Impact of Harmonics on the Performance of Over-Current Relays

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Abstract— **This Paper investigates the impact of power system harmonics on the performance of over-current relays. Simulation is performed on the IEEE 30-Bus system with heavy penetration of non-linear loads using ETAP software. Simulation results show that with significant harmonic contents in the power network, a relay malfunction will occur and they will trip in a wrong sequence when there is a fault in the system.**

Keywords — Over current relays, THD, Passive Filter

I. INTRODUCTION

Most of the litratures reveal that the performance of relays in presence of harmonics is not significantly affected when the total harmonic distortion (THD) is less than 20% [1]. As there has been a termendous increase in harmonic sources in the last few decades, harmonic levels of 20 % or even higher can be expected. Overcurrent relays have to operate with current transformers (CT) which may saturate and distort the current waveform causing a malfunction to the over current relays. Current transformer saturation usually affects the operation of protective relays. Saturation of CT can happen due to the presence of harmonics and in many cases saturated CT will fail to devliver a true reproduction of the primary during high fault conditions and thus may cause undesirable operations. When harmonic current exceeds the peak or rms thresholds, it may cause the relays to trip under conditions which would normally incur smooth running of the system without interruption [2]. Another type of relay that is effected by harmonics is the negative-sequence overcurrent relay which is designed to specifically function with negative sequence currents and it cannot perform upto its standard when waveform distortion starts to appear significantly in the circuit [3]. Electromechanical relays time delay characteristics are altered in the presence of harmonics even though they are not widely used nowadays, they are still used in some places. Digital and numerical relays usually have filters in them to filter out harmonics and thus are less prone to disoperation [4]. Harmonics can distort or degrade the operating characteristics of protective relays depending on the design features and principles of operation. Most relays monitor and measure the current (or voltage) amplitude, the distorted waveform can affect the relay's operation and result in power system reliability reducing and system damage; some of the relays can be affected by the harmonic frequency such as induction relays [5]. Traditionally, passive filters have been used to improve the power factor of the system and suppress the harmonics[6]. However, passive filters have some problems that discourage its implementation. Problems such as the unknown source impedance can influence the filtering characteristic as the system configuration varies and at specific frequency, anti resonance can occur between the source impedance and the filter, which may lead to harmonics amplification [7]. Active power filters are more flexible and viable and have become popular nowadays. These active power filters are able to compensate harmonics continuously, regardless of any change in the system loading conditions. However, active power filters configurations are more complex and require appropriate control devices to operate [8]. This paper investigates the effect of harmonics on the performance of over current relay. Simulation is performed on the IEEE 30-bus system with significant THD. A three phase short circuit fault is simulated on the system and relays tripping sequence is observed. Results show over current relays will have a wrong tripping sequence when there is a significant THD in the system. As a consequence, it will not isolate the faulty zone.

II. SYSTEM UNDER STUDY AND SIMULATION RESULTS

The IEEE 30-bus system (shown in Fig. 1) is simulated using ETAP Software. All data of the system can be found in [6].

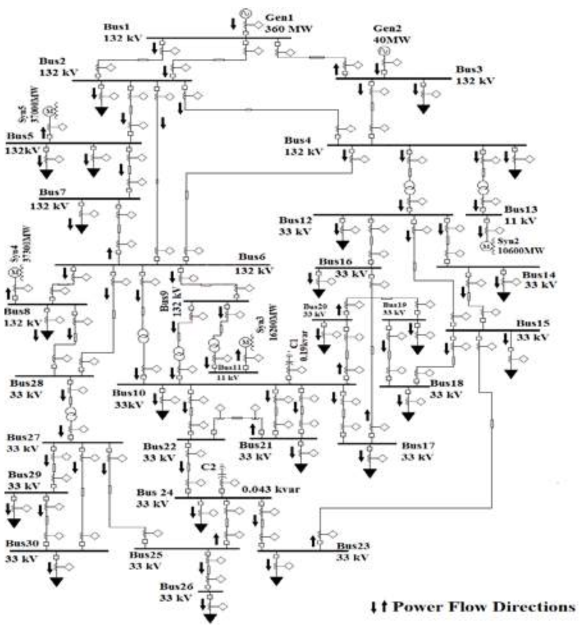

Figure 1: IEEE 30-BUS System

Linear loads were connected to the system at different buses and the THD was measured as almost 0% as there were no harmonic sources included. The negligible harmonic contents can be examined through the voltage waveform at bus 10 (shown in Fig. 2) which is almost purely sinusoidal. When a three phase short circuit fault is applied on bus 10 under such negligible harmonic contents, the over current relays will trip in a desired sequence shown in Fig. 3 to isolate the faulty bus.

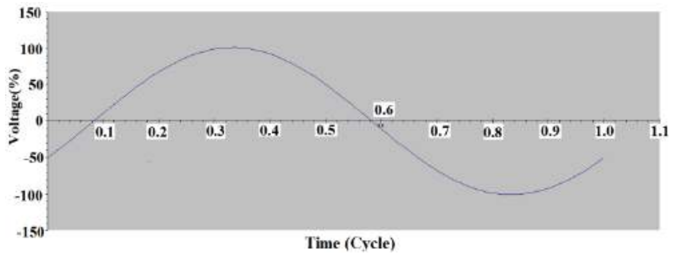

Figure 2: Voltage Waveform at Bus 10 with linear Loads

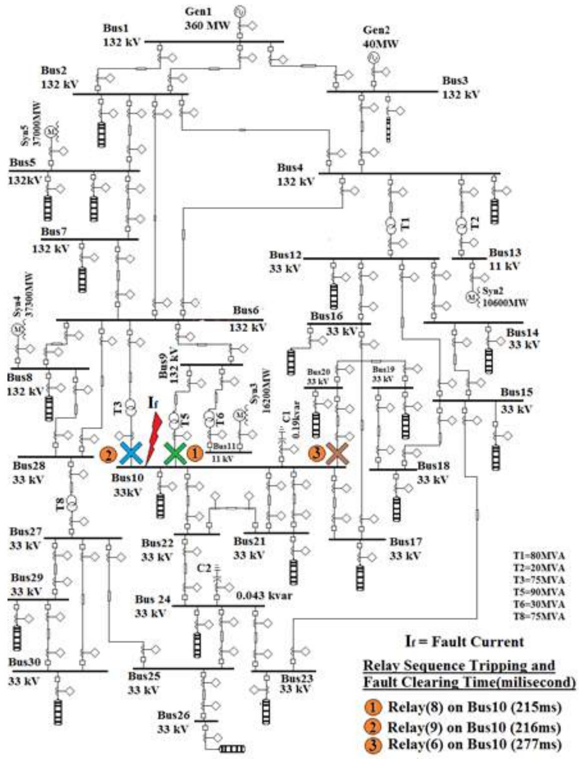

Figure 3: Tripping Sequence during 3 Phase Fault on bus 10 (THD is negligible)

Non-linear loads were then connected to the system at different buses such that the THD is reaching 20%. Fig. 4 shows the distorted voltage waveform on bus 10 due to such significant harmonic sources in the system and Fig. 5 shows the harmonic spectrum analysis of this voltage.

The same three phase short circuit fault is applied on bus 10. As can be seen in Fig. 6, under such significant THD, the relays will have undesired tripping sequence and they will not isolate the faulty bus.

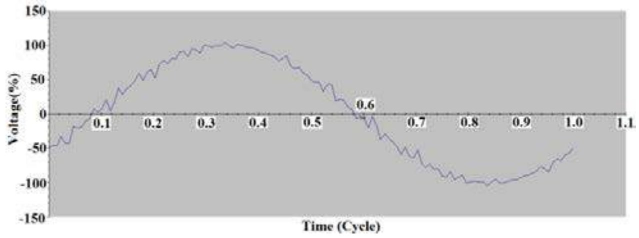

Figure 4: Voltage Waveform at Bus 10 with non- linear loads

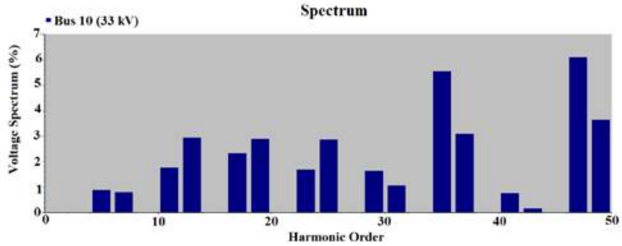

Figure 5: Spectrum Analysis of the voltage at bus 10 (no-filters)

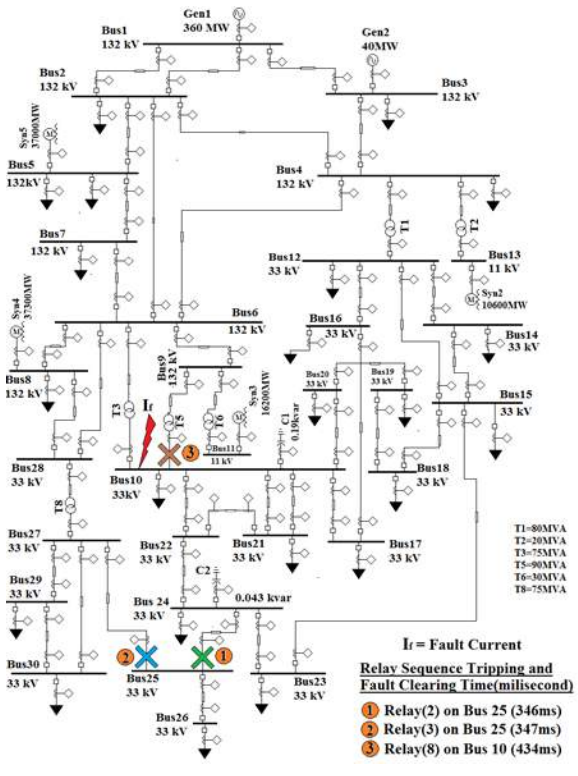

Figure 6: Tripping Sequence during 3 Phase Fault on bus 10 (THD = 20%)

To promote a correct sequence of relays tripping operation in the existence of significant THD, traditional methods such as single tuned harmonic filters can be used. In this paper 19 shunt passive filters. Each filter is tuned to suppress 16 odd harmonic orders are used and connected to different buses to reduce the THD to about 3.1%. The relay pickup values become much sensible to the relay operation after the installation of harmonic filters. Fig. 7 shows the effect of installing filters in the system on reducing the harmonic contents in the voltage waveform at bus 10.

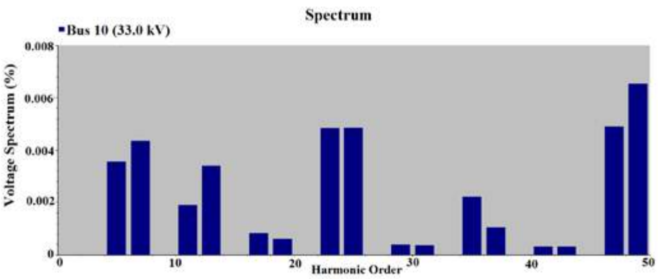

Figure 7: Spectrum Analysis of the voltage at bus 10 (with filter)

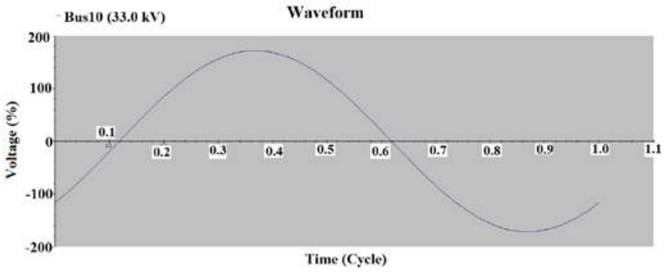

Figure 8: Voltage Waveform at Bus 10 with non- linear loads (with filters)

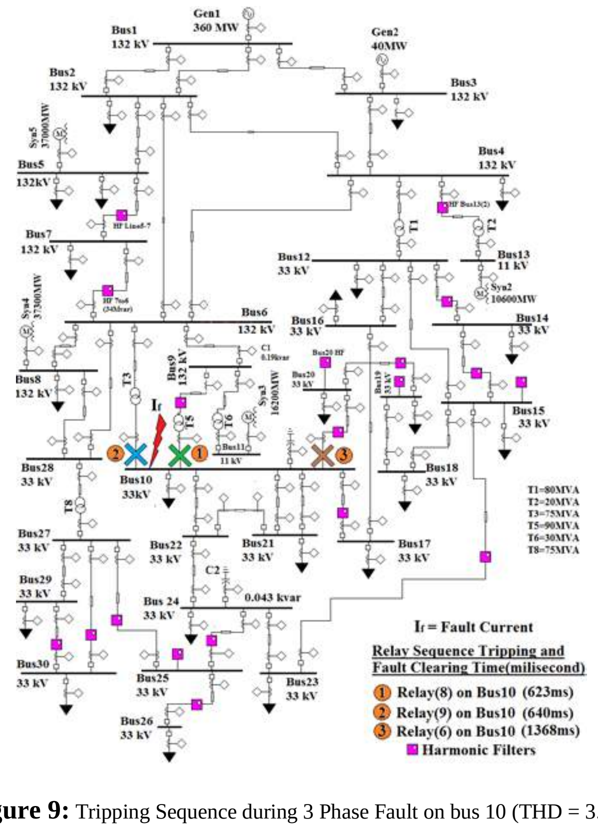

Figure 9: Tripping Sequence during 3 Phase Fault on bus 10 (THD = 3.1%)

The same 3 phase short circuit fault was applied on bus 10 while the passive harmonic filters are installed in the network as shown in Fig. 9 which shows a right sequence of relays tripping operation that is similar to case 1 when the THD was negligible.

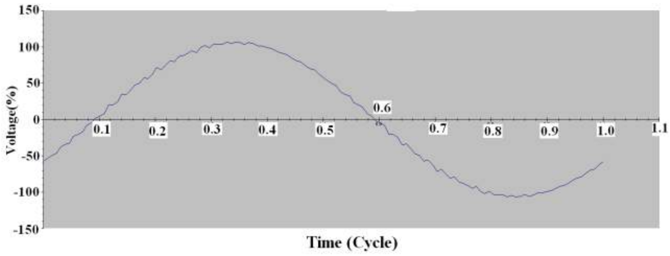

Figure 10: Voltage Waveform at Bus 10 (THD=10%)

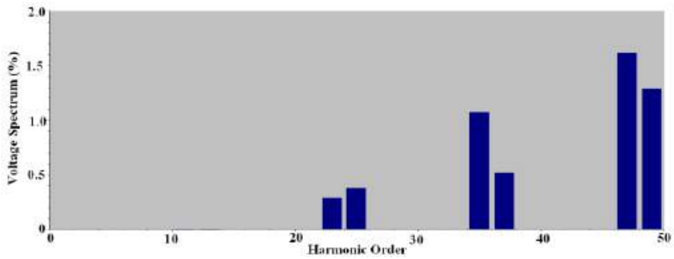

Figure 11: Spectrum Analysis of the voltage at bus 10 (THD=10%)

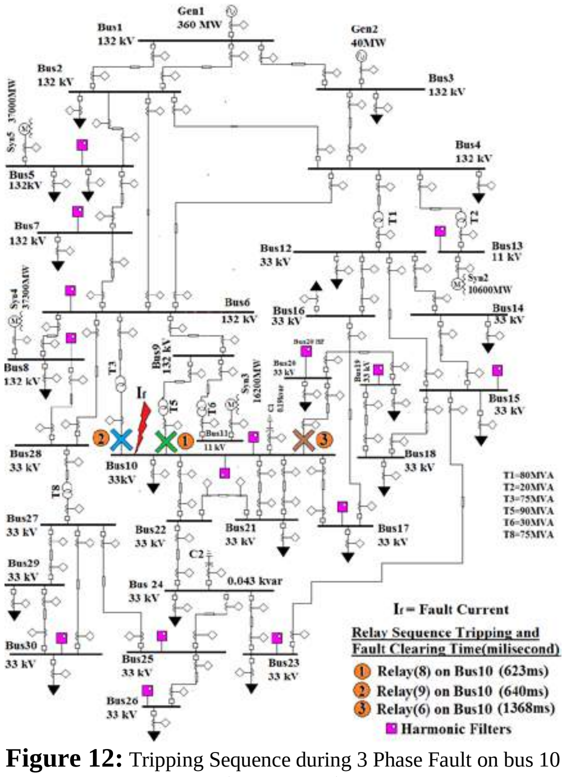

Figure 12: Tripping Sequence during 3 Phase Fault on bus 10 (THD = 10%)

It can be concluded that when the THD is 20% or more, the performance of over current relays will be affected and they will have a malfunction operation. Installing 19 passive harmonic filters tuned to suppress a significant number of harmonic orders is not a cost effective solution to the problem. As the performance of the relays are mainly depending on the THD level. The number of filters can be reduced as far the THD level will be reduced to a level lower than 20%. The harmonic filters were modified to suppress only two harmonic orders and the number of filters was reduced to 15. This reduces the THD level in the system to 10%. Fig. 10 shows some distortion in the voltage waveform at bus 10 and its harmonic spectrum is shown in Fig. 11.Fig. 12 shows the response of over current relays when a three phase short circuit fault is applied on bus 10 with 15 passive filters tuned at two harmonic orders installed at the system. The tripping sequence in this case is identical to the ideal case shown in Fig. 3.

III. Conclusion

Simulation results show that, when the THD is more than 20%, the over current relay's performance will be significantly affected and a malfunction will be caused. When a fault occurs in the system, the over current relay will not be able to isolate the faulty location as they will trip in an undesired way. Reducing THD to a level below 20% will mitigate this problem and a proper relay's operation can be retained. Passive harmonic filters are not a cost effective solution to the problem. One of the proposed solutions to the problem is the use of active filter approaches which can effectively eliminate all harmonic orders. However active filters have very complex configuration and require a complex control technique.

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IV. Bibliographies

Hillary Tin (SM90942700) was born in Rangoon, Burma on January 14, 1969. He graduated from Rangoon Arts and Science University in 1992 with Mathematics. Again, he graduated from Curtin University of Technology in Bachelor of Engineering (Electronics and Communications). Then, he finished master of engineering science (Power).
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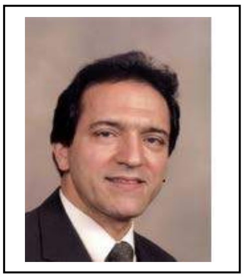

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