INVESTIGATION OF ELECTRONIC INSTRUMENTS AND METHODS FOR WEB-BASED ENERGY MANAGEMENT SYSTEM DEVELOPMENT

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Energy management systems exchange enormous amounts of information requiring quick access and data security. The communication and integration of data from various control centers, power plants, and substations, have become necessary. SCADA (Supervisory Control and Data Acquisition) systems are essential parts of the energy management systems that employ a wide range of computer and communication technologies. The paper presents development an electronic device to be connected to Internet-based SCADA system.

Keywords: SCADA, Ethernet, energy measurement, control

1. INTRODUCTION

Electric power system has been expanding and becoming more complex. Its functioning affects all public activities. The faults in electric supply lead to disturbances in industry, transport, healthcare, communications and etc. Correct function of such system requires reliable management. In order to make true decisions the need of fast and accurate information is very strong.

The typical applications of communications in the power system which require a real time information are:

- data acquisition from generation, transmission, distribution and customer facilities;
- communication among different sites, substations, control centers and various utilities;
- real-time information provided by power markets and weather service;
- database information exchange among control centers;
- relay settings adjustments;
- load frequency control and generation control;
- load shedding based on contingency analysis;
- control of devices such as AC transmission systems.

The use of the communications will be spread not only to the control, protection and acquisition tasks but also to the maintenance or the metering. Therefore, the system requires a high bandwidth and low latency data transmission which is susceptible to be increased in the future with innovative uses. In any case, the use of the communications is relayed to the transmission of information about the system to a center which will elaborate remedial actions in case of disturbances (protection, control) or will use the information to utilise them in other task of the power system (planning, control).

The Supervisory Control and Data Acquisition (SCADA) system is a part of the energy management system which mission deals with the data measurement, collection and transmission to a decision central control. SCADA usually process discrete and continuous information coming from measurements done in the field [1]:

- measurements: active and reactive power flows, bus voltages and network frequencies, for transmission networks at 2 or 4 seconds periodic update and for sub-transmission network at 20 seconds periodic update;
- signals: breaker positions with max. 1s delay, tap changer and isolator positions with max. 4 s delay;
- chronological registration of events, consisting in changes of status of protection systems, as well as switching and regulating devices, coming from each transmission bus and incident branches. Binary information associated to the component operating configuration is locally refreshed in terms of milliseconds;
- analog registration of significant quantities in instantaneous form (sampling time about 1 ms) or in RMS form (sampling time of about 100ms), including a subset of logical quantities to recognise protection system interventions.

The major components of the SCADA system are:

- substation remote data acquisition, metering, control unit such as RTU (Remote Terminal Unit);
- data processing unit such as a substation server or an Intelligent Electronic Device (IED);
- MMI (Man Machine Interface) and central data processing unit installed in the control enter.

2. Possibilities for Data Transmission in SCADA Systems

The data transmission can be analog or digital.

The advantages of digital transmission over the analog transmission can be summarized as follow:

- it is a low cost technology, digital equipment is less expensive to manufacture than analog;
- digital transmission provides higher quality in most respects than analog;
- an increasing amount of communication takes place between digital terminal equipment such as computers;
- high bandwidth links economical;
- better security: possibility of encryption.

The data transmission can be developed using different types of the communication media:

- fixed networks including public switched telephone and data networks;
- wireless networks including cellular telephones and wireless ATM (Asynchronous Transfer Mode), radio systems, microwave (radio signals operating in the 150 MHz to 20 GHz frequency range);
- power line carrier is the most commonly used communication media for protection function. However, this medium does not offer a reliable solution for wide

area data transmission. Communication with remote sites can not be maintained during a disturbance;

- computer networks including various dedicated LANs, WANs, and the Internet;

- the satellite network is another segment of the communications system that can provide important services which are difficult to carry out with normal communication techniques. These services include detailed earth imaging, remote monitoring of dispersed locations and time synchronization using signal from GPS (global positioning system).

Local area network is widely used as data communication backbone in many power system control and monitoring systems due to its high performance and scalability. Among different LAN systems such as FDDI, Ethernet, Token Ring, Token Bus, Ethernet is normally chosen as physical / data link layer network because of its predominant role the marketplace and the subsequence availability of low-cost implementation and associated network hardware (bridge, router and switch) [2, 3, 4]. In addition, the scalability of Ethernet is well defined with 10/100 MB implementations. Processors are available today with multiple Ethernet ports integrated into the chip and next generation designs are planned with Gigabyte Ethernet. Ethernet also supports open system and cross-platform architecture, information exchange and communication can be done with minimum effort.

Due to the above reasons, more and more substations currently make use of Ethernet as the main data communication backbone. Another interesting feature of local area network is its ability to support cooperative client/server application.

3. Aim of the Project

However, existing SCADA information management systems cannot satisfy the new challenges as more and faster information has now become desirable by many users [5, 6]. Technological advantages in networking have made it possible to develop a low cost communication system for accessing real time power system information over digital network. One solution to these problems is to connect the device to a PC and have the PC make the connection to the Internet via an Internet service provider using Secure Socket Layer. Unfortunately, this solution may not meet the low-cost criterion and, depending on configuration, can lack reliability.

An alternative to using a PC is an embedded solution: a small, rugged, low-cost device that provides connectivity capabilities of a PC at a lower cost and higher reliability. This device (sometimes referred to as an Internet gateway) is connected to the equipment via a serial port, communicates with the equipment in the required native protocol, and converts data to HTML or XML format. The gateway has an IP address and supports all or at least parts of the TCP/IP stack—typically at least HTTP, TCP/IP, XML file, just as if it were any PC server on the World Wide Web. In cases where the equipment incorporates an electronic controller, it may be possible to simply add Web-enabled functionality into the existing microcontroller.

The open nature of the Internet requires data security measures when implementing Internet-based SCADA systems. Processes, procedures, and tools must address availability, integrity, confidentiality, and protection against unauthorized users.

SCADA system gathers incoming power system data for further processing by a number of distributed processes. The architecture of Internet-based SCADA system which is developed to work with data bases is shown on Fig. 1. The structure is organised on three layers. The first layer consists of remote terminal units (RTU) which measure the values of the electric power system parameters. The second layer includes an applied server (Web server) and data base. The client interface is realised by standard Web browser.

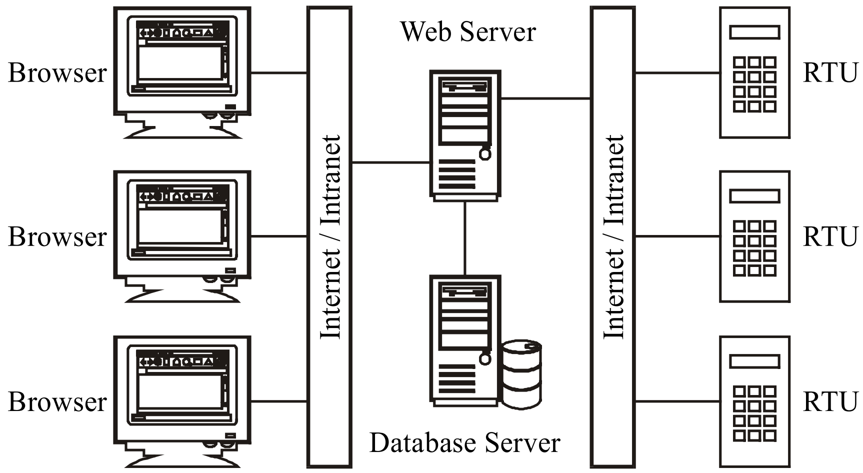

Fig. 1. Internet-based SCADA system architecture

The aim of the project is the implementation of an intelligent remote terminal unit supporting HTTP protocol based on TCP/IP. The remote terminal unit provides for the interface with the electric power system - collects field data and transmit commands to the executive devices. It includes analog-to-digital converters, digital inputs, digital-to-analog converters and digital outputs. In addition the intelligent remote terminal unit is intended to perform the function of the intelligent electronic device carrying out the network communications.

4. Circuit Proposal

Nowadays the data transmission in the electric power system is provided using analog and digital interfaces.

The output quantities of the analog outputs are load independent direct current or direct voltage signals with different ranges. For the current outputs the ranges are -5mA÷+5mA, 0mA÷20mA or 4mA÷20mA. Usually the range of the voltage outputs is 0÷10V.

The digital interface is usually serial in order to minimize the number of the wires. The standard is mainly RS485, RS232 or LON. There are custom defined interfaces also.

In order to be able to work together with the existing equipment the remote terminal unit has to support the interfaces mentioned above additionally with the Ethernet.

To perform the interface with the electric power system there is a need of analog-to-digital converters, digital inputs, digital-to-analog converters and digital outputs.

Thus the microcontroller intended to be built in the remote terminal unit must have enough resources to solve the tasks of its application.

After analysing the possibilities of different microcontrollers and by reason of continuation of previous projects the microcontroller MC9S12NE64 of Freescale Semiconductor has been chosen. It includes a 16-bit central processing unit (HCS12 CPU), 64K bytes of FLASH EEPROM, 8K bytes of RAM, Ethernet media access controller (EMAC) with integrated 10/100 Mbps Ethernet physical transceiver (EPHY), two asynchronous serial communications interface modules (SCI), a serial peripheral interface (SPI), one inter-IC bus (IIC), a 4-channel/16-bit timer module (TIM), an 8-channel/10-bit analog-to-digital converter (ATD) and digital inputs and outputs.

The block diagram of the intelligent remote terminal unit is shown on Fig. 2.

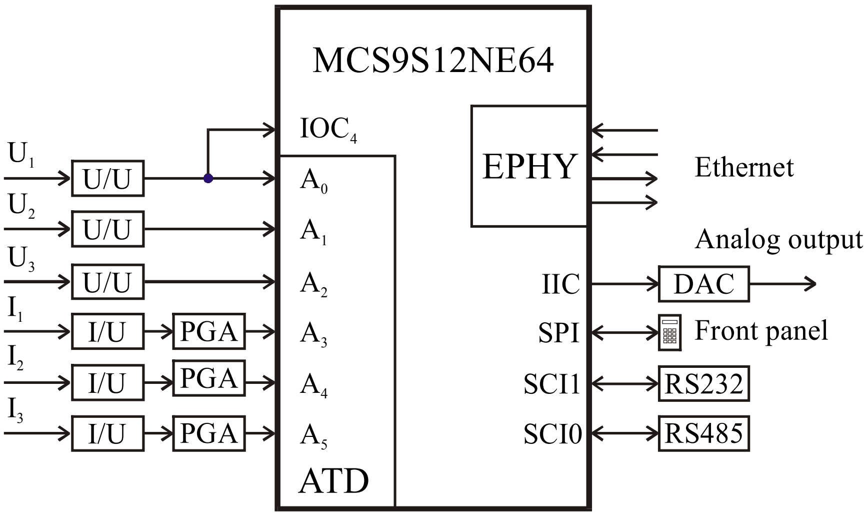

Fig. 2. Intelligent remote terminal - block diagram.

All modules of the microcontroller are used. The input signals are three voltages (U_1, U_2, U_3) and three currents (I_1, I_2, I_3). The signals are converted to voltage by voltage dividers and current transformers. To cover the wide dynamic range of the current programmable gain amplifiers (PGA) are used. The normalised signals are applied to the inputs of the analog-to-digital converter (ATD). The frequency of the electric power system is measured by using the channel IOC_4 and the function "input capture" of the timer module (TIM). The first of the serial communications interfaces modules with proper bus transceiver is used to meet the standard RS-485 and the second one - to meet the standard RS-232. The serial peripheral interface connects the microcontroller to front panel which is used for visualisation and programming. In order to support analog interface a serial digital-to-analog converter is added. The data is loaded via the inter-IC bus. Connection to Internet is performed using the integrated 10/100 Mbps Ethernet physical transceiver. Its main features assisting the application are:

- supports auto-negotiation;

- auto-negotiation next page ability;
- single RJ45 connection;
- 1:1 common transformer;
- baseline wander correction;
- digital adaptive equalization;
- integrated wave-shaping circuitry;
- far-end fault detect;
- MDC rates up to 25 MHz.

5. CONCLUSIONS

Power system substations become more complex due to the growth of new service requirements. The information must be transmitted under few milliseconds for the proper and adequate protection and control. The application of LAN and WAN communication technologies for substation's automation has become more and more common practice. Thus, the use of WAN communication between substations and between substations and control centres is now enabling the utilities to perform control and protection functions in a substation, using data from other sites and from different voltages levels. That would represent a rise of the transmitted data in the SCADA which leads to introducing intelligent remote terminal units.

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