(12) PATENT (11) Application No. AU 200038574 B2
(19) AUSTRALIAN PATENT OFFICE (10) Patent No. 773185

(54) Title
Multiple communications protocols in a protective relay

(51)[7] International Patent Classification(s)
H02H 001/00

(21) Application No: **200038574** (22) Application Date: **2000.02.11**

(87) WIPO No: **WO00/48282**

(30) Priority Data

(31) Number	(32) Date	(33) Country
60/119819	1999.02.12	US
09/437137	1999.11.10	US

(43) Publication Date : **2000.08.29**
(43) Publication Journal Date : **2000.11.02**
(44) Accepted Journal Date : **2004.05.20**

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(56) Related Art
APOSTOLOV ET AL "NETWORK INTERFACE MODULES FOR MICROPROC. RELAYS INTEG..." P309-312, DEV. IN POWER SYST. PROTECTION, MARCH 1997, CONF. PUB. NO.434, IEE LONDON

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H02H 1/00

A1

(11) International Publication Number: WO 00/48282

(43) International Publication Date: 17 August 2000 (17.08.00)

(21) International Application Number: PCT/US00/03417

(22) International Filing Date: 11 February 2000 (11.02.00)

(30) Priority Data:

60/119,819	12 February 1999 (12.02.99)	US
09/437,137	10 November 1999 (10.11.99)	US

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(81) Designated States: AU, BR, CA, CN, CZ, JP, KR, MX, PL, SG, ZA, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

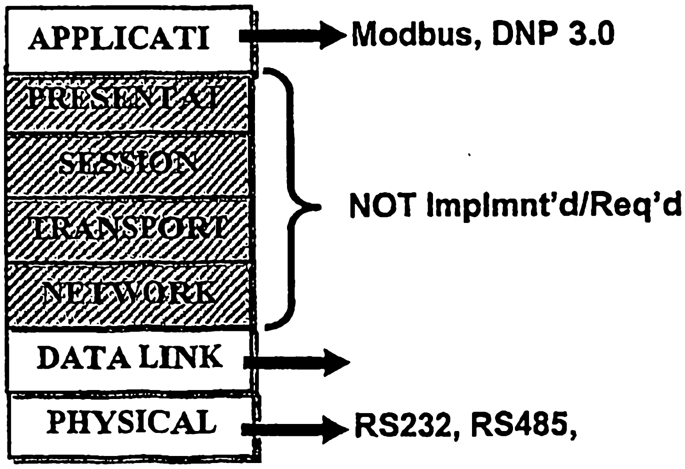
Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: MULTIPLE COMMUNICATIONS PROTOCOLS IN A PROTECTIVE RELAY

(57) Abstract

A protective relay and power system protection method which incorporates multiple user-selectable communications protocols over multiple communications ports. The relay can support multiple communications protocols over a single communications port, and can support simultaneous formatting and communication over multiple communications ports using different protocols. By supporting a full array of communication protocols in each relay, protective control functionality is enhanced.



MULTIPLE COMMUNICATIONS PROTOCOLS

IN A PROTECTIVE RELAY

BACKGROUND OF THE INVENTION

The present invention generally relates to digital protective relays and protective control of electrical power distribution systems. More particularly, the present invention relates to digital protective relays having communications capabilities.

Intelligent protective relays are known which incorporate a digital microprocessor for providing protective control of power distribution systems. There are known digital protective relays that have communications capabilities. However, the communications capabilities are typically relatively limited, and might include, for example, an application layer protocol such as Modbus RTU or ASCII for communication over a Universal Asynchronous Receiver Transmitter (UART) data link layer with an RS485, RS232 or other fiber optic physical layer interface. Typical digital protective relays having a communications capability support only one application layer communications protocol, even where the relay includes multiple communications ports.

U.S. Patent 5,680,324 discloses a communications processor for electric power substations. The communications processor includes an electronic network system with seventeen individual communications ports, four quadrature UART devices, each of which serves four of the ports, and a microprocessor which processes and control the flow of data under the control of stored control programs, command settings, and command logic. Relays, meters, or other intelligent electronic devices are connected to some of the ports, and remote terminal units, local computers, or a modem are connected to master ports. The communication processor has a capability of communicating with the various port devices through an ASCII communication format. The processor is capable of supporting simultaneous communication with multiple devices and users. However, the processor is a centralized communication device, which is separate and distinct from the protective relays, meters, and other port devices. Accordingly, the '324 patent does not focus on the communications capabilities of the relays or other port devices.

To further enhance the utility of a digital protective relay, and to provide more comprehensive protective control of power distribution systems, it would be desirable to improve the communications capabilities of digital protective relays. More particularly, it would be desirable for a protective relay to support multiple communications protocols and multiple communications network profiles. It would also be desirable for a protective relay to communicate concurrently over different types of communications networks, such as well-known local area networks (LANs), wide area networks (WANs), and the internet and to communicate sequentially in different protocols over the same communications port. It would further be desirable for a relay to allow user selection of the protocols and/or communications profiles. Known protective relays do not sufficiently address these needs.

BRIEF SUMMARY OF THE INVENTION

The present invention overcomes the problems described above, and achieves additional advantages, by providing for a protective relay which includes connections for operatively coupling the relay to an electrical distribution system, at least one communications port for communicating relay information over a communications network, and processing circuitry for monitoring the electrical distribution system via the connections, where the processing circuitry provides protective control for the electrical distribution system, generates relay information to be communicated over the communications network, and formats the relay information in one of a plurality of communication protocols. The communication network can be a LAN, WAN, the Internet, or other suitable network. The communications protocols can be selected by the user, and the relay can communicate using different communications protocols-simultaneously over separate communication ports, and serially over a single communications port.

By greatly increasing the communications capabilities of the relay, the present invention can provide greatly improved protective control of electrical power distribution systems.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention and its features and advantages can be understood more completely by reading the following Detailed Description in conjunction with the accompanying drawings, in which like reference numerals designate like elements, and in which:

FIG. 1 is a diagram showing the communications protocols supported in some known industrial communications systems;

FIG. 2 is a diagram showing the communications protocols supported by some known Profibus-based communications systems;

FIG. 3 is a diagram showing the communications protocols supported by some known Ethernet-based communications systems;

FIG. 4 is a diagram showing the present invention's support of seven layers of communications protocols;

FIG. 5 is a block diagram of a relay according to one embodiment of the present invention which supports the communications profile of FIG. 4;

FIG. 6 is a diagram showing an exemplary breakdown of communication classes and subclasses;

FIG. 7 is a diagram showing an exemplary protocol layering in a relay;

FIG. 8 is a diagram showing a top-level data flow in and out of the communication subsystem of the relay of FIG. 5; and

FIG. 9 is a detailed diagram of the internal processing components of the relay of FIG. 5.

DETAILED DESCRIPTION Of THE INVENTION

Referring now to FIG. 1, a protocol stack or communications profile of known industrial communications systems is shown. Such known systems support an application layer protocol, such as Modbus or DNP 3.0, a data link protocol, such as UART (which uses 8 bits, 1 stop bit, and no parity bits), and a physical layer protocol, such as RS232, RS485, or fiber optic communications. As shown in FIG. 1, the remaining layers of the ISO 7-layer OSI model for generic communications systems (presentation layer, session layer, transport layer, network layer) are not required or implemented in typical industrial communication systems.

FIG. 2 is a diagram showing the communications profile of a Profibus based communications system. This known system supports an application layer protocol in the form of FMS or DP, a data link layer protocol FDL, which is achieved by a chip set available from Siemens Corporation, and a physical layer protocol RS485. The Profibus system also supports the LLI protocol (for presentation and session layers) and the FMA protocol (for transport and network layers).

The protocol stack of conventional Ethernet (i.e., according to the IEEE 802.3 standard) communications systems is shown in FIG. 3. The protocol stack includes an application layer protocol such as Modbus or DNP 3.0, a data link layer protocol according to the IEEE 802.2 standard so known as CSMA/CD), and a physical layer protocol according to the IEEE 802.3 standard (also known as 10BaseT/5/2/FL). The transport and network layers are supported by the TCP/IP or UDP protocols, and the presentation and session layers are not implemented or required in an Ethernet based system.

It will be appreciated that none of the examples shown in FIGs. 1-3 support separate communications formats in all layers of the Industrial Standards Organization (ISO) open systems interconnect (OSI) 7-layer network model. Referring now to FIG. 4, the protocol stack of a relay according to an embodiment of the present invention is shown. The protocol stack includes an application layer format MMS, a presentation layer format RFC1006-Presentation, a session layer format RFC1006-Session, a transport layer format TP4, a network layer format CLNP, a data link layer format IEEE 802.2, and a physical layer format IEEE 802.3. By supporting all seven layer of the ISO/OSI model, the communications potential of each individual protective relay, and the protective control functions of the networked relays, are greatly enhanced.

Referring now to FIG. 5, a block diagram of an exemplary relay suitable for communicating over any one or more of the protocols of FIG. 4 is shown. The relay 10 includes connections 12 for operatively coupling the relay to an electrical distribution system 14. The relay 10 further includes one or more communications ports 16 for communicating relay information (e.g., monitored current and voltage parameters, or other power system data) over a communications network 18. While the communications network 18 is preferably a peer-to-peer communications network, it will be appreciated that other suitable communications networks can be used. The relay 10 further includes a microprocessor 20 which is suitably programmed for monitoring various parameters derived from the electrical distribution system via the connections 12, for providing protective control of the electrical distribution system 14 (e.g., to operate a circuit breaker or perform some other protective action), and for generating and formatting relay information to be communicated over the communications network 18. The microprocessor formats the relay information in any one of the plurality of communication protocols identified in FIG. 4.

The microprocessor is further suitably programmed to provide concurrent communications on the same or different communication channels; that is, the microprocessor 20 can: 1) format data for transmission over a single communication port in multiple data formats, which are selectable by the user; 2) receive data over a single communications port in multiple data formats by identifying and distinguishing between the format types of the received data; and transmit or receive data over multiple communications ports simultaneously in the same or multiple data formats.

An additional advantage of the present invention is achieved by the microprocessor 20's support of the TCP/IP protocol. As this well-known protocol is used for the transmission of data over the internet, the support of the TCP/IP protocol in each relay allows any relay associated with the power distribution system to be accessed from any device capable of internet communication. As a result, power system data can be collected remotely from any or all of the protective relays associated with the power distribution system. Further, the settings and operation of each relay can be adjusted remotely from any internet communication device. That is, the communication network 18 in FIG. 5 includes the internet. For purposes of network integrity, a security firewall (e.g., password-protected authentication scheme, many of which are well-known) can be implemented in the relay processor to prevent unauthorized changes to the relay settings and operation.

The ports 16 of the relay of FIG. 5 are configurable, via processor 20, to support different communications protocols, stacks, and physical layer interfaces, such as Ethernet or RS485, independently and concurrently. The processor 20 manages the communications ports 16, and can also "virtualize" the various transport mechanisms on Ethernet (e.g., UDP datagram socket, TCP socket) so that they can be treated as physical ports, allowing asynchronous serial protocols to operate over Ethernet.

According to one example, conceptually shown in FIG. 6, relay communications can be implemented using subclasses of two base classes -- COM_Port and COM_Application. Together, one instance of each of these classes is selected via processor 20 to implement a protocol.

COM_Port subclasses define physical layer requirements for specific serial hardware, or "virtual" serial ports (such as TCP or UDP host ports). The interface to the COM_Port class generally corresponds to the standard known as RFC 1006, and is described in a document entitled "ISO Transport Service on Top of the TCP", the entirety of which is incorporated by reference. This document defines a standard connection-oriented interface to support the TCP/IP protocol. It also supports connectionless via a mode setting command from processor 20. While in a "virtual" serial port, there may be several protocol layers implemented in the COM_Port (e.g. TCP/IP/Ethernet as in RFC 1006), these protocol layers are hidden, so that the object appears to its users to be a simple serial port.

COM_Application subclasses define the higher levels of the specific protocols. There may be several operating system interface (OSI) layers defined in a COM_Application object, depending on the specific protocol to be implemented.

Preferably, the COM_Application and COM_Port classes are written in software in a manner that allows any application to be used on any port. Alternatively, certain protocol types can be provided as a separate communications library with its own protocol stack, which can thus be implemented as a COM_Application class that does not connect to a port.

In general, setup and initialization for the physical ports 16 is done through the COM_Port classes. Each COM_Port object attaches itself to a COM_Application object whenever a protocol is designated (in the settings) for the port. In the process, it identifies itself to the COM_Application object so that there is a cross-reference between the two objects. The COM_Application object can therefore use functions in the COM_Port class, and vice-versa.

As shown in FIG. 6, the COM_Port communication class includes the following subclasses:

COM_Com1Port (which communicates on COM1 RS485); COM_Com2Port (communicates on COM2 RS485); COM_UdpPort (communications using UDP sockets); COM_TcpPort (communications using TCP sockets, as described in RFC 1006); and COM_RS232Port (communicates on an RS232 serial port). The COM_Application class includes the following subclasses: COM_ModbusApplication (Modbus protocol); COM_DnpApplication (DNP protocol); and COM_MmsApplication (MMS protocol).

FIG. 7 is a diagram that illustrates the protocol layering in a relay; that is, the layers of the COM_Application class. For a relay 10 having two physical ports 16, the microprocessor 20 can configure the ports 16 as Ethernet ports or physical serial ports, and the microprocessor 20 can also configure the relay to communicate over the configured physical ports 16 according to MMS, Modbus, or DNP 3.0. It will of course be appreciated that the present invention is not limited to the implementation of the specific communications protocols shown in FIG. 7, and that the principles of the present invention can be applied to other communications protocols.

Referring now to FIG. 8, an illustration of the top-level data flow in and out of the communication subsystem of the relay (that is, within or under the control of the microprocessor 20) of FIG. 5 is shown. The processes in this diagram are further decomposed in the sections corresponding to the base classes (COM_Application and COM_Port), and further yet in the sections for the subclasses. In the data flow diagram of FIG. 8, the "event signals" flow can include the following specific signals: Rx Frame signal, Tx Done signal, timeout signal, and connection signal.

Referring now to FIG. 9, a more detailed diagram of the internal processing components of the relay of FIG. 5 is shown. The relay receives current transformer and voltage transformer samples (at, e.g., 64 samples per power system cycle) from current transformer and voltage transformer inputs 22. The samples are processed in digital signal processor 24, which performs fundamental calculations of power system parameters, such as phasors, frequency, RMS values, etc., and which performs current and voltage signal acquisition and calibration. The DSP 24 exchanges various data with the microprocessor 20 (which can be, in one implementation, a PowerPC 860 microprocessor), such as DSP firmware, configuration data, sample & hold data, oscillography samples, etc. The processor 20 provides protection and control of the associated power system, programmable logic, metering, event recording, oscillography, and other appropriate functions.

The microprocessor 20 provides digital output data to digital outputs 26, and received digital input data from digital inputs 28. The microprocessor 20 further receives synchronization signals, such as those according to the well-known IRIG-B standard from a time code generator 30, can communicate with an external personal computer or a supervisory control and data acquisition (SCADA) system 32 using the Modbus or DNP protocols via the RS485 or Ethernet communications ports 16, and can also communicate with remote input/output modules 34 via the RS485 port 16. The remote input/output modules can be other protective relays connected to a communications network.

The relay 20 further includes a user interface panel processor 36 that receives user data via an input keypad 38, and provides the user data to the microprocessor 20. The user interface panel processor 36 also receives display and LED control data from the microprocessor 20 and displays this data to the user via LEDs 38 and alphanumeric display 40.

While the foregoing description includes numerous details, they are provided for illustrative purposes only, and are not intended to limit the scope of the invention in any way. The specific examples disclosed above can be modified in many ways by those of ordinary skill in the art without departing from the scope and spirit of the invention, as defined by the following claims and their legal equivalents.

Throughout the specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

The reference to any prior art in this specification is not, and should not be taken as, an acknowledgment or any form of suggestion that that prior art forms part of the common general knowledge in Australia.

The claims defining the present invention are as follows:

1. A protective relay, comprising:

connections for operatively coupling the relay to an electrical distribution system;

at least one communications port for communicating relay information over a communications network;

processing circuitry for monitoring the electrical distribution system via the connections, for providing protective control in the electrical distribution system, and for generating relay information to be communicated over the communications network, means for selecting at least one communication protocol to be applied to the relay information; and

the processing circuitry formatting the relay information in one of a plurality of communication protocols.

2. The protective relay of claim 1, wherein the communications network includes a local area network (LAN).

3. The protective relay of claim 1, wherein the communications network includes a wide area network (WAN).

4. The protective relay of claim 1, wherein one of the communication protocols is the TCP/IP protocol.

5. The protective relay of claim 4, wherein the communications network includes the internet.

6. The protective relay of claim 1, wherein there are at least two communications ports, and wherein the relay exchanges relay information over the at least two communication ports simultaneously.

7. The protective relay of claim 6, wherein the relay information exchanged over each communication port is formatted according to a different communications protocol.

8. The protective relay of claim 1, wherein the processing circuitry exchanges relay information over one of the at least one communications ports using different communications protocols.

9. The relay of claim l, wherein the processing circuitry allows a user to select one or more of the plurality of communications protocols.

10. A method for communicating information from a protective relay to a remote device over a communications network, comprising the steps of:

generating relay information in the protective relay;

selecting at least one communication protocol to be applied to the relay information;

formatting the relay information according to each of the communication protocols selected by a user; and

transmitting the relay information, via one or more communications ports in the protective relay, over the communications network in each of the user-selected protocols.

11. The method of claim 10, further comprising the steps of:

receiving relay information from the communications network via the one or more communications ports;

determining a communication protocol of the received relay information; and

acting on the received relay information.

12. The method of claim 10, wherein the plurality of user-selectable communications protocols includes the TCP/IP protocol.

13. The method of claim 10, wherein the communications network includes the internet.

14. The method of claim 10, wherein the communications network includes a Local Area Network (LAN).

15. The method of claim 10, wherein the communications network includes a Wide Area Network (WAN).

16. The method of claim 10, wherein the step of transmitting is performed by simultaneously transmitting relay information over different communications ports.

17. The method of claim 16, wherein the relay information for the different communications ports is formatted according to different ones of the user-selectable communications protocols.

18. A protective relay, comprising:

connections disposed on the protective relay, the connections allowing the relay to be operatively connected to an electrical distribution system;

at least one communication port connectable to a digital communication network, the communication port communicating relay information over the digital communications network;

processing circuitry contained within the protective relay, the processing circuitry being programmed to monitor and provide protective control to the electrical distribution system via the connections, to generate the relay information, means for selecting at least one communication protocol to be applied to the relay information, and to format the relay information in one of a plurality of communication protocols.

19. The protective relay of claim 18, wherein one of the plurality of communications protocols is the TCP/IP protocol.

20. The protective relay of claim 18, wherein there are at least two communication ports, and wherein the relay exchanges relay information over the at least two communication ports simultaneously.

21. The protective relay of claim 20, wherein the relay information exchanged over each of the at least two communication ports is formatted according to a different communications protocol.

22. A method for communicating information from a protective relay to a remote device over a communications network, comprising the steps of:

generating relay information indicative of one or more parameters of an electrical distribution network associated with the protective relay;

selecting at least one communication protocol to be applied to the relay information;

formatting the relay information according to each of the communication protocols selected by a user; and

transmitting the relay information in each of the user selected protocols over at least one of a plurality of communication ports connected to the communications network.

23. The method of claim 22, wherein the step of transmitting is performed by transmitting relay information over simultaneously over at least two of the plurality of communication ports.

24. The method of claim 23, wherein the relay information transmitted over a first one of the at least two communications ports is in a first data format corresponding to a first communication protocol, and wherein the relay information transmitted over a second one of the communications ports is in a second data format corresponding to a second communications protocol.

25. A protective relay, substantially as hereinbefore described with reference to the accompanying figures.

26. A method for communicating information from a protective relay to a remote device over a communications network, substantially as hereinbefore described with reference to the accompanying figures.

DATED this 8th day of March, 2004

GENERAL ELECTRIC COMPANY
By Their Patent Attorneys
DAVIES COLLISON CAVE

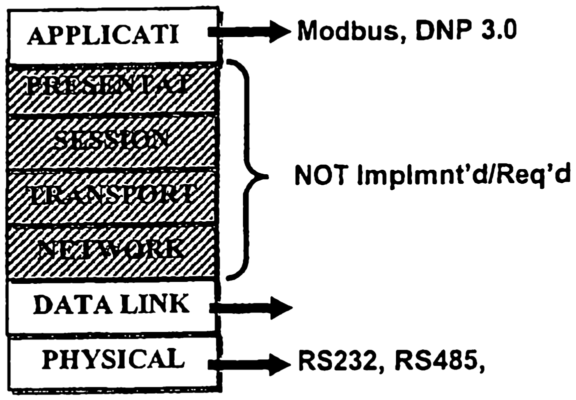


FIG. 1

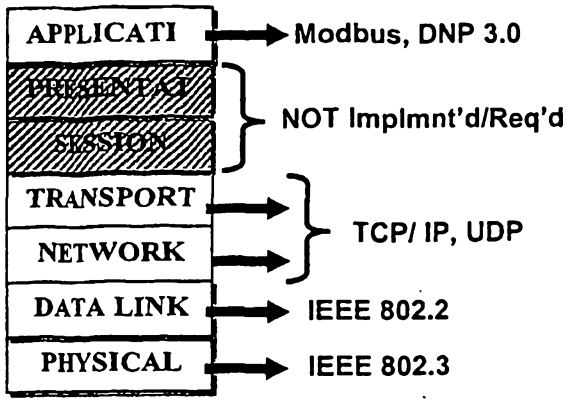


FIG. 2

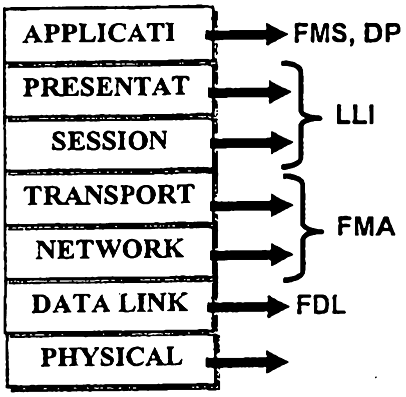


FIG. 3

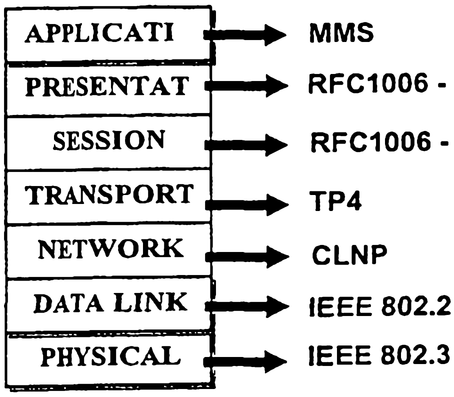


FIG. 4

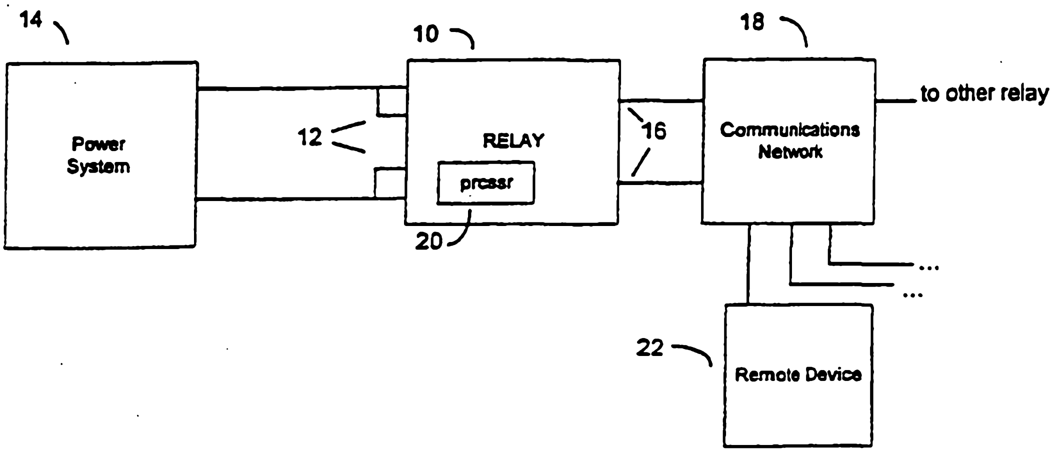

14
10
18
Power System
12
RELAY
prcssr
20
16
Communications Network
to other relay
...
...
22
Remote Device

FIG. 5

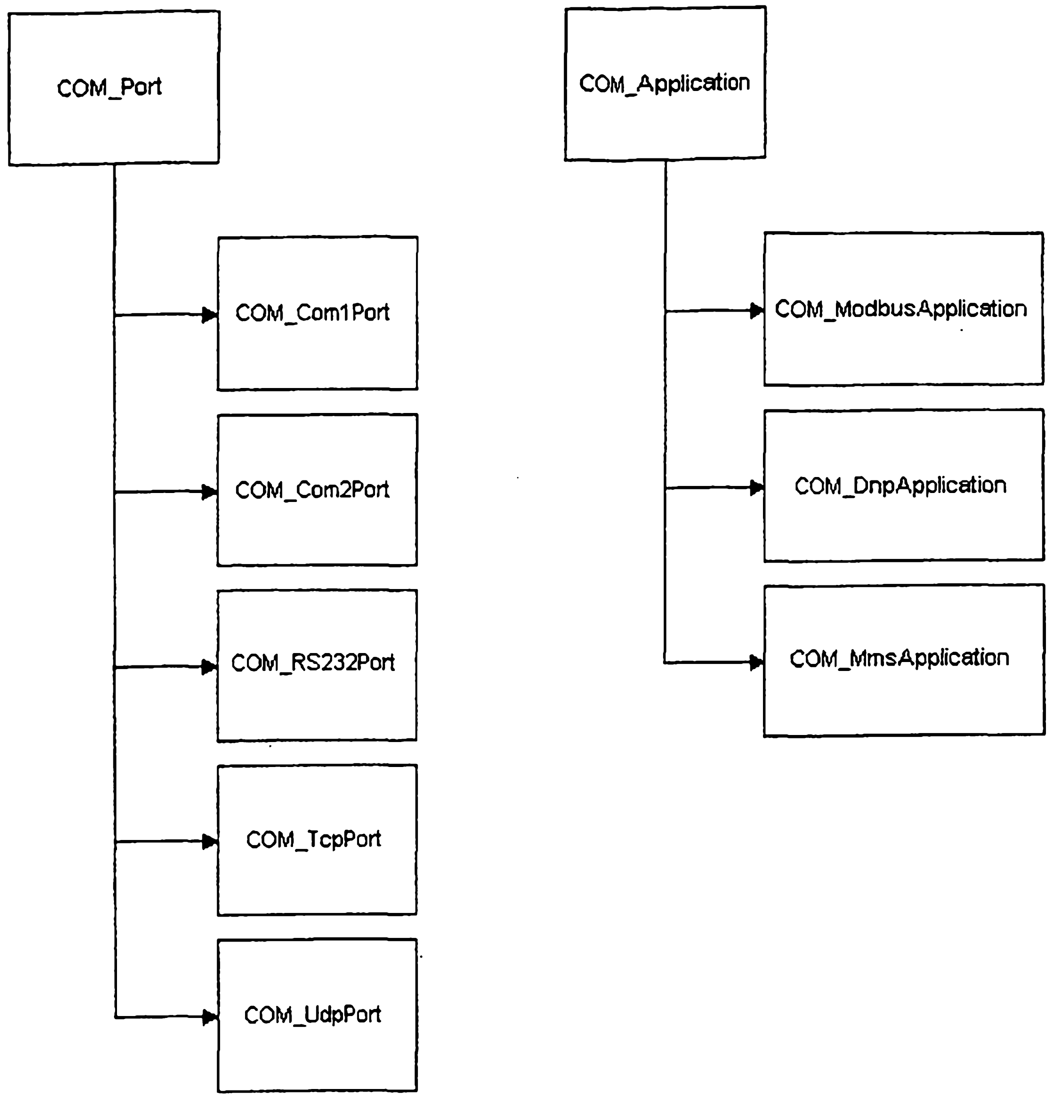

COM_Port
COM_Com1Port
COM_Com2Port
COM_RS232Port
COM_TcpPort
COM_UdpPort
COM_Application
COM_ModbusApplication
COM_DnpApplication
COM_MmsApplication

FIG. 6

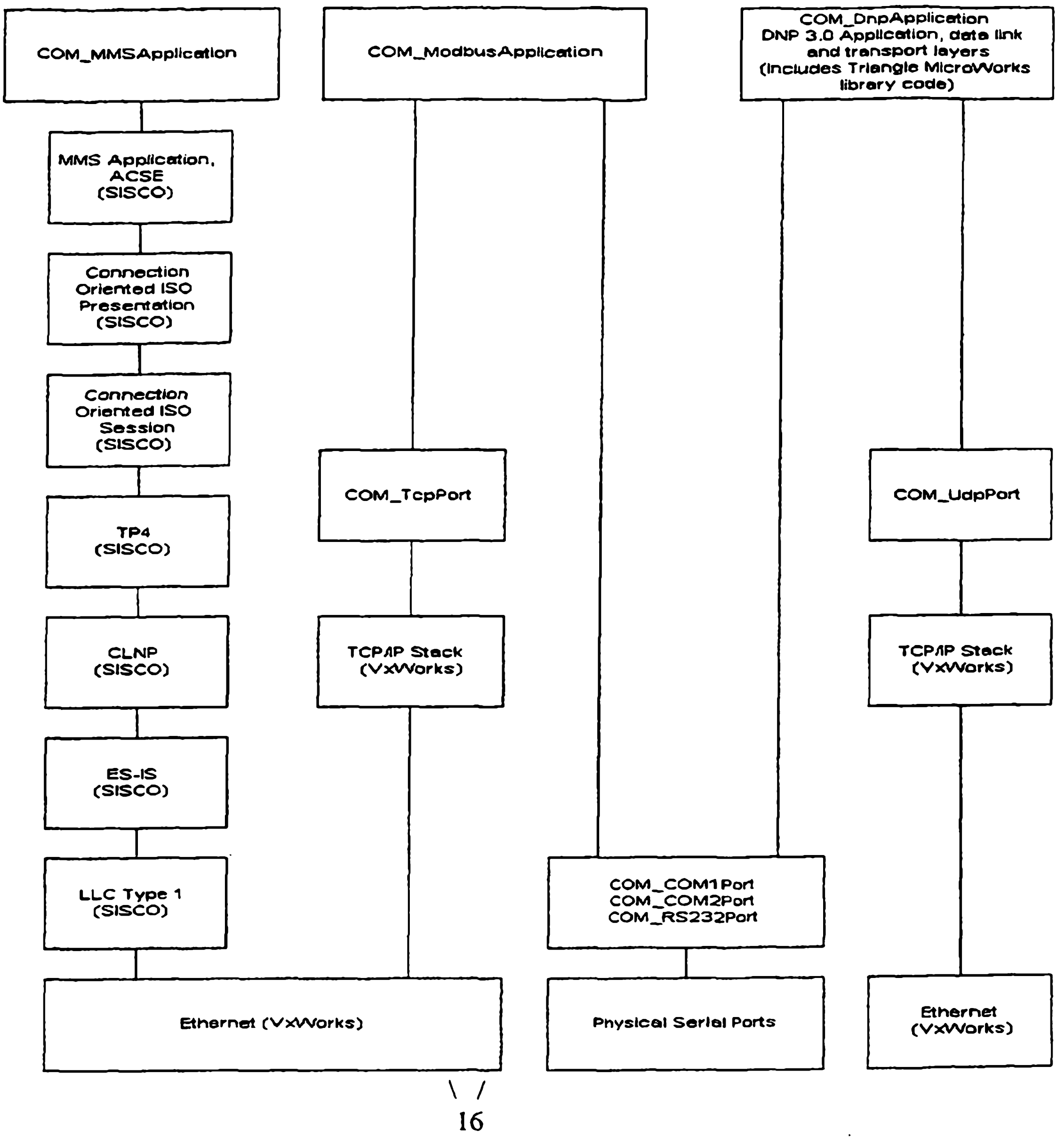
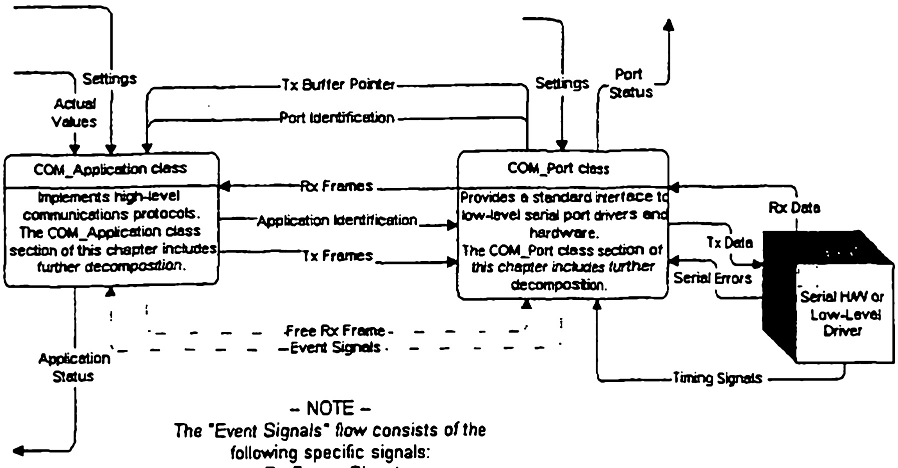

COM_MMSApplication
COM_ModbusApplication
COM_DnpApplication DNP 3.0 Application, data link and transport layers (includes Triangle MicroWorks library code)
MMS Application, ACSE (SISCO)
Connection Oriented ISO Presentation (SISCO)
Connection Oriented ISO Session (SISCO)
TP4 (SISCO)
CLNP (SISCO)
ES-IS (SISCO)
LLC Type 1 (SISCO)
COM_TcpPort
TCP/IP Stack (VxWorks)
COM_UdpPort
TCP/IP Stack (VxWorks)
COM_COM1Port COM_COM2Port COM_RS232Port
Ethernet (VxWorks)
Physical Serial Ports
Ethernet (VxWorks)
16

FIG. 7



- NOTE -
The "Event Signals" flow consists of the following specific signals:
Rx Frame Signal
Tx Done Signal
Timeout Signal
Connection Signal
The lower-level names are used on the class data flow diagrams

FIG. 8

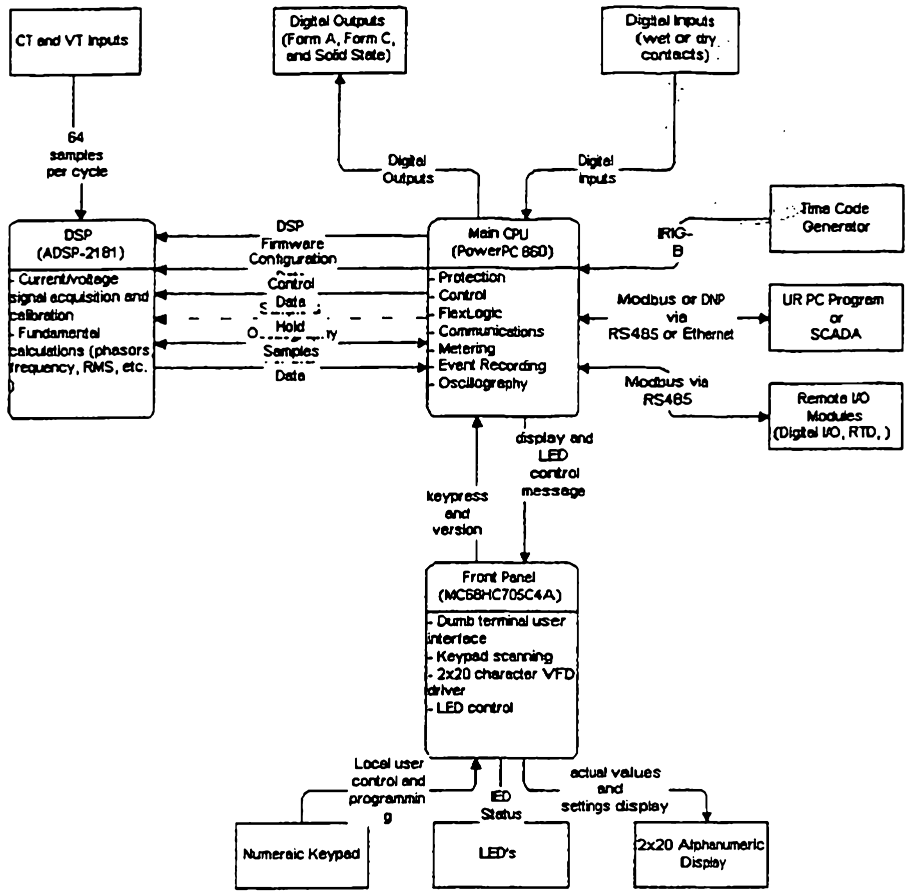

CT and VT Inputs
64 samples per cycle
DSP (ADSP-2181)
- Current/voltage signal acquisition and calibration
- Fundamental calculations (phasors, frequency, RMS, etc.)
Digital Outputs (Form A, Form C, and Solid State)
Digital Outputs
Digital Inputs (wet or dry contacts)
Digital Inputs
DSP Firmware
Configuration
Control
Data
Hold
Samples
Data
Main CPU (PowerPC 860)
- Protection
- Control
- FlexLogic
- Communications
- Metering
- Event Recording
- Oscillography
IRIG-B
Time Code Generator
Modbus or DNP via RS485 or Ethernet
UR PC Program or SCADA
Modbus via RS485
Remote I/O Modules (Digital I/O, RTD,)
display and LED control message
keypress and version
Front Panel (MC68HC705C4A)
- Dumb terminal user interface
- Keypad scanning
- 2x20 character VFD driver
- LED control
Local user control and programming
IED Status
actual values and settings display
Numeraic Keypad
LED's
2x20 Alphanumeric Display

FIG. 9