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DESIGN OF SINGLE AND DOUBLE TUNED SHUNT PASSIVE FILTER FOR POWER QUALITY IMPROVEMENT

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Abstract

Due to the advancement of electrical equipment most of the equipment is power electronics-based which is mostly used everywhere. Power electronics device is the main cause for the production of power quality problems, Harmonics are a major issue of power quality. This work describes a shunt passive filter for harmonics mitigation and reactive power compensation. Here single tuned and double tuned passive filters are discussed. It deals with the problem related to harmonics due to the nonlinear load. Three-phase thyristor loads are taken as a nonlinear load. For thyristor 180° scheme is used here. Thyristors are fired for seven different values of firing angle from 0° to 60°. The exhibition of a three-phase shunt passive filter is clarified in this paper. Simulations are carried out using MATLAB/SIMULINK. simulation results are presented.

Keywords: nonlinear load, shunt passive filter, Total Harmonic Distortion (THD), power quality, single tuned filter, double-tuned filter

I. INTRODUCTION

The power distribution system is designed in such a way that it operates with a sinusoidal voltage and current waveform at a constant frequency.

[1] Power quality is a major issue in the modern electrical distribution system due to the advancement of electrical equipment which is based on power electronics whose working is highly sensitive to the quality of the power supply. power electronics-based equipment has nonlinear characteristics, which is the main cause of harmonic generation. Power quality can be analyzed as harmonic distortion, voltage unbalance, voltage sag, voltage swell, voltage flicker, interruption partial, or total loss of one or more phases in the three-phase system. Voltage unbalances can be occurred due to the unequal distribution of single-phase load which may affect a three-phase system.

[2] Poor quality of power can affect the production in terms of loss, it can damage the electrical equipment, also increase power loss, and much more. For solving power quality issues some technical solutions have been provided like conventional methods, active filters with different types of controllers, passive filters, hybrid filters, etc. A passive filter is used mostly for harmonic mitigation and reactive power compensation for small and medium voltage equipment where cost is the main consideration. Passive filters are simple in design as it uses only R, L, and C elements and has less cost, and more reliable operation compared to active filter.

[3] Single tuned filters are mostly used due to the simplest design and least costly.

[4] Active filters can reduce power quality issues in small and medium voltage systems but due to high cost and complexity in design passive filters are more preferred.

[5] In this paper design and simulation of a three-phase shunt passive filter for harmonic reduction and reactive power, compensation has been demonstrated with the use of single tuned and double tuned passive filters.

II. SHUNT PASSIVE FILTER

shunt passive filter is a strategy of inductances, capacitances, and resistances organized in such a way, that it goes probably as a repeat discriminator, i.e., it gives low impedance way to harmonics fragment or we can say that it allows the passing of a few frequencies and disposes of others. It is possible to relate more than one dormant direct in one or the other shunt or series course of action arrangement. [6] Here shunt Passive filter is utilized. Shunt Passive filters are filters tuned at the necessary consonant segment to be sifted. The filter request can be of the principal, second, or third request, in light of the sifting necessities. The shunt Passive filter is extraordinarily influenced by the source impedance, which thusly is extremely hard to quantify. Generally, the Passive filter with a thyristor-controlled reactor (TCR) is utilized to filter harmonics, as well as remunerate receptive current parts. The benefits of passive filters are simple to upkeep, lower costs, and less intricacy.

There are two types of passive filters. [7] shunt passive filter, 2) series passive filter

1. Shunt Passive Filter

For the intersection out of the harmonic current in the apportionment system, it is the most widely recognized strategy. Shunt passive filters are moved toward a rule of either single tuned or bandpass channel development. As per its name shunt type channel is related to a system corresponding with the heap. The Detached channel offers a low impedance in the framework at the tuned repeat to involve all the connected current and at the given tuned repeat. Passive filters are constantly inclined to offer some responsive force in the circuit so the arrangement of an uninvolved shunt filter occurs for the two purposes one is the isolating explanation and another is to give open compensation inspiration driving correcting power factor in the circuit at the ideal level. The benefit with the unapproachable shunt type channel is that it simply passes on a limited quantity of current so the whole system AC control hardships are diminished differentiation with plan type channel. [7]

2. Series Passive Filter

Series Passive Filter is considered as a possible answer for consonant control for the voltage source kind of symphonious weights, (for instance, diode rectifier with R-L weight channel), It involves a ton of low squares tuned shunt filter tuned at fifth, seventh harmonic frequencies and high square tuned filter for 11th harmonic repeat. These inert filters square most winning fifth, seventh, and other higher-demand harmonic and subsequently hold them back from gushing into ac mains. Here, the presentation of the planned filter isn't a lot dependent on the stock electrical wonder. Regardless, it achieves a diminishing in dc transport voltage given the voltage drop across over filter parts. [8] The confined sort plan filter has a property of totally inductive sort or LC tuned ascribes. The important piece of the detached arrangement filter is the AC line reactor and DC association filter. [7]

III. PASSIVE FILTER DESIGN

Proposed tuned passive filters related in corresponding with the heap to ingest showed determined symphonious flows. The fundamental norm of using a detached channel is that the tuned recurrence channel will offer low impedance to the current through which consonant current will in general redirect in the structure. The standard sorts of latent symphonious channels join single tuned, twofold tuned, and high pass channels. Regardless, for straightforwardness single tuned and twofold tuned directs are considered in this work. The central shunt uninvolved sifting rule is to trap consonant flows in LC circuits, acclimated to the symphonious separating recurrence, and forgo the power structure.

1. Single Tuned Passive Filter

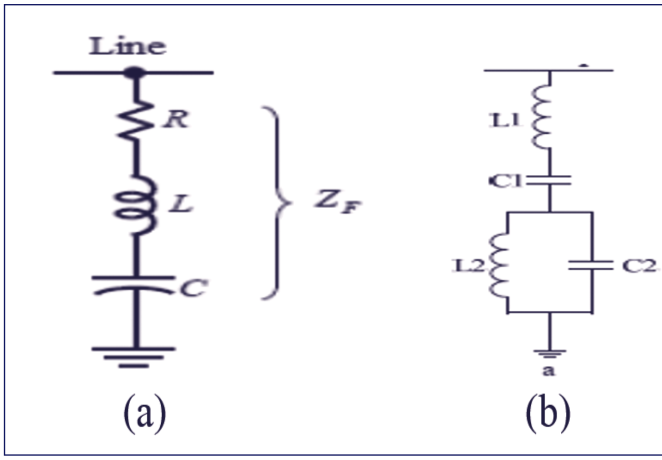
A single tuned third request filter configuration includes RLC parts in an arrangement as shown up in Fig 1 (a)

$$C_n = \frac{1}{L_n(2\Pi fn)^2} \tag{1}$$

$$R_n = \frac{Ln(2\Pi fn)}{Q} C_n \tag{2}$$

$$Q = R_n\sqrt{\frac{Cn}{Ln}} \tag{3}$$

Fig. 1 (a) Single tuned (b) double-tuned passive filter



In a single-tuned passive filter, the reactance of the inductor is identical to that of the capacitor at thunderous recurrence fn. where fn=frequency of the consonant segment, n=order of symphonious, Q=Quality factor, Rn=Resistance of the nth symphonious channel, Ln=inductance of the nth symphonious channel. In the proposed channel the shunt uninvolved channels are tuned to retain third symphonious streams and other higher-request music. Thusly, the source needs to supply simply a principal portion of the burden current. [9]

2. Double Tuned Passive Filter

Fig 1(b) shows the customary double-tuned filter,it comprises an arrangement full circuit and an equal thunderous circuit associated in an arrangement. The series full circuit offers low impedance at the series reverberation recurrence (ωs) while the equal resounding circuit offers high impedance at the equal reverberation recurrence (ωp). The mix of series and parallel reverberation circuits offers a low impedance way for the two full frequencies.[13] In the proposed channel the shunt passive filters are tuned to retain fifth, and seventh symphonious streams and other higher-request sounds. series reverberation and parallel reverberation recurrence ωs and ωp. can be communicated as [10]

$$\begin{bmatrix} \omega_S \\ \omega_P \end{bmatrix} = \begin{bmatrix} 1 / \sqrt{l_1 C_1} \\ 1 / \sqrt{l_2 C_2} \end{bmatrix} \tag{4}$$

The passive filters are used to direct power quality issues in the air conditioner dc converter with R-L burden. Additionally, besides assuaging the current harmonic, the passive filters similarly give receptive force compensation, as such, further improving the structure execution. Voltage and current source kind of harmonics delivering loads, overall, passive shunt filters and passive series filters are proposed. These filters isolated from lightening the current harmonics, moreover give confined responsive force pay and dc transport voltage rule. The introduction of these passive filters depends vivaciously depends upon the source impedance present in the system or contraption, as these filters go about as sinks for the symphonious flows. On the other hand, for voltage source type symphonious conveying loads, the use of the series passive filter is proposed. [11]

3. QUALITY FACTOR Q

The quality factor (Q), which chooses the sharpness of tuning, is associated with a scale that shows the degree of symphonious current retention sum. In such a manner, all filters will be one of the great or a low Q type as demonstrated by use. [12]

- Q depended upon R; in case it needs to high Q, it should get a lower R.
- Bandwidth is an opposite degree to Q. Hence, the recurrence selectivity of channels chose Q. For the model, high Q has a little BW and can pick recurrence precisely.
- The Q-factor of a circuit is dimensionless.
- A good filter will have a high Q-factor, yet not very high. Too high a Q-calculate results in a very narrow bandwidth, potentially removing some significant sign frequency parts.

The quality factor Q is the proportion of the middle recurrence of a band-pass channel to data transmission

i.e.,

$$Q = \frac{F_0}{Bw} = \frac{F_0}{F_2 - F_1} \tag{5}$$

A filter is a gadget that passes electric signs at specific frequencies or recurrence ranges while forestalling the entry of others.

IV. SIMULATION RESULTS AND ANALYSIS.

The MATLAB reproduction-based schematic of a three-stage thyristor framework with RL load with a Shunt passive filter has appeared in Fig 2. The reproduction is done in a discrete mode with an ode45 solver. Here in Shunt passive filters single tuned and double tuned filters are utilized. The single tuned filter is utilized for engrossing just third request harmonics. The double-tuned filter is utilized for engrossing fifth and seventh request harmonics.

The parameters used for the simulation studies are given below:

System Data:

Three-phase source V_{rms}=400v (line to line)

Source inductance L_S= 1mh

Load inductance L_L= 100mh

Load resistance R_L= 1 Ω

Filter Data:

Quality factor=345

Reactive Power Q=2500

Fig. 2 simulation of a three-phase system using Shunt passive filter

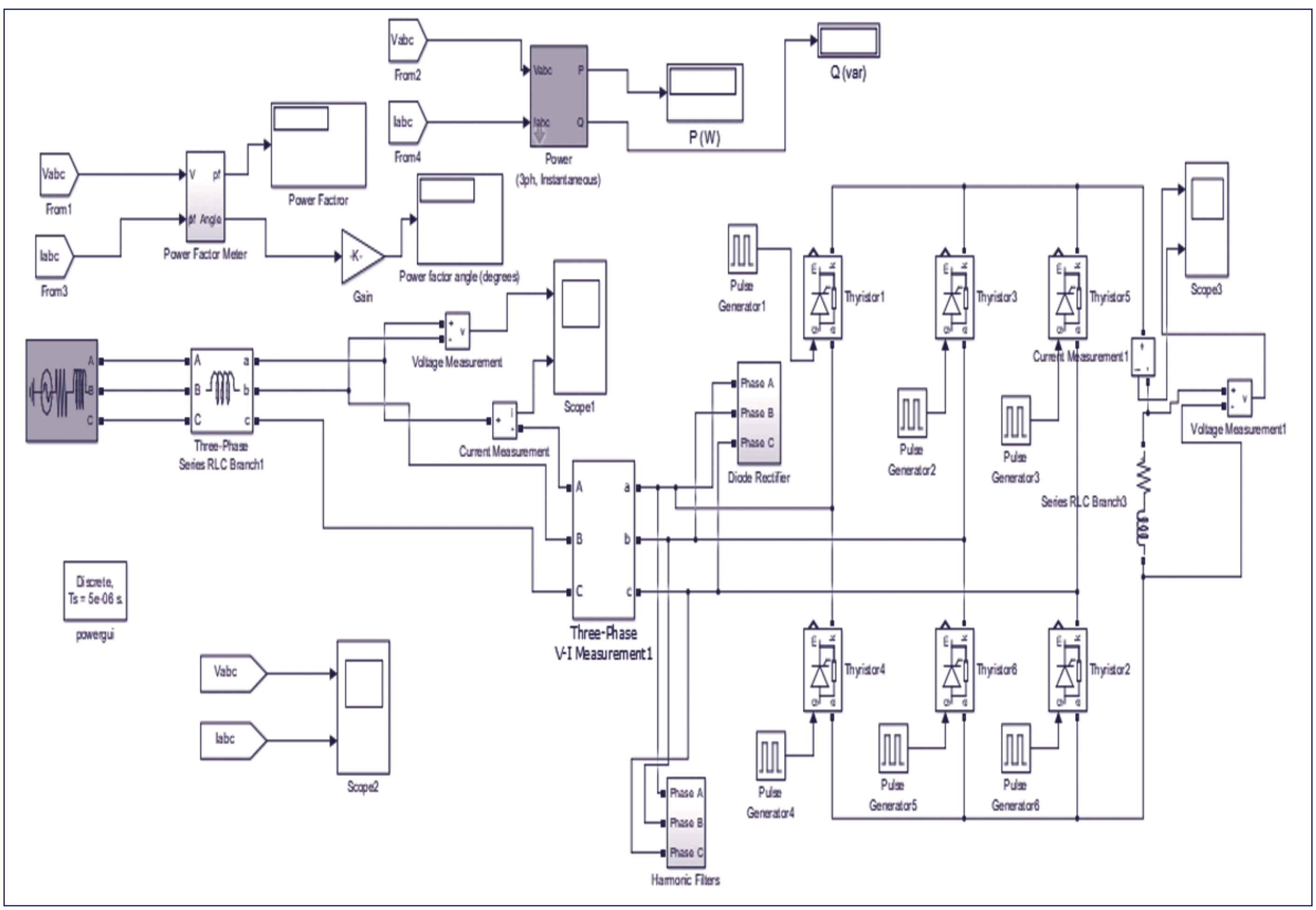


Fig 3-line voltage and current waveform for three-phase thyristor system for α=30° without filter

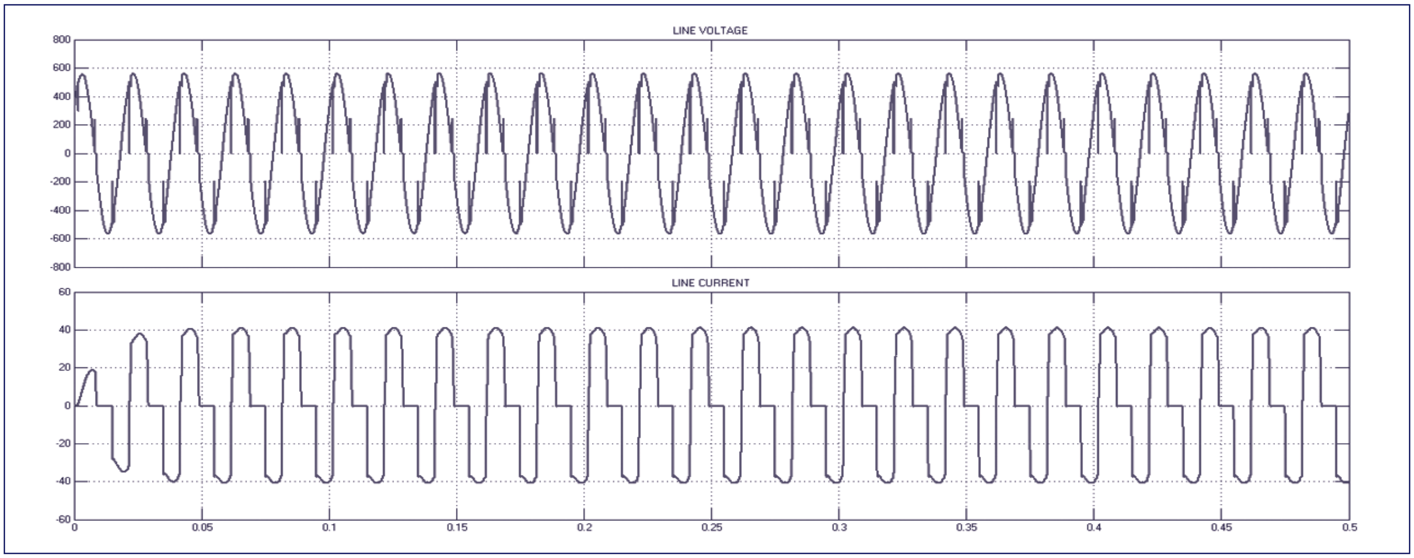


Fig 4 FFT analysis – Source voltage harmonic spectrum for three-phase thyristor system for α=30° without filter

FFT analysis

```
Sampling time      = 5e-06 s
Samples per cycle = 4000
DC component      = 3.485
Fundamental       = 557.8 peak (394.4 rms)
THD               = 9.21%

      0 Hz  (DC):          0.62%     90.0°
     50 Hz  (Fnd):       100.00%     29.3°
    100 Hz  (h2):          1.82%    125.1°
    150 Hz  (h3):          1.43%     -0.1°
    200 Hz  (h4):          1.85%    167.1°
    250 Hz  (h5):          0.71%     -1.7°
    300 Hz  (h6):          1.66%    264.1°
    350 Hz  (h7):          2.09%     50.5°
    400 Hz  (h8):          0.37%    189.9°
    450 Hz  (h9):          1.79%    162.9°
    500 Hz (h10):          2.14%    -66.0°
    550 Hz (h11):          0.55%     22.5°
    600 Hz (h12):          1.72%     57.9°
    650 Hz (h13):          1.97%    179.1°
    700 Hz (h14):          0.82%    257.0°
    750 Hz (h15):          1.49%    -47.2°
    800 Hz (h16):          1.59%     65.1°
    850 Hz (h17):          0.94%    145.3°
```

Fig 5 FFT analysis – Source current harmonic spectrum for three-phase thyristor system for α=30° without filter

FFT analysis

```
Sampling time      = 5e-06 s
Samples per cycle = 4000
DC component      = 8.637
Fundamental       = 35.84 peak (25.34 rms)
THD               = 64.76%

      0 Hz  (DC):         24.10%    270.0°
     50 Hz  (Fnd):       100.00%    -41.6°
    100 Hz  (h2):         42.61%    -25.3°
    150 Hz  (h3):         32.67%     38.7°
    200 Hz  (h4):          5.04%    -43.5°
    250 Hz  (h5):         10.15%    -21.7°
    300 Hz  (h6):         19.60%    -12.9°
    350 Hz  (h7):         11.21%     44.9°
    400 Hz  (h8):          5.14%      7.3°
    450 Hz  (h9):          5.71%    -54.7°
    500 Hz (h10):         12.11%     -3.1°
    550 Hz (h11):          6.13%     23.3°
    600 Hz (h12):          3.64%     46.2°
    650 Hz (h13):          5.44%    -54.2°
    700 Hz (h14):          6.83%     -0.8°
    750 Hz (h15):          6.10%     15.0°
    800 Hz (h16):          2.02%     70.0°
    850 Hz (h17):          3.95%    -37.2°
```

Fig 6-line voltage and current waveform for three-phase thyristor system for α=30° with Shunt passive filter

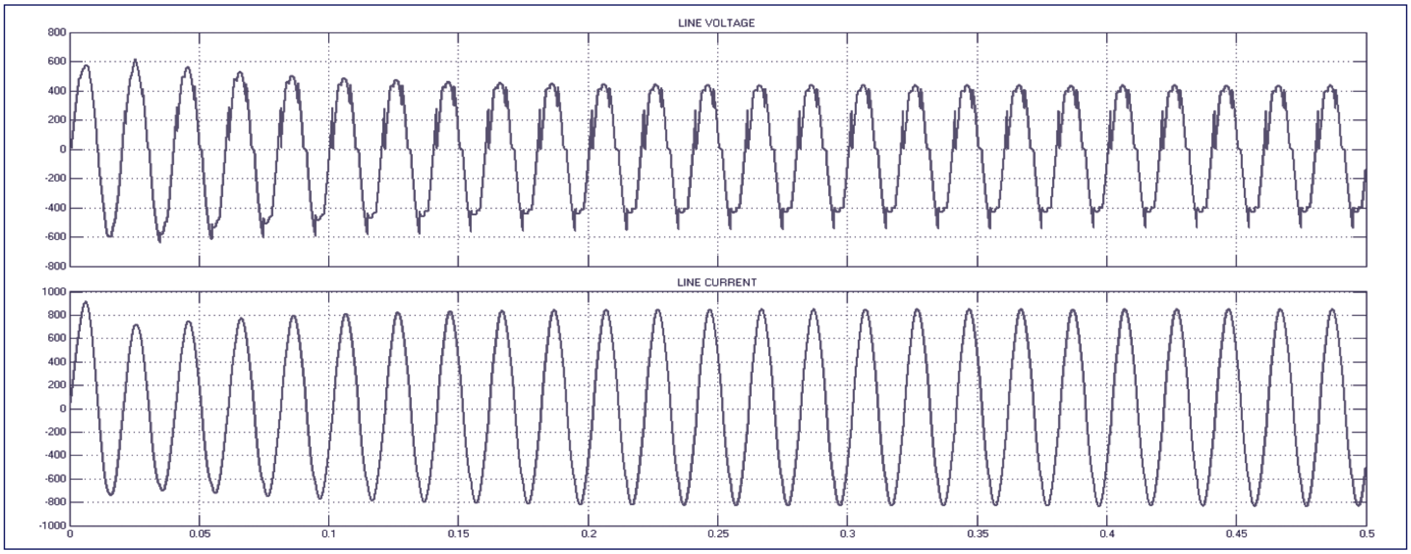
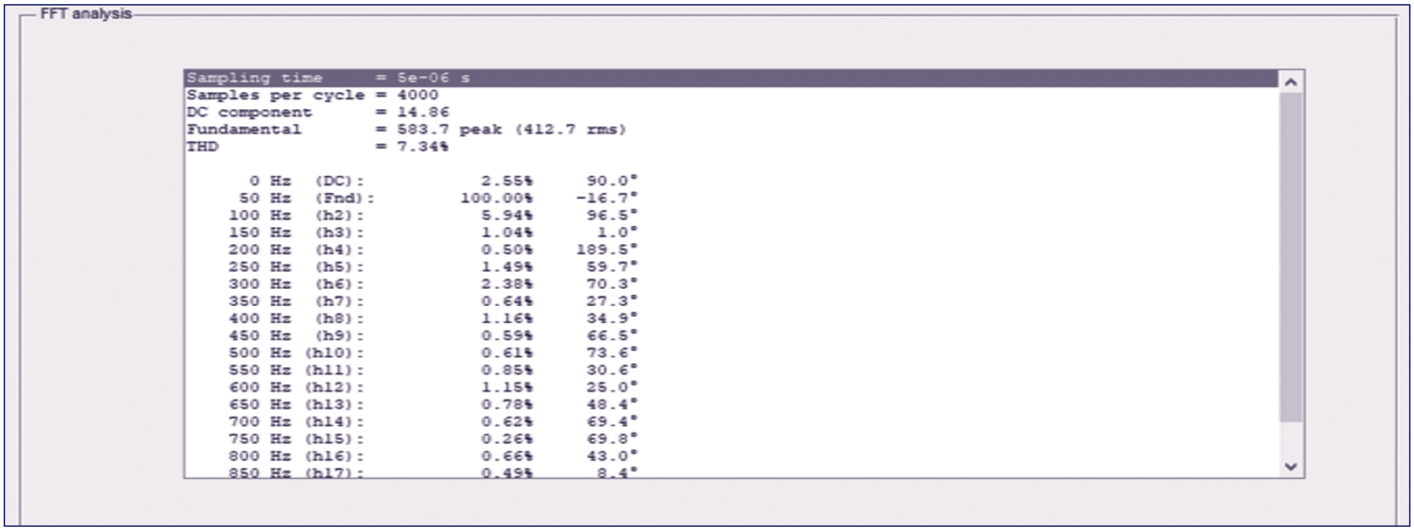


Fig 7 FFT analysis – Source voltage harmonic spectrum for three-phase thyristor system for α=30° with Shunt passive filter

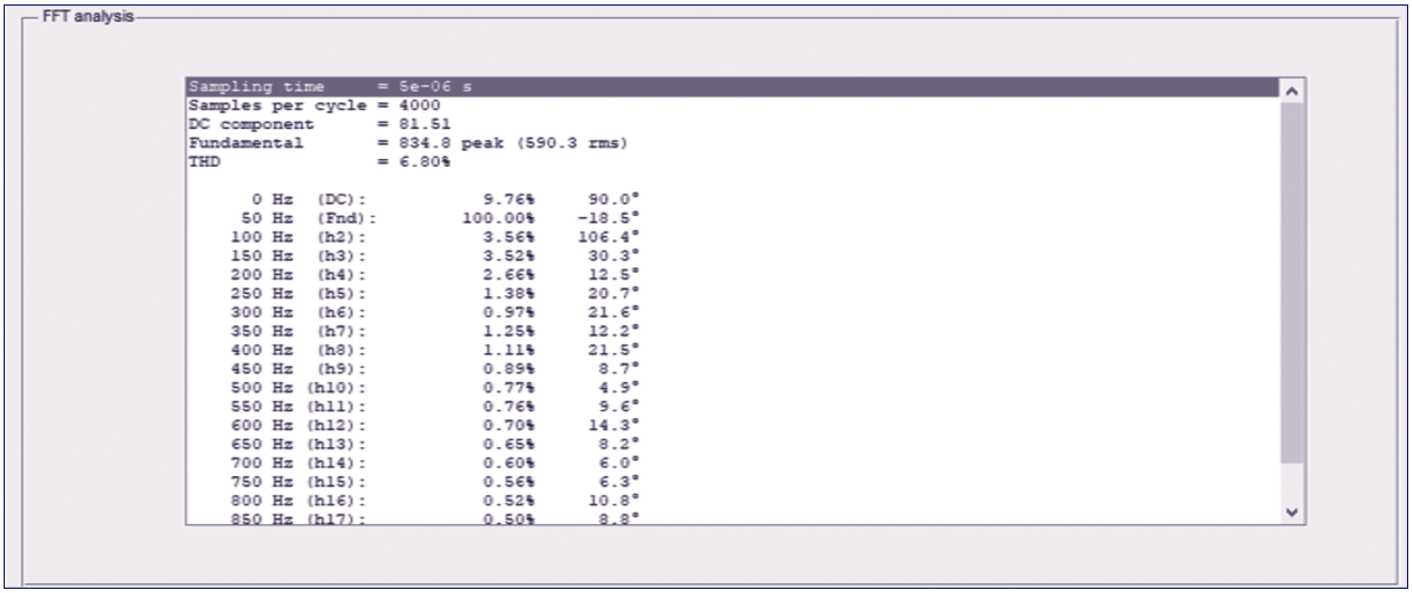


FFT analysis

```
Sampling time      = 5e-06 s
Samples per cycle = 4000
DC component      = 14.86
Fundamental       = 583.7 peak (412.7 rms)
THD               = 7.34%

   0 Hz  (DC):         2.55%     90.0°
  50 Hz  (Fnd):      100.00%    -16.7°
 100 Hz  (h2):         5.94%     96.5°
 150 Hz  (h3):         1.04%      1.0°
 200 Hz  (h4):         0.50%    189.5°
 250 Hz  (h5):         1.49%     59.7°
 300 Hz  (h6):         2.38%     70.3°
 350 Hz  (h7):         0.64%     27.3°
 400 Hz  (h8):         1.16%     34.9°
 450 Hz  (h9):         0.59%     66.5°
 500 Hz (h10):         0.61%     73.6°
 550 Hz (h11):         0.85%     30.6°
 600 Hz (h12):         1.15%     25.0°
 650 Hz (h13):         0.78%     48.4°
 700 Hz (h14):         0.62%     69.4°
 750 Hz (h15):         0.26%     69.8°
 800 Hz (h16):         0.66%     43.0°
 850 Hz (h17):         0.49%      8.4°
```

Fig 8 FFT analysis – Source current harmonic spectrum for three-phase thyristor system for α=30° with Shunt passive filter



FFT analysis

```
Sampling time      = 5e-06 s
Samples per cycle = 4000
DC component      = 81.51
Fundamental       = 834.8 peak (590.3 rms)
THD               = 6.80%

   0 Hz  (DC):         9.76%     90.0°
  50 Hz  (Fnd):      100.00%    -18.5°
 100 Hz  (h2):         3.56%    106.4°
 150 Hz  (h3):         3.52%     30.3°
 200 Hz  (h4):         2.66%     12.5°
 250 Hz  (h5):         1.38%     20.7°
 300 Hz  (h6):         0.97%     21.6°
 350 Hz  (h7):         1.25%     12.2°
 400 Hz  (h8):         1.11%     21.5°
 450 Hz  (h9):         0.89%      8.7°
 500 Hz (h10):         0.77%      4.9°
 550 Hz (h11):         0.76%      9.6°
 600 Hz (h12):         0.70%     14.3°
 650 Hz (h13):         0.65%      8.2°
 700 Hz (h14):         0.60%      6.0°
 750 Hz (h15):         0.56%      6.3°
 800 Hz (h16):         0.52%     10.8°
 850 Hz (h17):         0.50%      8.8°
```

Here 3 stage thyristors with RL load are associated it is a nonlinear burden, so the source voltage and current waveform become non-straight as demonstrated in fig 3 The voltage THD is 9.21% as demonstrated in fig 4 for α=30° without a filter. The current THD is 64.76% as demonstrated in fig 5 for α=30° without a filter.

Table 1 Comparison of Simulation Result without filter and with shunt passive filter

sr no	Firing angle	Without filter					Shunt passive filter				
		Power factor	Active power	Reactive power	Voltage THD	Current THD	Power factor	Active power	Reactive power	Voltage THD	Current THD
1	0	0.9358	333.6	574.8	9.03	46.55	0.9615	1017	-242.6	7.08	6.54
2	10	0.8964	314.1	541.8	9.31	51.50	0.963	1026	-245.2	7.09	6.92
3	20	0.8356	288.7	498.8	9.35	57.61	0.9643	1023	-240.2	7.17	6.87
4	30	0.7499	257.6	445.9	9.21	64.76	0.9749	985.8	-214.4	7.34	6.80
5	40	0.6404	221.3	383.9	9.48	70.27	0.9862	922.9	-183.1	7.41	6.74
6	50	0.5147	181.1	314.9	9.53	74.35	0.9917	888.9	-158	7.43	6.69
7	60	0.3877	139.3	242.8	8.93	77.28	0.9939	835	-194.8	7.40	6.64

Presently here when the shunt passive filter is associated in the framework and recreation is run, the information voltage is found close to sinusoidal and the information source current is found to be sinusoidal as demonstrated in Fig 6. for α=30° the THD estimation of voltage and current is diminished to 7.34% and 6.80% as demonstrated in Fig.7 and Fig 8 separately. The Power factor improved from 0.7499 to 0.9749 after harmonic compensation. The estimation of Active power improved from 257.6 to 985.8. Reactive power is repaid from 445.9 to - 214.4. Table 1 shows reproduction results with a shunt passive filter for each terminating point from 0° to 60°. As demonstrated in table 1 the THD esteem got in each reenactment for voltage and current isn't underneath 5% according to the IEEE standard 519-2014.

V. CONCLUSION

The proposed thought is to configure and create a shunt passive filter with a legitimate control plot. The fundamental target of this work is to decrease power quality issues that happened like diminished THD, repay receptive force, improve power factor, and improve the dynamic force. shunt passive filter decreased voltage THD to a decent worth. On account of THD, the point is to diminish lower request harmonics. Here the creator thought about 3rd,5th, and seventh request harmonic. Table 1 shows a Comparison of Simulation results without a filter and with a shunt passive filter. As demonstrated in table 1 the THD esteem acquired in each recreation for voltage and current isn't beneath 5% according to the IEEE standard 519-2014. Reenactment Result shows the proposed framework improves power quality to a decent incentive by utilizing the shunt passive filter.

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