Harmonic Mitigation using 36-Pulse AC-DC Converter for Direct Torque Controlled Induction Motor Drives

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ABSTRACT
This paper presents the design and analysis of a transformer based 36-pulse ac-dc converters which supplies direct torque controlled induction motor drives (DTCIMD's) in order to have better power quality conditions at the point of common coupling. The converters output voltage is accomplished via two paralleled eighteen-pulse ac-dc converters each of them consisting of nine-phase diode bridge rectifier. The design procedure of magnetics is in a way such that makes it suitable for retrofit applications where a six-pulse diode bridge rectifier is being utilized. The 36-pulse structure improves power quality criteria at ac mains and makes them consistent with the IEEE-519 standard requirements for varying loads. Furthermore, near unity power factor is obtained for a wide range of DTCIMD operation. A comparison is made between 6-pulse and 36-pulse converters (Polygon, Fork, and Hexagon) from view point of power quality indices. Results show that input current total harmonic distortion (THD) is less than 4% for the 36-pulse topologies at variable loads. The Delta/Hexagon connected platform could simplify the resulted configuration for the converters and reducing the costs.

Keywords: AC–DC converter, power quality, 36-pulse rectifier, direct torque controlled induction motor drive (DTCIMD).

1. Introduction

Recent advances in solid state conversion technology has led to the proliferation of variable frequency induction motor drives (VFIMD's) that are used in several applications such as air conditioning, blowers, fans, pumps for waste water treatment plants, textile mills, rolling mills etc [1]. The most practical technique in VFIMD's is direct torque controlled strategy in that it offers better performance rather than the other control techniques. Direct Torque controlled technique is implemented in voltage source inverter which is mostly fed from six-pulse diode bridge rectifier, Insulated gate bipolar transistors (IGBT's) are employed as the VSI switches. The most important drawback of the six-pulse diode-bridge rectifier is its poor power factor injection of current harmonics into ac mains. The circulation of current harmonics into the source impedance yields in harmonic polluted voltages at the point of common coupling (PCC) and consequently resulting in undesired supply voltage conditions for costumers in the vicinity. The value of current harmonic components which are injected into the grid by nonlinear loads such as DTCIMD's should be confined within the standard limitations. The most prominent standards in this field are IEEE standard 519 [2] and the International Electrotechnical Commission (IEC) 61000-3-2 [3].

According to considerable growth of Static Power Converters (SPC's) that are the major sources of harmonic distortion and as a result their power quality problems, researchers have focused their attention on harmonic eliminating solutions. For DTCIMD's one effective solution is to employ multipulse AC-DC converters. These converters are based on either phase multiplication or phase shifting or pulse doubling or a combination [4]-[19]. Although, in the conditions of light load or small source impedance, line current total harmonic distortion (THD) will be more than 5% for up to 18-pulse AC-DC converters. A Hexagon-Connected Autotransformer-Based 24-pulse AC-DC converter is reported in [7] which has THD variation of 4.48% to 5.65% from full-load to light-load (20% of full-load). A Zigzag-Connected Autotransformer-Based 24-pulse AC-DC converter is reported in [13] which has THD variation of 4.51% to 5.77% from full-load to light-load (20% of full-load).

Another T-Connected Autotransformer-Based 24-Pulse AC–DC Converter has also been presented in [14], however, the THD of the supply current with this topology is reported to vary from 2.46% to 5.20% which is more than 5% when operating at light load. The 36-pulse one was designed for vector controlled induction motor drives in [17] which has THD variation of 2.03% to 3.74% from full-load to light-load (20% of full-load) respectively but the dc link voltage is higher than that of a 6-pulse diode bridge rectifier, thus making the scheme nonapplicable for retrofit applications.

The delta/polygon-connected transformer-based 36-pulse ac-dc converter (shown in Fig. 1) for power quality improvement in [18] which has THD variation of 2.92% to 3.89% from full-load to light-load (20% of full-load) respectively and Delta/ Fork-Connected Transformer-based 36-pulse ac–dc converter (shown in Fig. 2) have been reported [19] for reducing the total harmonic distortion (THD) of the ac mains current. But these topologies require higher rating magnetics, resulting in the enhancement of capital cost. As is mentioned before, the Delta/Hexagon connected platform could simplify the resulted configuration for the converters and reducing the costs (shown in Fig. 3). The Delta/Hexagon scheme has an optimized configuration in this regard. The proposed design method will be suitable even when the transformer output voltages vary while keeping its 36-pulse operation. In the 36-pulse structure, two nine-leg diode-bridge rectifiers are paralleled via two interphase transformers (IPTs) and fed from a transformer. Hence, a 36-pulse output voltage is obtained. Detailed design tips of the IPT and totally the whole structure of 36-pulse ac-dc converter are described in this paper and the proposed converter is modeled and simulated in MATLAB to study its behavior and specifically to analyze the power quality indices at ac mains. Furthermore, a 36-pulse ac-dc converter consisting of a delta/hexagon transformer, two eighteen-pulse diode bridge rectifiers paralleled through two IPTs, and with a DTCIMD load Fig. 3.

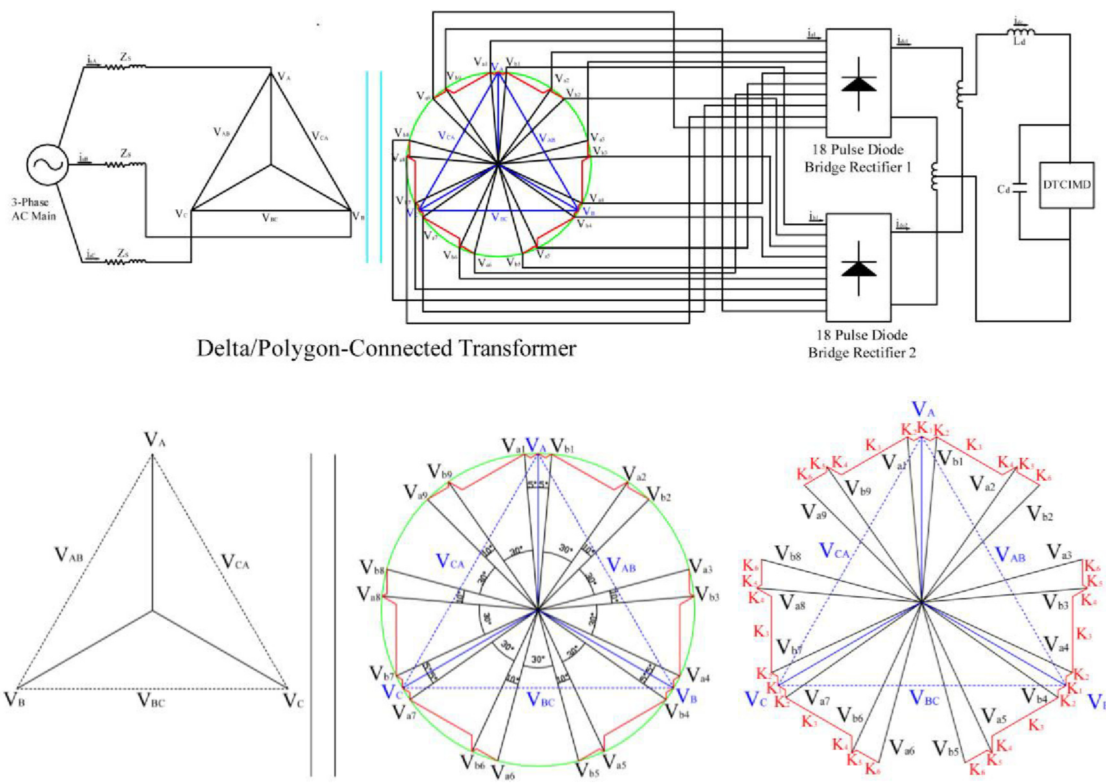

Figure 1. Transformer configuration, Winding arrangement, and Phasor representation of trans former for 36-pulse AC-DC converter having delta/Polygon connected secondary winding [18].