Challenges for Technology Innovation: An Agenda for the Future – Moreira da Silva et al. (Eds)
© 2017 Taylor & Francis Group, London, ISBN 978-1-138-71374-1

Lower-level communication line analysis of automated dispatch control systems of distributed facilities

A. Belousov, Y. Koshlich, A. Grebenik & I. Gvozdevskiy
Department of Informatization and Communication, Belgorod State Technological University after V. G. Shukhov, Belgorod, Russia

ABSTRACT: The article presents the analysis results of the physical environment of the data transmission between the technological equipment of automated dispatch control systems via RS-485. The purpose is to minimize the average functional level implementation cost of the automated dispatch control systems of distributed energy facilities through the organization's communication of equipment of lower level. In the article the analysis of approaches to communication equipment, analysis of wire line to be used as a physical medium for transmission of data and development of recommendations and proposals for the use of wired communication lines of the twisted pair and RS-485 for data transfer.

1 INTRODUCTION

The main tasks of housing and communal services sphere consist in comfortable habitat and human life activity creation. In this connection energy supply and life support systems have huge role. One of the ways of its improving in the part of energy efficiency increasing is distributed facilities Automated Dispatch Control Systems (ADCS) application (Trubaev et al. 2014.). Because of control centralization of distributed heterogeneous engineering systems of buildings with multivendor devices and different automation levels, the ADCS allow to raise operational efficiency of energy supply and life support systems and to decrease their accident rate.

Usually typical ADCS of distributed facilities has multilevel hierarchical structure as shown in the Fig. 1 (Bozchalui et al. 2015; Trubaev et al. 2015; Glagolev et al. 2013; Shnaider 2008.).

Lower level includes:

- measuring transducers which make measure such parameters from distributed facilities as pressure, temperature, energy consumption, etc. and transmit the data to upper level over communication controllers;
- local regulators (programmable logical controllers) of influx-and-extract systems, heating and boiler systems, hot water supply systems etc.

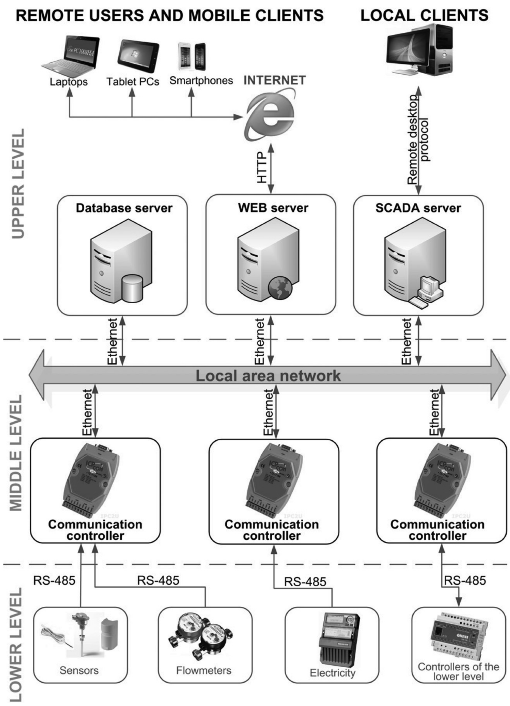

Figure 1. ADCS of distributed facilities structure.

Middle level is represented by communication controllers and dedicated or multifunctional programmable transmission interface converters which make data acquisition from distributed measuring transducers, data accumulation, front-end processing and information transmission to upper level of ADCS and control signal transmission from upper level to the lower-level local regulators.

Upper level of ADCS are servers hardware and software (SCADA-server, data base server, web-server) (Glagolev et al. 2013). The equipment make data acquisition from midrange controllers, distributed facilities data mining, data visualization and documentation, control of distributed energy facilities, obtaining information to analyze and make recommendations on distributed facilities management strategy.

2 LOWER LEVEL COMMUNICATION IMPLEMENTATION PROBLEM

2.1 *Problem*

One of the most expensive ADCS implementation points is the medium-level realization. The use of separate communication controllers for each subsystem (metering of electricity, hot and cold water, heating, control units supply and ventilation systems, etc.), which is part of ADCS within the same building, has relatively heavy costs. At the same time, reducing the number of communications equipment used entails necessity of increasing the length of lines, which in turn affects the speed of data transmission, since it is connected with the inversely proportional dependence. Moreover, installation of new communication lines also leads to increased costs.

The most common standards that used for ADCS interlevel interface realization are: RS-485, CAN, RS-232, RS-422, etc (Adinolfi et al. 2015; Fazackerley et al. 2015; Galloway et al. 2013; Thale et al. 2015; Yasar & Caner 2015.).

Choice the standard for the implementation of communication interaction with the lower functional level of ADCS is determined by many factors, such as data transfer rate, hardware and software compatibility, etc.

RS-232 enables the data transfer and some special signals transfer between a data terminal equipment and a communication device (data communications equipment) at a distance of 15 meters. In practice, depending on the quality of the cable used the required data transmission distance of 15 meters cannot be achieved (Yasar et al. 2015). Actually it can be achieved about 1.5 m at 115200 baud for unshielded flat or round cable. This is due to the fact that single-phase signals is used instead of differential signals and receiver matching requirements to the data communication line.

RS-422 as a lower-level equipment standard provides a balanced or differential one-way data transmission connectivity to "point to point" or multicast message delivery. The advantage of the RS-422 standard is a data transfer rate up to 10 MBauds for the 12 meters cable (Saha et al. 2013).

RS-422 interface is used much less than RS-485, usually not to create a network, but to connect the two devices at a large distance (up to 1200 meters) while the RS-232 interface is operable only up to 15 m.

CAN interface is designed to organize serial, high-reliability and low-cost communication bus in distributed control systems (Fazackerley et al. 2015). It allows organizing a multiplex channels and high-speed networks. But the following facts:

- intensive ordering information data towards transmission data;
- common standard absence to the high-level protocol;
- ADCS of distributed facilities lower-level equipment fewness make some limitation to ADCS lower-level communication line implementation.

In the basic CAN specification lacks many features required in distributed control systems, for example, data transmission necessary is longer than 8 bytes, the automatic allocation of identifiers between devices, the uniform control devices of various types and manufacturers. So soon after the CAN interface for him started to develop high-level protocols (CANopen, DeviceNet, CAN Kingdom, J1939 and SDS).

As a rule, widespread the lower-level automation equipment: electricity meters, metering devices, input-output modules have an RS-485 or CAN interface output.

More than 80% of the ADCS lower-level equipment as a communication interface use RS-485.

That creates the necessary prerequisites for the RS-485 interface using for the ADCS lower-level communication.

Moreover, its main advantages are

- bidirectional data communication over a twisted pare wires;
- interaction with multiple transceivers connected to the same line, that is the networking possibility;
- large communication line length;
- relatively high data speed rate.

2.2 *RS-485 using as a lower-level communication interface*

The RS-485 standard regulates the electrical parameters of a half-duplex multi-drop differential communication line such as "common rail" and represents one of the most popular physical layer standards for asynchronous data interface (Zhang et al. 2015). As a basis for the physical transmission medium is commonly used twisted—pair of wires, which are of equal length and twisted together.

Application of a transmitter with twisted-pair cable which meets the specifications of RS-485 reduces the two main sources of problems for developers of geographically distributed high-speed networks: radiated and induced electromagnetic interference. Compliance of data lines to RS-485 communication specifications can significantly reduce the electromagnetic disturbances. The RS-485 specification recommends that the impedance of the cable is 120 Ohms. The recommendation is necessary to calculate the worst-case loading and common-mode voltage ranges defined in the specification.

In case of considerable length of the network it is used the matching termination resistors. The resistors are mounted on the ends of the wire and contribute to the suppression of reflected waves generated in the transmission data. It should be noted that the terminating resistor can be neglected if length of the network wires is less than 300 meters installing.

If the resistance of the termination resistors does not match the characteristic impedance of the cable, the signal will be reflected, i.e. the signal will return through the cable and back is superimposed on the desired signal. Despite of the admissible deviation in the cable and resistor, a reflection will be inevitable. Significant differences of the parameters can cause a sufficiently large reflection that can lead to errors in the transmission of information.

2.3 *The task*

With this in mind, it is important to ensure the best possible proximity of the resistance values of the terminating resistor and the characteristic impedance. Given the above, it is necessary to choose the right type and length of wire line, and the value of the terminating resistor to minimize the number of communication equipment within the same building.

Thus, there is a need to analyze the existing wired data lines in order to identify their operation opportunities while reducing the quantity of communication equipment and identify the maximum-possible extent when designing their ADCS of distributed facilities automation.

3 EXPERIMENT

3.1 *900 meters data cable length experiment*

The purpose of the experiment is to identify the best-case value of matching resistor at increase of communication lines length to reduce the number of communication controllers. The scheme of experiment is shown in Fig. 2.

The main point of the experiment is when terminator resistance is changed, quantity of lost data packet is defined at different data transfer rate. The communication line length is about 900 meters that is created by maximum lower-level communication line length of ADCS of distributed facilities of BSTU after V. G. Shukhov (Belgorod, Russia). For the task it is used Modbus diagnostic function, which returns transmitted query data.

For example, to find the best values of matching resistance at a speed of 115200 baud it is necessary to set certain values of terminators at the ends of the connection line, after which in the program it is selected 115200 baud speed and test is started. If the error rate is unacceptable, the test is stopped and the value of the matching resistance is changed. The next step the test repeated at another speed.

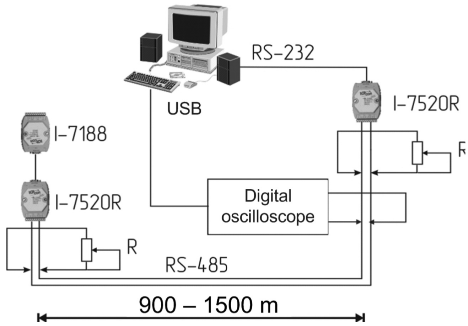

Figure 2. Scheme of the experiment.

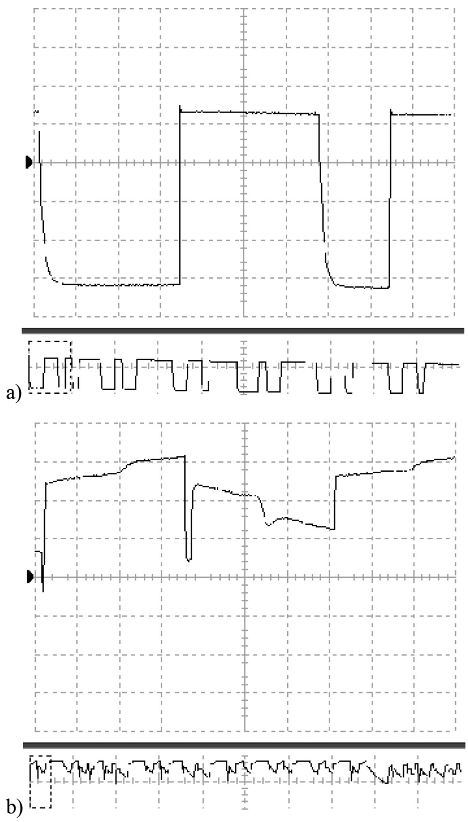

Figure 3. Oscilloscope waveform without matching resistors use: a) 1200 baud speed; b) 115200 baud speed.

3.2 *1500 meters data cable length experiment*

As quite often it is necessary to use existing lower level communication lines which were installed before, experiments with longer (up to 1500 meters) lower level communication cable were performed. A lot of twisted cable joints using allowed simulating data transmission in real-life environment on the lower level of ADCS of distributed facilities.

Fig. 3 shows oscilloscope waveform without matching resistors use.

As the Fig. 3b shown, data transmission is not possible at a speed of 115200 baud due to the presence of the reflected signal in the connection line, which is superimposed on the desired signal. In the result it is impossible to recognize the high and low logic levels.

75 Ohm matching resistor using at the same speed allows reducing the error rate up to 0.3% (Fig. 4a). If 195 Ohm matching resistor is using the error rate is 50% (Fig. 4b).

Figure 4. Oscilloscope waveform with matching resistors at 115200 baud speed: a) 75 Ohm matching resistor; b) 195 Ohm matching resistor.

Table 1. The error rate dependence of different terminators using at the different speeds.

Terminator resistance	Speed, baud 1200	2400	9600	14400	19200	38400	57600
5000	0%	0%	0,7%	0,8%	100%	100%	100%
2000	0%	0%	0,1%	0,2%	0,4%	100%	100%
1000	0%	0%	0%	0,15%	0,33%	100%	100%
750	0%	0%	0%	0,14%	0,26%	100%	100%
500	0%	0%	0%	0,14%	0,18%	0,2%	100%
380	0%	0%	0%	0%	0%	0,09%	100%
330	0%	0%	0%	0,18%	0,26%	0,32%	100%
250	0%	0%	0%	0,27%	0,4%	0,44%	100%

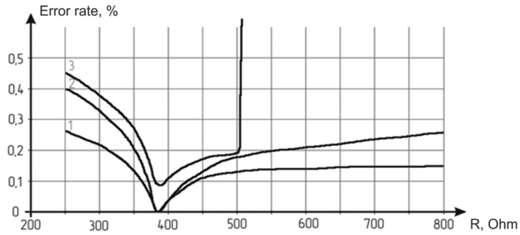

Figure 5. The error rate dependence of terminator resistance at the speeds: 1-14400 bauds; 2-19200 bauds; 3-38400 bauds.

At the same time, the use of high-resistance terminator leads to an increase of the level of the error rate. Experiments were carried out with the service software using to find the best matching resistance from series of 250–5000 Ohms. The results are represented in the Table 1.

On the basis of the made analysis (Fig. 5) it can be concluded the best matching impedance is the value of 380 Ohms.

4 CONCLUSION

In that way, when distributed facilities ADCS lower-level communication is introduced, it is important to choose correctly the type, length of the data communication line and resistance of the terminators.

The experimental results show that it is possible to achieve a relatively low noise level (up to 0.09% error rate at speed 38400 bauds), effectively using unshielded wire line connection up to 1 km length without using the signal repeaters with the 380 Ohms matching resistors.

Moreover, to minimize the costs for the ADCS lower-level communication lines laying for communication equipment via RS-485 as the physical environment of data transmission it is possible to use existing wired communication lines in the facilities, including unshielded twisted pair and two core telephone cable.

Following the developed recommendations helped in the design and introducing of telecommunication channels within the structure of the automated dispatch control system of distributed facilities of BSTU named after. V. G. Shukhov (Belgorod) (Belousov et al. 2014) up to two times to reduce the number of communication controllers of the medium functional level through the use of the existing data lines and to increase the length of the conductive line of information transmission via RS-485 without the signals repeaters.

REFERENCES

Adinolfi, F., Burt, G.M., Crolla, P., D'Agostino, F. Savi-ozzi, M. & Silvestro, F. April 2015. Distributed energy resources management in a low-voltage test facility. *IEEE Transactions on Industrial Electronics vol. 62(4)*: 2593–2603.

Belousov, A.V., Glagolev, S.N., Koshlich, Y.A. & Shevkunov, A.A. April 2014. Information and technologic provision of the automated supervisory control system for distributed housing and public utilities. *Innovative Information Technologies, Vol. 3*: 201–209.

Bozchalui, M.C., Cañizares, C.A. & Bhattacharya, K. Jan 2015. Optimal operation of climate control systems of produce storage facilities in smart grids, *Smart Grid, IEEE Transactions on, vol. 6(1)*: 351–35.

Fazackerley, S., Lang, D. & Nichol, C. May 2015. A low cost and flexible open source communications framework for temporally aligned sampling in distributed sensing systems. *IEEE 28th Canadian Conference on Electrical and Computer Engineering (CCECE)*: 842–847.

Galloway, B. & Hancke, G. P. Second Quarter 2013. Introduction to Industrial Control Networks. *IEEE Communications Surveys & Tutorials, vol. 15, no. 2*: 860–880.

Glagolev, S.N., Belousov, A.V., Koshlich, Y.A. & Bystrov, A.B. 2013. Energy consumption objects monitoring systems—problems of web-based access to technological information. *American Journal of Economics and Control Systems Management, vol. 1(1)*: 6–9.

Saha, S., Rahman, M. A. & Thakur, A. 2013. Design and implementation of a BIST embedded high speed RS-422 utilized UART over FPGA. *Fourth International Conference on Computing, Communications and Networking Technologies (ICCCNT)*: 1–5. Tiruchengode.

Shnaider, D.A. 2008. Computer-based supervisory control system of building heat supply on the basis of field technologies. *Computer Technologies, Automatic Control & Radioelectronics, vol. 17(117)*: 29–32. Chelyabinsk: South Ural State University.

Thale, S.S., Wandhare, R.G. & Agarwal, V. A. March-April 2015. Novel Reconfigurable Microgrid Architecture With Renewable Energy Sources and Storage. *IEEE Transactions on Industry Applications, vol. 51, no. 2*: 1805–1816.

Trubaev, P., Shirrime, K. & and Tarasyuk, P. 2014. Peculiarities of implementation of the energy management system in conditions of russian economy, *World Applied Sciences Journal, vol. 30(8)*: 990–994.

Trubaev, P.A. & Shirrime, K.J. 2015. Comparative analysis of Russian and international standards on energy management systems. *Energy-Safety and Energy-Economy, vol. 2*: 10–15.

Yasar, O. & Caner, H. 2015. Developing easy pluggable test equipments for factory and development testing of air defense gun system. *IEEE AUTOTESTCON*: 169–172. National Harbor, MD.

Zhang, C.L., Da Huang, Z., Zhou, G.Q. & Chong, K.T. 2015. Implementation of RS-485 Communication between PLC and PC of Distributed Control System Based on VB. *IOP Conference, Series: Materials Science and Engineering, vol. 83, no. 1*: 1–7.