Voltage Flicker Analysis and its Mitigation by STATCOM for Power Quality Improvement

Mekathoti Ravi Kumar[1] | Dr. D. Ravi Kishore[2]

[1]PG Scholar(HVE),Department of EEE,Godavari Institute of Engineering and Technology, Rajahmundry.
[2]Professor & Head,Department of EEE,Godavari Institute of Engineering and Technology,Rajahmundry.

ABSTRACT

Voltage flicker is considered as one of the most severe power quality problems (especially in loads like electrical arc furnaces) and much attention has been paid to it lately. The reason for this disturbance is mainly due to the large nonlinear loads such as electric arc furnaces. Due to the latest achievements in the semiconductors industry and consequently the emergence of the compensators based on voltage source converters, FACTS devices have been gradually noticed to be used for voltage flicker compensation.

This paper covers the contrasting approaches; dealing with the voltage flicker mitigation in three stages and assessing the related results in details. Initially, the voltage flicker mitigation, using FCTCR (Fixed Capacitor Thyristor Controlled Reactor), was simulated. Secondly, the compensation for the Static Synchronous Compensator (STATCOM) has been performed. The voltage flicker compensation by 8– pulse as well as 12 – pulse static synchronous compensator (STATCOM) has been performed.

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: *Power Quality, Voltage Flicker, Mitigation, STATCOM*

I. Introduction

Some industry processes such as induction and arc furnaces, car crushers, mine machinery, and others present large fluctuating loads to the supply. These fluctuations cause small variations on the supply voltage at the point of common coupling to other users. While the voltage variation may not be large in magnitude it is sufficient to cause the output of electrical lights to fluctuate or flicker. This effect can cause significant annoyance to other users and must be kept below the threshold of awareness [1].

The solution lies in the use of high speed IGBT inverter based shunt connected voltage regulators. A inverter based active VAR source is effective in combating flicker because it can modulate the current flowing in the supply very quickly at sufficient scale to create a correction voltage on the supply impedance [2]. The inverter will update the current flow many times per cycle giving effective control. It can also manage the available VARs to optimise the PST (rather than just the % variation) and to limit the impact on protection systems fault currents [3-6].

II. Objective of the Paper

The causes of power quality problems are generally complex and difficult to detect. Technically speaking, the ideal AC line supply by the utility system should be a pure sine wave of fundamental frequency (50/60Hz).Different power quality problems, their characterization methods and possible causes are discussed above and which are responsible for the lack of quality power which affects the customer in many ways. We can therefore conclude that the lack of quality power can cause loss of production, damage of equipment or appliances or can even be detrimental to human health [7-8]. It is therefore imperative that a high standard of power quality is maintained. This project demonstrates that the power electronic based power conditioning using custom power devices like DSTATCOM can be effectively utilized to improve the quality of power supplied to the customers.

The aim of the project is to implement DSTATCOM with different control strategies in the MATLAB, simulink using Simpower systems tool box and to verify and compare the results through various case studies applying different loads and study them in detail [9].

The term flicker is sometimes considered synonymous with voltage fluctuations, voltage flicker, light flicker, or lamp flicker. The phenomena being referred to can be defined as a fluctuation in system voltage that can result in observable changes (flickering) in light output. Because voltage flicker is mostly a problem when the human eye observes it, usually it is considered to be a problem of perception. There are, however, rare cases where voltage flicker can affect equipment operation such as electric drives and UPS systems. Voltage flicker can be separated into two types: cyclic and noncyclic. Cyclic flicker is a result of periodic voltage fluctuations in the system voltage, with noncyclic referring to occasional voltage fluctuations. An example of sinusoidal-cyclic flicker is shown in Figure 1.As shown in Figure 1, flicker is simply amplitude modulation where the main signal (60Hz for North America) is the carrier signal and flicker is the modulating signal. The usual method for expressing voltage flicker is similar to that of amplitude modulation. Voltage flicker is usually expressed as a percent of the total change in voltage with respect to the average voltage (ΔV/V) over a specified time interval [10].

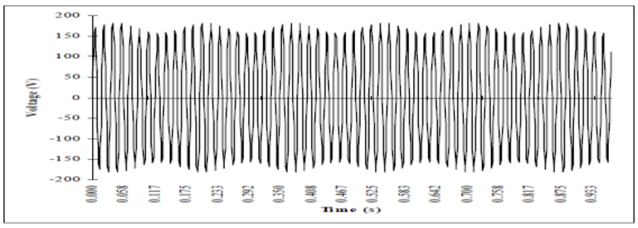

Fig 1 : Example Graph of Voltage Flicker

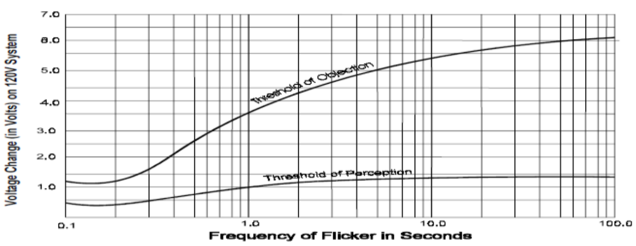

Fig 2 : General Flicker Curve

A. *Sources of Flicker*

Typically speaking, voltage flicker occurs on relatively weak systems with a low short-circuit ratio. This, in combination with considerable variations in line current over a short period of time, results in voltage flicker. As the load increases, the current in the line increases, thus increasing the voltage drop across line. This phenomenon results in a sudden reduction in bus voltage. Depending upon the change in magnitude of voltage and frequency of occurrence, this could result in observable amounts of voltage flicker. If a lighting load were connected to the system in relatively close proximity to the fluctuating load, observers would see this as a dimming (or flickering) of the lights. A common situation which could result in voltage flicker would be a large plant located at the end of a weak distribution feeder.

A common load which often causes voltage flicker would be an electric arc furnace (EAF) or welder. EAFs are non-linear, time-varying loads, which often cause large voltage fluctuations and harmonic distortion. Large induction machines undergoing startup or widely varying torque changes are also known to produce voltage fluctuations on systems. As shown in Figure 3, as an induction machine is started up, most of the power drawn by the motor is reactive. This results in a large voltage drop across distribution lines. Figure 4 demonstrates the affect on voltage of induction motor starting and torque variations. Although starting large induction machines across-the-line is not considered to be a recommended practice, it does however occasionally occur. Generally, motors are brought up to speed using reduced voltage starters or variable speed drives.

B. *Interharmonics*

In certain circumstances, superimposed interharmonics in the supply voltage can lead to oscillating luminous flux and cause light flicker. Voltage interharmonics are components in the harmonic spectrum that are non-integer multiples of the fundamental frequency. This phenomenon can be observed with incandescent lamps as well as with fluorescent lamps.

Sources of interharmonics include static frequency converters, cycloconverters, sub - synchronous converter cascades, induction machines and arc furnaces.

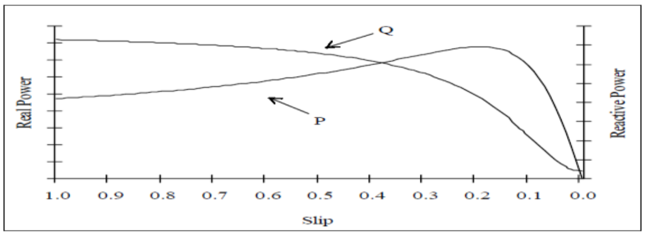

Fig 3 : Real and Reactive Power During Induction Machine Startup

III. INTRODUCTION TO POWER QUALITY

If there is any deviation of voltage, current and frequency at the load side then it is said to be power quality problem. Due to these power quality problems the performance of various sensitive loads is very poor. If we said that the power quality is good the voltage should be within permissible limits. The shape of the wave form should be pure sinusoidal. In all the three phases voltage should be same. Power supply should be consistent i.e. unremitting availability without break. Contemporary industrial machines and business-related computer networks are lying face down to many diverse failure modes. When the congregation line stops, or the computer network crashes for no obvious reason, very frequently the electric power quality is suspected. Power quality problems may be very difficult to troubleshoot, and often the electric power may not have any relation to the actual problem.

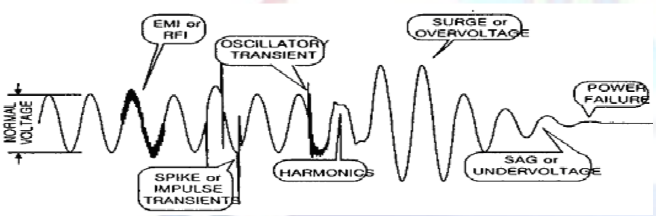

Fig 4: Power quality and reliability

Both the reliability and quality of supply are equally important. For example, a consumer that is connected to the same bus that supplies a large motor load may have to face a severe dip in his supply voltage every time the motor load is switched on. In some extreme cases even we have to bear the black outs which is not acceptable to the consumers. There are also sensitive loads such as hospitals (life support, operation theatre, patient database system), processing plants, air traffic control, financial institutions and numerous other data processing and service providers that require clean and uninterrupted power. In processing plants, a batch of product can be ruined by voltage dip of very short duration. Such customers are very wary of such dips since each dip can cost them a substantial amount of money. Even short dips are sufficient to cause contactors on motor drives to drop out. Stoppage in a portion of process can destroy the conditions for quality control of product and require restarting of production. Thus in this scenario in which consumers increasingly demand the quality power, the term power quality (PQ) attains increased significance [13].

Transmission lines are exposed to the forces of nature. Furthermore, each transmission line has its load ability limit that is often determined by either stability constraints or by thermal limits or by the dielectric limits. Even though the power quality problem is distribution side problem, transmission lines are often having an impact on the quality of the power supplied. It is however to be noted that while most problems associated with the transmission systems arise due to the forces of nature or due to the interconnection of power systems, individual customers are responsible for more substantial fraction of the problems of power distribution systems.

IV. INTRODUCTION TO FACTS DEVICES

Flexible AC Transmission Systems, called FACTS, which are power electronics devices. These devices have high controllability in power system. There are several FACTS devices which are used to control the power system. For the most part of the applications the controllability is used to avoid cost intensive [14]. FACTS-devices provide a better edition to changing functioning conditions and improve the usage of active installations. The basic applications of FACTS devices are:

- Voltage flicker compensation
- To control Power flow,
- Increase of transmission capability,
- To Voltage control,
- To compensate the Reactive power,
- To improve the Stability,
- For improvement of Power quality,
- For Power conditioning,
- Interconnection of renewable and distributed generation and storages.

According to IEEE FACTS can be defined as AC Transmission Systems incorporating power electronic devices other controllers (static controllers) to improve the Active Power Transfer Capability and controllability. Due to the increase in industries day by day there is a chance to increase in power demand. This leads to increase power system stabilizers. Due to rapid growth of power system stabilizers there are some disadvantages. Power outages and power interruptions are some of the problems which affect the customer as well as economy of any country. The above constraints affect the power quality. These problems can be overcome by improving the power system control. FACTS devices are one of the power system controllers to compensate the power quality problems. Figure 5 shows a number of basic devices separated into the conventional ones and the FACTS-devices [15].

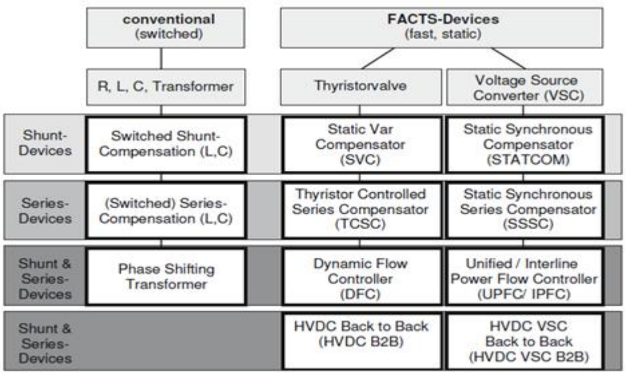

Fig 5: Overview of FACTS devices

V. Voltage Flicker

"Voltage flicker" does not actually exist, though this term is often heard. When lamps produce fluctuating light levels, and this is recognized by someone, we call this, "light flicker," or simply, "flicker." Flicker can be produced either by a problem in the light source or a fluctuation in the source voltage. If someone complains of flicker, and it is caused by voltage fluctuation, then its cause needs to be found. Sometimes flicker is caused by load fluctuations in the customer's equipment near the flickering lamp. Such problems can often be easily solved. If not, investigation must be taken beyond the meter into the utility system. This usually dictates that the flicker must be objectively measured. 4.1.1 Flicker Meter Flicker produced by fluctuating source voltage is measured indirectly by a flicker meter. The modern flicker meter measures voltage fluctuation and infers light flicker by taking into account the following: how often the voltage fluctuation occurs, how abruptly the voltage fluctuates, the kind of lamp, the sensitivity of the eye to light, and the brain's perception. All of these factors are modeled in a modern IEEE 1453 compliant flicker meter (this measurement is more complex than simply measuring voltage fluctuation and frequency).

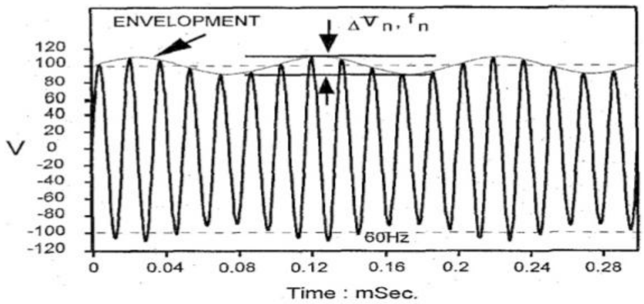

Fig 6: Voltage Flicker output voltage waveform

Fortunately, despite its internal complexity, an IEEE flicker meter's output is simple: if the output is greater than 1.0, the flicker is generally irritable to humans; if less than 1.0, it is not. These results have been successfully validated with many years of real-world testing in several countries. The flicker meter's main output is in a unit called Pst, meaning, "Perception of light flicker in the short term." Planned load characteristics should be obtained directly from the customer or equipment manufacturer. Gathering data for existing fluctuations requires the use of a recording voltmeter having a time resolution smaller than the occurrence of the flicker. Many recording voltmeters do not have sufficient resolution to perform this task.

VI. Voltage Flicker Compensation

Voltage oscillation was produced by a 3-phase flicker source. The Studied power system with complete STATCOM control and flicker source scheme is shown in figure 1. A STATCOM is used to regulate voltage on a 69KV transmission Network. A 440V load connected to a bus B1 through a 69KV/440V transformer represents a plant absorbing continuously charging currents similar to an arc furnace, thus producing voltage flicker. The STATCOM regulates the bus B3 voltage through the leakage reactance of the 3-phase two winding transformers by generating a secondary voltage .

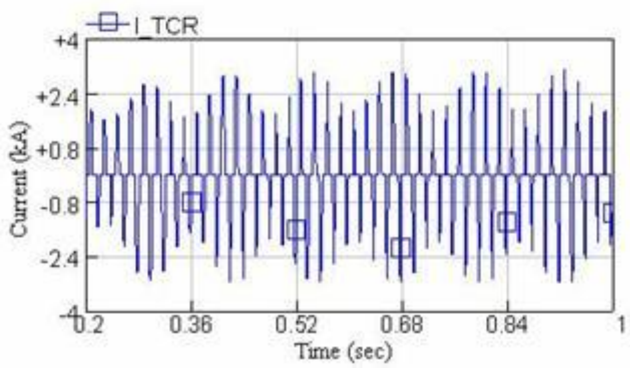

Fig.7 Voltage Flicker Compensation current wave form

A. 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.

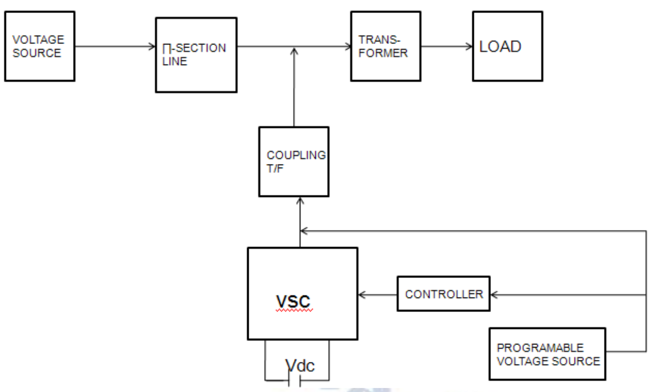

Fig.8 Block diagram of the investigated power system

The word "data" is plural, not singular. The subscript for the permeability of vacuum μ_0 is zero, not a lowercase letter "o." The term for residual magnetization is "remanence"; the adjective is "remanent"; do not write "remnance" or "remnant." Use the word "micrometer" instead of "micron." A graph within a graph is an "inset," not an "insert." The word "alternatively" is preferred to the word "alternately" (unless you really mean something that alternates). Use the word "whereas" instead of "while" (unless you are referring to simultaneous events). Do not use the word "essentially" to mean

VII. Simulation Results

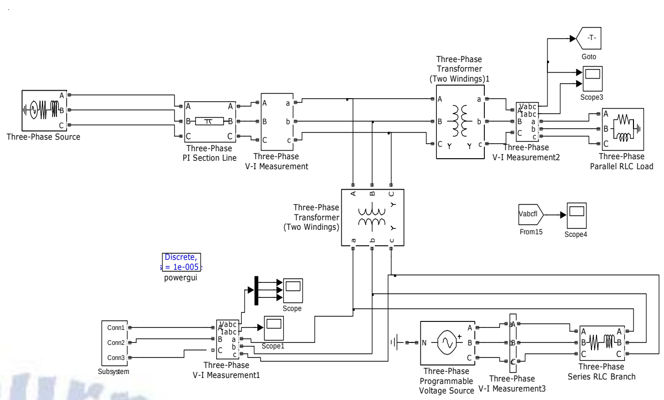

Fig .9 .Simulink diagram of 12-pulse voltage source converter STATCOM

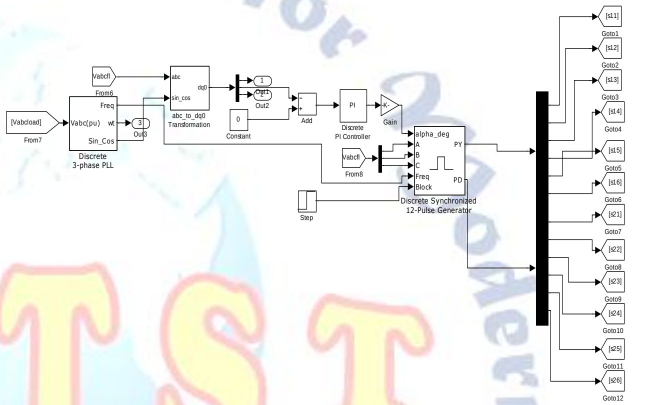

Fig.10 Control circuit for 12-pulse voltage source converter STATCOM

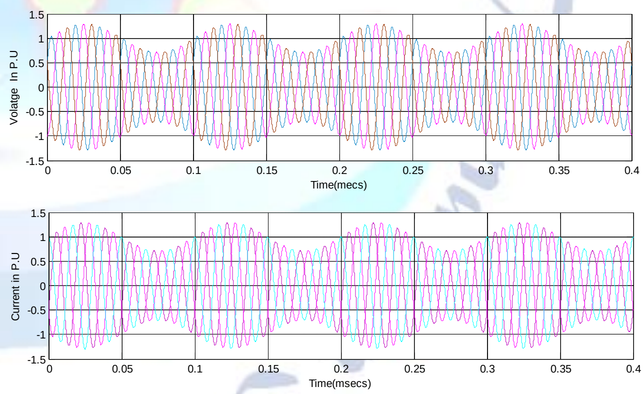

Fig.11. Output Voltage and Current of FCTCR

A. Compensation by Four Leg Inverter

The three-phase 8 – pulse VSC based STATCOM is shown in figure15 and figure16 . There are 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 witch 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 phasedifference 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.

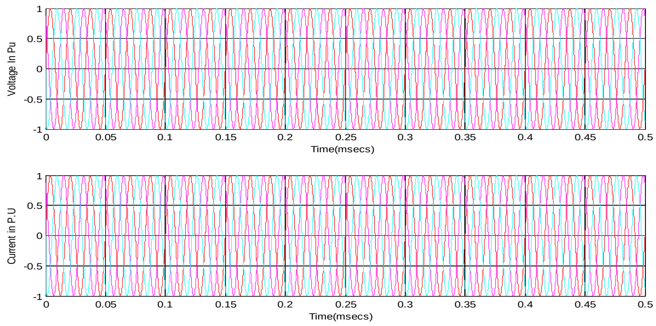

Fig 12.Output Voltage and Current of Four Leg Inverter

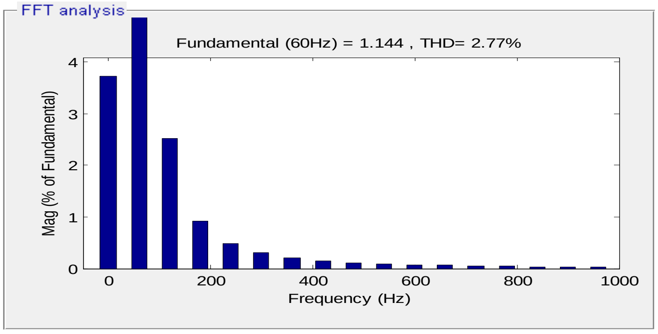

Fig.13 Output Voltage and Current of Four Leg Inverter in THD

B. Compensation 12 Pulse VSC-STATCOM

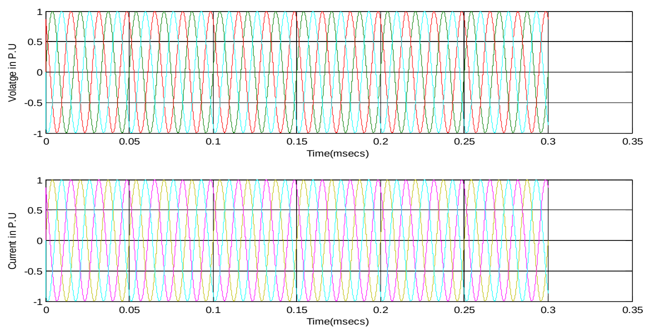

Fig.14 Output Voltage and Current of 12-Pluse Inverter

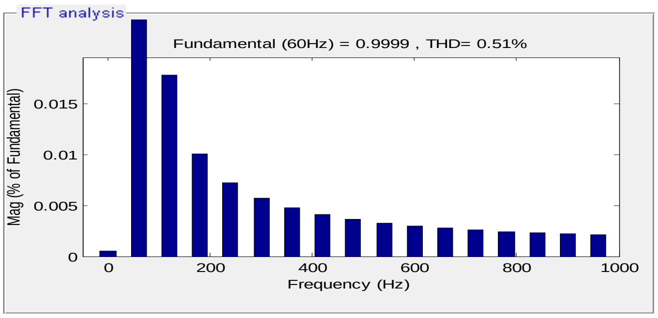

Fig 16. Output Voltage and Current of 12-Pluse Inverter in THD

VIII. 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 12-pulse STATCOM equipped with a harmonic filter. The obtained results clearly demonstrate that 12-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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