Implementation of Empirical Mode Decomposition Based Algorithm for Shunt Active Filter Integration with PV

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***Abstract*—In this paper, an online empirical mode decomposition (EMD) based algorithm is proposed for the control of a shunt active filter (AF) along with the integration of solar. Standard EMD algorithm has worked on the principle of time-scale difference between the upper maximum values and lower minimum values of a signal, and for a long time it has been considered good for offline analysis of signals. This paper deals with the real-time application of EMD for the control of AF under balanced and unbalanced loads. Linear interpolators are employed for construction of upper and lower envelopes to avoid computation complexity. Moreover, customized iterative computations for extraction of intrinsic mode functions maintain the efficiency of algorithm. The algorithm extracts the fundamental component of load current and helps in estimating reference currents. Simulations are performed on MATLAB/Simulink platforms.**

I. BACKGROUND INFORMATION

Empirical Mode Decomposition (EMD) is a widely used signal processing technique for non-linear and non-stationary data. Introduced by Huang et al. in 1998, EMD decomposes a signal into Intrinsic Mode Functions (IMFs), which represent the intrinsic oscillatory modes present in the signal. This technique has found applications in various domains, including biomedical signal analysis, structural health monitoring, and power systems. In the context of active shunt filters, EMD can enhance the effectiveness of harmonic compensation by isolating and processing specific frequency components.

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Traditional harmonic filtering methods, such as Fast Fourier Transform (FFT)-based techniques, often face limitations in handling time-varying signals and require prior knowledge of harmonic frequencies. EMD addresses these challenges by adaptively decomposing signals without requiring a prior information. existing studies demonstrate the efficacy of EMD in power quality improvement. For instance, researcher save employed EMD to extract fundamental and harmonic components for selective filtering. Such methods improve the dynamic response and accuracy of active filters, ensuring compliance with IEEE-519 standards for harmonic distortion limits.

The growing demand for clean and sustainable energy has led to the increasing integration of renewable energy sources such as solar photovoltaic (PV) systems into the power grid. While solar energy provides a green alternative to fossil fuels, its integration brings several challenges to power quality due to its intermittent and non-linear nature. Voltage fluctuations, harmonics, and reactive power issues are common problems observed in systems with solar integration. Shunt Active Filters (SAFs) are widely used power electronic devices designed to mitigate power quality issues such as harmonic distortion non-linear and non-stationary load conditions, especially when solar PV systems are involved.By integrating EMD with the control algorithm of the SAF, the system can more accurately detect and isolate harmonics and disturbances caused by solar PV fluctuations. This leads to more effective harmonic mitigation, better power factor correction, and enhanced stability of the power system.

II. LITERATURE SURVEY

- This paper presents a novel approach for harmonic filtering in a three-phase shunt active filter system, aligning the phase angle of the input current with the load's line frequency component. The control strategy, implemented digitally without sensing input voltages, uses a phase-shifting technique along with a resistor-emulator-type shaping strategy. Using Texas Instruments' TMS320F240 EVM, the algorithm is computationally efficient while achieving strong harmonic filtering performance, with analysis, simulation, and experimental results from a prototype on a 25-A nonlinear load.
- This paper details a controller design for a shunt active power filter using a PWM dc-to- ac converter, aimed at compensating harmonic currents from nonlinear loads. It features a two-layer structure: an outer layer generating current references with a repetitive algorithm for harmonic compensation, and an inner layer employing state-feedback for current control. Stability and robustness are analyzed, and the controller is validated on a prototype with various nonlinear loads, accounting for microcomputer and anti-aliasing filter delays.
- This paper introduces a bacterial foraging optimization algorithm to determine PI controller coefficients for active power filters, improving performance across varying conditions. Simulation results show that the bacterial foraging PI (BF-PI) controller achieves a satisfactory dynamic response and converges faster than genetic algorithms to reach the global optimum.

This paper enhances the dynamic performance of a shunt-type active power filter using artificial neural networks (ANNs) for rapid compensating current estimation. The approach leverages dc-link voltage dynamics and adapts weights in an adaline network to minimize total harmonic distortion, demonstrating effectiveness for both balanced and unbalanced loads in three- phase systems through extensive simulations and experiments.

- This paper presents a novel algorithm for real-time detection of fundamental frequency and harmonic components using discrete Fourier transform, optimized for active shunt filter applications in aircraft AC power systems with variable frequencies. The algorithm, implemented in Matlab/Simulink and validated through experiments, efficiently calculates compensating currents for distorted signals, outperforming traditional Phase Locked Loop and synchronous dq reference methods.
- This paper introduces a straightforward control algorithm for shunt active filters designed to compensate for harmonics and reactive power under nonsinusoidal supply conditions. Traditional approaches struggle to achieve both unity power factor and harmonic-free current due to conflicting requirements. The proposed algorithm employs the Lagrange multiplier technique to optimize this trade-off without relying on the conventional p-q theory, making it suitable for both single-phase and three-phase systems. It successfully achieves an optimized power factor within specified THD limits.

- This paper presents new strategies to enhance the transient response time of harmonic detection in shunt active power filters using adaptive filters. It examines two cases employing an adaptive notch filter: one utilizing the least mean square algorithm and the other using the recursive least squares algorithm to adjust coefficients. The synchronization of the filter's orthogonal input signals, generated through Clarke transformation of load currents, occurs automatically without a phase-locked loop, thereby reducing real-time computational demands. The authors provide simulations in MATLAB/Simulink to illustrate the algorithm and demonstrate practical implementation using the Texas Instruments DSP TMS320F2812, along with a discussion of the experimental results.
- This paper focuses on the hardware implementation of a shunt active filter (SAF) designed to compensate for reactive power, unbalanced loads, and harmonic currents. The SAF utilizes an adaptive-linear-element (Adaline)-based current estimator to ensure sinusoidal, unity-power-factor source currents. It senses three-phase load currents and employs the least mean square (LMS) algorithm to calculate weights for determining the fundamental-frequency component of load currents.

III. PROBLEM STATEMENT

The widespread use of non-linear loads in modern power systems introduces harmonic distortion, degrading power quality and increasing losses in electrical equipment. Conventional methods for harmonic mitigation often rely on static assumptions, limiting their effectiveness in dynamic environments where harmonic frequencies vary with time. This calls for advanced techniques that can adapt to real-time changes in the signal's harmonic content.

EMD-based approaches for active shunt filters aim to address this challenge by dynamically isolating and filtering specific harmonic components, ensuring better compliance with power quality standards.

The Implementation of Empirical Mode Decomposition (EMD) Based Algorithm for Shunt Active Filter revolves around addressing the challenges in controlling shunt active filters (SAFs) to effectively mitigate harmonics and improve power quality in electrical systems.

Key Issues /Problems

1. Harmonic Distortion: Electrical networks often suffer from harmonic distortion due to non-linear loads, which can lead to inefficiencies and potential damage to equipment. The implementation of an EMD-based algorithm aims to enhance the extraction of fundamental frequencies and harmonic components from distorted signals, thus improving the performance of SAFs in real-time applications .

2. Dynamic Response: Traditional control methods may struggle with the dynamic nature of electrical systems, especially under varying load conditions. The EMD technique provides a data-driven approach that can adaptively decompose signals into intrinsic mode functions, allowing for more responsive and accurate control strategies for SAFs.

3. Algorithm Efficiency: The effectiveness of EMD in extracting relevant frequency components hinges on its implementation efficiency. Issues such as over-decomposition or inadequate stopping criteria during the sifting process can compromise the accuracy of harmonic extraction. Thus, refining the algorithm to ensure optimal performance while minimizing computational load is critical.

4. Real-time Application: The proposed algorithm must be capable of operating in real-time environments, which necessitates robust performance under various operational conditions. This includes handling noise and ensuring that the extracted signals are reliable for further processing in the control of SAFS .

5. Integration with Existing Systems: Another challenge lies in integrating the EMD-based algorithm with existing shunt active filter architectures and ensuring compatibility with other control techniques. This requires careful consideration of system dynamics and potential interactions with established methodologies .

The problem statement emphasizes the need for an effective EMD- based algorithm that can accurately decompose signals for harmonic extraction, adapt to dynamic conditions, operate efficiently in real-time, and integrate smoothly with existing systems to enhance the functionality of shunt active filters.

IV.INNOVATION

The proposed solution leverages EMD to decompose voltage or current signals into IMFs, allowing selective filtering of harmonics in real time. Unlike traditional methods, this approach is data-driven and does not require prior knowledge of harmonic frequencies. The adaptive nature of EMD ensures superior performance in dynamic systems, making it a novel addition to active filter design methodologies

The implementation of an Empirical Mode Decomposition (EMD) Based Algorithm for Shunt Active Filters (SAFs) represents a significant innovation in power quality management. Here are the key aspects that highlight its innovative nature The adaptive nature of EMD ensures superior performance in dynamic systems, making it a novel addition to active filter design methodologies

Key aspects that highlight its innovative nature:

Advance Signal Processing

Dynamic Harmonic Analysis: EMD offers a unique approach to decompose complex current signals into intrinsic mode functions, allowing for precise identification and extraction of harmonic components. This capability surpasses traditional Fourier analysis methods by adapting to non-linear and time-varying signals, thereby improving the accuracy of harmonic detection and compensation.

Real-time Adaptability

Responsive Control Mechanism: The EMD- based algorithm enhances the SAF's ability to adapt in real-time to changes in load conditions and harmonic profiles. This adaptability ensures that the filter can effectively respond to dynamic electrical environments, providing continuous harmonic mitigation without the delays associated with conventional control methods.

Enhanced Compensation Techniques

Multi-frequency Compensation: Unlike traditional filters that may struggle with simultaneous harmonic mitigation, the EMD algorithm allows for the simultaneous extraction and compensation of multiple harmonic frequencies. This capability leads to more comprehensive power quality Improvement and reduces Total Harmonic Distortion (THD) more effectively than existing solutions.

Integration with Modern Technologies Compatibility with Hybrid Systems: The EMD- based approach can be integrated with hybrid filtering systems that combine both active and passive filtering techniques. This synergy allows for optimized performance across a broader range of frequencies and load conditions, enhancing overall system efficiency.Improved Energy Efficiency.

The Implementation of Empirical Mode Decomposition (EMD) Based Algorithm for Shunt Active Filters (SAFs) involves a novel approach to enhance power quality by effectively mitigating harmonics in electrical systems. Here's a detailed description of the idea, methods, and technologies used:

V. IDEA OVERVIEW

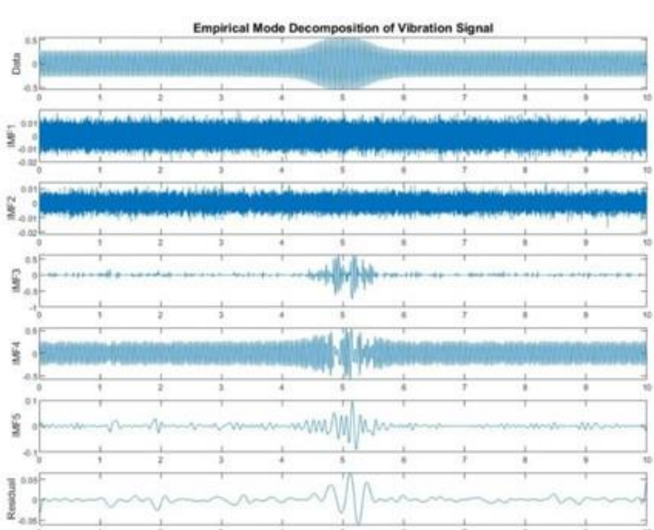
The primary goal of this implementation is to develop a real-time control strategy for shunt active filters that utilizes EMD to accurately extract harmonic components from distorted current signals. This allows for precise compensation of harmonics, thus improving the overall power quality in electrical systems.

Methods and Technologies Used

1. Empirical Mode Decomposition (EMD)

Signal Decomposition: EMD is employed to decompose complex current waveforms into intrinsic mode functions (IMFs). This process helps isolate the fundamental frequency and various harmonic components, enabling more effective analysis and control of the SAF.

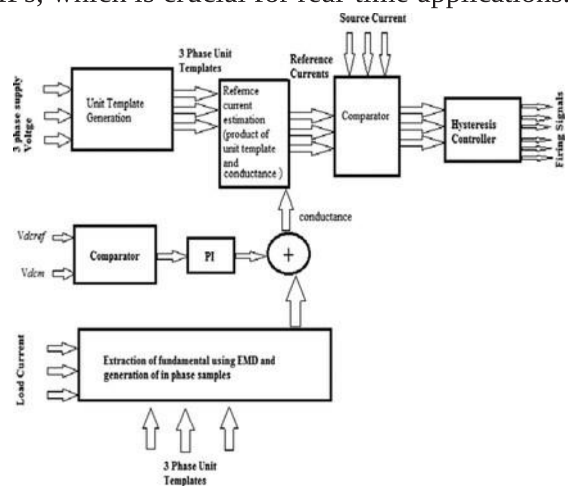
Real-time Application: The algorithm is designed for real-time operation, allowing the SAF to adaptively respond to changes in load conditions and harmonic profiles



2. Control Strategy

Reference Current Estimation: The extracted IMFs are used to estimate the reference currents required for the SAF to compensate for harmonics. This ensures that the filter operates efficiently under both balanced and unbalanced load conditions.

Iterative Computation: Customized iterative methods are implemented to maintain computational efficiency during the extraction of IMFs, which is crucial for real-time applications.

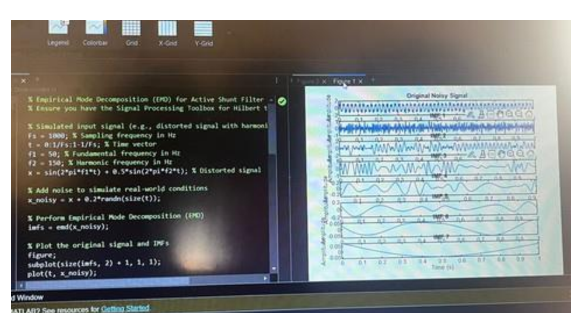


Block diagram depicting the control scheme for AF.

3. Simulation Tools

MATLAB/Simulink: The implementation involves extensive simulations using MATLAB/Simulink platforms. These simulations allow for testing various scenarios and validating the performance of the EMD- based control strategy before real-world application.

The output response in the matlab simulink



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4. Cascading Solar to the Inverter

In a solar PV system, energy generated by solar panels is in the form of DC (Direct Current). However, most electrical loads and the power grid operate on AC (Alternating Current). To make solar energy usable, especially in grid-connected systems or for household appliances, inverters are used to convert DC into AC. Stages of Cascading Solar to the Inverter:

Solar Panel Array:Converts sunlight into DC electricity using photovoltaic cells.Multiple panels are connected in series and/or parallel to achieve the required voltage and current levels.

Combiner Box: Combines outputs of several panel strings into one output.Includes protection devices like fuses, circuit breakers, and surge protection.

DC-DC Converter (Optional but common in MPPT systems): Performs Maximum Power Point Tracking (MPPT) to extract the maximum available power from the solar array.Regulates the output voltage and current.

DC Link/Bus:A stable DC line that carries the regulated DC voltage to the inverter input.Includes filtering elements like capacitors to remove ripples.

Inverter: Converts DC power into AC power.

Types: Grid-tied, off-grid, hybrid.

Contains control algorithms to match frequency, voltage, and phase of the grid or load.May include features like islanding protection, power factor correction, and data monitoring.

EMPIRICAL MODE DECOMPOSITION (EMD) FOR A SHUNT ACTIVE FILTER:

Empirical Mode Decomposition (EMD) is a powerful signal processing technique used to analyze non-linear and non-stationary signals. It decomposes a complex signal into a set of Intrinsic Mode Functions (IMFs), which represent different oscillatory modes of the original signal. This method is particularly useful for extracting the fundamental frequency components from distorted signals, making it applicable for controlling Shunt Active Filters (SAFs) to mitigate harmonics in power systems.

HOW DOES EMD WORKS:

The implementation of an Empirical Mode Decomposition (EMD) based algorithm for shunt active filters involves several key steps:

1) Signal Decomposition

2) Intrinsic Mode Function Criteria

3) Envelope Construction

4)Reference current extraction

5) Iterative process

1. Signal Decomposition:

The algorithm decomposes the distorted load current into Intrinsic Mode Functions (IMFs) using EMD, which separates the signal into oscillatory components that satisfy specific criteria. The EMD algorithm decomposes the input signal z(t) into multiple IMFs h(i) (t) and a residual r(t):

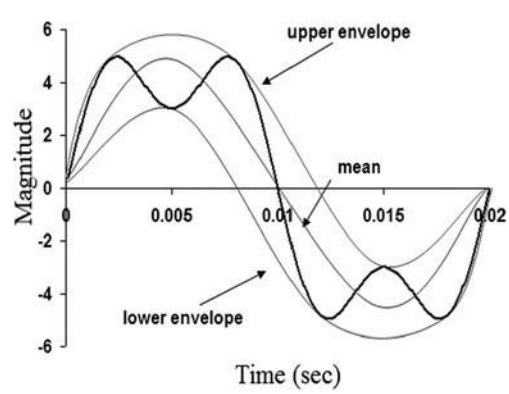
(t)= L Σ h(i)(t)+r(t)

Where I is the number of IMFs extracted from the signal.

2. Intrinsic Mode Function Criteria:

Each IMF must satisfy two criteria:

The number of extrema (maxima and minima) must be equal or differ by one.The mean of the envelope defined by the local maxima and minima must be zerReference Current Extraction: The fundamental component of the load current is extracted from the IMFs, which is then used to estimate the reference current needed for the active filter.



3. Envelope Construction:

For each IMF, upper and lower envelopes are constructed from the local maxima and minima, respectively. The average of these envelopes helps to isolate the oscillatory components of the original signal.

4. Reference Current Extraction:

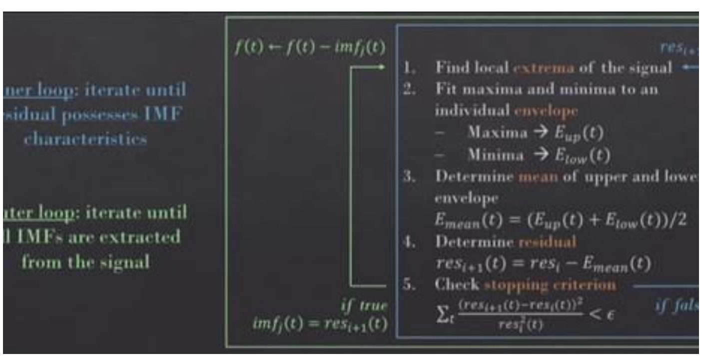
The fundamental component of the load current is extracted from the IMFs, which is then used to estimate the reference current needed for the active filter

5. Control Implementation:

Finally, the reference current is utilized to generate control signals for the shunt active filter, enabling it to compensate for harmonics and improve power quality

6. Iterative Process:

The process is repeated iteratively until no further IMFs can be extracted, resulting in a complete decomposition of the original signal into meaningful components.



ALGORITHM FOR HOW AN EMD WORKS

In a Shunt Active Filter, EMD helps separate harmonic components from the main signal.
This allows the controller to accurately detect and compensate unwanted harmonics, improving power quality.

Implementation Steps for Shunt Active Filter Control Using EMD:

1. Input Signal Acquisition: Collect the current waveform from the nonlinear load connected to the power system.
2. EMD Application: Apply EMD to decompose the distorted current signal into its IMFs.Identify and extract the fundamental frequency component from these IMFs, which represents the desired reference current for harmonic compensation.
3. Reference Current Calculation: Use the extracted fundamental component to calculate the reference current needed for the shunt active filter to inject into the system, effectively canceling out harmonics produced by nonlinear loads.
4. Pulse Width Modulation (PWM): Generate PWM signals based on the reference current obtained from the EMD process. These PWM signals control the switching of power electronic devices in the shunt new active filter.
5. Harmonic Mitigation: The shunt active filter injects a compensating current that is equal in magnitude but opposite in phase to the harmonic currents, thus mitigating their effects on power quality.
6. Simulation and Validation: Implement simulations to verify performance under various operating conditions. Hardware validation can also be performed using a cascaded transformer coupled multilevel inverter designed as a shunt active filter

VI. CODE FOR EMD BASED ALGORITHM FOR SAF:

```
clc; clear; close all;

% Load dataset

filename = '0.9inner-200watt.csv'; data =
readtable(filename);
% Extract three-phase currents la
= data.Current A;
Ib = data.Current B; Ic
= data.Current_C;
% Create a time vector
num_samples = length(la); Ts
= 0.001;
time_vector = (0:num_samples-1) * Ts;

%% Step 2: Plot Original Load Current Signals
figure;
subplot(3,1,1); plot(time_vector, la, 'b'); title('Original Phase-A Current'); xlabel('Time (s)'); ylabel('Current (A)'); subplot(3,1,2); plot(time_vector, lb, 'b'); title('Original Phase-B Current'); xlabel('Time (s)'); ylabel('Current (A)'); subplot(3,1,3); plot(time_vector, Ic, 'b'); title('Original Phase-C Current'); xlabel('Time (s)'); ylabel('Current (A)');

saveas(gcf, 'Step2_Original_Currents.png');

%% Step 3: Apply Empirical Mode Decomposition (EMD) imf_la =
emd(la);
imf_lb = emd(Ib); imf_lc = emd(Ic);

% Plot first 4 IMFs for Phase-A figure;
for i = 1:4
subplot(4,1,1);
plot(time_vector, imf_la(:,i)); title(['IMF',
num2str(i), ' of Phase-A']);
xlabel('Time (s)'); ylabel('Amplitude');
end
saveas(gcf, 'Step3_EMD_IMFs_PhaseA.png');
```

```
% Step 4: Filter out high-frequency IMFs
filtered_la = sum(imf_la(:, 3:end), 2); filtered_lb =
sum(imf_lb(:, 3:end), 2); filtered_Ic =
sum(imf_lc(:, 3:end), 2);
% Plot Filtered Signal
figure;
subplot(3,1,1); plot(time_vector, filtered_la, 'r'); title('Filtered Phase-A Current'); xlabel('Time (s)');
ylabel('Current (A)'); subplot(3,1,2); plot(time_vector, filtered_lb, 'r'); title('Filtered Phase-B Current');
xlabel('Time (s)'); ylabel('Current (A)'); subplot(3,1,3); plot(time_vector, filtered_lc, 'r'); title('Filtered Phase-C
Current'); xlabel('Time (s)'); ylabel('Current (A)'); saveas(gcf, 'Step4_Filtered_Currents.png');

%% Step 5: PI Controller Kp
= 0.5; Ki = 0.1;
s = tf('s');

Pl_controller = Kp + Ki/s;

ref_la = Isim(Pl_controller, filtered_la, time_vector);

ref_lb = Isim(PI_controller, filtered_lb, time_vector); ref_Ic = Isim(Pl_controller, filtered_Ic, time_vector);

% Plot Reference Currents figure;
subplot(3,1,1); plot(time_vector, ref_la, 'g'); title('Reference Current - Phase A');
xlabel('Time (s)'); ylabel('Current (A)');
subplot/312) plot/time vector ref Ih 'a') titlal'Reference Current - Phrase R'l- xlabel('Time
(s)'); ylabel('Current (A)');

subplot(3,1,3); plot(time_vector, ref_Ic, 'g'); title('Reference Current - Phase C');
xlabel('Time (s)'); ylabel('Current (A)');
saveas(gcf,   'Step5_Reference_Currents.png');

%% Step 6: Harmonic Compensation
harmonic_la = filtered_la - ref_la;
harmonic_lb = filtered_lb - ref_lb;
harmonic_Ic = filtered_lc - ref_Ic;
```

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```
% Plot Harmonic Compensation Currents figure;
subplot(3,1,1); plot(time_vector, harmonic_la, 'm'); title('Harmonic Compensation -Phase A'); xlabel('Time (s)'); ylabel('Current (A)');

subplot(3,1,2); plot(time_vector, harmonic_lb, 'm'); title('Harmonic Compensation -Phase B');
xlabel('Time (s)'); ylabel('Current (A)'); subplot(3,1,3); plot(time_vector, harmonic_Ic, 'm');
title('Harmonic Compensation -Phase C'); xlabel('Time (s)'); ylabel('Current (A)'); saveas(gcf,
'Step6_Harmonic_Compensation.png');

%% Step 7: Simulate SAPF Compensation

Vdc = 400;

Lf = 5e-3;

inv_gain = Vdc/max(abs([harmonic_la; harmonic_lb; harmonic_Ic]));

inverter_la = harmonic_la * inv_gain;

inverter_lb = harmonic_lb * inv_gain;

inverter_lc = harmonic_Ic* inv_gain;

compensated_la = la - inverter_la;

compensated_lb = Ib - inverter_lb;

compensated_lc = Ic - inverter_Ic
% Plot Compensated Currents

figure;

subplot(3,1,1); plot(time_vector, la, 'b'); hold on; plot(time_vector, compensated_la, 'r'); legend('Original',
'Compensated'); title('Final Compensation - Phase A');
xlabel('Time (s)'); ylabel('Current (A)');

subplot(3,1,2); plot(time_vector, lb, 'b'); hold on; plot(time_vector, compensated_lb, 'r'); legend('Original',
'Compensated'); title('Final Compensation - Phase B');
xlabel('Time (s)'); ylabel('Current (A)');

subplot(3,1,3); plot(time_vector, Ic, 'b'); hold on; plot(time_vector, compensated_Ic, 'r'); legend('Original',
'Compensated'); title('Final Compensation - Phase C');
xlabel('Time (s)'); ylabel('Current (A)'); saveas(gcf,
'Step7_Final_Compensation.png');
```

```
%% Step 8: Integrate Solar Panel
P_solar = 1000;
V_solar = 400;

I_solar = P_solar / V_solar; I_solar_converted = I_solar* efficiency; efficiency =
0.95;
% Plot Solar Contribution figure;
plot(time_vector, I_solar_converted * ones(size(time_vector)), 'k--', 'LineWidth', 2);
title('Solar Panel Contribution'); xlabel('Time (s)'); ylabel('Current (A)'); legend('Solar
Output');
saveas(gcf, 'Step8_Solar_Contribution.png');
%% Step 9: Summary Plot of All Steps - Phase A zoom_range = (time_vector >= 0.2) & (time_vector <=
0.3);

figure('Name','Integrated SAPF Summary - Phase A', 'Position', [100 100 1200 800]); subplot(4,2,1);
plot(time_vector, la, 'b'); title('Original Phase A'); xlabel('Time (s)'); ylabel('A'); subplot(4,2,2);
plot(time_vector, filtered_la, 'r'); title('Filtered Phase A'); xlabel('Time (s)'); ylabel('A'); subplot(4,2,3);
plot(time_vector, ref_la, 'g'); title('Reference Phase A'); xlabel('Time (s)'); ylabel('A'); subplot(4,2,4);
plot(time_vector, harmonic_la, 'm'); title('Harmonic Component A'); xlabel('Time (s)'); ylabel('A');

subplot(4,2,5); plot(time_vector, compensated_la, 'r'); hold on; plot(time_vector, la, 'b');
legend('Compensated','Original'); title('Full Time - Compensated Phase A'); xlabel('Time (s)');

subplot(4,2,6); plot(time_vector(zoom_range), compensated_la(zoom_range), 'r'); hold on;
plot(time_vector(zoom_range), la(zoom_range), 'b'); legend('Compensated', 'Original'); title('Zoomed -
Compensated Phase A'); xlabel('Time (s)');

subplot(4,2,7:8); plot(time_vector, I_solar_converted ones(size(time_vector)), 'k--','LineWidth', 2);
title('Solar Output Used for Compensation'); xlabel('Time (s)'); ylabel('Current (A)');

saveas(gcf, 'Step9_Integrated_Summary_PhaseA.png');

%% Save Data save('SAPF_Compensated_Currents.mat', 'time_vector', 'compensated_la',
'compensated_lb', 'compensated_Ic'); T = table(time_vector', compensated_la, compensated_lb,
compensated_Ic, ... 'VariableNames', {'Time', 'Compensated_la', 'Compensated_lb', 'Compensated_lc'});
writetable(T, 'Compensated_Currents.txt');

VariableNames', {'Time', 'Compensated_la', 'Compensated_lb', 'Compensated_Ic'}); writetable(T,
'Compensated_Currents.txt');

disp('SAPF with PI Control, Solar Panel, Inverter, and Inductor implemented. Results and plots saved.');
```

VII. OUTPUT RESULTS

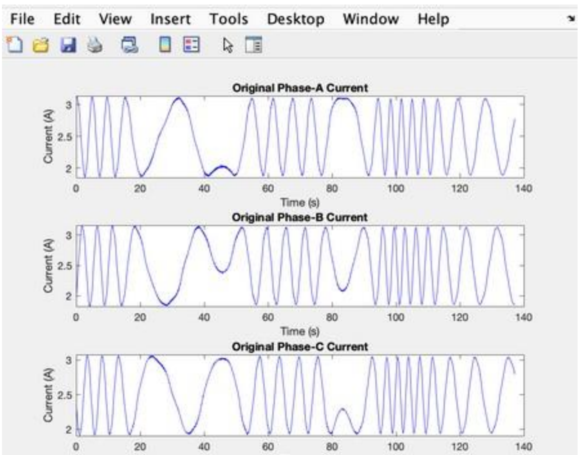

Fig.1 Original currents

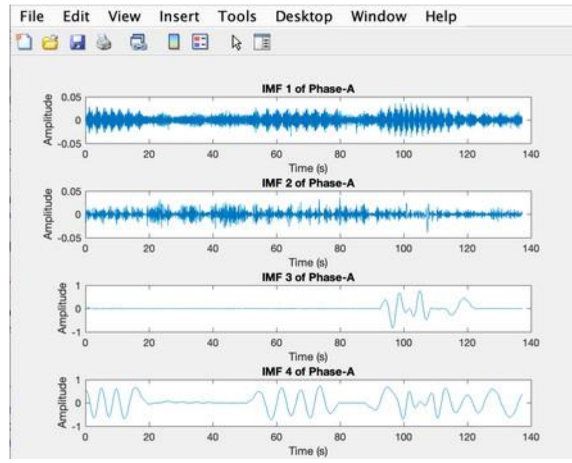

Fig.2 Different IMFS

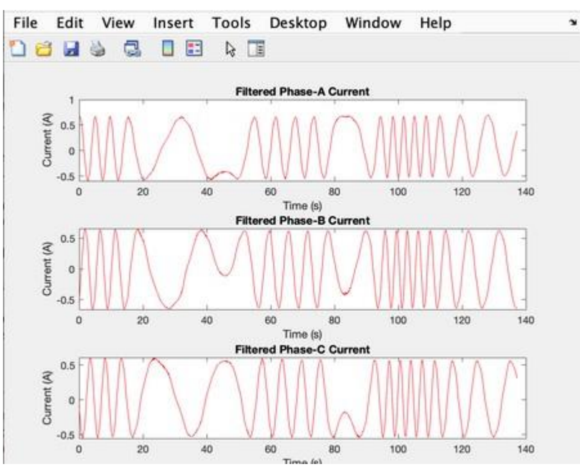

Fig.3 Filtered currents

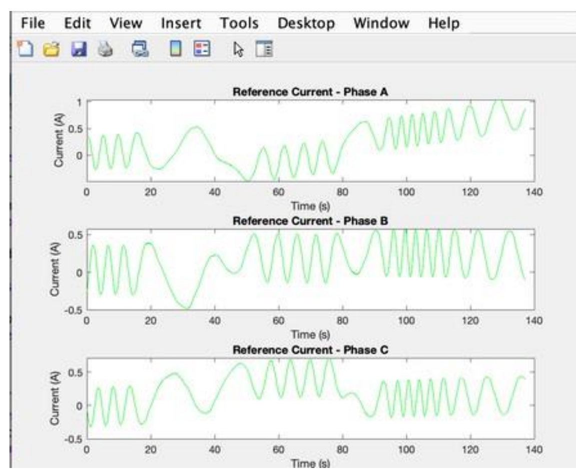

Fig.4 Reference currents

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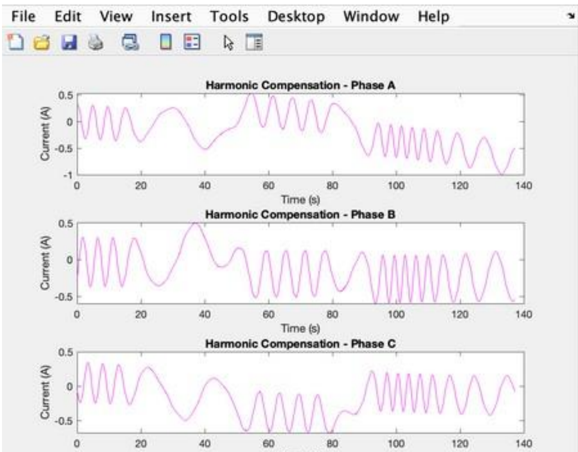


Fig.5 Harmonic Compensation

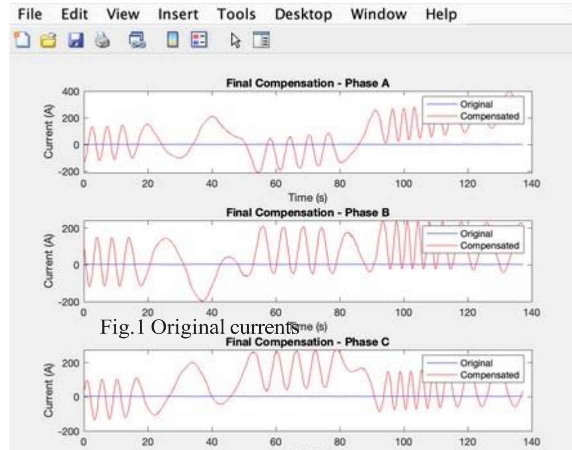


Fig.6 Final Compensation

OUTPUT RESULTS

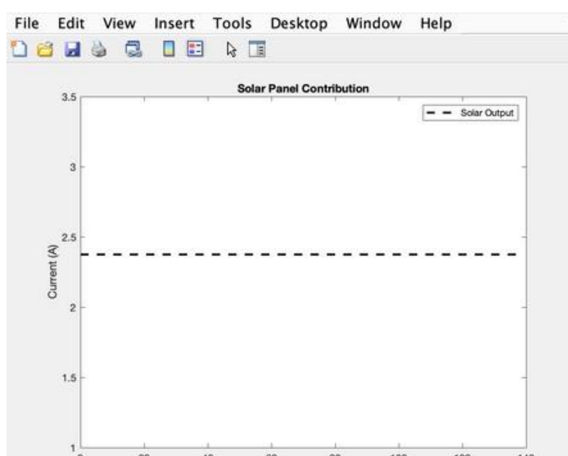
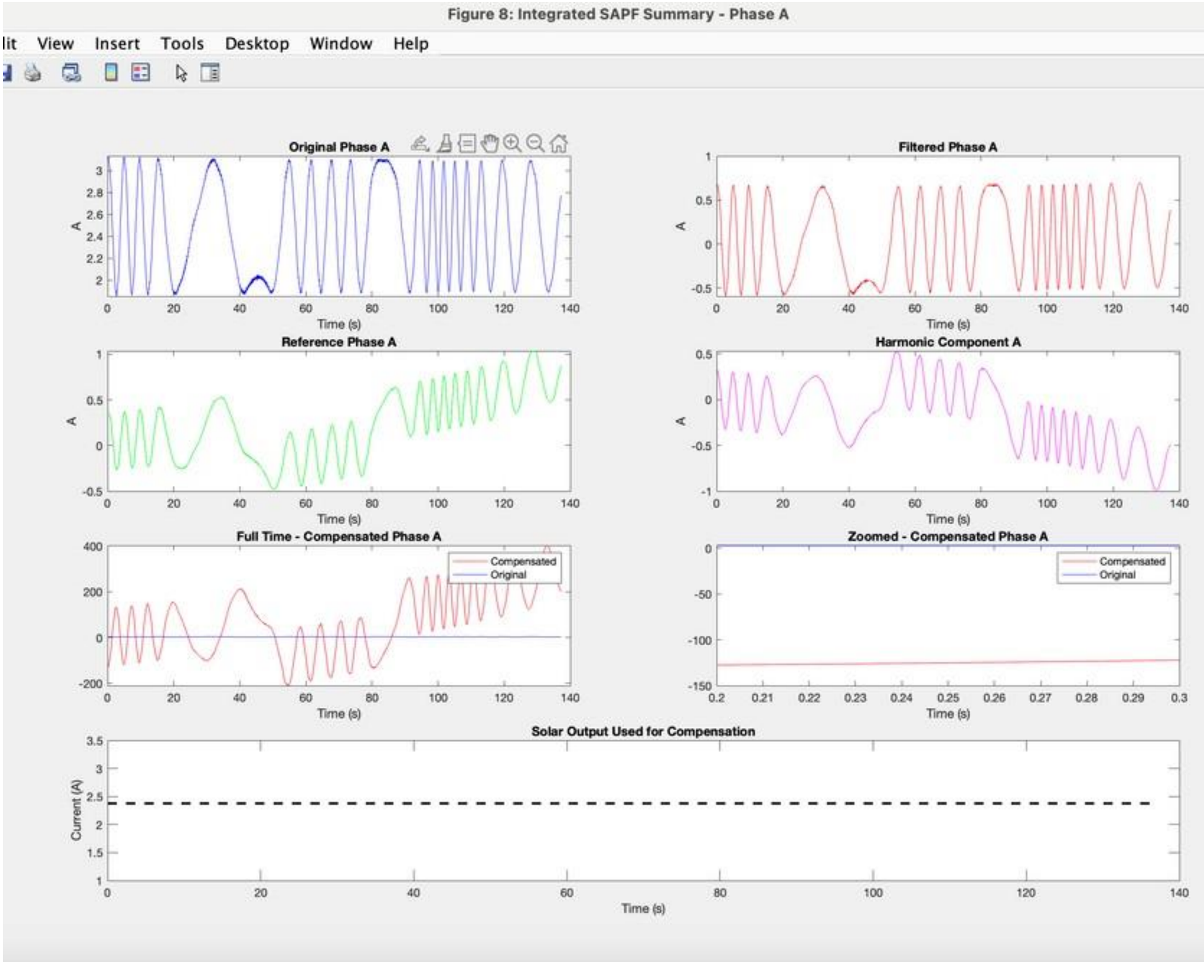


Fig.7 solar panel Contribution



Final output showing Filtered current with each stage involving

VIII. CONCLUSION AND FUTURE SCOPE

The implementation of an Empirical Mode Decomposition (EMD) based algorithm in a Shunt Active Filter (SAF) integrated with a solar power system effectively enhances power quality by dynamically identifying and eliminating harmonic distortions and reactive power components. EMD enables precise extraction of fundamental and non-fundamental components from load currents, allowing the SAF to generate accurate compensation signals. When applied in a solar-integrated system, the EMD-based SAF also aids in managing power fluctuations due to variable solar input, ensuring cleaner and more stable power delivery to the grid or load. The results demonstrate improved Total Harmonic Distortion (THD) levels and better power factor correction, validating the effectiveness of this approach in real-time conditions.

Real-Time DSP/FPGA Implementation:
Implementing the EMD algorithm on a Digital Signal Processor (DSP) or FPGA for real-time control can make the system suitable for commercial and industrial deployment.

Integration with MPPT:

Combining EMD-based SAF with Maximum Power Point Tracking (MPPT) algorithms can optimize both power quality and solar energy extraction.

Hybrid Power Systems:

Extend the approach to hybrid systems involving wind, battery storage, or fuel cells along with solar to enhance power management in microgrids.

Machine Learning Integration:

Use machine learning models to predict load profiles and solar variations

Hardware-in-the-loop (HIL) Testing:

Perform HIL testing to validate the performance of the proposed system under realistic grid

Grid-Tied Smart Inverter Design:

Integrate the SAF with smart inverter technology for bidirectional power flow and smart grid compatibility.

IX. REFERENCES

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