Chapter 1

1.0 Introduction

1.1 Background

The key aspects of electrical system have been introduced from over 100 years. Starting from there people have used different ideas and mechanisms to generate, transmit, distribute and utilize electricity. A power utilization system in Sri Lanka would be most commonly at low voltage, which is 3 phase 400V 50Hz. Ideally and as we have learnt 3phase 400V supply to a load is balanced. This means all the phases are equal in magnitude at 230V and the phases are equally spaced at 120° phase angles. Also if it is an ideal load the currents are equal in magnitude and equally spaced. Ideally the neutral current will be zero.

But in real industrial life we hardly find such situations. Most of the time supply voltages from source are not balanced. The voltage of each phase is not at 230V and they are not equally spaced. Also on the other hand when it comes to a set of single phase loads mostly the currents are not equal. Even in the case of 3phase loads there is a possibility that currents can be unbalanced. The currents of a load centre are not equal in magnitude and not equally spaced. In most situations the sinusoid current waveform is totally distorted with foreign components added due to the non linearity of the loads.

Harmonics has been a nuisance to operational engineers causing problems in the installation with heavy currents in the neutral and supply voltage entirely distorted. Harmonics is quite common these days due to the heavy use of electronic equipment including switch mode power supplies, variable speed and frequency drives, uninterrupted power supplies just to name a few.

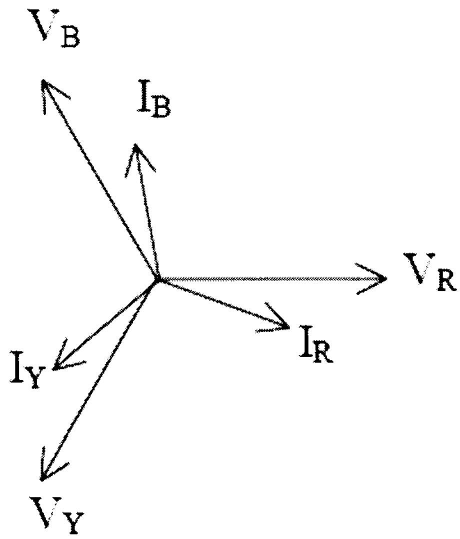

Figure 1 : A balanced system

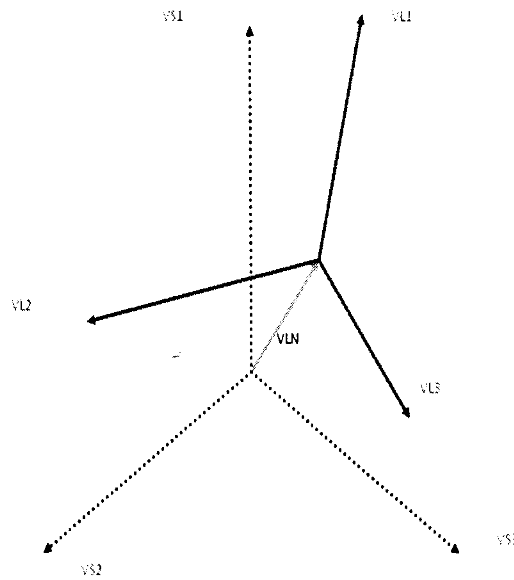

Figure 2 : An unbalanced system

The two figures above depict a balanced and an unbalanced system in a phasor diagram. Interesting point to note as in figure 1 of a balanced system is that the phase angle of any voltage phase with the corresponding current phase is the same. Whereas in the case of phase unbalanced system as in figure 2 the phase angles between the phases will be different. Therefore the neutral point will be shifted from the common ground and there will be a voltage of V_{LN} compared to ground at the neutral node. [2]

Unbalance voltages and unbalance currents go hand in hand. Which means unbalance current causes an unbalance voltage and this unbalance voltage causes an unbalance current. Unbalance loads and presence of non linear loads is the reason for unbalance irregular current waveforms. Unbalance phase currents causes a flow of neutral current. In an ideal system neutral current should be zero. But practically there exist a neutral current flow. The higher the imbalance the higher will be the neutral current. The plot below is typical case of a LV installation where the phases are unbalance and there is a considerable neutral current.

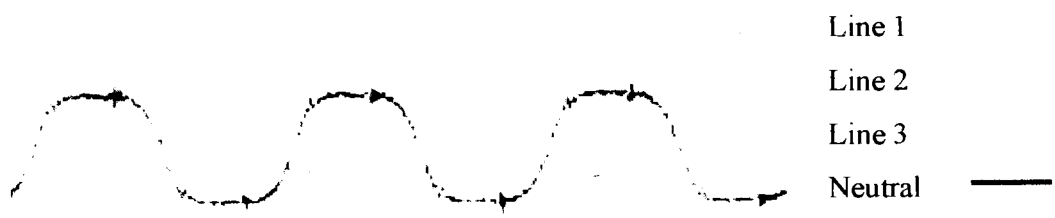

Figure 3 : Current waveforms of a load centre

The figure above is a very natural case of a waveform analysis. The figure shows one cycle each of each phase and the neutral plotted on a common time axis. The waveforms are totally distorted with unbalances and presence of harmonics in the system. Hence the resultant is a considerable neutral current showing a clear 3rd harmonic.

From the recent past this problem has raised due to the recent heavy use of electronic equipment. Switch mode power supplies that are very common in electronic devices is the main cause of the problem. In this case even if the load currents are balanced, there could be a neutral current due to the non linearity. This caused due to the generation of other frequency components higher than 50Hz, which reflects in the neutral. At times the neutral current can be more than the phase current. It is quite common in industry to have a neutral current twice as the phase current or at least one rating higher than the phase. This has been the practice by many electrical designers, installing contractors and consultants. It is no more a good practice with the rising cost of copper cables.

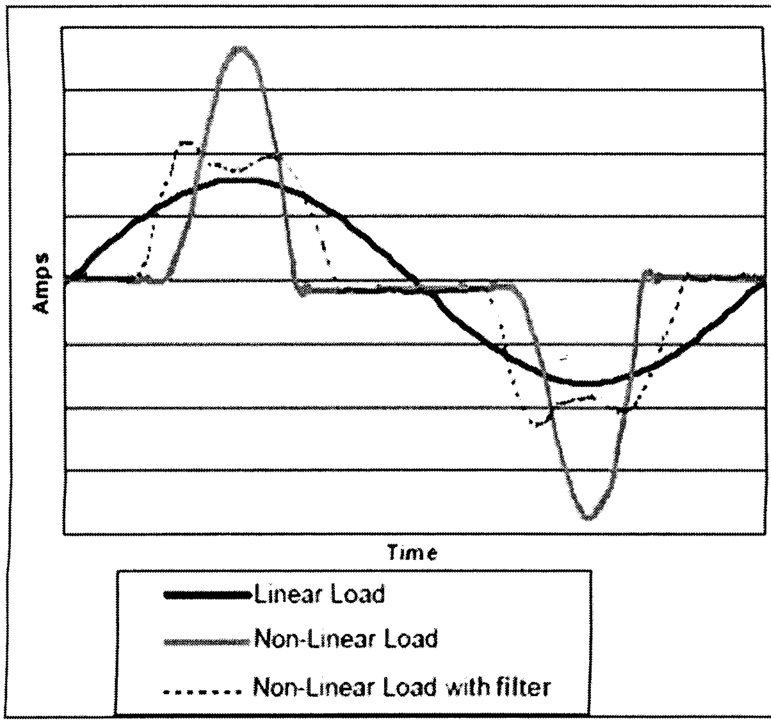

Figure 4 : Current waveforms of a linear, non linear and non linear with filtration system

The figure (Figure 4) above illustrates the behavior of a current waveform to linear, non linear and non linear with filtration loads. As per the figure a linear load will have a perfect sine wave with absolutely no distortion. In the case of a non linear load the waveform is entirely distorted having a very high peak to the original wave and the rise and fall is shifted from the zero crossings. The third waveform is a correction done to the distorted waveform by clipping the peak to reduce the unbalance and distortion. This filtration used has tried to match the non linearity to a close ideal sine waveform. But still the waveform is distorted.

This whole power quality problem is not something happening instantaneous nor for a short period. But the unbalances will remain in the system for considerable amount of time or even sometimes as long as it is rectified. It has always been the practice to blame the power supplier pointing the finger at unbalance voltage phase. But the bitter part is that the customer loads are not balanced nor harmonics is taken care of. Balancing current and reducing harmonics will be economic and energy efficient options rather than trying to balance phase voltages by variable transformers.

1.2 Motivation

The idea of this research is to find techniques and methodologies to keep the neutral current low. This will mean keeping the phase currents of the load balanced as well as keeping the harmonic levels at a tolerable value. Hence the voltage of the system will be balanced or more precisely the unbalance voltages will be reduced. The whole intention of this approach is to stop complaining electricity authorities over the issues related with loads. Ideally if all consumers can keep the currents balanced and harmonics reduced the distortion in the voltage waveform is minimized. While intending this concept the consumer also should not forget that the benefits he is going to achieve by fulfilling this criterion. Some of the major benefits are listed below, but not limited to those.[4] The benefits will be discussed in length in the later chapters.

- Reduction of energy losses from cable currents
- Overloading of cables
- Reduce on extra investment for cables
- Reduce losses due to heating
- Keep phase voltages balanced
- Reduced cost of maintenance
- Overheating or derating of transformer
- Overloading neutral conductors
- Excessive heating of wiring and connections
- Damaging of capacitor banks
- Resonance
- Malfunction of electronic equipment
- Communication interference
- Distorted supply voltage
- Increased power losses
- Logic faults in digital devices
- Errors in power metering
- Inadvertent thermal tripping of relays, circuit breakers and protective devices.