Multiport Power Electronic Transformer Topology for Traction Applications

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Abstract— This paper deals with the use of multiport power electronic transformer (PET) with multi winding medium frequency transformer (MW-MFT) for traction systems where in which single-phase line frequency medium voltage is converted into multiple medium frequency voltages. This system is proposed in order to reduce the size and cost of using the transformer in electric traction applications. The high frequency multiport PET can be used in locomotives, electric multiple units (EMU), marine propulsion, grid applications. This topology consist of multiple active bridge (MAB) circuits which act as isolation units. Voltage balancing control of DC source are described. Simulation results are presented to verify the performance of the proposed system.

Key words: Topology, Traction Applications

I. INTRODUCTION

Electric locomotives and EMUs commonly use Each module is connected to the separate medium frequency transformer(MFT). The AC input source is converted into DC output. Filters are used to suppress the harmonics produced in the DC voltage links. The converted output DC is fed to DAB circuit and the output of it is fed to traction inverters [Fig.2.],from which it is supplied into the traction motors[1]. The main drawback of this PET is the use of separate MFT for each module which increases the size and cost of the system. The fault occurs in cyclic manner due to the short circuiting of modules.

The existing systems limitations are turned into advantages of this proposed system. In this proposed system multiport PET topology is carried by using the MW-MFT isolation. This topology converts the single-phase medium frequency voltage into several medium frequency voltages and rectified to produce DC output links. The converted DC is fed to MAB (MW-MFT) [Fig.3.],where in which several DC links are given as output. [1]

Single phase line frequency transformers (LFT) with four quadrant power converters because of their reliability, simpler design and economical [1]. Besides of all these advantages they are not in operation in today's traction system due to its large size and weight and also due to second order harmonics produced due to the DC output voltage the primary winding of the LFT is directly connected to the overhead lines which gives AC input source from the grid. The secondary winding of the LFT is connected with the rectifier where in the AC input is converted into DC output[2]. These output DC links produces second order harmonics, in order to suppress the harmonics filters are placed. The output DC links are converted into AC with the help of traction inverters and it is fed to traction motors which are geared with the axial of the wheel which propels the locomotive [Fig.1.]

To compensate the limitations of LFT with four quadrant power converters, PET with DAB circuit was proposed. In this method single-phase line frequency AC voltage is converted into medium frequency voltages The output is fed as input to the traction inverters where it is converted into three phase AC and given to the traction motors.

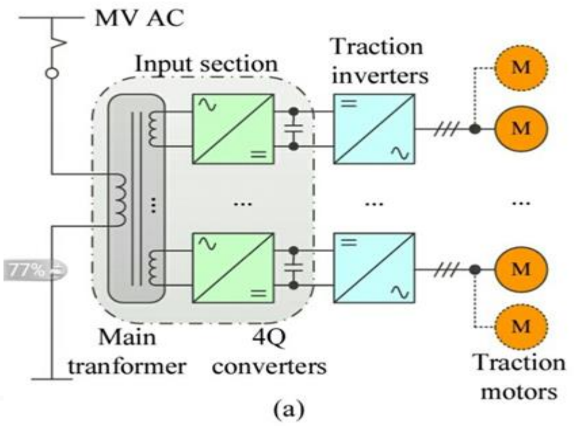

Fig. 1: single-phase line frequency transformer (LFT)

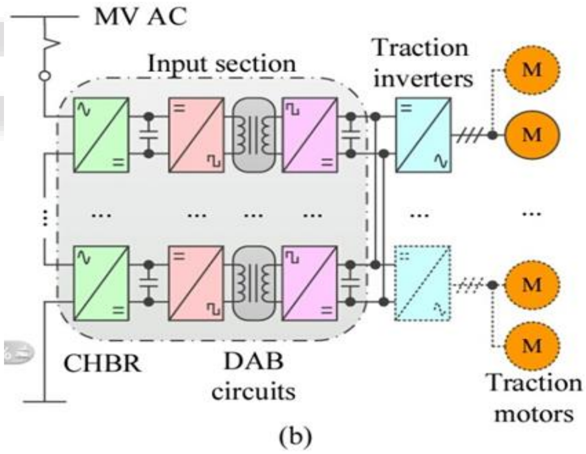

Fig .2: power electronic transformer configuration

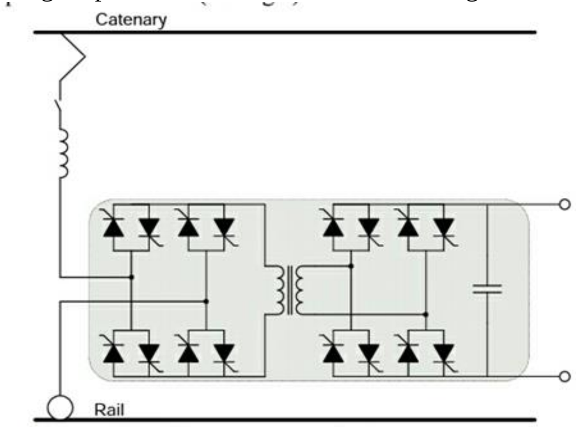

Fig. 2(a): medium frequenct transformer (MFT)

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II. STRUCTURE AND FUNCTION OF MULTIPORT-PET TOPOLOGY

A. *Structure*

The multiport-PET is the advanced topology proposed for electric traction applications. The multiport-PET is broadly divided into three main parts. The first part is the cascaded H-bridge rectifier (CHBR). This H- bridge rectifier is made up of semiconductor devices which converts the input AC voltage into DC. Filters are placed to reduce the harmonics produced due to DC output links. The second part is the MAB (MW-MFT) circuit. The MAB circuit consist of a inverter, MW-MFT and the converter set. The third part is the traction inverter where the DC output is converted into three phase AC and it is fed to the traction motors. The number of secondary windings of multi winding transformer is determined by the requirements of load. All windings of the transformer are linked by the same flux, therefore the load power cab be balanced naturally through the common transformer flux[1].

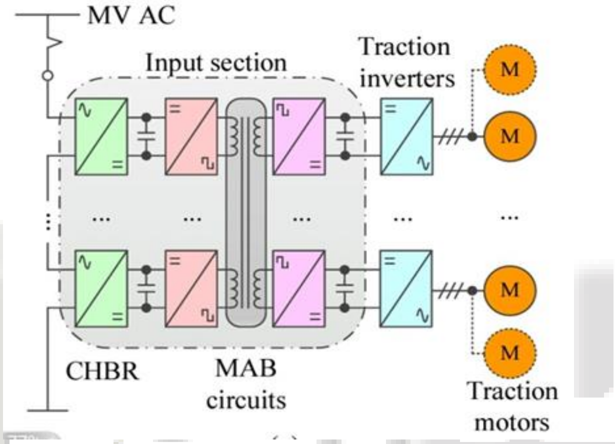

Fig .3: multiport power electronic transformer configuration

B. *Function*

25KV power supply is given to the traction system from the grid through the overhead line (or) catenary. From catenary, current will be smoothly collected by the pantograph. From the pantograph the medium voltage is supplied to CHBR, where the input medium AC voltage is converted to DC links. The generated DC links produces second order harmonics. These harmonics are suppressed using the filter. The output DC is fed to the MAB circuit where it is converted into several medium frequency voltages by means of MW-MFT. The output DC is converted into three phase AC while flowing through the traction inverters. From the traction inverters it is given to the traction motors. These traction motors are geared to the axiles of the wheel, hence wheel rotates. Wheels are fitted to the boggi, it is fixed to the body of the locomotive. Locomotive is coupled to the formation of coaches (or) goods. Finally resulting in train movement.

The motion of the train can be given as

a) Acceleration
b) Constant speed (or) free running
c) Coasting
d) Retardation due to braking

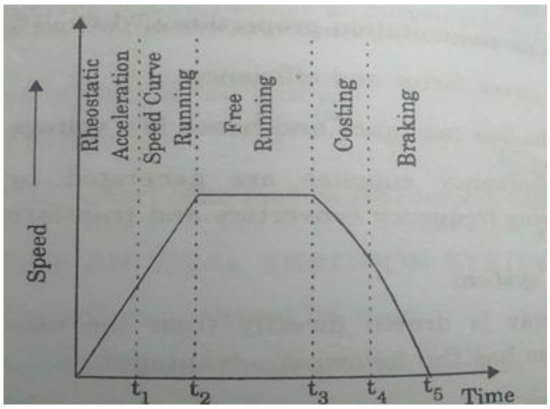

Fig. 4: Speed-time characteristics

The major advantages on using MW-MFT are,

a) The use of MW-MFT reduces duplication of transformers which reduces the size and weight of the transformer.
b) Since multi winding transformers are used common flux linkages are produced for both the modules, the load of different windings of the transformer can be different from each other.
c) The efficiency of multiport PET is higher than the general PET topology.
d) The power density is high in multiport PET than the typical PET configuration.

III. DC VOLTAGE BALANCING CONTROL

AC power of the MW-MFT isolations units are controlled by the relative voltage phases. In order to balance the DC voltages of each module. The power can be controlled by the feedback of DC voltages [1]. PID controllers are used to control DC voltages. The outputs of PI controllers are the reference currents of DC capacitors. Reference DC currents are the sum of capacitor currents and load currents. The reference powers are the products of reference DC voltages and reference DC currents.

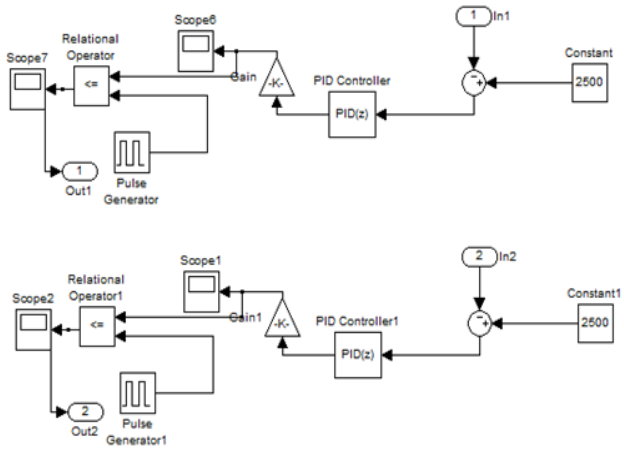

Fig. 5: Simulation diagram of PID controllers

IV. TOPOLOGY VERIFICATION

A. *Simulation Results*

At the time of 0s, the voltage balancing strategy starts working. The simulation result shows that the voltage is balanced steadily throughout the operation. The CHBR are in ZVS condition, even with no load, which culd decrease the switching losses of the system.

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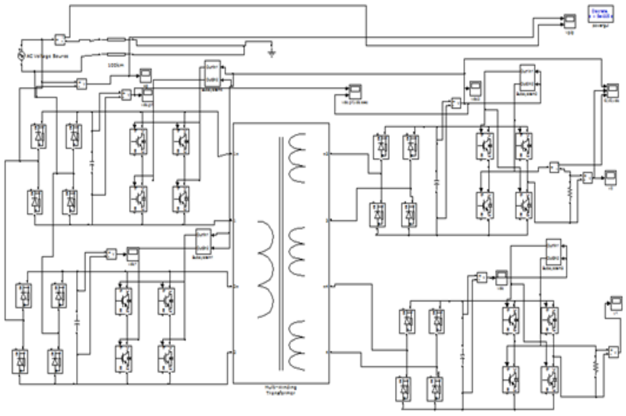

Fig. 6: Simulation circuit diagram of multiport PET

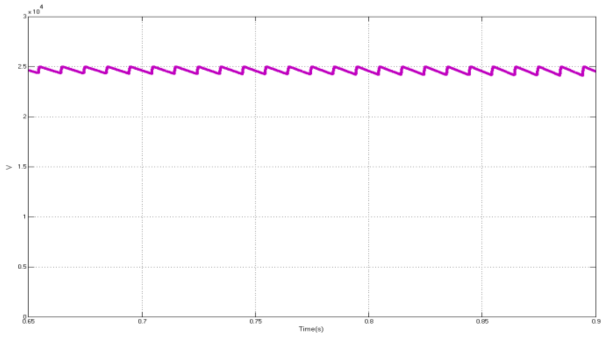

Fig. 7: Vdc waveform of multiport PET

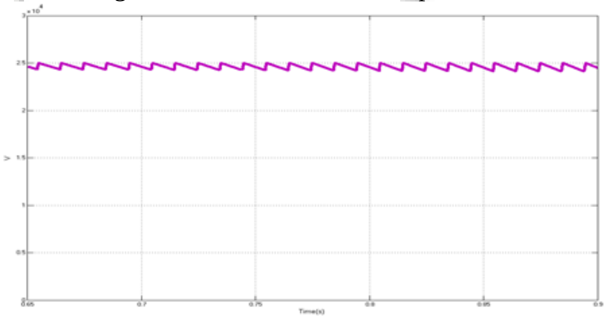

Fig. 8: Vdc1 waveform of multiport PET

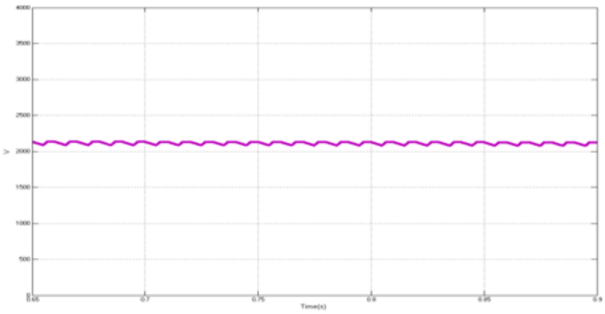

Fig. 9: Vdc2 waveform of multiport PET

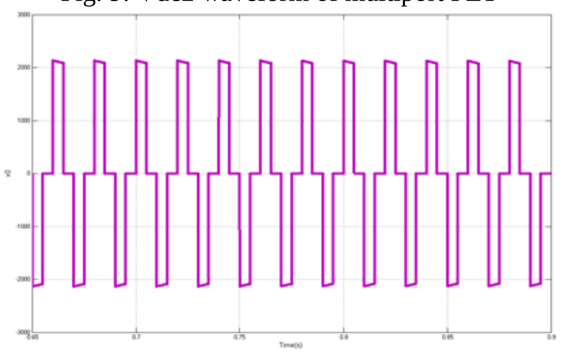

Fig. 10: V0 waveform of multiport PET

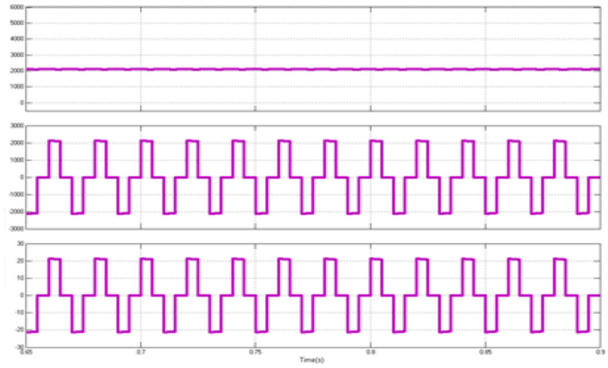

Fig. 11: V0, I0 , Vdc waveform of multiport PET

V. CONCLUSIONS

A multiport PET with MW-MFT isolation was analyzed in this paper. Power electronic transformers, providing a reduction in weight and volume accompanied by additional facilities, are considered a viable solution for the replacement of bulky low-frequency transformers. The feasibility of the proposed topology and voltage balancing control strategies is verified by simulation results.

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