PLC CONTROLLED ELECTRIC DRIVES CONNECTED INTO SERIAL INTERFACE WITH USS PROTOCOL

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ABSTRACT

The paper deals with application and experience of control system for nowoven textile production line. The line consists of real-time managed electric drives controlled by PLC. The PLC generates waveform of drive speed. PLC is used to control electric drives connected into serial interface. The communication between PLC and drives is realized by USS protocol, that is suitable for managing, configuration and monitoring of electric drives with MicroMaster frequency converter. The aim of research is continuous speed change. That means to find suitable configuration of PLC's software and parameters of frequency converters.

1 INTRODUCTION

The developers of Nonwovens Department made rotation machine STRUTO and ROTIS for nonwoven textile product. These two machines together create base for new kind of textile products. That new machine is placed in the school laboratory. The construction of the laboratory machine did not contain control system for drives and further necessary equipment. The development of the new control system was able to bring great chance and space for new very shape different nonwoven textile products. That production line consists of nine electric drives with five frequency converters. Five independent electric shafts managed by higher control system form these drives. Only two of these electric shafts are significant for final shape of nonwoven textile. These drives are very important a critical for control system.

New textile products made by production line and design of control system were integrated into research centre "Textiles" section "C – Measuring and Controlling The Textile Processes". How the production line looks like and works let see [3]. The textile net comes out card machine and comes in Serve drum that takes away this material with same speed as output card machine conveyer work. The Work drum has group of discs with big deep teeth. The rotation speed ratio between Work and Serve drums determine height of the final nonwoven textile. And the same ratio between Work drum and Output conveyor makes count of fold per metre that means material density. The Serve drum and remaining rotation units has not important influence for final shape of produced nonwoven textile.

The design of electric equipment includes the electric distribution board with all frequency converters, fuse switch disconnections, proximity sensors, pushbutton units, indicator lights, operator panel and control system and another electric staff. The research team of new nonwoven textile needs open control system for prototype that will have to purpose big variability and time shifted waveforms of rotation speed for each shaft. And economics situation in textile industry wants cheap and industrial standard control system. Those conditions were fundamental for control system selection. Suitable control system for this application is model with PLC (Programmable Logical Controller), operator terminal and frequency converters. The following configuration has suitable low final price:

- PLC SIMATIC S7 226 DC/DC/DC
- Operator terminal SIEMENS OP7
- Frequency converters SIEMENS MicroMaster 420 (MM420)

We did not use the PLC with built-in analogue outputs that can be used for control of drive speed because this variant is quite expensive and does not support on-line configuration of frequency converter. We decided to buy the PLC with two communication ports. One serial port is used for data transfers with operator terminal and second one is for speed control and configuration of drives connected into common serial bus. The Siemens company developed USS protocol (Universelles serielles Schnittstellen - Universal Serial Interface) for this kind of application. During control system evolution was discovered same troubles and questions about control system with USS protocol. The following text deal with analysis discontinuous control system with USS in application required continuous leading. The text informs about USS protocol features, will present standard problems and their solving and mathematics formulas for calculation suitable setting of control system for demanded quality and continuity of rotation speed.

2 USS PROTOCOL SPECIFICATION OVERVIEW

[1] The USS defines master-slave access technique for communication via a serial bus. Essential features of the USS protocol are:

- It supports a multi-point-capable coupling, e.g. RS-485 hardware
- Master-slave access technique
- Single master system
- Max. 32 nodes (max. 31 nodes for slaves devices)
- Simple, reliable telegram frames
- Easy to implement
- Operation with either variable or fixed telegram lengths

One master and a maximum of 31 slaves can be connected to the common continuous bus. The master selects the individual slave device via an address field in the telegram. A slave itself never can transmit without request telegram from the master. The master function cannot be transferred to another network node (single-master system). Communication is realized in the half-duplex mode.

Only cyclic telegram transfer can be used in drive technology. The master station is responsible for cyclic telegram transfer. All slave nodes are addressed one after the other in identical time intervals. The defined response time is very important for open-loop and closed-loop tasks for controlled drives. The master continually transmits telegrams to the slaves and waits for a response telegram from the addressed slave device. A slave must send a response telegram: if it receives an error-free telegram, and it addresses in this telegram.

The Siemens Company offer special USS library for PLC SIMATIC S7-200, which contains full implementation of USS protocol. The library composes four kind of instruction. The USS instruction for initialization of protocol, operations for read and write parameters of frequency converter and for speed control of drive. The typical and guaranteed time interval between two telegrams can be found in the SIMATIC S7 - 200 Manual [2] but we do measurement and simulation of it.

3 SYSTEM BEHAVIOUR AT DIFFERENT SETTING

Textile production line illustrated system behaviour at different setting. The production line has five separately real-time controlled drives by frequency converters connected to serial bus. PLC addressed control drives one by one in the unfinished cycle. Cardinal influence for drive control interval has communication speed of serial bus and number of converters connected to bus. The time interval increases with more converters and/or with lower communication speed. Big change of revolution between two time intervals promotes greater revolution inaccuracy of drive. The frequency converter has a lot of parameters for configuration. The quality of continuous rotation speed depends on the time interval, size and speed changes of rotation and ramp-up and ramp-down time parameters. The ramp-up time parameter defines acceleration rotation speed from standstill to maximum. In example situation is used sinusoid waveform to control rotation speed because is used for nonwoven textile production. Waveform is generated by PLC and transferred as discrete signal by USS protocol. The sinusoid typically has period in seconds range and size of change (amplitude) is about hundred rotations per minute. In the following text the period and amplitude are set: average S = 400 rpm, amplitude A = 200 rpm, period T = 5 s (standard testing signal).

Rotation speed response of the drive with system configuration: 5 converters, 9600 Baud transmission speed and the best ramp-up and ramp-down time “Fig 1”. The figure show situation when ramp times are counted as the best ramp-up and ramp-down times by formula “in (1)”. The ramp times are counted from time interval Tinterval between two data packets for concrete converter and maximal change of revolution on several signal periods ΔnMAX. This ramp times are the best. The simulation of control system is trusty because we compared many measurements on real drive with revolution sensor with simulated results. We made around a one hundred comparative measurements.

$$T_{UP\_IDE} = T_{DOWN\_IDE} = \frac{\Delta n_{MAX} \cdot T_{interval}}{2 \cdot A \cdot \sin\left(\frac{\pi \cdot T_{interval}}{T}\right)} [s] \tag{1}$$

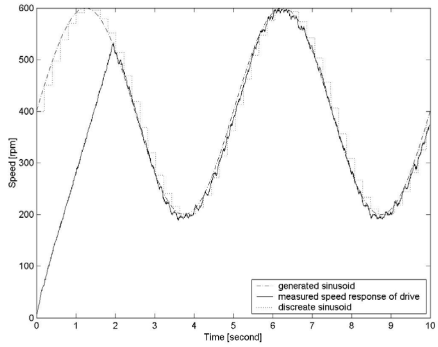

Fig. 1: *Speed response of system with the best ramp times counted by formula "in (1)"*

4 CONFIGURATION AND SETTINGS OF CONTROL SYSTEM

This paragraph shows how the quality waveform of drive revolution is defined for textile production line. In the following text we will not thing about waveform of drive revolution as general signal and take small point of view on this signal. As the quality waveform of revolution will be waveform with minimal sum of the error area. The error area is space created of drive response waveform over or under generated signal let see "Fig. 2". The scale of quality "in (2)" is summation of error areas in one period of signal. For textile production we will find ideal system settings where the summation of error area is minimal.

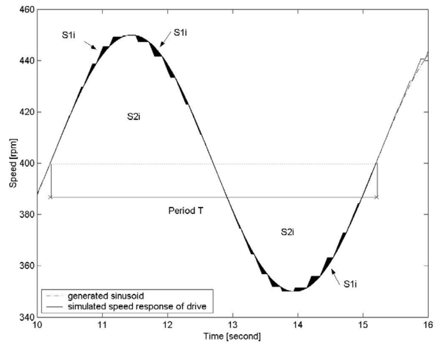

Fig. 2: *The error areas definition*

$$\text{Quality} = 100 - \frac{\sum_i S_{1i}}{\sum_i S_{2i}} \cdot 100[\%] \qquad (2)$$

The next and important point is quick and simple find method for definition area of application. To get this area we have to decide what are input and output variables of system and what are our goals. We know that control system have certain count of frequency converters, period and amplitude of control signal generated by PLC program and quality of drive speed waveform. Optional parameters are communication speed on serial bus, ramp-up and ramp-down time. We found dependence between those variables for the best ramp-up and ramp-down time "in (1)". We valued size of quality at system configurations "Fig. 3". Which are determined by number of drives and communication speed of serial bus. Time interval

Tinterval combines those two parameters.

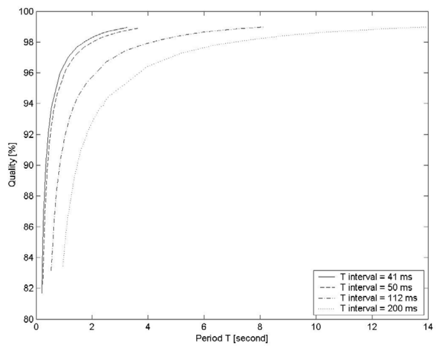

Fig. 3: Quality waveform dependence on s*ignal period and system configuration*

There is important empirical formula “in (3)” obtained from simulation processes. Its using is very easy and quick for machine designers.

$$\text{Quality}(T, T_{interval}, T_{Up} = T_{DOWN} = \text{best}) = 100.21 + 0.075 \cdot T_{interval} - \frac{0.32 + 74.21 \cdot T_{interval}}{T} [\%] \quad (3)$$

5 USS PROTOCOL EVALUATION FOR CONTINUOUS CONTROLLED APPLICATIONS

This article mapped USS protocol features. The simulation results are in graphs and are ready for electric designers who makes machine based on this control system model. The results give quick overview about suitable application. Obtained results will be used for expansion of control programme in the PLC controlled textile production line. When machine operator change kind of nonwoven textile the PLC have to change ramp-up and ramp-down times on frequency converters for same quality.

In generally this control model with frequency converters connected on serial bus is very popular for industrial application. The USS protocol is relatively cheap and simple protocol for control system then robust industrial standard Profibus is. The control of drives through serial bus brings many advantages as an online setting and diagnostics. The USS protocol is suitable for slow-changing action. But each application needs specific requirements for control and dynamics of electric drives. Somewhere USS protocol should by suitable variant and in the remaining cases must be use different protocol.

REFERENCES

[1] Siemens AG: “Universal Serial Interface Protocol USS Protocol”, Siemens Manual, 09.1994

[2] Siemens AG: “S7-200 Programmable Controller - System Manual”, Siemens Manual, 03/2000

[3] P.Privratsky: “The Control of Technological Line on Production Nonwoven Textile for Health Service”, Diploma thesis, TU Liberec, 2001