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An Energy Efficient Green Plug Filter Compensation Scheme for Hybrid Nonlinear Loads

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***Abstract* – This work presents a switched modulated filter compensation/modulated filter capacitive compensator (SFC/MFCC) scheme to improve electrical energy utilization, enhance power quality and reduce excursions on Distribution/Utilization hybrid linear and nonlinear/inrush type motorized loads on the AC electric utility systems. The dual pulse width modulated (PWM)-switched SFC/MFCC does function as harmonic mitigate tuned arm filter plus reactive compensation device for hybrid linear/ nonlinear/ motorized loads. This is achieved by complementary modulation of switching PWM action controlled by multi loop fuzzy logic controller. The pulse modulation is determined in each control time step by the aggregate sum of deviation errors in voltage and dynamic current/ power changes. The novel FMCC-SFC filter can be extended to other interface applications of nonlinear DC-AC grid systems and customized to voltage dynamic stabilization and voltage regulation tasks on AC grid systems.**

***Keywords* – SFC/ MDC Switched Filter, Dynamic Compensation Scheme, Fuzzy Logic Controller, Power Quality, Energy Efficient Utilization Nonlinear Loads.**

I. Introduction

The most of problems with power quality have become increasingly significant in electrical power transmission and distribution systems over the last two decades. This issue has been exacerbated by the growing adoption of renewable energy sources, such as distributed generation, in modern electrical networks. These changes have brought about a notable transformation in the operation of the electrical system [1, 2].

Additionally, Flexible AC Transmission System (FACTS) devices are power electronics-based devices that are designed to control and manage the flow of power on electrical grids and the best method to improve power quality. They can be dynamically adjusted to regulate voltage levels, control power flows, and stabilize system parameters. This makes them valuable tools for power frequency and improving the overall quality of electricity distribution [3, 4].

The use of FACTS components is the main goal to increase transfer capacity and ease the integration of renewable energy sources. The goal is to create a technique that, considering variables like voltage stability, power flow regulation, and transient stability, picks, and positions FACTS devices along the transmission line optimally [5, 6]. Also, FACTS uses fuzzy logic control as the PWM dynamic switching/regulation scheme to improve power quality and energy consumption for three-phase system loads. In contrast to other traditional PID controllers, it provides significant advantages. The benefits of FLC includes ease of use, affordability, and adaptability in the occurrence of an uncertain load with an unknown mathematical model or process dynamics. Problems relating to power quality [7].

Currently the most important power electronics, such as adjustable speed drives (ASD), energy-efficient light emitting diodes (LED), and programmable logic controllers (PLC), widely used in electronic equipment, have resulted in severe nonlinearity and a wide variety of electric load natures [13].

However, regardless of the power factor, the generating authority must install equipment capable of delivering a specific voltage and current even though, in a particular case, most of the voltage and current products will not be used effectively for increasing efficiency. Reactive compensation using capacitors increases power factor and lowers harmonic content in Nonlinear- load current. A modulated/switched-tuned arm filter (MFCC) is used to reduce harmonic currents, cut costs, and simplify filter design. Filters are primarily designed to reduce harmonic content to enhance power quality. The primary purpose of passive filters' characteristics is to improve power factor correction by reducing current harmonics. Passive filters have the drawback of being unable to adapt to the dynamic behavior changes of non-linear loads [8].

In order to reduce feeder active and reactive power. Harmonics well increase response on the electrical system to open, short circuit operation and load changing due to faults and load switching, fixed, switched, and modulated capacitor banks have been widely used in modern electrical system [5, 6]. Harmonics and dynamic switching excursions can result in electric equipment failure, malfunction, hot neutral, ground potential use, fire, and shock hazard in addition to poor power factor and inefficient utilization of electric energy manifested in increase reactive power supply to the hybrid load, poor power factor and severely distorted voltage and current waveforms. To improve efficiency, capacitors are employed which also leads to the improvement of the power factor of the mains [9, 41, 11, 12, 13].

While fixed power filters and capacitor banks have their place used to improve power quality by reducing harmonics and reactive power in electrical systems. Also, in improving power quality, they do have limitations when dealing with dynamic loads and potential resonance issues. Advanced solutions like active power filters and tuned passive filters offer more effective means to handle these challenges in industrial utilization networks [10, 8].

In this paper a new Low-Cost Flexible Alternating Current Transmission System FACTS -DVS/GP Device is validated using Matlab-Simulink Software Environment with a new fuzzy logic controller for voltage stabilization and efficient energy secure delivery to the load. The new FACTS-DVS/GP developed by the First Author utilized switches to implement dynamic error driven control strategies for improved response.

II. Literature View

R Betala looked at power factor issues at fast EV charging stations that were due to the switching of supplies in power electronics. The author proposed improving the power factor by utilizing an Active Power Factor Correction (APFC). This approach is based on a fuzzy logic fractional order controller that optimizes the input power factor and decreases harmonics distortion. The APFC has the potential to be applied more broadly in, for instance, 3-phase systems to enhance power consumption benefits and the power factor. R Raja, LJ Nirmal, PK Mani highlighted the significance of power quality concerns for engineers and power companies, emphasizing the role of devices like Dynamic Voltage Restorers (DVRs) to mitigate disruptions and enhance power stability in distribution networks, demonstrated through MATLAB/Simulink simulations [11]. The article focuses on the benefits of the CHB-DVR system for improving power quality on the distribution side, emphasizing its ability to mitigate voltage fluctuations, harmonics, and outages, and highlighting its potential for enhancing power stability and efficiency in industrial and commercial settings while suggesting future research directions including advanced control strategies and the integration of storage systems for increased reliability [12]. KYW Hong tested a "plug-and-play" AI-based framework for extracting real-time filter parameters as digital power control. The framework functions without any hardware modifications or extra sensors, instead using an LSTM network and a predefined control law. The model, which obtained reasonably accurate results for different filter orders, was also tested on a buck DC/DC converter set at various filter configurations [13].

Y Xu, B Zhou, W Wei, L Jiang, X Sun, T Zheng study introduced an energy storage control strategy for AC/DC hybrid systems after DC fault blocking, enhancing safe operation through a double-layer control approach, evaluated using a DC power transfer influence factor, and validated via simulations on a power grid model, demonstrating improved system stability and suppression of power oscillations. The article introduced an energy storage control strategy using DC power transfer factor evaluation in an AC-DC hybrid system after a DC fault, demonstrating improved AC system stability through energy storage's quick impact mitigation on AC lines and a double-layer control approach, validated using CEPRI36V7 power grid model simulations [14].

S Benisha, JA Roseline, K Murugesan, D Lakshmi, G Ezhilarasi, and P Muthukumar presented a costeffective approach using power factor correction (PFC) and a Cuk converter to improve power quality in low voltage applications integrated with a brushless DC motor (BLDC) drive and voltage source inverter (VSI) for reduced switching losses, with effectiveness evaluated across different modes and conditions through MATLAB/ Simulink simulations. A Cuk converter-driven BLDC motor is designed to achieve unity power factor, utilizing various operating modes in continuous and discontinuous conduction modes (CCM and DCM), with experimental validation favoring the DICM mode for improved power factor correction in low-power equipment [15]. A Busacca investigated experimentally the harmonic content and efficiency in a Cascaded HBridges Multilevel Inverter, using several different modulation methods. The author explored the effects of frequency switching on both harmonic distortion and efficiency for a 3-phase 5-level CHBMI prototype. The author also looked at different PWM techniques and modulation indices, discovering the differential sensitivity found in PD-, SCAMOD-, and CD-based schemes about harmonic distortion/efficiency and frequency switching [16].

W Miao, Y Yijun, S Lue, S Bo, H Haiyu presented a method deriving line outage distribution factors for N-2 double branch power flow transfer that enables rapid and accurate calculation of active power flow transfer after dual branch breaks, demonstrated through IEEE 39 bus system simulations, offering practicality for N-2 contingency assessment and power generation plan verification. The study addressed cascading faults' impact on power grid safety; the study developed a formula for calculating the N-2 power flow transfer distribution factor from N-1 outage factors, enabling quick active power flow assessment after dual line breaks, analyzing coupling effects and proposing a grid disconnection judgment method, with accurate simulation results suggesting applicability for N-2 contingency assessment and power system planning. At the same time, future work focuses on refining accuracy by considering grid loss and reactive power flow effects [17]. K Vinodhini, A. Sobiya, M. Gengaraj, M. Nanthini, M. Subashini, and L. Kalaivani addressed power quality challenges. The paper introduces a Fuzzy Logic Controller (FLC)-based boost converter for power factor correction aiming to enhance power factor, reduce harmonics, and regulate output.

Voltage in power systems, demonstrated through MATLAB/Simulink simulations, with controller robustness validated against traditional controllers. In an industrial combined power system, the proposed boost converter with a fuzzy logic controller improves power factor, reduces harmonic distortion, and provides regulated output voltage for enhanced overall system performance, presenting a viable and economical solution for industrial applications with the potential for further stability enhancement using advanced techniques like neural networks [18].

R Patil, RT Ugale study assessed AC-DC converter topologies for electric vehicle (EV) battery charging, focusing on boost converter-based power factor correction options such as traditional boost, interleaved boost, and bridgeless totem pole boost converters, aiming for high efficiency, good power factor, and compliance with IEEE Standards, simulated using Matlab/Simulink for universal AC input voltage and 400 V DC output. The paper presented power factor correction solutions using boost converters for EV battery chargers, comparing performance through circuit simulations; the results show interleaved boost PFC has lower harmonic distortion, bridgeless totem pole boost PFC has higher efficiency, achieving unity power factor, and the latter outperforms other boost PFC topologies for EV battery charging applications at 1 kW output power and 100 kHz switching frequency [19].

KRS Vadivu, A Anbazhagan, P Abirami, and RH Laitha investigated three-level full bridge power factor correction (PFC) converter's power quality parameters using different control strategies, namely Sliding Mode Controller (SMC) and Average Current Control (ACC), through simulations on MATLAB/Simulink. ACC demonstrates superior power quality results, achieving a power factor of 0.993 and THD of 0.12% while maintaining stability under varying line and load conditions. A Single-Stage Power Factor Correction (SSPFC) converter is designed with cascaded control loops using Sliding Mode Controller (SMC) and Average Current Control (ACC), resulting in enhanced power quality in terms of Total Harmonic Distortion (THD) and input Power Factor (PF), where ACC performs better with a PF of 0.9977 and reduced THD of 0.04%, even under variations in input voltage and load conditions, meeting IEEE-519 standards [20]. L. Sarker studied an interleaved, bi-phase, boost PFC topology, aiming to decrease harmonics and enhance power quality during the process of EV charging. The author proposed a 6-kW interleaved bi-phase boost PFC converter-based EV char- -ging system to satisfy IEEE 519-2019 standards. Regarding efficiency and Total Harmonic Distortion (THD), Sarker's model outperformed single-phase boost PFC systems as well as non-PFC ones [21]. M. Boutoubat's study investigated ways to control a wind energy conversion system (WECS). The author proposed using a Grid Side Converter (GSC) and regulating a Stator Side Converter (SSC) for MPPT as a means to stabilize DC voltage as well as improve the power factor. This would be achieved by building a cascade converter setup, thereby improving power quality and active power production [22]. I.S. Mohamed proposed a novel control strategy that combined a feed-forward Artificial Neural Network (ANN) and Model Predictive Control (MPC) for bi-level converters. The author aimed to improve performance and voltage quality for diverse loads by decreasing the THD. By conducting simulations under different operational conditions, Mohamed demonstrated that the model showed reasonably good efficiency in comparison with standard MPC [23].

III. System Description

Figure 1 illustrates the three-phase AC usage system supplying loads. Figures 3 and 4 depict the proposed novel dynamic error-driven tri-loop FLC applied to lower switching transients, current inrush excursions, as well as in the low voltage utilization system for effective power/energy utilization and power quality improvement for the type of load depicted in [24, 5]. The AC Three-phase system grid network is shown in Fig.

1. It comprises a synchronous generator (driven by Source) delivers the power to a local hybrid load (Linear, Induction Motor and DC ARC Load) and is connected to an infinite bus through 8km transmission line. The AC system consists of:

1. Three-phase AC Source.
2. Novel Modulated Filter-Capacitor compensator MFCC scheme.
3. Hybrid Nonlinear Load.
4. Transformer.
5. Transmission Line.

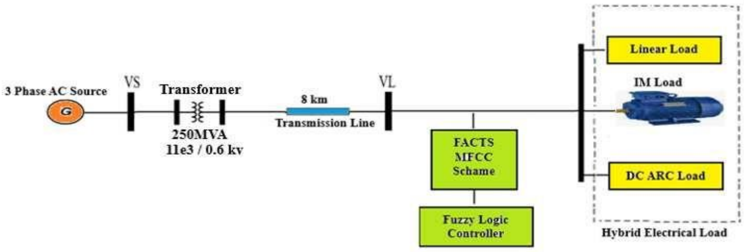


Fig. 1. Single-line diagram of the sample study AC system.

Power Transmission Efficiency and Power Factories that the efficient power transmission is a cornerstone of the modern electrical grid. Minimizing losses and maintaining reliability play a crucial role in providing a stable and cost-effective electricity supply to end-consumers while also contributing to sustainable energy practices [27]. Active power loss reduction strategies with power factor regulation efforts can lead to a more efficient power transmission system [25, 26]. The best way to ensure high efficiency is to minimize the active power loss during the power transmission process. At the same time, regulating the power factor (PF) is crucial during power transmission, as the PF contributes substantially to transmission efficiency [28, 29].

Transmission efficiency:

$$\eta_T = \frac{Receiving\ end\ power}{Sending\ end\ power} X\,100 \quad (1)$$

$$= \frac{VRIR\ \cos\phi R}{VSIS\ \cos\phi S} X\,100 \quad (2)$$

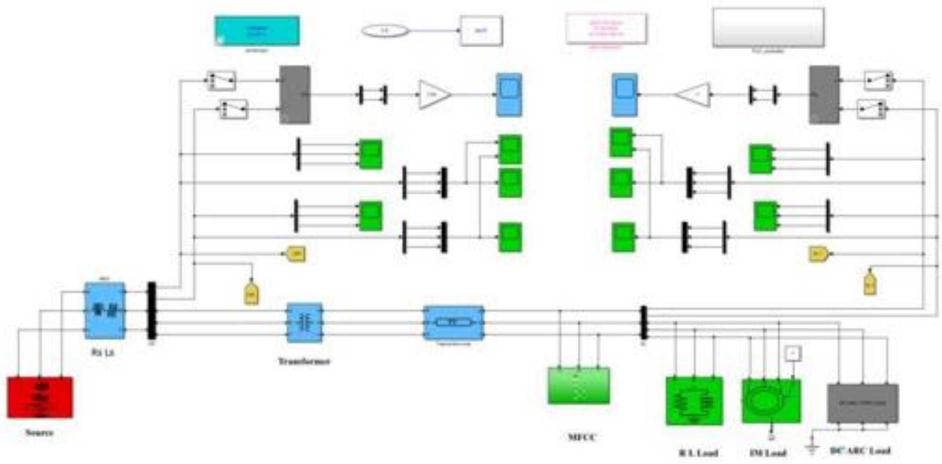


Fig. 2. Three Phase with Fuzzy Logic Controller and Hybrid Load.

IV. MFCC-Filter Compensator

The FACTS technology is used to enhance the efficiency, reliability, and control of power transmission in AC systems. One of the aspects of FACTS is the harmonics mitigation and power quality improvement in threephase systems. The IGBT switches are used in this work and controlled by two complementary pulses. Therefore, the equivalent admittance of the MFCC circuit can be changed with different operating states. If switch S1 is opened and S2 is closed, the resistor and indicator will be connected into the circuit. If switch S1 is closed and S2 is opened, the resistor and inductor will be shorted, which three phase capacitor bank will procure a capacitive admittance as seen in Figure 3. The IGBT switches are controlled by a novel tri-loop dynamic error driven PID controller [30, 31, 32].

In this context, FACTS system that incorporates a switchable type of capacitor bank can indeed play a crucial role in reducing the system harmonics. The MFCC is also controlled to absorb ripples and reduce current oscillations [33]. The idea behind the dynamic controller is to maintain stable voltage and current levels in the system and feed the errors to the SPWM and generate a series of pulses whose widths are adjusted to create a waveform that resembles a sine wave. SPWM is commonly used in applications like motor drives and power inverters with the duty ratio and the error value for renewable energy systems [34]. The MFCC used and tested with 3 Phase system is shown in Figure 3. The MFCC control scheme is based on decoupled current and voltage components of the Bus.

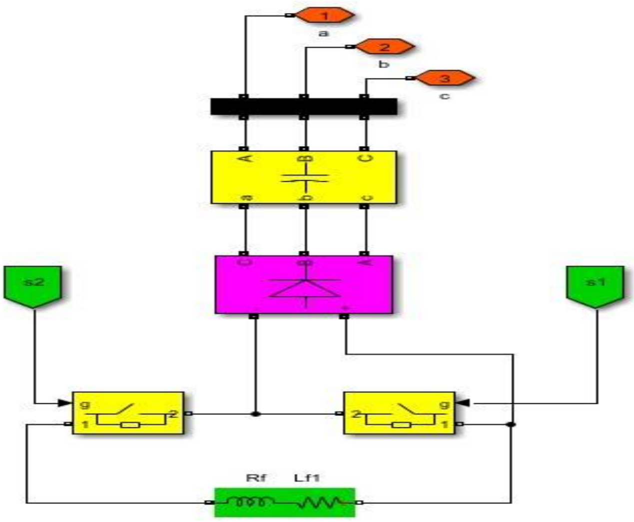


Fig. 3. MFCC Switched Green Plug-Filter Compensator (SFC) scheme.

The increased power with higher voltage and current ratings of power electronic converters used in MFCC also allows for adequate sizing and optimized operation [35, 36]. In this paper, the effectiveness of the MFCC scheme is fully validated using MATLAB /Simulink digital simulation. All the subsystem components are submodelled individually using the MATLAB /Simulink GUI environment and linked to determine the overall system model. The simulation of the proposed scheme has been carried out, and the dynamic performance of the system is tested for the proposed controller.

The MFCC must be connected across the Bus terminal to maintain constant voltage to allow the operation of the voltage source converter (VSC) with two control loops as shown in the Simulink model in Figure 3. The main duty of the capacitor bank is to feed the voltage path and current path as shown in Figure 4. The input of control loop 1 is the dynamic voltage change in the Bus, which produces an error with recognize to the measured value and then the error is used for voltage adjustment. The input to loop 2 is the dynamic current Bus, which has the same transfer function as the voltage loop [37, 38]. Renewables are playing a crucial role these days in the main grid. Renewables are intermittent, nonlinear and fluctuating and this affects its integration into the main grid [39-41]. One of the main disadvantages of renewables is the inertia problems. Most renewables are disconnected from the main grid during fault conditions due to the negative impact on the reactive power [42-45]. One of the advantages of the proposed compensator is to use it with renewables to reduce the faulted condition impact on the main grid.

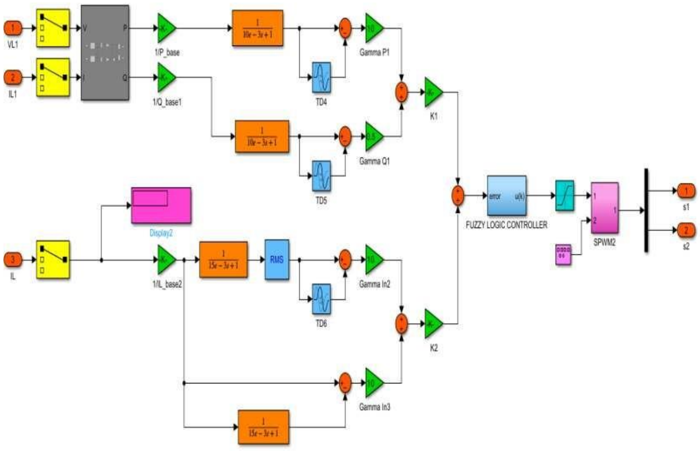


Fig. 4. Dynamic Error Driven Tri-regulation Controller.

V. Fuzzy Logic Controller

The Membership Functions are the basic elements of the fuzzy logic controller (FLC). Triangular membership functions are used in this study [39, 40, 25]. The input comes from the membership values of space necessary for the weight coefficients of each rule which are determined based on minimums [48-50]. After determining the weight coefficients of the required unit of blurring, the rules for multiplying these values are sent to the processed parts. The Fuzzy Logic Controller uses the exact method of de-fuzzification unit values to obtain the central areas. FLC systems design proceeds according to the logic block error feedback and input directly or by reference also is possible to perform data processing [51-54]. FLC will determine whether the limits of membership functions can be determined, as shown in Figure 5.

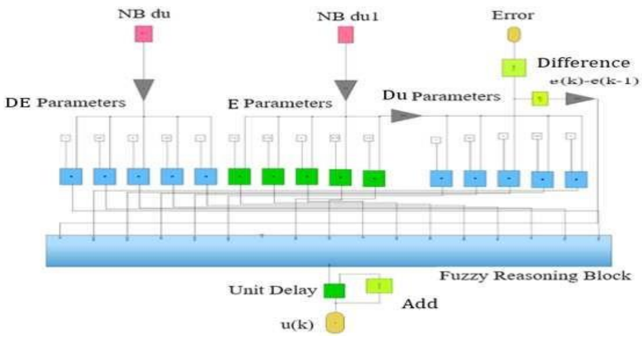


Fig. 5. Fuzzy Logic Controller MATLAB/Simulink Block Model Structure.

In Figure 6. There are elements of linguistic control rule base and database. Rules are processed in the fuzzy defuzzification unit to influence the result, which is sent to mark out the next step. Here are produced definitive results. In Figure 6 E(k) the error signal, e(k-1) refers to the change of error in a sampling period. M1, M2, and M3 are gain values. Du(k), clarifying a previous value of unit output and the D(k-1) gathered with D(k) are obtained and input of the system is given. These variables are produced according to the rule base unit rule table.

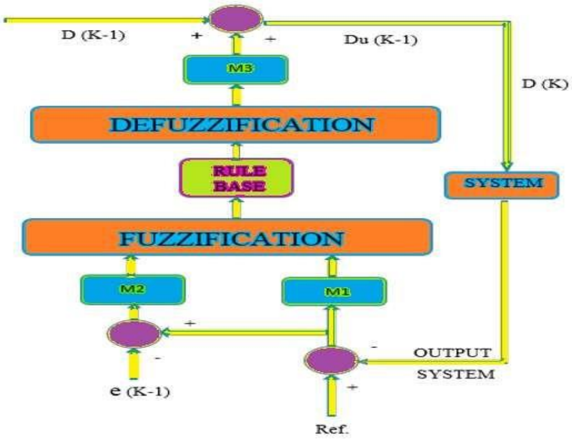


Fig. 6. block diagram of structure of fuzzy logic controller.

A basic structure of fuzzy controller membership functions has been used. The selection is completely arbitrary functions of membership triangle, trapezoid, sinusoid, Cauchy, bell, sigmoid, Gaussian types [55,56]. FLC is usually the input variables, control error (e), and the duration of a sampling error change (Δe) form. FLC according to these variables of the rule base unit, a rule table is created as shown in Table 1. Detailed description of the establishing the rule is presented in [57-60].

Table 1. FLC rules.

		Δe				
		NB	NS	Z	PS	P
e	PB	Z	PS	PS	PB	PB
	PS	NS	Z	PS	PS	PB
	Z	NS	NS	Z	PS	PS
	NS	NB	NB	NS	Z	PS
	NB	NB	NS	NS	NS	Z

(e-Δe) Rule Assign Matrix (5X5 = 25).

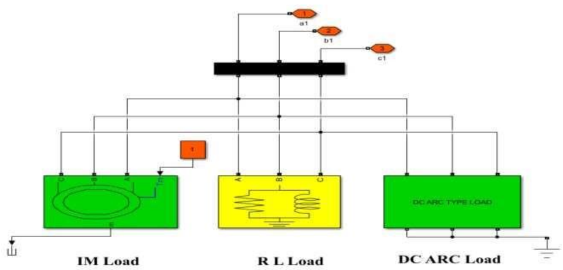


Fig. 7. Hybrid Loads feed by AC Smart Grid.

VI. Results Simulation and Discussion

Digital simulation results using the MATLAB/Simulink/Sim-Power software environment to verify the dynamic effectiveness of the introduced the 3-phase system for the proposed MFCC-based SFC scheme with feeding three types of industrial loads are presented here:

1. *Normal Operating Conditions using Time Scale from 0.0 to 0.4 Second on a Step of 0.05 Seconds:*

The integrated AC system model is dependent on the hybrid loads disturbances. The digital simulation dynamic responses at the source side is shown in figure 8 and Figure 9 depict the digital responses at the load bus without using the proposed filter. Figures 10 and 11 show dynamic responses at the source side and the load bus respectively after using MFCC. As seen from the figures there is an improvement in the dynamic response after using the proposed filter. Tables 2 and 3 show the changes in the voltage, current active and reactive power before and after using the filter. The results indicate that there is an improvement in the voltage, current, reactive power and power factor as indicated in Tables 2 and 3 for two cases based on using MFCC-FACTS device. Table 2 shows the results at the source bus with and without MFCC filter While Table 3 shows the same results but at the load bus. As seen from table 2 there is a huge improvement for the voltage at the source bus by 20% (the voltage is changed from 0.89 to 1.09) and at the load bus by 19% (the voltage is changed from 0.91 to 1.09). The current is also improved from 1.9 to 2.5 at the source bus which means there is an increase in its value by 6 % and the increase in the current at the load bus is around 4%. Also, it is clear that the active and reactive power are improved at both the source and load bus. The active power is increased by 8% at the source bus and by 3% at the load bus while the reactive power is increased at the source bus by 19% and by 7% at the load bus. However, special care should be taken in selecting the MFCC parameters to avoid possible parallel resonance with the induction generator or system inductance. It is clear that there is an improvement in voltage, current and power but the huge impact is in the reactive power increase at the source bus which is considered as an important advantage of MFCC special with the increasing penetration of renewable energy into the main grid as most renewable energy sources are having a negative impact on the grid during fault conditions. Using MFCC improves the performance of the system and increases its robustness, especially during faulty conditions. This is very important feedback especially in the presence of the renewable resources due to the low inertia during faulty conditions because of the dependency on the asynchronous generators and converters that have zero inertia which will affect the overall system performance.

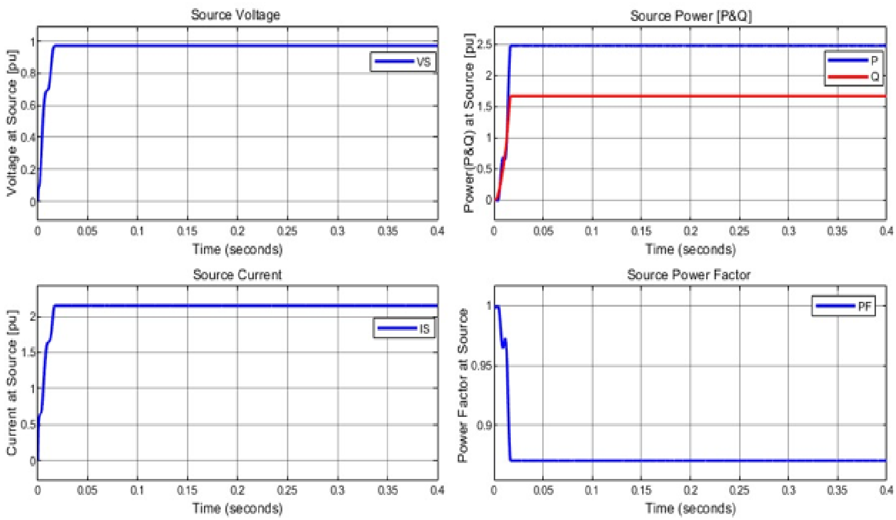


Fig. 8. V, I, P (P&Q) and PF at Source Bus without MFCC Filter and Hybrid Load.

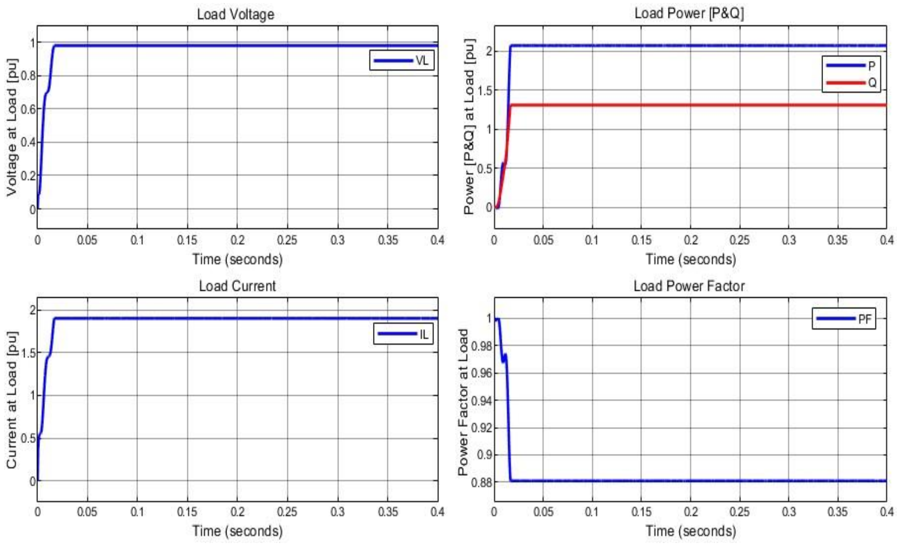


Fig. 9. V, I, P (P&Q) and PF at Load Bus without MFCC Filter and Hybrid Load.

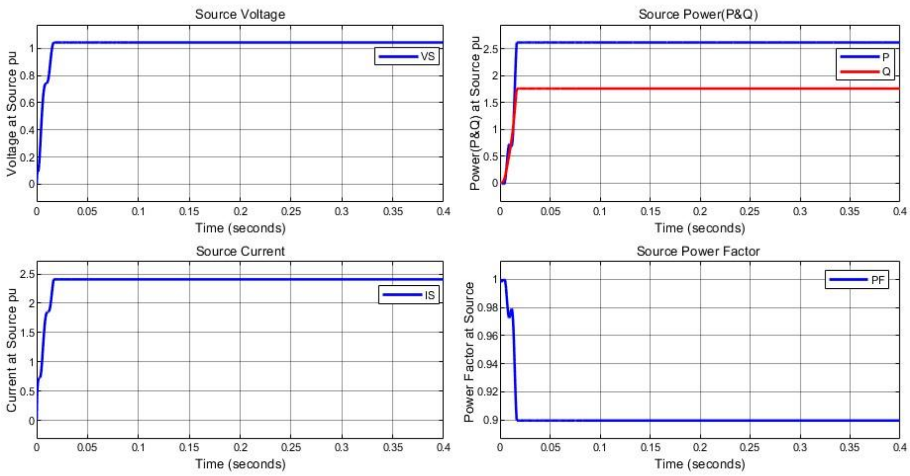


Fig. 10. V, I, P (P&Q) and PF at Source Bus with MFCC Filter and Hybrid Load.

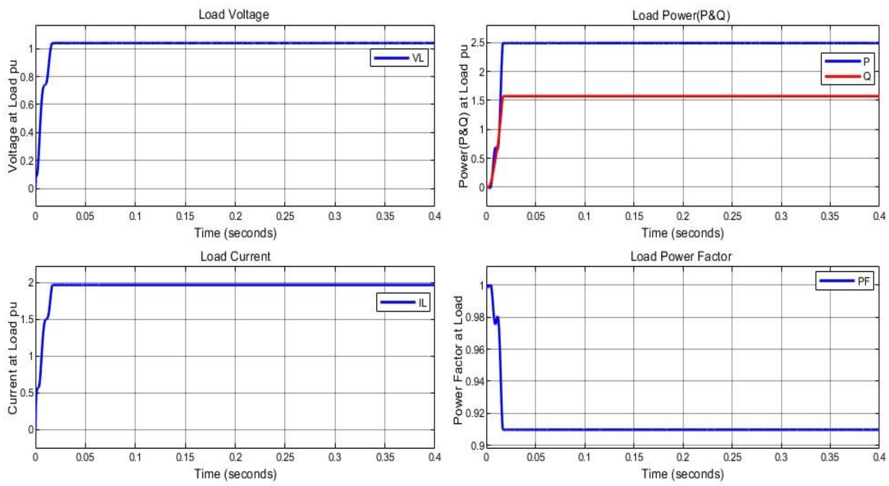


Fig. 11. V, I, P (P&Q) and PF at Load Bus with MFCC Filter and Hybrid Load.

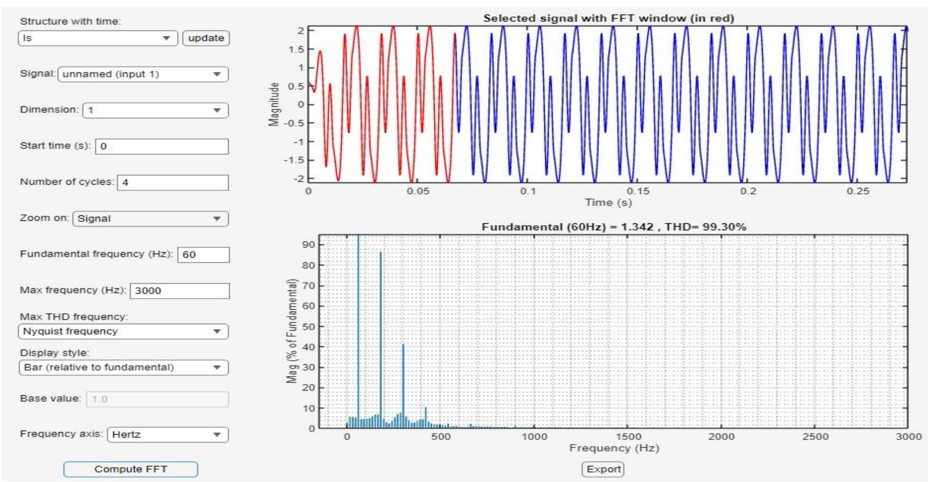
Figures 12 and 13 show the Fast Fourier Transform (FFT) for the current and the voltage at source Bus after using the filter and with the Hybrid Load.

Table 2. Dynamic Simulation Results Without and with MFCC Filter at Source Bus.

Response Name	Without MFCC	With MFCC
Voltage at Source Vs	0.89 pu	1.09 pu
Current at Source Is	2.38pu	2.4 pu
Active power at source bus (P)	2.5 pu	2.58 pu
Re Active power at source bus (Q)	1.52 pu	1.71 pu
Power factor at source bus (PF)	0.87 pu	0.90 pu

Table 3. Dynamic Simulation Results Without and with MFCC Filter at Load Bus.

Response Name	Without MFCC	With MFCC
Voltage at Load VL	0.91 pu	1.09 pu
Current at Load IL	1.95 pu	2 pu
Active power at Load bus (P)	202 pu	2.5 pu
Re Active power at source bus (Q)	1.48 pu	1.55pu
Power factor at source bus (PF)	0.88 pu	0.91 pu



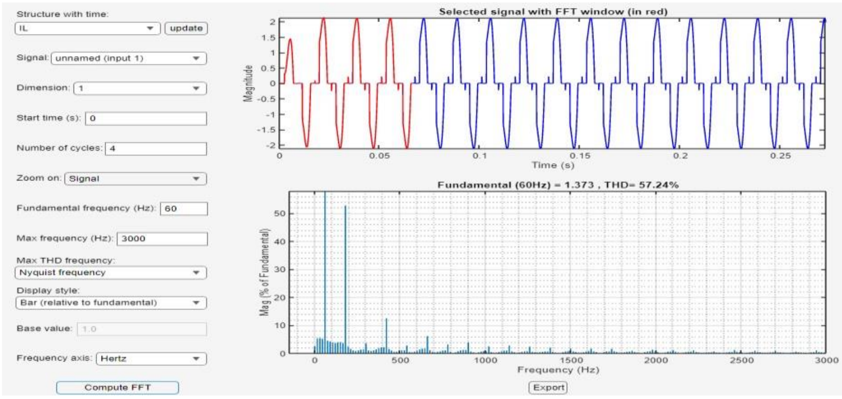


Fig. 12. FFT for Current at Source Bus with Filter and Hybrid Load.

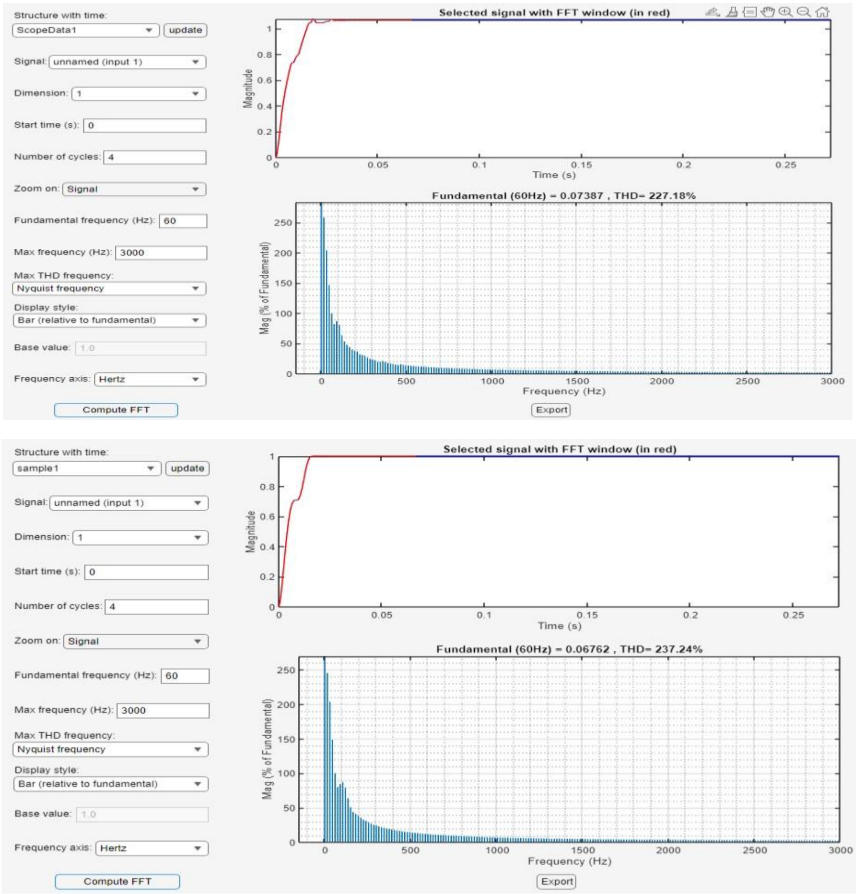


Fig. 13. FFT for Voltage at Source Bus with Filter and Hybrid Load.

In the next section the time scale is extended to 2 seconds to check if there will be further change or not.

2. *Hybrid Load with Extended Time Scale to 2 Second:*

As seen in Figures 14, 15, 16 and 17 the voltage, current and active and reactive power is stable and there is no fluctuation after adding the proposed MFCC for both the source and the load Bus.

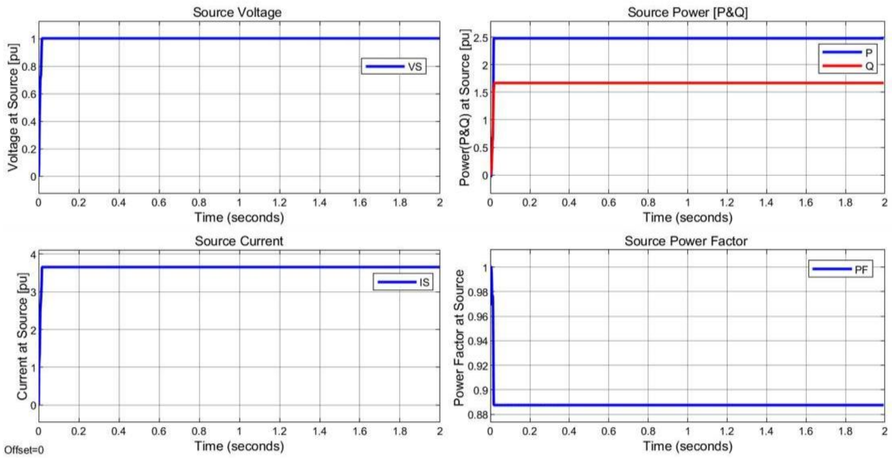


Fig. 14. V, I, P(P&Q) and PF at Source Bus Without Filter and Hybrid Load.

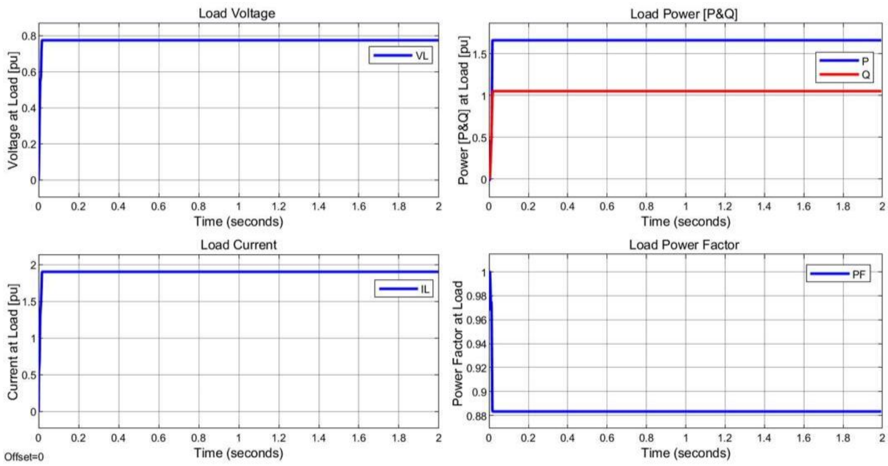


Fig. 15. V, I, P(P&Q) and PF at Load Bus Without Filter and Hybrid Load.

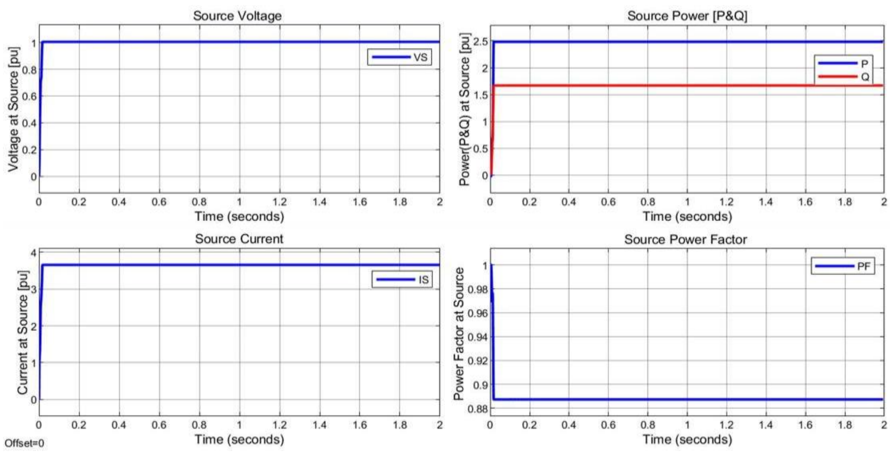


Fig. 16. V, I, P(P&Q) and PF at Source Bus with Filt er and Hybrid Load.

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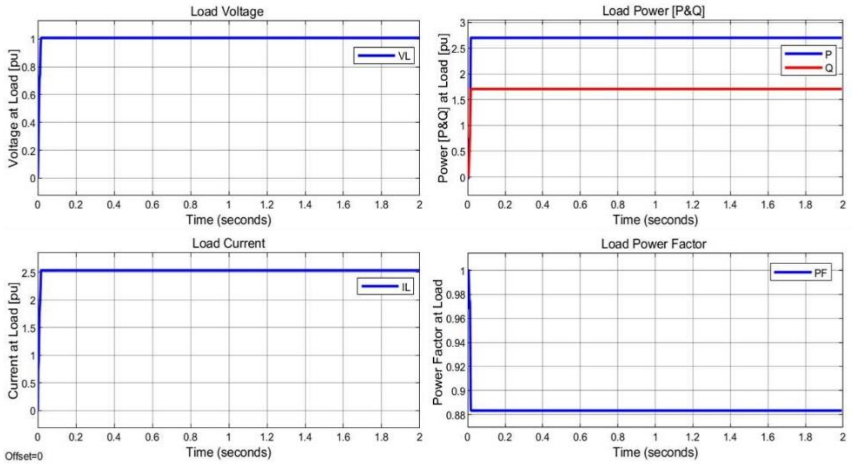


Fig. 17. V, I, P(P&Q) and PF at Load Bus with Filter and Hybrid Load.

Figures 19 and 20 show the FFT for Voltage at Source and load Bus.

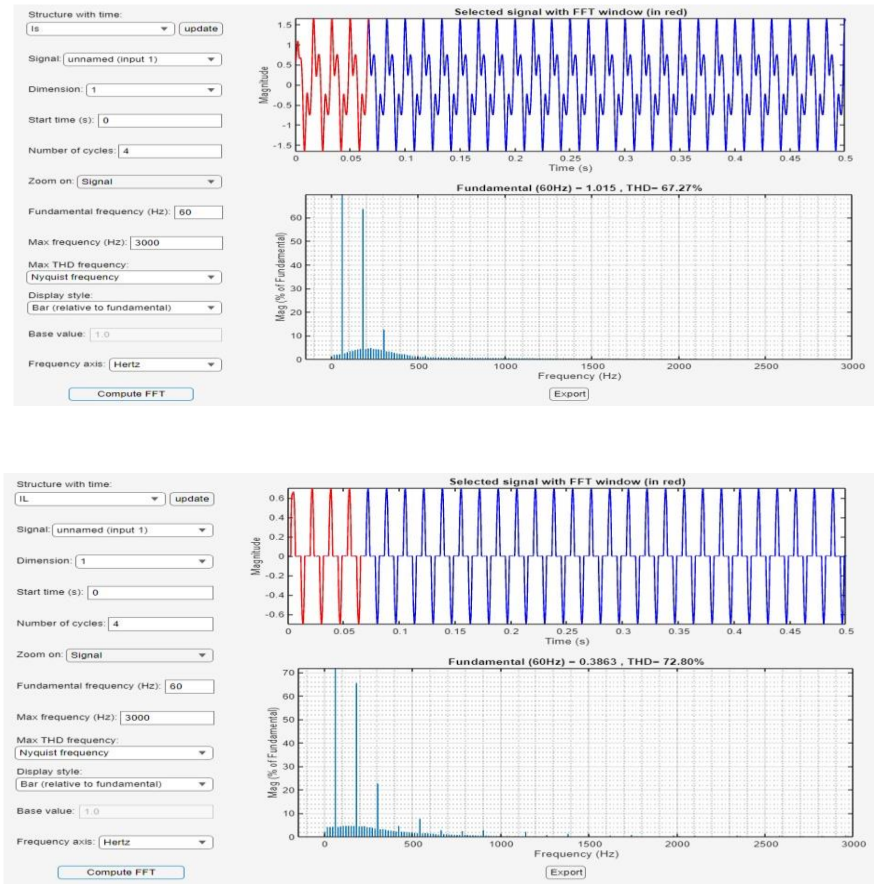


Fig. 18. FFT for Current at Source Bus without Filter and Hybrid Load.

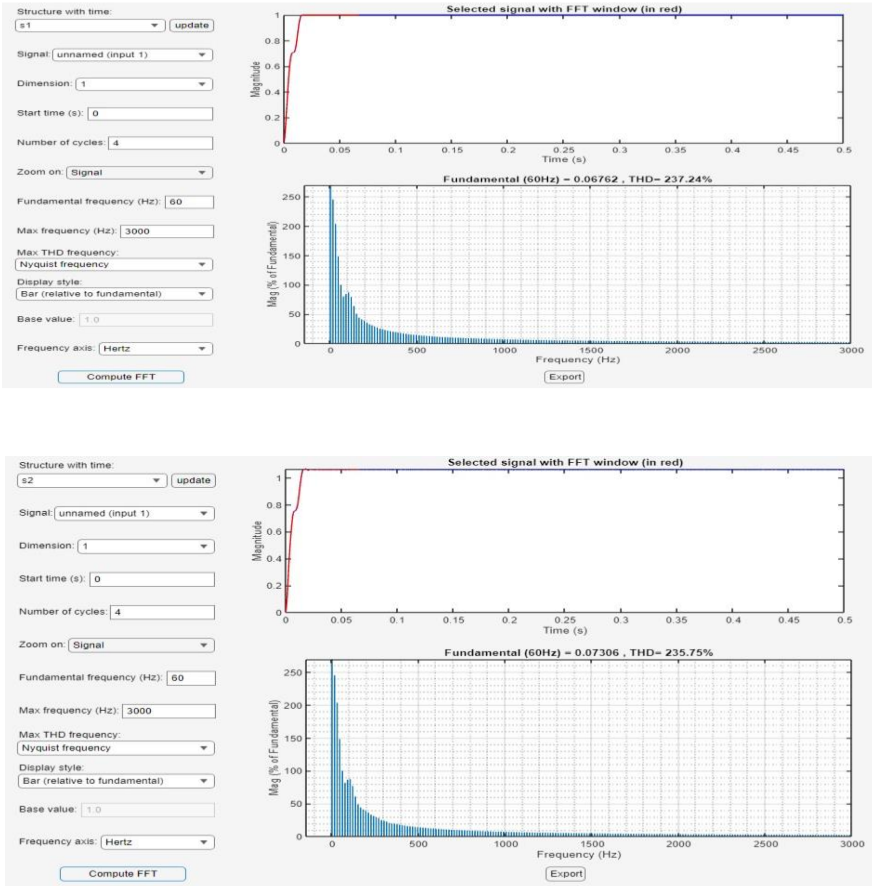
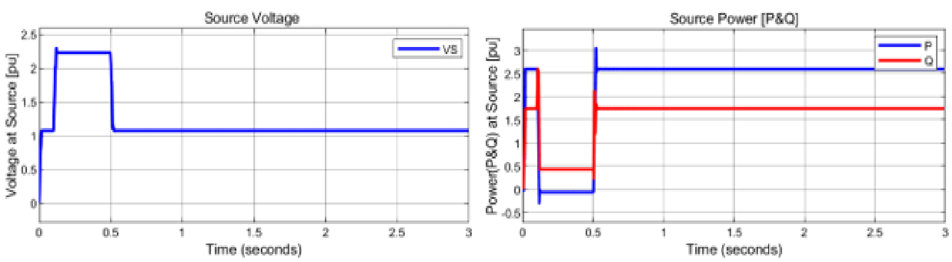


Fig. 19. FFT for Voltage at Source Bus without Filter and Hybrid Load.

3. *Load Changes with Open Circuit (OC) and Short Circuit (SC):*

To examine AC grid response to load excursions in the presence of the MFCC and without MFCC, the following conditions are dictated to the grid. Figures (20 - 25) show the results obtained with hybrid load for voltage, current. Active power (P), reactive power (Q) and power factor (PF) values with different cycle time of Open Circuit and Short Circuit at time scales.

A. *Time scale 3 second and open circuit for 0.1 second and short circuit for 0.5 second*



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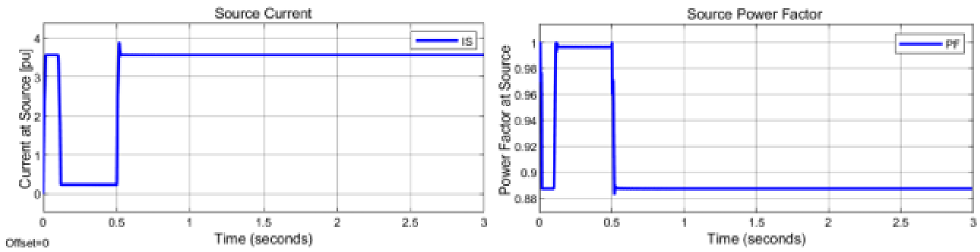

Fig. 20. The RMS V, I, P, Q, and PF at AC Source bus Vs under short circuit (SC) fault.

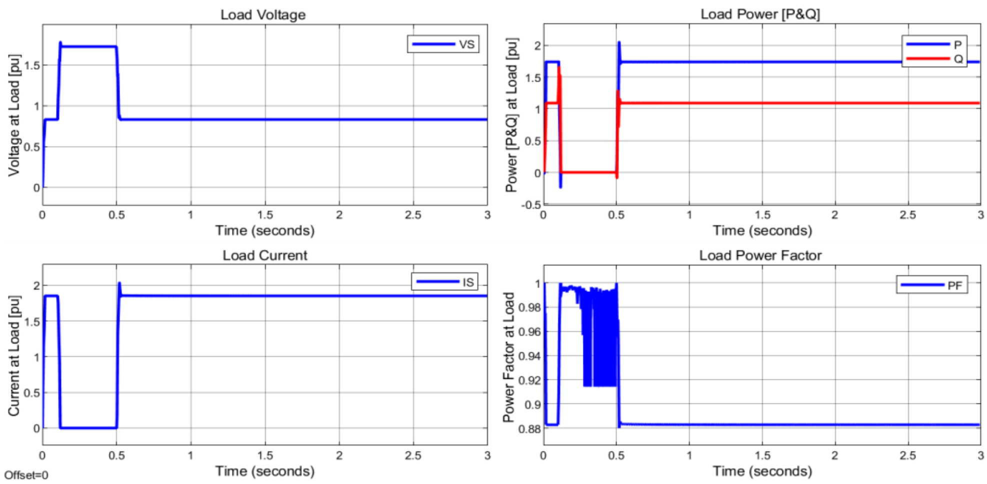

Fig. (21). The RMS V, I, P, Q, and PF at AC Load bus VL under short circuit (SC) fault.

B. *Time scale 2 second and open circuit for 20ms and short circuit for 100ms*

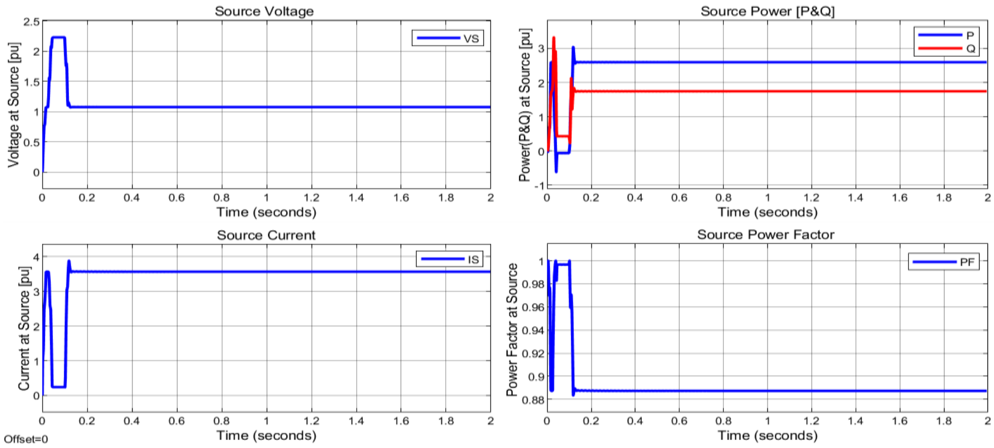

Fig. 22. The RMS V, I, P, Q, and PF at AC Source bus Vs under short circuit (SC) fault.

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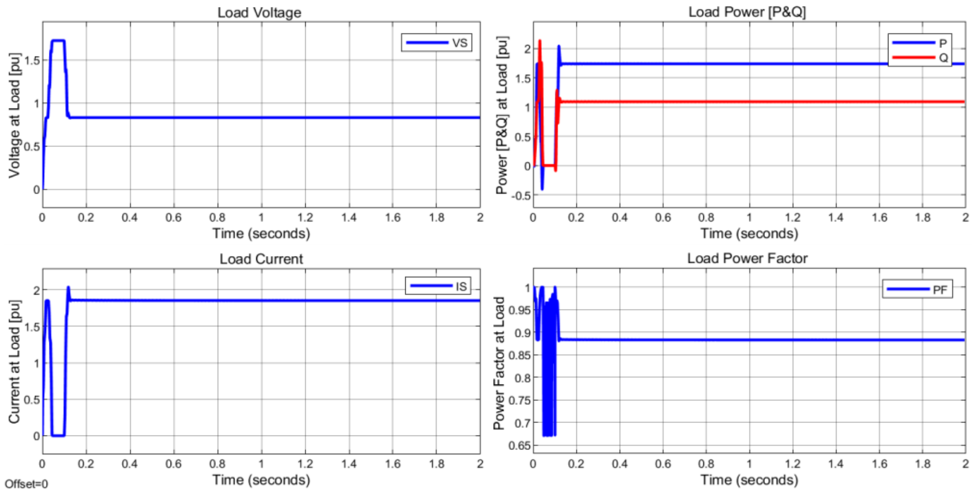


Fig. 23. The RMS V, I, P, Q, and PF at AC Load bus VL under short circuit (SC) fault.

C. *Time scale 2 second and open circuit for 0.63s and short circuit for 0.6s*

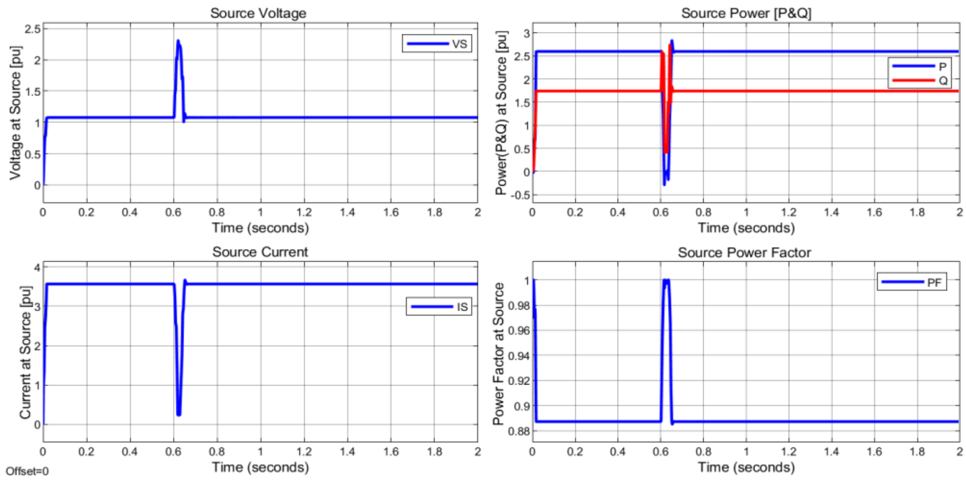
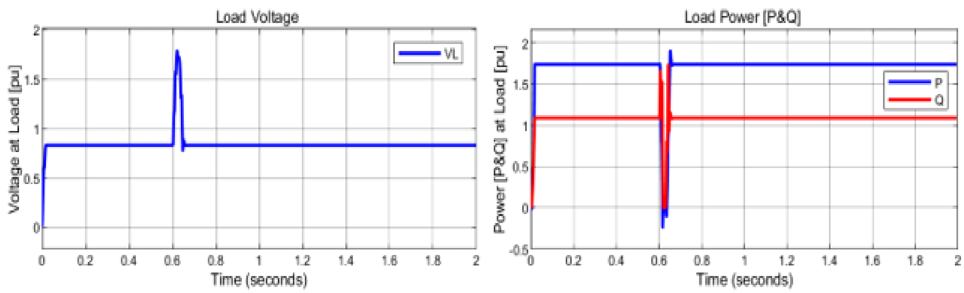


Fig. 24. The RMS V, I, P, Q, and PF at AC Source bus Vs under open circuit for 0.63s and short circuit for 0.6s



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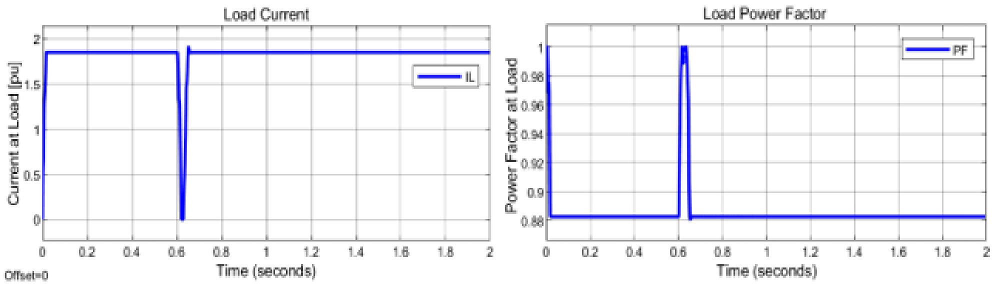

Fig. 25. The RMS V, I, P, Q, and PF at AC Load bus Vs under open circuit for 0.63s and short circuit for 0.6s

APENDIX A

Device	Value
FACTS-GP Controller	γ_p= 10 γ_Q = 0.75
Frequency	f_S=3700 Hz
Gains	K1 = K2 = 0.35

APENDIX B

Utility Grid	3 phases, 2 poles	
	11KV LL X/R ratio 10 MVA Short Circuit 75-100 MVA	
Transmission Line	500 KV (L-L), 8 km	
	R1/km=0.01273 Ω, R0/km=0.3864 Ω L1/km=0.9337mH, L0/km=4.1264 Mh C1/km=12.74e µF , C00/km= 7.751 µF	
Base Power VS Bus Base Power VL Bus	100 MVA 200 MVA	
Transformer	11 kv/600v at 300-500 KVA	
Frequency	3700 Hz	
MFCC	C_a=275µF, C_b=275µF, C_c=275µF	
	R_f=0.15Ω, L_f=3mH	
Hybrid AC Load	Induction Motor	30 MVA, 4 poles
		Rs=0.01965pu, Ls=0.0397 pu
		Rr=0.01909pu, Lr=0.0397 pu
		Lm=1.354 pu
	Linear Load	P=3000 KW, Q=4 MVAr
	Nonlinear Load	20 MVA, PF=0.85

VII. Conclusion

The paper presented a new switched modulated capacitive filter compensation scheme for distribution/ residential systems using nonlinear, inrush loads. The SFC-PWM switched filter used a complementary switching of two IGBT/ MOSFET to change action from tined arm -low pass filter to capacitive compensation. The SPWM-pulse modulation is controlled online by a fuzzy logic multi regulation loop based on aggregate weighted loop error weighted summation and configuration changes from capacitive compensation duty to power quality harmonics reduction of voltage and current transients. Using the ow-cost capacitive Bank-Tuned Arm Filter, (BTAF) dual functioning duties based on width module toon of online switching pulses controlled by the effective fuzzy logic multi regulator-multi loop weighted controller based on the dynamic error and rate of error at each control updating step improved the power quality performance of the system. The proposed SFC/MFCC filter is validated using different loads like DC ARC load, Induction Motor inrush loads as well as common seal type load. The SFC/MFCC filter is effective in enhancing energy utilization, reducing harmonic contents in voltages and current at source and load buses while improving power factor at the source. The SFC/MFCC filter can be extended to various energy efficient, power quality applications in DC-AC micro grids, renewable energy utilization, motor drives, battery charging schemes. The dual arm - SPWM double function SFC filter tuned arm and capacitive compensation is online controlled by a multi regulation fuzzy logic controller.

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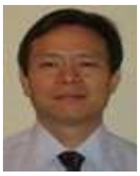

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