

THE STUDY OF SEVERAL VARIANTS OF THE TRACTION DRIVE WITH MIDDLE-FREQUENCY TRANSFORMER

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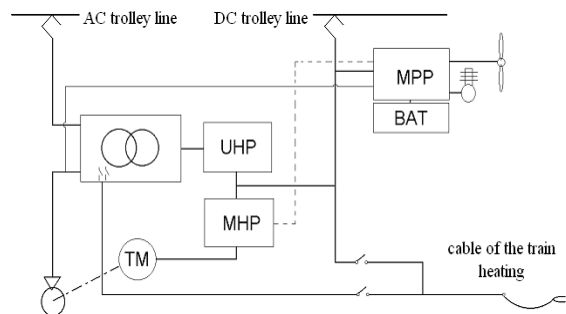
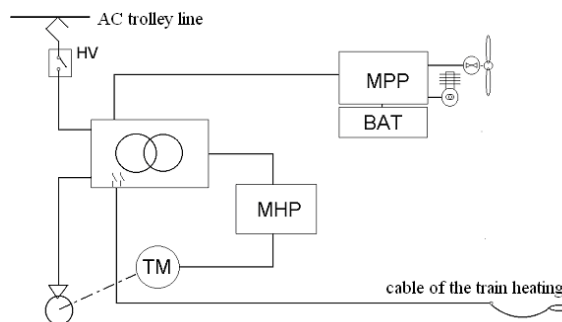
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Summary This paper presents research motivated by industrial demand for special traction drive topology devoted to minimization of traction transformer weight of traction vehicles. The main attention has been given to the special traction drive topology for AC power systems: input high voltage trolley converter (single phase) – middle frequency transformer (single phase) – output converter (single phase voltage-source active rectifier + three phase voltage-source inverter) - traction motor. This configuration can minimize traction transformer weight against topology with classical 50Hz traction transformer. Several variants of innovative topologies of the traction vehicles fulfil the weight reduce requirements have been presented.

1. INTRODUCTION

At the beginning, we can start describing configuration of the classical traction drive topology with the normal 50Hz (and especially 16,7 Hz) transformer situated at the input part of the traction vehicle as shown in Fig.1. In both cases, classical traction transformers are situated in the input part of the train vehicles and transformer outputs are connected to the traction converters for regulation the traction drives. Adjusting of the high level input trolley voltage to the applicable level and isolating character as well are the main aims of the traction transformer.

The high weight of the traction transformer worked at the frequency 50 Hz (and especially 16,7 Hz) leads to limitation of the maximal value of installed power in the traction vehicle. For example, we can install in the standard 4-axle locomotive maximal power 6 – 7 MW. Therefore in several applications (especially at the traction vehicles for high speeds), it is necessary to realise special topology of the traction drive which enables to achieve higher power (you will see in following chapters). Mainly special vehicles – e.g. electrical motor units – need this special traction topology more than locomotives.



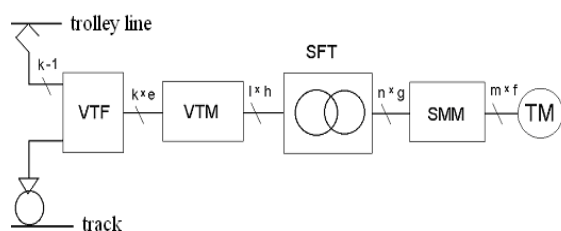
BAT – battery MPP – auxiliary drive converter
TM – traction motor UHP – main drive rectifier
HV – main switch MHP – main drive converter

Fig. 1. The topology of the classical train vehicle with 50Hz traction transformer at the input part– classical AC train (upper and left side) and multi power supply system train (lower)

2. TOPOLOGY WITH MIDDLE-FREQUENCY TRANSFORMER

Today we can see several low power applications using converter topology with middle-frequency transformer (e.g. UPS, switching supply sources, welding machines, etc.). According to the growing of the power electronic area (mainly the price decreasing of semiconductor components), we can look forward to the future using this idea for high power devices (e.g. traction application) as well. Basic topology of the electric drive with middle-frequency transformer is in Fig.2:

- Input converter (VTF in Fig.2) regulates input line voltage to the appropriate waveform for the middle frequency transformer (e.g. AC course with high frequency)
- Middle frequency transformer (SFT) galvanic insulates input and output and adjusts output voltage level
- Output traction converter modifies middle frequency course from transformer to suitable waveform for traction drive supply



SFT – middle frequency transformer

TM – traction motor **SMM** – middle voltage

traction converter **VTF** – high voltage filter

VTM – high voltage trolley line converter

Fig. 2. Topology of the electric drive with middle-frequency transformer

Basically the configuration of the input (VTM) and output (SMM) converter can be realised arbitrarily. In case of input and output AC voltage converters VTM and SMM can be design as direct (matrix converter [5] or similar topology [2,3]) or indirect (rectifier + voltage source inverter [4]) frequency converter.

In the Fig.2, several variants of number of phases change (letters k,l,m,n) and possibility of realisation of several potential level systems (letters e,f,g,h) are symbolically indicated. The most synoptical situation is single phase trolley line (it means $k=2$ in the Fig.2) and 3-phase supplying of the traction motor ($m=3$ in the Fig.2). For lower voltage levels, the single potential system is sufficient ($e=f=g=h=1$). However real traction applications present system which consists of several potential levels (see Fig.3B a 3D).

3. INPUT HIGH VOLTAGE CONVERTER REALIZATION

For designing high voltage converter, it is necessary to use high voltage semiconductor components (this should be an idea in the future – e.g. SiC based material) or special converter topology (following paragraphs) when input high voltage is spread on several active switches in serial connection. Number of semiconductor devices or whole semiconductor structures is high in the current time. For example using of the IGBT devices with 6,5 kV presents serial connection of the 13 transistors at the trolley line 25 kV. This number of devices has negative influence on the price of the drive and also on the potential decrease of reliability in comparison with classical solution.

There are several variants to realize high voltage converter (it means that input voltage is higher than operating voltage of each semiconductor component):

- Serial connection of semiconductor components – serial connection is very problematic and for realization it is necessary to guarantee voltage uniform spread – in steady state and transition state as well (e.g. using of special commutation circuits to correct balance of each layer).
- Special converter topology called – Modular Multi Level Converter [2] (see Fig.3 A). This converter is created by few arms and each arm should be making as a serial connection of single phase active rectifiers. So there is not serial connection of component but serial connection of converter arms.
- Converter topology with input voltage dividing at the converter entrance – e.g. high voltage multi level converter is connected through serial connection input capacitors (Fig.3 B). There is very important to guarantee voltage uniform spread at these capacitors [3] or using of special type of converter – for example matrix converter.
- Converter disposition very similar to the multi level converters – e.g. converter input part designed as a multi level converter with clamping diodes [Fig.3 C].
- Converter topology coming out of galvanic separate input converters connected to high voltage cascade in the input and connected to the different primary windings of middle frequency transformer in the output [4].

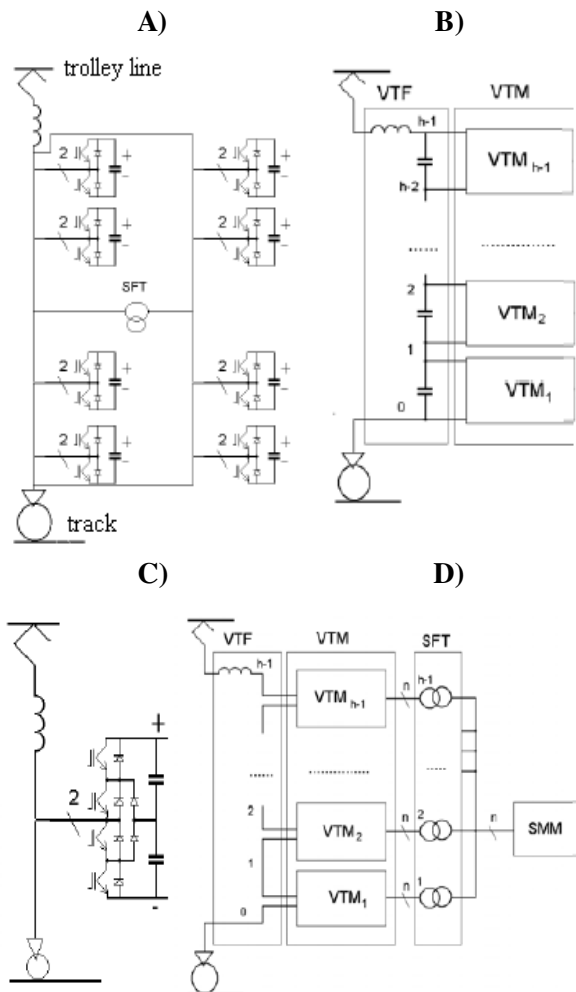


Fig. 3. Realization of the input high voltage converter – the topology of the electric drive with middle-frequency transformer

4. THE OTHER VARIANTS ENABLED WEIGHT REDUCTION

Except mentioned variants of the traction drive with middle-frequency transformer (Fig.2 and 3), it is necessary to think of other variants enabled weight reduction of the traction equipment. We can appoint for example using of the untraditional types of the traction motor (e.g. SMPM [1] or SRM [7]), also it is possible to use a traction transformer with more suitable parameters (e.g. superconductive traction transformer – [6]), respectively development of special variants of the drive topology absolutely without traction transformer. Some of these variants eliminate disadvantages of high power installed drives of the trains eventually disadvantages of the high voltage converters as well.

5. CONCLUSION

Several variants of innovative topologies of the traction vehicles fulfil the weight reduce requirements have been discussed. The main attention has been given to the traction drive topology: input high voltage trolley converter – middle frequency transformer – traction motor converter. At the mentioned variant, a lot of technical and economical problems can be supposed which will be necessary to solve. Concretely it is possible to suppose extensive problems especially at the realisation of the high voltage converter. However in the case of the successful solution of this ambitious project, we can suppose using achieved knowledge in other parts of the electrical engineering as well (e.g. area of Power engineering).

Acknowledgement

This work has been made within the research project of Ministry of Industry and Trade of Czech Republic MPO ČR FT-TA2/035.

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