

Analysis and Design of Power Electronic Transformer with Matrix Converter based Power Quality Improvement

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Abstract— A new type of transformer based on Power Electronics (PET) has been proposed in this paper, which realizes voltage transformation, galvanic isolation, and power quality improvements in a single device. The PET provides a fundamentally different and more complete approach in transformer design by using power electronics on the primary and secondary sides of the transformer. Several features such as instantaneous voltage regulation, voltage sag compensation and power factor correction can be combined into PET. This paper presents a novel topology of power electronic transformer. In the design process, the AC/DC, DC/AC, AC/AC converters and high frequency transformer have been used. One matrix converter operates as AC/AC converter in power electronic transformer. The designed power electronic transformer performs typical functions and has advantages such as power factor correction, voltage sag and swell elimination, voltage flicker reduction and protection capability in fault situations. The proposed power electronic transformer has been modeled using MATLAB/SIMULINK and Power quality improvement with proposed model has been verified by the simulation results.

Index Terms— Power electronic transformer; AC/AC Matrix converter; Power Quality; High Frequency Transformer

I. INTRODUCTION

Power quality has become an important issue in recent times when many utilities around the world find very difficult to meet energy demands which leads to load shedding and power quality problem. A power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in failure or a mis-operation of end user equipment's. Utility distribution networks, sensitivity industrial loads and critical commercial operations suffer from various types of outages and service interruptions which can cost significant financial losses. In order to solve power quality problems, some other remedies more than the installation of power quality monitors are needed [1].

A recent survey of Power Quality experts indicates that 50% of all Power Quality problems are related to grounding, ground bonds, and neutral to ground voltages, ground loops, ground current or other ground associated issues. Electrically operated or connected equipment is affected by Power Quality. Determining the exact problems requires sophisticated electronic test equipment. The following symptoms are indicators of Power Quality problems: Piece of equipment mis-operates at the same time of day, Circuit breakers trip without being overloaded, Equipment fails during a thunderstorm, automated systems stop for no apparent reason, Electronic systems fail or fail to operate on a frequent basis. Electronic systems work in one location but not in another location. The commonly used terms those describe the parameters of electrical power that describe or measure power quality are Voltage sags, Voltage variations, Interruptions Swells, Brownouts, Blackouts, Voltage imbalance, Distortion, Harmonics, Harmonic resonance, Inter harmonics, Notching, Noise, Impulse, Spikes (Voltage), Ground noise, Common mode noise, Critical load, Crest factor, Electromagnetic compatibility, Dropout, Fault, Flicker, Ground, Raw power, Clean ground, Ground loops, Voltage fluctuations, Transient, Dirty power, Momentary interruption, Over voltage, Under voltage, Nonlinear load , THD, Voltage dip, Voltage regulation.

The issue of electric power quality is gaining importance because of several reasons: The society is becoming increasingly dependent on the electrical supply. A small power outage has a great economic impact on the industrial consumers. A longer interruption harms practically all operations of a modern society. New equipment's are more sensitive to power quality variations. The advent of new power electronic equipment, such as variable speed drives and switched mode power supplies, has brought new disturbances into the supply system.

II. EFFECT OF UNBALANCED VOLTAGES

Transformers are widely used in electrical power distribution and power conversion systems to perform many functions, such as isolation, voltage transformation, noise decoupling, etc. Transformers are one of the most bulky and expensive parts in a power distribution and power conversion systems. The size of transformer is a function of saturation flux density of the core material and maximum allowable core and winding temperature rise. Saturation flux density is inversely proportional to frequency and increasing the frequency allows higher utilization of the steel magnetic core and reduction in transformer size. The subject of a high frequency link has been studied extensively in power electronic systems. Electronic transformer with concept of a high frequency AC link the primary purpose is to reduce the size and weight and volume and to improve efficiency winding. Unbalanced currents also create torque pulsation on the shaft resulting in audible noise and extra mechanical stresses [2].

III. POWER SYSTEM DESCRIPTION

Transformers are widely used in electric power system to perform the primary functions, such as voltage transformation and isolation. Transformers are one of the heaviest and most expensive devices in an electrical system because of the large iron cores and heavy copper windings in the composition. The size of transformer is a function of the saturation flux density of the core material and maximum allowable core and winding temperature rise. Saturation flux density is inversely proportional to frequency and increasing the frequency allows higher utilization of the steel magnetic core and reduction in transformer size, Voltage swells are not as important as voltage sags because they are less common in distribution systems. Voltage sag and swell can cause sensitive equipment to fail or shutdown, as well as create a large current unbalance that could blow fuses or trip breakers. These effects can be very expensive for the customer, ranging from minor quality variations to production downtime and equipment damage. There are many different methods to mitigate voltage sags and swells, but the use of a custom Power device is considered to be the most efficient method [3].

A new type of transformers based on Power Electronics (PET) has been introduced, which realizes voltage transformation, galvanic isolation, and power quality improvements in a single device. The PET provides a fundamentally different and more complete approach in transformer design by using power electronics on the primary and secondary sides of the transformer. Several Features such as instantaneous voltage regulation, voltage sag compensation and power factor correction can be combined into PET [4].

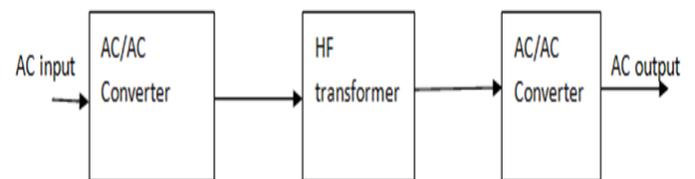


Fig. 1. Model of PET

IV. MATHEMATICAL MODELLING OF PET

The analysis of the three-phase electronic transformer system is similar to the single phase system. Let V_{ab} , V_{bc} , and V_{ca} be input line voltages with peak voltage V_m , and input angular frequency of ω .

$$V_{ab} = V_m \times \sin \omega t \quad (1)$$

$$V_{bc} = V_m \times \sin[\omega t - 2\pi/3] \quad (2)$$

V. MATRIX CONVERTER WITH LINEAR AND NONLINEAR LOAD

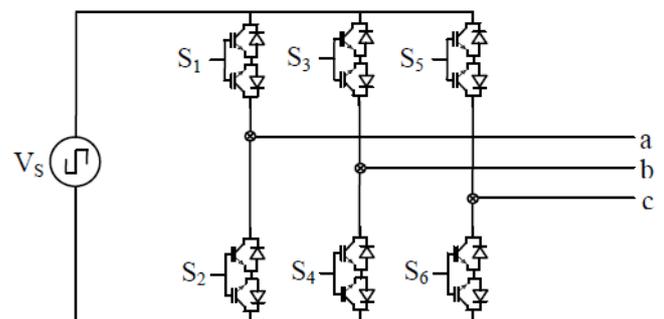


Fig. 2 Matrix Converter

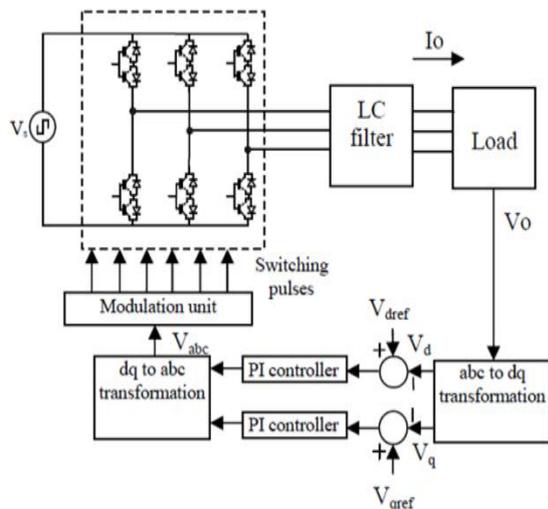


Fig. 3 Control of Matrix Converter

Matrix Converters (MC), which received significant improvements in recent years, are power electronic converters with high switching frequency and are able to generate three phase output voltages with variable frequency and, at the same time, with controllable input power factor [5]. When compared to the conventional Voltage-Source Inverter (VSI), MCs do not need a bench of electrolytic capacitors since there is no intermediate DC-link, which contributes to limit the usual VSIs lifetime, increasing electric losses, volume and costs. Furthermore, MCs allow bidirectional power flow and do not contribute significantly to the harmonic degradation of the input waveform voltage [6]. This is extremely important as it led to an endorsement of this converter, as an innovative and clean solution from the harmonic point of view. The MC has also been implemented recently in multi-level locomotives due to their light weight and small size, in order to replace the conventional back-to-back converters on board of railway vehicles as well as compact power sources for electromechanical variable speed drives, in this case AC motors [7]. The Matrix Converter is a power electronic converter made by several controlled semiconductor switches that directly connect each input phase to any output phase. The bi-directional switches have to commute in the right way and sequence in order to reduce losses and produce the desired output with high quality input and output waveforms. The MC converts directly the output into a desired magnitude and frequency, without using a DC-link, as in the conventional back-to-back converter. Furthermore, with the bidirectional switches, it is possible to

provide bidirectional power flow and controllable input power factor [8].

VI. SIMULATION AND RESULTS

The model of Power Electronic Transformer (PET) is simulated with linear and nonlinear for 2second.. The PET has three stages:- input stage, isolation stage and output stage. The PET is simulated with a three phase source and in linear and nonlinear load. The linear load is a three phase resistive load with 10kW. The nonlinear load is formed as a series combination of resistance and inductance are connected parallel to a three phase diode. The nonlinear load is represented as a subsystem.

Figure shows the output stage. In the output stage there is a matrix converter with a closed loop control. The nonlinear load is formed as a series combination of resistance and inductance are connected parallel to a three phase diode.

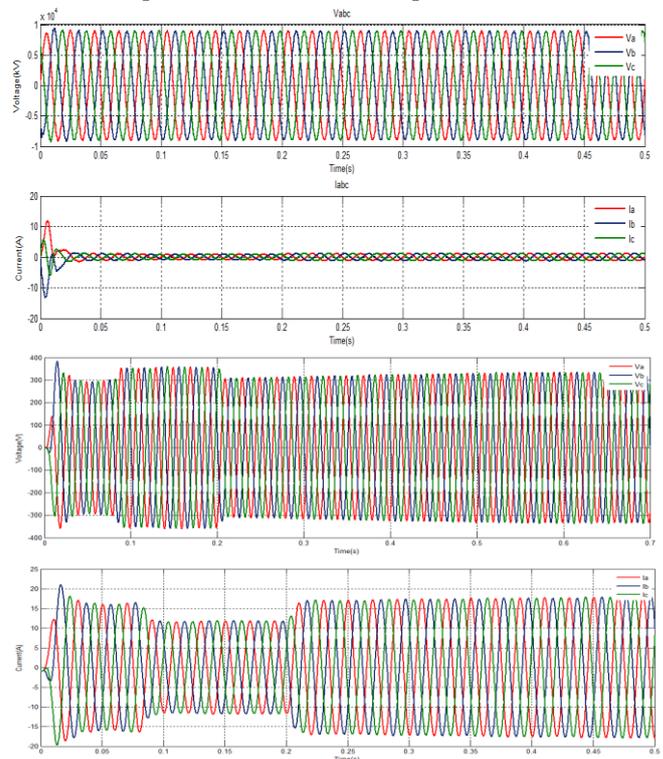


Fig. 4.a)Input voltage and current (b) Output voltage(c)Output current

VII. CONCLUSION

In this work a new configuration of power electronic transformer with DC-Link capacitor has been proposed. To obtain higher efficiency, the AC/DC and DC/AC converters have been integrated in one converter. The topology described in this paper has many advantages such as power factor correction, voltage regulation, voltage sag

and swell elimination, voltage flicker reduction. In proposed PET one AC/AC matrix converter is used to replace two converters and switching of matrix converter is easy and not complex. The operation of the proposed system was verified through simulations with MATLAB/ SIMULINK software. The theoretical as well as simulation results shows that the proposed PET model with current voltage regulator.

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