APPLICATIONS OF AN ELECTRONIC TRANSFORMER IN A POWER DISTRIBUTION SYSTEM

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Abstract:
A transformer is an essential component that performs numerous functions in electrical power distribution and power electronic applications. It is one of the most bulky and expensive components at its operating frequency (60/50 Hz). By operating at a higher frequency, the previously introduced electronic transformer concept has demonstrated significant reductions in size, weight, and volume. The concept of the electronic transformer is extended in this dissertation to the auto-connected phase-shifting type in order to reduce harmonics generated by nonlinear loads. It is demonstrated that the addition of primary and secondary side AC/AC converters results in phase-shifting. Magnetic components are operated at a higher frequency with the addition of converters, resulting in a smaller size and weight.

Keywords:
Electronic Transformer, Power, Power Distribution System, Power Electronic Applications, telecommunication power supply

Introduction:

A transformer is a static device that consists of a winding or two or more coupled windings with varying turns on a magnetic core to induce mutual coupling between circuits. The alternating current magnetic field generated in one winding induces a current in the other winding in proportion to the number of turns. Transformers are used solely in electrical power systems to transfer power via electromagnetic induction between circuits operating at the same frequency with minimal power loss, voltage drop, or waveform distortion. Transformers are essential components of both power distribution and power electronic systems. They can reduce high voltages in transmission at substations or increase currents to end-user requirements. Furthermore, transformers can perform a variety of functions such as isolation, noise decoupling, and phase shifting.

In reference [1,] an electronic transformer with the concept of a high frequency AC link is introduced. More research on electronic transformers has been conducted and published in recent years. The concept of electronic transformer is expanded upon in this dissertation. There are also proposed electronic transformer applications.

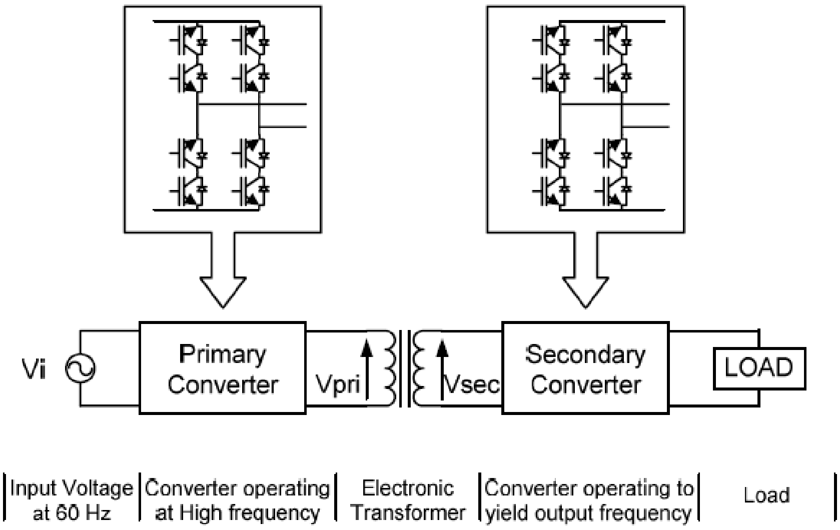

Figure 1: Block diagram of electronic transformer.

Figure 1 depicts a recent advancement in high power switching devices, an electronic transformer. By using an AC/AC converter on each primary or secondary side of the transformer, multi-stage power conversion can be reduced. AC/AC converters can achieve the desired frequency of AC voltage.

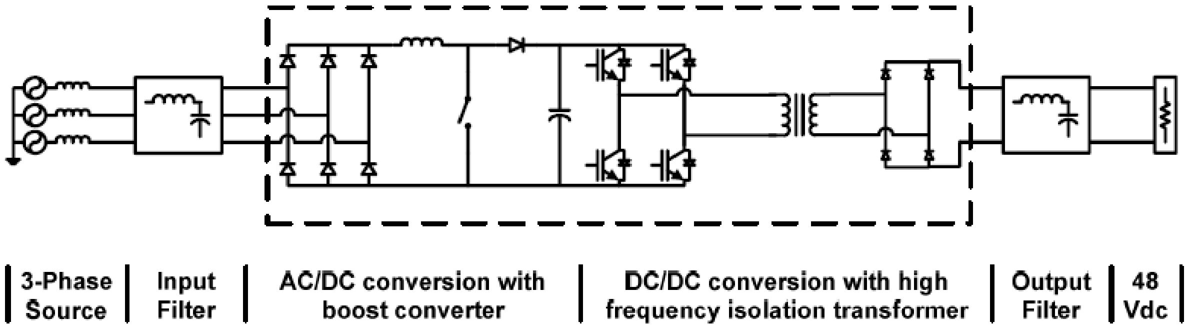

Figure 2: Typical telecommunication power supply

To achieve higher DC power with -48 VDC, modern telecommunication power systems require several rectifiers to be connected in parallel [2]. Due to cost considerations, such a rectifier typically employs diodes or silicon-controlled rectifiers to interface with the electric utility. Significant harmonic currents are generated by the rectifier type utility interface, resulting in a low input power factor and high total harmonic distortion (THD), which contributes to inefficient energy use.

Electronic transformer system:

introduces the concept of an electronic transformer with a high frequency AC link[1]. As shown in Figure 1.2, the electronic transformer system consists of static AC/AC power converters applied to the transformer's primary and/or secondary windings. Each converter contains bidirectional switches that allow for bidirectional energy flow. The low frequency (60/50 Hz) input voltage is converted to the desired high operating frequency voltage by the primary converter, and the secondary converter restores the original low frequency input voltage. The secondary converter is not required. It is required when the transformer supplies linear load type and the operation necessitates the operation of both primary and secondary side static converters. The subject of high frequency alternating current links has received a lot of attention in power electronic systems. The electronic transformer has the following advantages [3-4].

- Input and output characteristics are identical to those of a conventional transformer; efficiency is comparable to that of a conventional transformer.
- Snubber-free operation via a 4-step switching strategy.

- No additional harmonics are produced as a result of switching.
- Significantly smaller in size and weight than a standard transformer

Objectives:

The use of electronic transformers in power distribution and conversion systems is investigated. It should be noted that the proposed electronic transformer and the conventional transformer have identical performances. To realise high frequency operation of the transformer magnetic core, possible topologies employing static converters connected on the primary and/or secondary sides are investigated. Switch configurations, including the matrix converter concept, are discussed in order to reduce the number of converter switches.

Result and Discussion:

To achieve higher current DC output at -48 VDC, modern telecommunication power systems require several rectifiers to be connected in parallel [5-6]. To generate -48 VDC, commercially available telecom-rectifiers [7] use an AC to DC conversion stage with a boost converter, followed by a high frequency DC/DC converter. This type of rectifier generates significant 5th and 7th harmonic currents, resulting in a total harmonic distortion (THD) of less than 40%. Furthermore, the rectifier DC-link capacitor stage is bulky, adding weight and volume. In addition, the presence of multiple power conversion stages reduces efficiency.

Proposed switch mode power supply

Figure 3 depicts the proposed digitally controlled switch mode power supply based on a matrix converter. Six bi-directional switches are used in a matrix converter topology to convert a lower frequency (60/50 Hz) three-phase input directly to a high frequency (10/20 kHz) single phase output. The output is then rectified to -48 VDC using an isolation transformer. The digital control of the matrix converter stage ensures that the output voltage is regulated against changes in load as well as changes in input supply. [8]

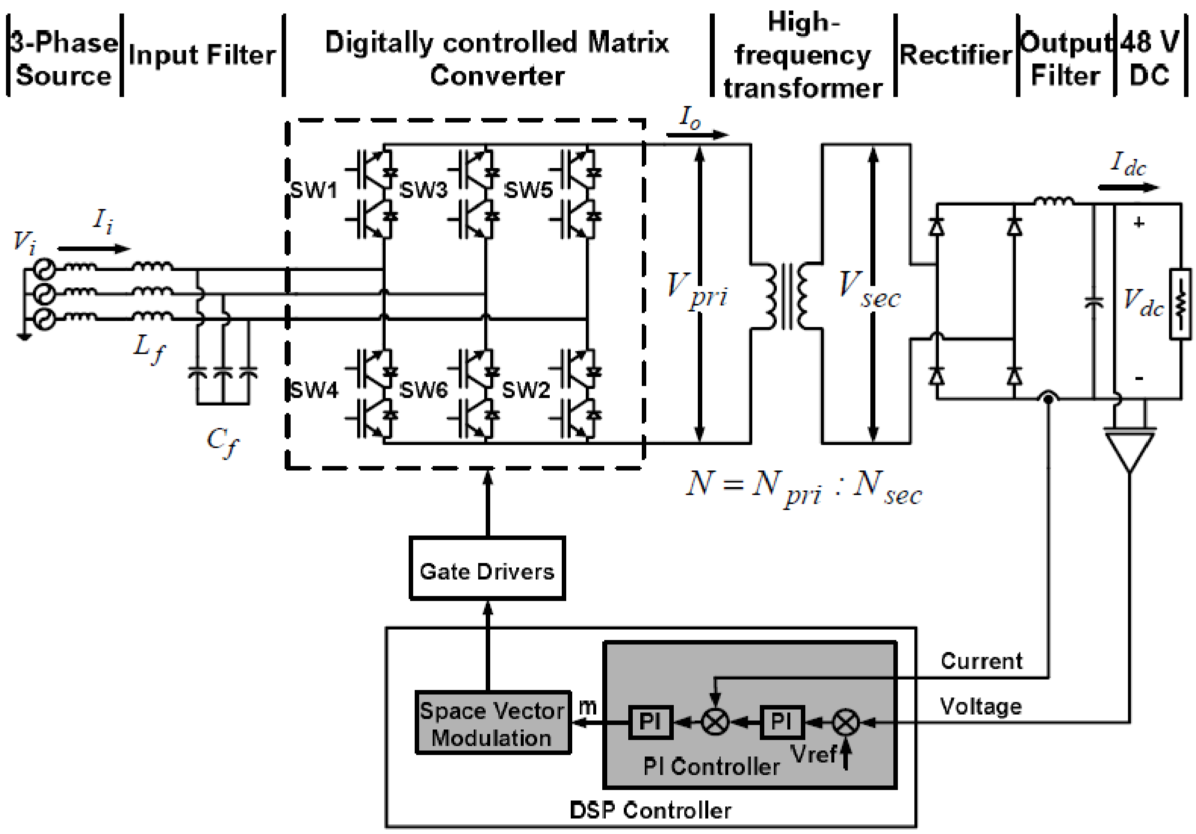

Figure 3: A digitally controlled switch mode power supply based on a matrix converter is proposed.

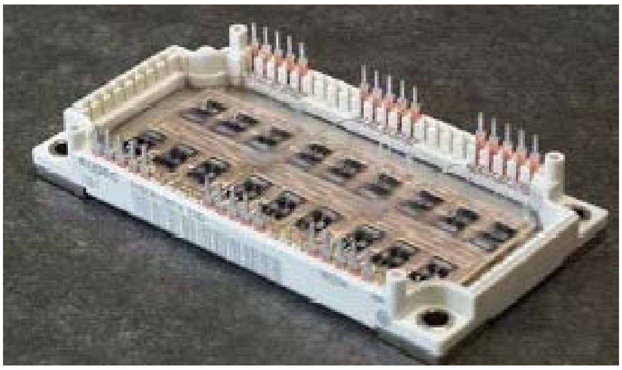

Figure 4: EUPEC 18-IGBT switch module for matrix converter implementation [9].

A matrix converter is a direct AC/AC converter that does not require a DC-link [10]. It benefits from bidirectional power flow, controllable input power factor, high reliability, and a compact design. Because of the system's high operating frequency, the size and weight of the transformer can be reduced. The space vector modulation technique is used on a matrix converter in this topology. Figure 4 depicts a three-phase to three-phase matrix converter module based on a 1200V IGBT introduced by EUPEC [10].

Applications of Electric Transformers

Electric transformers are essential in our daily lives because they either decrease or increase electrical current to meet our daily needs in the use of electrical appliances. Controlling the flow of voltages during charging is one of the applications of electric transformers, as unregulated voltage flow can result in electrical surges. And this could cause damage to the appliances being charged

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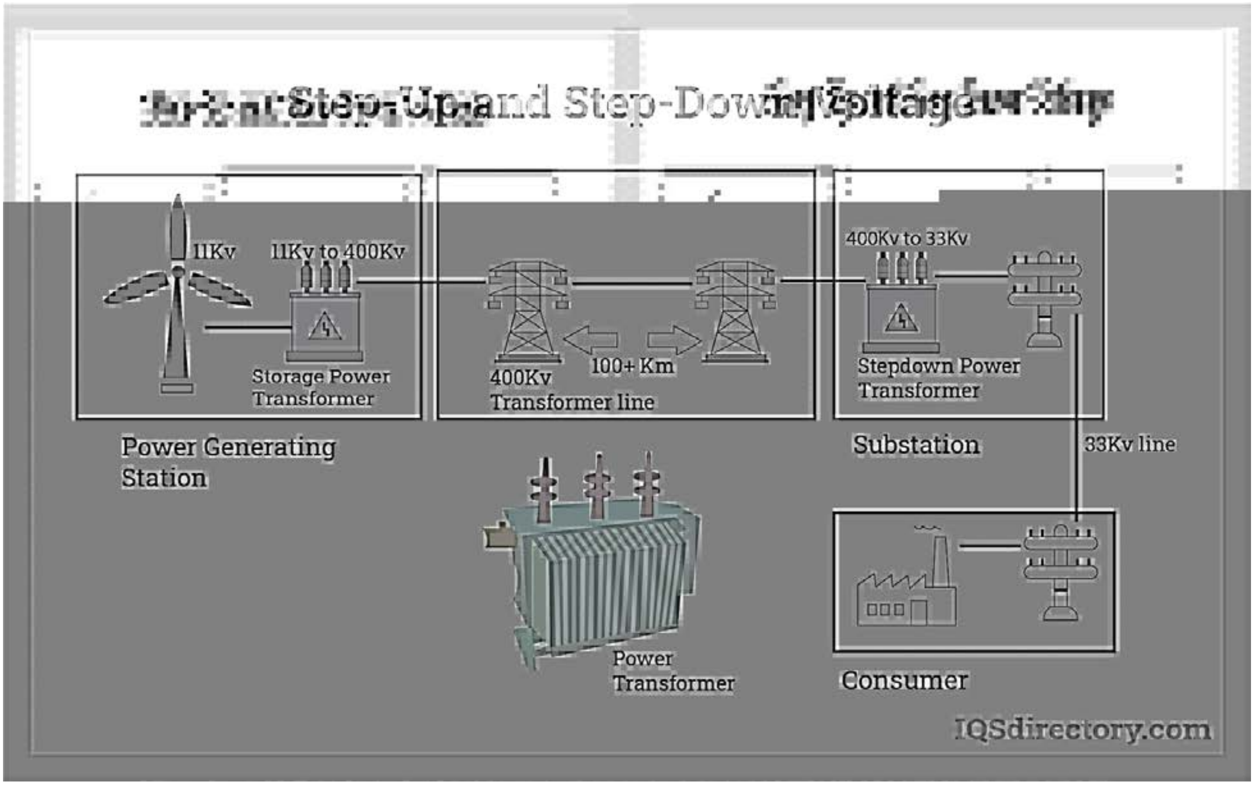

Figure 5: Applications of Electric Transformers

Steel manufacturing is another application for electric transformers. This is because high voltages are required in melting and welding, and when it comes time to cool, low currents are required after being generated by the electric transformer from the high voltages. Transformers power the electrolysis process in chemical processing. Transformers are required to regulate the electrical current that powers the chemical reaction. Aluminium, copper, and zinc are examples of electroplated metals. Electric transformers control the current in this reaction.

Conclusion:

This chapter demonstrated a digitally controlled switch mode power supply based on a matrix converter for telecommunication applications. For varying load conditions, the proposed space vector PWM method has been shown to produce high quality input current. The feasibility of a direct AC to AC matrix converter in telecommunication power supplies has been demonstrated experimentally on a 1.5 kW prototype.

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