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Embedded Platform Architecture for Substation Automation

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Abstract

For a more efficient and economical management of substations of power system areas, the concept of substation automation has been introduced using intelligent and ubiquitous IT techniques. In this paper, ubiquitous IT prototype hardware, functions and communication interfaces on an embedded platform for substation automation are proposed. Also, operating system architecture is suggested for the effective implementation of substation automation.

Key Words : Embedded Platform, Substation Automation, Ubiquitous IT techniques, Smart Substations, SCADA (Supervisory Control and Data Acquisition) systems

1. Introduction

The term ubiquitous can be defined as existing or being everywhere at the same time, constantly encountered, and widespread. When applying the ubiquitous concept to networking, computing and communicating technologies, the term ubiquitous implies that technology can be used anywhere and anytime [1-3].

Stated simply, ubiquitous computing is changing our daily activities in a variety of ways. When it comes to using today's digital devices and tools, terminal users or operators tend to communicate in different ways, be more active and efficient, conceive and use geographical and temporal spaces differently and have more control over their work. In addition, ubiquitous computing is global and local, social and personal, public and private, visible and invisible [1-3].

Ubiquitous IT (Information Technology) applied to mobile networking and ubiquitous computing refers to an emerging computing paradigm that aims at providing hardware and software means for offering user-friendly information and compatible communications, anywhere and anytime, as needed [1,3].

Substation control and operation is very important for a reliable electrical power system. Recently, the concept of smart substations has been introduced using intelligent and ubiquitous techniques for more efficient and economical substation management. It is clear that facilities,

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equipment and devices for smart substations have been deployed in ad-hoc network structures in many infrastructures and are widely used in a number of different kinds of applications including economic load dispatch, security monitoring, regulation of climate and other such functions. As our use of ubiquitous computing and communication devices has increased, we have gradually built greater functionality into our SCADA (Supervisory Control and Data Acquisition) / DCS (Digital Control Systems) systems. The by-product of these technological advances has been a lack of planned implementation of what we may refer to as high confidence devices and software [4,5].

In this paper, new ubiquitous prototype hardware and new function definitions for automation substation application in electrical power industrial areas are proposed. Communication interfaces on an embedded platform have also been built up and operating system architecture is suggested for efficient application. The proposed platform has been designed as a general purpose, multi-functional platform for smart substation application, and is even suitable for general ubiquitous IT terminals.

2. Smart Substation

The smart substation concept enables more reliable and more efficient real-time monitoring and control of the facility nodes installed in a substation. Smart devices can be added to traditional substation devices to perform intelligent functions and provide ubiquitous IT techniques for monitoring, control and management of the system. The main functions of a smart substation are summarized as follows:

- Intelligent analysis for alarm processing, bad data processing, etc.
- Intelligent control for auto-restoration, remedial or predictive action, and emergency state estimation
- Intelligent maintenance and management
- Intelligent physical safety
- Interconnection and application with a Geographic Information System (GIS).

The system structure of a smart substation is given in Fig. 1 [4]. The figure shows the general SCADA network topology that consists of nodes and terminals. Also, this figure presents a different kind of wire backbone network; each network layer is comprised of DCS LAN, Ethernet LAN and Serial Network communication. The substation's utilities, which manage distribution facilities from existing SCADA systems, applications or services, are available for the integration of the data from the proposed ubiquitous IT platform. The figure also shows how to build up new routes that connect to other nodes and terminals. If existing wire (serial bus) networks develop a fault or sustain damage, then the ubiquitous network reconfigures itself to bypass or detour the fault in the local substation.

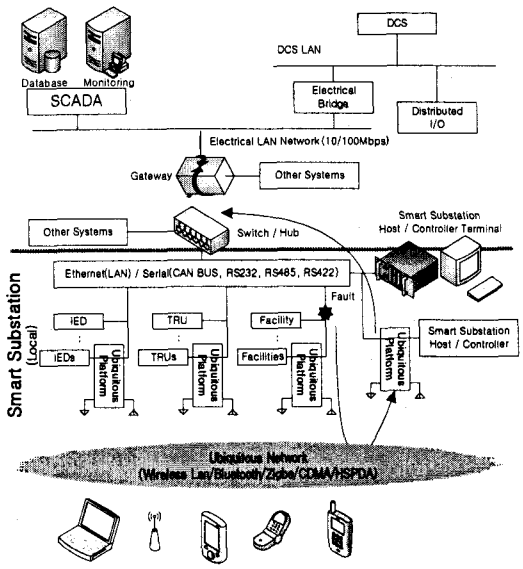

Fig. 1. System Structure of a Smart Substation

3. Implemented Platform for a Smart Substation

A smart substation network is constructed with various wired and wireless communication capabilities, i.e., a smart substation provides different kinds of communication interfaces [6]. Therefore, the terminals, nodes and RTUs of smart substations have provisions for communication, interconnection, and network compatibility. The proposed general-purpose ubiquitous IT terminal for SCADA supports existing SCADA interfaces and exports to the standard specifications and customized communication interfaces, for example, wireless LAN, Bluetooth and Zigbee.

Fig. 2 shows the architecture of the proposed platform. The terminal has multi-functional tasks and interfaces, which provide compatibility for mobile computing and the existing network intranet of the substation. The solution to the problem of creating a general-purpose smart substation terminal is to use an embedded system, with its own operating system, applications and customized hardware interfaces. Fig. 2 depicts the architecture of the implemented hardware and software (including operating and application systems) for ubiquitous and smart substation terminals under SCADA.

The platform architectures are designed with an embedded system based on a 32-bit ARM (v5TE) SoC core and an embedded Linux operating system kernel for multi-function and multi-purpose application. Basically, the hardware section provides standard wired communication such as CAN BUS (2.0b), USB, Ethernet (10/100M) and Uart, which are commonly used in local area networks with RS232 and RS485. The hardware also provides two PCMCIA slots, supporting an external wireless modem for wireless LAN (802.11b) and CDMA for a cellular telephone connection.

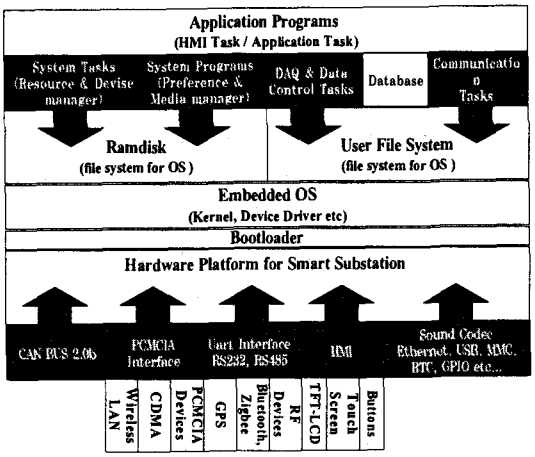

Fig. 2. Proposed Architecture of a Smart Substation Platform

The Ethernet and wireless LAN devices support the infrastructure, ad-hoc network, and web-based access, as well as TCP/IP, HTTP, FTP, Telnet, SMTP services for internet protocol. Additionally, the CDMA module provides SMS and PPP (Point-to-point protocol).

With this platform it is possible to create ubiquitous IT and sensor networks that are similar to RFID using Bluetooth, Zigbee and RF communication working through the Uart (RS232) interface. Table 1 describes the specifications and functions of the proposed ubiquitous smart substation terminals. This hardware platform has four kinds of modules (PCB boards): the main controller board (XScale PXA255), wire communication interface boards (Uart, Ethernet, USB etc.), interface boards (PCMCIA for wireless, flash memory and input/output connectors), and LCD modules. This platform provides standard interfaces and flexible communication devices; moreover, it supports various data storage methods.

This platform facilitates the connection of a web

camera using the USB interface and digital I/O sensors through GPIO, both of which are good functions for an autonomously operating substation. These functions therefore provide web-based monitoring, control, and security and can assist in the prevention of physical failures such as fires, floods and break-ins.

Table 1. Specifications of smart substation platforms

Items / Functions	Descriptions / Specifications
CPU	Intel XScale PXA255 400MHz ARMv5TE Arch, 32bit SoC Embedded Processor
Memory	64Mbyte RAM / 32Mbyte Flash (ROM)
Storage	PCMCIA/CF and SD/MMC Flash Memory including USB Mass Storage Devices
Operating System	Embedded linux kernel 2.4.19
Applications	Web (HTTP), FTP, Telent, SMTP, DBMS etc
GUI / MHI	Qt/Qtopia, touch screen 7inch LCD
Audio / Sound	Setreo AC'97 Codec compatible / CS4202
Ethernet	10/100[Mbps] combo Ethernet controller
GPS / GIS	NMEA-0183 protocol / Uart (TTL RS232C)
Uart Interface	RS232C, RS485
Wire Communications	USB Host/Client/OTG 2.0, CAN BUS 2.0b
Wireless Communications	PCMCIA (x2) I.F.: Cellular CDMA 2000 1x, Wireless LAN (11[Mbps]/802.11b), Uart I.F. (selectable): Bluetooth, Zigbee, RF modules
Auxiliary Interfaces	IrDA, I2C, I2S, SPI, SSP etc

Fig. 3 shows the proposed hardware platform for a smart substation. The implemented wired communications are connected to an existing substation backbone (Ethernet) SCADA, which is interconnected with a local standard network (CAN BUS, RS232, RS485).

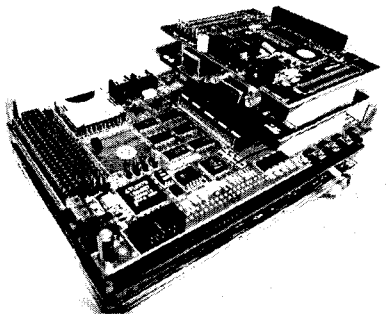

Fig. 3. Proposed Hardware Platform Terminal of a Smart Substation

The wireless interface provides two different network ranges: the wider range is covered by the wireless LAN, CDMA and HSDPA modules that are connected to higher layer networks; and the smaller range is covered by the Bluetooth, Zigbee and RF module through the Uart interface.

These intricate and diverse communication networks provide the ubiquitous IT benefits and compatibility. Interconnecting wired and wireless topologies provide uninterrupted communication networking with bypass routes, and provide an alternative network for damaged communication wires or out of service equipment. Each electrical SCADA system and facility should be evaluated to determine which configuration for communication is the best solution.

4. Conclusion

Recently, intelligent and ubiquitous IT techniques have been introduced for more efficient and economical management of substations in electrical power areas. Networks of smart substations are constructed using mixed wired and wireless communication techniques and provide different communication interfaces. Terminals, nodes and IEDs of smart substations have several functions that can communicate among themselves with good network compatibility.

In this paper, the issues of ubiquitous networking, security, smart substations and a general purpose terminal platform for Smart substations of electric power systems are reviewed. A ubiquitous IT application platform that provides the following benefits and advantages for smart substation facilities are proposed:

a) Compatible connection interface for communication network
b) Flexible networking for wired and wireless topologies
c) Uninterruptible SCADA network
d) More reliable, efficient control and management
e) Integrated and multi-functional platform

In the future, more studies on the security of smart substations will be required to ensure safe operation.

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Biography

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