THD Reduction and Mitigation of Voltage flicker by Four Leg inverter

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ABSTRACT

Voltage flicker is a disturbance in electrical power systems. The reason for this disturbance is mainly due to the large nonlinear loads such as electric arc furnaces. A STATCOM is considered as a proper technique to mitigate the voltage flicker. Application of more suitable and precise power electronic converter leads to a more precise performance of the compensator.

The voltage flicker compensation by 6 – pulse, 8-pulse and 12 – pulse static synchronous compensator (STATCOM) has been performed. In this case, injection of harmonics into the system caused some problems which were later overcome by using 8 pulse and 12- pulse assignment of SATCOM and RLC filter. This paper deals with the voltage flicker mitigation and reduction in total harmonic distortion (THD) and compared the results in detail.

The obtained results show that STATCOM is very efficient and effective for the compensation and mitigation of voltage flicker and harmonics all the simulation results have been performed on the MATLAB Software.

KEYWORDS:
Keyword 1, Keyword 1, Keyword 1, Keyword 1, Keyword 1, Keyword 1,

I. Introduction

The relationship between power quality and distribution system has been a subject of interest for several years. The concept of power quality describes the quality of the supplier voltage in relation to the transient breaks, falling voltage, harmonics and voltage flicker. Voltage Flicker is the disturbance of lightning induced by voltage fluctuations. Very small variations are enough to induce lightning disturbance for human eye for a standard 230V, 60W coiled-coil filament lamp. The disturbance becomes perceptible for voltage variation frequency of 10 Hz and relative magnitude of 0.26%. Huge non-linear industrial loads such as the electrical arc furnaces, pumps, welding machines, rolling mills and others are known as flicker generators. In this respect, the quality of supplied voltage is significantly reduced in an electrical power system and the oscillation of supplied voltage appears to be a major problem.

Electric arc furnace, the main generator of voltage flicker, behaves in the form of a constant reactance and a variable resistance. The transformer-reactance system is modelled as a lumped reactance, a furnace reactance (included connection cables and busses) and a variable resistance which models the arc. Connecting this type of load to the network produces.

Voltage flicker is mainly generated by the non linear industrial loads like electric arc furnace. Electric arc furnace behaves as variable resistance and constant reactance. If this type of load is connected in the network, this produces a variation in voltage at point of common coupling (PCC) [6]. which models the arc. Connecting this type of load to the network produces voltage variation at the common point of supply to other consumers. The equation for voltage drop is given by (1):

$$\frac{\Delta V}{V_n} = \frac{R\Delta P + X\Delta Q}{V_n^2} \quad (1)$$

Where,

V_n is the source voltage,

ΔQ and ΔP are the variation in reactive and active power,
X & R are short circuit reactance and resistance respectively

Two types of structures can be used for the compensation of the reactive power fluctuations that cause the voltage drop:

A: shunt structure: in this type of compensation, the reactive power consumed by the compensator is kept constant at a sufficient value.
B: series structure: in this type, all the efforts are done to decrease the voltage drop mentioned above, and finally the reactive power is kept constant despite the load fluctuations by controlling the line reactance.

Bumpy ride in an elevator, in other instances the effects can be harmful to electrical equipment. Typically, the deleterious effects of power frequency disturbances are predominantly felt in the long run and such disturbances do not result in immediate failure of electrical devices. The effects of power frequency disturbances vary from one piece of equipment to another and with the age of the equipment. Equipment that is old and has been subjected to harmful disturbances over a prolonged period is more susceptible to failure than new equipment. Fortunately, because power frequency disturbances are slower and longer lasting events, they are easily measured using instrumentation that is simple in construction. Most common power quality problems are:
(a) Voltage sag (dip)
(b) Voltage swell
(c) Harmonics
(d) Interruptions
(e) Voltage spike
(f) Noise
(g) Voltage unbalance
(h) Distortions
(i) Transients
(j) Voltage flicker

A two-bus system is exploited to fulfil the investigation of the presented procedure. All the simulations are done according to the usage of MATLAB software. The related compensation was performed first by FCTCR. Afterwards, a 6-pulse voltage-source converter STATCOM was used to compensate for the voltage flicker. With respect to the harmonic problem in this stage, a 8-pulse and 12-pulse voltage-source converter STATCOM was designed to isolate load harmonics and mitigate the propagation of voltage flicker to the system in the next stage. The obtained results clearly confirmed the efficiency of the 8-pulse STATCOM to complete the voltage flicker mitigation.

II. Controlling System

The concept of instantaneous reactive power is used for the controlling system. Following this, the 3-phase voltage upon the use of the park presented by Akagi has been transformed to the synchronous reference frame (Park or dq0 transformation). This transformation leads to the appearances of three instantaneous space vectors: Vd on the d-axis (real or direct axis), Vq t h e q-axis (imaginary or quadrature axis) and V0, from the 3-phase voltage of Va, Vb and Vc. The related equations of this transformation, expressed in the MATLAB software, are as follows:

A new technique based on a novel control algorithm, which extracts the voltage disturbance to suppress the voltage flicker, is presented in this thesis. The concept of instantaneous reactive power is used for the controlling system. Following this 3Ø flicker voltage has been transformed to synchronous reference frame by the use of abc to dqo transformation (Park's transformation). To implement the synchronous reference frame some kind of synchronizing system (phased looked loop) should be used. 3Ø AC system load voltage is the input to the phase locked

loop (PLL), this PLL can be used to synchronize on a set of variable frequency, and 3Ø sinusoidal signals.3Ø PLL block provides three outputs. From the output of PLL sinωt and cosωt value are given to
abc to dqo transformation, this transformation leads to the appearances of three instantaneous space vectors: vd on the d-axis (real or direct axis), vq on the q-axis (imaginary or quadrature axis) and v0, from 3 – Ø phase flicker voltage of va, vb and vc. The related equations of this transformation, expressed in the MATLAB Simulink software, are as follows:

$$V_d = \frac{2}{3}[V_a \sin(\omega t) + V_b \sin(\omega t - \frac{2\Pi}{3}) + V_c \sin(\omega t + \frac{2\Pi}{3})] \quad (2)$$

$$V_q = \frac{2}{3}[V_a \cos(\omega t) + V_b \cos(\omega t - \frac{2\Pi}{3}) + V_c \cos(\omega t + \frac{2\Pi}{3})] \quad (3)$$

$$V_0 = \frac{1}{3}[V_a + V_b + V_c] \quad (4)$$

Network. If the compensation current of the above equation is injected to the network, the whole voltage flicker existing in the network will be eliminated. Regarding the equation, related to the dq-transformation of the 3-phasevoltages to the instantaneous vectors, it is obvious that under the conditions of accessing an average voltage flicker, Vd and V0, the obtained values are close to zero and Vq is a proper value adapting to the voltage oscillation of the network. This state of the 3-phase voltage flicker is presented in the following figures (simulated in the MATLAB Simulink package):

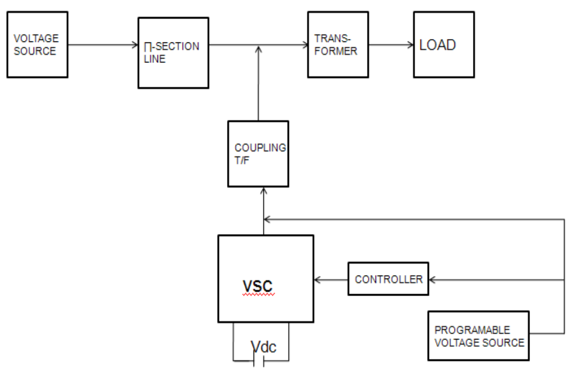


Fig.1 Block diagram of the investigated power system

Park's Transformation of 3-phase flicker voltage to the instantaneous vector's is given to demux block, it extract the component of an input signal and output's the components as separate signals Vd, Vq and V0.The active and reactive components of the system are represented by the direct and quadrature component, respectively, the decrease of the voltage flicker of the network and the compensating control to decrease the voltage flicker can be limited only based on the amount of the imaginary component of the instantaneous voltage (Vq), so to decrease the voltage flicker controlling system uses only Vq to control the STATCOM, the obtained Vq is entered as an input to the sum block and other input to the sum block is constant value zero, it indicates the Vq per unit reference value.

III. Simulation Results

Simulation of 6-pulse voltage source converter STATCOM connected to the Power System

The load voltage and the flicker source voltage are given to phase locked loop (PLL) and ABC to dq transformation blocks respectively. From the control circuit trigger pulse are given to the corresponding GTO's, by adjusting the conducting angle of the GTO's the generated voltage and then the injected or absorbed reactive power of the STATCOM are controlled. shows SIMULINK diagram of 6 pulse voltage source converters STATCOM connected to the power system.

Shows the compensated output load voltage and harmonic spectrum respectively by 6 pulse voltage source converter STATCOM. It can be observed that the compensated output load voltage is 1.15pu (maximum value), the voltage flicker existing in the output load voltage is 0.15pu (15%), the considerable existing characteristic harmonics in the output load voltage wave form in addition to the fundamental component are 5th, 7th, 11th, 13th and higher. It can be observed from the harmonic spectrum that THD is 8.95%. 5th, 7th, 11th and 13th.

Simulation of 8-pulse voltage source converter STATCOM connected to the power system:

The three-phase 8 – pulse VSC based STATCOM is shown in figure 9. There are 8 switches in the converter each converter is made up of Thyristor/ MOSFET with a diode connected in anti-parallel. In this type of STATCOM, each switch is triggered and turn off one time per line voltage cycle. In this case, each switch in a single branch is conducted during a half-cycle (180 degree) of the fundamental period. The combined pulses of each leg have a 120 degrees phase difference to produce a balanced set of voltages. By controlling the triggering angle of the thyristor we can control the generated voltage of the STATCOM and also the absorbed/injected power of the STATCOM. The compensated output voltage of the eight pulse VSC based SATACOM is shown in the figure 2.

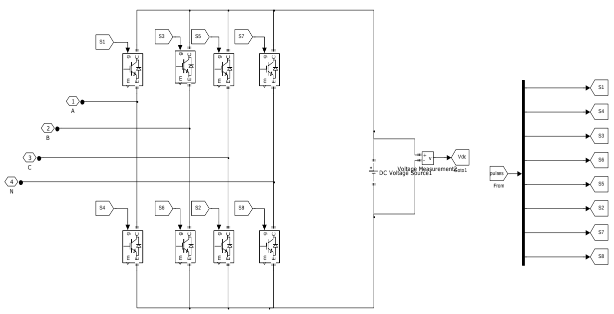


Fig 2: the circuit diagram of a 8-pulse voltage-source converter STATCOM

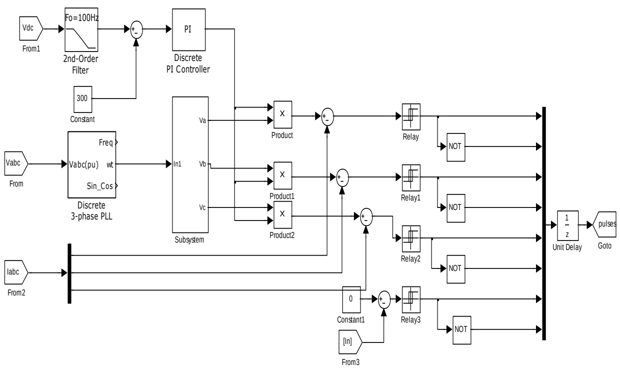
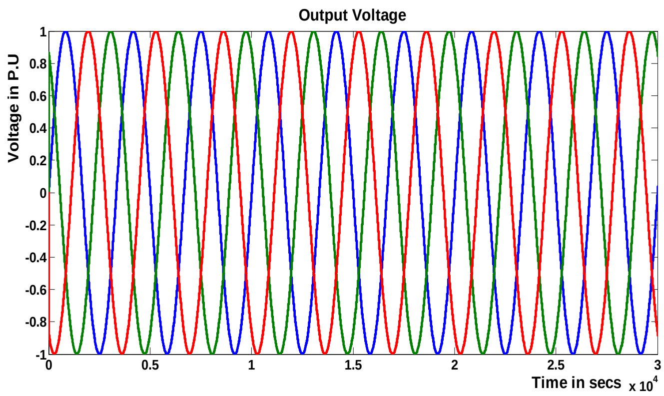


Fig 3 Control Circuit for STATCOM



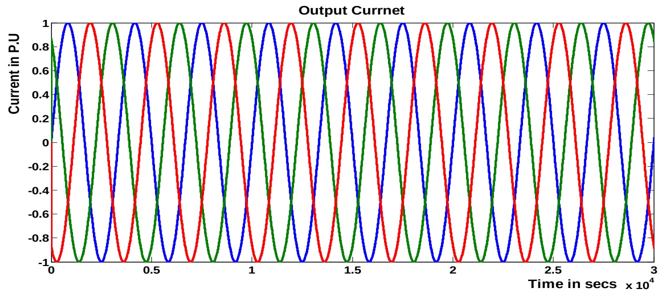
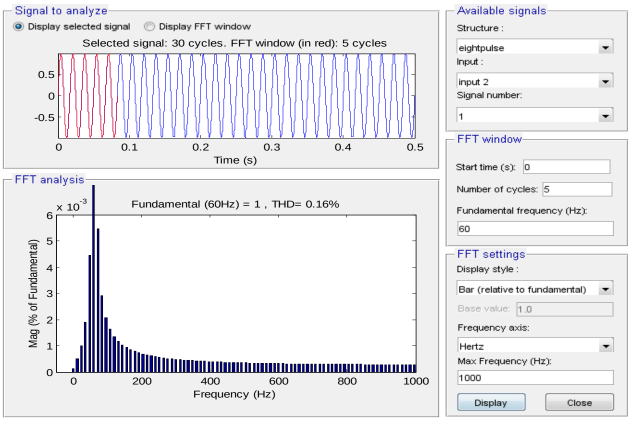
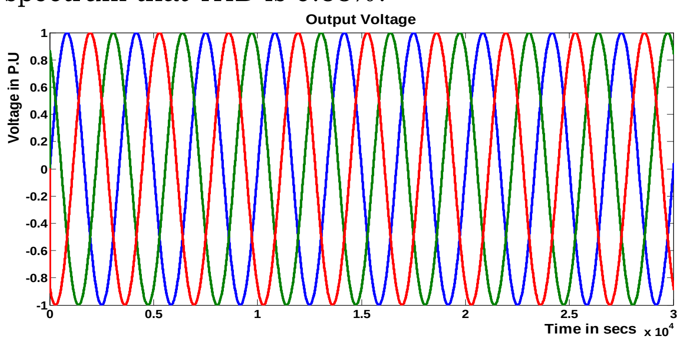


Fig 4: The compensated output voltage and current by 8-pulse voltage source converter STATCOM

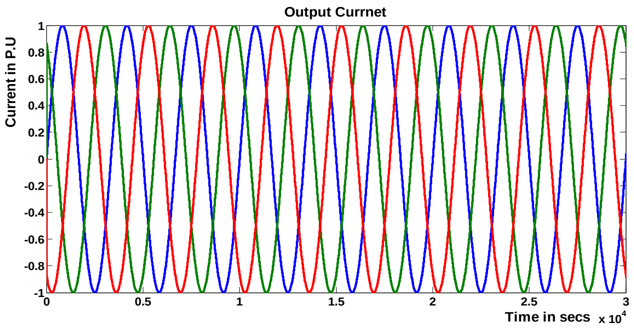


Simulation of 12-pulse voltage source converter STATCOM connected to the power system:

In this compensation, pulse generator outputs 1and 2 are two vectors of six pulses, are given to the two 6-pulse converters connected respectively to the Y winding and Δ connected windings of 3Ø transformer (three windings). The pulse train to one converter is shifted by 30 degrees with respect to the other. Fig 5.6 shows SIMULINK diagram of 12 pulse voltage source converters STATCOM connected to the power system. The output load voltage mitigated by 12- pulse voltage-source converter STATCOM and its harmonic spectrum are shown in figures 5.7 and 5.8 respectively. In this respect, the voltage flicker is completely removed from the output load voltage. It can be observed from the harmonic spectrum that THD is 0.53%.



(a)



(b)

Fig5: The compensated output voltage and current by 6-pulse voltage source converter STATCOM

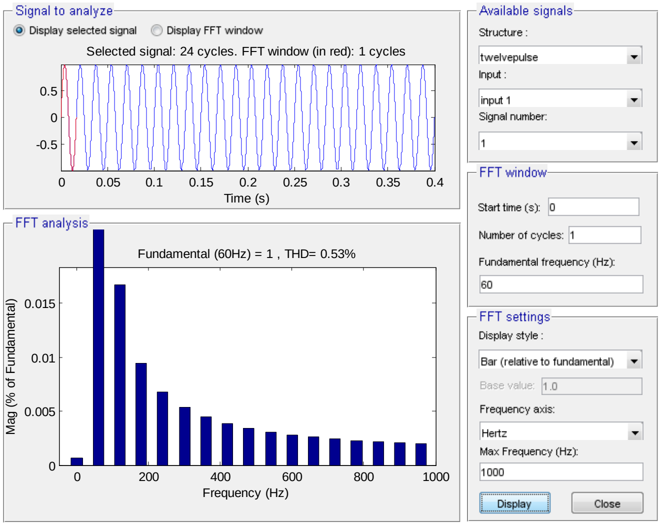


Fig 6: FFT Analysis for the compensated output voltage by 12-pulse voltage-source converter STATCOM (THD = 0.53%)

Comparison Table

	THD Value
With 4 leg Inverter	0.16
With 12 pulse converter	0.53

IV. Conclusion

In this paper , the application of three phase inverter technology based on voltage-source converters for voltage flicker mitigation has been investigated and simulation results emphasized its significant effect. A 6 – pulse STATCOM is decreasing the voltage flicker by 50 %. However, there is injection of the harmonic from 6-pulse inverter into the system which can be improved with the increase of the voltage source converters of STATCOM using a 8 pulse and 12-pulse STATCOM equipped with a harmonic filter. The obtained results clearly demonstrate that 8-pulse STATCOM equipped with a harmonic filter can reduce the voltage flicker completely and the output is obtained with minimum THD value.

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