SIGNIFICANT REDUCTION OF THE CURRENT AND VOLTAGE HARMONICS AND BALANCE THE UNBALANCED PHASES WITH MULTIFUNCTION PARALLEL ACTIVE FILTER-AFQ IN KERMAN MOTORS AUTOMOBILE FACTORY IN BAM-IRAN

Zeinab ABDOLZADEH
KGUAT[1],SKED CO[2]– Iran
Abdolzadehz@yahoo.com

Mojtaba SAMAREH
SKED CO – Iran
Mojtaba_1351@yahoo.com

Arash RAHMANI
Bne-Energy CO - Iran
Rahmani_behinehniroo@yahoo.com

Roohollah FADAEINEJAD
KGUAT – Iran
Rfadaein@ieee.org

Abdolvahid MAHDAVINIA
SKED CO - Iran
Avmnia@yahoo.com

ABSTRACT

In this paper the effect of multi-function parallel active filter to improve power quality for one of Bam-in Kerman province-automotive industries (Kerman motors) is been reviewed. All the equipment with electronic control devices contains: rectifiers, modulators and switch devices which because of the material used for their semi-conductors , the consumed current of this equipment are non-sinusoidal with high distortion. By measuring the power quality in a several month period before and after installing active filter parallel to each paint substation transformers, the results indicates that the mean reduction of voltage harmonic is 55% and the current harmonic is 78%, furthermore the energy consumption in each electrolyze is reduced to 29% compared with when no filter is installed. In addition the economic calculations show that the returned investment will be in 26 month and the saving will be 253166$ in ten years.

INTRODUCTION

Increment in operating non-linear loads and the number of sensitive consumers, increases the need for a suitable power quality in a power system [1]. Most power systems are three phase and are designed for a balanced situation. Unbalanced procedure will cause negative and zero current sequences. These components will therefore lead to undesired additional losses in transmission systems, electrical machines, AC torque fluctuation, transformer saturation, rectifier ripple increment, additional null current, and reducing the total capacity used in the network [2]. All the equipment with electronic control devices contains: rectifiers, modulators and switch devices which because of the material used for their semi-conductors, the consumed current of this equipment are non-sinusoidal with high distortion. In the studied automotive industry before installing filter the parameters measured shows that the electrical load in the paint substation transformers suffer from voltage harmonics about 7% and current harmonics about 40% which is higher than the European standard EN50160 [3]. According to the power quality problems in the paint substation transformer such as: the negative power consumption, high voltage and current harmonics, unbalanced phases in the system and existence of same angle harmonics (harmonic coefficients 3), installing an active filter with the ability of balancing load was suggested. Multifunction parallel active filters are capable of canceling harmonics, balance phases in the power system, eliminate the returned null current, reactive power compensation, reduce voltage drop in cables and transformers, reduce temperature and transformer losses, reduce voltage waveform distortion, change the current waveform to a sinusoidal form and etc. Therefore using parallel active filter is one of the effective methods used for compensating reactive power and cancelling harmonics [4]. The increment in harmonics will cause increment in oil, wiring and hot points temperature, and this will lead to the reduction of transformers lifetime [5].

In this paper after describing the problems of power quality in paint process due to electrolyze in Kerman motors in city of Bam, the power quality measured by power analyzer device is investigated. And the details of the active filter installed parallel to the electrolyze transformer and the improvement in canceling harmonics after installing the filter is reviewed and in the end the economic advantages of installing an active filter is calculated.

VEHICLE PAINTING ELECTROLYZE LINE AND POWER QUALITY PROBLEMS

The industry studied in this paper has two paint line, in each line first by catodic electro deposition the vehicle will negatively be charged and then the positive paint will stick to the body. In the electrolyze procedure the output voltage and the energy consumed is controlled by 6 rectified thyristors and by controlling the fire angle. This rectifying in the electrolyze process will cause the high harmonic ranges from 3 to 21 (percent overall distortion of the current 40 percent). The other disadvantage of the electrolyze

1 Kerman Graduate University of Advanced Technology
2 South Kerman Electrical Power Distribution Company

process is the increment of transformers temperature, transformer losses and energy losses. Figure 1 shows the paint line rectifier circuit.

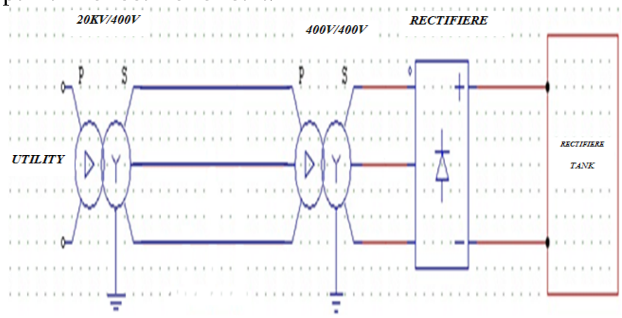

Fig1: The paint line rectifier circuit

Measuring power quality before installing active filter , according to the results of measuring power quality of all the transformer's output in a six-month period by power quality analyzer (CVMK2 type make with circutor company Spain, Barcelona), it is observed that the paint substation transformers in the plant have the most power quality pollution [11-12]. The CVMK2 installed in the paint substation transformer is presented in figure 2.

Fig 2: The CVM installed in the paint substation transformer

According to the measurements result, the harmonic voltage deviation caused by nonlinear devices in paint substation varies between 3 to 6.8 percent with the average of 3.9 percent. The maximum harmonic voltage deviation is 6.8 percent which is higher than the European standard EN50160 [3]. Figure 3 shows graph of voltage THD.

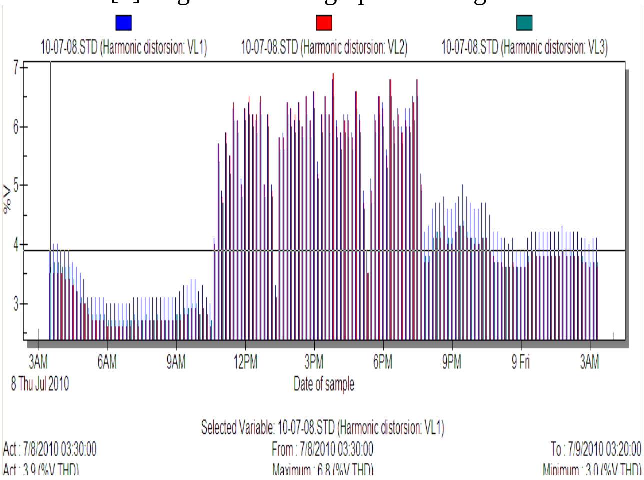

Fig 3: The graph of voltage THD

The harmonic current also varies between 9 to 41.3 percent (Figure 4). The maximum harmonic current deviation is 41.3 percent which is higher than the standard [3].

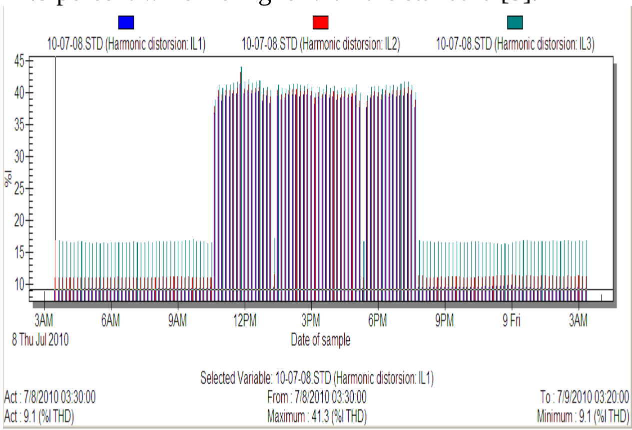

Fig 4: The graph of current THD

Figure5 shows the transformer loss coefficient (K Factor) with coefficient 100. As it is shown in figure 5 the transformer losses deviation is approximately 10.38. The standard for transformer loss deviation is 1.7. The harmonic pollution in paint substation cause transformer loss exceeds more than six times more than the standard value [3,6].

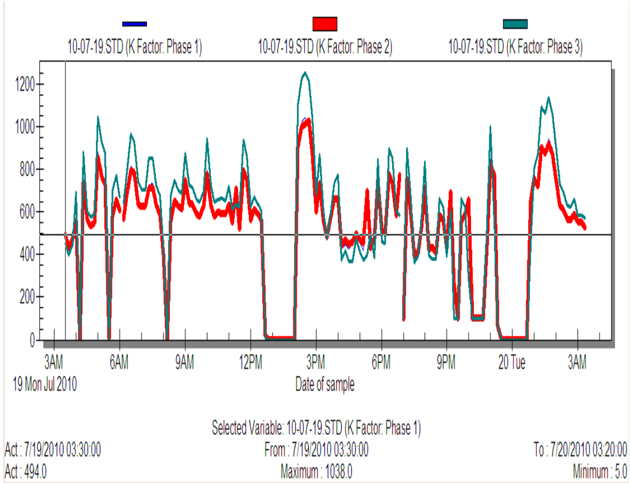

Fig 5:The graph of K Factor

MULTIFUNCTION ACTIVE FILTER

In order to cancel and reduce high values of load harmonics (Current harmonics 3, 5, 7, 9 , 11 and …), installing an active filter was suggested (passive filters have the ability to cancel one or two harmonics but the active filter can cancel a high range of harmonics, in addition the passive filters cannot cancel the returned null current but the active filters have this ability) [7]. Due to the unbalanced phase in plants paint substation, 3rd harmonic is in a high value therefore using an active filter with the ability of load balancing plays an important role. The capability of compensating reactive power in no load situation and exiting from compensating reactive power in load situation, lead to use a filter with such ability. Therefore the required active filter should have the ability to cancel high range of harmonics, load balancing and reactive power compensation in no load situation in order to improve power factor [8-9]. According to what has mentioned above, a multifunction active power is used.

The active filter current is calculated by equation 1 [11].

$$I_{AF} = 1.2 * \%(CurrentTHD) * I_{LOAD_{MAX}} \qquad (1)$$

Where I_{AF} is active filter current, Current THD% is total harmonic distortion of current and $I_{LOADMAX}$ is maximum load current. By assuming 40% for the THD and 300 amps for the load current, the active filter current is calculated 144 amps. According to the current calculated for the active filter the nearest chosen current is 150 amps which can be supplied by AFQ-150 model manufactured by Circutor company Spain, Barcelona[11]. Because of the DSP used in the microprocessor control system of this filter, and the ability of controlling current and reactive power harmonics, this filter will cancel harmonics by balancing current and the reactive power is compensated which leads to the reduction of problems due to harmonics and energy consumption. Active filter has no limit on canceling harmonics and can cancel all the current harmonics up to the50th order (2500 Hz) and user-selection of harmonic frequencies to be filtered for a higher efficacy, by first measuring systems harmonics and then using the values measured to inject the required current. By canceling 3rd harmonic and it's multiplications the returned null current is reduced. The other properties of the active filter is balancing load, reactive power compensation, cable and transformer voltage drop reduction, temperature and transformer loss reduction, avoid resonance phenomena and these filters offer a configurable function priority for an optimal use of the filter capabilities according to the installation needs[8]. Figure 6 shows the location of filters installed in the paint substation in Bam automotive industries.

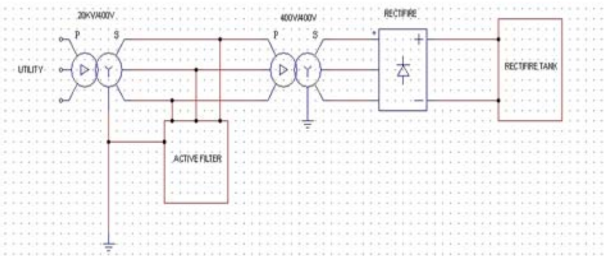

Fig 6: The position of active filter on paint line substation

After installing active filter and measuring the paint substation output parameters, it has been observed that the voltage harmonics is reduced up to 55% and current harmonics up to 78%, in addition voltage and current in each phase is balanced and the power factor in no load mode is increased from 0.6 to 0.95 capacitance, and in load mode is increased from 0.65 to 0.92 inductance. Figure 7 shows voltage harmonic and figure 8 shows current harmonic before and after installing the filter.

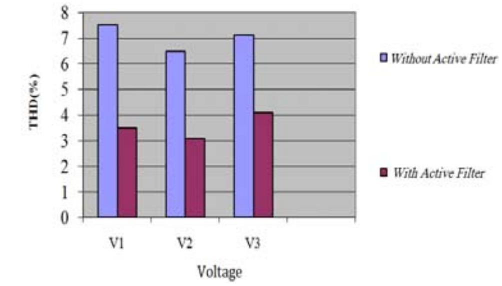

Fig 7: value of harmonic of voltage before and after installation active filter

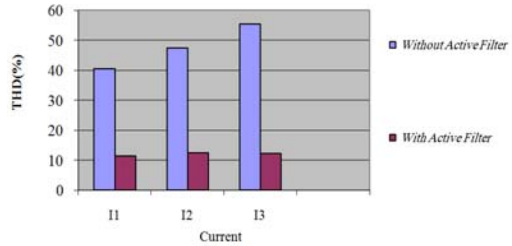

Fig 8: value of harmonic of current before and after installation active filter

ECONOMIC ANALYZING

In this section by using mathematic calculation the economic saving after installing filter in electrolyze line in automotive industry is illustrated. The calculations are according to the latest prices announced by Tavanir Co [3]. Since the new prices are arisen in a ladder form, the returned investment duration is reduced .In this paper we assume that the price is the actual energy price. Since the situation of the two paint substation transformer is equal, only one transformer is calculated.

Before installing filter

Electrolyze line 1:

The amount of power consumption is approximatly 180 KW.

$$E_1 = \sum_{N=1}^{30} \left(\sum_{t=1}^{24} P_{1tN} \right) \qquad (2)$$

Where

E_1 is the energy consumed by electrolyze line 1

P_{1tN} is the power consumed by line 1 in time t and Nth date.

T is the time and N is the number of the day.

According to the equation 2 we can see that the energy consumed during a month period is about 129600 KWh and in addition harmonics will cause eddy current losses. The effect of the harmonics on increasing eddy current losses is indicated in equation 3 and 4[10]. In this paper due to harmonics the eddy current losses increased up to 10%.

3 Iran Power Generation Transmission & Distribution Management Company

$$P_{eh1} = P_{ef\,1} \sum_{h=1}^{h=h_{\max}} I_{h1}^{2} h^{2} \quad (3)$$

$$K = \sum_{h=1}^{h=h_{\max}} I_{h1}^{2} h^{2} \quad (4)$$

P_{eh1} is the eddy current percentage due to harmonics in the electrolyze transformer
P_{ef1} is the eddy current due to transformers current without harmonics
h is the harmonics number
I_{h1} is the percentage of current harmonic magnitude divided by the fundamental frequency magnitude.
K is the transformer loss coefficient in harmonic condition

Therefore the transformer energy losses E_{loss1} (Equation 5) is extracted by multiplying the transformer energy consumption by the transformer loss.

$$E_{loss1} = E_1 * P_{eh1} \quad (5)$$

According to this equation the transformer energy loss is 12960 KWh. Here the total energy (Equation 6) consumed by line 1 electrolyze according to the transformer losses is 142560 KWh and the cost of energy $Cost_{E_{total1}}$ calculated by equation 7 and assuming the price of each KWh 0.033$ will be 4700$.

$$E_{total1} = E_1 + E_{loss1} \quad (6)$$

$$Cost_{E_{total1}} = E_{total1} * 0.033\$ \quad (7)$$

The calculations for electrolyze line 2 is the same as electrolyze line 1.

After installing filter

Electrolyze line 1:

After installing parallel active filter the total energy consumed $E_{totalWF1}$ is reduced to 101600 KWh. By using filter the harmonic due to energy consumption $E_{hormonics}$ is canceled. In addition the transformer energy loss $E_{lossWF1}$ is also reduced (Equation 8).

$$E_{totalWF1} = E_1 - E_{hormonics1} + E_{lossWF1} \quad (8)$$

In this case the energy consumption cost will be 3350$.
In order to calculate the economic effectiveness(EE) $\%Cost_{EE}$ after installing filter according to the costs before and after will reduce up to 29% in each month which is 1350$ (Equation 9).

$$\%Cost_{EE} = \left(Cost_{E_{total1}} - Cost_{E_{totalWF1}}\right) / Cost_{E_{total1}} * 100 \quad (9)$$

Since the price of the filter is 35417$ the returned investment will be 26 month. And since the lifetime of the filter is approximately 10 years the economic profit will be 126583$.

We can conclude that by paying 70834$ (since we have two lines) the returned investment will be 26 month and the total profit will be 253166$ in ten years. It has to be mentioned that according to the profits due to the reduction of depreciation of the equipment, their maintenance and the increment in energy consumption price the economic profits would be more.

CONCLUSION

In this study the current and voltage harmonics and other power quality problems before and after instating multifunction in Bam automotive industry is investigated. It had been observed that after installing parallel active filter on each substation transformer, the voltage harmonic reduced 55% and current harmonics 78% and the energy consumption in each electrolyze line reduced to 29% compared by the time when filter is not installed. In addition the return investment will be 26 month and the economic saving will be 253166$ after ten years.

REFERENCES

[1] A.Chaoui, J.P Gaubert and F. Krim,2010, " Power quality improvement using DPC controlled three-phase shunt active filter ", *Electric Power Systems Research*, vol.80, No.6, pp.657-666.

[2] H.Akagi, Y. kanazawa, , 1984" Instantaneous Reactive Power Compensator Comperising Switching Devices Without Energy Storage components," *IEEE Tran*s. Ind. App.,Vol.IA-20 , no.3,PP. 625-630.

[3] European standard EN 50160 Voltage characteristics of electricity supplied by public distribution systems, CENELEC TC 8X, 2006.

[4] H. Akagi, S. Srianthumrong, Y. Tamai, 2003 “Comparisons in circuit configuration and filtering performance between hybrid and pure shunt active fiters”, IEEE 38 th Conf. on Industry Applications, Vol. 2, pp.1195-1202, Oct.

[5] Damnjanovic, G. Feruson, 2004 “The Measurement and Evaluation of Distribution Transformer Losses under Non-Linear Loading, ”IEEE Power Engineering Society General Meeting, pp.1416-1419.

[6] Harmonic Standard IEC 61000-3-4, IEEE , 519- 1992.

[7] Design Standard IEC 60146 Semiconductor Converters.

[8] Safety Standard EN 50178 ,Electronic equipment for use in power installations,1997.

[9] Electromagnetic Compatibility EN 55011, Industrial, scientific and medical (ISM) radio-frequency equipment-Electromagnetic disturbance characteristics - Limits and methods of measurement,2007.

[10] H.J. Bollen, Y.H.GU,2006 "Signal processing of power quality disturbances", *IEEE Power engineering Society*,Canada,207-208.

[11] Www.Circutor.Com

[12] Www.Bne-Energy.Com