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POWER QUALITY ANALYSIS IN ELECTRICAL ARC FURNANCE

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Abstract: Eletric Arc Furnaces are unbalanced, nonlinear and time varying loads, which can cause many problems in the power system quality. As the use of arc furnace loads increases in industry, the importance of the power quality problems also increase. So in order to optimize the usages of electric power in EAFs, it is necessary to minimize the effects of arc furnace loads on power quality in power systems as much as possible. At the current time, Electrical arc furnaces is designed for very large power input ratings so that these devices can cause large power quality problems on the electrical network like harmonics, inter-harmonics, flicker and voltage imbalances.

I. INTRODUCTION

At the current time, Electrical arc furnaces is designed for very large power input ratings so that these devices can cause large power quality problems on the electrical network like harmonics, inter-harmonics, flicker and voltage imbalances. The Voltage-Current characteristic of the arc is non-linear, what can cause harmonic currents. These currents, when circulating by the electric grid can produce harmonic voltages, which can affect to other users. In costing and limitation, there are some definitions and standards to quantify the disturbance levels, such as IEC, 1999, IEEE 1995, and IEEE, 1996. The total harmonic distortion (THD), short-term voltage flicker severity (Pst), and long-term voltage flicker severity (Plt) are used. However, sometimes it is desired to record voltage and current waveforms in the specified duration to track the disturbance levels.

Power quality

Institute of Electrical and Electronic Engineers (IEEE) Standard IEEE 1100 define power quality as; "A concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment". But this is not the only analysis. Another simple and more concise definition might state: "Power quality is a set of electrical boundaries that allows equipment to function in its intended manner without significant loss of performance or life expectancy" Definition that hold two things that we demand from electrical equipment: performance and life expectancy. Another definition of power quality, based on the principle of EMC, is as follows:

Power quality refers to a wide variety of electromagnetic phenomena that characterize voltage and current at a given time and at a given location on the power system

Power quality can be interpreted by the existence of two components:

Voltage quality: It expresses the voltage deviation from the ideal one and can be interpreted as the product quality delivered by the utilities.

Current quality: It expresses the current deviation from the ideal one and can be interpreted as the product quality received by the customers

The main Power quality disturbances are:

- Harmonics;
- Flicker;
- Transients;
- Voltage Sags;
- Interruptions.

Flicker

An electrical arc furnace (EAF) changes the electrical energy into thermal energy by electric arc in melting the raw materials in the furnace. During the arc furnace operation, the random property of arc melting process and the control system are the main reasons of the electrical and thermal dynamics. That will cause serious power quality problems to the supply system.

The fundamental component of the current drawn by an EAF produces fluctuations of the voltage in the nearby distribution system. These fluctuations are the reasons of the phenomenon known as flicker. The voltage changes as much as 0.3~1% with frequencies between 2 and 8 Hz

Method for calculate flicker

There is many formulas to calculate the flicker here is,

1. Short Circuit Ratio Method,

$$SC\ Ratio = \left[\frac{MVA_{SC}@PCC}{MVA_{EAF}}\right]$$

SC ratio: Short circuit ratio
MVAsc: Short Circuit at Point of Common Coupling, MVA
MVAeaf : EAF Transformer Loading, MVA

2. SCVD Method (MW),

$$SCVD_{MW} = \left[\frac{2 \times MW_{EAF}}{MVA_{SC}@PCC}\right] \times 100$$

Where;
SCVDmw=Short circuit voltage depression, %
MWeaf = Real Power of EAF, MW
MVAsc = Short Circuit at Point of Common Coupling, MVA

To avoid flicker, value should be lower than 1.6 %. This method can only be used in working installation since it needs value of real or actual power during operation.

3. SCVD Method (V)

$$SVCD = \left[\frac{V_{OC} - V_{SC}}{V_{OC}}\right] \times 100$$

Where,
SCVD =hort circuit voltage depression, %
Voc=Voltage at open-circuit condition, V
Vsc=Voltage at short-circuit condition, V
This method required load flow analysis which are many times not known during project conceptualization.

4. Pst Method,

$$P_{st}99\% = \left[\frac{MVA_{SC} o f_{EAF} @PCC}{MVA_{SC} @PCC}\right]$$

Where,
Pst99%= Predictibility @ 99% in short time (st=10min, and lt=2hrs)
MVAscEAF =Short Circuit at Electrodes tips with view from point of common coupling
MVAsc@PCC= Short Circuit at Point of Common Coupling, MVA
Kst=EAF Severity Factor(48 ~ 85 for EAF Loads)
To avoid flicker problems Pst should be lower than 1.3%.
This method needs calculator to know furnace severity factor which depends upon raw material to be used in furnace. (Scrap, Molten Metal, Reduced iron etc.)
Flicker Limits in Terms of Pst and Plt
IEEE Standard 1453 – IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems is the key standard with regard to flicker. Some of the key points of this document are noted as follows.

- Plt is the measure of long-term perception of flicker obtained for a two-hour period. This value is made up of 12 consecutive Pst values.
- Pst is the measure of short-term perception of flicker obtained for a ten-minute interval.
- As a general guideline, Pst and Plt should not exceed the planning levels given in Table 1 more than 1% of the time (99% probability level) with a minimum assessment period of one week.

Table Planning levels for Pst and Plt in MV, HV, and EHV power systems

	Planning levels	
	MV	HV-EHV
Pst	0.9	0.8
Plt	0.7	0.6

For LV and MV power systems the flicker levels listed in Table 2 are recommended and are based on 95% probability levels

Table 5.4.2 – Compatibility levels for Pst and Plt in LV and MV power systems

	Compatibility levels
Pst	1.0
Plt	0.8

As survey done in JSPL RAIGADH and obtain flicker value by calculation as further given below.

$$P_{ST99\%} = 4.1371 \qquad P_{ST95\%} = 3.4968$$

II. LITERATURE SURVEY

Time rolls on and shadow falls but the work carried out by the important personalities will always be the stepping-stone for the future revelations. Following are the research works have been investigated. In this paper [1] studies that due to very large electrical loads EAF cause voltage flicker problem in the power system due to their non-linear and random electrical characteristics. Voltage flicker (cyclic and stochastic) causes annoying sensation experienced by human eye and is a very important power quality parameter. In this paper, a Matlab- Simulink based flicker severity analysis module has been proposed to analyses voltage flicker in the network under multiple EAF operation fed from a substation. In this module a new system-modeling strategy is proposed. The power system is modeled and simulated in Simulink and instantaneous voltage data is analyzed by a separate Matlab program. With this module, a power system containing two parallel EAFs is modeled and simulated and the short-term flicker severity index of voltage at point of common coupling is calculated. In this paper studies [2] about The aspects of power quality in PCC where an ARC furnace for steel melting with alternating current is connected. By measurements of flicker, harmonics content in voltage and current, the preservation of the reference levels for the supply voltage and emission limits for the furnace as a customer are evaluated In that way the clear estimation of the power quality aspects in light of modern standards is given. In this paper study [3] of field measurements of power quality indices at the terminals of an Electric Arc furnace connected at 34.5 kV to a 230 kV 60 Hz network in Saudi Arabia. The power quality indices that are measured are total harmonic distortion for voltage and current , individual harmonics, and flicker for short and long terms (Pst, Plt). In addition, other electrical parameters are measured as well such as voltage (Vrms), current (Irms), active power (P), reactive power (Q), power factor (PF), and frequency. In this paper study[4] about voltage flicker problems in the electric power network. Reduction of voltage flickers by conducting furnace controls, such as electrode controls, or by adding compensation equipment, such as power factor corrector and static var compensator, are widely used in the industry. In order to achieve the best result, an accurate model for flicker analysis and prediction is essential.

III. SUMMARY OF LITERATURE SURVEY

From the above literature survey, it could be concluded that as per IEEE standard the value should be 0.9 accepted so the flicker value should be reduced by the compensation the network.

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