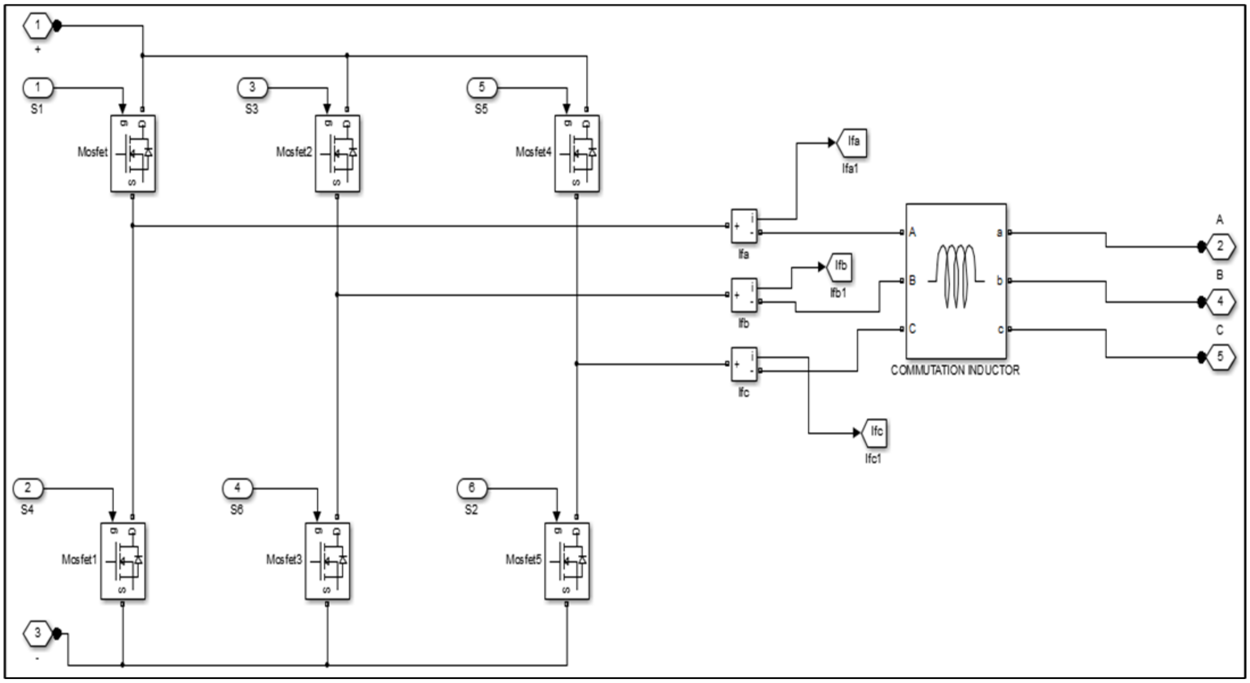


Fig.3.18 Subsystem of shunt inverter

SR NO.	SYSTEM	SUBSYSTEM	PARAMETER	VALUE
1	INVERTER (SHUNT)	COMMUTATION INDUCTOR	INDUCTANCE	0.5 H

3.3 Matlab Simulation of Series Active Power filter

- The First Generation Control Circuit

The First Generation Control Circuit for a Series Active Power Filter (SAPF) was developed to mitigate harmonics and improve power quality in electrical systems. Series APFs are typically used to suppress voltage harmonics, balance unbalanced loads, and mitigate voltage sags/swells by injecting a compensating voltage in series with the supply.

Overview of First Generation SAPF Control Circuit

This generation of control used relatively simple control strategies, analog/digital circuits, and relied on classical control methods.

Basic Components:

1. Voltage Sensing Circuit
   - Detects source voltage and load voltage.
   - Usually involves voltage dividers and isolation (via opto-isolators or transformers).
2. Reference Voltage Generator
   - Generates a reference voltage (usually sinusoidal) to compare with the distorted voltage.
   - Assumes ideal source voltage as the reference.
3. Error Detector / Comparator
   - Compares the actual voltage with the reference voltage.
   - The error is used to generate a control signal.
4. Controller
   - Often a Proportional-Integral (PI) controller or sometimes hysteresis control.
   - Adjusts the injection voltage to minimize the error.
5. Pulse Width Modulation (PWM) Generator
   - Converts the control signal into gate pulses for the inverter.
   - Uses techniques like Sinusoidal PWM (SPWM) or Hysteresis Band PWM.
6. Series Injection Transformer
   - Couples the inverter's output voltage in series with the supply.

- Isolates and protects the power filter circuit from the grid.

7. Inverter (Voltage Source Inverter - VSI)
   - Generates the compensating voltage based on control signals.
   - Usually based on IGBTs or MOSFETs for switching.

Control Strategy:
The control in first-generation SAPFs typically followed this approach:

1. Synchronous Reference Frame Theory (SRF) or Instantaneous Reactive Power Theory (pq Theory) may not have been used initially (they appeared in later generations).
2. The system relied on line synchronization using Phase-Locked Loops (PLLs).
3. Compensation focused mainly on:
   - Voltage harmonics
   - Voltage imbalance
   - Voltage dips/swells

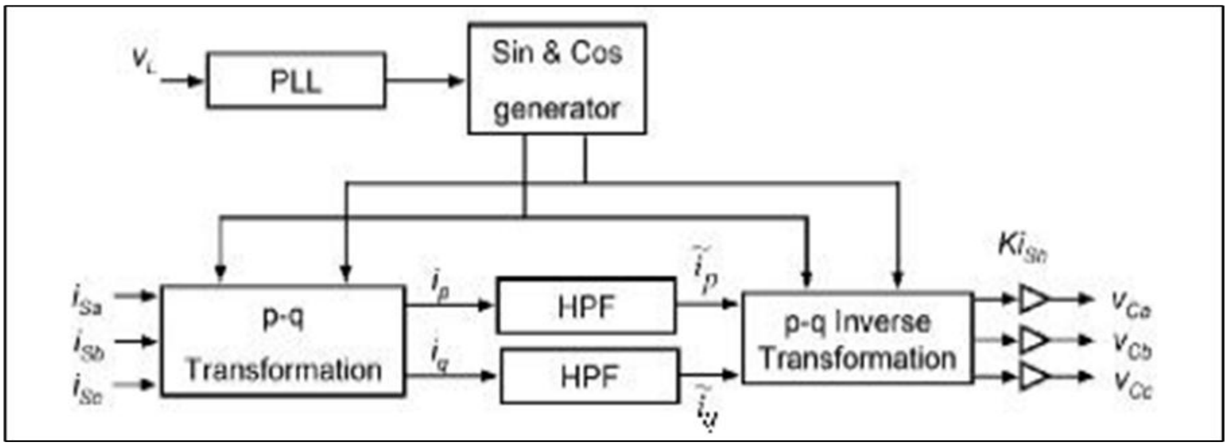


Fig.3.19 First Generation Control Circuit

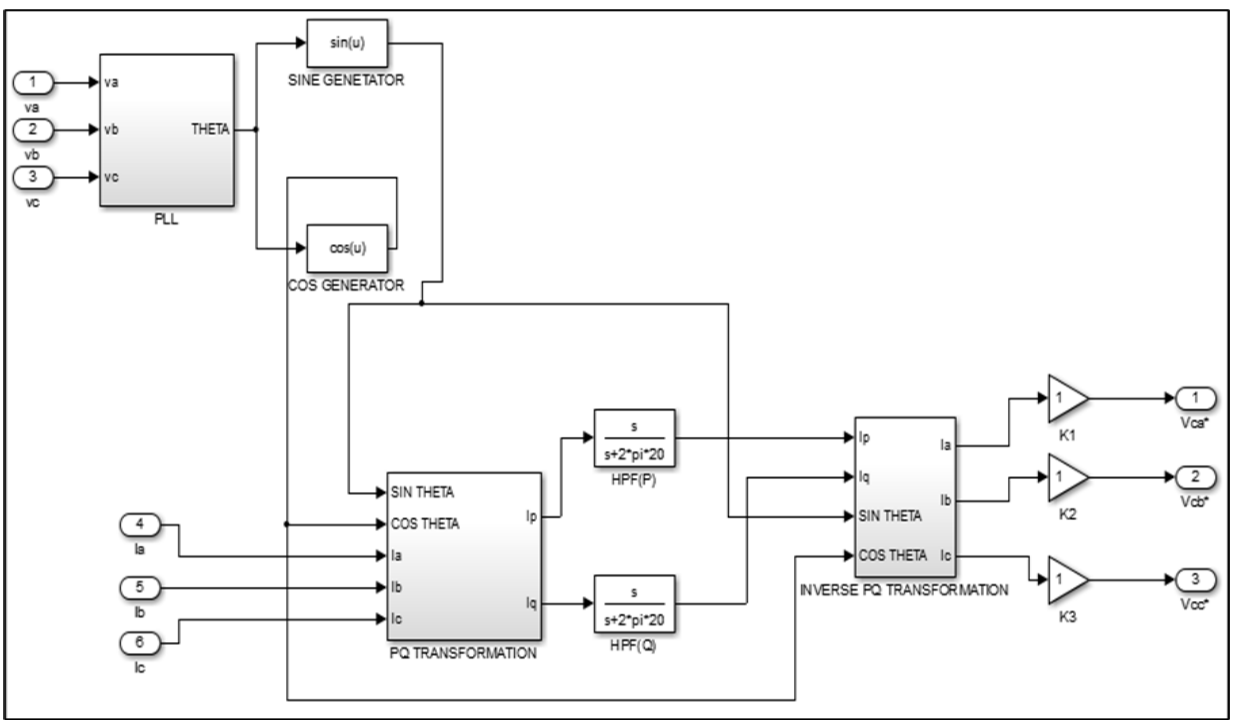


Fig.3.20 Simulation blocks of First Generation Control Circuit

SR NO.	SYSTEM	SUBSYSTEM	PARAMETER	VALUE
1	PWM VOLTAGE CONTROL		SWITCHING FREQUENCY	1 kHz

Phase locked loop (series)

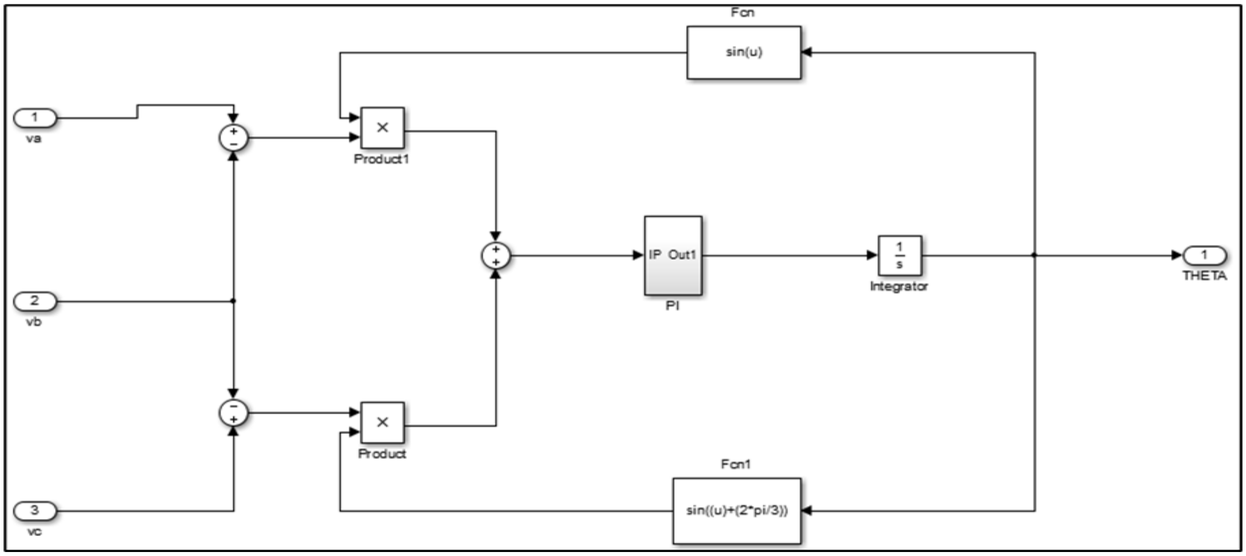


Fig.3.21 Phase locked loop (series)

$$V_{ab} \cdot i_a + V_{cb} \cdot i_c = P_{3\phi}$$

Subsystem of pi controller (series)

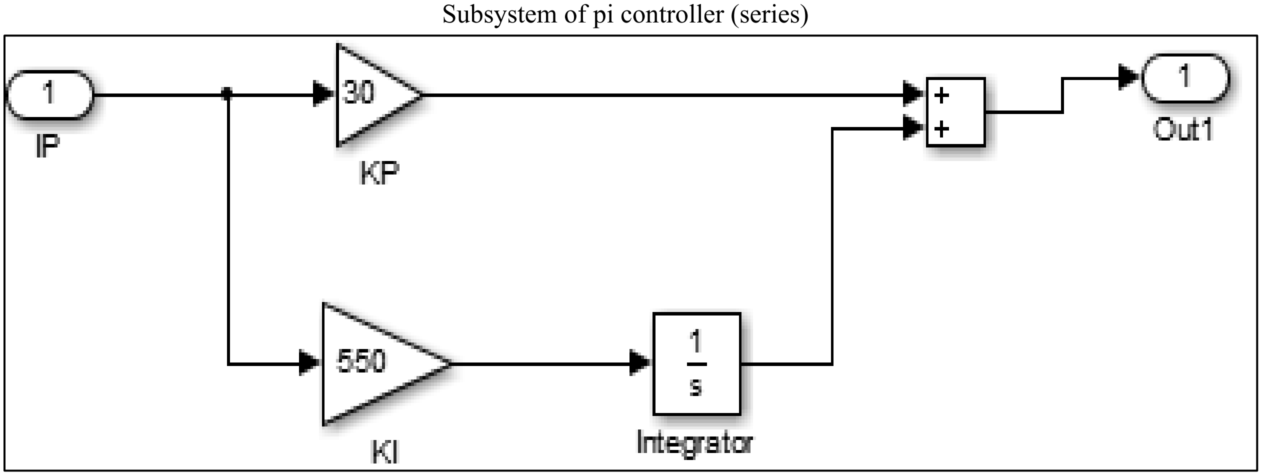


Fig.3.22 Subsystem of pi controller (series)

SR NO.	SYSTEM	SUBSYSTEM	PARAMETER	VALUE
1	PLL CIRCUIT	PI CONTROLLER	KP	30
			KI	550

Subsystem of PQ transformation (series)

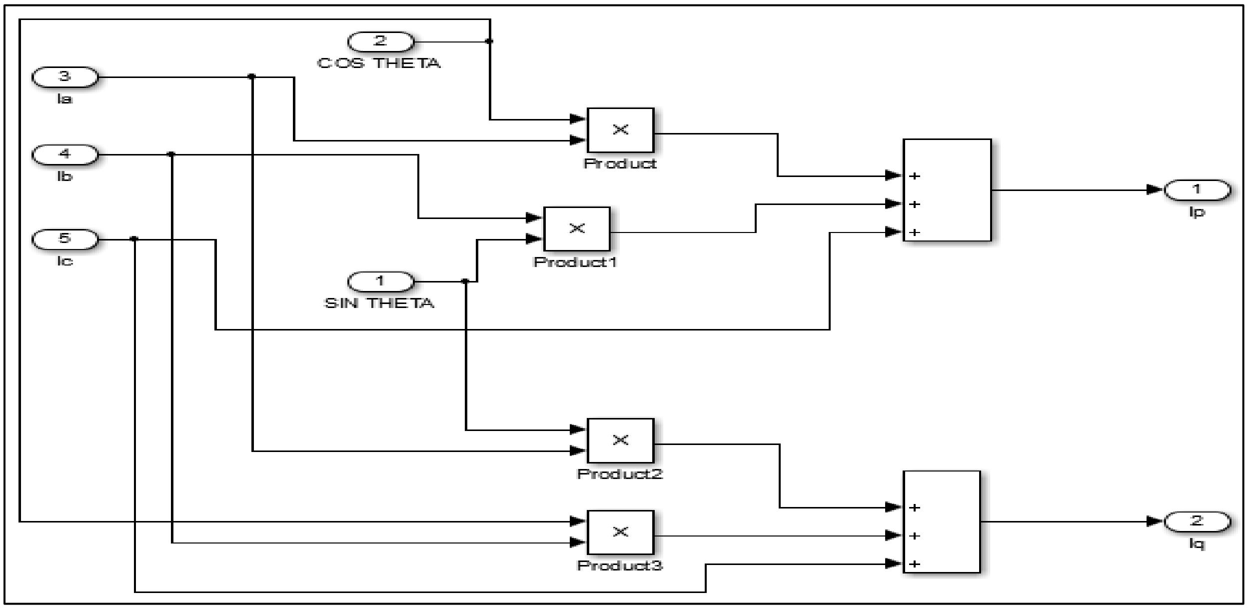


Fig.3.23 Subsystem of PQ transformation (series)

$$\begin{bmatrix} i_p \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \sin\theta & \cos\theta & 1 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

$$i_p = i_a \cos\theta + i_b \sin\theta + i_c$$

$$i_q = i_a \sin\theta + i_b \cos\theta + i_c$$

Subsystem of inverse PQ transformation (series)

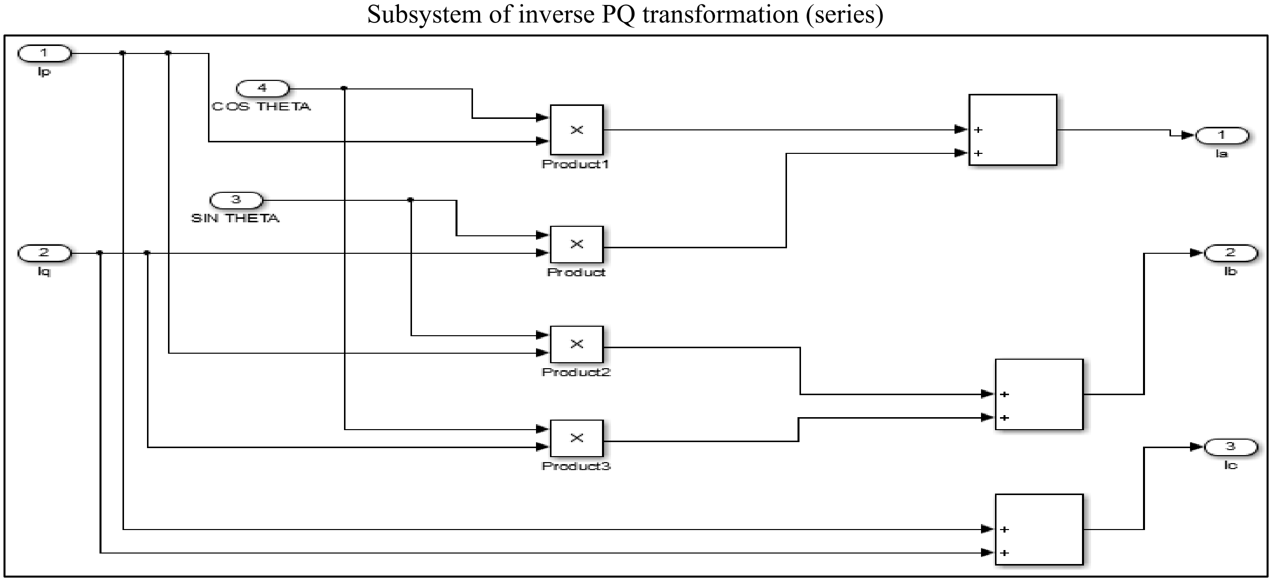


Fig.3.24 Subsystem of inverse PQ transformation (series)

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ \sin\theta & \cos\theta \\ 1 & 1 \end{bmatrix} \begin{bmatrix} i_p \\ i_q \end{bmatrix}$$

$$i_a = i_p \cos\theta + i_q \sin\theta$$

$$i_b = i_p \sin\theta + i_q \cos\theta$$

$$i_c = i_p + i_q$$

Subsystem of PWM voltage controller (series)

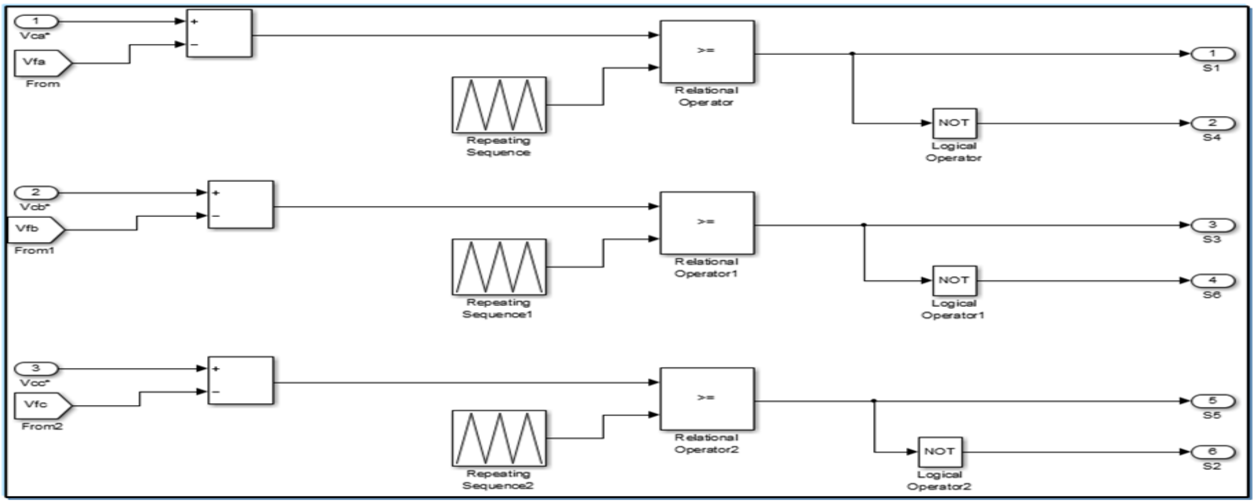


Fig.3.25 Subsystem of PWM voltage controller (series)

- Power Stage: Includes the switch (e.g., MOSFET), inductor, diode, and capacitor; controls power delivery to the load.
- Voltage Feedback: Senses output voltage and feeds it back for regulation.
- Control Algorithm: Usually a PI or PID controller that processes the voltage error.
- PWM Generator: Converts the control signal into a PWM signal to modulate the switch.
- Gate Driver: Drives the power switch with proper timing and voltage.
- Protection Circuitry: Monitors for faults like overvoltage, overcurrent, or overheating.

Simulation of series inverter

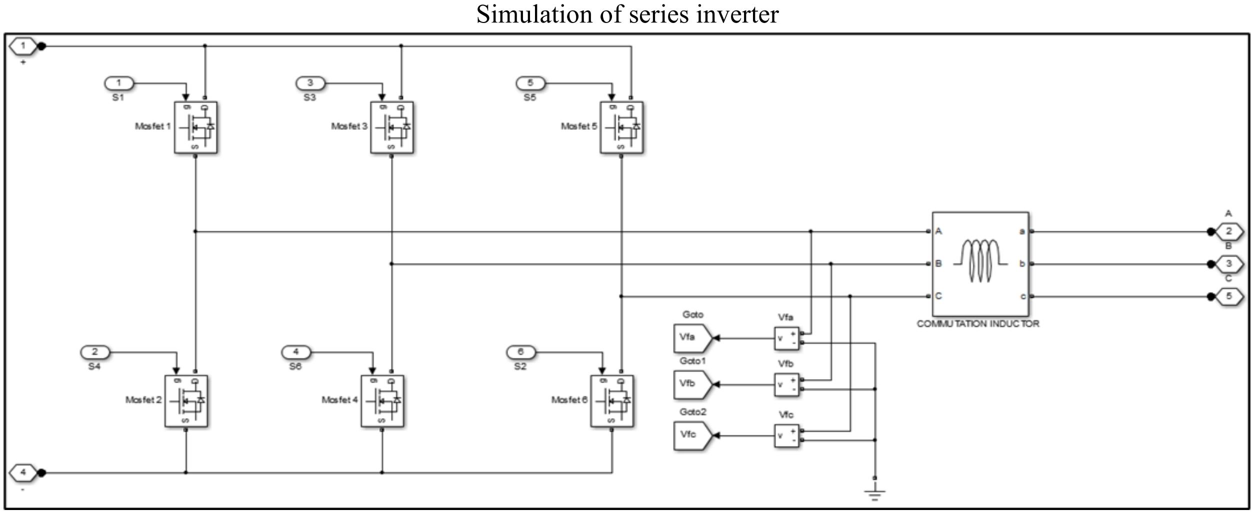
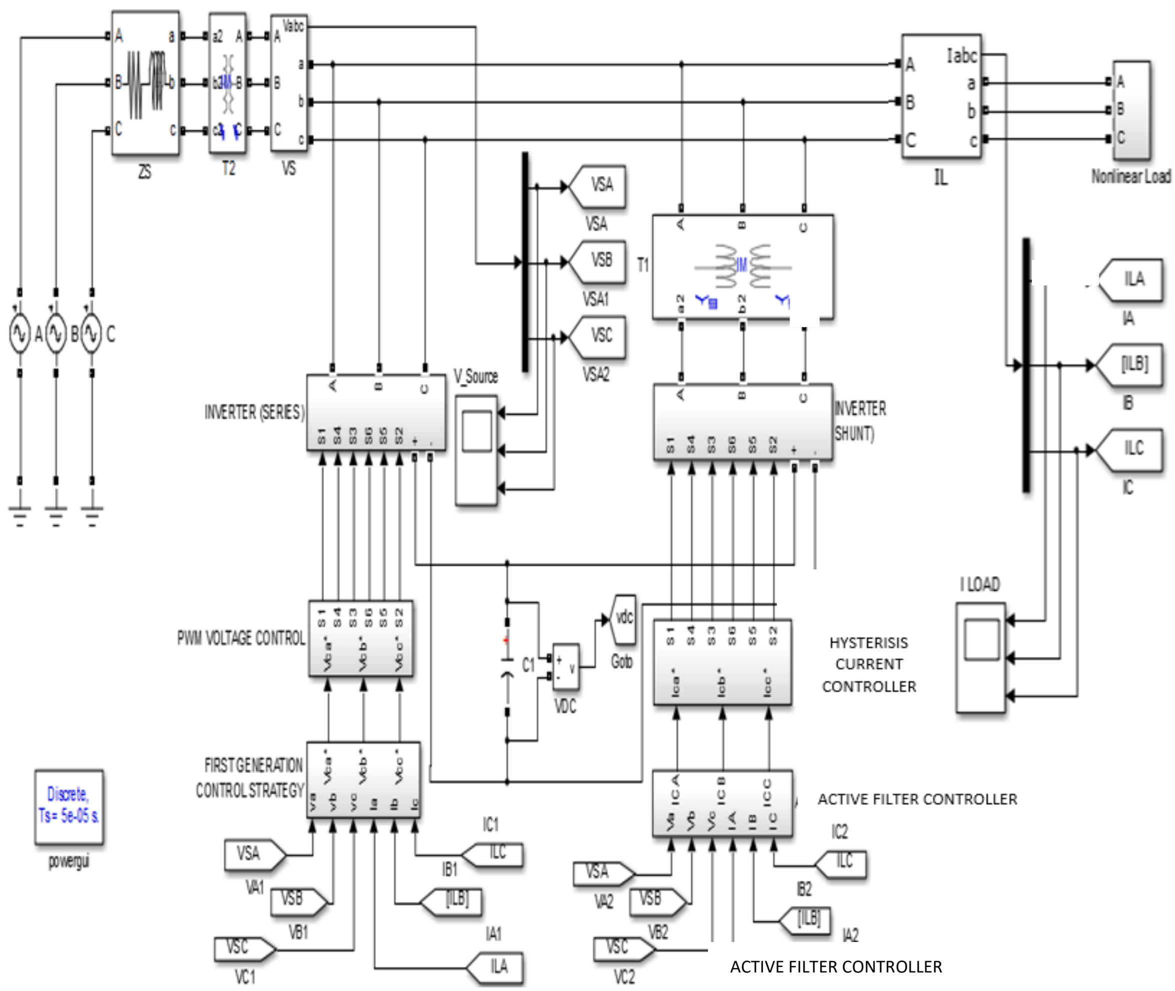


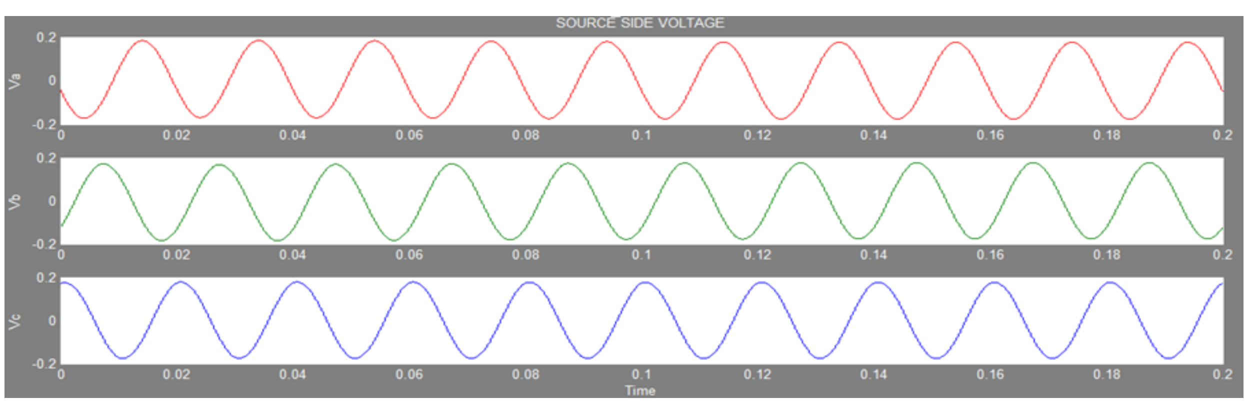
Fig.3.26 Subsystem of PWM voltage controller (series)

SR NO.	SYSTEM	SUBSYSTEM	PARAMETER	VALUE
1	INVERTER (SERIES)	COMMUTATION INDUCTOR	INDUCTANCE	1 mH

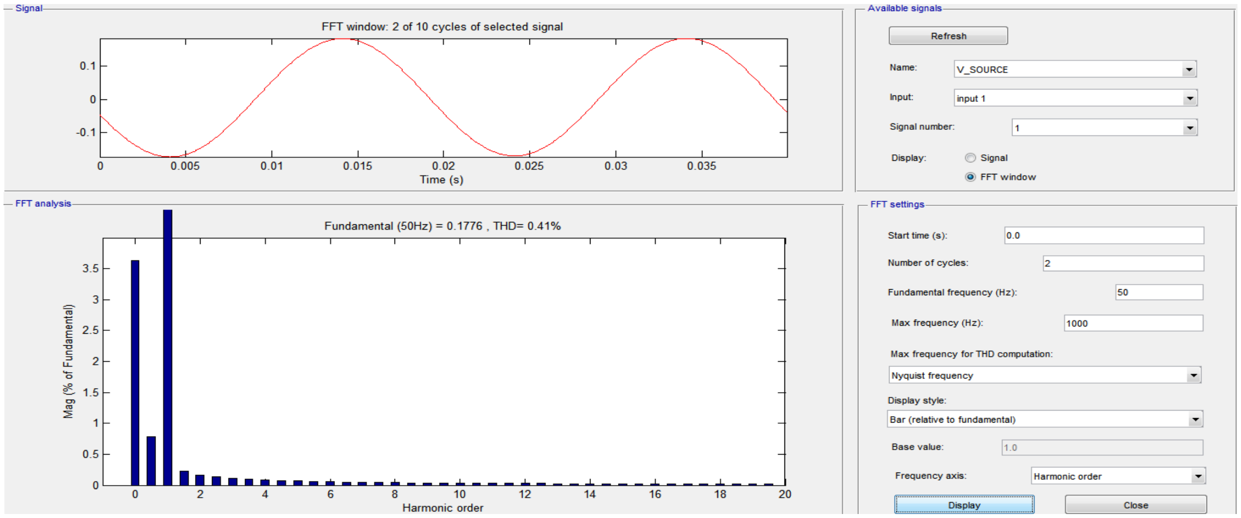
Simulation of Main Diagram With Hybrid UPQC



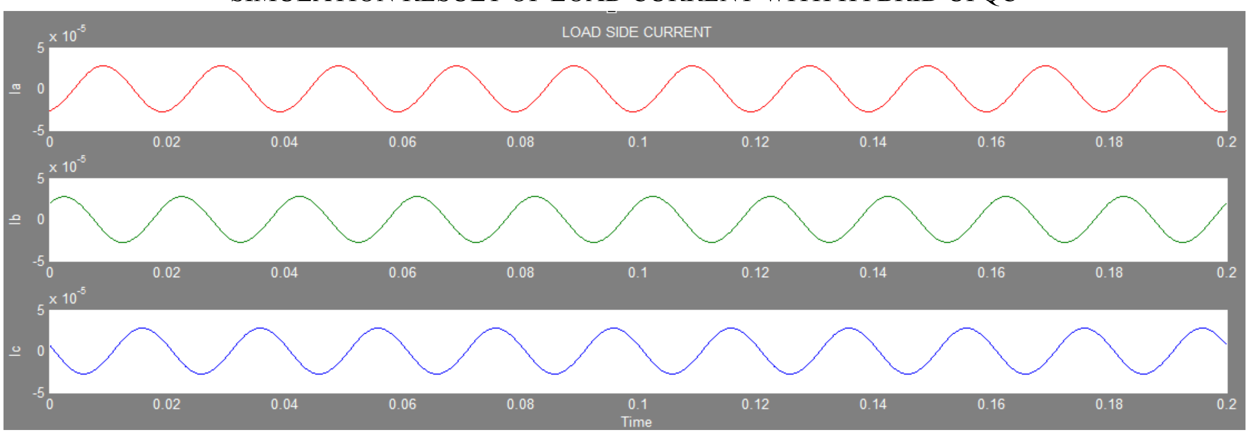
SIMULATION RESULT OF SOURCE VOLTAGE WITH HYBRID UPQC



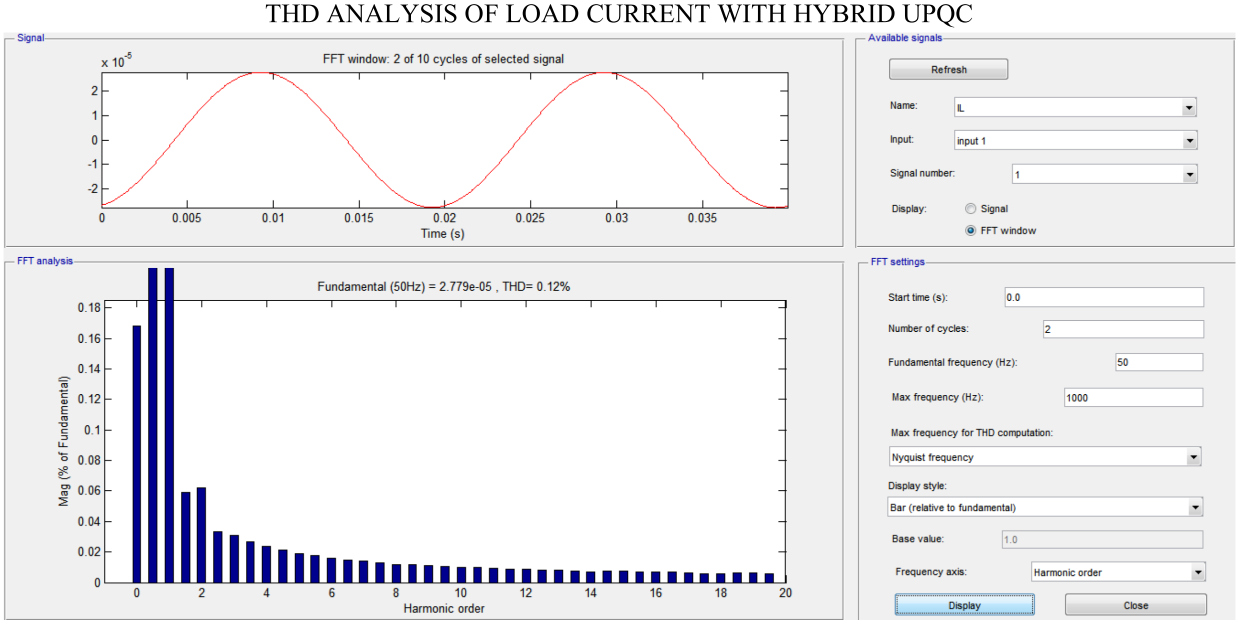
THD ANALYSIS OF SOURCE VOLTAGE WITH HYBRID UPQC



SIMULATION RESULT OF LOAD CURRENT WITH HYBRID UPQC



THD ANALYSIS OF LOAD CURRENT WITH HYBRID UPQC



COMPARISON OF RESULTS

SR. NO.	Electrical QUANTITY	%THD WITHOUT UPQC	%THD WITH UPQC
1	SOURCE VOLTAGE	12.56	0.41
2	LOAD CURRENT	25.54	0.12

SR NO.	SYSTEM	SUBSYSTEM	PARAMETER	VALUE
1	SOURCE	SOURCE IMPEDANCE	RESISTANCE	1 OHM
			INDUCTANCE	12 mH
		SOURCE VOLTAGE	VOLTAGE	230 V (RMS)
2	3-φ SERIES TRANSFORMER (Y-Y)		RATING	100 KVA, 50 HZ
			PRIMARY	400 V
			SECONDARY	400 V
3	3-φ SHUNT TRANSFORMER (Y-Y)		RATING	250 MVA, 50 HZ
			PRIMARY	325 KV
			SECONDARY	200 KV
4	NONLINEAR LOAD (UPS)	3-φ INDUCTOR BRANCH	INDUCTANCE	5 mH
		RESISTOR	RESISTANCE	1 OHM
		CAPACITOR	CAPACITANCE	1 μf
		3-φ RESISTOR BRANCH	RESISTANCE	50 OHM
5	INVERTER (SERIES)	COMMUTATION INDUCTOR	INDUCTANCE	1 mH
6	PWM VOLTAGE CONTROL		SWITCHING FREQUENCY	1 kHz
7	PLL CIRCUIT	PI CONTROLLER (SERIES)	KP	30
			KI	550
8	INVERTER (SHUNT)	COMMUTATION INDUCTOR	INDUCTANCE	0.5 H
9	HYSTERESIS CURRENT CONTROLLER	SWITCH ON POINT		0.1
		SWITCH OFF POINT		-0.1
10	PWM CURRENT CONTROL		CUTOFF FREQUENCY	33 Hz
11	ACTIVE FILTER CONTROLLER	P-LOSS AVG.	CUT-OFF FREQUENCY	50 Hz
12	PLL CIRCUIT	PI CONTROLLER (SHUNT)	KP	1200
			KI	1200
13	ACTIVE FILTER CONTROLLER	DC VOLTAGE REGULATOR (PI CONTROLLER)	KP	1
			KI	20
14	COMMON DC LINK CAPACITOR		CAPACITANCE	500 μf
15	PASSIVE FILTER (5th ORDER)	LC PARALLEL BRANCH (3 SET)	INDUCTANCE	0.4 μH
			CAPACITANCE	1 f
16	PASSIVE FILTER (7th ORDER)	LC PARALLEL BRANCH (3 SET)	INDUCTANCE	0.4 μH

Design Table

IV. CONCLUSION

A Unified Power Quality Conditioner (UPQC) is an advanced power electronics device that provides voltage and current compensation for improved power quality. Designing a UPQC requires knowledge of power electronics, control systems, and real-time signal processing. With modern advancements in AI and smart grids, UPQC technology is becoming more efficient and widely used in industrial, commercial, and renewable energy systems.

Future Work:

- Tuning of PLL
- Remaining shunt & series filter design completion.

- Completion of UPQC Simulation design and all expected results.

BIBLIOGRAPHY AND REFERENCES

[1] Mauricio Aredes et al., 'Control Strategies for Series and Shunt Active Filters', IEEE Power Tech Conference, 2003.
[2] Hideaki Fujita and Hirofumi Akagi, 'The Unified Power Quality Conditioner', IEEE Transactions on Power Electronics, 1998.
[3] Bhim Singh et al., 'A Review of Active Filters for Power Quality Improvement', IEEE Transactions, 1999.
[4] Vinod Khadkikar, 'Enhancing Electric Power Quality Using UPQC', IEEE Transactions, 2012.
[5] M. Sharanya et al., 'Harmonic Mitigation Using Unified Power Quality Conditioners', Research India Publications, 2014.