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Compensation of Voltage Flickerin Induction Motor Drive by Using Facts Devices in Conjunction with Voltage Source Converter

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Abstract -The power quality issue will take new dimension due to power system restructuring and shifting trend towards distributed generation. Huge loss in terms of time and money have made power quality problems a major anxiety for modern industries with non-linear loads in electrical power system. 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 and assessing the related results in details. Initially, the voltage flicker mitigation, using Static Synchronous Compensator (STATCOM) has been performed. In this case, injection of harmonics into the system caused some problems were overcome. The obtained results show that STATCOM is very efficient and effective for the flicker compensation. Inverter systems are used in a wide variety of applications as a front-end power conditioning unit in Electric drives, Uninterruptible power supplies, High Voltage DC transmission, Active power filters, reactive power compensators in power systems, Electric vehicles, Alternate energy systems and Industrial processes. All the simulations have been performed on the MATLAB/Simulink Software.

Key Words - Power Quality, Voltage Flicker, Static Synchronous Compensator (STATCOM),RLC Filters

I. INTRODUCTION

Power quality issues is an issue that is becoming increasingly important to electricity consumers at all levels of usage. PQ related issues are of most distress because of the extensive use of electronic equipment. In arrears to this, various PQ issues arises like voltage sag or dip, very short and long interruptions, voltage spike, voltage swells, harmonic distortion, voltage fluctuation, noise, voltage unbalance and altered our power system. Power quality problems have been attracting the eye of researches for decade. The presence of voltage disturbances at the point of common coupling (PCC) results in malfunction of sensitive industrial instrumentality, that turn out grid part failures, such as transformers, and economical losses. FACTS devices are the possible answer to shield sensitive loads against the most significant voltage disturbances, voltage harmonics, imbalance and sags [1]. Definition of power quality may vary from person to person because we cannot define what power quality we only define what good is or bad power quality is as we can see that two identical devices or pieces of equipment might react differently to the same power quality parameters due to differences in their manufacturing or component tolerance [2]. According to institute of Electrical and Electronic Engineers (IEEE) Standard power quality is defined as a, “the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment”. The focus of this survey is on the use of FACTS devices in mitigation of PQ problems [3-6]. Voltage flicker occurs when heavy loads are periodically turned on and off in a weak distribution system. If the distribution system’s short circuit capacity is not large enough, voltage fluctuations will occur. Starting large motors require an inrush of current, which causes a decrease in voltage. This voltage depression may cause a visible flicker on lighting circuits connected to the same power system. Voltage flickering can be extremely harmful to sensitive electronic equipment. Computerized equipment requires stable voltage to perform properly. For this reason, voltage flicker is a major power quality problem. The magnitude of the voltage flicker depends upon the size and type of the electrical load that is producing the disturbance. A sag in voltage can also cause a voltage flicker; sudden voltage drops in the electrical distribution system can generate inrush current which can travel to sensitive equipment [7-9].

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 [10]. 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% [11]. Huge non-linear industrial loads such as the electrical arc furnaces [12], 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 [13] which models the arc. Connecting this type of load to the network producesvoltage variation at the common point of supply to other consumers. The relative voltage drop is expressed by equation

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

where ΔP and ΔQ are the variation in active and reactive power; Un is the nominal voltage and R and X are short circuit resistance and reactance. Since R is usually very small in comparison to X, ΔU is proportional to Q (reactive power).

Therefore, voltage flicker mitigation depends on reactive power control [5].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.

In addition to the aforesaid procedures for the compensators, the active filters are used for the voltage flickers mitigation as well. Furthermore, the mitigating devices based on Static VAR Compensator (SVC) such as Thyristor Switched Capacitor TSC, Thyristor Controlled Reactor (TCR) and FCTCR are the most frequently used devices for reduction in the voltage flicking. SVC devices achieved an acceptable level of mitigation, but because of their complicated control algorithms, they have problems such as injecting a large amount of current harmonics to the system and causing spikes in voltage waveforms.

Advent of FACTS devices make them ideal for use in a power system and especially in the voltage flicker mitigation. In this respect, the FACTS devices based on voltage-source converters have been able to improve the problems related to SVC [5].

A new technique based on a novel control algorithm, which extracts the voltage disturbance to suppress the voltage flicker, is presented in this paper. The technique is to use STATCOM for voltage flicker compensation to overcome the aforementioned problems related to other techniques. The concept of instantaneous reactive power components is used in the controlling system.

A two-bus system is exploited to fulfill 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 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 12-pulse STATCOM to complete the voltage flicker mitigation.

II. INTRODUCTION TO POWER QUALITY

The power quality problem is defined as any problem manifested in voltage, current or frequency deviations that result in mal-operation of customer equipment. The power quality problem causes the deterioration of performance of various sensitive electronic and electric equipment. The good quality of power can be specified as the supply voltage should be within guaranteed tolerance of declared value. The wave shape should be pure sine wave within allowable limits for distortion. The voltage should be balanced in all three phases. Supply should be reliable i.e. continuous availability without interruption Modern industrial machinery and commercial computer networks are prone to many different failure modes. When the assembly line stops, or the computer network crashes for no apparent reason, very often the electric power quality is suspected. It is a convenient culprit, as it is invisible and not easy to defend. Power quality problems may be very difficult to troubleshoot, and often the electric power may not have any relation to the actual problem. For example, in an industrial plant the faults of an automated assembly machine may ultimately be traced to fluctuations in the compressed air supply or a faulty hydraulic valve. Or in an office building, the problems on a local area network may be find their root cause with coaxial cable tee locations that are too close together, causing reflections and signal loss.

The contemporary container crane industry, like many other industry segments, is often enamored by the bells and whistles, colorful diagnostic displays, high speed performance, and levels of automation that can be achieved. Although these features and their indirectly related computer based enhancements are key issues to an efficient terminal operation, we must not forget the foundation upon which we are building. Power quality is the mortar which bonds the Foundation blocks. Power quality also affects terminal operating economics, crane reliability, our environment, and initial investment in power distribution systems to support new crane installations.

To quote the utility company newsletter which accompanied the last monthly issue of my home utility billing: 'Using electricity wisely is a good environmental and business practice which saves you money, reduces emissions from generating plants, and conserves our Natural resources.' As we are all aware, container crane performance requirements continue to increase at an astounding rate. Next generation container cranes, already in the bidding process, will require average power demands of 1500 to 2000 kW – almost double the total average Demand three years ago. The rapid increase in power demand levels, an increase in container crane population, SCR converter crane drive retrofits and the large AC and DC drives needed to power and control these cranes will increase awareness of the power quality issue in the very near future. .

A. Power Quality Problems

Power Quality can be defined as the deviation of voltage, current and frequency at the distribution side. The problems due to the poor power quality include:

- High harmonic in distribution system
- Lower Power Factor
- Voltage Transients
- Low Voltage than nominal voltage in system
- High Voltage than nominal voltage

The AC and DC adjustable speed drives utilized on board trunk cranes are important contributors to total harmonic voltage distortion and current distortion. Whereas silicon controlled rectifier phase control creates the desired average power factor, DC silicon controlled rectifier drives operate at less than this. In accumulation, line notching occurs when silicon controlled rectifiers commutate, creating transient peak revival voltages that is 3 – 4 times the nominal line voltage. That depends up on the dimension of drives and system impedance. Due to power quality problem the systems disturb.

The power quality problem severity and the frequency of the system vary with the speed of the drive. If the drives are operating at low speeds, high amount of harmonic current is injected by the DC and AC drives and also the power factor will be low when drives are operating initial acceleration and deceleration periods. Low power factor require a greater kVA demand load on the utility. Due to the lower power factor the life span of the sensitive load will decrease and also it affect the voltage stability. DC drive SCR line notching creates voltage transients, high harmonic signals and AC drive voltage chopping are the sources of noise in the sensitive loads. Power quality can be improved through:

- By correcting Power factor,
- By connecting special line notch filtering,
- By connecting harmonic filter,
- By suppression of Transient voltage surge,
- By providing proper earthing systems.

B. Power Quality Benefits

Power Quality problem plays a very important role in the distribution side. If Power quality is good in the electrical power system the following benefits are achieved.

- Equipment Reliability
- Power System Adequacy
- Environment
- Economic Impact.

III. INTRODUCTION TO FACTS

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. 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 1.shows a number of basic devices separated into the conventional ones and the FACTS-devices.

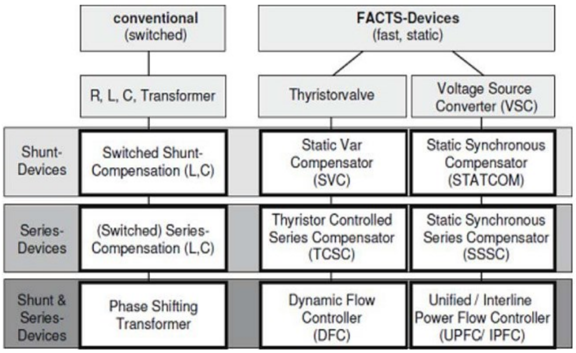

Fig.1. Overview of FACTS devices.

IV. VOLTAGE FLICKER

Flicker is a difficult problem to quantify and to solve. The untimely combination of the following factors is required for flicker to be a problem: 1) some deviation in voltage supplying lighting circuits and 2) a person being present to view the possible change in light intensity due to the voltage deviation. The human factor significantly complicates the issue and for this reason flicker has historically been deemed "a problem of perception." The voltage deviations involved are often much less than the thresholds of susceptibility for electrical equipment, so major operating problems are only experienced in rare cases. To office personnel, on the other hand, voltage deviations on the order of a few tenths of one percent could produce extremely annoying fluctuations in the output of lights, especially if the frequency of repetitive deviations is 5-15 Hz. Due to the clear relationship between voltage deviation and light response, the term "flicker" often means different things to different people with the interpretation primarily governed by the concerns of a particular discussion.

Flicker Measurement Introduction The power supply network voltage varies over time due to perturbations that occur in the processes of electricity generation, transmission and distribution. Interaction of electrical loads with the network causes further deterioration of the electrical power quality. High power loads that draw fluctuating current, such as large motor drives and arc furnaces, cause low frequency cyclic voltage variations that result in: flickering of light sources which can cause significant physiological discomfort, physical and psychological tiredness, and even pathological effects for human beings, problems with the stability of electrical devices and electronic circuits.

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 [20] has been transformed to the synchronous reference frame (Park or dq_0 transformation). This transformation leads to the appearances of three instantaneous space vectors: V_d on the d-axis (real or direct axis), V_q on the q-axis (imaginary or quadrature axis) and V_0, from the 3-phase voltage of V_a, V_b and V_c. The related equations of this transformation, expressed in the MATLAB software, are as follows:

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

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

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

A dynamic computation shows that the voltage oscillations in the connecting node of the flicker generating load to the network are created by 3 vectors: real current (ip), imaginary current (iq) and the derivative of the real current with respect to time dip/dt. In general, for the complete voltage flicker compensation, the compensating current (ic) regarding the currents converted to the dq0 axis is given as [3]:

$$i_c = j\left(i_q + i_p \frac{R}{X} f + \frac{1}{\omega}\frac{di_p}{d\omega} f + k\right) \quad (5)$$

Where R and X are the synchronous resistance and reactance of the line and f is the correcting coefficient. The constant k is also used to eliminate the average reactive power of the network [3]. 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-phase-voltages 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.

V.INDUCTION MOTOR

Induction Motor (1M) An induction motor is an example of asynchronous AC machine, which consists of a stator and a rotor. This motor is widely used because of its strong features and reasonable cost. A sinusoidal voltage is applied to the stator, in the induction motor, which results in an induced electromagnetic field. A current in the rotor is induced due to this field, which creates another field that tries to align with the stator field, causing the rotor to spin. A slip is created between these fields, when a load is applied to the motor.

Compared to the synchronous speed, the rotor speed decreases, at higher slip values. The frequency of the stator voltage controls the synchronous speed [12]. The frequency of the voltage is applied to the stator through power electronic devices, which allows the control of the speed of the motor. The research is using techniques, which implement a constant voltage to frequency ratio. Finally, the torque begins to fall when the motor reaches the synchronous speed. Thus, induction motor synchronous speed is defined by following equation,

$$n_s = \frac{120f}{p}$$

Where f is the frequency of AC supply, n, is the speed of rotor; p is the number of poles per phase of the motor. By varying the frequency of control circuit through AC supply, the rotor speed will change.

VI. SIMULATION AND ANALYSIS OF THE RESULTS

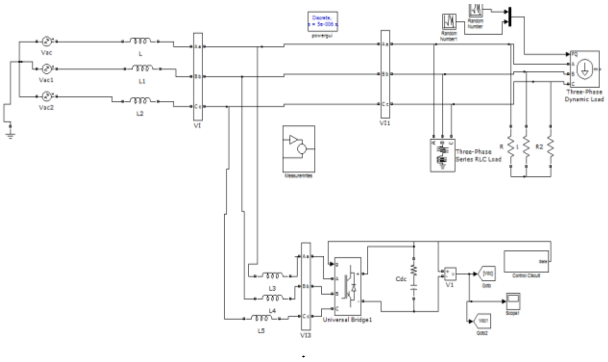

Fig.1.Simulink circuit for STATCOM.

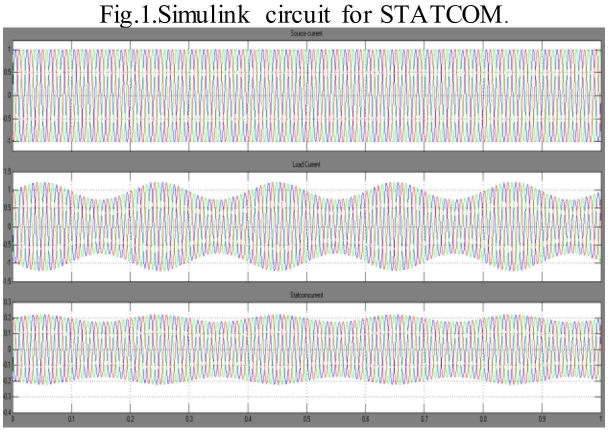

Fig.2. simulation results for (a) source current (b) load current (c) STATCOM current.

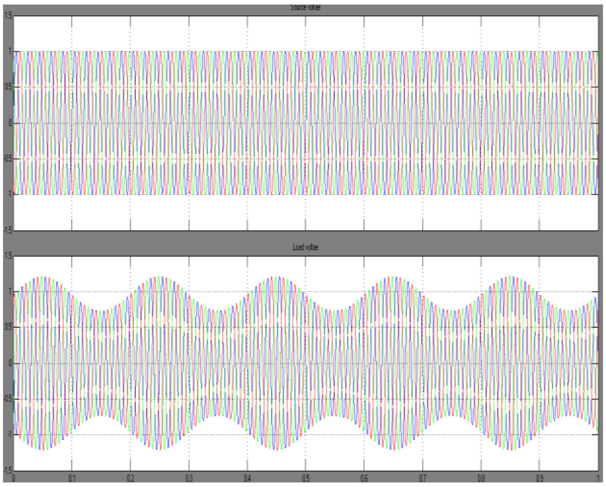

Fig.3Simulation results for source voltage and current.

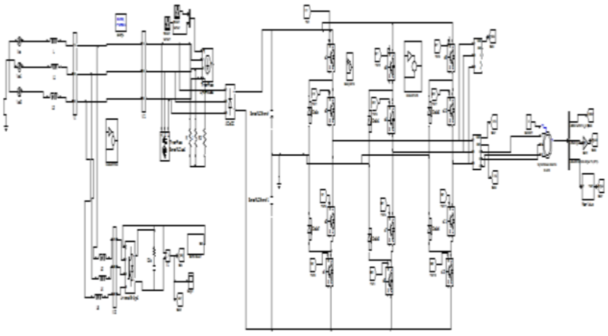

Fig.5. Simulink circuit for STATCOM based induction motor drive and faults.

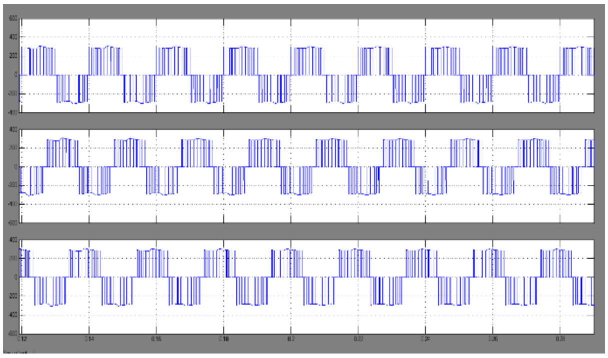

Fig.6. simulation results of Inverter Phase To Phase Voltage.

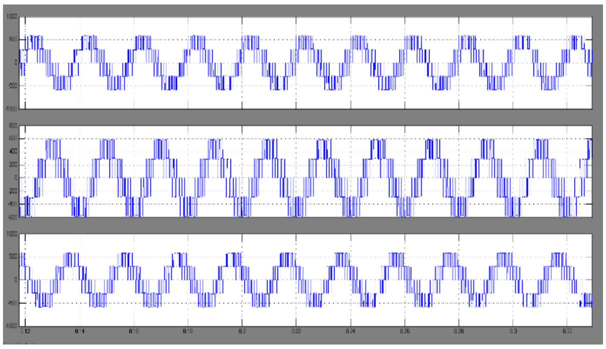

Fig.7. Simulation result of inverter line to line voltages.

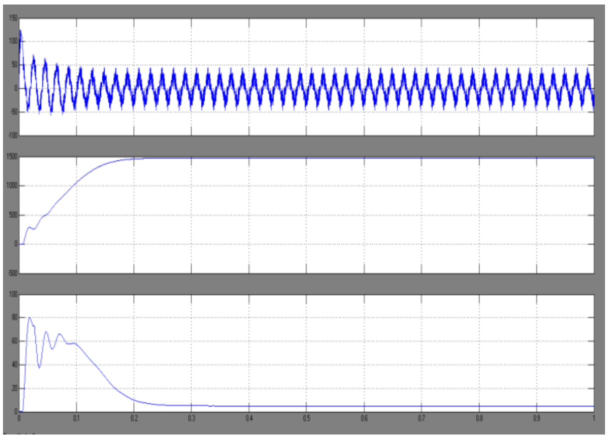

Fig.8. Simulation Results for Stator Currents, Speed and Torque of Induction Motor.

VII. CONCLUSION

Mitigation is done and the results are compared and contrasted. First, a 6- pulse voltage-source converter STATCOM is used to compensate for the voltage flicker without harmonics. All the simulated results which have been performed in MATLAB show that a 6-pulse STATCOM is efficiently effective in decreasing the voltage flicker of the generating loads. However, there is injection of the harmonic from STATCOM into the system which can be improved with the increase of the voltage source converters of STATCOM. The analysis of voltage source inverter fed induction motor drive was presented. The three phase PWM inverter fed induction motor drive is simulated using the circuit model developed.

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