Synopsis

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Degree for which submitted: Ph.D. | Department: Electrical Engineering

Thesis Title: An Investigation on Harmonics and Active/Reactive Power of Asymmetrical Operation of 12-Pulse Converter and Mitigation of Harmonics

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Month and year of thesis submission: July 2016

The proliferation of power electronics based equipment in the power system has a profound impact on the quality of the power supply world over. High power industrial loads, such as adjustable speed drives, uninterruptible power supply (UPS), thyristor converters, etc., which are the prerequisites for realizing energy efficiency and productivity benefits and low power domestic loads such as television sets, fax machines, computers, domestic inverters, small power supplies, etc., draw strongly distorted currents resulting in non sinusoidal supply voltages across power system network[1]. Furthermore, conventional loads such as large arc furnaces and single phase welding machines also contribute significantly to the fluctuation, unbalance and flicker in supply voltages. By looking towards the recent development in the different types of power electronics converters and their industrials applications, growth rate of industries, automation in the industry, its is expected that the use of equipment based on power electronics technology would further increase in future and the distortion problem in the supply become a more and more Sevier.

Use of multi pulse converters has become a common practice in order to minimize the harmonics in applications with large non-linear loads where the harmonics must be kept under certain limits[2]. The harmonics mitigation performance of multiple drive is far superior to the well-known 6- pulse drive even the cost is high. So the proper assessment of harmonics performance is necessary before put into the utility. 12-pulse converter is used for large DC drives in the industry. The converter is consists of two 6-

pulse converters connected in series or in parallel. The supply current harmonics in the 12-pulse converter is 12N ± 1 when both the converter is working in equal firing angle. But normally the 12-pulse converter is connected to a transformer having a two 30-degree phase shifted secondary winding. Looking to the difference in leakage inductance of the transformer secondary and the source inductance, there is a possibility of presence of 5^{TH} and 7^{TH} harmonics in the supply.

Most of these converters are SCR based six pulse converters[3]. Line commutated phase control converter have several shortcoming for both rectification and inversion. At reduced dc voltage level the phase controlled converter requires a large amount of reactive power. With constant dc current and without commutation reactance, the converter ac current displacement power factor angle is equal to the firing angle. The commutation overlap further increases the firing angle and decreasing the power factor.

To keep the required reactive power constant at a different active power required by the converter a six pulse converter has a limitations and 12- pulse converter can solve the problem by operating in asymmetrical firing angle mode. This configuration is useful for applications where converter load rating, which are mostly DC drives, range beyond MW rating. When these drives are operate at very low speeds the VAR[7] drawn tend to be extremely large due to high motor current being drawn to maintain high operating torque. With 12-pulse converters, it is also possible to achieve low Var (Q) by operating in an asymmetrical firing mode. The effect of source inductance on the performance of the converter has a major role in the operating range of converter for constant VAR operation. The effect of source inductance is to be considered.

The presence of 6N ± 1 harmonics in the input current, in the input current is more severe in asymmetrical mode as compared to the equal firing angle mode. The injected harmonics, reactive power burden, unbalance, and excessive neutral currents cause low system efficiency and poor power factor. Harmonic contamination has become a major concern for power system specialists due to its effects on sensitive loads and on the power distribution system. Harmonic current components

1. Increase power system losses,
2. Cause excessive heating in rotating machinery,
3. Can create significant interference with communication circuits that share common right-of-ways with AC power circuits,

4. And can generate noise on regulating and control circuits causing erroneous operation of such equipment

To mitigate the harmonics, harmonic filter is required. Harmonic pollution is regarded as being one of the major problems that degrade electric power quality. Particularly, harmonic resonance in power distribution systems can cause excessive voltage and current waveforms distortion with a consecutive instability, abnormal operation or damage of electric components. Passive filter have already been considered a good alternative for a current harmonic compensation and displacement power factor correction[6]. Shunt passive filter exhibits lower impedance at a tuned harmonic frequency than the source impedance to reduce the harmonic current flowing into the source. In principle, filtering characteristics of the shunt passive filter are determined by the impedance ratio of the source and the shunt passive filter. For an increasing number of applications, conventional equipment is proving insufficient mitigation of power quality problems. The level of harmonics distortion has traditionally been dealt with the bank of passive tuned filters. Their application for harmonic reduction has many limitations. Therefore, the active power filtering has been researched over past one decade and is being developed in order to overcome the limitations of passive filters. The application of active filter[3] is capable to obviate most of the problems created by non-linear loads and further more these filters offer flexibility in control of reactive and harmonic power, with good dynamic performance.

Therefore, the motivation behind the work presented in this thesis are:

- To develop 12 pulse converter using two six pulse converter which can operate in equal as well as asymmetrical firing angle mode.
- To analyse the converter for constant active / reactive power operation under asymmetrical operation.
- To analyse converter operation with effect of source inductance for constant active / reactive power operation.
- To design a passive filter and analysis of the converter.
- To design and develop hybrid series active filter to mitigate harmonics using SRF and PQ methods.
- To design and develop Combined hybrid series active filter to mitigate harmonics.

- To develop prototype model for 12 pulse converter with passive filter and hybrid active filter and analysis.

A brief description of the research work reported in the thesis is given below:

Chapter 1 introduce the application of multi pulse converter and configuration of different converters which presents a brief state-of-art survey of research work carried out in the areas 12 pulse converter and mitigation of harmonics. The various control algorithms are presented for the harmonics mitigation.

Chapter 2 gives the detailed operation of 12 pulse converter operating under asymmetrical and symmetrical firing angle mode. The effect of source inductance is a major limitation for operating a converter under constant active / reactive power control. The region of operation is generated for constant active / reactive power operation. The harmonic pattern for different order of harmonics and Total Harmonic Distortion is carried out.

Chapter 3 gives the detail design of passive filter and simulation of converter with passive filter. The converter is analysed with passive filter. The harmonic pattern for different order of harmonics and Total Harmonic Distortion is carried out.

Chapter 4 gives the necessity of active filter. The hybrid series active filter is simulated. The combined hybrid series active filter is simulated and results are compared.

Chapter 5 shows the experimental verification of 12 pulse converter analysis, operating under asymmetrical firing angle operation with and without passive filter for constant Active / reactive power operation. It also gives details experimental results of 12 pulse converter with hybrid active filter. The input current harmonics have been analyzed for different firing angle operation of 12 pulse converter.

Chapter 6 gives the conclusion of the work carried out and the importance of this industry to keep required reactive power constant when more than one power electronic equipments are connected and using a 12 pulse converter it can be possible with mitigation of harmonics. It also include possible ways for future expansion.

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