HARMONICS INVESTIGATION IN A STEEL FACTORY

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ABSTRACT

For many years, the reliable distribution of electric power has been plagued by common problems such as interruptions, voltage sags and swells, as well as voltage flicker, and transients. The impact of these problems has gotten worse in recent years due to the nature of the loads that are served by the power system. Increased use of automated, computer controlled processes means that industrial energy customers are often adversely impacted by disturbances that originate on the transmission or distribution system. Customers that formerly had little or no difficulties with the quality of their electric supply are now experiencing costly disruption of critical manufacturing processes due to voltage disturbances. These process disruptions result in millions of dollars of lost production, scrapped product and clean-up each year. The paper presents the different power quality problems encountered by some of the plants of this industrial city, from which data was measured and recorded. Solutions exercised by such companies to solve such problems are mentioned. The paper suggests and recommends solutions to increase savings and reduce power quality problems and therefore plant productivity

INTRODUCTION

A major cost to a steel factory facility is the energy used to power the arc furnace for the melting and refining process. Operation at low power factor results in additional voltage drop through the power system yielding a lower system voltage on the plant buses. Low system voltage increases the melt time and will add to the overall plant operating costs per ton. Low power factor can also result in additional costs in the form of penalties from the electric-utility company [1-2, 8]. Capacitor can be applied in steel factory facilities for a wide range of benefits. The capacitors will improve the power factor of the system; reduce billing penalties imposed by the electric power utility, and increase system voltage-boosting productivity. The system losses are also reduced improving the electrical system efficiency. However, harmonic sources in the steel mill can interact with capacitor banks resulting in problems if they are not properly applied. The effect of harmonics varies depending on the type of load. In some cases such as a resistance heating load all of the applied voltage does useful work; although, in most cases involving transformers and motors only the 60-hz component of the voltage does useful work and the harmonic component generates useless heat. Sensitive electronic control circuits, timers, and logic circuits may be affected if the supply voltage is distorted [3-5].

Harmonic analysis, load flow analysis, and power factor correction in steel plant in Saudi Arabia, were considered for two reasons: 1) the planned installation of a new ladle furnace; and 2) the correction of the overall plant power factor to a value above 0.90 lagging to eliminate utility penalties.

BRIEF STEEL PLANT SYSTEM DESCRIPTION

The steel plant system consists of 49 buses and 38 two winding transformers. The plant is fed from two utility substations at 230 KV and through four 230/34.5 KV transformers. From 34.5 KV many 34.5/13.8 KV transformers are installed to feed difference load including three electric Arc Furnaces (EAF1, EAF2, EAF3) and two Ladle Furnaces (LF1, LF2). Part of The single line diagram of the arc furnaces of this system is shown in figure 1.

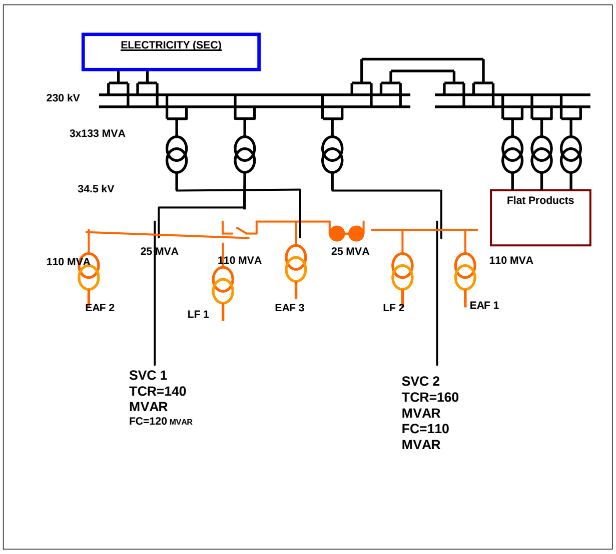

Figure 1 Partial single line diagram of steel plant system.

This system was simulated by using a software package and the results of load flow, total harmonic distortion, and power factor at some buses are shown in table 1.

Table 1: Load flow, THD, and power factor results

BUS #	Nominal Voltage (KV)	LF Voltage (p.u)	LF Angle (deg)	THD (%)	Power Factor
1	230.00	1.00	0.00	6.47	56
2	34.50	0.95	-1.90	10.31	59
3	34.50	0.95	-1.90	10.31	59
5	34.50	0.95	-1.90	10.30	59
45	0.48	0.91	-3.80	10.11	58
46	0.48	0.91	-3.80	10.11	58

FILTER DESIGN

A generic term used to describe those types of equipment whose purpose is to reduce the harmonic current or voltage flowing in or being impressed upon specific parts of an electrical power system, or both. A filter generally consisting of combinations of capacitor, inductors and resistor that have been selected in such a way as to present a relative minimum (maximum) impedance to one or specific frequencies [4].

The filter is tuned slightly below the harmonic frequency of concern. This allows for tolerances in the filter components and prevents the filter from acting as a direct short circuit for the offending harmonic current. Further allows the filter to perform its function while helping to reduce the duty on the filter components. It also minimizes the possibility of dangerous harmonic resonance should the system parameters change and cause the tuning frequency to shift slightly higher [6, 7].

Filter Components

Capacitors
Capacitors are composed of standard units that are connected in series or parallel for obtain the desired overall voltage and KV rating [5].

Inductors
Inductors used in filter circuit need to be designed bearing in mind the high frequencies involved. Inductors rating depend mainly on the maximum RMS, current. The inductors and resistors form the ground side of a tuned filter [5].

Tuned Filter

A single tuned filter is a series RLC circuit tuned to the frequency of one harmonic .its impedance is given by

$$Z_1=R+ j (wL-1/wC) \quad (1)$$

Which at the resonant frequency fn reduces to R. There are two basic design parameters to be considered prior to the selection of R, L and C. these are the quality factor Q, and the relative frequency deviations. It is generally more convenient to deal with admittances rather than impedance in filter design

$$Y_f=1/R\ (1+j2s\ Q) =G_f + j\ B_f \quad (2)$$

Where

$$G_f = Q/X0(1+4s^2Q^2) \quad (3)$$

$$B_f =2sQ^2/ X0(1+4s^2Q^2) \quad (4)$$

$$X_0=\sqrt{\frac{L}{C}} \quad (5)$$

The harmonic voltage at the filter bus bar is

$$V=I/Y_f + Y_s \quad (6)$$

Therefore, to minimize the voltage distortion it is necessary to increase the overall admittance of the filter in the parallel with the a.c system. The harmonic voltage increases with (s) [4]. In term of Q and s can be equation (6) can be written as follows:

$$V=I\{(Gs+1/R(1+4s^2Q^2))^2+(Bs-2sQ/R(1+4s^2Q^2))^2\}^{-1/2,} \quad (7)$$

Table 2: Filter Data

Filter Location	Order	Rated KV	Kvar	XL	Q
Bus # 1	2^{nd}	230.00	35035.00	377.47	75.00
Bus # 5	5^{th}	34.50	30572.00	79.00	39.50
Bus # 5	7^{th}	34.50	24745.00	120.20	84.10

Table 3: Load Flow, THD, and Power Factor Results

Bus #	**Nominal Voltage (KV)**	**LF Voltage (p.u)**	**LF Angle (deg)**	**THD (%)**	**Pf**
1	230.00	1.00	0.00	1.24	0.98
2	34.50	0.99	-2.30	2.95	0.99
3	34.50	0.99	-2.30	2.95	0.99
5	34.50	0.99	-2.30	2.95	0.99
45	0.48	0.95	-4.00	2.92	0.97
46	0.48	0.95	-4.10	2.92	0.97

Single-tuned filters were designed for Hadeed plant system according to above theories and its input data are provided in table 2. The results of load flow, total harmonic distortion, and power factor of buses 1, 2, 3, 5, 45, and 46 after installing filter are shown in table 3. Also the spectrum and waveform of bus 34.5 kV is provided in figure 3.

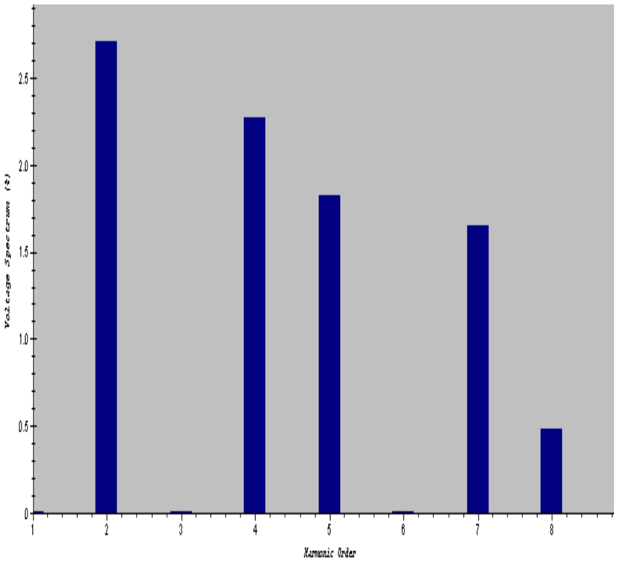

Figure 2: Spectrum of voltage at bus 34.5 kV

CONCLUSION

Due to presence of three arc furnaces and two ladle furnaces in this steel facility, one expects harmonics are considerably high in the steel plant without any filtering. Also, due highly inductive load of this steel plant the

power factor needs to be corrected to match that of the utility [8]. Harmonic studies are becoming an important component of power system planning and design. Steel plant engineers are striving to meet with utility, and IEEE standard for harmonics as well as power factor. Considerable efforts have been made by the plant engineers in recent years to improve the management of harmonic distortion in power systems and meet the utility requested power factor levels.

Results obtained from steel plant system the power factor are low at about seven buses one of them bus number 1 the utility bus were the power factor found 0.56. The power factor of all the buses ranged between 0.56 and 0.59 which considered very low for the utility power factor which is 0.93. Results obtained from the harmonic studies indicate again that many buses of the plant including the utility bus have violated they IEEE-519 1992 standard. One has to remember that using software to analyze the practical conditions it is important to understand the assumption made and the modeling capabilities, of the non-linear elements.

The author has met with plant engineers and discusses mitigation of the harmonic level as well as improvement of the power factor. Harmonic filters were designed to suppress low harmonic order frequencies and were installed at the different buses, the filtered harmonic of this plant were mainly for the 2nd, 5th, and 7th harmonics. The plant operations with installation of the designed filters have improved the power factors to reach 0.97. The authors highly recommend cost analysis of designed filters KVAR with harmonic and other benefits, periodic system studies especially when new equipments are added to the plant. Also power quality measurements will be necessary to double check harmonics order found through simulation.

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REFERENCES

[1] J. Arrillaga, D. A. Bradley, and P. S. Bodger, “Power System Harmonics”, John Wiley & Sons, New York, 1985.

[2] “Recommended Practices and Requirements for Harmonic Control in Electric Power Systems”, IEEE Standard 519-1992, IEEE, New York, 1993.

[3] G. T. Heydt, Electric Power Quality, Stars in Circle Publications, West LaFayette, IN, 1991.

[4] R. C. Dugan, “Simulation of Arc Furnace power systems”, IEEE Trans. on Industry Application, Nov/Dec 1980, pp. 813-818.

[5] M. F. McGranaghan, R. C. Dugan, and H. W. Beaty. “Electrical Power Systems Quality”, New York: McGraw-Hill, 1996.

[6] Task force on Harmonics Modeling and Simulation, "The modeling and simulation of propagation of harmonics in electric power networks Part I: Concepts, models and simulation techniques," IEEE Transactions on power Delivery, Vol. 11, NO.1, January 1996, pp.

[7] Victor A. Ramos JR, “Treating Harmonics In Electrical Distribution system” Technical Consultant Computer Power &Consulting Corporation, January 25, 1999.

[8] M. H. Shwehdi, et Al,” Power Factor Essential and causations,” IEEE-PES summer Meeting Singapore, July, 2000