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EMC OF CONVERTERS FOR INTERLOCKING DEVICE

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1. Introduction

At the reconstruction of the second railway corridor the new electronic interlocking device developed by Automatizace železniční dopravy (AŽD) was used in the railway stations. A control system and a drive of electromotive switch actuators are also parts of interlocking device. The drive control of the electromotive switch actuator is made by the contact switching devices at the classical systems. The couple of special relays are used for drive switching-over of switch actuator. These relays have to comply with the enormous reliability requests due to their construction and used contact materials.

The delivered interlocking devices for the second railway corridor are contactless with high rate of microprocessor technology utilization. The requirements for contactless electronic switching were implemented at control of electromotive switch actuators too. It was not possible to use the contactless electronic relays considering high safety and reliability requirements of devices, because breakdown can arise at these devices during fault, thereby unwanted switching-over of railway switch. It was decided to use the frequency converters for feeding of motors of switch actuators in several stations from the reason of drive characteristics improving and the reason of possibilities verification and characteristics of safe contactless switching of switch actuators motors.

The frequency control drive is operated in isolated system 3x 400 V. The cubicle switchboard for control and feeding of 16 electromotive switch actuators form the base unit. The switchboard contains particularly frequency converters, filters, interfaced and

control circuits of switch actuators and also overvoltage protections. The control circuits are galvanically separated from power part with electric strength 4 kV.

The motors of switch actuators are fed by unshielded cables from the switchboard. The length of cable between frequency converter and motor depends on localization of railway switch in railway station and it can reach up to 1.2 km. The special secure control signals used for hardware unblocking of converters are necessary except the standard control signals for switching of drive with defined direction of rotation which are set by computers via converter interface cards. The existence of these signals is given by increased requirements for operation safety [1-2].

At converter dimensioning, it came out from measuring results and frequency converter for motor with constant power 1.5 kW was used. The detailed information about the technical solution of the switch actuator drive is in [3-4].

The drive system of switch actuators with frequency converter was being developed and activated in co-operation with academic workplaces. These workplaces participated especially in hardware modifications of mass produced frequency converters, the solution of interface between frequency converters and computers of interlocking devices and the solution of EMC problems.

2. EMC of Frequency Control Drive

The EMC of devices at network side is protected by network filter and reactors. The network filter is common for all converters in switchboard and it is dimensioned for parallel operation of five drives because the simultaneous switching of higher number of railway switches is not supposed at station operation. The EMC security at converter output is significantly intensive and costly where length of unshielded cables to motor is supposed up to 1.2 km. The frequency converter works with switching frequency of PWM 10 kHz. Usage of three-phase sinus filters, which eliminate higher current and voltage harmonics, was only one way to interference elimination at converter output. The interference elimination at converter output was measured and evaluated by independent company according to standard EN 50121-3-1. The measurings were made by using selective microvoltmeter in 9 kHz to 30 MHz band [4].

Magnitude of parasitic signal in signal lines led parallel with lines for feeding of motor and magnitude of parasitic signal in distance 10 m from power line were found out. The length of line was 1 km from motor to converter. The level of parasitic signals did not exceed the given values by standards and the levels of parasitic signals were not measurable at numerous frequencies. The findings of measurings certified the usability of designed type of sinus filter which is dimensioned for 2.2 kW motor. The filter is connected as gamma element. The filter reactors have ferrite cores and their inductivity in unsaturated state is 12 mH. The capacity of filter capacitors is 2 μ F. The effect of sinus filter is qualitatively visible from Fig.1 and Fig.2. The waveform of output delta voltage of

converter is on Fig. 1 and voltage of output sinus filter is on Fig.2. The elimination of higher harmonics by filter is considerable.

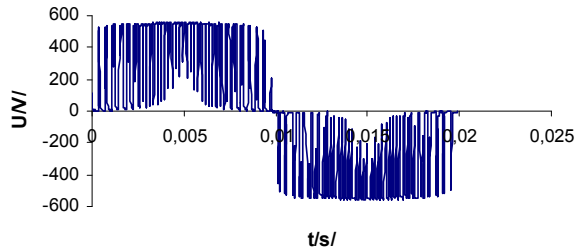


Fig. 1 The delta voltage output of frequency converter.

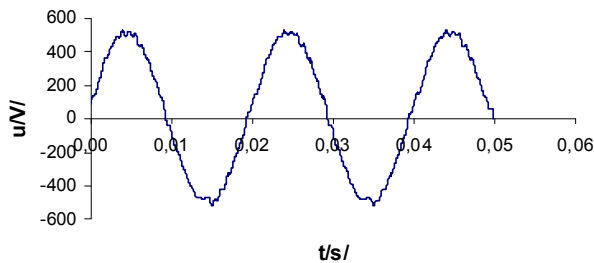


Fig. 2 The delta voltage of sinus filter output.

3. EMC solved at Interlocking Device

Usage of sinus filter is in the given application essential however its usage did not avoid occurring of some parasitic effects due to frequency converter with PWM. The parasitic capacities of power IGBT (Insulated Gate Bipolar Transistor) modules of converters are in range from tenths to units of nF. The relatively high parasitic currents with these capacities can arise because dv/dt at power elements run into values over 1000 V/ μ s [5].

The other parasitic capacities occur at the cable. The values of these capacities are in range tenths of nF/m. The parasitic capacities of motor reach the values in range units of nF. Although the cable and motor are fed by voltage, which is behind the sinus filter, it turned out that this filter does not eliminate higher harmonics of current and voltages without remainder. The structure of circuit with these parasitic capacities is on Fig. 3. The parasitic couplings, particularly capacitive couplings of converter, cable and motor, emerged as problematic in operation [6]. The certain potential came through the parasitic capacities of motor on the case of switch actuator in rail yard. Thereafter the danger voltage to earth occurred on the case of the switch actuator because the magnitude of the voltages depended on isolation quality of switch actuator case from earth. At the worst cases the values of this voltage got over 100 V. These problems do not occur at the quality manufactured standard drives with frequency converters, because

the converters work in isolated system and all electrically passive parts are connected with earthed potential or possibly with protective earthed conductor. The problem was solved at last by connection of capacitor nodes in sinus filters and following earthing of these nodes. But this connection activated protection of isolative state because current of this protection was closed through discharge resistors of sinus filter capacitors. This problem was solved by centre disconnecting of discharge resistors from centre of sinus filter capacitors. The majority of switch actuators operated without any problems after these adjustments, defective shutdown of converter occurred at only a few drives sporadically and casually during switching-over of railway switches. In the case the converter reported the error of overload by current at starting. The pure theoretical solution was almost impossible in this case because the whole system is very sophisticated from viewpoint of PWM frequencies.

This sophistication is given particularly by existence of many parasitic capacities in the system, the stochastic wave effects at feeding cable to motor and high dv/dt at frequency converter output. Moreover the specific configuration of drive is dependent on localization of switch actuator in station rail yard and trace of feeding cables.

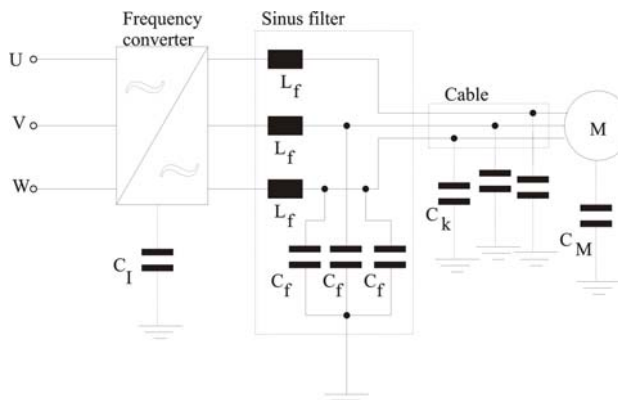


Fig. 3 Circuit structure of switch actuator drive.

4. Solution of Contactless Switch

The above mentioned solution of contactless switch is functional and provided valuable experiences from which it proceeded at the next research in this field [7-9]. The high price and difficult solution of EMC problems are disadvantages of device. The functional sample of new conception switch was constructed and tested in co-operation with academic workplaces in regard of AŽD interest to continue in research of solution possibilities of contactless safe switches. The conception of this switch is original and it was patented. The new conception of switch does not work with PWM, wherewith are given preconditions to elimination of EMC problems. The preconditions to marked reduction of price in comparison with the first version of device are given by own construction as well.

The absence of frequency starting of motor at the new solution in comparison with the native solution is the disadvantage. The mechanical characteristics are the same as at the direct connecting of motor to the network. The used motor has resistance cage and reaches up to high break torque and the current switch actuators are operated this way at the railways it is not this disadvantage radical. The rectification of input AC voltage and its transformation to alternating voltage is the fundamental idea of new conception of safe switch. From this the safety DC intermediate circuit originates. At the fault – puncture of some of power elements, in this case the creation of three-phase system at the output of switch does not happen. The faultless function, at all contactless switched elements of the circuit including their excitations by exactly defined signals, is necessary to creation of this system.

The new developed device works only with sinus voltages and currents. The DC intermediate circuit without any filter element is created for each feeding phase i.e. the whole circuit is fed from galvanic decoupling three-phase source with galvanic decoupling of individual phase to one another. The creating of common node of phases is done behind the safe switch. Usage of isolation transformer is given also by request to creation of isolation feeding system which is necessary from viewpoint of the function of the whole interlocking device. The whole conception of power connection is obvious from Fig. 4. The safety DC intermediate circuit is put only between two feeding phases of motor, the third phase is connected directly because this phase without synergy with other phases cannot create rotary field at connected electric motor.

The waveform of output voltage in the phase is the same as the waveform of input voltage but the transistor inverter represents in connection with DC intermediate circuit the safe switching element. The reservation of drive is safeguarded by five contactless solid state relays, which are connected behind safe switch. This relays are not shown in the circuit structure.

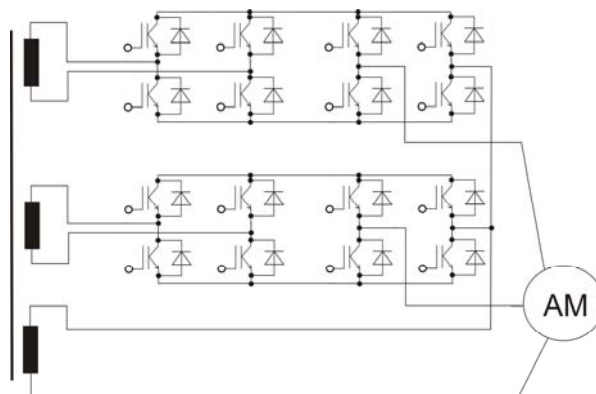


Fig. 4 Circuit structure of the new version of safe switch.

At the present it is assumed that the new version of contactless switch will be practised in the final applications.

4. Conclusion

Usage of frequency converters as element for safe contactless switching of motors of switch actuators of railway switch proves both from viewpoint of mechanical characteristics of drives and from viewpoint of protection of necessary functions under conditions of safe railway operation. Many problems with EMC of frequency converter with PWM operated in insulated systems with long feeding cable between converter and motor occurred in unexpected range. Considering very different conditions of using particular drives in real operation, it was not possible to use the theoretical processes to solution. Although many problems were solved satisfactorily, it is necessary to note that EMC of described application is not possible to regard as concluded. From this reason the described system was not used at the next process of building of the second corridor at the Czech Republic. At the present the contact electrical devices are used for switching of motors of switch actuators of railway switches, but the patented solution of safe contactless switch, which works without PWM, is made ready. In general it can be stated on the basis of experience with the described application that usage of classical industrial frequency converters in isolated system, in addition with long feeding cable to motor, is from viewpoint of electromagnetic compatibility very problematic. It is suitable to give priority to the classical solutions under meeting usual criteria for structure at applications of frequency converters from viewpoint of EMC.

Acknowledgements

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Resumé

EMC měničů pro zabezpečovací zařízení

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Článek se zabývá problematikou elektromagnetické kompatibility (EMC) frekvenčně řízeného pohonu elektromotorického přestavníku pro železniční výhybky. Pro napájení asynchronního motoru přestavníku je využíván frekvenční měnič s šířkově pulsní modulací (PWM) a výstupní sinusový filtr. Uvedený pohon je napájený frekvenčním měničem přes dlouhý nestíněný kabel a je provozován v izolovaném systému napájecích napětí. V článku jsou analyzovány problémy EMC vyskytující se jak při vývoji tak při provozu pohonu. V závěru článku je uvedena nová verze bezkontaktního bezpečného přestavníku, který pracuje bez použití PWM.

Summary

EMC of Converters for Interlocking Device

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The paper deals with problems of electromagnetic compatibility (EMC) of frequency control drive of electromotive switch actuator of railway switch. The frequency converter with Pulse Width Modulation (PWM) and the output sinus filter are used for feeding of the asynchronous motor of the switch actuator. This drive is operated in isolated system of feeding voltages. The drive is fed by frequency converter with unshielded cable. The EMC problems occurring at development and operating of drive are analyzed. The new version of contactless safe switch, which works without PWM, is presented at the end of this paper.

Zusammenfassung

EMV der Umformer für Speisung der Eisenbahnsicherungsanlagen

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Der Artikel präsentiert die Fragen der EMV eines frequenzregulierten Antrieb der Elektromotoren für Eisenbahnweichen. Für die Speisung dieser Asynchronmotoren benutzt man einen Umformer mit Breit-Puls-Modulation (PWM) und einen Sinusausgangsfiler. Dieser Antriebmotor ist mit einem Frequenzumformer über einen langen nichtgeschirmten Kabel gespeist und im Netz mit isolierter Speisespannung betreibt. In dem Artikel sind die Probleme mit der EMV, die in der Entwicklung oder auch im Betrieb dieser Anlage analysiert. Im Artikelschluß ist eine neue Ausführung eines kontaktlosen Weichenantriebmotor beschrieben, die ohne PWB arbeitet.