Remote Supervising of Power Plant

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Abstract. With the fast growth of power plant, traditional communication protocol cannot meet the actual requirements. We have to find a way to deal with this situation. In this paper, we put forward an information model and a communication protocol for remote supervising of power plant. Based on our information model, a supervised object is the basic and the least unit of supervising information. A supervised object contains 6 elements. We developed a Supervising Information Library termed as SIL to manage and store supervised objects. The SIL employs an arborescence structure. A branch contains a group of supervised objects. And each leaf stores a single supervised object. We proposed a proprietary protocol, abbreviated as RSPPP at the application layer of communication protocols. RSPPP Protocol works in 4 operation modes. The message of RSPPP protocol includes three fields and is described by Abstract Syntax Notation One. TLV (Type, Length, and Value) method is used to encode message for transmission. In our system, an Acorn RISC Machine is used as the central processor. The \( \mu \)C/OS II is employed as operating system. Our system occupies a ROM space of about 920 bytes and a RAM space of about 710 bytes when running in AT91SAM9263.

Introduction

Electricity is one of the most important forms of energy in a country. By the end of 2014, China’s power installed capacity reached 1 billion 360 million kilowatts. And 5550 billion kWh of electrical power was produced in China 2014. In recent years, Automatic control technology, computer network and information technology are utilized widely in power plants. For instance, a kind system called Supervisory Control and Data Acquisition abbreviated as SCADA are installed in electric power industry [1-4, 8]. These systems utilize IEC870-5-101, DNP3, MODBUS, or CDT as communication protocols. With the fast growth of power plant, these traditional communication protocols cannot meet the actual requirements. We must find a way to deal with this situation.

We have studied in a comprehensive way the framework and structure of supervising systems for power plant. For remote supervising of power plants, we designed an information library called Supervising Information Library denoted by SIL and put forward a proprietary network protocol, denoted by RSPPP (abbreviated from Protocol of Remote Supervising of Power plant).

In this paper, our study program is described in great detail. The framework of power plant supervising systems is introduced in section 2. The information model is put forward in section 3. In section 4, we designed a proprietary application-layer protocol for the supervising system.

Framework for the Remote Supervising Systems

The framework of remote supervising systems of power plant is shown in Figure 1. In a supervising system, there are two kinds of stations. One kind of stations is referred to as the control center. The other kind is termed as supervising stations. One master terminal unit (abbreviated as MTU) is installed in the control center. Various types of remote terminal units (abbreviated as RTU) are installed in supervising stations. Performance parameters of electric power plant are supervised by means of remote terminal units. Varieties of measuring sensors are connected to remote terminal units.
Parameters of the performance of electric power are measured and transmitted to the control center. Where after the measured data is stored, analyzed, and processed.

![Diagram](image)

Figure 1. Framework of remote supervising systems for power plant.

Parameters generally supervised include total positive power, positive peak power, positive valley power, electric voltage, and electric current and so on.

**Information Model of Electric Power Plant**

In remote supervising systems of electric power plant, the control center exchange a variety of information with supervising stations over Internet. The information includes supervised data, controlling instructions, equipment status, station descriptions and the like. All these information above is known as supervising information. We utilize information model to manage and store supervising information. Information model of the remote supervising system describes the information structure and the supervising information library.

The supervised object is the basic and least unit of supervising information. As depicted in Figure 2, a supervised object contains 6 elements, i.e. a descriptor element, an identifier element, a syntax element, an access element, a status element, and a definition element. The descriptor element is the textual name of a supervised object. The identifier element is designed to identify a supervised object, and has to be unique in a whole supervising information library in a whole supervising station. The identifier element belongs to OBJECT IDENTIFIER data type. The syntax element defines the data type and structure associated with this supervised object. Table 1 enumerates several data types frequently utilized in supervising systems of electric power plant. The access element defines ways how the control center accesses a supervised object. The available values of the access element contains read-only showing that control center may read from this object only, write-only showing that control center may write to this object only, read-write showing that control center may both read from and write to this object, not-accessible showing that control center cannot access this object. The status element provides the current status of a supervised object. The status element has 3 available values, i.e. mandatory, optional, and obsolete. The mandatory status suggests that this object has to be implemented by every supervising station. The optional status suggests that this object may be implemented optionally. The obsolete status suggests that this object has been replaced by other object and is no longer used. The definition element is a human-readable textual definition of a supervised object. We have to implement this supervised object exactly on this definition to keep its consistent semantics in every supervising station.
As an instance, we examine the supervised object currentAInstant. This object keeps track of the current of phrase A of electric power plant, and is defined as follows:

**OBJECT**: currentAInstant \{3 1 1\}

- **Syntax**: INTEGER
- **Definition**: “The current voltage of phrase A in volt”
- **Access**: read-only
- **Status**: Mandatory

For this object, object descriptor element is currentAInstant, object identifier element is \{3 1 1\}. This object belongs to an INTEGER data type. The control center can read from it, but cannot write to it. It must be implemented in supervising information library of every supervising station.

The supervising objects are defined by Abstract Syntax Notation version 1 (abbreviated to ASN.1) [5], and encoded by Basic Encoding Rules (abbreviate to BER) [6]. The BER describe how instances of supervised objects are encoded and transmitted over the Internet. It employs the Type, Length, and Value approaches and is abbreviated to TLV approaches.

The supervising information library, denoted as SIL for short, takes arborescence structure (as shown in Figure 3). It contains one root, several branches, and a lot of leaves. Each branch stores a group of supervised objects. And each leaf stores a single supervised object. The system group of the supervising information library contains 5 objects (as depicted in Table 2).

In current group, there are 3 subgroup, i.e. current A, current B and current C. Each subgroup contains 2 objects. For currentA subgroup, the two objects are currentAInstant and currentAAverage.
For convenience of processing, we use integer with 4 bytes as the data type of electric current. Its unit is mill-ampere. The maximum value of this data type is 4295 kilo-ampere, exceeding the maximum current of electric power plant.

**Communication Protocols**

We utilize TCP/IP model as communication protocol. TCP/IP model contain 5 layers, i.e. physical layer, data link layer, network layer, transport layer and the application layer. In the application layer, we put forward a proprietary protocol, and name it as Protocol for Remote Supervising of Power Plant (denoted as RSPPP for short) to ensure efficiency and security of the communication between control center and supervising stations.

**Table 2. Objects in system group.**

| Identifier | Descriptor     | Syntax            | Access    |
|------------|----------------|-------------------|-----------|
| 1.1        | systemName     | OCTET STRING      | read-only |
| 1.2        | systemModel    | OCTET STRING      | read-only |
| 1.3        | systemManufacturer | OCTET STRING   | read-only |
| 1.4        | systemLocation | OCTET STRING      | read-only |
| 1.5        | systemUpTime   | Time Ticks        | read-only |

The message of Protocol for Remote Supervising of Power Plant consists of three parts, i.e. StationID, RSPPP type and RSPPP PDU. The StationID part is designed to authenticate the identity of other party involved in the communication.

RSPPP PDU stands for the protocol data unit of Protocol for Remote Supervising of Power Plant, and store information to be communicated between control centers and supervising stations. RSPPP PDU type defines the types of this message. We have designed 5 types of RSPPP PDUs, i.e. SuperviseRequest PDU, SuperviseNextRequest PDU, SetRequest PDU, Response PDU and Trap PDU.

The first 4 type PDUs of Protocol for Remote Supervising of Power Plant belong to the basic PDUs. The basic PDU consists of three fields, i.e. Supervise-id, Supervise Status and Object-bindings. The Supervise-id field specifies uniquely every supervising request operation. The Supervise Status field is defined for Response PDUs, and supply information about how a supervising station has fulfilled supervising request from control centers. Optional values for Supervise Status include noSuchObject, tooBig, badValue, etc. The noSuchObject status suggests there is no such supervised object as requested by a control center in the whole SIL of a supervising station. The tooBig status indicates that too many objects are requested in a single request message. The badValue status indicates that a control center attempts to set an invalid value to a supervised object.

In object-bindings part of the message of Protocol for Remote Supervising of Power Plant, object-ids and object-values appears in pairs. The object-ids specify which supervised objects are requested by a control center or a supervising station. The object-values provide data to be transferred to a control center, or to be written to a supervised object in a supervising station.

Supervising stations post a Trap PDU to control centers as an alarm in case an emergency appears. The Trap PDU is composed of 4 fields. The Station-name field indicates which station that has posted this Trap PDU. The Time-stamp field indicates the time when the Trap PDU is posted. Trap-type field indicates the type of this Trap PDU. For Trap-type, several optional values are available, e.g. RTURestart value (indicating that one remote terminal units at a supervising station is restarted), authentitionFailure value (indicating that the control center fails to be authenticated), alarm value (indicating that one or more parameters of performances of power plant exceed the thresholds) and so on. The Object-binding filed in the Trap PDU supplies details about this trap operation.

The Protocol for Remote Supervising of Power Plant operates in 4 modes of operations, that is, Supervise operation, Supervise-next operation, Set operation, and Trap operation.

In Supervise operation mode, a control center first transfer a Supervise-Request PDU to supervising stations, and specify the parameters to be inspected by object-id in object-bindings field of this PDU.
After receiving this PDU, the supervising stations search for the values of the requested objects in the
local supervising information library, and then put these found values into the object-bindings. Finally,
the supervising stations transfer a Response PDU with requested values back to the control center
who has issued the Supervise-request command.

The Set operation mode is designed for a control center to write values to supervised objects in a
supervising station. In this way, control center can configure supervising stations remotely over
Internet. After Set operation, the supervising station will return to the control center a response PDU
with the same value in the object-bindings and with status information to indicate whether the Set
operation is successful.

We should know that the supervising station, instead of the control center, is active in the Trap
operation mode. The supervising station initiates a communication session with a control center when
any emergency appears, for instance, some equipment is out of order. In this case, the supervising
station posts a Trap PDU with related information about the emergency in it to the control center.

Different computers employ different internal data structure. If these computers communicated
directly over Internet with each other, one computer may misconceive the other computer. To deal
with this problem, we utilize ASN.1 (for short from Abstract Syntax Notation One) to present
RSPPP messages. ASN.1 applies Basic Encoding Rules (BER for short) to define instances of
objects. The BER utilizes Type, Length and Value approach (TLV for short) to encoding data for
transmission.

Several object types frequently used in remote supervising of power plant and their BER codes are
listed in Table 3. For instance, 526 voltage (i.e. 526000 millivoltage) is represented as five bytes, i.e.
02 03 08 06 b0 according to Basic Encoding Rules.

| object type | INTEGER | OCTET STRING | SEQUENCE | IDENTIFIER |
|-------------|---------|--------------|----------|------------|
| BER code    | 2       | 4            | 48       | 6          |

The whole message of Protocol for Remote Supervising of Power Plant is of sequence data type,
and its type code is 48. When building a message, we make use of a byte with the value of 48 as a sign
of the beginning of this message, and the value of the following byte indicates the length of the
message.

**Implements of Sil and RSPPP**

We utilize AT91SAM9263 as the central processor of our remote terminal units. The supervising
information library and Protocol for Remote Supervising of Power Plant are implemented on the top
of μIP of μCOS-II system [5]. To store elements of a information object, we define a structure of C
language as following.

```c
struct infobody {
    char id[30];
    char name[30];
    char type[20];
    char access[20];
    char status[20];
    char dscrpt[100];
};
```

The structure is composed of six members corresponding to 6 elements of an information object.
Values of all elements of an information object are stored in character data types.

We have implemented the protocol for Remote Supervising of Power Plant. Firstly, we should
ascertain that we have received the first byte of the message of Protocol for Remote Supervising of
Power Plant. We do this by checking whether the value of the byte equals to 48. After receiving the
first byte of the message of Protocol for Remote Supervising of Power Plant, we try to receive the second byte, whose value we use as the length of the message of Protocol for Remote Supervising of Power Plant. We utilize this byte to manage receiving the rest byte of the message of Protocol for Remote Supervising of Power Plant. According to object identifier in the received message, we look for the value of this object in the supervising information library of the local supervising station. Then we fill the found value of this object in response message and transfer it to the control center that has release this request message.

**Summary**

We studied the information model and communication protocol for remote supervising of power plants. We defined a supervised object as the basic and least unit of supervising information. A supervised object contains 6 elements. We established an information library, referred to as the supervising information library (denoted as SIL for short) to manage supervised objects. The supervising information library takes arborescence structure. It consists one root, several branches, and a lot of leaves. Each branch stores a group of supervised objects. And each leaf stores a single supervised object.

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