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Investigation of Power Quality Issues of EAF and Mitigation of Harmonics

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Abstract - *Present days the steel industry is rapidly growing in the world. The power quality is the main problem in steel plant where arc furnace is having drastic load due non-linear loads the causes current imbalance, distortion of voltage and flicker effect on load. A DSTATCOM is implemented for mitigation harmonics and reactive power compensation has been carried by SRF and IRPT theories has been implemented process has proved feasible. The simulation has been carried in MAT LAB/ Simulink software.*

***Key Words*: Power Quality, Arc Furnace, Harmonics, Flicker, DSTACOM, SRF, IRPT**

1. INTRODUCTION

The rapidly growing steel manufacturing industry has huge power quality issues. The power system engineers turned towards the mitigation of power quality issues. The quality of power has greater impact on consumer end as well as utility. The major issue not maintain of the power factor at unity, due to linear and nonlinear load causes the voltage harmonics, current harmonics, swag, swell, flicker on distribution end. The equipment at the loads may not work properly because of these problems, the lines could be overloaded, audible noise in the machines and many more problems. Harmonics increase the electronic interference, audible noises, machine and line heating and other losses. Some of the loads, such as induction motors, require an enormous amount of reactive power hence it needs huge amount of lagging current from the supply side and hence power factor lagging and voltage swell occurs. The reactive power capacity of supply load decreases, the only way to solve this problem is to produce this power where it is necessary. The excessive line losses are minimized in this way.

The power quality problem can be compensated by using active filters, passive and hybrid filters. The passive filters having drawbacks of size, overloading and fixed compensation issues. Active filters are fast, light weighted and smaller in size. For particular aspects necessary filters has been used. It can be decided by size, cost effect of and optimum solution of filters are considered.

The active filter consist of controlled inverters where connected by lines using coupling transformers or inductors. The inverter having capacitor in VSC or inductor in CSC. The DSTATCOM must have small sized elements for the better operation of DSTATCOM. The DSTATCOM can be controlled by magnitude or current by controlling of filters phase out put voltage. DSTATCOM exhibits exchange of active power and reactive power along the lines it needs some source. It can solve reactive power compensation, low power factor, flicker, harmonics. The control strategy used are SRF and IRPT theory are used in DSTATCOM.

2. MODELLING

Electric arc furnace has been modeled using Cassie-Mayr model which can be expressed as:

$$g = g_{min}+[1-\exp(-\frac{i^2}{I_t})]\frac{v\cdot i}{E_0^2} + \exp\left(-\frac{i^2}{I_t}\right)\frac{i^2}{P_0} - \theta\frac{dq}{dt} \quad (1)$$

$$\theta = \theta_0 + \theta_1 \cdot \exp(-\alpha|i|) \quad (2)$$

$$v= \frac{i}{g} \quad (3)$$

Where,

i = Arc current

v = Arc voltage

g = Arc conductance

E_0= Momentarily constant steady state arc voltage

θ_0 =constant

θ =arc time Constant

θ_0=constant

$\propto$ = Constant

P_0 = Momentarily power loss

I_t =Transition current

g_{min} = Minimum conductance

Cassie's model has been found to define the time before the current zero in which the post-arc system is better represented as Mayr's model. While Cassie's theory looked at high-current arcs with convection as the dominant feature of energy transfer while Mayr's paper looked at low-current arcs with thermal conduction transfer as the main feature of current zero action.

3. DSTATCOM

The DSTATCOM circuit consist of electric furnace as load which is connected in three phase three wire distribution system as shown in figure. The DSTATCOM consist of standard three phase two stage inverter. The electric arc furnace is designed as time variant current controlled nonlinear resistance. The time varying load results in fluctuating load current under circuit operation .The PCC will having a voltage fluctuation or voltage flicker depending on impedance of line voltage flicker depending on impedance of line reactor. The frequency of modulating voltage is in the range of 5 to 25 Hz. To compensate voltage flicker, fluctuating load currents in EAF, a control algorithms has been developed .Which are instantaneous reactive power theory (p-q theory) and synchronous rotating reference frame theory(d-q theory) applied to non-linear arc furnace load.

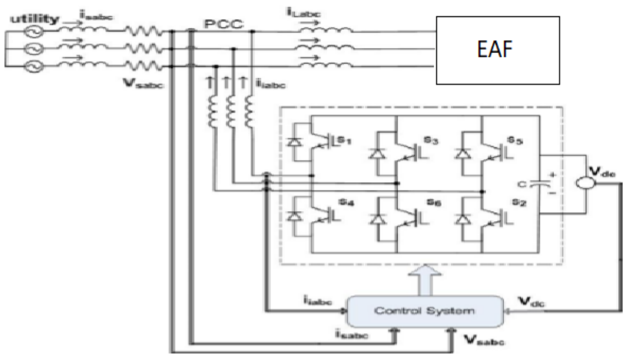

FIG-1:.DSTATCOM with EAF model

3.1. Control strategy

There are two popular discussions on control strategy for DSTATCOM which are IRP and SRF theory. These two theories are used to generate the reference source current used to generate pulses for the VSC of DSTATCOM.

a. Instantaneous reactive power theory

IRP theory which is also known as p-q theory transforms three phase voltage and current system to phase co-ordinate transformation or Clark-concordia transformation.

Which is defined as following

$$\begin{bmatrix} V_o \\ V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (4)$$

$$\begin{bmatrix} i_o \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (5)$$

In case of three-phase 3-wire system $V_0=0$ and $i_0=0$.In case of new coordinate system stationary orthogonal reference frame theory, imaginary and instantaneous real power are expressed as follows,

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (6)$$

Finally current expression can be expressed as function of the power quantities.

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{V_\alpha^2 + V_\beta^2} \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \quad (7)$$

In this principle the three phase components of voltage and current are transformed. Then those components are used to measure the active and reactive power of the three phases. The advantage of using the Clarke transformed part to quantify actual and reactive is that the basic power components behave like a dc signal so that the reference source current signals can be easily filtered out. Instead, using inverse Clarke transformation this current can be converted back into the actual phase quantity. The generation of reference source currents can be modified by changing the powers used to compute them according to the DSTATCOM requirement or function.

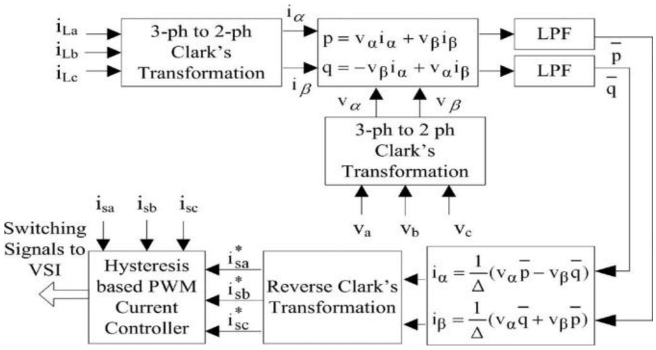

FIG-2: IRPT control method

b .Synchronous reference frame theory

The SRF theory, clark-park transformation the load current quantities into dq0 components from the supply voltage the transformation sin and cos components used. The definition of dq0 is the axis of directness, quadrature, and zero. The three phase components are rotated with fundamental frequency in the park transformation. The fundamental frequency component thus appears to be stationary with fundamental frequency whereas the signals other than the fundamental frequency appear to be oscillating. Now low pass quantities are filtered in the dq0 current quantities to get the basic current quantities. The quantities of the filtered current are transformed back into the quantities of the phase using the inverse park-clark transformation which is the source current. The component d shows the current responsible for the active power similarly the current component q shows the current responsible for the reactive power and 0 component current shows a supply balance. The system considered under balanced condition.

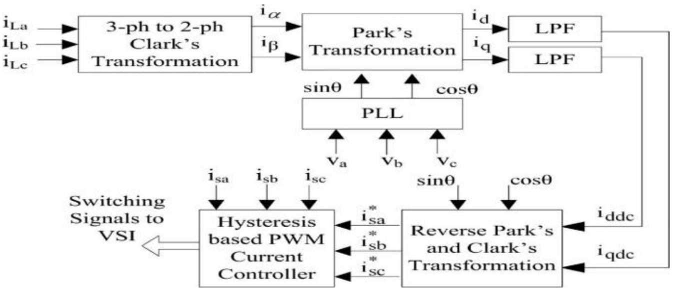

FIG-3: SRF control method

$$\begin{bmatrix} i_d \\ i_q \\ i_o \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\ -\sin\theta & -\sin(\theta - \frac{2\pi}{3}) & -\sin(\theta + \frac{2\pi}{3}) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (8)$$

$$\text{Where } \theta(t) = \int_0^t w_e(t)dt + \theta_o \quad (9)$$

4. Simulation Result

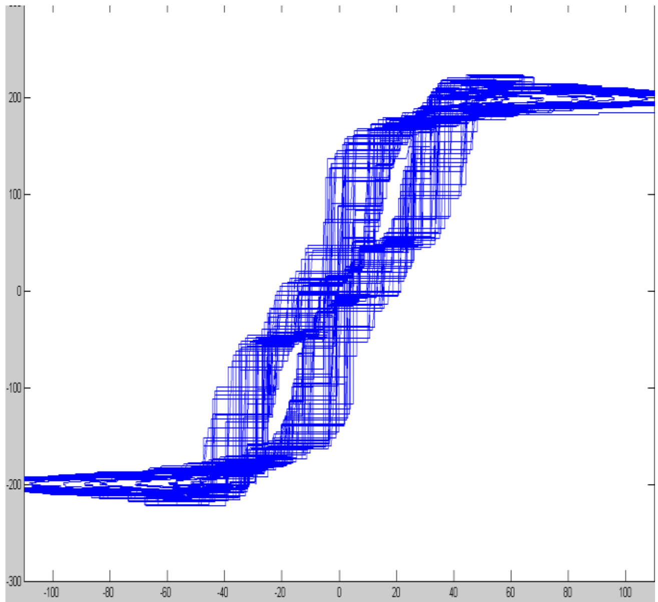

FIG-4: Electric Arc Voltage-current Characteristics

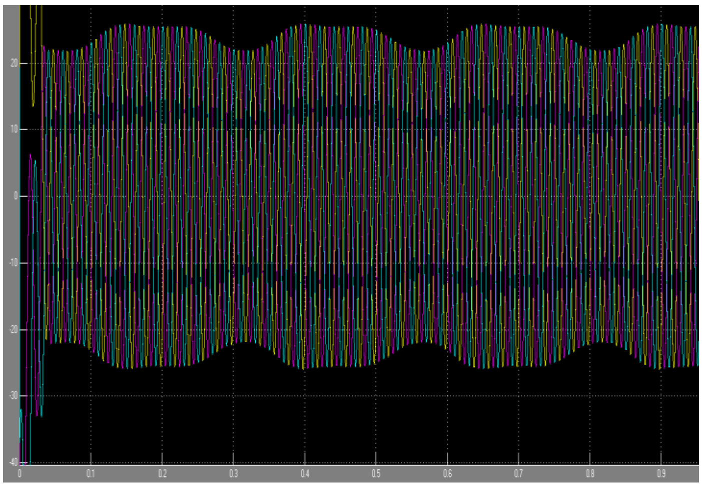

FIG-5: Three Phase Arc Current Waveform.

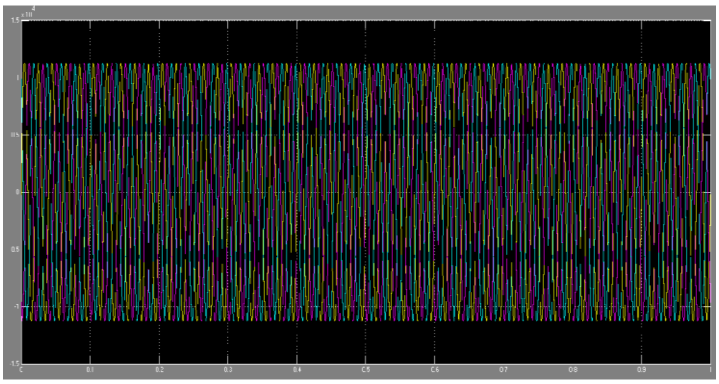

FIG-6: Three Phase Voltage Flicker Curve.

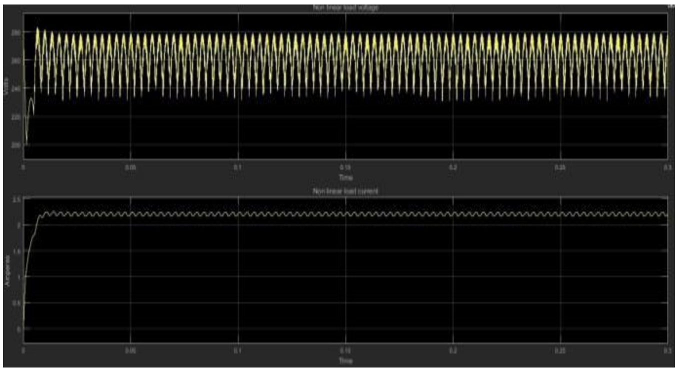

FIG-7: Current and Voltage of non linear load

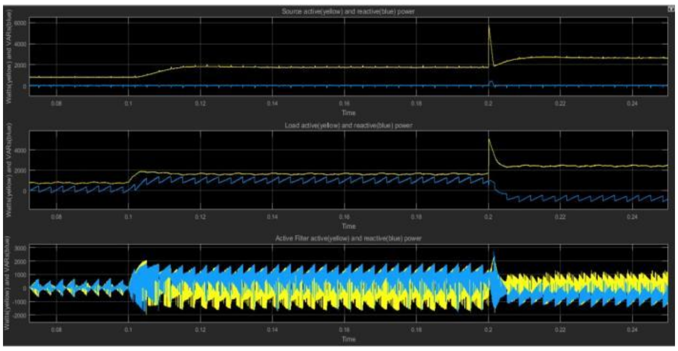

FIG-8: Power in case of SRF

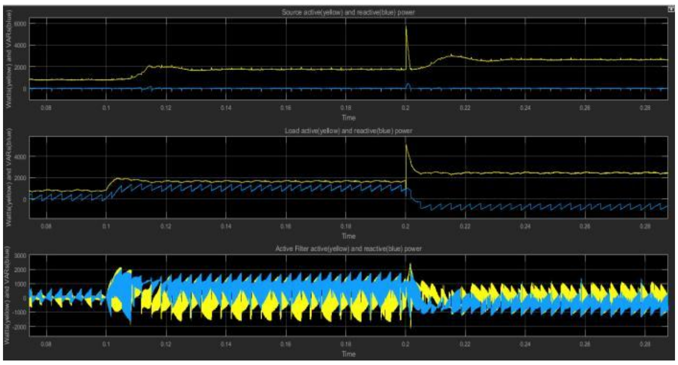

FIG-9: Power in case of IRPT

5. CONCLUSION

DSTATCOM control strategy derived by SRF and IRPT methods. The simulation is done on MATLAB/SIMULINK. The SRF and IRPT Methods are effective for mitigation of flicker.

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