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Passıve Fılter Desıgn And Applıcatıon For Reducıng Harmonıcs

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ABSTRACT
In this study, the design and application of a passive filter circuit has been carried out in the electrical facilities to prevent the wave shape distorted due to harmonics that distort the waveform of the sinus current and amplitude due to various reasons. Three phase full rectifier circuit is used as load in filter design. The reason for basing the three-phase full rectifier circuit is the switching process with power electronics elements in the process of rectifying the sine signal. Due to this switching frequency, harmonics occur in the switching regions in the current drawn by the load. There are differences between simulation and practice results. There are many factors in different results in simulation and practice. The reasons such as the inductance values of the coils are produced tolerantly, the differences caused by the tolerance in the capacitor value, the inability of the load and the filter to be fully isolated from the system, and therefore the harmonics caused by other devices in the transformer system to flow from the low impedance path created by the filter into the ground.

KEYWORDS: *Harmonic, passive filter, resonance, three phase full rectifier*

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I. INTRODUCTION

In power systems, non-linear loads are permanently connected, unlike transients and other distortions are produced[1]. In 1888, Tesla familiarized the concept of poly-phase systems after that in 1890, at Portland, Ore a 1st power transmission line of length 13 miles at frequency of 132 Hz was setup [2], [3]. In the same year, Bedell studied the field of alternating current and also studied the effects of alternating current wave forms in power systems [3], [4]. In 1893, at Hartford engineers dealing with a heating problem of a motor had selected harmonics analysis as a technique to identify the causes of motor heating and tried to solve the problem[4], [5]. Steinmetz discouraged the use of high frequency in power systems because of the high transmission line resonance[6]. As the harmonic currents pass through the line impedance of the system, harmonic voltages appear, causing voltage distortion at the PCC [7], [8], [9]. The power quality problems in power utility distribution systems are not new, but recently their effects have gained public awareness. Advances in semiconductor device technology have fuelled a revolution in electronics and power electronics over the past decade, many factories and heavy loads which are recently installed highly affect power quality due to their non-sinusoidal current[10]. Using of the artificial neural networks is one of the methods for harmonic detection. [11]. Using of the artificial neural networks is one of the methods for harmonic detection. [12].

Parallel resonance of power transformer and compensation capacitors in factories increases harmonic distortion. Harmonics are used in electrical machines, various elements of the power plant, electronic devices, etc. They cause various losses, malfunctions and damage in many areas. With this study, the harmonic amount has been greatly reduced.

II. MATHEMATİCAL ANALYSİS OF HARMONİCS

When all periodic functions are opened to a series called the Fourier Series, the first term can be written as a constant, and other terms as a series of sine and cosine of the multiples of a variable.A non-sinusoidal voltage is shown mathematically in equation (2.1).

$v(\omega t) = V0 + V1 \sin(\omega t + \varphi 1) + V2 \sin(2\omega t + \varphi 2) + \ldots + Vn \sin(n\omega t + \varphi n)$ ………… (2.1)

Here;

v(ωt): Instantaneous Value,
V_0: mean value of the curve v (ωt),
V_1: The maximum value of the main harmonic component of the v (ωt) curve,
Vn: n of the v (ωt) curve. The maximum value of the harmonic component,
Angle: Angle difference according to the reference is shown as. If the expression of the voltage shown in equation (2.1) is opened in the form of sinωt and cosωt, equation (2.2) is obtained.
$v(\omega t) = V0 + a_1 \sin\omega t + a_2 \sin_2\omega t + \ldots + an \sin n\omega t + b_1 \cos \omega t + b_2 \cos_2\omega t + \ldots + bn \cos n\omega t$ …. (2.2)

III. PASSIVE FILTERS USED IN THE APPLICATION

3.1 Simulation circuit

It contains the signal results of the three-phase full rectifier circuit before filtering. Three-phase full rectifier circuit switched with thyristors. Thyristor switching is performed in driver circuits used to drive loads used in this circuit and other industries. As the switching angle for thyristors increases, the harmonics produced in the circuit increase. This is not a desired situation. 100mH inductance has been added to prevent harmonics consisting of 3-phase transformers in simulation. The value of the resistance at the output of the three-phase full rectifier circuit in the system is 100 ohms. An ammeter is connected to one of the phases to see the signal shape of the currents and to measure its value. Powergui block has been added to see detailed values of harmonics in the system. Thanks to this block, FFT analysis is performed. With FFT analysis, harmonic signal patterns can be seen. Similarly, in block diagram, in the frequency band, the percentage of THD and the amplitudes of the currents can be seen. As seen in this graphic, harmonics have not been completely destroyed.

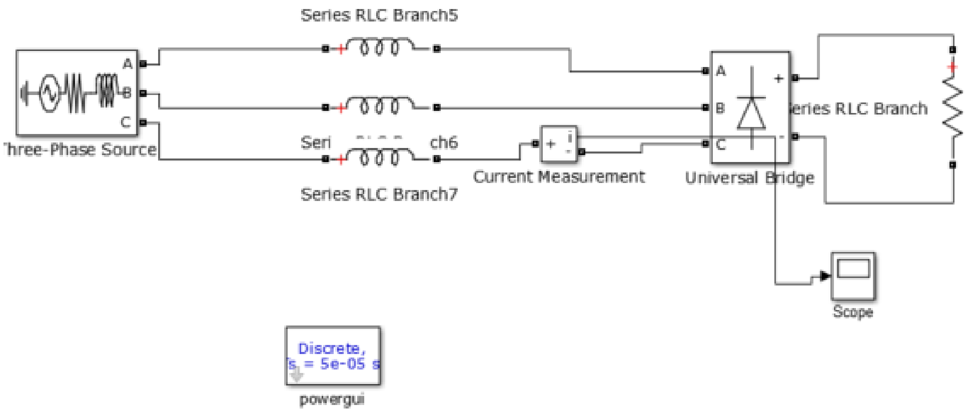
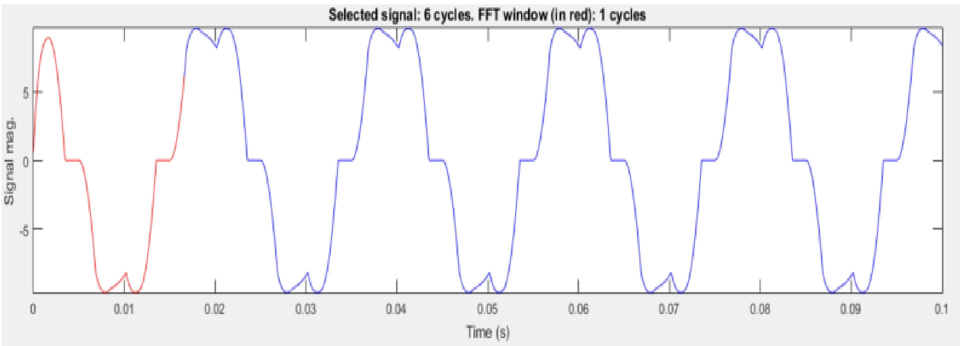


Figure 3.1 The circuit used for simulation



Şekil 3.2. Simülasyonda elde edilen dalga şekli

Aşağıda yükte 1. frekans seviyesi ve 11. Frekans seviyesi arası oluşan ayrıntılı harmonik listesi ve THD değerleri görülmektedir.

THD = 20.85%
Akım = 9.471 peak (6.697 rms)
50 Hz (Fnd): 100.00 %
100 Hz (h2): 4.72%
150 Hz (h3): 4.16%
200 Hz (h4): 3.67%
250 Hz (h5): 20.71%
300 Hz (h6): 3.17%
350 Hz (h7): 7.43%
400 Hz (h8): 2.82%
450 Hz (h9): 2.52%
500 Hz (h10): 2.23%
550 Hz (h11): 3.72%

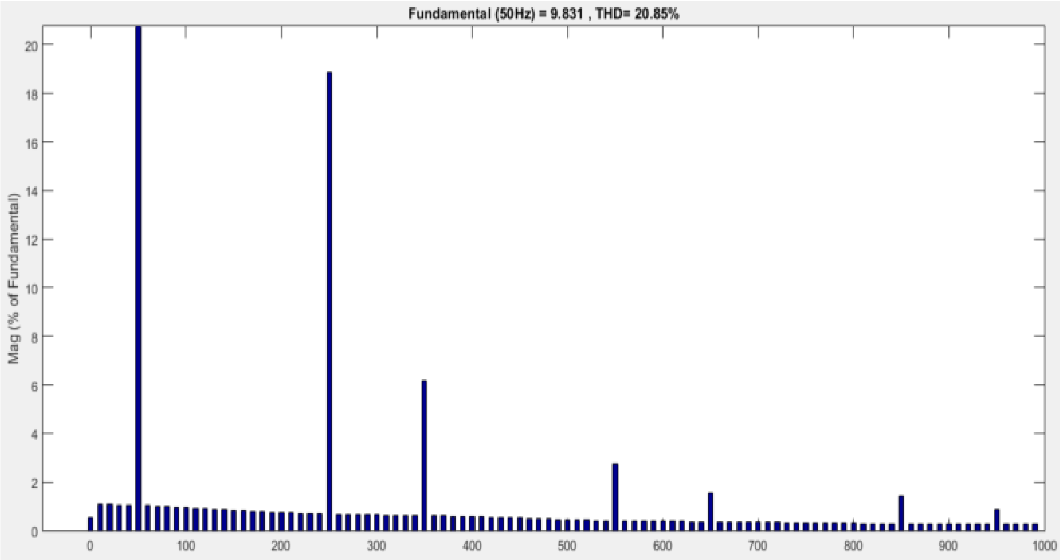


Figure 3.3 Harmonic graph of the load examined in simulation

3.2. Parallel passive filter circuit to reduce harmonics

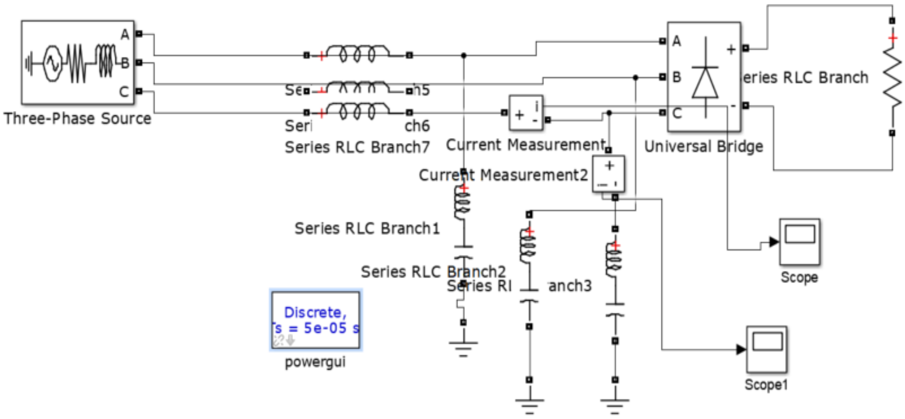


Figure 3.4. Block diagram of the parallel passive filter circuit

Among the elements used in the passive filter, the value of the inductance is 600mH and the value of the capacitor is 1000 microfarates. However, the transition to resonance, which is one of the disadvantages of the parallel passive filter, has taken place and the currents have undesirably high values.

As seen in Figure 3.5, the signal shape of the load compensated with the parallel passive filter has become a complete sine. In the list below, the newly formed THD value of the filtered load and the new harmonic values between the 1st frequency level and the 11th frequency level are shown below.

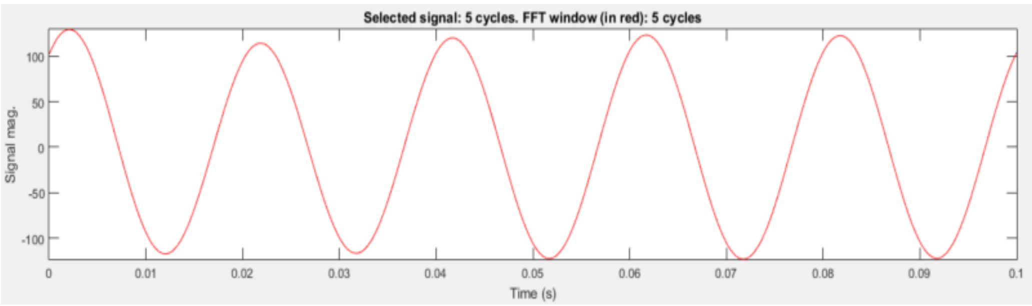


Figure 3.5. Waveform obtained from parallel passive filter circuit

- Akım = 120.8 peak (85.45 rms)
- THD = 1.40%
- 50 Hz (Fnd): 100.00%
- 100 Hz (h2): 0.26%
- 150 Hz (h3): 0.11%
- 200 Hz (h4): 0.06%

- 200 Hz (h4): 0.06%
- 250 Hz (h5): 0.02%
- 300 Hz (h6): 0.03%
- 350 Hz (h7): 0.03%
- 400 Hz (h8): 0.02%
- 450 Hz (h9): 0.02%
- 500 Hz (h10): 0.01%
- 550 Hz (h11): 0.01%

When the results obtained from the Passive Filter are compared with the harmonic values in the unfiltered load, it is seen that the parallel passive filter reduces the harmonics. However, the disadvantage of the parallel passive filter is that it appears that the currents resulting from the resonance of the load are unwantedly high and reach 100 A level. Although the element values selected in the filter eliminate the harmonics, it is not very suitable to use these values for the filter because it is in resonance.

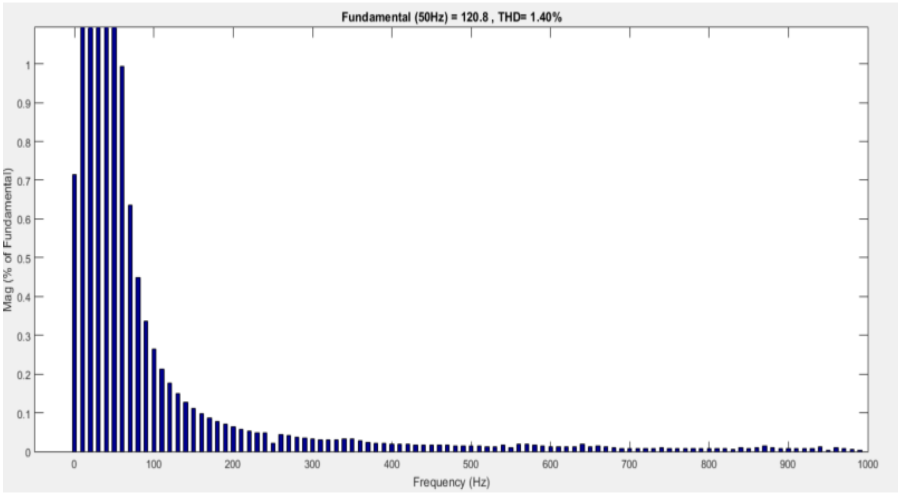


Figure 3.6. Harmonic graph obtained from parallel passive filter in practice

In the passive parallel filter in Figure 4.1, the value of the inductance used to prevent the load from entering resonance is selected as 4mH and the value of the capacitor is 90µF.

The current graph of the load generated when the new filter is applied in the simulation after changing the values of the parallel passive filter elements to prevent the parallel passive filter from entering into resonance, which is examined in Figure 3.4, is shown in Figure 3.7. As can be seen, a resonance condition has not occurred. As a result, there was not a very high increase in load currents. Both the signal shape was corrected as sine and the load current was at reasonable values. This filter circuit made in simulation has been applied.

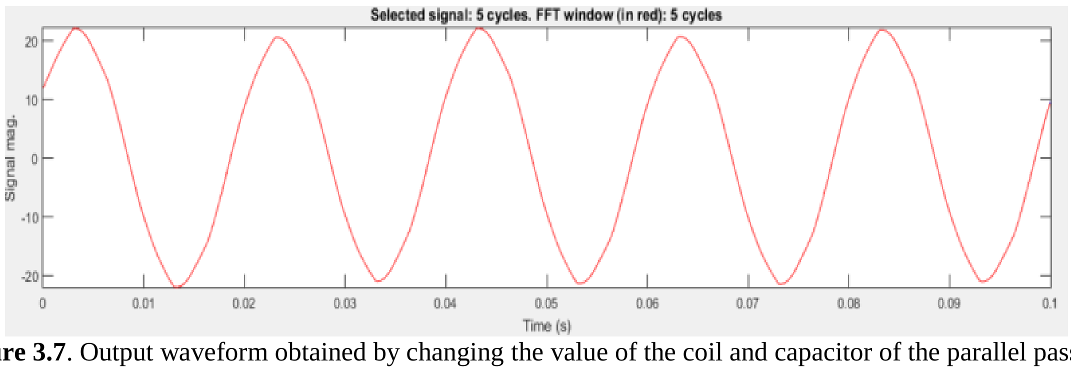


Figure 3.7. Output waveform obtained by changing the value of the coil and capacitor of the parallel passive filter

Below are the newly formed THD value of the filtered load by changing the values and the new harmonic values between the 1st frequency level and the 11th frequency level.

- Akım= 20.93 peak (14.8 rms)
- THD = 2.28%
- 50 Hz (Fnd): 100.00%
- 100 Hz (h2): 0.23%
- 150 Hz (h3): 0.17%
- 200 Hz (h4): 0.13%
- 250 Hz (h5): 1.81%
- 300 Hz (h6): 0.11%
- 350 Hz (h7): 0.70%
- 400 Hz (h8): 0.08%

- 450 Hz (h9): 0.08%
- 500 Hz (h10): 0.07%
- 550 Hz (h11): 0.27%

When the harmonic values obtained in the output of the filter whose values are changed are examined, the result obtained from this comparison is not enough in some cases in the parallel passive filter design to correct the harmonics and correct the signal. The maximum value of the current and the rms value should be thoroughly examined. It should be ensured that the filter does not resonate the load.

IV. CONCLUSION

Harmonics have a number of undesirable effects on the distribution system. They affect both technically and economically. In this study, three phase full rectifier circuit is used as load in filter design. The reasons such as the inductance values of the coils are produced tolerantly, the differences due to the tolerance in the capacitor value, the inability of the load and the filter to be fully isolated from the system and therefore the tendency of the harmonics originating from other devices in the transformer system to flow from the low impedance path created by the filter into the ground.

Simulation and application measurement results before filtering;

Simulation result;
THD = 20.85%
Current = 6.697 A rms

Application result;
THD = 28.6%
Current = 11.16 A rms

Simulation and application measurementresults in Parallel Passive filter:

Simulation results; **Application results;**
Current = 6.48 A rmsCurrent = 14.8 A rms
THD = 2.28% THD = 13.6%

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