Remote Data Acquisition System for Hydro Power Plants

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Abstract – **The paper presents a computerized measuring system, based on up-to-date method, for surveying and monitoring of hydroelectric power stations HPS. The SCADA system for hydro power plants is a two level hierarchical system. Its components are the dispatcher level and the hydro power plant level.**

Keywords: – Hydroelectric power station, multi-level system, SCADA, serial interface.

1 Introduction

The hydroelectric power stations are undergoing a modernization process for operating optimization. One of the main ways to improve a hydropower development (hydropower station) is to equip it with SCADA-type acquisition and control systems [1].

The system shown in figure 1 is based on an architecture distributed and two hierarchical levels: the process, local level (located in the HPS) and the territorial dispatching level (located in Hydropower Dispatcher level). The system includes programmable automatic equipments, intelligent electronic devices, data transmission system and computers, [2, 3, 4]. The monitoring system connects three distinctly different environments. The substation, where it measures, monitors, controls and digitizes; the Control Room, where it collects, stores, displays and processes substation data; the Dispatcher Center, where it stores and displays incoming data. A communications pathway connects the three environments [5, 6].

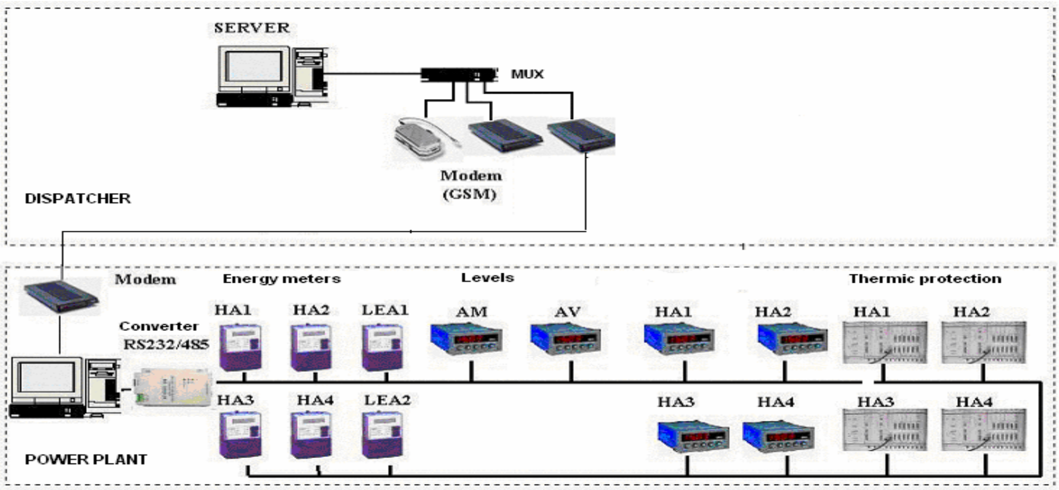

Figure 1. Multi-level system architecture

2 Hydro Power Plant Level

Central computer of the data acquisition system, located in the hydro power plant, provides measurements performance according to a preset program, the instrumentation existing at this time and remote communications by RS485 bus, using Master-Slave architecture and IEC1107, Modbus RTU, ASCII protocols.

The system includes measurements of the water levels, temperatures and main electrical parameters of the hydro generator. Data and messages through a display on "view station" [7].

2.1 Inteligent Electronic Devices

At this level, a main component is the RS-232C/RS-422/485 converter module. It contains a RS-232C / RS-422/485 galvanic isolated communication channel at 9600 baud.

Prometer is a microcomputer based energy meter, a bidirectional advanced meter with logging memory and communication, supplied by CEWE Instrument [8]. Prometer not only measures energy with a class of accuracy 0.5S but also all the different parameters of a three-phase system, such as current, voltage, frequency etc. The meter has a serial communications interface. RS 485 is used when multiple devices are installed at a site or when communicating at longer distances. If there are several meters installed within a reasonable distance, these can be installed with RS 485/422 for linking together as a network. The meters can be read off with a directly coupled PC. In the case of remote reading, the meters are coupled to a common modem. Reading the Prometer from software uses the IEC1107 protocol. Character format is this: 1 start bit, 7 data bits, 1 parity bit (even parity), 1 stop bit.

The digital indicator type DMP 240 from Penny & Giles Controls Ltd. is used for indication of water level and differential level measurements. This electronic unit is suited for use with one 2-wire submersible pressure transmitter type SGS601. The pressure transmitter is immersed in the water and gives a 4-20 mA power signal proportional with the hydrostatic pressure. The serial 4-wire RS422/485 communications interface allows connection to a master device via a multidrop bus. The instrument can use three protocols: ASCII native (no checksums), ASCII Modbus and binary Modbus RTU.

A CPT-60 Thermic Protection Unit, manufactured by ICE Felix, is realized by means of a compatible IBM PC Programmable Logic Controller and an alphanumeric display console CA-64APK with keyboard. An ISaGRAF application runs in QNX (real time Unix) operating system. The protection unit can be integrated into a SCADA system. The thermic protection unit configuration consists of the central unit with peripherical modules for stocking the application, five thermoresistance modules (60 connection points maximum), one digital module of 24 output channels with REED relays, and a communication processor in MODBUS protocol.

2.2 RS 485 & RS 422 Serial Interface

These standards are used in industry for control systems and data transfers [9].

. The binary information is given by the signal polarity. Differential inputs ignore different earth potentials of the transmitter and the receiver. For

RS422 & RS485 the cable can be up to 1200 meters long, without repeaters.RS 422 is intended for point-to-point communications, like RS 232. It is used for extend a RS232 line in industrial environments. The international standard defines an interface with up to 10 receivers for a single transmitter. The receiver input impedance is 4 kOhm. A termination resistor of 100 Ohm is connected to the end of the line. Main reasons for correct termination are reflections at the ends of the line and the minimum transmitter load requirements.

RS 485 exits in two versions. In first version shown in figure 2, all devices are connected to a single twisted pair, with a ground signal. The line needs to have a terminating resistor at both ends.

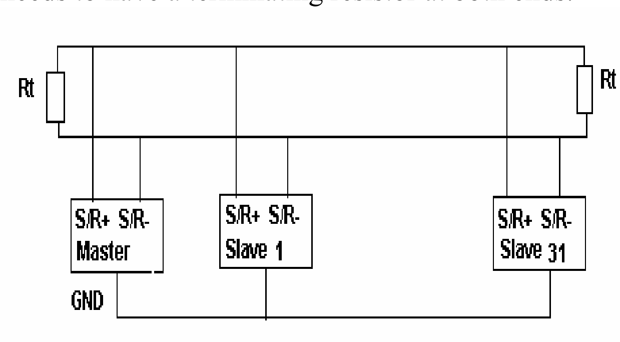

Figure 2. Multipoint communications

Standard assumes speed of 10 Mbit/s. Speed is limited by the resistance of the very long line, and following the signal loss. Capacity of the cable and the skin effect, when the current begins to flow only on the surface of the conductors, need to be considered as well. For example, a data transfer speed of 9600 baud is limited by the maximum capacity of 30-40 nF. If an application requires more than 32 devices several options are available. The simple is to use a RS 485 repeater.

2.3 Data Communications Protocols

2.3.1 ASCII

This is a command sent to an instrument:

;001 RA 2 1<CR><LF>

This is what each piece of the command does:

; start of the command;

001 instrument address (may range from 000 to 247);

RA read analogue; other commands: **SA -** store analogue; **RL**- read logic**; SL**-store logic;

2 data location (here is displayed value filtered);

1 for read commands RA and RL, this is the number of consecutive parameters to read from the instrument; for write commands, it is the data to be written (ON/OFF for logic writes).

Analogue and logic locations corresponding to setup parameters can be read and written to via the serial interface. Some read-only locations, for example displayed value, can never be written to via comes. Listings in location order are given in the setup guide. The instrument may be configured using the front panel or the interface: display filtering, configuring serial communications, configuring alarms, user linearization, calibration and scaling operations, etc.

In case of difficulty with comes, there is a command witch resets the instrument:

;XXX SL 155 ON<CR><LF>

2.3.2 IEC 1107

This international standard has been established by International Electrotechnical Commission. It describes a method for data exchange for meter reading, tariff and load control. This standard presents hardware and protocol specifications for local systems. The protocol permits the reading and programming of tariff devices. The data transmission protocol consists of four alternative modes of operation. All modes offer the provision of automatic data readout. In addition, mode C allows for programming of the tariff devices.

Communication in mode C (see figure 3) is bidirectional and is initiated by the transmission of a request message to the tariff device.

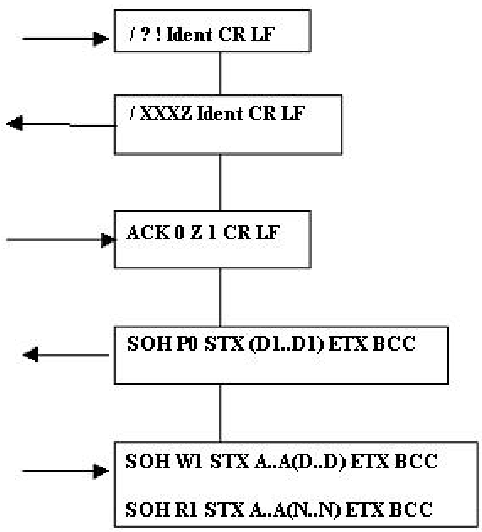

Figure 3. Transmission protocol for mode C

Explanations of messages contents:

SOH -start-of-header character (code 01H)

STX - start of text (code 02H) – *frame start character in the block check*
ETX - *end of text (code 03H)* - end character in the block
ACK - *acknowledge (code 06H)*
"R1"- *read command* - read ASCII coded data
"W1"-*write command* - write ASCII coded data
Identification - manufacturer-specific, printable characters
Z- *baud rate identification* ("0"… "5" characters for 300…9600 baud)
BCC - *block check character*

Write command **W1** will be followed by **ACK** or **NAK**. For the write command, the value represents a data string. The address is the start location to witch the data is to be written.

Read command **R1** will be followed by **STX (D..D) ETX BCC** or **NAK** as reply. For the read command, the address is the start location from witch data is read. The value represents the number of locations to be read including the start location.

2.3.3 Modbus

Modbus protocol enables, via the master, the interrogation of several intelligent slaves. A multidrop link connects together the master and slaves. The master, or the supervisor, controls the exchanges, and only the master takes the initiative. Only one device can be in the process of transmitting on the line at any one time. No slave can send a message itself without first having been invited to do so. The master addresses a slave by supplying it with four types of data: the slave's address, the function required from the slave, data zone, exchange control.

The transmission mode used in system is RTU mode. The data are transmitted in binary code. Each 8-bit byte in a message contains two 4-bit hexadecimal characters. The main advantage of this mode is that its greater character density better data throughput than ASCII. The format for each byte is: 1 bit start, 8 data bits, least significant bit sent first, 1 bit for even/odd parity, no bit for no parity, 1 stop bit if parity is used, 2 bits if no parity.

The address field of a message frame contains eight bits. Valid slave device addresses are in the range of 0 ... 247 decimal. The individual slave devices are assigned addresses in the range of 1 ... 247. A master addresses a slave by placing the slave address in the address field of the message. When the slave sends its response, it places its own address in this address field of the response to let the master know which slave is responding. Address 0 is used for the broadcast address, which all slave devices recognize.

The function code field of a message frame contains eight bits (RTU). When a message is sent from a master to a slave device the function code field tells the slave what kind of action to perform. Examples are to read the ON / OFF states of a group of discrete inputs, to read the data contents of a group of registers, to write to designated or registers. When the slave responds to the master, it uses the function code field to indicate either a normal (error-free) response. For a normal response, the slave simply echoes the original function code. The listing bellow (see table 4) shows the function codes supported by controllers.

Code	Nature of the functions
01	Reading of N output bits
03	Reading of N output words (16 bits)
16	Writing of N output words (16 bits)

Table 4. The function code

The error-checking field contains a 16-bit value implemented as two 8-bit bytes. The error check value is the result of a Cyclical Redundancy Check calculation performed on the message contents. When the CRC is appended to the message, the low-order byte is appended first, followed by the high-order byte. For applications using host computers, a detailed example in Visual Basic, [10, 11] code of CRC generation is given bellow:

```
Sub crcgeneration(message)
 Dim  crc, char, bit
 crc = 65535
For char = 1 To Len (message)
   crc = crc  Xor  Asc (Mid$ (message, char, 1))
   For bit = 1 To 8
     If (crc And 1) <> 0 Then
       crc = (crc \ 2)
       crc = (crc Xor 40961)
     Else
       crc = (crc \ 2)
     End If
   Next bit
Next char
 crc = (crc And 65535)
 crc2 = (crc \ 256)
 crc1 = (crc - (crc2 * 256))
 End Sub
```

The entire message frame must be transmitted as a continuous stream. An interval of at least of 3.5

character times marks the end of the message.

An exception answer is sent back by the slave when it cannot carry out the request it has received. The answer code is the question function code in addition with H80. The slave returns a code that is equivalent to the original function code with its most significant bit set to logic 1. The error code could be:

- 1 - the function is not recognized by the
- slave
- 2 - the addresses are not present
- 3 - the value are not permitted
- 4 - the slave has started to carry out the request but cannot continue to process it completely.

The function code **03** enables the reading of output words witch can be written and read in the slave by the master. Details of the frames are as follows:

Question

Slave	03	Address		No. of words		CRC	
		MSB	LSB	MSB	LSB	LSB	MSB
1 byte	1 by	2 bytes		2 bytes		2 bytes	

Answer

Slave	03	Number of bytes read	Value of first word			Value of last word		CRC	
			MSB	LSB		MSB	LSB	LSB	MSB
1b	1b	1 b	2 bytes			2 bytes		2 bytes	

2.4 Object Based Software

Because of its simplified approach to application development with the focus on rapid development of user interfaces, database connectivity and easy extensibility, Visual Basic has become a widely adopted technology for PCs running Win32 operating systems [12, 13]. Extensibility of the VB development environment is provided through the use of plug-in tools that are based on the Component Object Model, or COM. All Win32 operating systems and applications are based on COM. The core of the Microsoft Win32 operating systems model is described using the Component Object Model, which was released in 1993. COM breaks down everything into manageable pieces. The way components fit together is clearly defined by the COM specifications and source code, which is available and licensable from the The Open Group, formerly OSF and X/Open.

The HMI (human-machine interface) application requires a few user input screens and simple data logging. Until recently, the use of Visual Basic for industrial HMI applications was limited by the performance of interpreted code at runtime and the lack of tools for industrial applications such as control system hardware connectivity and data visualization. New technologies based on COM have removed these barriers by extending the suite of tools and objects available to the Visual Basic developer.

HMI provides the ability to read data from programmable logic controllers or intelligent electronic devices and write data back to the PLCs and IEDs [14]. The display of data, input of data, and initiation of the read and write transactions from the user interface is handled using built-in objects in Visual Basic: text boxes, labels, lists and command buttons. The objects are called ActiveX controls, formerly known as OCX's or OLE custom controls. An ActiveX control is a small piece of software, written to the COM specifications, that is like a “black box” and has properties, methods, and events. ActiveX controls are also available for database access, alarm reporting, basic trending, and more.

3 Dispatcher Level

The dispatcher level is in charge of collecting and archiving the data coming from the hydro power plants and presenting this data to the dispatchers [15].

The remote communication server gathers the information from the hydro power plants connected by means of modems over GSM or phone lines. The dispatcher level is in charge of collecting and archiving the data coming from the hydro power plants and presenting this data to the dispatchers. These are real and reactive power flow (watts and vars), voltages and currents and other measurements, like water levels. Analogue data is refreshed periodically so that the operator can be assured the data on his screen is relevant. It generates energy report (shown in figure 5) and graphical representations based on the data stored in the system database [16, 17].

Data 01-Sep-05

Interval	Strejesti	Arcesti	Slatina	CHE Ipotesti		CHE Draganesti		CHE Frunzaru		CHE Rusanesti		CHE Izbiceni	
orar	Trafo	Trafo	Trafo	Trafo 1	Trafo 2	Trafo 1	Trafo 2	Trafo 1	Trafo 2	Trafo 1	Trafo 2	Trafo 1	Trafo 2
0<>1	15.21	24.46	19.11	18.35	17.96	9.53	9.35	8.88	8.79	18.62	18.85	13.34	13.43
1<>2	15.06	24.65	18.77	18.17	17.80	9.50	9.33	11.07	10.97	17.36	17.57	13.42	13.50
2<>3	15.14	24.48	18.80	18.23	17.87	9.55	9.36	13.62	13.48	15.93	16.13	13.63	13.71
3<>4	14.84	24.72	17.36	18.20	17.82	9.48	9.32	13.78	13.63	16.09	16.28	13.39	13.48
4<>5	14.62	24.51	16.65	18.33	17.97	9.51	9.33	13.80	13.66	15.91	16.12	13.76	13.86
5<>6	14.58	24.65	16.38	18.06	17.70	9.53	9.35	13.75	13.60	16.27	16.47	13.47	13.56
6<>7	14.62	23.51	16.04	18.23	17.86	9.46	9.28	13.80	13.64	16.93	17.16	13.48	13.57
7<>8	15.26	23.11	15.90	18.79	18.42	9.60	9.42	13.53	13.39	15.65	15.85	13.40	13.49
8<>9	14.78	15.15	11.09	17.77	17.40	9.47	9.30	13.72	13.57	16.88	17.10	13.50	13.60
9<>10	14.88	19.33	9.03	18.40	18.03	9.47	9.30	13.84	13.69	15.88	16.06	13.59	13.69
10<>11	14.33	24.64	9.10	18.42	18.05	9.44	9.26	13.72	13.58	16.45	16.66	13.68	13.79
11<>12	1.68	23.91	9.16	18.08	17.71	9.32	9.16	13.66	13.51	16.47	16.64	13.42	13.50
12<>13	0.00	24.08	16.90	17.51	17.15	9.42	9.25	13.85	13.71	16.50	16.68	2.33	2.33
13<>14	0.00	23.94	18.07	18.36	17.98	9.47	9.29	13.70	13.55	16.49	16.67	3.12	3.16
14<>15	0.00	23.93	18.06	18.30	17.91	9.46	9.29	13.69	13.56	16.48	16.64	8.95	8.98
15<>16	8.56	24.15	17.98	16.64	16.28	9.44	9.26	12.72	12.56	16.42	16.61	11.58	11.67
16<>17	15.50	23.90	18.08	15.51	15.20	9.39	9.21	11.05	10.93	16.35	16.50	13.41	13.40
17<>18	15.45	24.43	18.20	15.38	15.05	9.39	9.23	10.71	10.59	15.42	15.61	11.47	11.52
18<>19	16.57	24.92	18.21	15.73	15.39	9.47	9.29	11.08	10.96	12.73	12.84	11.42	11.50
19<>20	16.43	24.79	18.17	15.55	15.23	9.26	9.09	10.95	10.81	10.43	10.52	13.02	13.11
20<>21	16.57	25.00	18.29	15.40	15.08	9.19	9.03	10.98	10.87	10.74	10.83	13.43	13.52
21<>22	16.65	24.83	18.30	16.20	15.86	9.25	9.08	11.05	10.92	10.72	10.82	12.94	13.04
22<>23	16.48	24.70	18.26	15.11	14.81	9.19	9.02	12.27	12.14	13.64	13.78	13.29	13.38
23<>24	16.52	24.66	18.15	15.52	15.21	9.20	9.01	12.96	12.80	14.89	15.01	12.87	12.96
	303.73	570.45	394.06	414.24	405.74	225.99	221.81	302.18	298.91	369.25	373.40	289.91	291.75
				819.98		447.80		601.09		742.65		581.66	

Figure 5. Energy report

4 Conclusions

Modern information technology architecture distributes the computing resources into clients and servers in electroenergetical systems .

Winsock control comes with Visual Basic 6 and is used to create flexible applications that access the low-level functions of the Transmission Control Protocol/Internet Protocol.

There are two separate applications, one of which is a server and the other is a client. Both client and server interact with each other to exchange data on-line. Client sends a request to the server and the server, which is connected to a database, retrieves the information requested by the client from the database and returns the requested information back to the client. Database is located in the HPS, on a machine different from the one that hosts the client application, located in Hydropower Dispatcher level.

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