

ROTOR POSITION MEASUREMENT OVER INDUSTRIAL COMMUNICATION NETWORK

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Abstract – PROFIBUS is the common industrial communication network in modern industrial plants across Europe. It can be used for control of sensors and actuators. Typical example is electric drive. In this paper some experimental results of rotor position measurement and control of two electrical drives are described. Data acquisition is done over industrial communication network.

Experimental results and the solution for rotor position control and measurement of two electrical drives via PROFIBUS industrial communication network is analyzed and discussed, for two different hardware configurations.

Keywords: real-time position measurement, industrial communication network PROFIBUS, electric shaft

1. INTRODUCTION

By definition, electrical shaft consists of two or more electrical drives, all working in synchronicity. It is usually used in applications in which classical mechanical shaft can't be used, due to its length or some other restrictions. Typical applications are crane lifts, paper and textile industry. It can be realized using present component structure in modern industrial plant, where control is done over industrial communication network. Described application deals with control of both rotors speed and position. Precise rotor position real-time measurement is important, due necessary exact feedback information.

2. LABORATORY MODEL

Laboratory model consists of programmable logical controller (PLC, type S7 315-2DP or S7 316-2DP, cycle time up to 1 ms), PROFIBUS network (baud rate up to 12 Mbps) and two electrical drives. Each electrical drive has synchronous motor permanent magnet (SMPM) with resolver as positioning sensor. Resolver is fed by 5 kHz voltage supply. Rotor position information is measured in two different ways. In master drive (modern digitally controlled inverter), information is transferred to PLC as a double integer. The slave drive (analogue controlled), converts resolver signal to increment sensor signal with 1000 or 500 increments per revolution. Distributed module IM-178 counts increment sensor impulses up to 1.5 MHz, and also transfers this information as double integer to the PLC over industrial communication network.

Speed or torque reference is controlled by PLC over industrial communication network.

Except in "Electrical shaft" there is also master-slave configuration in PROFIBUS network, PLC acts as master, and drives as slaves. PLC controls speed/torque of those drives in order to achieve required rotor position.

3. REFERENCE MEASUREMENT

Verification of data, collected by PLC via PROFIBUS, is made by another measurement system. It consists of 128 channel digital acquisition device, with 14-bit resolution, and up to 80ks/s sampling rate (MUSYCS). Increment sensor signal (0-5V) is transferred from MUSYCS to PC via ISA slot interface card, and analyzed with FAMOS software.

Rotor position $\mathcal{G}_{AB}(t)$ can be calculated from both increment sensor signals $A(t)$ and $B(t)$ (1) or only from one increment sensor signal $A(t)$, which results $\mathcal{G}_A(t)$ (2).

$$\mathcal{G}_{AB}(t) = \int_0^t \left(\dot{A}(t) \left(B(t) - \frac{B_{\max}}{2} \right) + \dot{B}(t) \left(A(t) - \frac{A_{\max}}{2} \right) \right) dt \quad (1)$$

$$\mathcal{G}_A(t) = \int_0^t \text{abs}(\dot{A}(t)) dt \quad (2)$$

Equation (2) have smaller accuracy, without determination of positive or negative position increment, but in some experiments it can be used, for example when all position increments are of the same polarity.

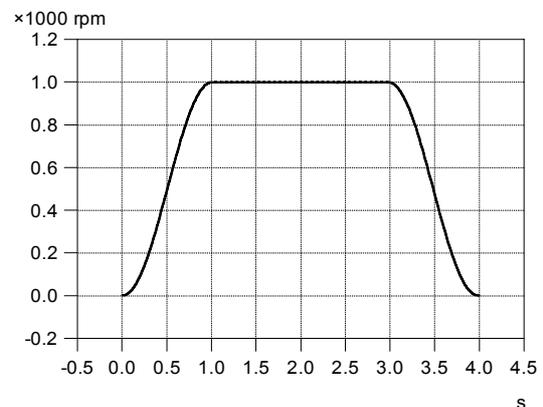


Fig. 1. Speed

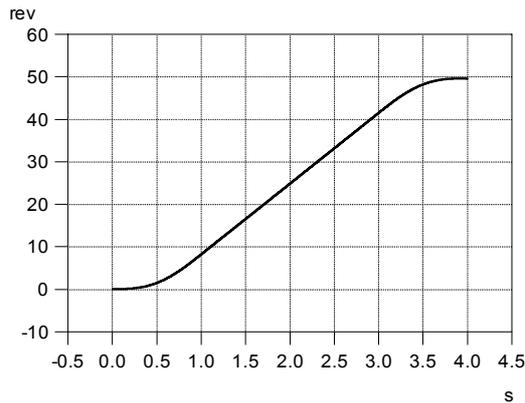


Fig. 2. Position

Typical speed trajectory of those drives is shown on Fig. 1 and Fig. 2, with controlled sinusoidal acceleration and deceleration segments. Those trajectories are used in experiments.

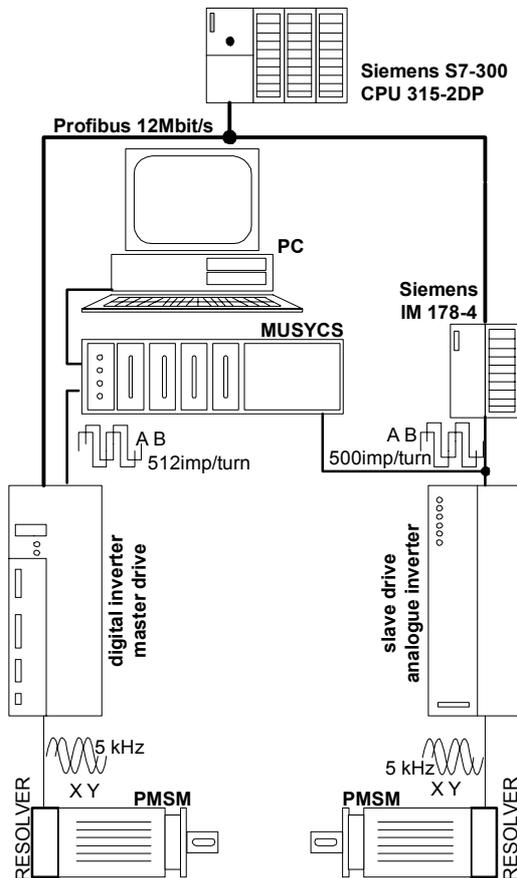


Fig. 3. Laboratory model

4. MEASUREMENT

Model and measurement are shown on Fig 3. PLC gets information's about rotor position in cycles. The best realized cycle time of this model is 3 ms.

Due to resolution res of increment sensor signal, error ε_{in} of 6,28 mrad is inevitable (3).

$$\varepsilon_{in} = \frac{2\pi}{res} = \frac{2\pi \text{ rad/rev}}{500 \text{ imp/rev}} = 6.28 \text{ mrad/imp} \quad (3)$$

This error (3) could be minimized by higher increment sensor resolution (up to 2000 increment per revolution).

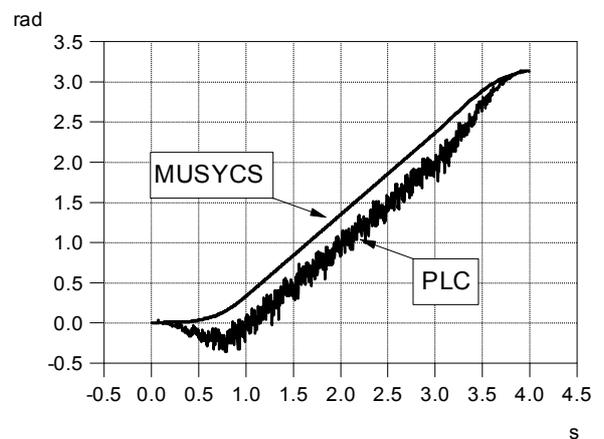


Fig. 4. Error between drives measured by MusyCS and PLC

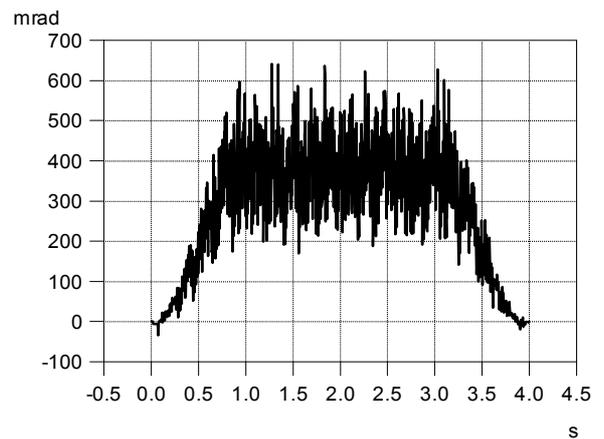


Fig. 5. Accuracy, (difference between errors measured by MusyCS and PLC)

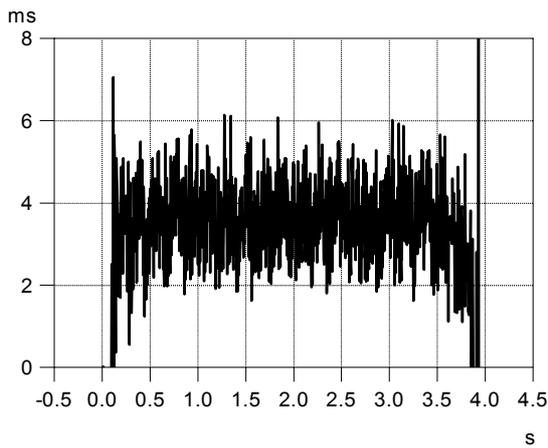


Fig. 6. Time deviation of readings

Achieved accuracy on the end of experiment (at experiment time of 4 s) is under 5 mrad, Fig. 4. In this point there is no rotation, so static accuracy is under 5 mrad.

Accuracy through whole experiment, dynamic accuracy, is under 642 mrad, Fig. 5. Approximately 100 times bigger than static one. Due average accuracy trajectory and speed similarity, and high static accuracy, it is assumed that the rotor position reading time of master and slave drive is not coincident.

Division of position accuracy and speed results with time difference, shown on Fig 6. Experiments are done for different PLC cycle time, from 3 ms to 20 ms. For each experiments results were similar.

Solution for higher position reading accuracy is better time definition of reading rotor position values, which can be realized by DP constant cycle time and by PLC synchronous functions.

Two different types of PLC are used in laboratory model. Difference between them is possibilities of synchronous DP functions (SYNC and FREEZE), and constant DP cycle time.

PLC accesses to inputs (incremental sensor inputs) and outputs on network asynchronously. Synchronous DP functions synchronises reading or writing distributed inputs and outputs on industrial communication network. Those functions allows user to coordinate data communication with several slaves.

DP slave in SYNC mode stores output data, transferred with Data_Exchange telegram, in a local transfer buffer of the DP slave. After receiving the SYNC command, the DP slave transfers the data stored in the transfer buffer to the outputs. In this way, it is ensured simultaneously activation outputs of several DP slaves (synchronises).

When a DP slave receives FREEZE command from the DP master, the currently quoted input data of the DP slave is stored in the transfer memory on the DP slave and thus frozen. The DP master then sends a Data_Exchange telegram to read this frozen input data from the transfer memory of the DP slave. This control command permits simultaneous (synchronous) transmission of the input data currently queued on the DP slaves.

DP cycle, Fig 7 and Fig 8., comprises a fixed part and variable part. Fixed part is made up of the cyclic telegrams

containing the bus access control and the I/O data communication with the DP slaves. Variable part of the DP cycle is made up of number of event controlled, non-cyclic telegrams.

In the field of the drive control constant DP bus cycle time and thus constant I/O data exchange is advantageous. Synchronization of several drives require a constant bus cycle time.

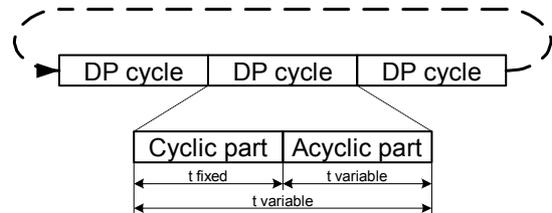


Fig. 7. Setup of variable PROFIBUS DP cycle

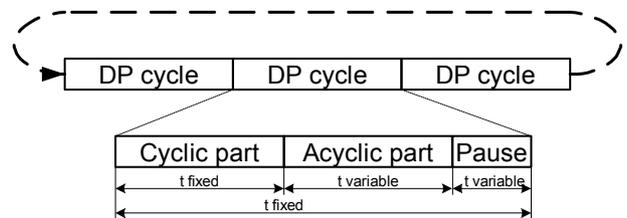


Fig. 8. Setup of constant PROFIBUS DP cycle

At 1000 rpm deviation of single drive position value readings is shown of Fig. 9. Time deviation is up to 2 ms, which corresponds to position of 200 mrad for single drive, or 400 mrad for pair of drives.

By implementing DP constant cycle time and synchronous position readings, time deviation reduces to 0.3 ms, which corresponds to position of 30 mrad for single drive, or 60 mrad for pair of drives, Fig. 10.

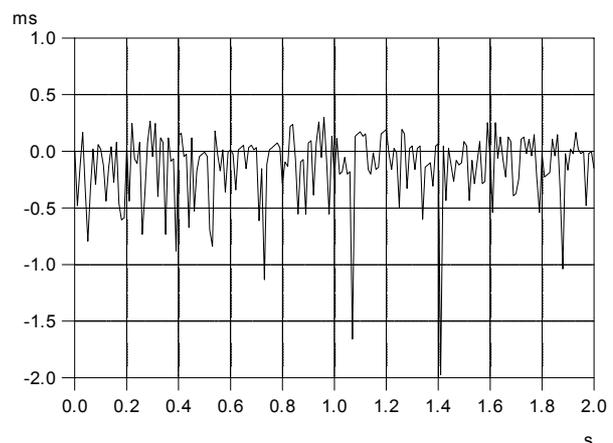


Fig. 9. Time deviation by free DP cycle and no synchronous functions

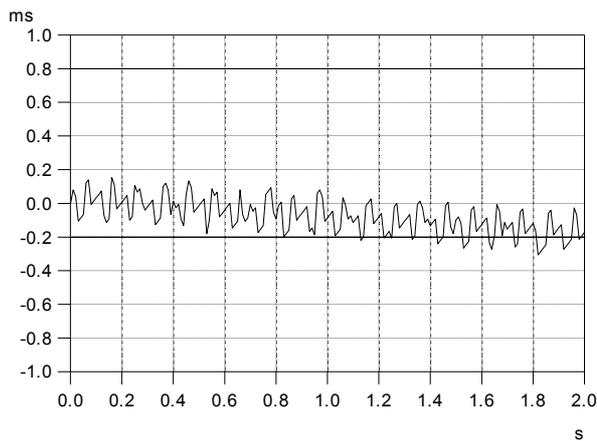


Fig. 10. Time deviation by constant DP cycle and SYNC and FREEZE synchronous functions

4. CONCLUSION

Precise rotor position real-time measurement is important, due necessary exact feedback information.

From experimental results (Fig 9 and Fig 10) it can be seen that rotor position accuracy increases with using DP constant cycle time and implementing synchronous functions.

Achieved static accuracy of position readings is under 0.08%. Dynamic accuracy in experiments with no use of DP constant cycle time and synchronous functions is 20.5%. With using those functions dynamic accuracy increases significantly to 0.98%. This accuracy is still for 10 times lower then static one, but usable.

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