

THE SIMULATION OF THE TRACTION DRIVE WITH MIDDLE-FREQUENCY TRANSFORMER

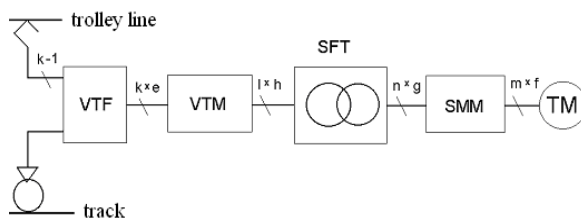
P. Drabek, M. Pittermann, M. Cedl, M. Los

Department of Electromechanics and Power electronics, Faculty of Electrical engineering, University of West Bohemia
Univerzitni 26, 306 14, Plzen, tel.: +420 377634437, mail: drabek@kev.zcu.cz

Summary: This paper presents research motivated by industrial demand for special traction drive topology devoted to minimization of traction transformer weight against topology with classical 50Hz traction transformer. The special traction drive topology for AC power systems consists of input high voltage trolley converter (single phase matrix converter) – middle frequency transformer – output converter - traction motor has been described. The main attention has been given to the control algorithm of the traction topology (inserting of NULL vector of matrix converter and Two-value control of secondary active rectifier).

1. INTRODUCTION

Today several low power applications using converter topology with middle-frequency transformer can be seen (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.1.



SFT – middle frequency transformer **TM** – traction motor
SMM – middle voltage traction converter **VTF** – high voltage filter
VTM – high voltage trolley line converter

Fig. 1: Topology of the electric drive with middle-frequency transformer

- Input converter (VTM in Fig.1) 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

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 [1,5,6] or similar topology [2,3])

or indirect (rectifier + voltage source inverter [4]) frequency converter.

2. SINGLE PHASE MATRIX CONVERTER

The single phase matrix converter is the one possibility of input high voltage converter according to the Fig. 1. Matrix converter can be understood as an alternative today standard indirect frequency converter (Active voltage rectifier – DC voltage bus – Voltage source inverter) for AC drives supplying.

Fig. 2 shows scheme of the traction drive with single phase matrix converter as an input traction converter which supplies middle-frequency transformer. The circuit consists of input high voltage filter connected to the input of the matrix converter which supplies middle-frequency transformer. The output of the transformer connects single phase active voltage rectifier, three phase voltage source inverter supplying AC motor is added through the DC bus line. Filter with capacitor is situated in the input of the matrix converter and the inductive load (winding of the transformer) is connected at its output. These facts have to be taken into account at the control of matrix converter – it cannot short circuit input terminals and disconnect output terminals at the same time.

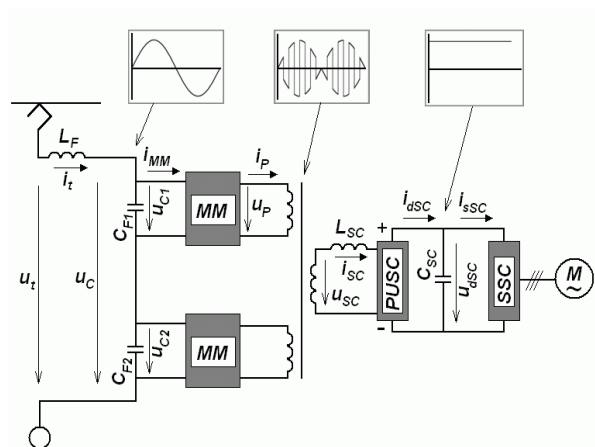
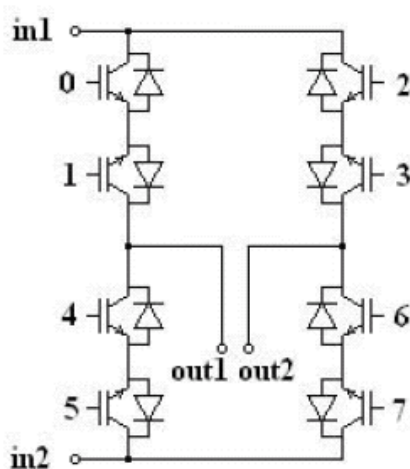


Fig.2: Topology with single phase matrix converter as a primary high voltage traction converter.

For control of the matrix converter following methods have been considered:

- **PWM**
- **Frequency control**
- **Inserting of NULL vector**
- **Two valued control**
- **Control by secondary active voltage rectifier**
- **Inserted commutations**

Detailed scheme of 1f matrix converter is shown in Fig.3. Switching individual branches proceed by sequential crossing within switching states. More details about converter commutation you can find in [1]. To control matrix converter following stable switching states will be used:



- 0167** – Input of matrix converter is directly connected to the output (**state “1”**)
- 2345** - Input of matrix converter is reversely connected to the output (**state “-1”**)
- 0123 (or 4567)** – Input of the matrix converter is disconnect and the output is short circuit (so-called NULL vector) (**state “0”**)

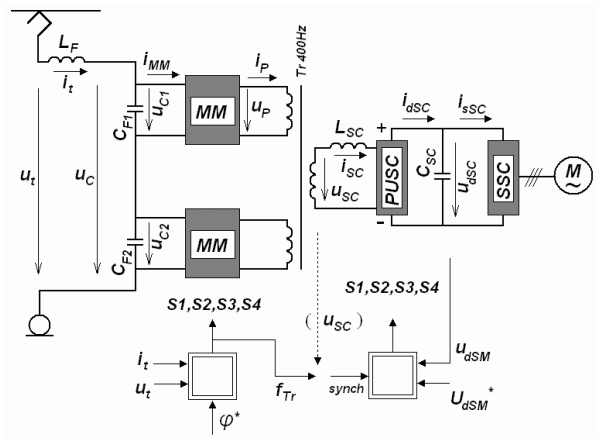
Fig.3: Detailed scheme of 1f matrix converter with individual transistors

From control methods mentioned above the controlling by inserting **NULL vector** will be consider.

3. CONTROL OF MATRIX CONVERTER INSERTING NULL VECTOR

At this control method the output active voltage rectifier takes square current waveform from middle-frequency transformer (two-value control) and primary high voltage converter (single phase matrix converter) ensures sinusoidal phase current taken from trolley line by inserting appropriate NULL vector to the control algorithm. At the same time the matrix converter controls phase shift

between trolley line voltage and current by inserting **NULL vector**. Detailed block diagram with synoptical charts of mentioned control method is presented in Fig.4 and Fig. 5.



MM is 1f matrix converter – primary converter
PUSC is secondary active voltage rectifier, *SSC* is secondary voltage inverter
 L_F is reactor of input filter of primary converter, C_F is capacitor of input filter, L_{SC} is clamping choke of the secondary converter

Fig.4: Power circuit of the drive with control circuit for control of the matrix converter inserting NULL vector

The proposed control method uses switching frequency 400Hz according to possibilities of high power semiconductor devices. Fig.6 and Fig.7 show appropriate simulation results of middle frequency topology. In the up-hand picture you can see variables of primary matrix converter – voltage and current of the trolley line, output current and voltage of the matrix converter flow to the primary winding of the middle frequency transformer. In the low-hand picture you can see variables of secondary active rectifier – input current and voltage (output variables of the transformer), hysteresis band of the input current, output voltage in the DC bus, average switching frequency (due to two-value control).

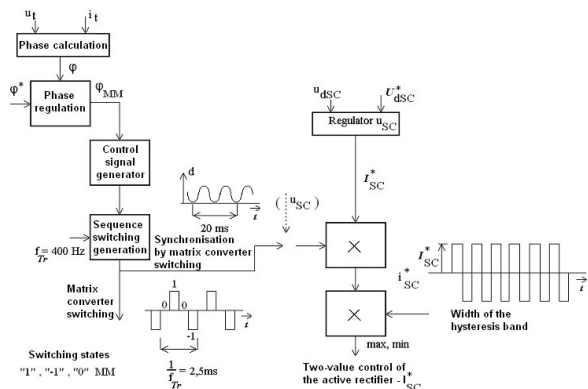


Fig.5: Block control scheme of the matrix converter inserting NULL vector and two-valued control of secondary active voltage rectifier

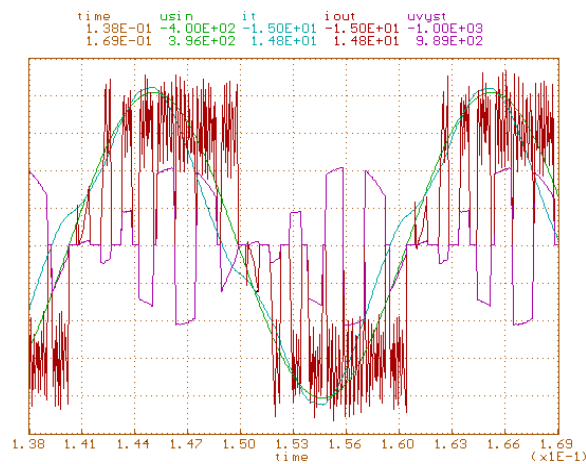


Fig.6: Simulation results of primary matrix converter (input and output variables) for following parameters: $U_t=230V$, $P=3kW$, $LF=40mH$, $CF=50\mu F$, $LSC=1mH$, $CSC=4mF$

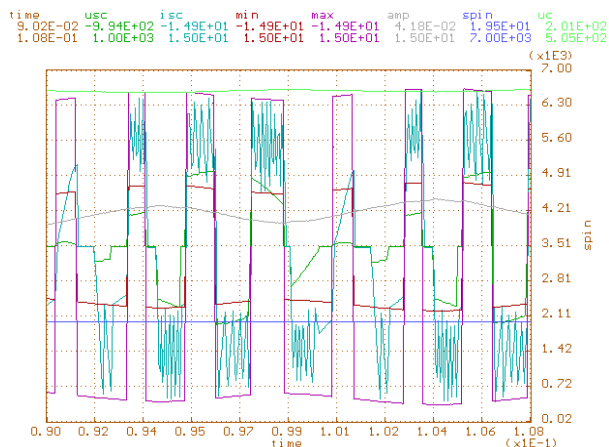


Fig.7: Simulation results of secondary active rectifier (input and output variables) for following parameters: $U_t=230V$, $P=3kW$, $LF=40mH$, $CF=50\mu F$, $LSC=1mH$, $CSC=4mF$

4. CONCLUSION

The main attention has been given to the traction drive topology: input high voltage trolley converter (single phase matrix converter) – middle frequency transformer – traction convert (single phase voltage-source active rectifier + three phase voltage-source inverter)er - traction motor. Control method of matrix converter using NULL vector and two-value control of secondary active rectifier has been proposed. These control methods ensure sinusoidal waveform and zero phase shift of taken current from trolley line. The actual research is focused on the improvement of converter behavior under distortion of trolley power line voltage and implementation of proposed control methods to the experimental model of the traction drive with middle-frequency transformer.

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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