

# AC Arc Furnaces Flicker Measurement without and with a SVC System Connected

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**Abstract.** An AC arc furnace is an unbalanced, nonlinear and time varying load, which can cause many problems to the power system quality. Different studies on arc furnaces harmonics analysis can be found in the bibliography of the topic nevertheless it is very difficult obtain an exact model that take into account all the parameters that have influence in the process then for this reason it is necessary to take measurements in different conditions. In this paper we'll present the harmonics distortions, flicker and unbalance results and conclusions about three different measurement campaigns on a iron and steel industry (SNL) with an AC arc furnace of 83 MW (170 TM) with a transformer of 120 MVA connected by a dirty line of 220 kV (55 km) with the Carregado Substation where there are another nets connected with industrial and domestic consumers.

**Keywords:** Flicker, harmonics, power quality, measurements, arc furnaces.

## 1. Introduction

An electrical arc furnace 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 furnace operation, the random property of arc melting process and the control system are the main reason of the electrical and thermal dynamics that will cause serious power quality problems to the supply system[9].

Harmonics, inter-harmonics, voltage flicker and unbalance are the power quality problems which are introduced to the power system as a result of nonlinear and stochastic behaviour of the arc furnace operation. The nonlinear voltage-current characteristic of the arc

can cause harmonic currents which when circulating by the net can produce harmonic voltages which can affect to other users.

The furnace shell is isolated and it is represented a star connection of the three arcs, then if a three-phase arc furnace operation were balanced, the zero sequence components of the current wave would be null. Really, unbalance operation is the normal situation in the meltdown process and this produces zero sequence harmonics in the arc current. However, due to the influence between phases, these harmonics components do not reach the values that we would find in the current wave of a single-phase operation arc.

Different studies on arc furnaces harmonics and flicker analysis can be found in the bibliography of the topic, for example, in [1] it is presented an arc model to carry out harmonic analysis of an AC three-phase arc furnace with a single-phase circuit. This model is based on V-I characteristic of the arc and takes into account the effect of the arcs unbalance over the zero sequence harmonics.

Nevertheless, take into account that the arc melting process is a stationary stochastic process it is difficult to obtain an accurate model for an arc furnace load. The factors that affect the arc furnace operation are the melting materials, the electrode position, the electrode arm control scheme, and the system voltage and impedance. For all of these reasons it is very important to take measurement.

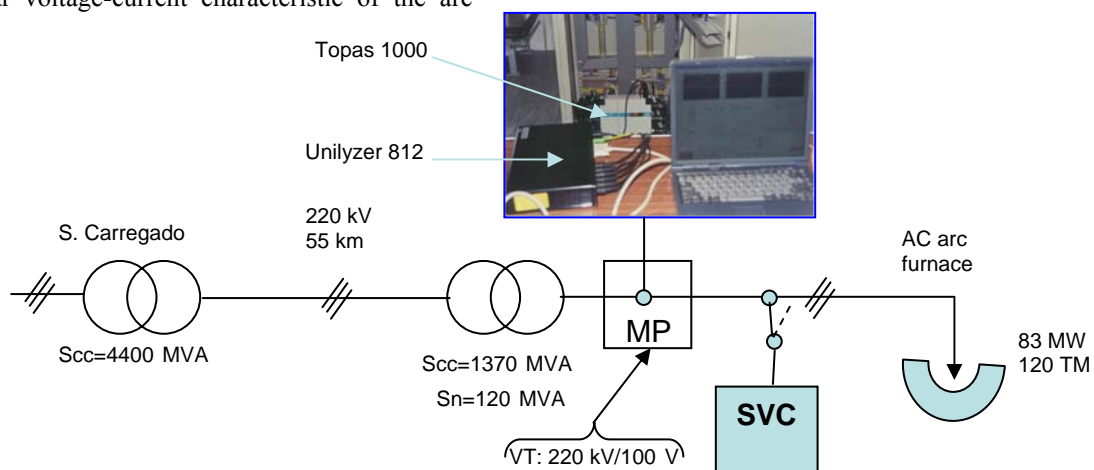


Fig.1. Electrical circuit chart of the arc furnace supply from Carregado Substation

The fundamental component of the current drawn by an electric arc furnace 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.

The importance of AC electric arc furnaces in flicker generation is high. Due to their randomly electric behaviour and the intermittent operating cycle (tap-to-tap) the influence in the quality of the power systems is always negative. If the steel making factory is electrically situated close to a medium size town through a HV electrical grid, it will be important to consider the influences of the situation and magnitude of the different power supplies to this interconnected grid.

In a modern shop such a furnace would be expected to produce a quantity of 55 metric tons of liquid steel in approximately 70 minutes from charging with cold scrap to tapping the furnace. Each batch is called a "heat". Enormous variations exist in furnace design details and operations, depending on the end product and local

## 2. Measurements results

We have taken flicker measurement at the point of common coupling of the factory without any compensating device. The figures 2 and 3 represent the obtained results for Pst and Plt. Like we can see in this charts the level of Pst and Plt flicker is very high.

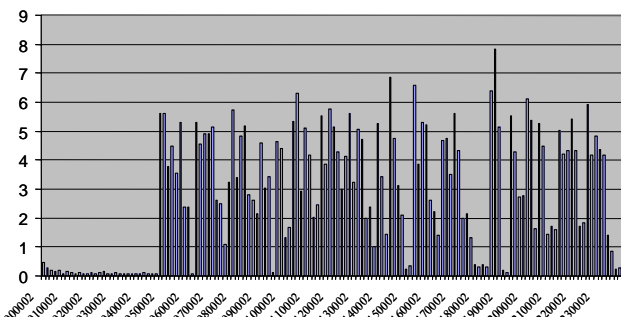


Fig.2. Chart of the short term flicker (Pst) of phase 1 (2003-2-11) without SVC and the arc furnace working at  $\approx 30$  MW.

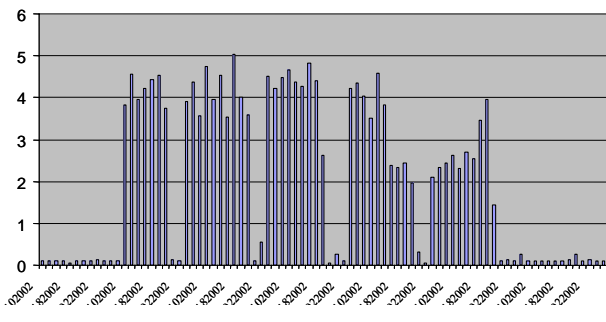


Fig.3. Chart of the long term flicker (Plt) of phase 1 without SVC and the arc furnace working at about 30 MW.

conditions, as well as ongoing research to improve furnace efficiency. To produce a ton of steel in an electric arc furnace requires on the close order of 400 kilowatt-hours per short ton of electric energy, or about 440 kWh per metric tonne; the theoretical minimum amount of energy required to melt a tonne of scrap steel is 300 kWh (melting point  $1520^{\circ}\text{C}/2768^{\circ}\text{F}$ ), then the arc furnaces factories consuming (and paying) high amount of electric energy and they are always a good customers and "have to be" treated as such, even more now when the market has been deregulated and electric companies have to look for places to sell the energy they can generate. This means that it can be interesting to develop a method to "share" the responsibility in flicker mitigation between the customer and the electric utility. For example it could be possible for the supply company to require some amount of flicker compensation (up to  $P_{st}=1,7$  or  $P_{st}=2$ ) at the PCC if they are able to find a place in its grid where the connection of that fluctuating load will not generate any kind of inconvenience to the normal user.

Building new lines, installing new and bigger transformers or moving the point of common coupling to a higher voltage level are the traditional methods to deal with problem of poor power quality in distribution system. These methods are expensive and time-consuming. Installing the compensation equipment in the immediate vicinity is a straightforward and cost-effective way of dealing such problem.

An equally rapid compensating device is required to remedy and prevent the spreading of the power quality problem caused by electric arc furnaces. Currently, the most widely used method for flicker compensation is the connection of shunt static VAR compensators based on thyristor-controlled reactor (TCR's). In figure 4 we can see schematically a static VAR compensator with TCR's. A TCR consist of a reactance connected in series with a pair of thyristor with a fixed value parallel-connected capacitor.

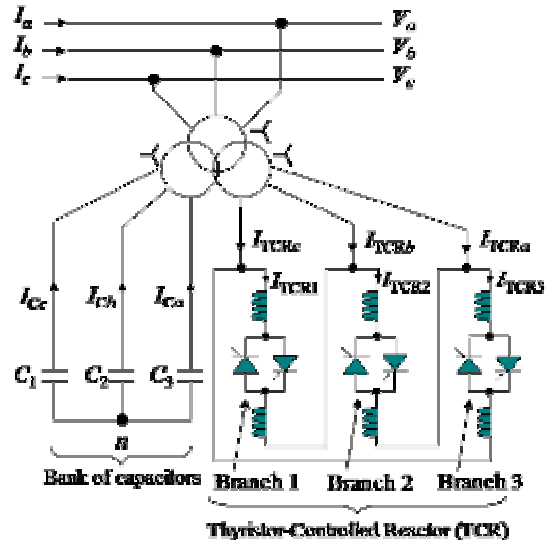


Fig. 4. Scheme of a shunt static VAR compensator.

Even though these methods have success in solving the flicker problem by reactive power compensation, they are unable to supply any portion of the fluctuating real power drawn by the furnace.

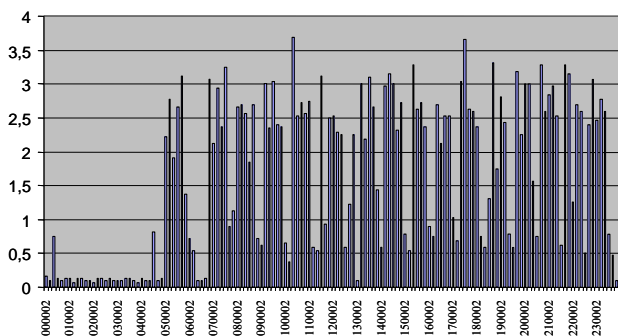


Fig.5. Chart of the short term flicker (Pst) of phase 1 (2003-2-18) with SVC and the arc furnace working at about 30 MW.

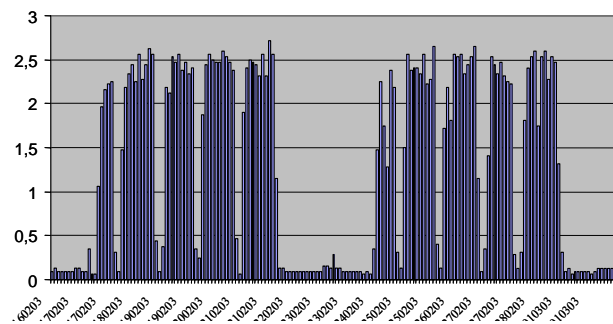


Fig.6. Chart of the long term flicker (Plt) of phase 1 with SVC and the arc furnace working at about 30 MW.

There are controversial arguments about the effectiveness of active power compensation to solve flicker problems. Nevertheless if we observe the figures 5 and 6 which charts show the measurement results obtained at the same factory and common coupling point we can affirm

### 3. Conclusions

In normal conditions but working at about 30 MW below the nominal power (83 MW) and with SVC we can conclude briefly:

The levels of the flicker, long term flicker and short term flicker for 95% of the measurements values (Pst95%) in the Carregado Substation are just in the limits of the EN 50160 standard. The maximum value of the Pst95% obtained at the factory measurement point was 3,313 that means 1,031 at the Carregado Substation. This value was produced the 19 of February, 2003, in phase 2 with a consumed power of 30.690 kW.

Time domain analysis of the arc furnaces with a three-phase circuit are quite costly concerning computation time, and those which are accomplished on a single phase

without any doubt that the SVC produce a very important reduction of flicker.

TABLE I.- Summary of the flicker Pst95% at the Measurement Point of the SNL factory and transmitted to the Carregado Substation without and with a SVC system and the arc furnace working at about 30 MW.

SNL FLICKER MEASUREMENTS WITHOUT SVC					
FLICKER Pst95 AT THE MEASUREMENT POINT					
DATE	D 9	D 10	D 11	D 12	D 13
PHASE 1	0,125	6,031	6,313	6,031	5,938
PHASE 2	0,156	5,750	6,313	6,375	5,781
PHASE 3	0,125	5,688	5,625	5,688	5,188
Pst95 FLICKER TRANSMITTED TO CARREGADO SUBSTATION					
DATE	D9	D10	D11	D12	D13
PHASE 1	0,039	1,878	1,965	1,878	1,849
PHASE 2	0,049	1,775	1,965	1,985	1,800
PHASE 3	0,039	1,771	1,751	1,771	1,615
SNL FLICKER MEASUREMENTS WITH SVC					
FLICKER Pst95 AT THE MEASUREMENT POINT					
DATE	D 16	D 17	D 18	D 19	D 20
PHASE 1	0,156	2,906	3,281	3,313	3,280
PHASE 2	0,156	2,844	3,281	3,313	3,219
PHASE 3	0,188	2,750	3,031	3,156	3,094
Pst95 FLICKER TRANSMITTED TO CARREGADO SUBSTATION					
DATE	D16	D17	D18	D19	D20
PHASE 1	0,049	0,905	1,022	1,031	1,021
PHASE 2	0,049	0,885	1,022	1,031	1,002
PHASE 3	0,058	0,856	0,944	0,983	0,963

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