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IMPLEMENTATION OF INTRINSICALLY SAFE SCATTERED CONTROL, COMMUNICATION AND SIGNALLING SYSTEMS USING ATUT-NET NETWORKS

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The paper presents the method of execution the scattered control, communication and signalling systems for mining industry using LonWorks networks. The above mentioned system is composed of separate nodes provided with neuron chip as well as a transceiver (with 78kbit/s operation speed) with proper interfaces. Transceiver provides access of each node to symmetrical pair in bus cable of the system using LonTalk protocol. Supplementing the bus cable with an audio core, interlocking core as well as supply core allowed creation of ATUT-NET network which permits the digital signal transmission between nodes, voice signal transmission between nodes, transmission of audio warning signals as well as programmed voice messages and execution of hardware and software interlocks. Modification of transceiver output circuits as well as proper realisation of supply system enabled to gain the intrinsically safe ATUT-NET network.

1. INTRODUCTION

The characteristic feature of control and signalling systems arranged in mining workings is the large distance and high requirements related to operation reliability. Taking into consideration the cabling costs limitations, application of serial transmission seems to be advisable; it permits transmission of larger quantity of signals using one pair of cores by means of proper protocol of medium access. Due to reliability of signal transfer it is necessary to use cyclic redundancy check sums (CRC) to verify the correctness of received messages.

Taking into account methane hazard, which occurs in most of mines, it is necessary to apply the physical layer of network, which provides intrinsically safe systems. The transmission protocol applied should be as flexible as possible in order to enable easy development or reconfiguration of the system. Because of costs reduction as well as increase of software reliability, it is advisable to apply network protocols, which were implemented in series production of integrated circuits.

2. LonTalk PROTOCOL AND ITS BASIC PARAMETERS

One of network protocols which meet the above mentioned requirements is LonTalk protocol developed in Echelon, Motorola and Toshiba companies. The protocol was implemented in high technology/specialised NeuronChip integrated circuits which compose three processor units: application processor, network processor and medium access processor [1]. Separating these functions makes the application processor programming more easier, which executes only tasks being necessary in specified node of given control and signalling system.

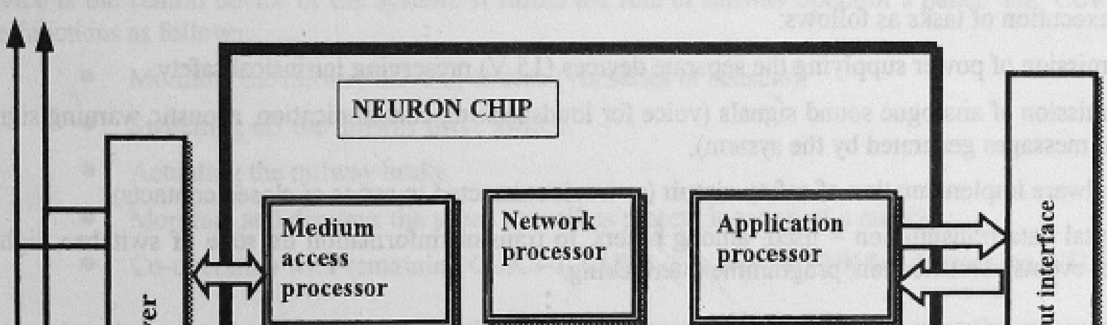

Fig. 1: LonWorks network node diagram using NeuronChip integrated circuit and a transceiver

These systems co-operate with transceivers matched to signal transmission method applied. // Programming the LonWorks networks is made easier by applying the special Neuron C language, which determines so called network variables – i.e. transmitted to every authorised node of network by means of such method which provides their simultaneous updating. An access to the transmission medium is executed by means of special version of the protocol, i.e. p.-persistent CSMA [2,5]. The special feature of this protocol is random selection of moment of transmission, which makes possible decreasing the probability of data collision originated from different nodes decreasing the network capacity and extending the effective transmission time. This is not deterministic protocol [2, 3] (because transmission moment is generated by random), however, if a network is relatively low loaded, for instance, by means of application of superordinated master-slave protocol– one can determine intervals, in which, at specified probability, system response time to an external event is included (for instance, actuating a sensor or user order).

3. LonWorks NETWORK INTRINSTIC SAFETY

In mining applications, the problem of intrinsic safety of applied signal transmission has significant meaning. LonWorks network was primarily mainly provided to serve the building industry automation [4, 5], however, IS-78 intrinsically safe channel specification was developed recently [6, 7] furnished with proper transceivers provide to operate in explosive hazard environment (for instance in mining and chemical industry) The characteristic features of this channel are as follows:

- transmission speed 78.125 kbit/s,
- maximum cable length (ended with terminators),
- limiting the node number connected to given section up to 8 pieces,
- limitation of current value in every cable segment up to 65mA.

In case of an installation arranged on area of several kilometres (a case which occurs very often in mining workings) is it necessary to divide the whole network to separately supplied segments of lesser length, divided using proper galvanic separators.

4. ATUT-NET network based on LonWorks network.

On the basis of NeuronChip MC143120 integrated circuits as well as proper transceivers (FFT-10A), ATUT-NET network was developed, taking into consideration special requirements occurring in coal mines signalling and control network. The six-core bus cable of core application as follows:

+ positive power supply pole
- negative power supply pole
NA - "a" core of LonWorks network
NB - "b" core of LonWorks network
AU – acoustic signals transmission core for loudspeaking communication (audio)
BL – interlocking core

connects the separate network nodes.
This bus provides execution of tasks as follows:

- transmission of power supplying the separate devices (15 V) preserving intrinsical safety,
- transmission of analogue sound signals (voice for loudspeaking communication, acoustic warning signals, verbal messages generated by the system),
- hardware implementation of safety circuit (a circuit connected in series of closed contacts),
- digital data transmission – used, among others, to transmit information on state of switches, lighting panels, events identification, programme interlocking.

The necessity to meet the intristic safe conditions as well as power of intrinsically safe supply units requires dividing ATUT-NET network into supply zones. Every segment is supplied only from one supply unit and audio and interlocking cores of adjacent zones are separated galvanically in a special node called analogue separator. Connecting the supply units in parallel is forbidden due to intrinsic safety conditions.
To improve the safety the double system of interlocking control is used based on hardware interlocking connection (normally closed contacts connected in series) as well as programme interlocking (interlocking and switching off signal is transmitted in analogue form by LonWorks network).
The programme interlocking makes possible the simple identification of an element which causes interlocking. Measurements made in integrated ATUT-NET applications proved the programme interlocking introduces delay of 100-200 ms; this is the value to be accepted in application executed up to now.

The integral part of the network is **loudspeaking communication sub-system**, which performs priority handling of transmission, identification of transmission spot, transmission and emission of warning-communication signals and verbal messages.

The below mentioned nodes can co-operate in ATUT-NET network:

1. **CUKS-1** control-signalling device provided with 7 control inputs used to supervise the bi-stable information (switched on/switched off type) as well as four outputs used, for instance, to control the information panel.
2. **CUKS-2** control panel provided with 12-key keyboard and five-digit seven-segment display, which performs the function of operator's panel providing the control of state of any devices connected to the network.
3. **CUKS-3** universal loudspeaking signalling device providing simplex communication, verbal messages, warning-communication signals as well as co-operation with safety circuit connected in series.
4. **CUKS-4** universal synoptic panels mapping the operation state of other devices connected to ATUT-NET network by means of LEDs, seven-segment displays or LCDs
5. **CUKS-5** operator's desk

The below mentioned components are indispensable to operate the network:

- **SSA-1** analog signals separators dividing the ATUT-NET network into separate supply zones,
- **SSC-1**, **SSC-2** digital signals separators, fulfilling the function of routers,
- **ZIM** intrinsically safe supply units

The signalling and control system operation using ATUT-NET network is based on highly reliable *master-slave* protocol (the superordinated one in relation to LonWorks protocol). It cat be shortly characterised as follows:

1. The dispatcher's desk (a synoptic panel) sends periodically the REQUEST message to every node of the network. Lack of answer is interpreted by dispatcher's panel as node damage and proper information is displayed on synoptic panel.
2. In nodes, which handle the output elements (for instance, semaphores or displays), the cyclic receiving of a message with response request on node state is expected. Failure to receive this message in given time is interpreted by process as a damage (for instance, transmission break) and causes the determined behaviour of given, for instance, node (red light in semaphore).
3. Some messages related to node state can contain information on battery voltage drop in a node below a preset value; this fact can denote a longer lack of supply voltage in cores (+,-)
4. Actuation of a sensor causing the interlocking causes immediate (taking into consideration time limitations of LonWorks protocol) transmission of proper message to the superordinated node.

5. EXAMPLE OF ATUT-NET NETWORK APPLICATION IN MINING.

ATUT-NET network had been developed to control suspended or floor railways. The CUKS-5/K digital control device is the central device of the system. It fulfils the role of railway operator's panel. The CUKS-5/K device fulfils the functions as follows:

- Monitors the railway drive operation (via series of sensors),
- Switching off the railway drive switch,
- Actuating the railway brake,
- Monitors and displays the speed as well as present location of a railway,
- Co-operation with remaining CUKS-1, CUKS-2 as well as CUKS-3 devices via ATUT-NET network.

A pulse generator is coupled with the shaft of railway drive, which transmits the pulses to dispatcher's desk. Counting the pulses being correlated with direction of railway motion allows determining and displaying the present location on railway speed. Location of railway on the route causes the proper verbal messages to be heard by the personnel (for instance, approaching to a railway station, approaching to a curve, etc). The CUKS- .. devices arranged along railway route fulfil the functions as follows:

- They permit loudspeaking conversation to be performed between any devices of the system,
- They make the emission possible of warning acoustic signals and verbal messages,
- They control displaying the "STOP" lighting transparents at access roads to railway route,
- They switch off and interlock the railway. Actuation of interlocking switch in CUKS devices or limit switch located at the end of railway route together with displaying the information on dispatcher's desk on which switch caused interlocking.

- They control displaying the transparents "PERSONNEL RIDE"" and " TRANSPORT OF MATERIALS " at personnel and materials stations.

A correction sensor of railway location on the route is connected to any CUKS device. Actuation of this sensor causes setting the counter of railway location to strict determined value.
Dispatcher's desk obtains information on sensor state connected to every CUKS device as well as performs the control using MASTER-SLAVE protocol, which is superordinated in relation to LonTalk protocol of LonWorks network.

6. CONCLUSIONS

LonWorks network (ATUT-NET version) is a convenient tool for designing the intrinsically safe control and signalling systems operating in mine underground. LonTalk protocols provides large transmission reliability. Using the NeuronChip brand integrated systems and transceivers facilitate significantly and accelerate the network design process. Neuron C, LonBuilder specialised software facilitates programming the network applications. Very flexible method of addressing of separate nodes allows easy reconfiguration and development of the network.
Several application of ATUT-NET network was executed in Polish mining, among others, to control suspended cableways or floor railways as well as circulation of carriages at shaft-bottom.

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