IMPROVEMENT OF POWER QUALITY IN ELECTRIC ARC FURNACE OPERATION CASE HARMONICS

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Abstract: *It is very well known that electric arc furnace (EAF) as a three-phase charge one of the most important generators of harmonic currents, reactive power and unbalanced conditions in electrical power systems. To study the effect of the harmonics, it is necessary to know the values of the electrical parameters of the arc furnace electrical installation as well as how the arc can be modelled. Our electric arc furnace model is implemented using a numerical simulation environment. In this paper we treats the harmonic that generated by the DC EAF in all positions of the three electrodes, that is to say when the electrode in high position and in low position "flooded in the liquid", and in every stage we determines the THD and the proportion of the harmonic most major. Finally this study shows the best working of a DC EAF that offers e the minimum of the THD and harmonic and it contributes in the increase of the length of the life of the transformer and the cables.*

Keywords: *EAF, Harmonics, Modelling, Simulation, Power Quality.*

1. Introduction.

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. From power quality viewpoint, an electric arc furnace represents one of the most challenging candidates among industrial loads. When the arc is striking through the scraps it appears like a short circuit on the secondary side of the furnace transformer. The short circuit current keeps changing in response to the melting conditions of the furnace content (scraps) [1, 2-4].

An arc furnace transfers electrical energy to thermal energy in the form of an electric arc to melt the raw materials held by the furnace. The arc is established between an electrode and the melting bath and is characterized by a low voltage and a high current Electric arc furnaces (EAFs) are widely used in steelmaking and in smelting of nonferrous metals [11, 12].

The EAF is the central process of the so-called mini-mills, which produce steel mainly from scrap. Typical EAFs operate at power levels from 10MW to 100MW. The power level is directly related to production throughput, so it is important to control the EAF at the highest possible average power with a low variance to avoid breaker trips under current surge conditions. For efficient power control, good dynamic models of EAFs are required [5].

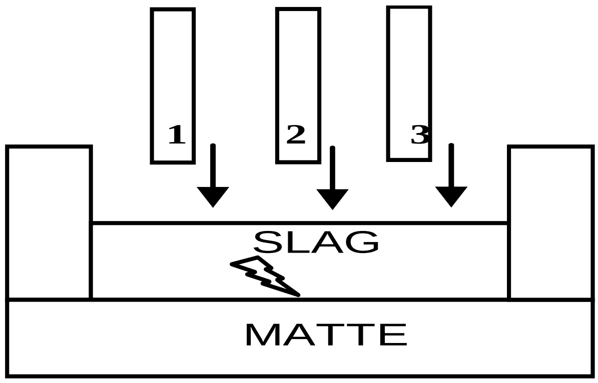

Fig.1 Physical Model of EAF [2]

The precise control of chemistry and temperature encouraged use of electric arc furnaces during World War II for production of steel for shell casings [10]. Today steelmaking arc furnaces produce many grades of steel, from concrete reinforcing bars and common merchant quality standard channels, bars, and flats to special bar quality grades used for the automotive and oil industry. A typical steelmaking arc furnace is the source of steel for a mini-mill, which may make bars or strip product. The steelmaking arc furnace is generally charged with scrap steel, though if hot metal from a blast furnace or direct-reduced iron is available economically, these can also be used for steelmaking [5, 10].

2. Advantage of a DC EAF

DC mode of operation ensures high arc stability, eliminates inrush currents and disturbances in Power System [14].

- Reduce metal loss by 2 - 4 -5 %.
- Reduces electrode consumption by 60%.
- Lower energy consumption by 5 - 7%.
- Absence of Hot Spots and Lower refractory consumption by 20%.
- DC flicker is 20% of AC flickers as current control reduces fluctuation of reactive power, Can also work on weak lines.
- Homogeneous temperature & composition due to intense stirring in molten metal.
- Ability to melt high percentage of DRI in the charge.
- Fewer mechanical components with less wear & tear reduce maintenance costs to only 40%.
- Environment friendly system with lower dust load by 80% & hence lower cost of pollution control equipment by 505.
- UNIARC does not require Static VA Compensators for operation.

3. Model description of a DC EAF

Our EAF melt steel, is applying by a DC current to load steel scrap by means of graphite electrodes. Compose essentially a 225/63 kV step-down transformer, and a second three wind transformer, one is coupled star and the other in a triangle, feeds a twelve pulse rectifier as shown in the following figure [15].

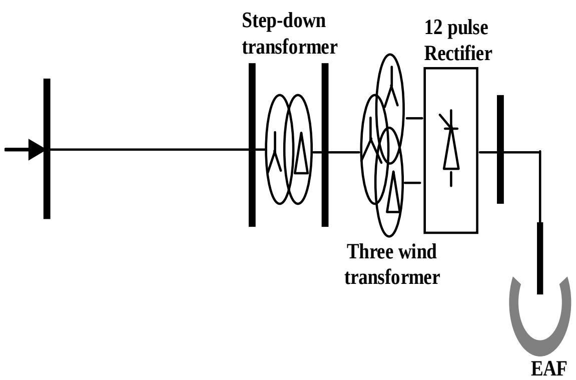

Fig.3 Modelled dc arc furnace plant

The opportunities of the DC EAF simulator is mainly based on the release of twelve pulse rectifier (i.e. the number of electrodes used 1, 2.3), as well as the use of neutral connection. A typical DC arc furnace plant, is modelled as it is shown in Fig. 3.

4.1. Twelve pulse rectifier

The principle consists in using a transformer with two secondary delivering voltage delayed of 30° between them, each of these secondary supply a rectifier in bridge of Graëtz that achieves a 12 pulses DC current [5]. So this structure regroups two converters, a bridge, with a star-star connection (PD3) and another bridge star-triangle connection (S3).

The rectifiers must provide identical continuous currents so that the alternating currents in the secondary of the transformers take the same values. In these conditions, there is a recombination of the harmonic currents, generated by each of the rectifiers to the primary of the transformer and the calculation shows that the harmonic of rang 6 k ± 1 are eliminated [13, 14].

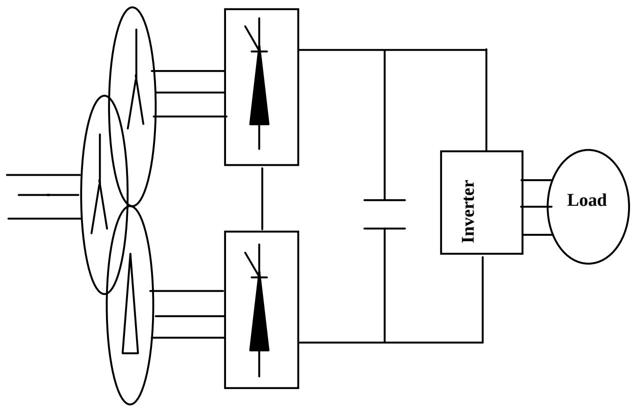

Fig. 4 Twelve pulse rectifier.

The first is three phase to a connection star / star, therefore its current profile is represented as follows.

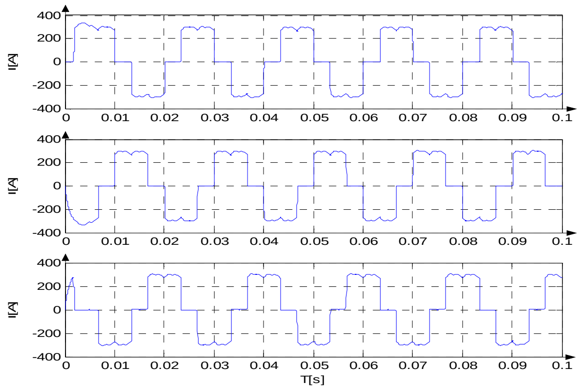

Fig. 5 Current at the star of transformer rectifier

The second is three phase set to a connection star / triangle, therefore its current profile is represented as follows.

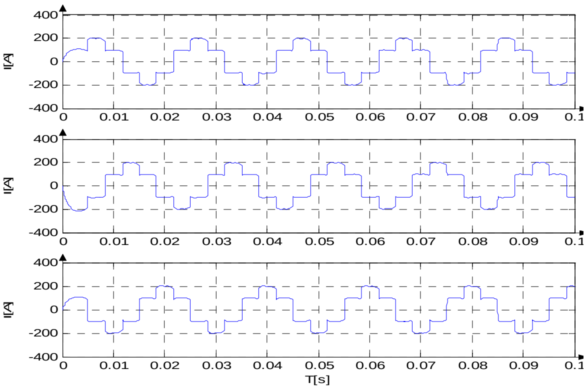

Fig. 6 Current at the triangle of transformer rectifier

The recombination of the two rectifiers' gives a bigger current with fewer harmonic (harmonic 5 and 7 are nil) and its current shape is as follows.

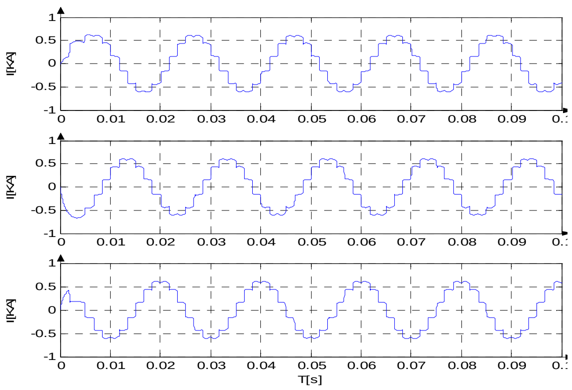

Fig.7 Current of twelve pulse rectifier

4.2. Modeling and approximation

The EAF is modeled together with the neighboring network [6] .The circuit equation of the furnace transformer to the end of electrodes can be writhen as follow.

$$E_{tr} = \sqrt{3} Z_1 I_e + U_1 \quad (1)$$

Where U_1, I_e & Z_1 are respectively electrode voltage, current and impedance of EAF transformer with flexible cable

Then, $$Z_1 = \frac{[E_{tr} - U_1]}{\sqrt{3} I_e} = \frac{\Delta U_1}{\sqrt{3} I_e} \quad (2)$$

$$Z_1 = \sqrt{R_1^2 (I_2, T) + X_1^2 (T)} \quad (3)$$

$$R_1 = \frac{P_{EAF} - P_{arc}}{3 I_e^2} \quad (4)$$

Where:

P_{EAF} : is total active power of EAF.

P_{arc} : is the active power of arc.

So, from equations (1, 2, and 3) we can deduct

$$X_1 = \frac{1}{\sqrt{3} I_e} \sqrt{\Delta U_1^2 - \frac{[P_{EAF} - P_{arc}]^2}{3 I_e^2}} \quad (5)$$

$$R_{arc} = \frac{P_{arc}}{3 I_e^2} \quad (6)$$

$$Q_{EAF} = Q_{arc} + \Delta Q \quad (7)$$

$$Q_{arc} = Q_{EAF} - 3 I_e^2 X_1 \quad (8)$$

Where:

Q_{EAF} is total reactive power of EAF

Q_{arc} is the reactive power of arc

$$X_{arc} = \frac{Q_{arc}}{3 I_e^2} \quad (9)$$

Following to the treatment an empirical model is proposed [14, 15]:

$$R_{arc} = A_R(u) e^{\alpha(u) d} \quad (10)$$

Where:

$$A_R = \frac{[0,7.(U-210)^2 + 1,7]}{50^2}.10^{-3} \quad (11)$$

$$\alpha = 0,097 e^{0,011(90-U)} - \frac{1,7}{(U-112)^2 + 80} + \frac{100}{(U-360)^2 + 50} \quad (12)$$

$$X_{arc} = A_X(u) d^2 + B_X(u) \quad (13)$$

Where:

$$A_X = 1,05.10^{-3} e^{0,075(90-U)} \quad (14)$$

$$B_X = \frac{3,14}{153} - 3.10^{-3} e^{0,075(90-U)} \quad (15)$$

d : The distance between electrode and scrap.

5. Harmonics Analysis

There are many problems that can arise from harmonic currents flowing in a power system. Some are easy to detect. Other problems may exist and persist because harmonics are not suspected as the cause. Harmonic currents cause higher RMS current and voltage in the system. Twelve pulse rectifier configurations have been used for applications demanding lower harmonic levels than can be achieved using either traps or reactors. The theoretical benefits of 12 pulse rectification include cancellation of 5^{th}, 7^{th}, 17^{th}, 19^{th}, etc harmonics [7, 9]. The arc is supplied via a rectifier and is more stable than the arc in AC furnaces. The current drawn can be broken down into:

- A spectrum similar to that of a rectifier.
- A continuous spectrum lower than that of an AC

arc furnace.

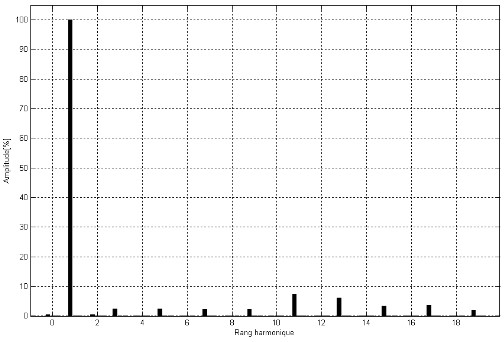

Fig.8 Harmonic spectrum of a DC EAF

But experience and analysis of the results also highlight a number of non harmonic characteristics, amplitude non negligible, especially in the area of low frequencies (harmonics ranges 5 and 7) [13, 14].

6. Optimization of the operation

We explore all the possibilities and positions of the three electrodes of our DC EAF phase and it pulls whenever the percentage of harmonics “5, 7, 11 and 13" and total harmonic distortion **(THD)**.

To optimize the working of a DC EAF to follow the following stages is necessary.

Consider: 1: Electrode in low position.
0: Electrode in high position.

The results of simulations are represented on the following table:

Table 1 .Possible state for the movements of electrodes

STATE			H_5 (%)	H_7 (%)	H_{11} (%)	H_{13} (%)	THD (%)
0	0	0	2,54	2,97	3,40	4,21	**22, 27**
0	0	1	9,01	6,56	7,78	5,49	**50, 35**
0	1	0	0,56	0,43	5,09	2,87	**6, 51**
0	1	1	4,87	2,44	8,53	7,92	**13, 59**
1	0	0	12,84	9,82	7,55	5,30	**38, 49**
1	0	1	2,35	3,53	7,06	5,88	**10,00**
1	1	0	6,25	1,87	7,25	6,87	**79, 59**
1	1	1	2,22	2,66	5,55	4,44	**10,03**

The working of the EAF always begins the arcing in single phase i.e. only one electrode flooded in the liquid then two-phase and in the end three phase that is to say all electrodes below in low position: therefore our proposition serves to find the diagrams that offer the minimum of the harmonic generated, as well as the corresponding THD therefore the best working is as follows:

First state 01 (000) then state 03 (010) then 06 (101) finally state 08 (111) that correspond to harmonic under the norms, especially “5 and 7”. Therefore the ordering of the stages of movements of the electrodes is as follows.

Table 2 Proposed states for the movements of the electrodes

STATE			H_5 (%)	H_7 (%)	H_{11} (%)	H_{13} (%)	THD (%)
0	0	0	2,54	2,97	3,40	4,21	**22, 27**
0	1	0	0,56	0,43	5,09	2,87	**6, 51**
1	0	1	2,35	3,53	7,06	5,88	**10,00**
1	1	1	2,22	2,66	5,55	4,44	**10,03**

So the best cycle of melting proposed is presented in the figure.9

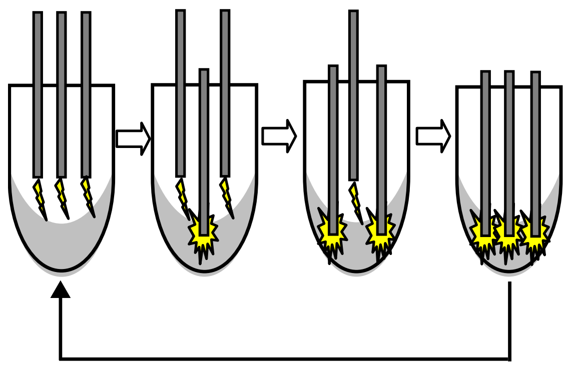

Fig. 9 Cycle of melting proposed

7. Conclusion

This paper presents a new DC Electric Arc Furnace model which implanted under numerical environment. In this article, we test the different possible cases for movements of the three electrodes following the tab N° 01. Then it is determined whenever the specter of harmonics and the THD of each stage. Finally, we deduct the proper “best” working which offers a minimum of harmonics, i.e., which is a good power factor and a THD reduced. In the end, our work falls within the overall framework of improving the quality of electrical energy level seats industrialists such as steelmaking.

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