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A Novel Power Conditioner Based On Electronic Transformer for High Frequency Ac Link


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ABSTRACT

Electronic transformer, with concept of a high frequency AC link, is introduced in reference. More studies on electronic transformer have been done and published in the past many years. In this dissertation, the concept of electronic transformer is further explored. Proposed electronic transformer applications are also presentedSmart grid structure could be very complex. Active power electronic transformers, composing an important part of the smart grid, could have many roles in that stochastic and variable system. The modular structure (consisting of many base modules) is the key to obtain the needed flexibility. The goal of this research was to develop a base module of the active power electronic transformer to be used later as a standard building block in more complex systems. To guarantee the power quality on the HV grid side, the base module has power factor correction functionality. The performance of the base module was verified by computer-aided simulations.

INDEX TERMS:- ***PFC, power electronic transformer, power conditioner, nonlinear loads, SST.***

1. INTRODUCTION

A transformer is a static device consisting of a winding, or two or more coupled windings, with different number of turns on a magnetic core, for inducing mutual coupling between circuits. The alternating current magnetic field created in one winding induces a current in the other in the electrical power systems to transfer power by electromagnetic induction between circuits at the same frequency with very little power loss, voltage drop or waveform distortion.

Transformers are important equipment in power distribution system as well as in power electronic system. They can step down high voltages in transmission at substations or step up currents to the needed level of end-users. Additionally, many functions, for instance, isolation, noise decoupling or phase-shifting can be achieved through transformers.

A low frequency (60/50 Hz) transformer is one the most bulky and expensive components in electrical power system. There have been inclusive studies to reduce size and weight of the transformer.

The size of a transformer is a function of the saturation flux density or core material, current density of conductor, and operating frequency of excitation. Therefore, employing high current density wire materials, such as high temperature superconductor or employing advanced core materials, such as a finer grade of steel or an amorphous, which has higher saturation flux density, can reduce the size and weight of a transformer.

The saturation flux density is inversely proportional to frequency. Therefore, the size reduction can be achieved by increasing frequency through a static converter. Development of power electronic converters and

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switching devices advance as high frequency link system is researched. The study shows concerns on high EMI and losses.

Electronic transformer, with concept of a high frequency AC link, is introduced in reference. More studies on electronic transformer have been done and published in the past many years. In this dissertation, the concept of electronic transformer is further explored. Proposed electronic transformer applications are also presented.

As from aforesaid, operating magnetic core at high frequency is an approach to reduce the size and weight of transformers. The electronic transformer concept, which magnetic core operates at high frequency, has been applied to phase-shifting transformer and telecommunication power supply application.

II. DESCRIPTION OF THE MODEL ACTIVE POWER ELECTRONIC TRANSFORMER

In this chapter, an ongoing project on power electronic transformer is introduced. The advantages of the proposal are stated. The concept of the high frequency AC link is further explored. The focus of this chapter is to realize an electronic transformer as a power delivery component in electrical distribution systems. The primary purpose is to reduce the size and weight and volume and to improve efficiency.

2.1 Development of Intelligent Universal Transformer

Electrical Power Research Institute (EPRI) has been researching on Intelligent Universal Transformer (IUT). It is proposed to replace conventional distribution transformer with the state-of-the-art power electronic system. An intelligent and controllable system can provide multiple transformer functions, such as voltage transformation, voltage regulation, non-standard customer voltages (DC or 400 Hz AC), voltage sag correction, power factor control, and distribution system status monitoring to facilitate automation. The IUT will be a foundation of Advanced Distribution Automation (ADA) that will transform distribution systems into multifunctional power exchange systems.

The IUT assembly layout is shown as block diagram in Fig. 2.1. The layout is based on solid state transformer previously discussed in CHAPTER I. It requires 2 power conversion stages: rectifying stage and inverting stage.

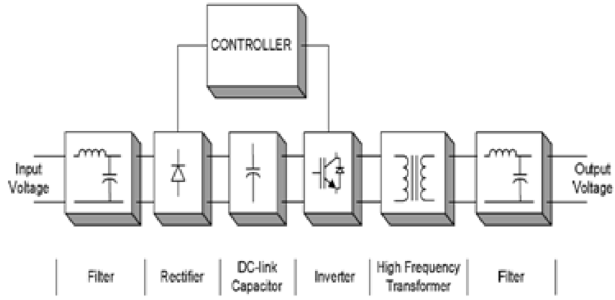

Fig. .1. EPRI intelligent universal transformer (IUT) layout.

The advantages of the IUT over conventional distribution transformer are:

- Improved Power quality
- DC and alternative frequency AC service options.
- Integration with system monitoring, advanced distribution automation and open communication architecture.
- Reduced weight and size
- Elimination of hazardous liquid dielectrics.
- Reduced spare inventories.

To make the IUT possible, an advanced high voltage power electronic circuit topology and a family of high voltage, low current power semiconductor (switching devices and diodes) have to be developed. Additionally, the IUT must have a standardized information model, as embedded software, which makes the IUT compatible with standardized open utility communication architecture.

Some drawbacks of the approach can be stated as followed

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- ➢ Multiple power conversion stages can lower the transformer efficiency.
- ➢ DC-link capacitors are required.
- ➢ The transformer lifetime is shorter due to storage devices.

2.2 Electronic transformer system

As mentioned, electronic transformer with concept of a high frequency AC link is introduced. The electronic transformer system consists of static AC/AC power converters applying to primary and/or secondary windings of the transformer as shown in Fig 1.2. Each converter contains bi-directional switches, which provide bi-directional energy flow. The low frequency (60/50 Hz) input voltage is converted to desired high operating frequency voltage through the primary converter, then the secondary converter restores the original low frequency input voltage. The secondary converter is optional. It is needed when the transformer supplies linear load type, and the operation requires both primary and secondary side static converters to operated synchronously. The subject of high frequency AC link has been studied widely in power electronic system.

The electronic transformer has advantages as followed.

- ➢ Identical input and output characteristic as a conventional transformer.
- ➢ Efficiency compatible with a conventional transformer.
- ➢ Snubber-less operation through 4-step switching strategy.
- ➢ No additional harmonics generated due to switching.
- ➢ Significantly smaller size and weight than a conventional transformer.

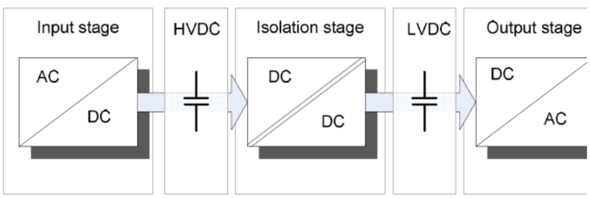
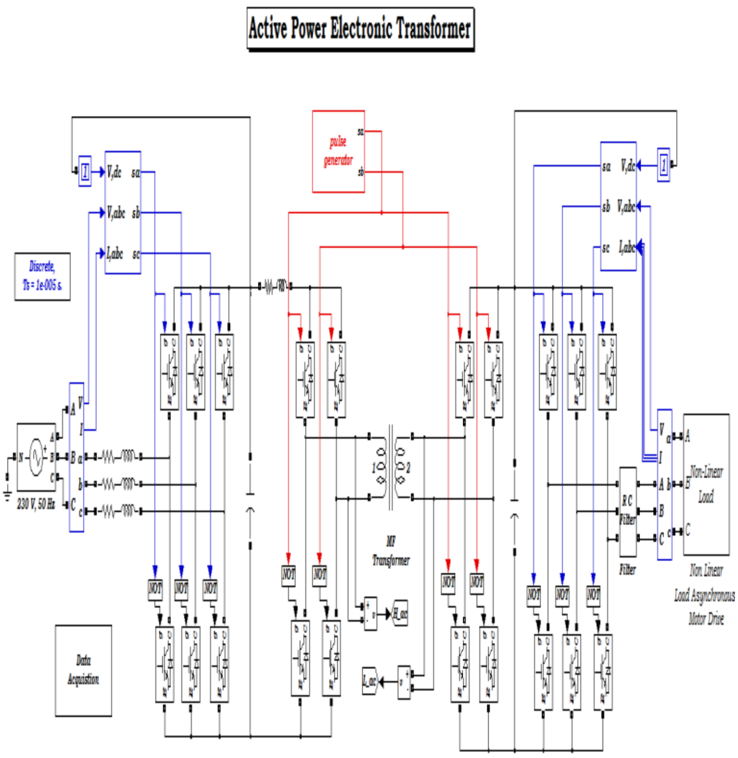


Fig. 2. Active Power electronic transformer 3 stage topology

III.SIMULATION RESULTS



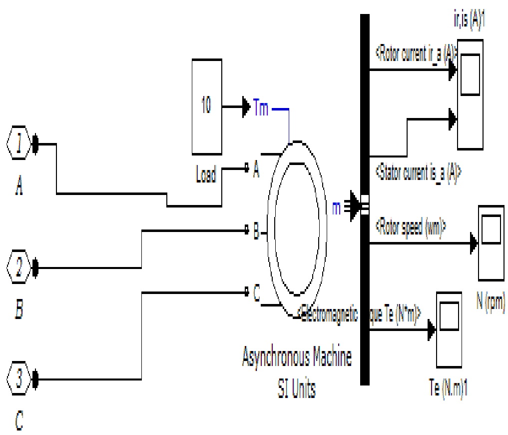


Fig.3 Non-Linear Load

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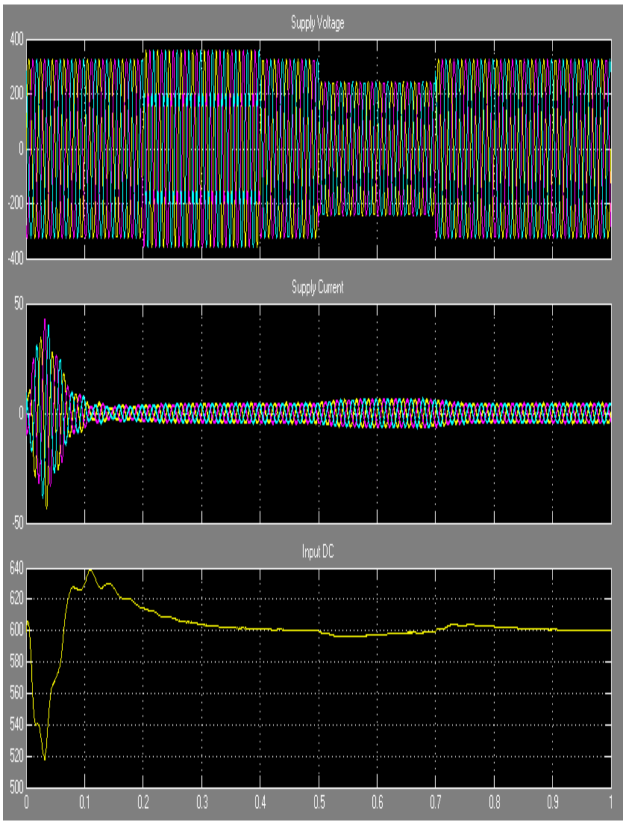

Fig.4 VS,IS, VDCin

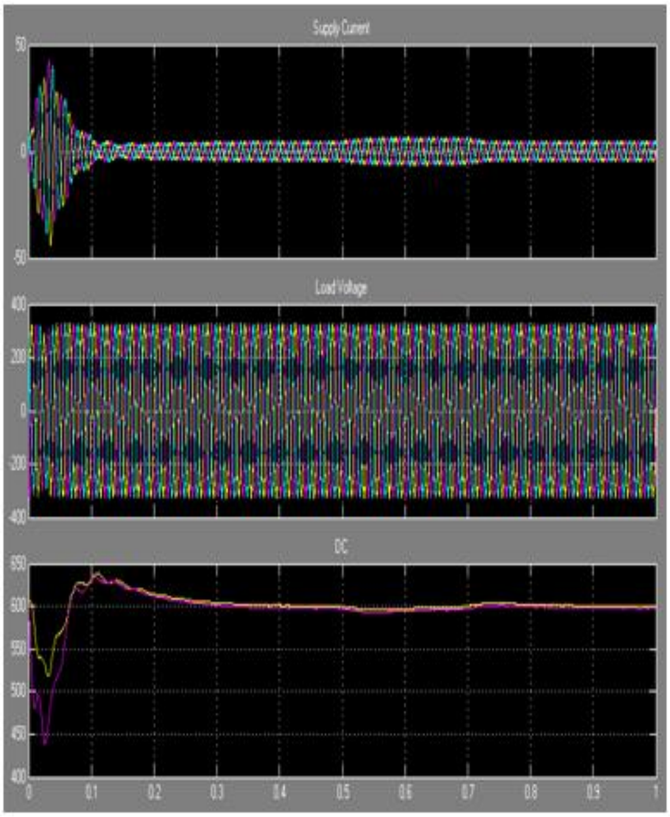

Fig.6 IS,VL,Source&Load DC Voltage

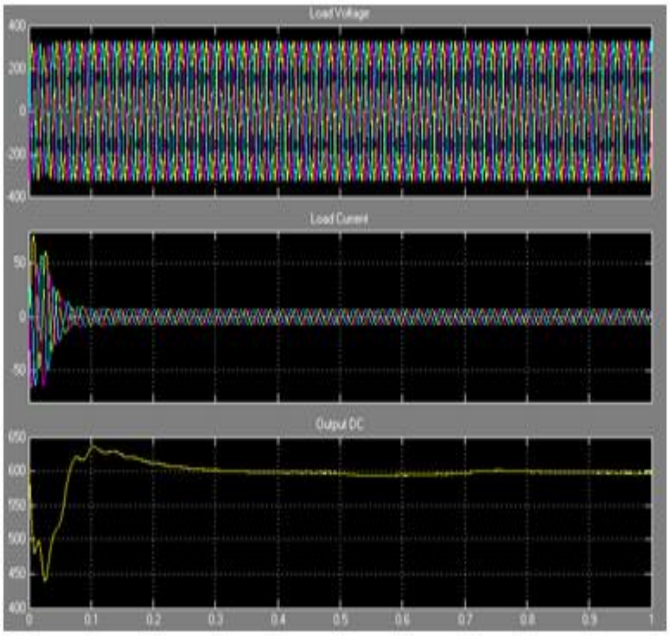

Fig.5 VL,IL,Vdcout

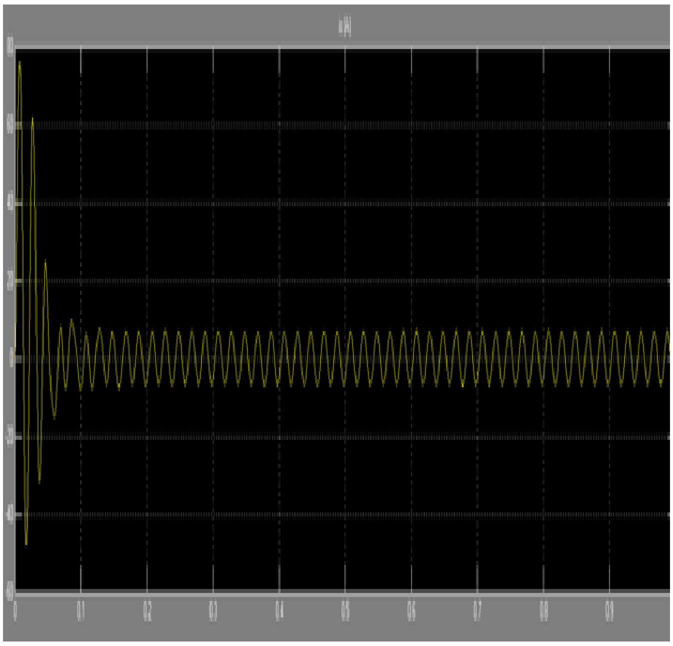

Fig.7 Stator Current

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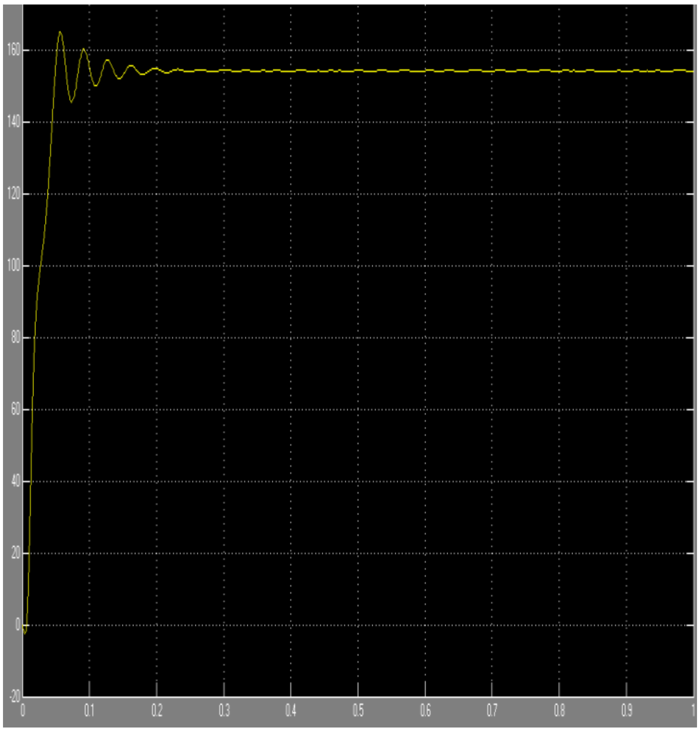

Fig.8Rotor Speed

IV.CONCLUSION

An active power electronic transformer (APET) could have many roles in the smart grid. The modular structure (consisting of many base modules) is the key to obtain the needed flexibility. The base module of the APET that could be used later as a standard building block in more complex systems was proposed and evaluated. The base module is a single-phase system consisting of different converters. In addition to providing galvanic isolation between the input and the output, it isolates input from output distortions. Thus, the input voltage disturbances have no effect on the output ones, and vice versa. In general, the power quality is improved in both ports: input and output. The performance of the proposed base module of the APET was verified by computer-aided simulations using MATLAB/SIMULINK.

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