Prospects of “One-level” Architecture of Control Systems on the basis of Ethernet Network - DCS "Tornado-N" with “One-level” Architecture on the basis of Ethernet

Oleg V. Serdyukov

Institute of Automation and Electrometry
Siberian Brunch Russian Academy of Science
Akademika Koptiuga ave, 1a, Novosibirsk, Russia

Abstract. Modern DCS of technological processes have “multi-level” architecture. The “low” level of DCS is represented by controllers. They provide three main functions: data acquisition, processing and control of object. Input-output devices are connected directly to controller for information interchange with object and processing unit (CPU). The upper level connects controllers together and provides their interaction with "the top" level of a system. In systems with such architecture, controller which needs to obtain variables connected to an other controller, it requires to have a special complex service for interconnection with the other controller: for performance of base “low” level function of input-output, upper level is involved. Many suppliers of control systems do not have a solution for it, i.e. the data exchange function of controller in vast majority of systems is absent. Level of today's network technologies allows to construct homogeneous “one-level” control system on the basis of a high-efficiency local network, for example Fast Ethernet. In such systems network is used not only for interaction of workstations, servers, but for direct interaction with input-output devices, connected directly to Fast Ethernet network. Thus the concept of classical controllers disappears and control algorithms may be carried out in any point of the system.

1 Introduction

The idea of common bus interface now exists for more than 30 years. This principle is being used to construct separate subsystems (e.g. computers, controllers) and integration of such subsystems. There exists a majority of bus interfaces for these purposes.

Bus (e.g. PCI) merges all the primary devices in computers and servers, bus interface in controllers merges all processor and I/O modules. Thus, different subsystems use different inner bus interfaces. Modern distributed control systems (DCS) of technological processes have “multi-level” architecture. The “low” level of controllers providing information interchange and commands with object through the devices of input-output, connected directly to the controller (Figure 1).

The next upper level connects controllers together and provides their interaction with "the top" level of a control system. In systems with such architecture, controller

Serdyukov O. (2009).
Prospects of “One-level” Architecture of Control Systems on the basis of Ethernet Network - DCS ”Tornado-N” with “One-level” Architecture on the basis of Ethernet.
In *Proceedings of the International Workshop on Networked embedded and control system technologies: European and Russian R&D cooperation*, pages 75-80

which needs to obtain variables connected to an other controller requires to have the special complex service for interconnection with the other controller, i.e. for performance of base "low" level function of input-output, upper level will be involved.

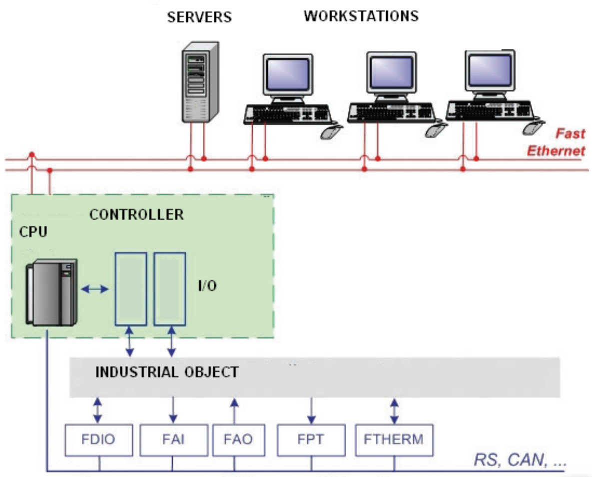

Fig. 1. Traditional heterogeneous architecture.

This problem not so is simple, as may seem and many suppliers of control systems do not have a solution for it, i.e. the data exchange function of the controller's in vast majority of systems is absent. The level of today's network technologies allows to construct homogeneous "one-level" control system on the basis of a high-efficiency local bus interface (Fig. 2). In such systems the network is used not only for interaction of workstations, servers, but for direct interaction with input-output devices, connected directly to network. It is quite possible to suggest the possibility of building the whole system based on one common bus interface (a homogeneous system). Nowadays Ethernet technology gives the developers of Industrial Control Systems all the sufficient facilities.

2 Fast Ethernet Bus

Analyzing the history of computer systems progress one can note such tendency that with development of new technologies the system constructor gets an opportunity to deal with more and more higher-level interfaces of informational exchange. Nowadays Ethernet is a Bus Interface of high-level for building DCS. If I/O modules are connected directly to the common-system bus interface, we have different architecture of DCS with a list of new advantages; controllers are assumed as something different from familiar sight.

Thus the concept of classical controllers disappears. Control algorithms can be carried out in any point of the system, but for reasons of reliability it is more preferable and better to allocate special computing devices of "an automation server".

It is possible to consider such architecture almost "ideal", possessing nearby considerable advantages. It is possible to expect that the future development of control systems will go this way.

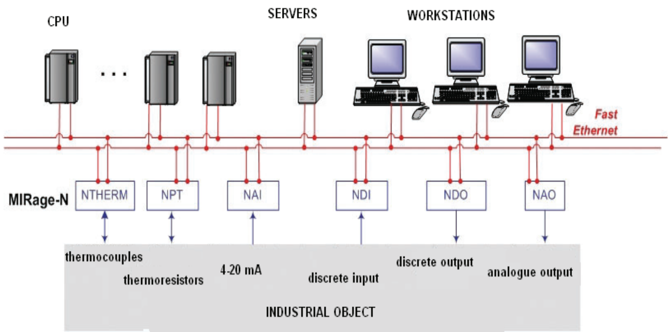

Fig. 2. Homogeneous architecture.

The main goal of "Modular Systems Tornado" company's (www.tornado.nsk.ru, Nosovibirsk, Russia) developers was to create the automation facilities for maximum broad spectrum of process tasking, to have an opportunity to use these facilities on really large major industrial objects. MIRage-N I/O modules with duplex Ethernet bus may be successfully implemented not only in systems of general-automation use but the module line is sufficient for objects with enhanced reliability, fail-safety and high-availability requirements. Distributed I/O modules of this product line can be implemented both as parts of DCS and for local means of visualization and maintenance.

Unlike the other products of distributed I/O, MIRage-N line provides the data of industrial workflow directly to the common Fast Ethernet industrial bus aggregating all elements of the automation system: CPU modules, servers and workstations.

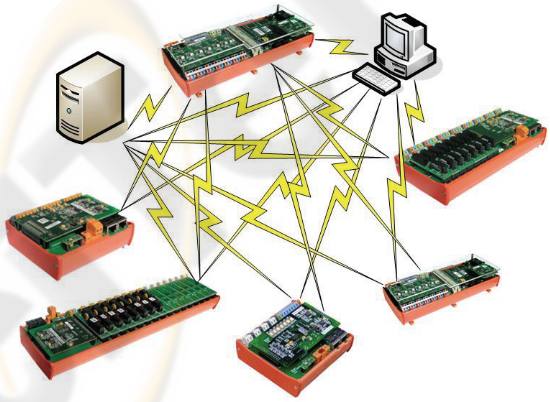

Fig. 3. MIRage-N: equal right DCS member.

Architecture with absence of controllers (in usual assumption) gives a new degree of freedom to developer. There is no need in affixment of I/O modules to the specified definite CPU (like in all common systems). This factor substantially simplifies the process of DCS cabinet's construction: MIRage-N modules transfer data to any active CPU of the system attaining the state of distribution of data collecting and data processing.

2.1 MIRage-N Advantages

Thereby systems with distributed I/O based on MIRage-N modules have such advantages:

- It's standard and innovative, specified by use of progressive Ethernet technologies and organization of data transfer services by copper cables, optical cables and radio communication;
- Fail-safety provided by duplex Ethernet bus. Communication channel restoration is an expensive long-run and complicated procedure. Duplication of the industrial bus gives an opportunity to detect and restore the failure troubles. Such system is operable and runs even with failure of one communication subsystem. Also according to requirements it is possible to duplicate the functional parts and assemblies of the system;
- Reduction of charges: as an industrial bus interface, Fast Ethernet (10/100 Mbit/sec) gives a wide variety of computing sources from industrial CPU to PC-compatible devices that dramatically reduces the upper-level cost of industrial control system. Distributed structure of the system allows to make changes "on-site" enhancing operational and metrological characteristics of the system and substantially reducing expenditures for cable materials;
- High Availability: the system architecture allows to make hot-swap of any system element, replacement of defective modules without an impact on the rest of the system with minimum time;
- hot-swap of any system element, replacement of defective modules without an impact on the rest of the system with minimum time;
- Convenience in exploitation. The module construction allows the mounter to make the replacement of defective elements without demounting of field cables. Signals from sensors are plugged directly in MIRage-N modules in WAGO spring clips that do not require periodic maintenance;
- Scalability, extensibility. The functioning system may be populated with additional modules. The scaling procedure does not require any modification of functioning part of the system. Industrial interface bus of large and major industrial objects may contain several segments that use different communication mediums, e.g. copper wire, optical cable and radio connection;
- Developed software for integration of MIRage-N modules with ISaGRAF programming environment. Developed applications include .dll libraries implementing Modbus interfaces; OPC DA server supplying compatibility with SCADA systems for Windows OS supplying duplex Ethernet bus interface; components for usage of modules in LabView environment;
- Fixed time cycle of data acquisition for all devices equal to time of answering interval for one device (1 msec). The possibility of same time device scan rids from necessity of passive reply wait.

Open standards and technologies used in bus interface modules MIRage-N give the possibility to develop and maintain any systems of automation with different configuration of Ethernet, any processing devices, any programming environments and SCADA-systems, servers, e.t.c. The configuring of MIRage-N modules and visualization of data is maintained with "Configurator" software.

Unified module body of MIRage-N allows the installation of the module on DIN-rail (35 mm), it provides electrical insulation, galvanic isolation, fail-safe connection of the sensor cables. Field cable cross section square is 0,08 to 2,5 mm2.

2.2 Module Construction

Every MIRage-N module is a two-part construction – motherboard and plug-in boards - mezzanines. Mezzanines contain all the active elements. Figure 4 features MIRage-N parts:

1. Motherboard with no active elements;
2. Field Terminal blocks;
3. Mezzanine connectors;
4. Protective device;
5. Power supply connection;
6. Fast Ethernet connection inputs.

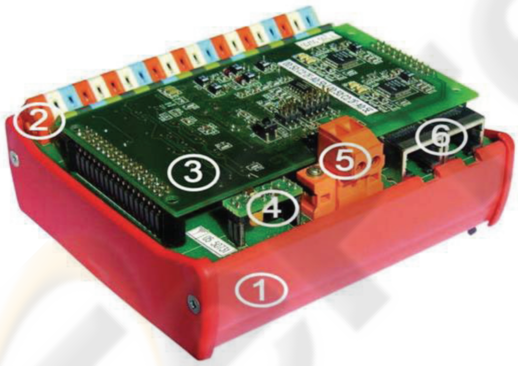

Fig. 4. MIRage-N module construction (with cover removed).

2.3 MIRage-N Line

The MIRage-N line includes all types I/O modules to fulfil the requirements of Industrial Control Systems:

- MIRage-NAI – 16 differential channels or 32 single channels, analogue signal input -20 + 20- mA, -10 +10 V, 16-bit delta-sigma ADC, 3-pole digital filter, individual DC-DC converter to power supply of sensor.
- MIRage-NDIO – 24 discrete channels. 12 input channels, 12 output channels. 24 V, 220 V.
- MIRage-NDI – 24 input channels. 24 V or 220 V, 4mA input current.

- MIRage-NDO – 24 output channels. 24 V or 220 V AC/DC: 3 A – AC, 0,5 A – DC.
- MIRage-NAO – 4 analogue output channels, 8 programmable discrete channels.
- NIRage-NTHERM – 8 analogue channels, thermocouples.
- MIRage-NPT – 8 analogue channels, thermoresistors.

The company "Modular Systems Tornado" has finished system engineering of DCS "Tornado-N" with “one-level” architecture on the basis of Ethernet. Today DCS “Tornado-N” is used to build industrial control systems of large power units for power stations.

3 Conclusions

In architecture where all system elements are connected directly to integrated Ethernet bus interface the developer gets one of the most promising solutions applicable in DCS development. DCS “Tornado-N” architecture with common Ethernet bus based on MIRage-N distributed I/O line gives substantial economic benefits; in comparison with other world well-known industrial automation companies DCS “Tornado-N” decreases expenses up to 30 % in major automation systems of heat and power engineering plants with hundreds and thousands of signals and furthermore gives developer new levels of freedom in system construction allowing to use different connection schemes and benefit from open standards and technologies underlying in described approach philosophy.

Described above architecture approach is currently being implemented in automation systems of power stations, thermal power plants and other major industrial objects in Russia and CIS and demonstrated it’s positive qualities.
It is very likely that soon this approach will become the most widespread architecture in modern DCS.

References

1. Serdyukov, O.V., Timoshin A.I., 2005. Paper templates. In *Bus interface of industrial controllers development*. IAE, Novosibirsk.
2. Serdyukov, O.V., 2006. *Tornado-TM complex*, ISUP, 1(9). Moscow.
3. Serdyukov, O.V., 2008. *DCS “Tornado”: life in major power engineering*, REM magazine. Moscow.
4. Lubashin, A.N., 2007. *Industrial Ethernet: form office to industrial plant*, The Industrial Ethernet Book. Moscow.
5. Kolesnikov, S., 2005. *Technologies and protocols of data transfer in industry: Fast Ethernet* . IT in industry.
6. Krugliak, K.V., 2003. *Ethernet networks in industrial automation: faster, longer, reliable.* STA, 1/2003.