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Assessment of Harmonics In Electrical Power Systems: Causes, Effects And Reduction Using Active Filters

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Abstract: *This paper investigates the causes, effects and reduction of harmonics currents in electrical power systems using active filters. The study evaluatesthe characteristic harmonics produced by semi-conductor converter equipment using Mathematical modeling to determine the amount of total harmonic distortion of voltages and currents at the point of common coupling; while three-phase Active filter and twelve-pulse converter were applied to mitigate harmonics currents and voltages distortion. The results revealed that power electronics devices and non-linear equipment generate harmonics currents of integer multiples of the fundamental 50Hz frequency. These causes equipment overheating, insulation stress,electromagnetic interferences noise in adjacent telephone signal or communication lines, utility meters record measurement incorrectly resulting in higher billings to consumers, thyristor firing errors in converter installations and false tripping of protective devices.Active filter injects compensation voltage into the system which compensates voltage sags and harmonics on the load side; voltage unbalance is corrected; harmonic component of load currents cancelled and the current drain from the mains supply becomes sinusoidal with unity power factor.It removes current harmonics by injecting equal but opposite harmonic current.The 12-pulse converter eliminate the 5^{th} and 7^{th} harmonics to a higher order where the 11^{th} and 13^{th} becomes the predominant harmonics.*

Keywords: *Active filters, Harmonics currents, Harmonic Frequency, Non-linear loads, Power Electronics, Point of common coupling, Total harmonic distortion.*

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I. Introduction

Power system harmonics have been presented since the invention of AC as a means of power transmission. However, harmonic problems became more critical mainly due to the substantial increase of non-linear loads due to the technological advances, such as the use of power electronic circuits and devices, in ac/dc transmission lines or loads in the control of power systems using power electronics or microprocessor controllers. Prior to the appearance of power semiconductors, the main sources of waveform distortion were electric arc furnaces, the accumulated effect of fluorescent lamps and to a lesser extent electrical machines and transformers.Power electronicsconverters create current harmonics. The power electronics equipmentdraws current which contains fundamental component and higher order harmonics. The impedance offered by the inductance to the different harmonics current will be different. As a result the voltage wave shape at load point will become distorted. This causes malfunctioning of other load equipment connected to the same load point. Other negative effects due to harmonics include overheating, overvoltage due to resonance condition at some harmonics, error in metering, malfunctioning of relays, interference (noise) with communication and control signals [1].The power electronics equipment can draw power, from the ac system, at a low power factor. This can cause overloading of generation, transmission and distribution equipment. In anideal power system, the voltage supplied to the customer equipment, and the resulting loads current are perfectsine waves [2]. In practice, however, conditions are never ideal, so these waveforms are often quite distorted. This deviation from perfect sinusoids is usually expressed in terms of harmonic distortion of the voltage and current waveforms [3].

II. Description

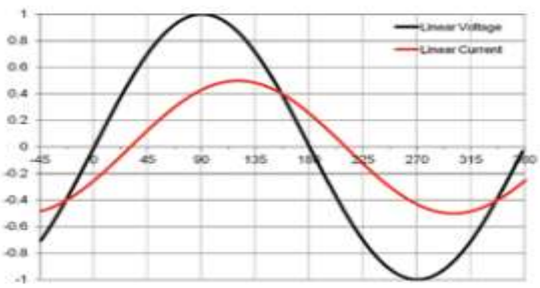
Power systems are designed to operate at frequencies of 50 or 60Hz. However, there are certain types of loads that produce currents and voltages with frequencies that are integer multiples of the 50 or 60 Hz basic frequency. These higher frequencies are form of electrical pollution which causes distortion in supply waveform, and it is called power system harmonics [4, 5]. Harmonics are defined as the sinusoidal components of a repetitive waveform which consist of frequencies that are exact multiples or harmonic orders of fundamental frequency. Harmonics are currents, usually in multiples of the supply fundamental frequency, produced by non-linear loads such as the AC to DC power conversion circuits [6]. Harmonic is a component of a periodic wave having a frequency that is an integral multiple of the fundamental power line frequency of 50 Hz as shown in Table 1 [7, 8]. Total harmonic distortion is the contribution of all the harmonic frequency currents to the fundamental. Applications of power electronics loads are continually overtaking industry space from other types of loads, especially because of their ability to help the conservation of energy and provide better control over traditional processes [2].

Table 1: Determining Characteristic Harmonics

Harmonics	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	13th	..	50th
Frequency	50Hz	100Hz	150 Hz	200 Hz	250 Hz	300 Hz	350 Hz	400 Hz	450 Hz	500 Hz	550 Hz	650 Hz		2550 Hz

A linear load connected to an electric power system is defined as a load which draws current from the supply which is proportional to the applied voltage, for instant, resistive, incandescent lamps etc. Example of voltage and current waveforms of a linear load is shown in figure 1[9, 10].

A load is considered "non-linear" if its impedance changes with the applied voltage. Due to this changing impedance, the current drawn by the non-linear load is also non-linear i.e. non-sinusoidal in nature, even when it is connected to a sinusoidal voltagesource, for example computers, variable frequency drives, discharge lighting etc. Figure 2 shows voltage and current waveforms of non- linear load. These non-sinusoidal currents contain harmonic currents that interact with the impedance of the power distribution system to create voltage distortion that can affect both the distribution system equipment and the load connected to it [11].



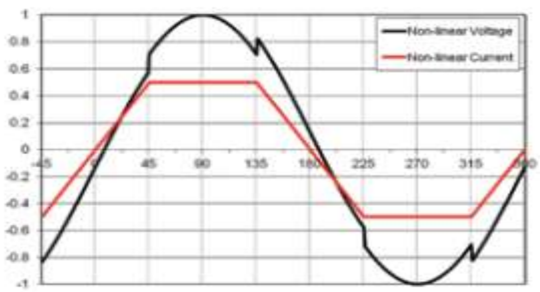


Fig 1: Voltage and Current waveform oflinear load **Fig 2:** Voltage and Current waveform of non-linear load

III. Materials And Methods

3.1 Generation of current Harmonic

Harmonics are the by-products of modern electronics. They occur frequently when there are large numbers of personal computers, uninterruptible power supplies (UPS), variable frequency drives (AC and DC) or any electronic device using solid state power switching supplies to convert incoming AC to DC. Non-linear loads create harmonics by drawing current in abrupt short pulses, rather than in a smooth sinusoidal manner.The current consists of fundamental component and higher order frequencies which are integer multiples of 50 Hz fundamental frequency. The listed cases are some common causes of harmonic currents.

a) Television and personal computers at home and offices use switched mode power supplies. These supplies produce third harmonic current which can have a magnitude equal to about 80% of the magnitude of fundamental component.
b) If three-phase voltages applied to a three-phase converter are unbalanced even harmonics can be produced, generally, only odd order harmonic occur.
c) Because of presence of harmonics in current wave shape, series and parallel resonance conditions can occur for any of the harmonic frequencies. If series resonance occurs even small voltage can cause high current at that frequency. If parallel resonance occurs even a small current can cause high voltage at that frequency.
d) Cycloconverter generate number of harmonics which are integer multiples of 50 Hz frequency and also some harmonics which are not integer multiples of 50Hz frequency.
e) Arc furnaces commonly used in steel industry produce harmonics of many frequencies; some of these frequencies are notintegermultiples of 50Hz frequency.
f) A large number of consumers install shunt capacitors for power factor improvement at their premises. These capacitors are, in effect, parallel with the distribution transformer. The use of these capacitors can create parallel resonance especially at 5^{th}, 7^{th} and 9^{th} harmonics.

Static power converters utilize power semiconductor devices for power conversion from AC to DC, DC to DC, DC to AC and AC to AC; and constitute the largest non-linear loads connected to the electric power systems. These converters are used for various purposes in the industry, such as adjustable speed drives, uninterruptable power supplies, switch-mode power supplies etc.

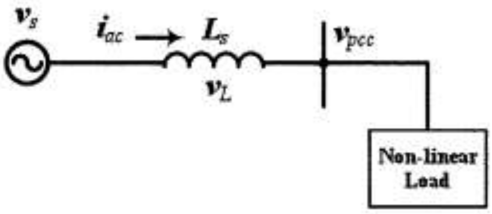


Fig 3: Single line diagram of Power Distribution System.

Table 2: Harmonics and their Magnitudes of Some Power Electronic Equipment.

HARMONICS	SMPS*	FLUORESCENT LAMPS	SIX PURSE AC DRIVE	SIX PURSE DC DRIVE
Fundamental	100.0	100.0	100.0	100.0
2	0.7	1.0	1.08	4.7
3	90.0	12.5	3.8	1.2
4	1.0	0.3	0.5	1.4
5	80.1	1.8	80.5	33.5
6	1.3	0.1	1.5	0.0
7	64.8	0.7	77.5	1.5
8	1.4	0.1	1.2	1.7
9	47.9	0.5	7.5	0.4
10	1.0	0.1	0.7	0.3
11	30.5	0.2	46.3	8.6
12	0.8	0.1	1.0	0.0
13	16.0	0.2	41.3	1.2
14	0.4	0.0	0.2	1.2
15	3.0	0.1	5.7	0.3

*Switched Mode Power Supply (SMPS) [1].

These static power converters used in a variety of applications draw non-linear i.e. non-sinusoidal currents and distort the supply voltage waveform at the point of common coupling (PCC). The PCC is a point between the system owner or operator and a user [12, 13].The PCC is usually taken as the point in the power system closest to the user where the system owner or operator could offer service to another user. Frequently for service to industrial users e.g. manufacturing plants via a dedicated service transformer, the PCC is at the HV side of the transformer. For commercial usersi.e. office parks, shopping malls, etc. supplied through a common service transformer, the PCC is commonly at the LV side of the service transformer. In general, The PCC is a point on a public power supply system, electrically nearest to a particular load, at which other loads are, or could be connected and is located on the upstream of the considered installation[10, 14, 15]. Figure 3 shows a single line representation of the power distribution system with the point of common coupling (PCC). The source voltage (*vs)* is assumed to be purely sinusoidal and the system impedance is represented by an inductance *Ls*. Table 2 present's data of the harmonics created by some commonly used power electronic equipment. As can be seen in table 2, some even order harmonics are also produced by power electronic equipment. It is also seen that the magnitude of some harmonics is almost the same as that of fundamental especially in switched mode power supply.

In general, a non-sinusoidal waveform frequency f (t) repeating with an angular frequency ω can be expressed in equation 1

$f(t)=F_0 + \sum_{h=1}^{\infty} f_h(t) = \frac{1}{2}a_0 + \sum_{h=1}^{\infty}\{a_h \cos(h\omega t) + b_h \sin(h\omega t)\}$(1)

Where $F_0 = \frac{1}{2}a_0$ is the average value, in equation1,

$a_h = \frac{1}{2\pi}\int_0^{2\pi} f(t)\cos(h\omega t)d(\omega t)$ h = 1, 2,……., ∞(2)

$b_h = \frac{1}{2\pi}\int_0^{2\pi} f(t)\sin(h\omega t)d(\omega t)$ h = 1, 2,……., ∞(3)

From the above equation, the average value for $\omega = 2\pi f$ is;

$F_0 = \frac{1}{2}a_0 = \frac{1}{2\pi}\int_0^{2\pi} f(t)d(\omega t) = \frac{1}{T}\int_0^{T} f(t)dt$(4)

Therefore, the rms value of all the harmonics components including the fundamental is (i.e. h=1) combinedis

$$F_h = \frac{\sqrt{a_h^2 + b_h^2}}{\sqrt{2}} \quad (5)$$

The characteristic harmonics produced by semiconductor converter equipment are based on the number of rectifiers used in a circuit and can be determined by the expression as;

$$h = np \pm 1 \quad (6)$$

Where, h = order of harmonics
n = an integer 1, 2, 3, 4, 5,…..
p = number of pulses per cycle.

For a single phase bridge rectifier, the number of p = 2 for one cycle of line frequency and therefore the characteristics harmonics are; h = n*2 ± 1 = 1 (fundamental), 3, 5, 7, 9, 11 …..

For a three phase bridge rectifier, since the number of pulses p = 6 per line frequency cycle, the characteristics harmonics are;h = n*6 ± 1 = 5, 7, 11, 13, 17, 19, 23, 25, 35, 37…

The amount of distortion in the voltage or current waveform is quantified by means of an index called the total harmonic distortion (THD). According to [4], it is defined as a ratio of the root-mean-square of the harmonic content to the root-mean-square value of the fundamental quantity and expressed as a percent of the fundamental. i.e. total harmonic distortion of voltage at the PCC,[14, 15].

$$\%THDvpcc = \frac{\sqrt{\sum_{h=2}^{\infty} V_{PCCH}{}^2}}{V_1} x\ 100 \quad (7)$$

Similarly, total harmonic distortion of current

$$\%THD_1 = \frac{\sqrt{\sum_{h=2}^{\infty} I_h{}^2}}{I_1} x\ 100 \quad (8)$$

The harmonics up to the 50[th] order are used to calculate the *% THD*, however, the harmonic components of order greater than 50 can be included when necessary.

According to [4], the total effect of distortion in the current waveform at the PCC is measured by the index called the total demand distortion(TDD), as a percentage of the maximum demand current at the PCC. Figure 4 shows the distortion in the waveform of V_{PCC}due to the flow of non-linear current through the finite system impedance.

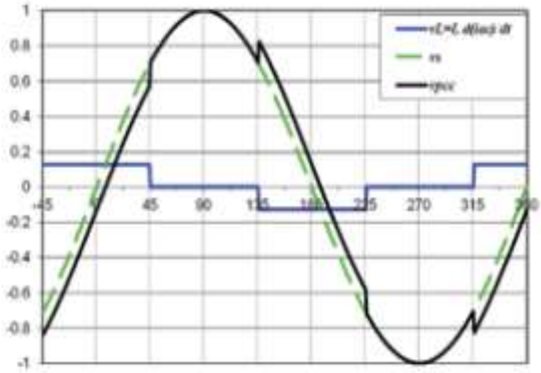


Fig 4: Distorted voltage waveform at the PCC.

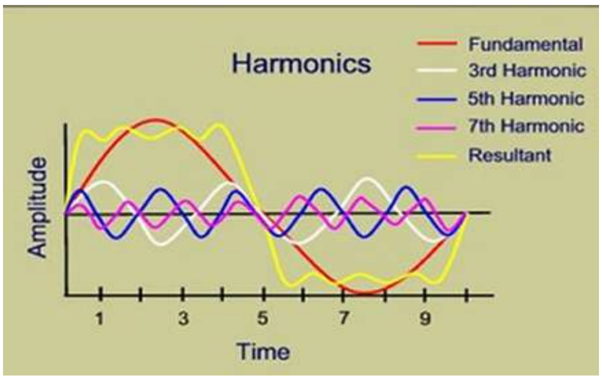


Fig 5: Symmetrical complex waveform

The notches in the voltage wave are caused by the commutating action of the rectifier. Ideally, when the rectifier is fed from an infinite source, the current wave shape is rectangular and in this case voltage notching does not occur.Figure 5shown symmetrical complex waveformsconsisting of the fundamental, 3[rd] harmonic, 5[th] harmonic, 7[th] harmonics and the resultant harmonic as illustrated in the figure in which the positive portion of the wave is identical to the negative portion and symmetrical waveforms only contain odd ordered harmonics, i.e. 3rd, 5th, 7th etc. Whereas the asymmetrical waveforms are the waves in which the positive and negative portions of the wave are different or asymmetrical. The asymmetrical waveforms contain even i.e. 2nd, 4th, 6th etc and odd ordered harmonics[10]. It is observed that,the higher the harmonic components of a quantity, the larger the distortions of this quantity; In other words, the larger the deviations of this quantity from the sinusoidal fundamental frequency. The harmonic components of the voltages and currents are integer multiples of the fundamental frequency. For instant, on 50Hz supply, the 3rd harmonic is 3 x 50Hz (=150Hz); the 5th harmonic is 5 x 50Hz (=250Hz), and so forth. When all harmonic currents are added to the fundamental a waveform known as complex wave is formed[9, 11].

3.2 *Harmonic Reduction Using Active Filters*

Majority of large power three-phase electrical nonlinear equipment's often requires mitigation equipment in order to attenuate the harmonic currents and associated voltage distortion to within necessary limits. An active filter consists of a semiconductor device along with some passive component. It is similar to a pulse width modulated voltage source inverter. It can be a shunt active filter or Series active filter. In this paper, both Shunt active filter and the Series active filters to mitigate harmonics will be considered.

a) Use of Series Active Filters

A series active filter is coupled to the system through a current transformer. This active filter is always a pulse width modulated (PWM) voltage source converter.Figure 6 shows aseries active filter composed of a three-phase voltage source inverter, coupled to a three-phasesystem through current transformers, along with second order passiveLC filter and ripple frequency filter.The series active filtercompensates the harmonics by presenting a high impedance path to them so that the harmonic currents are forced to flow through the LC passive shunt filter connected in parallel with the load. The high impedance is created by generating a voltage of the same frequency as the harmonic current to be eliminated. In addition, the voltage unbalance is corrected by injecting a voltage component of the fundamental frequency in series with the supply voltage.Series active filter compensates the harmonics as well as voltage unbalances. Therefore the power rating of PWM voltage source inverter used in this filter is more than that used in other approaches. The three current transformers isolate the PWM inverter from the source and also help in matching the voltage and current ratings of inverters with those of the system. The passive LC filter plays an important role in the compensation of load current harmonics. It is seen that Series active filter is a voltage compensator; itinjects a compensation voltage into the system and, is thus, controlled voltage source which compensates voltage sags and harmonics on the load.

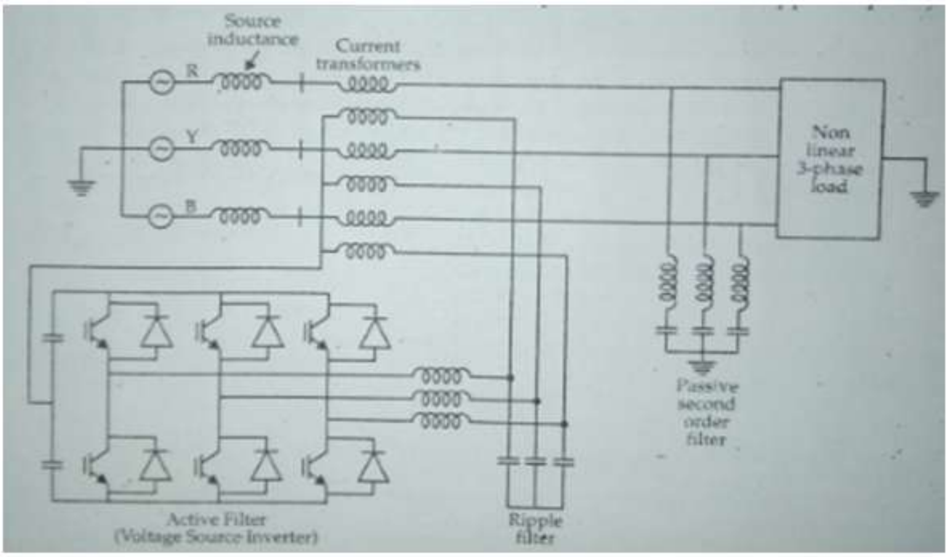


Fig 6: Series Active Filter in a Three-phase System.

b) Use of Shunt Active Filters

The Shunt active filter comprised of the insulated gate bipolar transistors (IGBT) bridge and DC bus architecture similar to that seen in AC pulse width modulated (PWM) drives. The DC bus is used as an energy storage unit. The active filter measures the distorted current wave shape by filtering out the fundamental current from the nonlinear load current waveform, which then fed to the controller to generate the corresponding IGBT firing patterns to replicate and amplify the distortion current and generate the compensation current, which is injected into the load in anti-phase i.e. 180° displayed to compensate for the harmonic current. It removes current harmonics by injecting equal but opposite harmonic current.Therefore, harmonic component of load current is cancelled and the current drain from the mains becomes sinusoidal with unity power factor. The combination of non-linear load and Active filter becomes an ideal resistor as seen from the source.Figure 7, illustrates a simplified power circuit schematic of a shunt-connected active filter. The electromagnetic interference (EMI) and carrier filters are passive L-C networks. The EMI filter provides common mode filtering, i.e., between all phases and earth and a measure of differential mode filtering between phases.The carrier filter attenuates the IGBT bridge carrier frequency of about 5 kHz to 20 MHz depending on the rating of the active filter – on higher ratings greater than 300 A, the switching frequency is usually reduced to minimize device power losses.

Other methods of harmonic reduction include the application of the twelve-pulse converters as analyzedherein.

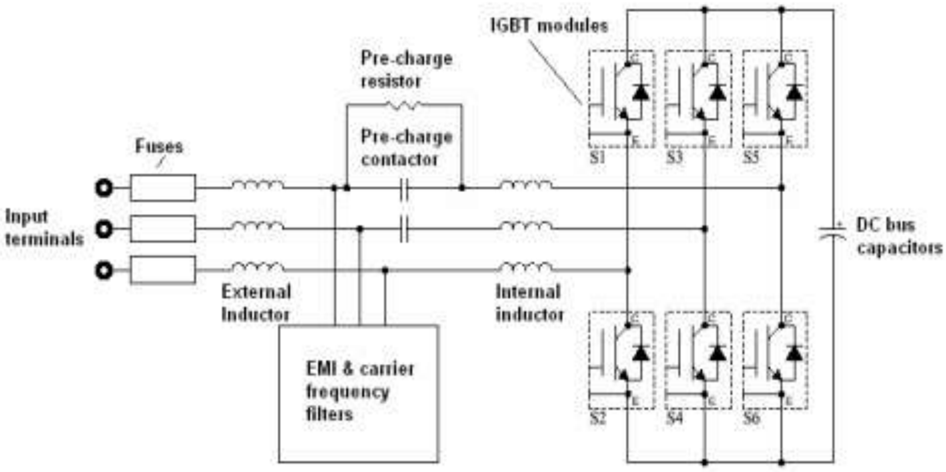


Figure 7: Power Circuit of Shunt-connected Active Filter

C) Twelve (12) Pulse Converters

In this configuration, the front end of the bridge rectifier circuit uses twelve diodes instead of six. Figure 7 illustrates the elementary diagram for a 12-pulse converter front end.The advantages are the elimination of the 5th and 7th harmonics to a higher order where the 11^{th} and 13th become the predominate harmonics. This minimized the magnitude of harmonics, but will not eliminate them. The disadvantages are cost and construction, which also requires either a Delta-Delta or Delta-Wye transformer to accomplish the 30° phase shifting necessary for proper operation. This configuration also affects the overall drive system efficiency rating because of the voltage drop associated with the transformer configuration requirement.

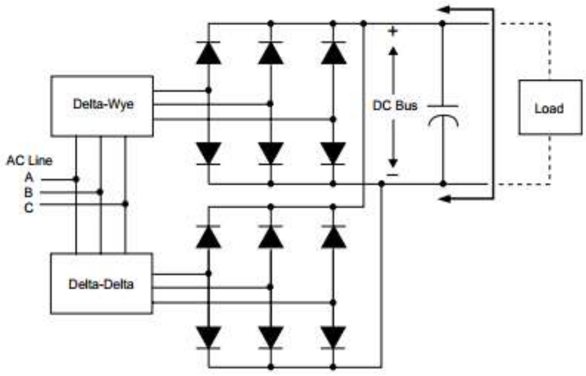


Figure 8: Twelve-Pulse Converters for AC drive

IV. Analysis And Results

4.1 Effects of Harmonics

The effects of three-phase harmonics on circuits are similar to the effects of stress and high blood pressure on the human body. High levels of stress or harmonic distortion can lead to problems for the utility's distribution system, plant distribution system and any other equipment serviced by that distribution system.

The effect of harmonics are classified into four general categories which includes effects on the power system itself, effects on consumer load, effects on communication circuits and effects on revenue billing. On the power system, harmonic currents cause equipment overheating and thermal loss-of-life. This can be a concern for electric motors or transformers. Harmonics can interfere with relaying and metering to some degree. Harmonics can also cause thyristor firing errors in converter and Static VAr Compensators (SVC)installations, metering inaccuracies, and false tripping of protective devices. The performance of consumer equipment, such as motor drives and computer power supplies, can be adversely affected by harmonics. In addition, harmonic currents flowing on power lines can induce noise on nearby communication lines. Harmonic voltage distortion can cause equipment insulation stress, particularly in capacitors. When harmonics cause the voltage impressed on the capacitor bank to be distorted, the peak voltage can be high enough to cause a partial discharge, or corona, within the capacitor dielectric. This can eventually result in a short circuit at the edges of the foil and failure of the capacitor bank. High harmonic currents cause fuse blowing in capacitor banks. This results in a loss of reactive power supply to the system which can cause other problems. Harmonic voltage distortion can also affect revenue billing by introducing error into kilowatt hour metering systems that rely upon accurate discernment of the voltage zero. And, of course harmonic current sums with fundamental current demanded by facility loads to directly increase net billable kilowatt demand and kilowatt hour consumption charges.

As shown in figure 4, when a non-linear load draw distorted current from the supply, the distorted current flow through all of the impedance between the load and power source. The associated harmonic currents passing through the system impedance cause voltage drops for each harmonic frequency. The vector sum of all the individual voltage drops results in total voltage distortion, the magnitude of which depends on the system impedance, available system fault current levels and the levels of harmonic currents at each harmonic frequency. These causes

a) High fault current (stiff system)
b) Distribution system impedance and distortion is low and
c) Harmonic current draw is high.

Some of the negative effects that harmonics can have on plant/ equipment include the following:

i. Generators

In comparison with utility power supplies, the effects of harmonic voltages and harmonic currents are significantly more pronounced on generators especially. Stand-alone generators used a back-up or those on the ships or used in marine applications) due to their source impedance being typically three to four times that of utility transformers. The major impact of voltage and current harmonics is to increase the machine heating due to increased iron losses, andcopper losses, since both are frequency dependent and increase with increased harmonics. Excessive harmonic voltage distortion will cause multiple zero crossings of the current waveform. Multiple zero crossings affect the timing of the voltage regulator, causing interference and operation instability. To reduce this effect of harmonic heating, the generators supplying nonlinear loads are required to be derated. In addition, the presence of harmonic sequence components with nonlinear loading cause's localized heating and torque pulsations with torsional vibrations.

ii. Transformers

The effect of harmonic currents at harmonic frequencies causes increase in core losses due to increased iron losses i.e., eddy currents and hysteresis in transformers. In addition, increased copper losses and stray flux losses result in additional heating, and winding insulation stresses, especially if high levels of *dv/dt*i.e., rate of rise of voltage are present. Temperature cycling and possible resonance between transformer winding inductance and supply capacitance can also cause additional losses. The small laminated core vibrations are increased due to the presence of harmonic frequencies, which can appear as an additional audible noise. The increased rms current due to harmonics will increase the copper losses. The distribution transformers used in four-wire i.e., three-phase and neutral distribution systemshas typically a delta-wye configuration. Due to delta connected primary, the Triple i.e. 3rd, 9th, 15th… harmonic currents cannot propagate downstream but circulate in the primary delta winding of the transformer causing localized overheating. With linear loading, the three-phase currents will cancel out in the neutral conductor. However, when nonlinear loads are being supplied, the triple harmonics in the phase currents do not cancel out, but instead add cumulatively in the neutral conductor at a frequency of predominately 180 Hz (3rd harmonic), overheating the transformers and occasionally causing overheating and burning of neutral conductors.

iii. Induction Motors

Harmonics distortion raises the losses in AC induction motors in a similar way as in transformers and cause increased heating, due to additional copper losses and iron losses in the stator winding, rotor circuit and rotor laminations. These losses are further compounded by skin effect, especially at frequencies above 300 Hz. Leakage magnetic fields caused by harmonic currents in the stator and rotor end windings produce additional stray frequency eddy current dependent losses. Substantial iron losses can also be produced in induction motors with skewed rotors due to high-frequency-induced currents and rapid flux changes i.e., due to hysteresis in the stator and rotor. Excessive heating can degrade the bearing lubrication and result in bearing collapse. Harmonic currents also can result in bearing currents, which can be however prevented by the use of an insulated bearing, a very common practice used in AC variable frequency drive-fed AC motors. Overheating imposes significant limits on the effective life of an induction motor. Squirrel cage rotors can normally withstand higher temperature levels compared to wound rotors. The motor windings, especially if insulation is class B or below, are also susceptible to damage due to high levels of rate of rise of voltage such as those attributed to line notching and associated ringing due to the flow of harmonic currents. Harmonic sequence components also adversely affect induction motors. Positive sequence components i.e., 7th, 13th, 19^{th}, will assist torque production, whereas the negative sequence components 5th, 11th, 17^{th}.. will act against the direction of rotation resulting in torque pulsations. Zero sequence components i.e., triple harmonics are stationary and do not rotate, therefore, any harmonic energy associated with them is dissipated as heat. The magnitude of torque pulsations generated due to these harmonic sequence components can be significant and cause shaft torsional vibration problems.

iv. Cables

Cable losses, dissipated as heat, are substantially increased when carrying harmonic currents due to elevated powerlosses, the cable resistance, R, determined by its DC value plus skin and proximity effect. The resistance of a conductor is dependent on the frequency of the current being carried. Skin effect is a phenomenon whereby current tends to flow near the surface of a conductor where the impedance is least. An analogous phenomenon, proximity effect,is due to the mutual inductance of conductors arranged closely parallel to one another. Both of these effects are dependent upon conductor size, frequency, resistivity and the permeability of the conductor material. At fundamental frequencies, the skin effect and proximity effects are usually negligible, at least for smaller conductors. The associated losses due to changes in resistance, however, can increase significantly with frequency, adding to the overall powerlosses. Power cables carrying harmonic loads act to introduce electromagnetic interference (EMI) in adjacent signal or control cables via conduction and radiated emissions. This EMI noise has a detrimental effect on telephones, televisions, radios, computers, control systems and other types of equipment. Correct procedures with regard to grounding and segregation within enclosures and in external wiring systems must be adopted to minimize EMI. At the installations where power conductors carrying nonlinear loads and internal telephone signal cable are run in parallel, it is likely that voltages will be induced in the telephone cables.

v. Lighting

One noticeable effect on lighting is the phenomenon of flickeri.e., repeated fluctuations in light intensity. Lighting is highly sensitive to root mean square (RMS) voltage changes; even a slight deviation is perceptible to the human eye in some types of lamps. Superimposed interharmonic voltages in the supply voltage are a significant cause of light flicker in both incandescent and fluorescent lamps.

Other negative effects of harmonics are

a) Power factor correction capacitors are generally installed in industrial plants and commercial buildings. Fluorescent lighting used in these facilities also normally has capacitors fitted internally to improve the individual light fittings own power factor. The harmonic currents can interact with these capacitances and system inductances, and occasionally excite parallel resonance which can over heat, disrupt and/or damage the plant and equipment.
b) Any telemetry, protection or other equipment which relies on conventional measurement techniques or the heating effect of current will not operate correctly in the presence of nonlinear loads.
c) Conventional meters are normally designed to read sinusoidal-based quantities. Nonlinear voltages and currents impressed on these types of meters introduce errors into the measurement circuits which result in false readings, resulting in higher billings to consumers. The consequences of under measure can be significant. Fuses and circuit breakers will not offer the expected level of protection. Harmonics can cause false or spurious operations and trips, damaging or blowing components for no apparent reason. It is therefore important that only instruments based on true root means square (RMS) techniques are used on power systems supplying nonlinear loads.
d) There is also the possibility of both conducted and radiated interference above normal harmonic frequencies with telephone systems and other equipment due to variable speed drives and other nonlinear loads, especially at high carrier frequencies. EMI filters at the inputs can be installed on drives and other equipment to minimize the possibility of inference.

V. Conclusion

Power electronicsequipment and non-linear loads generates current harmonics. Thestudy investigates the causes, effects and reduction of harmonics in electrical power system using Active filters. Evaluation of the causes and effects of harmonic currentson the power systemincluding harmonics distortions were presented.

Harmonic currents cause equipment overheating and thermal loss-of-life to electric motors and transformers. Harmonics interfere with relaying and metering; and also cause thyristor firing errors in converter and Static VAr Compensators (SVC) installations. Mathematical modeling was employed to calculate the amount of total harmonics distortions (THD) of voltages and currents at the point of common coupling. Methods of harmonics mitigations were analyzed using the active filters and the twelve pulse converter. Active filters offer good performance in the reduction of harmonics and the control of power factor. These minimized or reduced the magnitude of harmonics currents and voltages distortion present in power circuits to within limits.It removes current harmonics by injecting equal but opposite harmonic current.

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