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Intelligent RTU: An Industry Smart Data Acquisition

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Abstract:
It is a SCADA unit of remote terminal system which can be used to interface with any kind of data acquisition systems at distant places due to its modular architecture. The added feature is that the Input output channel of the RTU is expandable. Ideally any number of data acquisition cards can be connected at a time and be made to interact with the system. CPU automatically identifies the type of I/O card inserted. It can be connected to SCADA, which controls several units in industries. All I/O channels are isolated and protected against ESD, EFT and voltage surges. System is equipped with communication interfaces like RS485, RS232, USB, GPRS, and Ethernet. Memory unit includes SD card.

1. Introduction

For energy deficit countries, Supervisory Control and Data Acquisition (SCADA) design based energy management systems for optimal distribution is very important. It involves development of Remote Terminal Unit which is an essential component of any high grade SCADA system and it is functioning as remote field data interface. Remote terminal unit (RTU) is a system that interfaces objects in the physical world to a supervisory control and data acquisition system by transmitting data to a master system, and by using commands from the master supervisory system to control connected modules.

This Intelligent RTU is an advanced SCADA system with CPU independent design using modular architecture. It support high end and low end applications. Modular architecture helps functional partitioning and it can drive more functions and easy redesign. Individual channel configuration feature is an added advantage for our system. Redundant CPU option helps to prevent any system failure due to master CPU defects. The system provides IO card expansions. We can connect any kind of devices like energy meter, GPS receiver etc. Features of I/O card includes, Intelligent I/O cards with independent channels, they are auto detectable cards and it can send card type and capability information to host processing module. Each channel is configured independently and these are protected from ESD, EFT and Surges. Communication is established by using RS-485 with MODBUS RTU protocol.

2. Architecture and Features

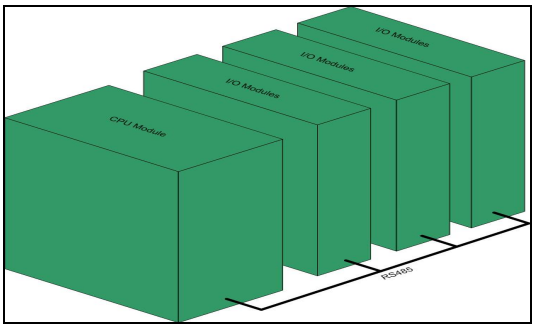

Figure 1: The modular architecture of proposed system

2.1. Modular Architecture

When we are designing a system, it mainly comes under two categories. Firstly develop the system using known theories and based on real-time implementation. Second method is to develop in a modular manner, design various units of the system separately or divide the system into smaller sub units. And it can be used in various systems and it can drive more functions. CPU module independent design with modular architecture helps the designer to develop a low cost flexible system. It is based on functional partitioning into scalable, reformattable isolated modules with technology transparency and extension capability.

2.2. Features of the System

- CPU module independent design
- Modular Architecture (Suitable for high-end and low-end applications)
- Redundant CPU option
- Intelligent I/O Modules
- Easy to attach High resolution DAQ
- Distributed configurations
- Easy to expand the I/O's
- Easy to attach other compatible devices

The above mentioned features, makes it a simple and advanced system for industry application. It can be used to interface all kind of DAQ systems. Modular architecture helps functional partitioning and it can drive more functions and easy redesign. Individual channels configuration feature is an added advantage for our system. . Redundant CPU option helps to prevent any master CPU failures

2.2.1. Block Diagram

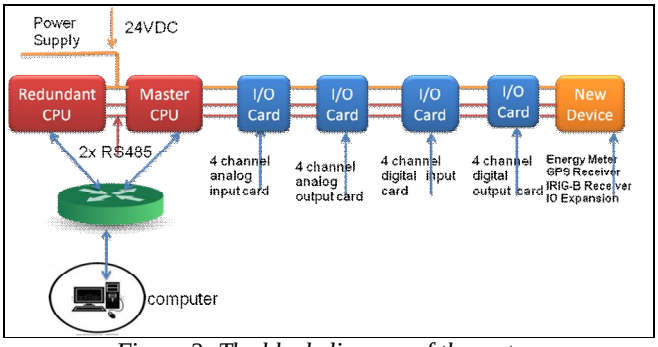

Figure 2: The block diagram of the system

2.3. IO Card

It's a hybrid module with analog input, analog output, digital input and digital output options. All channels are independent and isolated. Some of the features mentioned below.

- Auto detectable (Ability to detect the card type and capability information)
- Independent channels
- All channels are isolated (~2kV)
- All channels are protected against ESD, EFT, Surge
- Each channel can be configured independently

2.4. Master CPU

It controls and monitor slave modules connected to the system. The controlling information's is sending to connected slaves by the help of unique slave Id .Master CPU is controlled by SCADA software in the PC, Master and Redundant modules are connected to the PC via Ethernet. Additional security is required to prevent from operating wrong device or receiving bad control messages.

This is provided in the form of select-before operate sequence, mentioned below.

- Master to slave control select message
  Function code: Control address: set point
- Slave to Master
  Function code: Control address: set point
- Master to slave control execute message
  Function code: Control address
- Slave to Master acknowledge the message
  Function code: Control address

2.5. Redunatant CPU

The stand by redundant system is one identical secondary unit of master module, which is connected to the system permanently. It is just a spare unit. This redundant module is not synchronized with master CPU. The spare one always receives signals from master periodically and once it blocks, it send a request to master and wait for its response. If response or acknowledgement is not received redundant module takes care of the control and act as a master. Once failed module is repaired and replaced then it becomes a redundant one.

In systems without redundancy option, system down time depends on how quickly the following problems can be rectified

- Failure detection
- Problem Diagnosis
- Repair and replacement of damaged system
- Returning the system into fully operational

2.6. SCADA-User Interface

It is a user interface for controlling and monitoring RTU modules/ IO actions in the industries. It is designed for controlling industry process and monitoring the environmental conditions, and it is a multi channel operating software. It is also capable of handling independent 16-256 channel inputs from IO cards. These inputs may be a combination of thermocouple, RTD, Pressure transducers or voltage/current based sensors. Expansion board may be remote from the base unit for SCADA application.

It can be configured on our PC, gathering and maintaining data in Excel compatible files. PC with Secure connection allows remote monitoring. Advantages of SCADA mentioned below.

- Large amount of data can be stored and recorded by the computer
- Many types of data can be viewed from anywhere, not just on site.
- Faster process and improved quality.
- Minimize faults and downtimes, there by improved efficiency. Also it achieves maximum profitability.
- Maximized safety. Public as well as on sites.

3. Theory of operation

It is an advanced system for industrial as well as distributed control applications. It is designed for high reliability and also very flexible and independent intelligent system. It has auto detecting capability.

It include many distributed IO cards (similar or different types: AI, AO, DI, .DO, HYBRID), Master CPU, Redundant CPU and a SCADA software at controlling station. SCADA control the actions performed by various IO cards by the help of master CPU. Master CPU is the core part of the system, which controls IO functions as well as gathers data from IO cards. Redundant CPU option is another advantage of this system. It protects the system from master failures. When failure occurred, redundant CPU acts as a master and the master be easily replaced without affecting the normal operation of the system. After replacing the master, replaced module acts like a redundant CPU, because both are same module.

After powering up, the system initialization process occurs. IO card start its function and gets data (from analog input and digital input), based on a timer interrupt. When any signal comes from the master during AI, DI operation the request will be in queue. And it will be processed after data acquisition.

3.1. IO CARD - Block Level Design

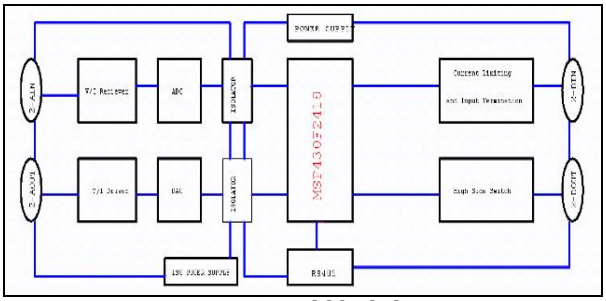

Figure 3: IO card-block diagram

3.2. Communication : RS484 with MODBUS RTU

Communication between Master and Slave established by the help of half duplex balanced line RS-485 system. It allows a transmission up to 1.2km. Communication on a MODBUS is started by a Master (called "Query") to slave. And slaves responding to master based on its query.

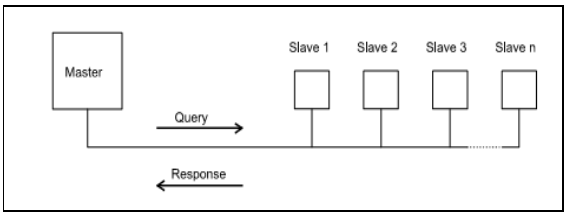

Figure 4: Master-Slave Communication

Message format of a MODBUS is mentioned blow;

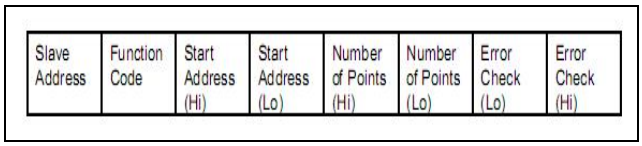

Figure 5: Query

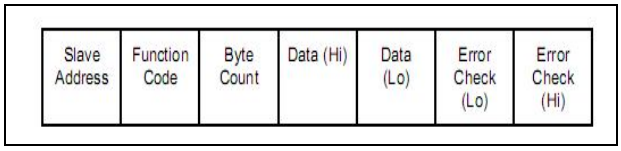

Figure 6: Response

RTU mode: Each 8 bit in a message includes two 4-bit hex characters. Advantage of this over ASCII is that greater density allows better data throughput with same data rate, however message is transmitted in a continuous manner.

3.3. Firmware Overview

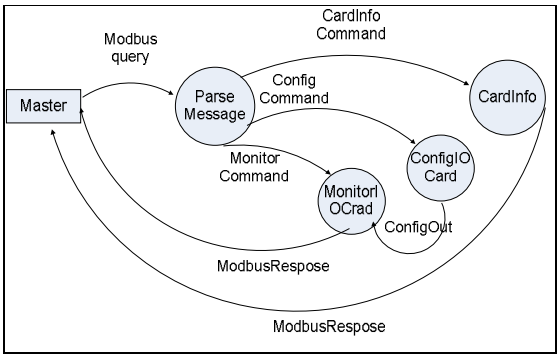

Figure 7: Data flow Diagram

The Master send query to IO cards/slaves, and it is commonly under three commands namely card info command, config command and monitor command. Timer interrupts and UART interrupts are used for proper functioning of the system. After system initialization and default configuration IO Card starts its functioning and get data from analog inputs and digital inputs using timer interrupts. Master send queries by the help of UART and it will be in queue when timer ISR is servicing. After timer ISR, Command from master is serviced and the data acquisition process will be continued after this ISR.
Master commands broadly classified into three types

- Card Information Command
- Configuration Command
- Monitoring and Controlling Command

List of Registers Required:

- Type Identifier
- Di_Channel_Number
- Do_Channel_Number
- Ai_Channel_Number
- Ao_Channel_Number
- Channel Identifier
- Parameter Type
- Edge Type
- Pulse Type
- Pulse Duration
- Voltage Type

Explanation for each register is given as below:

- Type Identifier: To identify the type of device connected. It could be any integer value from 1 to 5 where 1=Di, 2=Do, 3=Ai, 4=Ao , 5= Hybrid.
- X_Channel_Number: Indicates the maximum number of channels available for the X device. This register is read according to the value in Type Identifier. For ex: if Type Identifier = 2, then read Do_Channel_Number. If Type Identifier =5, read all X_Channel_Number registers.
- Channel Identifier: To indicate which channel

- Parameter Type: Indicates the type. If Type Identifier = 2 (Do), then, possible values are 1= state, 2=Edge and 3=Pulse Duration. If Type Identifier = 1(Di), then the possible values are same as those when Type Identifier =2(D0) along with 5 = pulse count. If Type Identifier = 3 (Ai) or 4(Ao), then 1= voltage, 2= Current.
- Edge Type: Indicates whether rising (1) or falling (2) edge.
- Pulse Type: To indicate if positive (1) or negative (2) pulse.
- Pulse Duration: To give the duration of Pulse.
- Voltage Type: Indicates whether Level (1) or threshold (2).

4. Result and Future Scope

The below mentioned block indicating the set up of above mentioned system and the slaves working based on command from master and IO cards getting data from its analog and digital input alternately and also it process the command from its master using UART interrupt.

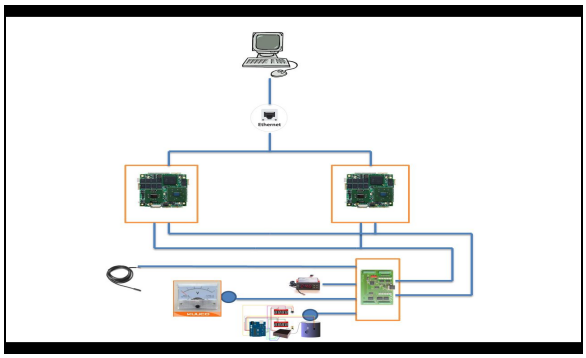

Figure 8: Intelligent RTU

The Intelligent RTU is an advanced system with modular architecture. In future, it can modified by the help of advanced wireless technology like Bluetooth, wifi, Zigbee etc. By using wireless sensor network data can be collected by the IO card remotely and whole communication we can establish by the help of this wireless technology. FPGA Implementation is one of the future scopes. It can be modified to real-time DAQ and advanced energy meters with simultaneous sampling techniques

5. References

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