Voltage flicker mitigation using DSTATCOM

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Abstract— Voltage Flicker is a low frequency modulation of the supply voltage. Voltage Flicker is characterized by a slow change in the Voltage magnitude with frequencies between 0.5 Hz to 30 Hz, which appears as a super imposed signal on the fundamental signal. The super imposed signal that is generated due to the voltage flicker appears as a change in the fundamental signal envelope. The major source of voltage flicker is due to Arc Furnaces. In this paper an Arc Furnace LAB model is developed and implemented in a MATLAB/Simulink Power System Blockset (PSB). The fast response of the DSTATCOM makes it the efficient solution for compensating Voltage Flicker. A new control algorithm is introduced to mitigate the Voltage Flicker. The main objective of the new control algorithm is to restore the voltage to its normal value. Two sequential control steps achieve this objective. In the first step, the control technique depends mainly on restoring the voltage by injecting reactive power. In the second step, amplitude modulation, k, varies to alter the injected voltage according to the instantaneous load voltage variation, after the voltage level is raised. The voltage at PCC is compared before and after compensation.

Keywords— Distribution Static Synchronous Compensator (DSTATCOM); Fast Fourier Transform (FFT); Point of Common Coupling (PCC);Digital Storage Oscilloscope (DSO).

I. INTRODUCTION

Quality of power is prime concern to power companies and hence power Quality problems have a significant impact in electrical power system.. Power system currently faces serious problems arising from voltage flicker, which is an important threat to power quality .In industries, during the operation of an electric arc furnace (EAF), the electric poles short circuit and enormously unstable current is produced, causing current flow to change significantly and, in turn, causing serious voltage flickers that influence the other loads connected at point of common coupling. The changes caused by voltage flickers have two effects: Objectionable light flicker to nearby customers and disruption of sensitive load, such as computers.

According to IEEE Std-100, Voltage flicker is defined as "The impression of fluctuating luminance or color occurring when the frequency of the light stimulus lies between a few hertz and fusion of images".

Frequency modulation of the supply voltage that is less than 0.5 percent can cause voltage flicker, if the modulating signal lies in a band of frequencies between (0.5-30) Hz. It is reported that a small voltage fluctuation of less than 5-10Hz can cause visible and uncomfortable incandescent flicker. The flicker phenomenon may be divided into two general categories i.e. cyclic flicker and Non-cyclic flicker. Cyclic flicker is caused by periodic voltage fluctuations due to the operation of loads such as spot welders, compressors (or) Arc welders. The magnitude of the cyclic voltage flicker component varies randomly. Non-cyclic flicker corresponds to occasional voltage fluctuations; the starting of large motors most often causes non-cyclic flicker. Some time varying loads such as Arc furnaces, Welders and Chipper motors that may cause cyclic as well as Non-cyclic flicker.

MATHEMATICAL MODEL OF VOLTAGE FLICKER

Voltage flicker waveform can be modeled as amplitude modulated waveform, where the modulated signal is sinusoidal of random frequency and amplitude. The following model can express the mathematical model of the voltage flicker.

$$S(t) = \left(A_0 + \sum_{i=1}^{n} A_i\,(t)\cos(\omega_i\, t + \theta_i) * \cos(\omega_0\, t + \theta_0) \right) (1)$$

Where

A_0=Magnitude of the fundamental voltage at ω0

$A_i(t)$=Magnitude voltage flicker

ω_0= supply frequency

ω_i = voltage flicker frequency

θ_i= phase angle of the modulating signal

θ_0= phase angle of the fundamental signal

The FFT is applied for the above the mathematical model of the voltage flicker to find the frequency of voltage flicker which lies between (0.5 Hz -30Hz). The simulation results show flicker frequencies.

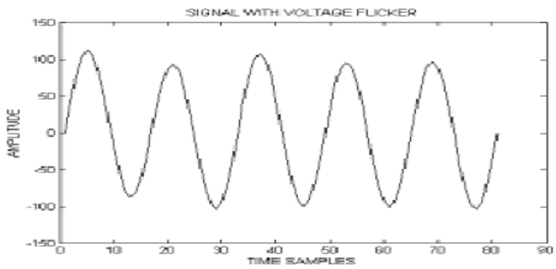


Fig. 1. Voltage flicker waveform

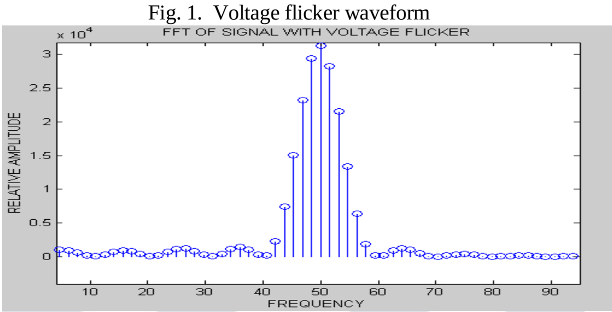


Fig.2. FFT of the voltage flicker.

IMPLEMENTATION OF SINGLE PHASE ARC FURNACE MODEL

MATLAB supports a number of block sets, which can be accessed from the simulink environment and thus makes simulation easier. Power system block set is used in building the power system model.

The implementation of the model in MATLAB simulink environment is shown in Fig.3 .It is modeled as a subsystem and connected to the power system circuit as a circuit component .The current absorbed from the power system is injected as the input to the model.

The model behave as a controlled source, namely it takes the system current as an input and assigns the terminal voltage value at each time step. On simulation the arc current, arc voltage, primary and secondary voltage waveforms can be obtained.

The implementation of the model in MATLAB simulink environment is shown in step.

Differential equation:

$$K_1 r^n + k_2 r\left(\frac{dr}{dt}\right) = (k_3/r^{m+2}) = (k_3/r^{m+2}) i^2 \quad (2)$$

This can be written as

$$\frac{dr}{dt} = (k_3/k_2) r^{m+3} i^2 + (k_1/k_2) r \quad (3)$$

And, the arc voltage given by $v = i/g$**I /g**

The proposed arc furnace model is connected to a simple single-phase supply system. The point of common coupling corresponds to the primary of the arc furnace transformer.

Simulation Parameters of single phase Arc furnace model:

TABLE I.

Source	50 KV
z_{th}	R=0.346Ω and L=9.8 mH
Transformer nominal power	60 MVA
Primary voltage	46 KV
Primary winding	$R_1 = 0.002$ p.u, $L_1 = 0.55$ p.u
Secondary voltage	770 KV
Source	50 kV
Secondary Winding	$R_2 = 0.002\ p.u,$ $L_2 = 0.55\ p.u$
Magnetisation resistance	500 p.u
Magnetisation reactance	500 p.u

Arc Furnace:

$$K_1 r^n + k_2 r\left(\frac{dr}{dt}\right) = (k_3/r^{m+2})i^2 \qquad (4)$$

Parameters for differential equation k1=3000, K2=1, k3=12.5, m=0, n=2

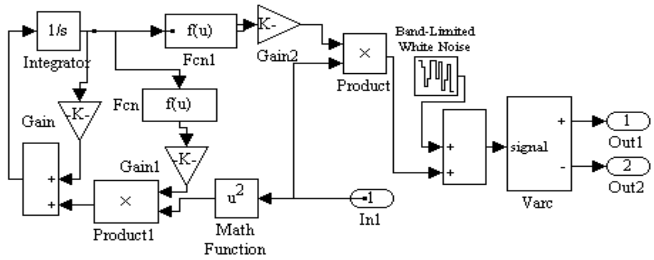


Fig. 3.The Implementation of Power Balance Arc Model

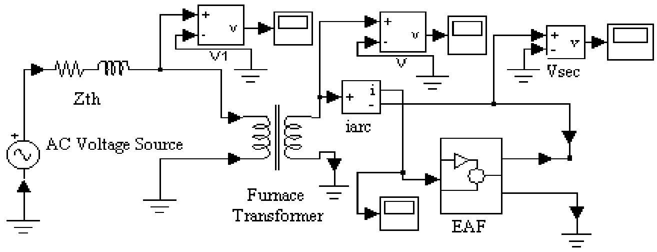


Fig. 4.Single-phase electric arc furnace model

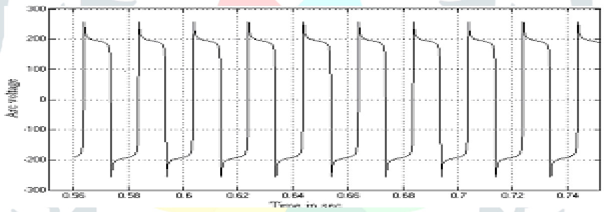


Fig.5. Arc voltage obtained by Single-phase mode

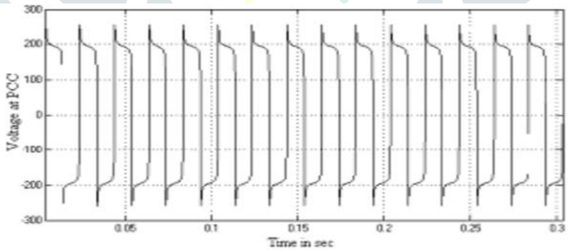


Fig.6. Voltage at point of common coupling

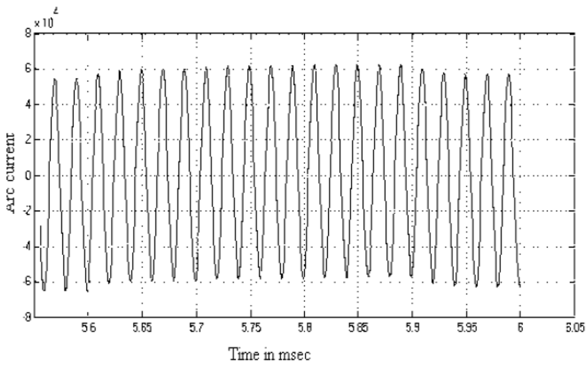


Fig. 7.Arc current obtained by simulation of Single-phase model

IV.FLICKER GENERATION IN THE LABORATORY

CIRCUIT DETAILS:

A single-phase 1:1 isolation transformer (250V/250V) is connected across single-phase 230V, 50Hz AC Supply. An autotransformer (4KVA), Incandescent lamp, Potentiometer (2.2KΩ, 82KΩ) is connected in parallel with secondary of the isolation transformer. The one of the secondary terminals of the autotransformer is connected with Lead Bar. Another terminal is connected by copper wire and copper plate. A probe from Digital Storage Oscilloscope is connected across 2.2KΩ resister for measurement purpose.

OPERATION:

When the secondary terminals of the autotransformer are short circuited, the voltage at the point of common coupling (PCC) is reduced. While the voltage at PCC will be released to its original value when the secondary terminals are open circuited. The lamp absorbs this variation. Because it is well known that the most sensitivity load that can be affected by voltage flicker are lamps. On the basis of investigations, become eyes uncomfortable when it senses a small voltage flicker of 0.3% to 0.5% at the frequencies of 7 to 10 Hz. Hence, the voltage flicker bearing ability of lamps is very important if high illumination quality is required.

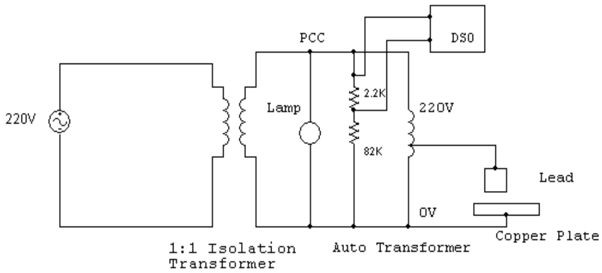


Fig. 8.Circuit Diagram for Voltage Flicker Generation in Laboratory

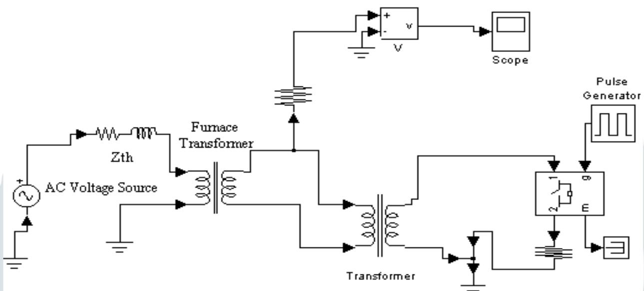


Fig. 9.Single-phase Voltage flicker MATLAB /Simulink lab model

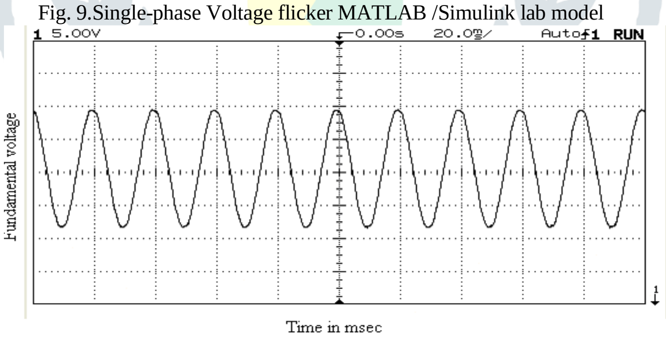
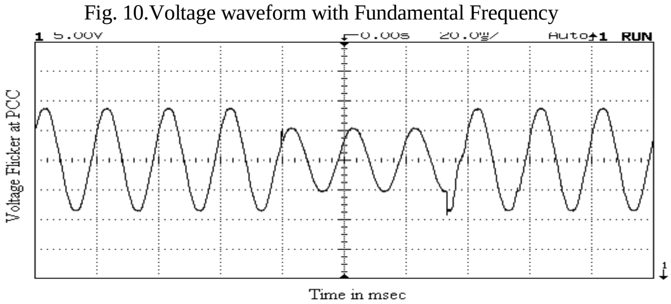


Fig. 10.Voltage waveform with Fundamental Frequency



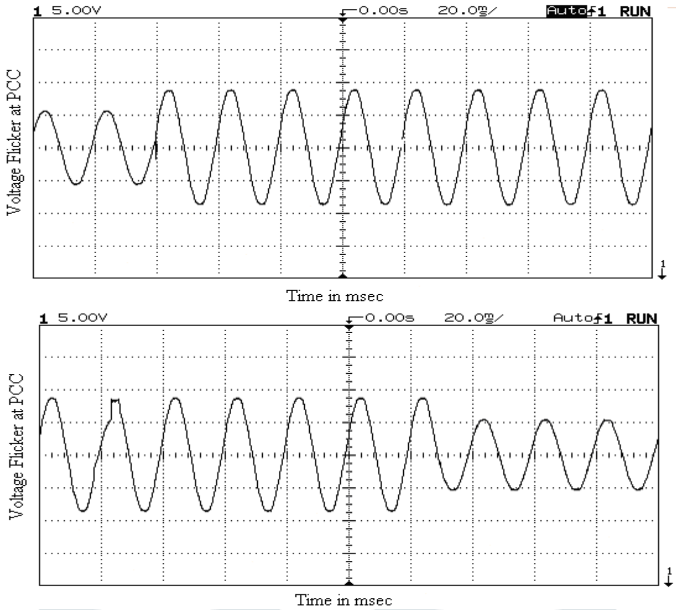


Fig. 11.Voltage Flicker Captured Using DSO

CONTROL TECHNIQUE FOR COMPENSATION OF VOLTAGE FLICKER

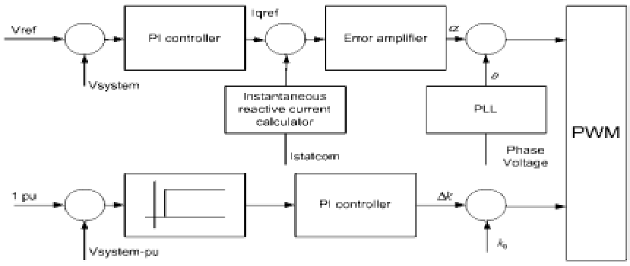


Fig.12. Control block for voltage flicker compensation.

This technique is developed to raise the voltage level at PCC. Fig. 9 reveals the voltage flicker of Lab model at the primary side of autotransformer without any kind of compensation. Fig. 13 reflects the per unit value of the terminal voltage waveform.

In the shunt-mitigating device (STATCOM), this compensates for the reactive power consumed by the loads. The ultimate objective of all voltage flicker-mitigating devices is to stabilize the voltage at the load terminals.

In the first stage, an error signal is obtained by comparing the reference voltage with the instantaneous load voltage measured at the load point. The PI controller processes the error signal and generates the iq reference. The error amplifier processes the error signal and generates the required angle α to drive the error to zero (i.e) the load RMS voltage is brought back to the reference voltage. A control technique that includes the reactive current as injected reactive power and the voltage rise is non-linear. This non linearity affects the accuracy of the mitigation and the time response of the controller to the variations in the load voltage. So it is imperative to modify this control technique too accurately and adaptively compensate for voltage flicker. In the second step, a proper modification is implemented to compensate for voltage flicker. The amplitude modulation, k, varies to alter the injected voltage according to the instantaneous load voltage variation, after the voltage level is raised.

VI. SIMULATION RESULTS

The single phase voltage flicker MATLAB simulink lab model and real time model are developed and the combination of the DSTATCOM with instantaneous reactive current injection mode control algorithm firmly establishes the visibility of stabilizing the voltage level within permissible levels regardless of the nature of non-linear loads. The simulation and hardware results show that the voltage levels are raised from 0.6p.u to 0.9p.u.

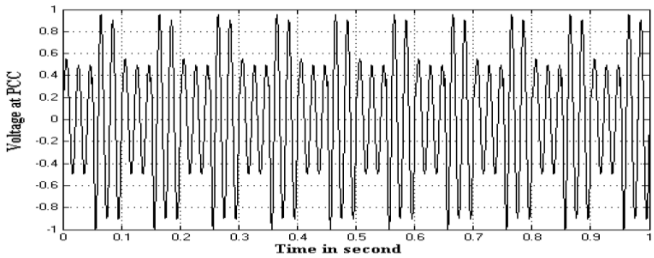


Fig.13. Per unit voltage at Voltage flicker Lab Model before compensation.

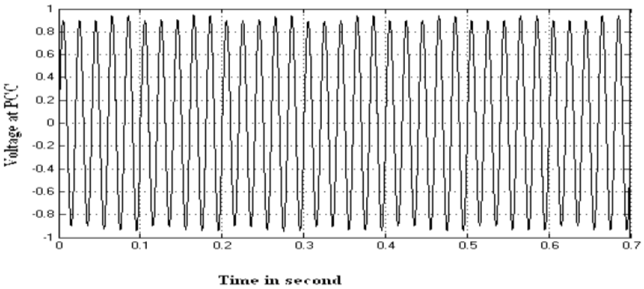


Fig.14. Compensated voltage flicker using DSTATCOM with modified Control.

VII. Conclusion

This article introduces a novel control technique through which voltage flicker is reduced so that it is below the irritation region according to IEEE and IEC Standards. The combination of the DSTATCOM and the proposed control algorithm firmly establishes the viability of stabilizing the voltage level within permissible levels regardless of the nature of non-linear loads.

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