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Energy Saving and Influence of the Harmonic Correction Filter on the Power Electric System in IRALCO Company

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Abstract- In an ideal AC electric power system, voltage and frequency are stable in every part of the power supply and clear of harmonics also power factor will be equal to one. These parameters are independent of the size and characteristics of consumption loads .Therefore, all of the loads are designed to be the best performance at a specific voltage. According to the characteristics of power systems and loads attached to them, their quality power supply can be removed from the ideal case. Given that the extraction of aluminum from alumina by electrolysis method is used based “Hall-Héroult process”. Therefore, this method requires DC voltage with very high currents, With respect to the production, transmission and distribution of electrical energy is based on AC systems and used power rectifier devices to convert AC voltage to DC voltage. these devices due to the nonlinear characteristic of the voltage - current are produced harmonics and confusion, so for reactive power compensation should be used harmonic filtering .This article described the energy saving , reduce power consumption ,improve power factor and other Influence of the harmonic filtering on the power electric system in” Iralco Company”.

Keywords- *reactive power compensation, power factor, harmonic filtering, power*

I. INTRODUCTION

Approximately 30% of primary energy resources is consumed to produce electrical energy in the world and Almost all of this energy transmission by alternating current at a frequency of 50 or 60HZ then distribution and consumption. Recently the design and operation of power systems with maximum efficiency and the highest level of reliability and safety is very important. Therefore the reactive power control which is an important factor in the power factor is of great importance. Power factor (PF) is, in fact, a measure of efficiency. When the PF reaches unity (as measured at the utility power meter), it can be said that the electrical system in the plant is operating at maximum efficiency. Depending on the local utility rate structure, a PF below target PF may result in higher utility power bills than are necessary. Most utilities charge for peak electrical demand on each month’s electrical bill. The demand charge is to allow the utilities to recoup part of their capital investment in the distribution network they operate. Each customer pays a demand charge for its peak operating load. Often inherent in the structure of these demand charges is an allowance for some inefficiency but most utilities will offer an incentive to their customers to keep electrical efficiency (measured by power factor) high. Power factor correction devices improve overall electrical efficiency upstream of their point of connection in the electrical network and can be used to minimize utility kVA demand charges. Power electronic devices that have rapid and frequent load variations have become abundant today due to their many process control related and energy saving benefits. However, they also bring a few major drawbacks to electrical distribution systems such as harmonics and rapid change of reactive power requirements. Many industrial facilities place poor power quality at the top of the list of inefficiency factors responsible for losses due to reduced productivity and lower quality of products. Optimal electrical power utilization becomes a challenge, as well as a necessity to keep up with ever increasing energy demand without drastic increases in energy costs. Large industrial, commercial and institutional power users can benefit from centralized medium voltage reactive power compensation systems. Medium voltage solutions typically require lower initial capital expenditures ($/kVAR) than low voltage solutions while addressing most common power quality problems. Medium voltage metal-enclosed compensation systems provide centralized solution approach with attractive installation options supporting the scale and scope of large electrical services. Typical installations can be found at automotive, pulp/paper, steel, petrochemical, mining/mineral and other large industrial facilities. Many large commercial and institutional customers with medium voltage distribution network can also take advantage of medium voltage reactive compensation systems. Low voltage capacitor compensation systems can provide similar benefit of centralized solution at attractive costs for most mid and small industrial, commercial and institutional users. It offers very flexible, yet effective power factor compensation system in the low voltage network. Power factor (PF) is, in fact, a measure of efficiency. When the PF reaches unity (as measured at the utility power meter), it can be said that the electrical system in the plant is operating at maximum efficiency. Depending on the local utility rate structure, a PF below target PF may result in higher utility power bills than are necessary.[1-4]

II. EXPERIMENTAL PROCEDURE

A. Reactive Power

Power factor can be improved by either increasing the active power component or reducing the reactive component. Of course, increasing the active power component for the sole purpose of Power factor correction would not be economically feasible. Thus, the only practical means for improving the system's power factor is to reduce the reactive power component. One method of reducing this component is to provide reactive power locally close to the load. This method will improve the power factor from the point where the reactive power source is connected. When applying power factor correction capacitors in the presence of harmonics, a couple of issues come to surface. First, capacitors are a natural low impedance path for harmonic currents and will, therefore, absorb these energies. This increase in capacitor current results in higher element temperature which reduces the life of the capacitor. Also, because capacitors reduce the network impedance, capacitors can actually increase the level of harmonic current on the network. It is important to remember that while capacitors do not produce harmonic currents, they can magnify their effects. Furthermore, harmonic voltages present on the network create voltage stresses on the capacitor. The second and potentially more serious concern, is network resonance. When capacitors are added to the network, they set up a parallel resonance circuit between the capacitors and the network inductance. Harmonic current components that are close to the parallel resonance point are magnified .The magnified current can cause serious problems such as excessive voltage distortion, nuisance fuse and breaker operation, overvoltage tripping of drives and insulation breakdown within motors, transformers and conductors. Both risks increase with the size of the capacitor bank. The larger the size of the cap bank, the higher the risks. With the increase of non-linear loads in power systems, the voltage and current waveforms are becoming more distorted and power quality is deteriorating. Because of this development it has become essential to assess any adverse effects which harmonic may produce in a system. These effects are best ascertained by carrying out field measurements [1. These measurements need to be compared to a standard to evaluate whether or not they are harmful. In the USA an American Standard (IEEE) applies and in Europe IEC Standard applies. Measured harmonics significantly higher than the recommended levels would be considered unacceptable. motors, capacitors, supply circuits etc. It is essential to limit harmonic content in waveforms.[5]

B. Harmonics

Harmonic currents are caused by nonlinear loads connected to the distribution system. A load is said to be nonlinear when the current it draws does not have the same wave shape as the supply voltage. The flow of harmonic currents through the system impedances in turn causes voltage distortion in the distribution system. Equipment consisting of power electronic circuits are typical nonlinear loads. Such loads are increasingly more abundant in all industrial, commercial, and residential installations and their percentage of the total load is growing steadily. these nonlinear devices are often thyristor or diode rectifiers which contribute to the deterioration of the power quality in the networks.

III. EFFECTS OF HARMONICS

A. Transformers

Harmonic currents cause an increase in copper losses and stray flux losses. Harmonic voltages cause an increase in iron losses. The overall effect is a higher temperature rise, as compared to purely fundamental sinusoidal current and voltage operation. It shall be noted that these additional losses due to harmonics will rise in proportion to the square of the current and frequency, resulting in decreased fundamental loading capacity of the transformer. When selecting correct rated power for the transformer to supply non-linear loads, an adequate derating should be made to ensure that the temperature rise of the transformer will remain within permissible limits. Also it should be kept in mind that all additional losses due to the harmonics will be paid by the customers in terms of kilowatt hours consumed. Harmonics applied to the transformer can also lead to increased audible noise.

B. Power Cables

Non-sinusoidal currents in conductors will cause more heating than that what would be expected for the RMS value of the waveform. This additional heating is caused by two phenomena known as skin effect and proximity effect, both of which depend on frequency as well as conductor size and spacing. These two effects result as an increased ac resistance, which in turn leads to increased I^2*R_{AC} losses.

C. Motors and Generators

The main effect of the harmonic currents and voltages in rotating induction and synchronous machinery is increased heating caused by the iron and copper losses at harmonic frequencies. These additional losses lead to decreased machine efficiency and can also affect the torque developed. Pulsating torque output can affect product quality in cases where motor loads are sensitive to such variations. As examples from sensitive loads some synthetic fiber spinning and some metal working applications can be mentioned. Also in case of rotating machinery, harmonics can increase audible noise emission as compared with sinusoidal magnetization. Harmonic pairs like 5th and 7th can create mechanical oscillations at 6th harmonic frequency in a generator or in a motor-load system. Mechanical oscillations are caused by oscillating torque's due to the harmonic currents and the fundamental frequency magnetic field. If the mechanical resonance frequency coincides with the electrical stimulus frequency, high mechanical forces can be developed and there is a risk of mechanical damages in the machinery.

D. Electronic Equipment

Power electronic equipment is sensitive to harmonic distortion of the supply voltage. This equipment is often synchronizing its operation to the voltage zero crossings or to other aspects of the voltage wave shape. Harmonic distortion of the voltage can lead to the shifting of the voltage zero crossing or change the point where one phase to phase voltage becomes higher than another phase to phase voltage. Both of these are important points for different kind of power electronic circuit controls. Misinterpretation of these points by the control systems can lead to the malfunction of the control system. Disturbances of the telecommunication equipment are also possible due to the inductive or capacitive coupling between power and telecommunication lines. Computers and some other kind of electronic equipment like programmable controllers require usually that the total harmonic voltage distortion (THD) of the supply is less than 5% and one individual harmonic component is less than 3% of the f fundamental voltage. Higher distortion values may result in disoperation of the control equipment, which in turn can lead to production and process interruptions, which can have high economical consequences.

E. Switchgear and Relaying

Like in other type of equipment too harmonic currents cause also in switchgear additional losses leading to increased heating and reduced fundamental current carrying capability. An increased temperature of some insulating components results in shortening of their lifetime. Older solid-state tripping devices on low voltage circuit breakers have responded to the peak currents. This type of tripping devices may cause nuisance tripping in feeders supplying non-linear loads. New tripping devices respond to the RMS values of the current. The response of the protective relays to the distortion depends a lot on the measuring principle used and t here is no any common rules which could be used to describe what is t he impact of harmonics on large variety of the relays. However it can be said that normal harmonic distortion levels in networks do not cause problems in relay operation.

F. Power Factor Correction Capacitors

Capacitors differ from other type of equipment due to its capacitive nature, which can dramatically change the system impedance under system resonant condition. The react acne of a capacitor bank decreases with the higher frequencies, and therefore, bank acts as a sink for higher harmonic currents. This effect increases the heating and dielectric stress of the insulation material. Frequent switching of non-linear magnetic components like transformers can produce harmonic currents, which will add to the loading of the capacitors. It should be noted that the fuses usually do not provide overload protection for the capacitors. The result of the increased heating and voltage stress due to harmonics is a short ended life time. The major concern arising from the use of capacitors in power systems is the possibility of the system resonance. This effect leads to harmonic voltages and currents that are considerably higher than they would be in the case without resonance.

IV. HARMONIC MITIGATION

There are various harmonic mitigation methods that we can use to address harmonics in the distribution system. They are valid solutions depending on circumstances, and have their pros and cons. Line reactors (LR)/DC bus chokes/isolation transformers This is the simplest form to reduce harmonic current caused by non-linear load, typically converter-based devices. Inductors or isolation transformers, installed ahead of the load, can reduce the harmonic current content up to 50% and reach TDD levels of 30-40%. Typically, LRs are less expensive than transformers.

A. Tuned Harmonic Filters

A tuned harmonic filter is a type of passive filter. We call it passive as it consists of passive elements such as an inductor and capacitor. Inductor (Lp) and capacitor (C) provides low impedance path for a single (tuned) frequency. An inductor (Ls) is required to detune the filter from the electrical system and other filters' resonance point. This type of filter is very application specific. It can only mitigate a single frequency, and it injects leading reactive current (KVAR) at all times. But it is economical if you only need to deal with a dominant harmonic in the facility. It normally can reach TDD target of 20%.

B. Broadband Filters

As its name indicated, a broadband filter is designed to mitigate multiple orders of harmonic frequencies. You will notice the similarity and the difference of its circuit from the tune filter. Both inductors (L) could have impedance > 8%, which means you could see a 16% voltage drop across the filter. Its physical dimension is normally very large, and it generates quite high heat losses (> 4%). A well-designed broadband filter can meet TDD target in the 10% range. However, broadband filters have their limitation and are not suitable for certain harmonic load applications.

C. Multi-pulse Transformers/Converters

The 12 or 18 pulses variable frequency drive (VFD) has been developed to address the harmonic issue caused by common 6 pulses VFD. The input is connected to the transformer's primary winding, then the outputs are connected with two separated phase-shifted secondary winding to two sets of rectifiers. This configuration reduces the current harmonic distortion to a 10% range (12 pulses). For the 18 pulse VFD, an additional secondary winding and a set of rectifiers are added in to the scheme. It can achieve 5% TDD. The 18 pulse VFD is replacing the 12 pulse as the prevailing choice in multi-pulse solutions. It can reach 5% TDD at device level. However, it is normally very bulky, has larger heat loss and a higher operating cost when comparing to other solutions.

D. Active Harmonic Filter (AHF)

The concept of an active filter is to produce harmonic components, which cancel the harmonic components from the non-linear loads. An AHF is a highly-effective device that cancels multiple order harmonics in the distribution system. It is installed as a parallel device and scaled via paralleling multiple units. It can handle different type of loads, linear or non-linear. It addresses harmonics from a system point of view and can save significant cost/space in many applications. Its performance level can meet TDD 5% target. [6-15]

V. RESULTS AND DISCUSSIONS

At the time when aluminum was discovered in 1807, it was predicted that aluminum could be decomposed by electrolysis. But, at that time, it was extremely difficult to obtain inexpensive and powerful electric energy for this purpose. In the 1860s, inexpensive and stable DC electric energy was made available by the achievement of Mr. Siemens of Germany and Mr. Gram of Belgium. Thus, a means for performing aluminum smelting by electrolysis was established. Aluminum smelting requires a high DC current for the electrolytic process. Generally, a high DC current is obtained from an AC power source using rectifier equipment. As the result of technical innovation from the 1960s, older type rectifier equipment, i.e., rotary converters, mercury rectifiers and contact converters, have been replaced by semiconductor rectifiers using selenium and silicone technology. IRALCO company is one of the largest companies in the production of primary aluminum in Iran. Given that the extraction of aluminum from alumina by electrolysis method is used based "Hall-Héroult process". Therefore, this method requires DC voltage with very high currents, With respect to the production, transmission and distribution of electrical energy is based on AC systems and used power rectifier devices to convert AC voltage to DC voltage. Recently, even higher voltage and higher current rectifier equipment has been realized thanks to the development of Semiconductor elements for this purpose. And these devices Due to the harmonic current and voltage distribution network and can be the degradation power quality. Therefore IRALCO Company is used of single-frequency and multi-frequency filters for reactive power compensation and harmonic correction. These types of filters are composed of RLC circuits and their performance based on the creation is resonant of a specific frequency and at the frequency makes this filter reduces the harmonic which are distortions of systems.

According to IRALCO company the" new plan" has four stations rectifiers with 12-pulse unit and which is equal to 48 phase, therefore harmonic filters are designed based on the type rectifiers. Loads of these rectifiers' stations include 210 pot with a current of 200 kilo amperes which are connected series as both a voltage of approximately 960 volts. Loads of these rectifiers stations, include 210 pot with a current of 200 kilo amperes which are connected series as both a voltage of approximately 960 volts and in heavy demand by about 210 MW. Before installation these filters, power factor of the network was 0.839 and after that installation filters with capacity about 65000 KVAR for reactive power compensation, the power factor of the network is about 0.92 then with the installation of these devices improve the power factor correction system and the amount of electricity bill has been reduced dramatically.

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