Enhancing the Force Quality for Electric Circular Segment Heater Utilizing DSTATCOM

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Abstract—This paper presents recreation investigations of an Electric arc heater (EAF) displaying and voltage gleaming moderation in the MATLAB environment. EAF was demonstrated as a present source controlled by a non-direct resistance. Voltage flash is a wonder of irritating light force variance, caused by EAF has been a major power quality concern for both power companies and customers. A model was developed for electric arc furnace and the controller for DSTATCOM was designed based on D-Q model for reactive power management which helps in the mitigation of the flicker. Both are applied in the simulation studies of distribution static synchronous compensator (DSTATCOM) for voltage flicker mitigation.

Key words: Electric Arc Furnace (EAF), Flicker Mitigation, Power Quality, Reactive Power, DSTATCOM, Chua’s Circuit, Dynamic Arc Model, Simulink

I. INTRODUCTION

Flicker is the sensation that is experienced by human eye when subjected to changes in the illumination intensity. The maximum sensitivity to change in illumination is in the frequency range of about 5 to 15 Hz. The fluctuating brightening of light is caused by amplitude variation of the input voltage to the light. Large industrial loads such as large motor drives for driving mechanical loads and electric arc furnaces (EAF) are used for melting and refining metals. As the notoriety and utilization of the circular segment heater loads in the business increment, so do the power quality problems as a result of this progress. Voltage glint, presence of symphonic burden streams can be given as case of antagonistic impacts presented by curve heaters. Utilities and customers are concerned about these effects and try to take precautions to minimize them. Therefore, obtaining the time response of an electric arc furnace becomes important in investigating the impact of these nonlinear, time varying loads on the power quality of the overall power system. Consequently, building up a precise and simple to utilize curve heater model has been an essential. The voltage current characteristic of the arc is nonlinear, and is the cause of harmonic currents. These harmonic currents, when circulated in the electric network can generate harmonic voltages which in turn can affect other users. The arc furnace is a non-linear load and a large source for the glint. To limit the effects of these disturbing loads compensation devices have to be connected at the Point of Common Coupling (PCC). Flicker mitigation devices can be connected in shunt, series or in the combined mode. The presence of EAF in a distribution network causes the voltage to flicker due to the large and random variation of the reactive power drawn from the source, voltage harmonics due to the nonlinear electric arc resistance, and phase unbalance due to the highly unbalanced phase currents. The voltage flicker whose frequency varies from 1Hz to 10 Hz can cause the incandescent lamps and the television picture to glitter and cause the malfunctioning of sensitive electronics equipment. Severe flicker can also cause unsteadiness in the speed of an electric motor and reduction in the efficiency of EAF and other electrical tools. Due to the above mentioned disorder caused by EAF, the electric power quality of the interconnected system gets degraded. There are different methods for modeling EAF and in general these models may be broadly classified as (a) Time domain analysis methods [1-9] (b) Frequency domain analysis methods [1, 2, 10, 11] (c) Chaotic variation methods [12,13]and (d) Model based on EAF’s cyclic draw of active and reactive power[14].

The most generally utilized gadgets for remuneration of voltage flash capacity by directing the EAF arool parts [15-17], static VAR compensator (SVC) and DSTATCOM Distribution Static Compensator (DSTATCOM), which consists of an IGBT-based voltage source converter, uses advanced power switches to provide fast response and flexible voltage control at the connection for power quality improvement in distribution systems. The flicker mitigation techniques for EAF described so far in literature [18-23] have used basic and an estimated model of an EAF which is responsible for the flicker generation. In this paper, rather than utilizing single esteemed piece-wise direct v-i qualities of the circular segment heater load, a dynamic and multi-valued v-i characteristics are obtained by solving the corresponding differential equation, whose parameter is the arc length and the forcing function is the arc current. In order to represent the flicker effect, a low frequency chaotic signal is modulated with the arc voltage. The future model is connected to the system as a controlled voltage source.

II. MODELLING OF ELECTRIC ARC FURNACE

Fig. 1 shows the single line diagram of electric arc furnace. Existing simulation models of electric arc furnace are developed in the environment of Eletro Magnetic Transient Program (EMTP). Be that as it may, in this product has downsides like constrained reproduction time and setting up control unit trouble. All these problems can be overcome by using MATLAB software.

Fig. 1: Single line diagram of arc furnace
Our model is composed of two main parts: the first part is about the use of dynamic, multi-valued voltage current characteristics of the electric arc. In the second part, a chaotic circuit is used to represent the arc furnace voltage fluctuations, which are chaotic in character.

A. Dynamic Performance of Electric Arc

The dynamic v-i Characteristics of arc furnace load is obtained by using a general dynamic arc model in the form of a differential equation derived in [27]. The approach taken in [27] is fundamentally different from the previous methods ([25], [26], and [28]), that represent the electric arc in terms of their static v-i characteristics. The dynamic arc model will liberate changes in the v-i characteristics as the operating conditions change in the power system. Therefore, starting from the power balance equation for the electric arc, the following differential equation that represents the general dynamics of the arc model is derived in [9].

\[ K_1 r^n + k_2 r \frac{dr}{dt} = \frac{k_3}{r^{m+2}} i^2 \]  

(1)

Here “r”, which remains for the circular segment range, is picked as a state variable as opposed to taking curve resistance or conductance. While solving equation 1, the parameters are chosen as \( k_1 = 3000 \), \( k_2 = 1 \), and \( k_3 = 12.5 \). And the arc voltage is then given by.

\[ V = \frac{i}{g} \]

Where \( g \) is defined as arc conductance and given by the following equation.

\[ g = \frac{r^{m+2}}{k_3} \]

B. Chaotic Time Variation

The chaotic module of the arc furnace voltage is supplied from the well-known chaotic circuit of Chua [29, 30]. Chua's circuit is implemented in MATLAB/Simulink environment by using new Power System block set. It has been shown that in order for an independent circuit consisting of resistors, capacitors, and inductors to present chaos, it has to contain the following [29].

- At least one locally vigorous resistor,
- At least one nonlinear element,
- At least three energy storage element.

Chua's circuit [29, 30] is the simplest such circuit that satisfies the above conditions; moreover it is the only physical system for which the presence of chaos has been verified. These two properties of this circuit forced its use as a chaos generator in this work.

III. MODELING OF DSTATCOM FOR EAF FLICKER MITIGATION

PWM signal switched DSTATCOM can be used for voltage flicker mitigation. To study the effect of DSTATCOM controller for voltage flicker mitigation in a steel plant distribution network with EAF model is shown in figure 3.

The DSTATCOM basically consists of three main parts: A Current Controlled PWM Inverter with DC capacitor, the coupling inductors, and a shut circle controller. The coupling inductor in each phase serves both as a converter output current filter and an inductive coupler between the mains phase and the respective converter phase voltage.

The DSTATCOM controller is shown for reactive power compensation mode. The arc furnace load will generate voltage fluctuations near PCC, which is the main cause for sparkle. To mitigate this sparkle the DSTATCOM is connected in shunt with the system. This DSTATCOM compensates the reactive power of arc furnace. When the arc furnace consumes power and reactive power, the voltage of PCC is decreased from the original value. To compensate the voltage of the PCC back to its original value, the DSTATCOM introduces the reactive power at the PCC.
power and instantaneous reactive power. Similarly, the load power and inverter power also contain of active and reactive components. For full reactive power compensation of the load, the inverter has to supply reactive power of the same magnitude, but of opposite sign. Thus, in such a case, the reactive power drawn from the source is zero.

A. DSTATCOM Controller for Flicker Mitigation of EAF

The block diagram of the DSTATCOM controller for flicker mitigation is shown in Fig. 4. The three-phase source voltages (Vsa, Vsb, Vsc) are applied to three-phase Phase Locked Loop (PLL) to coordinate the three-phase voltages at the converter output with the zero crossings of the fundamental component of the supply phase voltages. The PLL provides the synchronous reference angle θ required by the abc-dq0 transformation.

With a specific end goal to keep up the responsive force drawn from the source as zero, the output currents of the three phase bridge inverter are measured in such a way that the inverter supplies the required reactive power. Thus for flicker mitigation, the source reactive power sets the reference for inverter control which sets iq reference (iqref) as zero. The reactive current supplied by the source (iq) is subtracted from the reference value (iqref=0) to obtain the error in reactive current for full benefit. This error signal is processed through a PI controller block to obtain the reference voltage signal (Vqref), which is fed to the dq0-abc transformation block. The reference for id (idref) comes from the DC link voltage PI controller, which maintains the DC link voltage (Vdc) at reference value (Vdcref=1000v). The active current supplied by the inverter (id) is subtracted from the reference value (idref) and this error signal is managed through a PI controller block to obtain the reference voltage signal (Vdref), which goes as another input for dq0-abc transformation. PI compensators for current and voltage loops are tuned to give the optimum performance. The output voltage signals of transformation block (dq0-abc) act as reference voltages (Via, Vib, Vic) for PWM signal generators of bridge inverter. These signals are compared with a triangular carrier wave to obtain PWM signals for bridge inverter phases.

IV. RESULT AND DISCUSSION

As we know that Arc furnace is common non-linear load on the Power system, the Current harmonics developed from load injected to power system. So the other loads connected to Power system are getting the disturbance. So maintaining the power quality of the system is main challenge for the power engineers.

Maintaining the power quality is maintaining the near sinusoidal waveforms of power distribution bus voltage at rated voltage magnitude and frequency. So in order to maintain the power quality, voltage flickers and harmonics should be reduced. Reactive power component is the main cause for this voltage flickers.

FACTS devises are used to preserve the power quality. STATCOM is one of the main devise of FACTS family. By this STATCOM we can maintain power quality by injecting or observing the reactive power depending on the condition shown in figure 3. In this STATCOM which we have used, a 48 pulse voltage sourced converter with initially charged capacitor. This inverter makes the operation of injecting and absorption of power depending on controlled pulses of STATCOM controller.

The entire system for flicker mitigation of EAF using DSTATCOM is simulated using MATLAB.

Fig. 5 shows the voltage and current waveform without DSTATCOM in the distribution system.

Fig. 6 shows the FFT analysis in which we got THD around 40%.

Fig. 7 shows the voltage and current waveform with connecting the DSTATCOM in the distribution system and fig. 8 shows the FFT analysis in which THD is reduced around 0.01%.
This paper proposed the recreation investigation of the DSTATCOM with non-straight V-I qualities based curve heater model, for flicker mitigation by injecting reactive power of equal magnitude but reverse sign to that of reactive power drawn by the arc furnace. It is observe that the DSTATCOM can moderate the flicker generated by the non-linear V-I characteristics of arc furnace model. This paper likewise giving the THD count previously, then after interfacing the DSTATCOM in the conveyance framework. The entire system for flicker mitigation of EAF using DSTATCOM is simulated using MATLAB software.

REFERENCES


