ZANCO Journal of Pure and Applied Sciences
The official scientific journal of Salahaddin University-Erbil
https://zancojournals.su.edu.krd/index.php/JPAS

ISSN (print):2218-0230**, ISSN (online):** 2412-3986**, DOI: http://dx.doi.org/10.21271/zjpas**

RESEARCH PAPER

High Harmonic Reduction Using Passive Filters of Mountain Steel Company

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A B S T R A C T:
An increasing amount of power electronics has created an immediate effect on the value of the electrical power source. Both of high control manufacturing loads and national loads explain harmonic in the system voltage. In this paper, characterized by nonlinear loads, are classified into two types of harmonics, current source harmonics, and voltage source harmonics. Harmonic distortion has usually been deleted via the usage of LC passive filter. The proposed technique is to get lower THD as long as possible and high power factor and high efficiency, properties of the passive filter is demonstrated in experiments for harmonic compensation in MOUNTAIN STEEL Company before and after filtering, by taking the voltage THD of a different time in a day.

KEY WORDS: Harmonic Compensation, Passive Filter, Total Harmonic Reduction (THD), Higher Harmonics (HH).

DOI: http://dx.doi.org/10.21271/ZJPAS.33.1.19
ZJPAS (2021) , 33(1);178-187 .

1. INTRODUCTION:

With the new expansion concerning power electronics technology know-how entire types over electrical energy transformation becomes actual than the power load beside not many watts in conformity with several tens of megawatts the use of thyristor control switches and MOSFET transistors including switching frequency up to countless tens over kilohertz. The portion of such applications is rising continuously. As into promoted international locations, the percentage regular drives primarily based on the electrical device power of bracing in imitation of unregulated in the meantime.

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Article History:
Received: 30/08/2020
Accepted: 29/09/2020
Published: 20/02 /2021

There is no misgiving that uses particular technological know-how will increase the efficiency of electrical energy. For example, among the USA within the length beyond 1985 to 1995, 60 devices have been reconstructed of thermal power plants where 300-frequency-controlled gadgets on the electric-powered drives of the range from 630 go to 4500 kW. The annual pecuniary impact used to be expressed within saving 1 billion kWh concerning electrical power (Semenov, 2011).

However, the use of specific gadgets has a critical drawback; the current stretched via to them is non-sinusoidal. This occurrence would not be unsafe if it did no longer affect the mean factors of the power system. (Muhammad, 2016).

The higher harmonic currents reason a number of adverse outcomes in under the electric equipment. The followings are the major ones Reduction on the period concerning the electrical equipment. According to imitation of the Canadian Electrical Association, along a distortion component over source voltage close in reproduction of 10%, the tools work lifestyles is sizeable reduces , that decrements is assessed at accordant values 32.5% by way of single-phase machines 18% intended for three-phase machines 5% for transformer -Extra losses into the transformer windings.

This agreement concerning whether is how much really transmitted transformer influence along an extent among THD (Total Harmonic Distortion) the current stream via the transformer windings enhanced aging pertaining to cable insulation appropriate in accordance with accelerated heating the surface of the bottom proper in imitation of the float concerning higher harmonious currents the possibility concerning resonance at the frequency regarding higher harmonics (Kuznetsov et al., 2005) Leading according to a sharp decline among the characteristic over electricity and, as like consequence, under the miscarriage of electrical equipment. For example, of some of installations filters adjusted according to a frequency of 500 Hz along with a movement about 100, then each choked the circuit of a power capacitor element taking 15 segments on sixty-five k var. The capacitor of its filters failed afterward for about two days. The purpose was the attendance of a harmonic along with a frequency of 350 Hz, among shut vicinity in accordance to which resonance prerequisites have been detected between power capacitors and tuned filter. It is quite needed in conformity to account overload current of devise compensations for reactive power. As such, units commonly apply capacitors banks (Baranov, 2016).

Overload occurs due in imitation according to the capacitor banks, a non-sinusoidal voltage that reasons developed harmonic currents about considerable value due to the fact with any increase of the frequency cause to the resistance of capacitors decreases. Since Capacitor banks are a piece of the entire electrical scheme, which includes electric circuits, it is fundamental by thinking about rising the higher harmonics of an electrical circuits, which is a great issue within studying their belongings over the operation regarding capacitor banks.

(Ameen and Ibrahim, 2016) In this work author has been proposed the elimination method built on the rotor current controller employed a relative integral and multi resonant controller PI+MR to overpower the stator current. A six and twelve order resonant controller has been used to remove the positive (7th and 13th) and negative (5th and 11th) current harmonics. As an outcome, the impressions of the negative sequence 5th and 11th and positive sequence 7th and 13th voltage harmonic on the stator current were reduced; the THD for the stator current was reduced from 5.63% to 0.37.

2-PROPOSED PROCESS

While machines work on producing steel bar in MOUNTAIN STEEL Company in Erbil it will create a large amount of harmonics that cause bad effect on the surrounding zone. The proposed process of this paper is to show how it could be compensating harmonics in this Company by using passive filters. This filter causes eliminating harmonics which connected on the bus before filtering to show the effect of compensating harmonics on bus after filtering in different times and different loads to get best power factor and minimum THD.

3-THE FEATURES OF THE OCCURRENCE OF HIGHER HARMONICS IN THE ELECTRICAL NETWORKS

As mentioned earlier, due to the need to selecting the means of higher harmonics compensation, the problem of determining the parameters of the electrical network arises.

As we know, for calculating a non-sinusoidal state of the power supply we used to replace the source of non-sinusoidal voltage by a set of sources of sinusoidal voltage connected in series, the frequencies of which correspond to the harmonic frequencies, and amplitudes to the spectrum of non-sinusoidal voltage. Nonlinear load, as a set of sources of sinusoidal current, frequency and amplitude which correspond to the harmonics.

Voltage and current distortions occur in the electrical network due to many reasons. Depending on the source and nature of the higher harmonics occurrence, selects the methods of their compensation. The region of propagation of higher harmonics of current and voltage also affects the choice of means of dealing with them (Salimi, 2019). Sources of current harmonics are various types of non-linear loads. Among them it is necessary to highlight the devices that convert electrical energy that are built on power semiconductors. Devices based on them are widely used nowadays in industry. The most common are AC / DC converters or rectifiers (Garcia-Cerrada et al., 2007). Such devices are based on 6^{th}-and 12^{th}-pulse rectification circuits. Rest multi-pulse rectification circuits based on parallel connection of6^{th}-pulse groups. It should be noted that the increase in the quality of consumed electric power by increasing the pulsation of rectification, leads to a significant increase in the price of the product and a decrease in its reliability(Lange and Redlarski, 2020).

As a rule, the type of the higher harmonic sources is determined by the algorithm of the production process. Depending on the type of industrial production can be distinguished the dominant non-linear load, generating higher harmonic currents. So for metallurgical plant, of this type of consumer is a valve converter. Such a load belongs to the most powerful concentrated sources of higher harmonics. The total power of the electronic converter technology reaches in such production 80-90% (Skamyin and Belsky, 2017) .

In chemical production, the main type of non-linear load is controlled valve converters. These valve converters most often performed on a 12-pulse scheme and are designed for voltage 6-35kV with a rectified current of 12.5-25kA. At the pulp and paper production are set different mechanisms equipped with adjustable drives with thyristor valve converters with power up to 10kVA. The following devices may also act as sources of higher harmonics:

- Installation of electric arc welding. The power of such industrial single-phase automated devices reaches 1.5 MVA, and three-phase - several MVA;
- Gas discharge lamps (mercury and fluorescent) widely used for lighting industrial premises. Installed power reaches several megawatts.

From the above it should be concluded that the converter valve is the main type of non-linear load and therefore, particularly should focus on it.

The literature provides data on the ratio of effective values of higher harmonic currents in fractions of the main harmonic current. So for a six-pulse converter for 5,7,11,13,17,19,23 and 25 harmonics these ratios are: 0.2, 0.14, 0.10, 0.07, 0.06, 0.053, 0.043; and 0.04 (Konstantinou et al., 2013).

In works on determining the effect of higher harmonics on the network it is customary to represent non-linear load as a current source that are connected in parallel and have amplitude values corresponding to non-linear load spectrum. However, the initial phases of these sources are taken as 0 °, those energy characteristics remain unrecorded, namely the shift phases between current and voltage at each harmonic. Obviously, this fact, in some cases, will be of great value when theoretically determines the effect of higher harmonics.

As mentioned earlier, due to the need to selecting the means of higher harmonics compensation, the problem of determining the parameters of the electrical network arises.

As we know, when calculating a non-sinusoidal state of the power supply we used to replace the source of non-sinusoidal voltage by a set of sources of sinusoidal voltage connected in series, the frequencies of which correspond to the harmonic frequencies , and amplitudes to the spectrum of non-sinusoidal voltage. Nonlinear load, as a set of sources of sinusoidal current, frequency and amplitude which correspond to the harmonics Consumed by non-linear load current. At the same time, the initial phases of current and voltage sources are set to be equal to 0 °.

In this case, the calculated equivalent circuit of the supply system would take the form shown in Figure 1, where a set of sinusoidal voltage source V^1 , V^2, ... V^{n-1} , V^n is modeled the phase voltage of the source to a set of current sources $I^1, I^2, \ldots, I^{n-1}, I^n$ nonlinear load, LL - linear load, L_S – The inductance of the system.

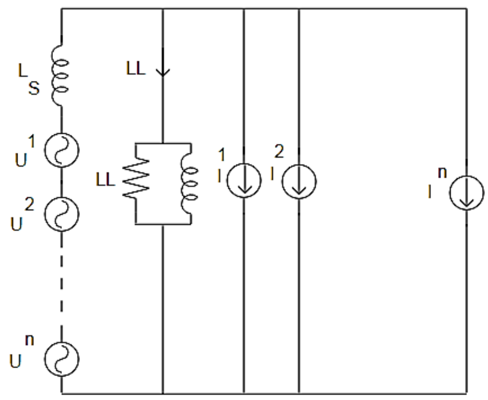

Figure 1: Networks single-phase equivalent circuit

The value of any current flowing through the power system elements, including the current I_{LL}, in non-sinusoidal mode of operation of the electrical network is determined by the expression

$$I = \sqrt{I_1^2 + I_2^2 + \cdots + I_n^2}, \qquad (1)$$

Where, I- is the effective value of non-sinusoidal current, I_1- is the effective value of the current of the main harmonic, I_2, I_n - the effective value of the currents higher harmonics. The components of the current I_{LL} will be determined by the superposition method at each frequency separately. Consider three options for schemes with sources of higher harmonics:

In the first version of the interposition of sources of higher harmonics at the fundamental frequency, the calculated circuit will have one source of supply voltage and current source of the main harmonic of the nonlinear load. And therefore, at the fundamental harmonic frequency, the magnitude of the phase shift angle will affect the circuit calculation. At the higher harmonics only one source will be present and therefore, the phase magnitude of the supply source will not affect the determination of the circuit's parameters.

In the second variant of the mutual position of the sources of higher harmonics in the considered calculated circuit will be present one power supply source at both the main frequency and higher harmonics, therefore, as in the first variant, the initial phase will not affect the determination of circuit parameters.

Consider the last option when the source is non-sinusoidal voltage feeds the circuit containing non-linear load. Then by the method of superposition, the current in the circuit will be determined by the expression (1), but with considering the system (2)

$$\begin{bmatrix} I^{(1)} = I_U^{(1)} + I_1^{(1)} \to I^{(1)} \\ I^{(2)} = I_U^{(2)} + I_1^{(2)} \to I^{(2)} \\ \dots . \\ I^{(n)} = I_U^{(n)} + I_1^{(n)} \to I^{N} \end{bmatrix} \qquad (2)$$

Where $I^{(1)}, I^{(2)}, \dots . I^{(n)}$ are vectors of the effective values of the higher harmonic (HH) currents, and

$I_U^{(1)}, I_U^{(2)}, \dots . I_U^{N}$,- the vectors of the effective values of the higher harmonic(HH) currents, determined by the influence on the circuit only non-sinusoidal supply voltage, $I_1^{(1)}, I_1^{(2)}, \dots . I_1^{(n)}$ vectors of effective values of higher harmonic(HH) currents, determined by the influence on the circuit only nonlinear load,$I_{(1)}, I_{(2)}, \dots I_{(n)}$ - The effective values of currents of higher harmonics(HH).

4-THE MAIN INDICATORS. CHARACTERIZING THE PRESENCE OF HIGHER HARMONICS

The flow of current of higher harmonics on power electrical equipment causes various negative electromagnetic phenomena described earlier. There are government standards around the world that limit harmonic level. One of the main indicators of the quality of electricity-coefficient of non-sinusoidal voltage, determined from the expression:

$$K_{NS}\% = 100. \frac{\sqrt{\sum_{v=2}^{n} U_v^2}}{U_{rated}} \qquad (3)$$

Where U_v is the effective (r.m.s) value of the voltage of v^{th}- harmonic; U_{rated}- circuits rated (nominal) voltage; n - the sequence number of the last accounted for harmonics. This parameter corresponds to the(Total Harmonic Distortion (THD) (Shmilovitz, 2005).

Usually the coefficient of non-sinusoidal for medium voltage is in the range of 5-8%. Calculation of coefficient of non-sinusoidal voltage executes up to 25 harmonics.

This indicator of the shape distortion of a sinusoid voltage or current most often used for rationing the quality of electrical energy because of its ease of use, however, it has several disadvantages: The information of the value of individual amplitudes of harmonics and their phases is unrecorded.

However, it is known that various harmonics affect the network in different ways (harmonics are multiples of three, harmonics forming positive and negative sequence), and the generalized indicator of this information does not carry, which can lead to incorrect understanding the processes occurring in the network, to inaccurate prediction of harmonic levels, and, as a result, to the error in determining the parameters mode of operation of the power system.

Therefore, in some cases uses an additional indicators of the quality of supply, form factor:

$$K_F\% = 100.\frac{I_{rms}}{I_{av}} \quad (4)$$

Where, I_{rms} – is the currents mean square value, I_{av} - is the average value of the current;

Specific harmonic content in the spectrum (Harmonic Factor)

$$HF^{(n)} = \frac{I^{(n)}}{I^{(1)}} \quad (5)$$

Where, $I^{(1)}$ – is the root mean square current of the main harmonic, $I^{(n)}$- is the r.m.s current of the n^{th} harmonic The Distortion Index

$$K_D = \frac{\sqrt{\sum_{n=2}^{\infty}(U^{(n)})^2}}{U} \quad (6)$$

Where, U- is the r.m.s voltage value, $U^{(n)}$ – is the r.m.s voltage of the n^{th} harmonic.

Symmetry coefficient

$$K_S = \frac{P}{\sqrt{P^2+Q_R^2}} \quad (7)$$

Where, P -active power, Q_R is the effective value of reactive power in the presence of HH.

Identity factor

$$K_{ID} = \frac{\sqrt{P^2+Q_R^2}}{\sqrt{P^2+Q_R^2+D^2}} \quad (8)$$

Where, P -is the active power, Q_R - the effective value of the reactive power in the presence of HH, D- power of distortion (Cheng et al., 2000).

The power factor is one of the most used network performance indicators in the presence of higher harmonics. This indicator is not quality indicator electricity. However, its value depends on current distortion and voltage.

$$P.F = \frac{P}{\sqrt{P^2+Q_R^2+D^2}} = \frac{P}{S} = \frac{P}{UI} \quad (9)$$

Where P- is the active power, Q_R -is the effective value of the reactive power in the presence of HH, D is the power of the distortion, I-is the effective current value , U - the effective value of the voltage.

5- METHODS AND MEANS OF HIGHER HARMONICS COMPENSATION

In various situations, the enterprises required to reduce the distortion level of the shape of the supply voltage curve to acceptable values. For these purposes, various installations of higher harmonic compensation are applied.

There are several classifications of HH compensation devices, but they are mainly differs by the method of supplying the higher harmonics:

- Passive filters, which consist only of passive elements, such as inductance, capacitance and resistance;
- Active filters, which in addition to passive elements have power semiconductor switches and their control system;
- Hybrid filters, consisting of an active filter and a passive filter.

Passive filters can be set to compensate current harmonics from entering the system in case if the nonlinear load locally causes significant harmonic distortion. Passive filters are an inexpensive tool compared to most other anti-distortion devices. Their structure consists only of passive elements (inductance, capacitance and resistance), tuned to the frequency harmonic current or voltage, which need to be reduced.

Passive filters are most effective when they are installed close to non-linear load. The resonant frequency of the power system should be accurately determined at the places of harmonic distortion caused by nonlinear load.

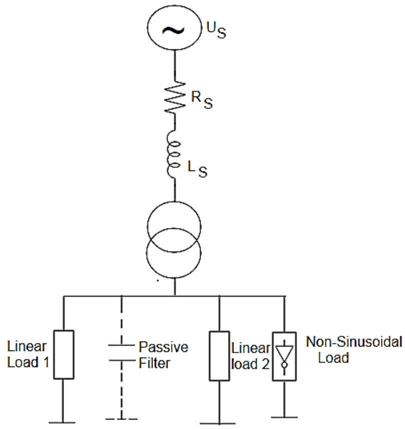

Figure 2: Connection of Passive Filter

In practice, passive filters are added to the system, starting with lower order harmonics that must be compensated. For example, installing a seventh harmonic filter usually requires installing fifth harmonic filter.

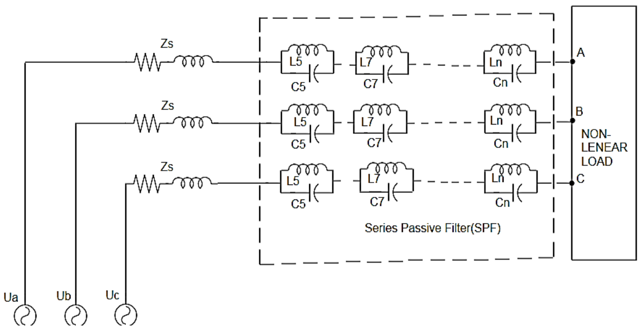

Figure 3: Connection Diagram for a 3-phase series passive filter

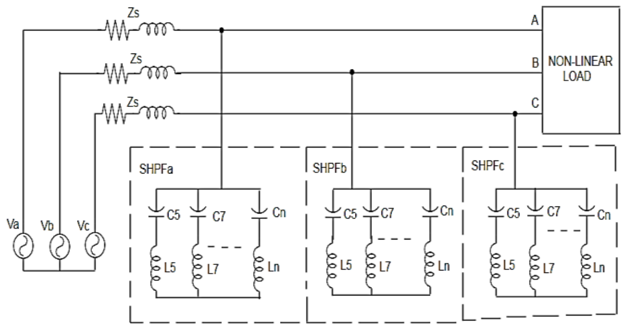

Figure 4: Connection diagram of a 3-phase shunted passive filter

There are various types of passive filters for single phase and three-phase systems according to parallel (Figure 4) and series (figure 3) connection. Filters with the parallel connection are more common in practice. They provide the interval of low resistance for flow the harmonic currents.

Passive filters connected in parallel permits only a part of the total load current and would have lower efficiency compared with serial connected filters which can fully conduct load current. As a result, filters with parallel connection are used because of their low cost and the possibility of providing reactive power compensation on the main frequency.

Thus, the design, manufacture and the realization of passive filters are simpler and easier than other devices, such as synchronous compensators and active filters and they have the following advantages:

- Are reliable, economical and relatively inexpensive;
-Can be manufactured at high power (up to several MVA);
-Does not require high operating costs;
-Can provide fast response time, which improves the quality of electric energy;
-Unlike rotating machines (for example, synchronous machines or compensators) passive filters do not contribute to the appearance of short circuit current;
- In addition to improving power quality, well Sophisticated passive filters can be used to power factor correction and reduce the voltage drop associated with the inclusion of large loads (for example, powerful asynchronous machines).

These advantages led to the widespread use of passive filters in various branches of power systems. However, engineers also encountered some limitations and disadvantages of passive filters that can force alternative solutions, such as active and hybrid filtration systems. Disadvantages of passive filters are as follows:

- Compensation or reduction of only certain harmonics, big size;
- Possible of resonance with the resistance of the supply system on the main or other frequencies;
-The complexity of changing the tuned frequency and filter size after installation;
- A decrease in filter efficiency may occur due to changes in its parameters (caused by aging, deterioration, and temperature impacts) and non-linear characteristics of the load;
-For the reliability, the filter resistance must be less than the systems resistance, which can be a

problem for powerful or hard systems (Massoud et al., 2004) ;
The resonance between the system and the filter can lead to amplification of the action of harmonic current, thus, the developer is limited in the choice of tuned frequencies;
- May require special protective and monitoring devices to control the switching overvoltage's, despite the fact that filter contain reactors;
Due to those disadvantages in some cases there is the need to use active filters. Electrical equipment's built on the basis of semiconductor elements, is an alternative to passive filters for compensation of higher harmonics. One of the advantages of these devices is the automatic change of compensation parameters depending on conditions arising in the power grid.
Active filters are used when dynamically changing spectrum flowing a distorted current. Used active filters have parallel (Figure 2) and serial connection diagram (Figure 3) depending on the type of the distortion source.

Active filters constructed on the elements of power electronic, generates currents of higher harmonics corresponding to the current specter flowing through the electric circuit, but opposes it in phase as a result the compensation of higher harmonic of currents occurs. Compared to passive filters, these devices are more expensive and not suitable for most small businesses.

6- RESULT AND DISCUSSION

In this paper, I tried to use the recording data of the MOUNTAIN STEEL company, which contains two transformers of [132/36] kV respectively, the models that are used the passive filter for compensating harmonics, because it requires less maintenance. Table 1 shows the voltage THD of a system before filtering, and table 2 is voltage THD after filtering for different times in a day with different loads. Moreover table 3 shows compensating higher harmonics to get maximum power factor in different loads and different values of capacitor and inductors with series and parallel combination as shown in table 4.THD is an important part it should be as low as possible, higher power factor in power system means lower THD and high efficiency and lower pick currents. We can notice that using passive filter causes to reduce total harmonic distortion in the output of the system that shows in figures 6 and 7, respectively. In this system as shown in (figure 5), using RLC passive filter for compensating 2nd order harmonics and LC filter for other orders of harmonic for compensation to get higher power factor.

Table 1 THD % of Voltage bus without using passive filter with time

Time (PM)	V1 THD_f	V2 THD_f	V3 THD_f
4:34	2.5	2.3	3.6
5:00	1.4	1.3	1.5
5:30	1.3	1.3	1.6
6:00	1.1	0.9	0.8
6:30	0.9	1	1.7
7:00	1.2	1	1.2
7:30	1.6	1.1	1.3
8:00	2	1.5	1.1
8:30	1.3	1.9	1.5

Table 2 THD % of Voltage bus with using passive filter with time

Time (PM)	V1 THD_f	V2 THD_f	V3 THD_f
4:34	1.5	1.5	1.6
5:00	1.6	1.5	1.6
5:30	1.6	1.5	1.5
6:00	1.2	1.3	1.3
6:30	1.5	1.7	1.7
7:00	1.5	1.5	1.5
7:30	1.5	1.5	1.5
8:00	1.5	1.3	1.4
8:30	1.5	1.5	1.7

Table 3 Bus data by passive filters for different loads

p1(Mw)	p2(Mw)	p3(Mw)	v1 THD	v2 THD	V3 THD	A1 THD	A2 THD	A3 THD	PF1	PF2	PF3
1.57	1.56	5.04	1.5	1.5	1.5	9.9	13.3	54.4	0.5	0.59	0.63
1.519	1.618	5.3	1.5	1.4	1.2	9.4	12.3	52.6	0.5	0.58	0.63
10.55	8.93	9.72	1.3	1	1.5	3.5	5.9	5.7	0.93	0.886	0.94
12.26	10.26	12.52	1.3	1.3	1.5	12.1	17.2	7.1	0.816	0.777	0.83
13.34	12.76	13.1	1.3	1	0.9	7.2	5.5	4.3	0.225	0.918	0.96
13.79	13.54	13.77	1.3	1	1.5	6.9	3.6	5.7	0.929	0.913	0.94
14.4	14.17	14.47	1.4	2.3	2	3.7	11.2	12.7	0.96	0.915	0.93
14.65	13.93	14.54	1.9	1.4	1.6	10.7	9	6.3	0.925	0.898	0.91
15.17	14.02	14.029	2.5	2.3	3.6	10.4	14	26.9	0.875	0.809	0.78
15.89	15.6	15.98	1.7	1.5	1.7	3.4	3.3	3.1	0.95	0.952	0.98

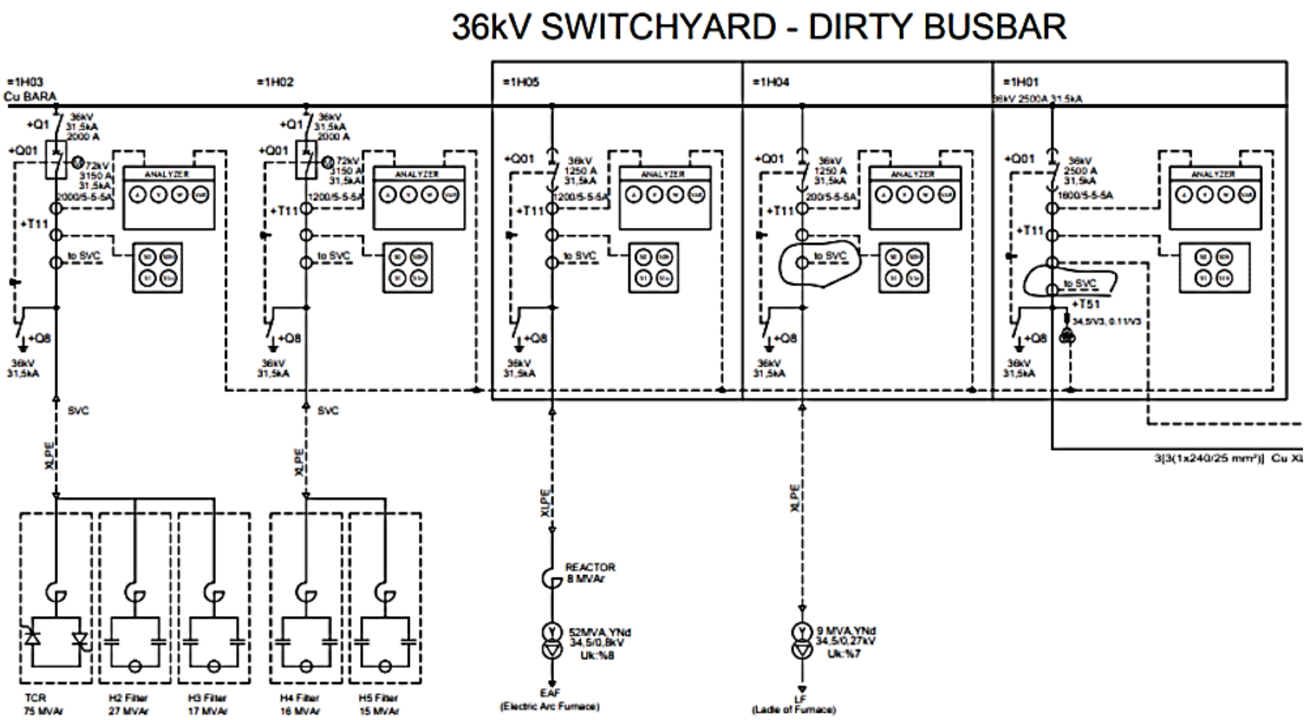

Figure 5: model of Mountain steel company buses with passive filter

Table4 capacitor and inductor values for series and parallel combination

Model	Capacitor C5 (MF)	Inductor L5 (mH)	Capacitor C7 (MF)	Inductor L7 (mH)
Series	24.8	70.4	30.7	25.5
Parallel	37.6	16.57	45.2	9.015

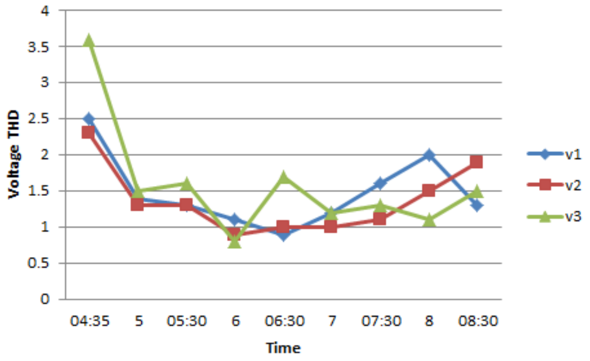

Figure 6 : voltage THD for different times whithout filter

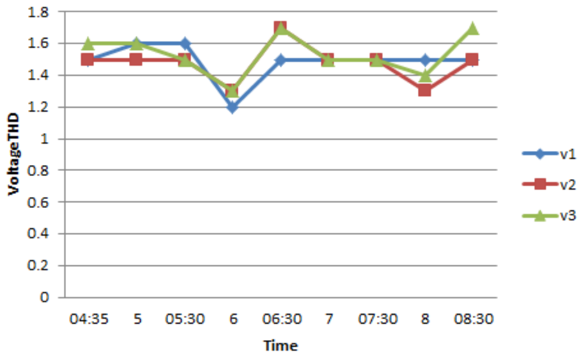

Figure 7: Voltage THD for different times of with filter

7-CONCLUSIONS

In this paper, characterized by nonlinear loads which classified into two types of harmonics, current source harmonics, and voltage source harmonics. To reduce the effect of higher harmonics use of passive filter which connected on bus which have higher harmonics in the system of this company, which eleminated harmonic effects on this bus by passive filter every second in a day, we notice that harmonic changes sharply on the buses before filtering, but in table 2 harmonic voltage THD has been smoothed by the effect of the passive filter, which has benefit for protecting equipments from sudden damages of the system. Also, series reactor connected to the transformer to mitigate harmonics.On the other hand, using SVC (static var compensation) causes to making stability and regulating the active power of the system, decrasing phase current, and bypassing third harmonic goes to connecting the transformers in Δ-Ŷ.

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