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RESEARCH ON TESTING STAND WITH SYNCHRONOUS MOTOR WITH PERMANENT MAGNETS

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1. Introduction

Department of Electrical Engineering, Drive Section has been dealing with research work in field of drive control since 2004. The testing stand of traction synchronous motor with permanent magnets (PMSM) was the significant part of the traction drive prototype.

This stand was lent by Research Institute of Railway Rolling Stock to Transport Faculty Jan Perner, University of Pardubice. It is also used by Department of Transport Means to research of mechanical properties of contact between wheel and rail. At present these researches are proceeding concurrently.

The main goal of Drive Section is research in field of motor control. This control will be used at traction drive with PMSM for application of rail transport and city local transport in particular. Advantages of PMSM are known well. The torque from viewpoint of dimension and weigh of drive is the greatest advantage. This characteristic makes possible realization so-called direct drive (i.e. drive of axle or wheels without use of any gearbox) from viewpoint of vehicle construction. Direct drives with other motors (e.g. asynchronous motors) are not possible to place in vehicle because they have too big dimensions. Applications of simple direct drive of wheel simplify the whole construction of low-floor vehicle from mechanical point of view. This simplification of construction leads to time and financial savings from viewpoint of maintenance and other operating costs.

2. Testing stand

The testing stand contains a drive wheel unit. At conception of low-floor trams this drive will operate. Various conceptions of direct drive (e.g. drive without gearbox) were considered during realization of this stand.

The goal was to reach the simplest structure of drive which will create conditions for good drive characteristics of vehicle. Structure with partial cushioned motor drives of wheel by parallel spheroid joint was chosen. The real situation is shown in Fig. 1.

Fig. 1 *Testing stand with PMSM*

Motor is placed in silentblocks which enable its swing in horizontal direction. Wheel is situated on swinging arm pushed by pneumatic roller. This roller makes pressure to wheel up 4 to 50 kN which represents pressure of real wheel from vehicle. PMSM type SRT 225-S44 was made by VÚES Brno. This motor prototype was developed just for this testing stand. It is represented by 44 poles drive with inner rotor and liquid cooling. Cooling is done by two channels in stator jacket, see Fig. 2.

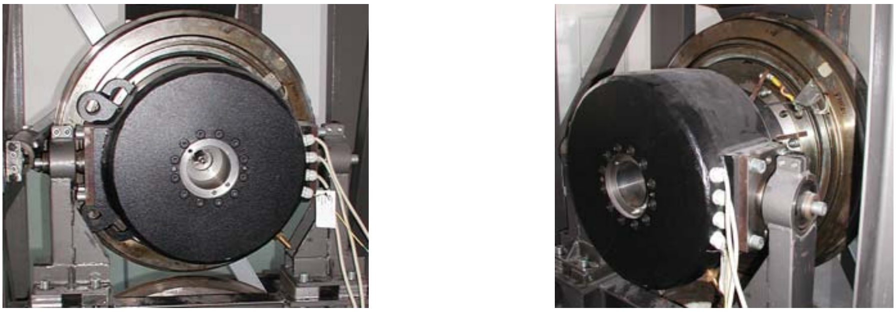

Fig. 2 *Synchronous motor with permanent magnets*

Asynchronous motor for measuring is added to testing stand. This motor is connected with axle of endless rail of stand by clutch. Asynchronous motor type MAF315S – 10 by MEZ Brno, factory Drásov is used as loading drive for load tests. This loading drive is fed from converter MICROMASTER 440 by Siemens. The converter is completed by breaking converter which enables breaking of whole drive. The speed sensor is placed on asynchronous drive and the sensor makes possibility of speed feedback for frequency converter of load drive. This represents top standard voltage converter which enables vector control with speed feedback. During last year torque sensor with dimension ±2000 Nm was added to loading drive between loading drive and endless rail, see Fig. 3.

Fig. 3 *Converter MICROMASTER and torque sensor*

The loading drive operates in recuperative mode made by feeding from the same DC intermediate circuit for PMSM converter and asynchronous motor MICROMASTER converter. Energy losses on breaking resistor are supposed only for emergency out of machine, is not occur by this structure, see Fig. 4.

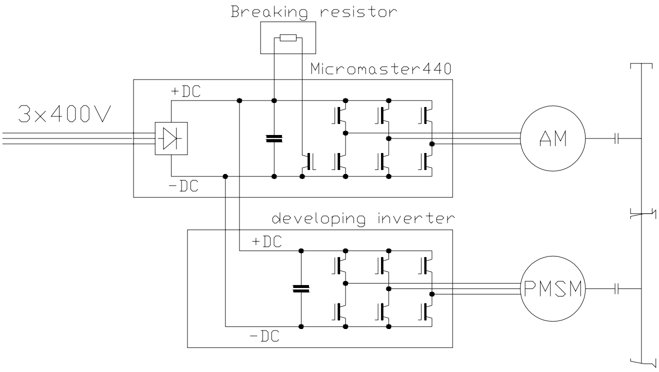

Fig. 4 *Diagram of converters structure*

3. Developing converter versions for PMSM

Originally developing converters for PMSM were designed and realized at Transport Faculty, University of Pardubice. In the first stage only low power converters were created, at which verification of control algorithms of control PMSM was realized at no-load mode, were constructed for tests of traction PMSM control.

Current version of power part, which enables tests under full-load, was purchased from company SEMIKRON. The purchased converter type B6CI 1100_772-175F by SEMIKRON is composed from three double transistors IGBT units SKM400GB124D which enable to switch current up to 400 A (25°C) and peak current up to 600 A. Tests of drive under nominal load and overload (e.g. maximal current of motor PMSM is 368 A) are possible to do with this over dimension converter. Converter has three exciters type SKHI22A. These exciters are constructed only in elementary connection, thus it was necessary to do adjustment of input control and output fault voltage signals. Correction circuits of voltage levels were utilized from previous version of converters.

Testing connection from previous versions of converters has been already used at this version. Converter by SEMIKRON has large-capacity capacitors (9 units with 4700µF/400V) which represent input circuit. Total capacity is 4700µF/1200V. This converter was built up in switchboard for reason of safety and EMI, see Fig. 5.

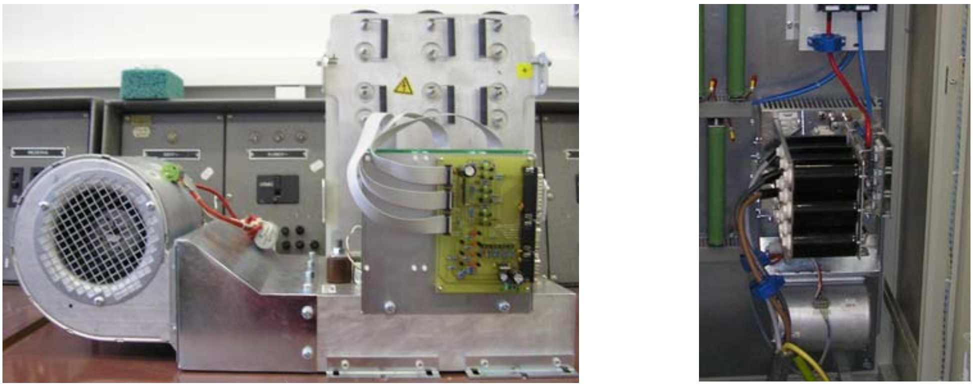

***Fig. 5** Converter by SEMIKRON and its installation*

The conception of structure of feeding part and control part were designed according to diagram, see Fig.6. Control system with processor TMS320C240 by Texas Instruments is placed on board TPP1 by Unicontrols and used for tests.

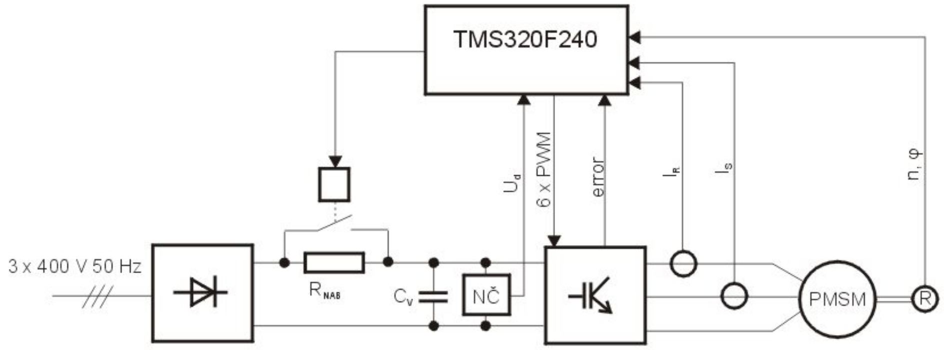

Fig. 6 *Conception of structure converter*

4. Position sensors

Nowadays, great attention is paid to evaluation without position sensors of synchronous drive rotor but usage of these sensors still predominates at practical applications.

Four-pole resolver as rotor position sensors by ATAS Náchod is utilized at testing stand. Resolver is electrical rotary machine which works as rotary transformer. It is constructed from rotor, which has actuated winding, and from stator which has two windings turn through 90°. Resolver has, except these windings, other windings in rotor and stator which are used to transmission of power to actuated winding between stator and rotor. Advantage of resolver over against optical sensors (IRC) is mainly in insensitivity to impurities and discrimination ability is given only by evaluation method. Evaluating electronics with circuit AD2S1200 by ANALOG DIVICES is utilized for signal evaluation of resolver. This circuit enables communication with control system of drive by IRC signals using 12-bit parallel or series bus. The system evaluates absolutely in 2048 positions per speed and generates information about faultless evaluation. In case of fault, it gives fault message. PMSM motor has 44 poles in this testing stand and used resolver is four-pole. For this case, 360 electrical angles correspond to 372 positions give by sensor at control.

5. Conclusion

The describing research workplace underwent plenty of modifications during the year 2007. The new configuration of power electronic part of control for testing workplace was adopted from first configuration of control which turned out very suitable. This configuration is composed from assembly of three switchboards made by external firm. The first switchboard contains complete control of loading drive and the second switchboard is used as unit for protections and testing resistance. The developing converter SEMIKRON for PMSM including its DSP control unit, voltage and current sensors and evaluating circuits of all sensors for testing workplace are placed in the third one. Hereafter the whole testing stand was also modified by torque sensor. This sensor, which is place between loading drive and endless rail, enables to compare real torque with calculated torque by mathematical model in DSP processor for research. Next reason of placing sensor is research in field of contact between wheel and rail. Others sensors, which enable to measure speed of wheel and endless rail, were placed on testing stand for this sort of research. The slip between wheel and endless rail is being found out on base of proceeding of sensor values. The next planned stage is change of DSP control unit and some evaluation circuits for new developing unit and circuits. The new control unit will be represented by 32-bit DSP processor 2812. This processor due to its bigger operation power will allow realizing more demanding control algorithms. The achieved configuration of testing workplace has the top technical level which will be improved for purposes of next research.

Lectured by: doc. Ing. Jaroslav Novák, CSc.

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Resumé

VÝZKUM NA TESTOVACÍM STENDU SE SYNCHRONNÍM MOTOREM S PERMANENTNÍMI MAGNETY

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Článek popisuje výzkum na testovacím pracovišti se synchroním motorem s pernamentními magnety (SMPM) v průběhu posledního roku. Hlavní cílem Oddělení pohonů, Katedry elektroetechniky, elektroniky a zabezpečovací techniky v dopravě je výzkum řízení trakčního pohonu. K tomuto účelu se využívá testovací stand s SMPM. V článku je uvedneno aktuální uspořádání, konstrukce a složení testovacího standu se snímači včetně vyvíjeného měniče pro řízení pohonu. Výhody zvoleného pohonu jako menší objem, hmotnost a moment setrvačnosti, velká momentová přetižitelnost, vyšší účinnost, možnost přímého pohonu vedou k hlavnímu důvodu nasazení u trakčních pohonů.

Summary

RESEARCH ON TESTING STAND WITH SYNCHRONOUS MOTOR WITH PERMANENT MAGNETS

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The paper deals with the description of research on the testing stand and actual configuration of testing stand last year. This stand was lent by Research Institute of Railway Rolling Stock to Transport Faculty Jan Perner, University of Pardubice. Department of Electrical Engineering, Drive Section has been dealing with research work in field of drive control since 2004. This control will be used at traction drive with traction synchronous motor with permanent magnets (PMSM) for application of rail transport and city local transport in particular. It is also used by Department of Transport Means to research of mechanical properties of contact between wheel and rail. At present these researches are proceeding concurrently.

The main goal is a research in field of control of traction PMSM. Advantages of PMSM are known well. The torque from viewpoint of dimension and weigh of drive is the greatest advantage. This characteristic makes possible realization so-called direct drive (i.e. drive of axle or wheels without use of any gearbox) from viewpoint of vehicle construction. Direct drives with other motors (e.g. asynchronous motors) are not possible to place in vehicle because they have too big dimensions. Applications of simple direct drive of wheel simplify the whole construction of low-floor vehicle from mechanical point of view. This simplification of construction leads to time and financial savings from viewpoint of maintenance and other operating costs.

Zusammenfassung

REGULIERUNGSTRUKTUREN DES FAHRANTRIEBES MIT DEM PERMANENTMAGNETSYNCHRONMOTOR

Ondřej ČERNÝ, Radovan DOLEČEK

Es wird in diesem Aufsatz die Forschung mit einem Permanentmagnetsynchronmotor (PMSM) auf der Testarbeitsplatz im Verlauf des vergangenen Jahres beschreibt. Das Hauptziel der Abteilung der Antrieben, des Lehrstuhls der Elektrotechnik, Elektronik und Sicherungstechnik im Verkehr, ist die Erforschung der Steuerung der Traktionsantriebes. Zu diesem Zweck wird ein Teststand mit dem PMSM benutzt. Angegeben werden in diesem Beitrag die Anordnung, Konstruktion und Komplettierung des Teststandes mit den Sensoren samt dem Umformer für die Steuerung des Antriebes, der entwickelt wurde. Es gibt diese Vorteile des gewählten Antriebes: Umfang, Gewicht und Moment der Trägheit sind kleiner, ferner groβe Momentenüberlastbarkeit, gröβere Wirksamkeit und Möglichkeit des direkten Antriebes begründen in ausreichendem Maβe den Einsatz bei den Traktionsantrieben.