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ELECTRIC QUANTITIES MEASUREMENT IN INDUCTION MACHINE TESTING USING PROFIBUS INDUSTRIAL COMMUNICATION NETWORK

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Abstract − Nowadays, there is greater tendency to automate different processes. Not only in industry application (steel, auto, pharmaceutical industry) but also in other aspects of life. One of the main new automation technologies which enables simultaneous control and measurement in industrial environment is technology based on PROFIBUS industrial communication network with more than 2 million installed units all around the world.

This paper describes usage of PROFIBUS industrial communication network in induction motor testing. Over the PROFIBUS the overall test is controlled and most of the relevant quantities are measured (motor current RMS value, speed, torque, voltage, winding and bearing temperature…).

Key words: measurement, PROFIBUS industrial communication network, electric machine testing

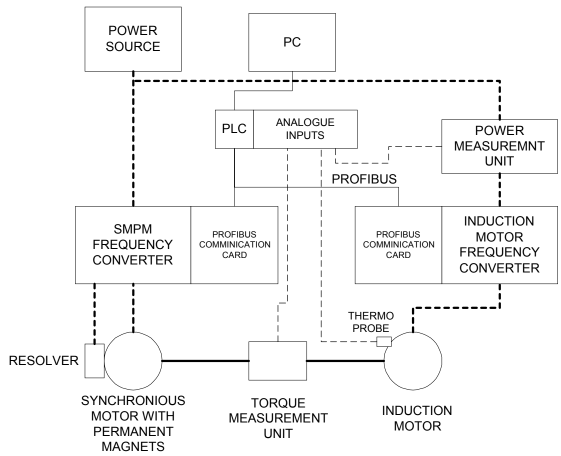

Fig. 1. Laboratory model of system for drives monitoring, diagnosing and testing using PROFIBUS communication network

1. INTRODUCTION

Knowledge on electric machine state is very important especially in industries where electric machines are working uninterruptedly. When machine state deteriorates there is often a very short time till that machine stops working properly or at all. Therefore the machine tests are very important to take place as often as possible and if possible during normal working conditions. Sometimes it is enough to permanently monitor some parameters (temperature of windings and bearings, currents, etc.)

The system described in this paper is designed to monitor, diagnose and test electric machines while they work by measuring all relevant quantities.

2. SYSTEM DESCRIPTION

This system is based on programmable logic controller (PLC – Siemens 315-2 DP) that operates with two frequency converters (Fig. 1). Controller adjusts parameters of both converters via PROFIBUS practically on-line. That means that change of parameters, which do not need converter to stop working, is done instantaneously. The other types of parameters are changed when converter is in stop mode. PLC (Fig. 2) also collects data from thermal probe placed on inductor motor stator winding, power measurement unit and torque measurement unit. Those signals are analogue and connected to PLC through analogue input cards. PROFIBUS industrial communication network connects PLC with frequency converters for both drives (induction motor and synchronous motor with permanent magnets - SMPM) – Fig. 3. Besides changing of converter parameters, PLC receives data on current, voltage, electromagnetic torque speed and position of both motors via PROFIBUS. SMPM has 2,8 kW and induction motor 2,2 kW. SMPM works, in this case as active and passive load to induction motor.

Fig. 2. PLC with analogue and digital input modules and power supply

The best PLC cycle time, achieved with chosen system, is 5 ms. This would not be enough to monitor waveforms of electrical and mechanical quantities during dynamic processes, but it was sufficient to monitor RMS values of relevant quantities.

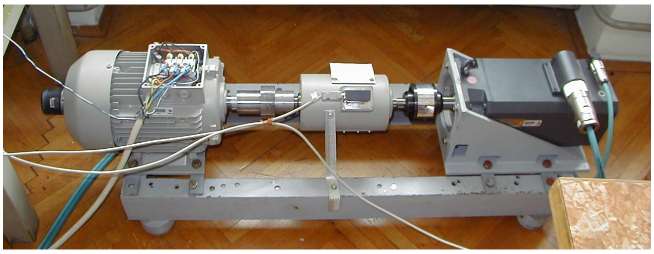

Fig. 3. Induction motor (left) coupled with SMPM (right). In the middle there is torque measurement unit

PROFIBUS has transfer rate of 12 Mb/s. Measurement of voltage, current, speed of both machines and SMPM torque is performed by frequency converters and as double integer sent via PROFIBUS to PLC. Torque is measured directly on the shaft, between two machines (Fig. 3), by device based on strain gauge. The strain gauge resistance change (linear to torque) is transferred into 4-20mA analogue signal, which is connected to analogue input PLC card (with 12-bit resolution). The same analogue card receives data from power measurement unit (Fig. 4). This unit has three modules (for each phase). In this measurement two modules were used (Aaron). Each module receives voltage and current signals (voltage from transformer, and current from LEM module). Power measurement unit has relative accuracy of 0,5%.

Fig. 4. Power measurement unit

Switching frequency of converter transistors for pulse with modulation motor control is 20kHz, and there are lots of problems considering measurement at those frequencies.

Therefore the power is measured before converters. The converter power consumption is partly measured and assessed, and motor power is than calculated.

Temperature is measured with temperature probe Pt-1000. This signal is converted and amplified into 4-20 mA analogue signal and connected to analogue input PLC card (with 8-bit resolution).

The RMS voltage and RMS current of both drives, speed, electromagnetic torque of SMPM and temperature of SMPM are measured with sensors placed in converters or motors. Those analogue values are transformed into numbers and as double words (32-bit) collected by PLC every 5 ms via PROFIBUS. In order to manage this, there are PROFIBUS communication cards built in each converter.

3. MEASURED RESULTS

The following induction motor tests were made with this system: No-load test, Retardation test, Temperature-rise test and Load test.

The following diagrams were made out of recorded data:

- Load test: mechanical power versus electrical power, current versus electrical power, speed versus electrical power, slip electrical power, power losses electrical power, power factor electrical power, efficiency electrical power, torque electrical power
- No-load test: current versus voltage, power factor versus voltage, power losses versus voltage, power losses versus voltage squared
- Temperature-rise test: temperature versus time
- Retardation test: speed versus time

During retardation test diagram 'speed vs time' was recorded (Fig. 5). As it can be seen the curve is smooth (without any filtering) which shows that cycle time (sample rate of 5 ms) is good enough for that type of monitoring. In retardation test inertia of induction motor is determined ($J=0{,}0277\ kgm^2$).

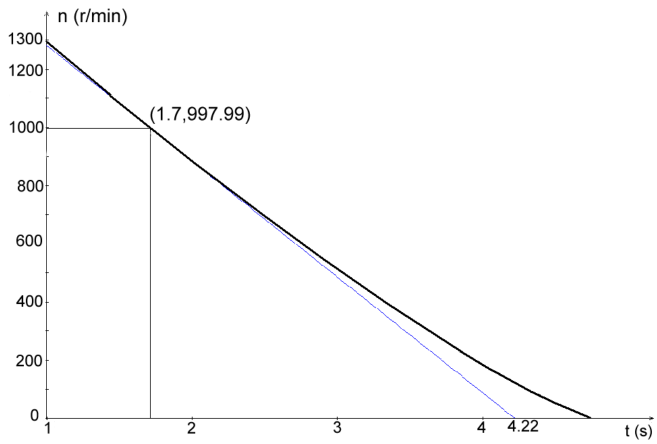

Fig. 5. Speed versus time diagram recorded during retardation test

Of course there are some inaccuracies in those measurement. This can be seen in Figs. 6 – 8. The red spots are actual measured values, and the black line is approximation of those values.

The deviation is, never the less, very small.

All measurements were compared with classical measurements (involving analogue measurement instruments for power, voltage, current…).

The comparison was made and measurements made via PROFIBUS are within 5% of accuracy.

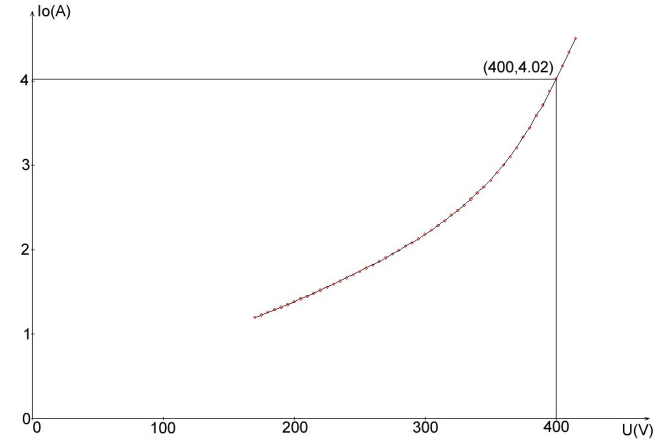

Fig. 6. Current versus voltage diagram recorded during no-load test

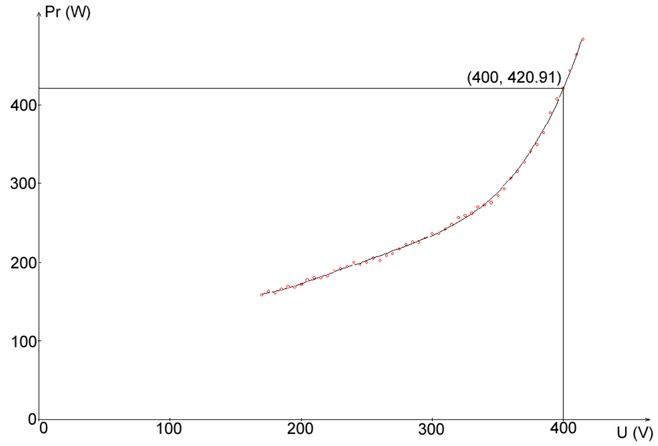

Fig. 7. Power versus voltage diagram recorded during no-load test

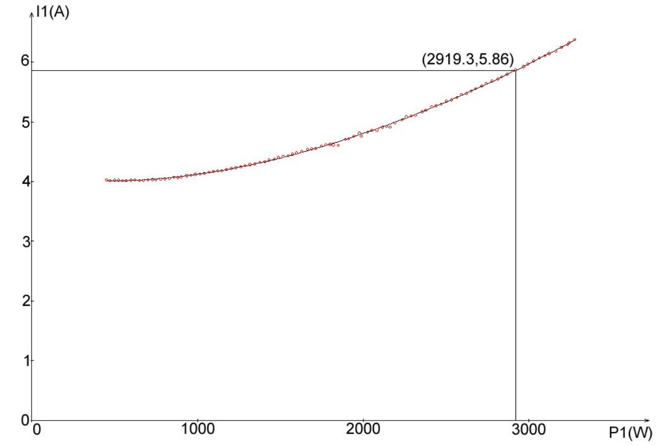

Fig. 8. Current versus voltage diagram recorded during load test

4. CONCLUSION

PROFIBUS based system for induction machine control and testing based on low cost PLC with 5 ms cycle time (i.e. sample rate) proved satisfactory results. If more expensive PLC with better cycle time (1-2 μs) would be used this system could even measure waveforms of electrical and mechanical quantities. This would additionally improve diagnostic capability and with use of some numerical tools also determine types of faults and in some cases exactly the place of each fault. This system is definitely proven to be able to deal with this sort of problems and could have real application in industrial environment.

5. REFERENCES

[1] Blevins T., Kinney T., "How Fieldbus Can Influence Your Next Project", *Control Engineering*, September 1996, pp 133-138

[2] Bah M.D., Traore S., "Data Acquisition and Automated Measuring System. Application to Synchronous Machine Analysis", *ACEMP'92*, 27-29. May 1992, Kusadasi, Turkey, Vol. 2/2

[3] Babb M., "PLCs: Looking Around for More Work to Do", *Control Engineering*, October 1996.

[4] Hofmann H., Sauer H.J., "Effect of Fieldbus Technology on Digital Instrumentation and Control for Power Plants", *Kerntechnik 60*, 1995, 5-6, pp. 245-247.

[5] Garrone P., "Digital Fieldbus Technology Unleashes Full Potential of Intelligent Field Devices", *I&CS*, February 1997, pp. 25-29.

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