



A review on Analysis of Compensation of neutral current in three-phase, four-wire (3P4W) systems

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Abstract-Now a days Electrical load demand increases rapidly in all area of domestic network, supplied by three wire and single neutral conductor to each load and forming a three phase four wire (3P4W) system. In that electrical atmosphere each load having unbalancing condition, which causes the situation of non-linear characteristics in neutral conductor carrying neutral current due to use of various switching power electronics devices in day to day life, which harms the neutral conductor and causes defect on loading of distribution transformer while consider the safety and reliability of the consumers. Various methods have been surveyed in literature to overcome this problem. This review paper carried out a comprehensive survey of neutral current compensation methods and their technical and economical limitations. Simulations analysis carried out for single phase shunt active power filter in MATLAB environment in this paper.

Keywords: Neutral current, three-phase four wire system, Non-linear load, harmonics, Shunt active power filter

I. INTRODUCTION

The three-phase, four-wire (3P4W) electrical distribution systems have been widely employed to deliver electric power to single-phase and/or three-phase loads in manufacturing plants, commercial and residential buildings. In these systems single phase supply to small loads is provided by one of the phase conductors and neutral wires. To balance the load on each of the phases, the single-phase loads are evenly distributed to the various floors. In practice, these single-phase loads are not completely balanced, thus resulting in a net current flowing through the neutral conductor. These are not the only sources for neutral current but there are other sources such as non-linear loads, where even perfectly balanced single-phase non-linear loads on 3P4W system can result in significant neutral current. Nonlinear loads, such as power electronic based equipment, have phase currents which are non-sinusoidal and the vector sum of balanced, non-sinusoidal, three-phase currents does not necessarily equal to zero and result current in the neutral conductor [7]. With sinusoidal load currents, the neutral current depends only on the system unbalance. But, in a

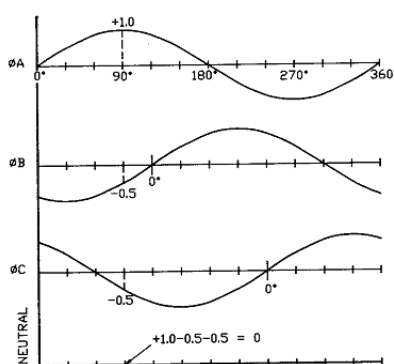


Figure 1. Balanced linear 3-phase loads result in zero neutral current [1].

Balanced system with harmonic distorted current waveforms, only the triplen harmonics (i.e. with harmonic order multiple of 3) contribute to the neutral current. When both harmonic distortion and load current unbalance are simultaneously present, the neutral current may contain all harmonics [1].

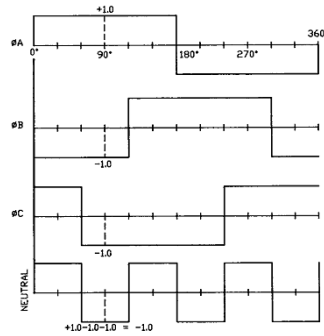


Figure 2. Example of Balanced non-sinusoidal 3-phase loads having neutral current [1].

The paper discusses the problems of high neutral currents, recommended practices for handling the excess neutral currents and presents comprehensive review of technical and economical limits for compensating these neutral currents.

II. .METHODS AND MATERIAL

Neutral current in three-phase power systems is often thought to be only the result of the imbalance of the phase currents. With electrical network, very high neutral currents have been observed even when the phase currents are balanced. Unbalanced and non-linear loads on 3P4W system causes excessive neutral current and the problems related to the excessive current in the neutral conductor are [7]:

- **Overloading of distribution feeders and transformers:** With four current carrying conductors, the distribution system feeders and transformers may overload and cause additional heat loss [7].
- **Common mode noise:** The voltage difference between neutral and ground causes common mode noise in 3P4W power systems. This common mode voltage can result in the malfunction of sensitive electronic equipment. One form of common mode noise in three-phase power systems is the voltage difference between neutral and ground. With high harmonic neutral currents, the impedance of the neutral conductors at the harmonic frequencies can cause significant neutral conductor voltage drops.

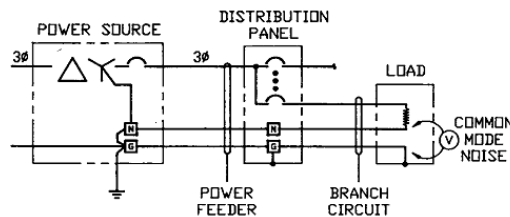


Figure 3. Common Mode noise in a 3-phase power system [7].

Computer loads are generally nonlinear loads. The typical current waveform and harmonic content of the two popular computer power supply connections are shown in Figure [7]. The current of typical line-to-line connected power supplies contains no triplen harmonics [7]. However, the typical current of line-to-neutral connected power supplies is very rich in triplens.

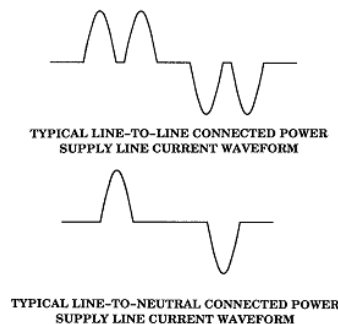


Figure 4. Line to line & line to neutral currents waveform [1].

- **Flat-topping of voltage waveform:** The power supplies use the peak voltage of the sine wave to keep the capacitors at full charge, reductions in the peak voltage appear as low voltage to the power supply, even though the rms value of the voltage may be normal [7].
- **Wiring failure:** In old buildings, load growth with passage of time makes size of neutral conductor insufficient and cause wiring failure and poses a fire hazard [7].

Recommended practices for handling excess neutral currents

The high neutral currents in 3P4W system have detrimental effect on both distribution system and end users. The recommended practices and temporary measures recommend by different agencies to reduce/eliminate the neutral current are given below.

- **Over sizing of neutral conductor:** Over sizing of neutral conductor is an expensive solution, while the overloading of distribution transformer and feeder remains unaddressed [7].
- **Derating of distribution transformer:** With non-linear loads, the maximum loading of transformer should be reduced to below its rated capacity to avoid overheating the distribution transformer and excessive distortion in output voltage. Derating of transformers for three-phase three wire supplies and 3P4W power supplies are similar, yet they have significantly different crest factors and neutral current [7].
- **Separate neutral conductors:** Use of separate neutral conductors for non-linear loads to avoid shared neutral conductors is also practiced. However, this is almost impossible where loads are widely scattered.

The above recommended practices are effective temporary measures and have serious drawbacks. The only solution for handling these excess neutral current is to incorporate the neutral current compensation devices. There are various approaches reported in the literature for compensating neutral currents. Passive solutions such as zero sequence harmonic filters, synchronous machine, specially designed transformers and active solutions such as 3P4W active power filters (APF). Details of these methods are given below [1].

A. Passive harmonic filters

The filtering of excess neutral current in 3P4W systems was achieved through the use of single phase passive filters connected between each phase conductor and the neutral wire. These passive harmonic filters comprise of passive elements such as inductors, capacitor, and resistors and tuned to a particular harmonic frequency(s) [6]. A solution for filtering current harmonics in 3P4W networks based on the usage of a four-branch star connected filter topology is depicted in Figure 4.1.1. And presented in [6]. This topology has four individual star-connected passive branches (three phase-branches and one neutral branch). The impedance of the phase branches of the filter are identical and different from neutral branch. The phase branches are tuned to the positive/negative sequence harmonics such as 5th, 7th and/or 11th, 13th and the neutral branch is tuned to 3rd and/or 9th.

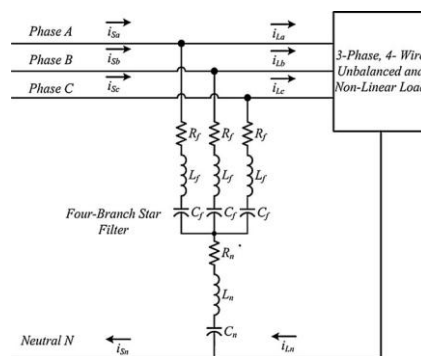


Figure 5. A four branch star connected passive filter [7].

Passive solutions, albeit simple, are bulky and expensive. Also, the sensitivity of the components to temperature and aging can result in ineffective filtering as the critical frequencies and the quality factor drifts. Another bigger problem is the possibility of exciting a resonance condition with the ac system impedance, which can worsen the situation [6].

B. Synchronous machine as a filter

Recently, in such systems, the harmonic currents of the neutral line have been significantly increasing by use of nonlinear loads such as personal computers and electronic office machines. These excessive harmonic currents bring about the following problems:

- 1) Wiring failures;
- 2) Elevating of neutral potentials.
- 3) Overheating of transformers.

Most of the harmonic currents generating in the neutral line are zero-sequence harmonics (i.e., the third and its multiples). For this reason, a technique to compensate for the zero-sequence harmonic currents is required in the three-phase four-wire systems.

To meet this requirement, absorption of all the zero-sequence harmonic currents of the neutral line by a synchronous machine [5]. When the armature winding is arranged in a 2/3 short-pitch winding, the zero-sequence reactance of the synchronous machine becomes minimum value. The proposed method utilizes such a characteristic, which allows harmonic compensation by the synchronous machine. One of the notable features of this method is that several harmonics can be simultaneously absorbed without additional control. The only limiting factor of the zero-sequence harmonics is armature resistance of the synchronous machine. Hence, it is possible to absorb all the zero-sequence harmonic currents by the synchronous machine. Figure shows the basic system in which the synchronous machine is used for absorbing the zero-sequence harmonic currents [7].

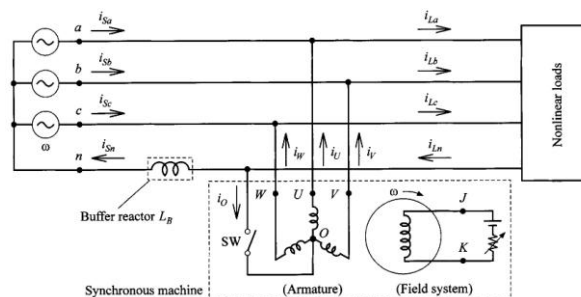


Figure 6. Schematic diagram for neutral current compensation with synchronous machine [7].

In this method the synchronous machine is connected in shunt between the utility and nonlinear load. The neutral point of the armature winding of synchronous machine is connected to the neutral line through a switch. A buffer reactor is installed on the utility side of the neutral line so that the harmonic compensation characteristics do not depend on the impedance of the utility side. This method does not require any additional controller and the synchronous machine can be operated as a synchronous condenser to control the reactive power in distribution systems and/or operate as a motor or generator set. However, its compensation characteristics depend on zero-sequence impedance of the synchronous machine and buffer reactor.

The high initial and maintenance cost of the synchronous machine limits its application. The passive neutral current compensation technique using different transformer topologies can reduce/eliminates the neutral current to a great extent.

C. Simulation Work and Result

For single phase load, to compensate harmonics in neutral current single phase active power filter designed at PCC of network with help of DC link capacitor to feed needed power in system.

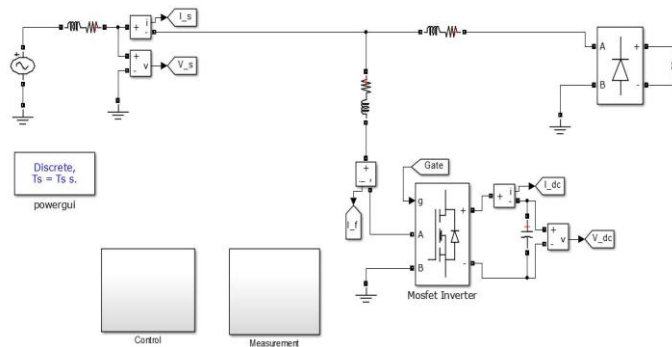


Figure 7. Simulation to single phase active power filter [7].

In single phase active power filter with use of shunt compensation devices, demanding power is supplied through the capacitor link. With a single phase load and system a virtual network is modelled for case study shown in figure. With reference current of supply, the feedback is appeared to DC link connected to MOSFET inverter forming a harmonic filter. Controlling of inverter and measuring block is given below.

Control block

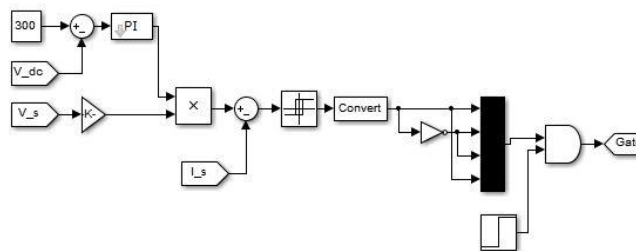


Figure 8. control block diagram [7].

Measurement block

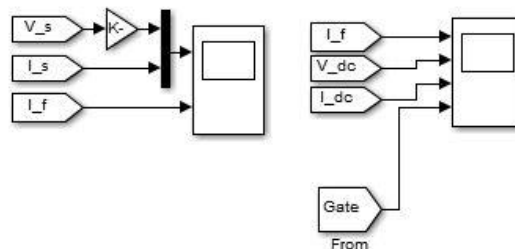


Figure 9. Measurement block diagram.

Simulation Result

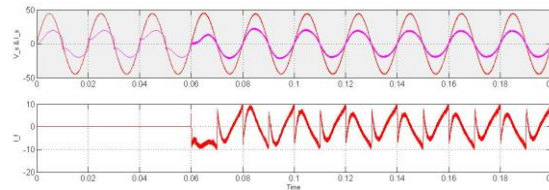


Figure 10. Output waveform of V_s & I_s , i.f.

By simulating above configuration, the output result looks like shown in figure. Up to 0.6 sec capacitor gets charged and after that it starts to feed reactive power in PCC and fulfil the demand as shown in figure. Also THD% for harmonic elimination is carried out for various cycles as shown in below figure.

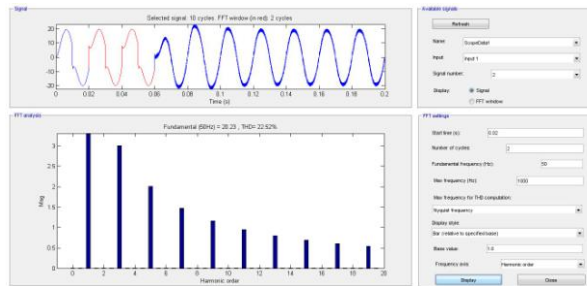


Figure 11. FFT analysis before compensation at 0.02 sec.

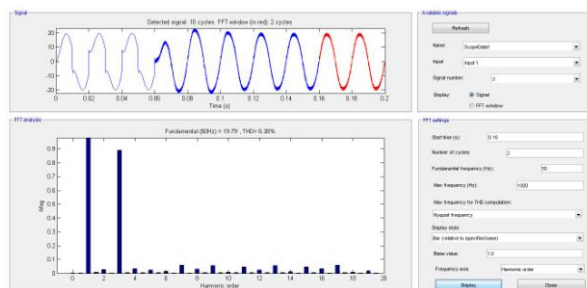


Figure 12. FFT analysis after compensation at 0.16 sec.

III. CONCLUSION

With help of a SIMULINK in MATLAB analysing simulation with a single phase active power filter on load side total harmonic distortion (THD %) decreases

Table. 1. THD% v/s TIME

TIME	THD%
0.06	19.24
0.08	6.89
0.12	6.40

In way that shunt active power filter supply the needed power to compensate neutral current due to nonlinear load characteristics causes harmonic distortion into supply current. Table 1 shows THD% decreases as capacitors gets time to charged and feed the supply at PCC on system network.

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