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Architecture Design and Analysis of a Distributed Test and Control System Based on New Power Supply System

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Abstract—**General system architecture and multi- of a distributed test and control system is discussed. Then, according to specific testing and certification requirements of a new power supply system in a vehicle, architecture of a distributed test and control system is optimized. By using and improving a multi-communication mode organically, the system based on new power supply system is designed hierarchically. Functions of the system, such as data acquisition, preliminary data analysis and control instructions issuing are realized. Data exchange between the management layer and subsystems in control layer is achieved. The remote terminal in management layer can not only exhibit real time graphical display of overall system operation, but also calculate and analyze experimental data as well as storing the experimental results. It is proved that the system can fully meet testing requirements of new power supply system. At the same time, the design concept and the architecture provide some new ideas for distributed test and control systems improvement on system architecture and data exchange.**

Keywords-Distributed measurement and control system; data exchange; construction technology; multi-communication mode

I. INTRODUCTION

Accompanied by rapid development of computer network technology, control technology, testing technology and intelligent sensor technology in recent years, Test and Control System(TCS) has taken a great leap from a simple instrument to a centralized computer teat and control, then to a Distributed Test and Control System (DTCS) [1~2].

There are many ways to construct a DTCS, but main part of the DTCS is Client/Server(C/S) mode for its simplicity and intuition [3]. However, C/S mode only simply classify autonomous behavioral entities as 'control client' and 'test server', and interactive relationship between them is limited to control the client's request and test the server's passive response. Therefore, If we use the C/S mode to build a DTCS, we may find it hard to confirm the server's location in a network, hard to handle the interoperability and load balance, as well as difficult to upgrade the client.

To overcome limitations of the C/S mode describe above, many scientists and scholars have put forward new improved modes, such as web-based mode, B/S-based mode, middleware-based mode(multilayer C/S mode), and have been applied to build a DTCS in practice[4~8].

Primary data interactive modes used in DTCS network are listed as following:

① RS232C/RS485: The most common lower layer protocol of serial communication interface, which usually sensitive to noise and transport distance. Especially when system operating environment is relatively poor, it often causes data signal distorted and serious delay[9].

②Industry fieldbus: we can make data exchange in time by using many kinds of fieldbus. Since there isn't an unique communication standards because of market competition, equipments used different fieldbus can't really be interconnected till now. This limitation have seriously hampered promotion and application of industry fieldbus[10~11].

③Ethernet: this technology enjoys rapid rate and short frame in data transmission. However, because of uncertainty of CSMA/CD protocol in data link layer, real time ability of the Ethernet is very poor[12].

It can draw a conclusion from above that each communication model has its advantages and disadvantages respectively. Only using a single communication mode for DTCS designing and application may easily lead to functional deficiencies and partial insufficiencies in TCS.

Based on actual requirements of the new power supply system, this paper built a new DTCS using a multi-communication mode, and adopting a novel network architecture called single-C/multi-S mode. Meanwhile, a variety of data exchange models is combined to design and develop a new DTCS. Technologies and equipments related to three basic sectors(electricity generation, distribution, and consume) of electrical system in a vehicle during operation are argued, analyzed, developed and demonstrated using the new designed DTCS based on based on DC power supply system in high voltage. It is proved that the designed DTCS meets the test requirements through experiment, and the system has a certain significance for promotion and reference.

II. ANALYSIS AND DESIGN OF THE SYSTEM

According to specific functions of each node, the DTCS is built with three layers and two-level network based on new power supply system. Its detail structure is illustrated in Fig.1.

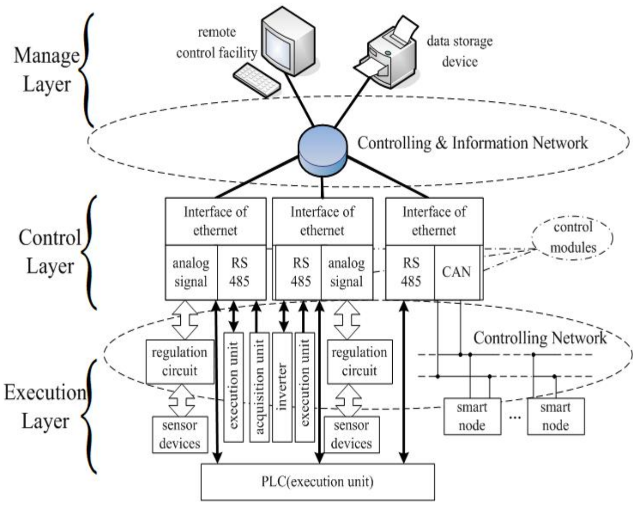


Fig.1. The whole structure of DTCS

Three layers of the DTCS are named Manage Layer (ML), Control Layer (CL) and Execution Layer (EL) according to specific features of each layer. Each one is connected with adjacent layers by data cables to form the two-level network.

ML contains the remote control facility and data storage device, which connects to every test and control subsystem on site in a star topology. By acquiring all data from each test and control subsystem, the remote control facility can reflect real time operation conditions of them correctly. Data storage device collects all valid operation data of the system, and stores them into a database using certain format and rule. It is also capable of feature querying historical data, alarm and malfunction records, so entire operation condition of the system can be statistical, analyzed as well as the following results printing out. The printed results can be used for backup and in query.

CL is the core of the designed DTCS. Corresponding to three sections of the new power supply system, that is, power generation, storage, transmission and distribution. CL also can be decomposed into three independent test and control subsystems. The first one is used to control a main (generator start) power supply. The second one controls auxiliary (generator start) power supply. The last one is used to achieve smart regulation of loads. Such three modules control its own unit independently, and work together to accomplish verification of the power supply system.

EL is consisting of many actuating equipment and sensors, the key function of EL is to accomplish operation data collection of the system and execute instruction from CL.

III. CONTROL & INFORMATION NETWORK

Based on three layers and two level networks, the Controlling & Information Network(C&IN) is consisting of ML and CL. The fundamental purpose of C&IN is to transmit information and share resource, so that it can real time control overall operation conditions and store all key information of the DTCS.

The C&IN adopts a new architecture, which is called single-C/multi-S mode, to achieve communication between ML and CL. Contrary to a common DTCS, the designed DTCS in this paper use each test and control subsystems in CL as servers, and the remote control facility as client. After the application program executing, the single-client should initiate a request at first, then it connects these 'servers' one by one. The 'servers' through a monitoring network receive timely response to the client's requests after their connection being built, the 'servers' begin to collect and analysis data from EL on site. Besides, they send data to the 'client' periodically. The 'client' will analyze these data which will be displayed and stored in time.

Low level communication mode in C&IN follows the standard TCP/IP protocol. Data type and length of the data frame can be adjusted flexibly for meeting real time application requires.

Method of data frame checksum in C&IN is double check, which checks data frame length first, then check whether the two data in data frame header and end is equal to default setting. If they are not equal, the frame will be discard. This error will be written into the database for future querying.

Considering actual environment where the DTCS worked is alternating high voltage. A variety voltage and current changes, especially frequency transformer starts and three-phase alternating current output will cause serious electromagnetic interference. Thus, data transmission in local area network will be affected, and may appear a phenomenon which can be called 'fiction' interruption. The 'fiction' interruption is an abnormal status that either side of the communication (usually is the subsystems in CL) may receive a signal presented as terminating the communication. The communication side received the signal cancels connection with the other side, while the other side continues to be connected, so data exchange between ML and CL ends abnormally. In order to solve this problem, an asynchronous timer is designed to monitor data exchange interrupt. If data exchange is interrupted without an interrupt instruction sent from CL, the remote control facility in ML will reset the asynchronous timer, and then record the error into the database. When the asynchronous timer has reached a set time, the remote control facility in ML will break connection with subsystems in CL, and then reconnect them. If the reconnection is successful, data exchange between both sides will move on again. By using such method, the 'fiction' interruption problem can be addressed effectively. Specific software architecture is shown in Fig.2.

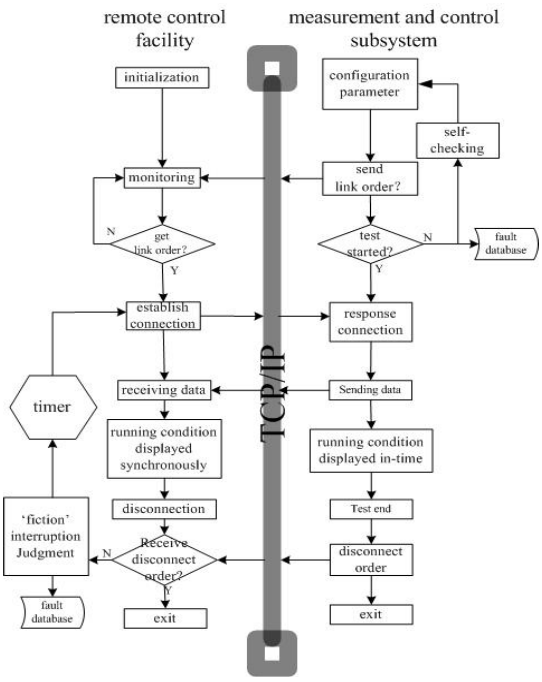
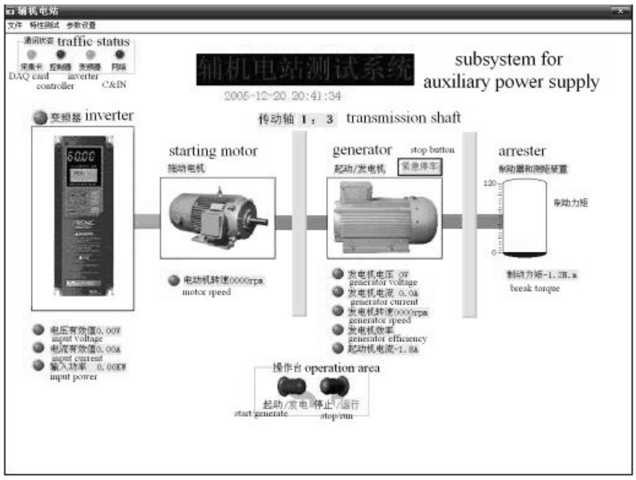


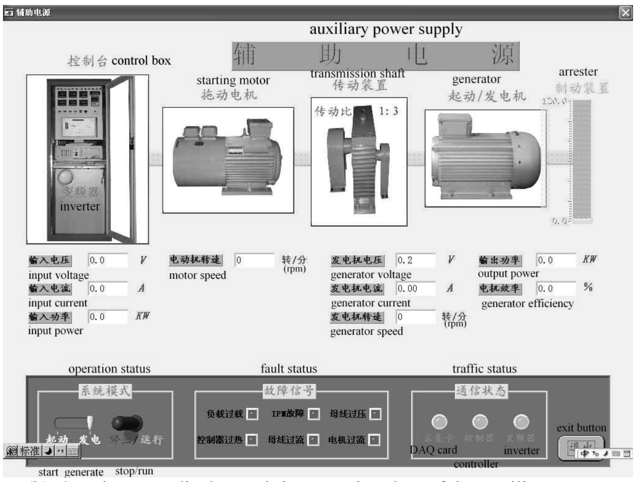
Fig.2. Software flow chart of Control& Information network

Using single-C/multi-S mode to form the C&IN has several advantages: ①Normal operation of subsystems in CL is not interrupted, and they only create their own 'servers' by themselves when their programs starting, and wait for connection request from the remote control facility at any time. ②The remote terminal in ML has the initiative to obtain data, so it is easy for ML to realize an overall control on all operation data and avoid a problem of distribution the order of data transmission in single-S/multi-C mode.

An example for data synchronization in C&ID is illustrated in Fig.3.Fig.3 (a) is the main panel of auxiliary power supply in subsystems, which is designed to start and control power supply. By operating virtual buttons on the main panel, auxiliary power supply can be controlled. Meanwhile, the entire operation conditions of its test and control subsystem is displayed on the panel intuitively and timely by virtual display control. ML uses the Ethernet and communication protocol based on practical needs to complete a data exchange with the subsystem in CL. Thus, ML obtains real time operation conditions of the subsystem. The remote control facility uses a virtual instrument panel shown as Fig.3 to display real time running condition of the auxiliary power supply in CL synchronously.



(a) .Running condition of the test and control subsystem for auxiliary power supply



(b). Synchronous display real time running data of the auxiliary power supply transferred from the remote control facility

Fig.3 data synchronization in C&ID (Annotate:The Engish words in Fig.3 are added designedly in order to avoid confusing the reader)

IV. CONTROL NETWORK

Control Network (CN) is constructed by CL and EL. The main function of CN is to realize effective control on the plant and complete accurate data acquisition from sensors.

Because of a variety of actuators and sensors, which have different interfaces, single communication mode easily leads to limitation on device selection, and also increases costs of the whole system. Besides, a single communication mode will relatively concentrate risk trend of the system, and it may affect performance of the whole TCS.

Making full use of interfaces that already exist in subsystems, taking into account practical requirements, multi-communication mode including RS485/CAN/analog signals are used to build a system control network frame so as to optimize the performance of CN.

A. Test and control subsystem for main(auxiliary) power supply

Current output, voltage output, output of power controller and output of voltage regulator is sent to CL in the form of analog signal. Data exchanges between CL and voltage regulator, frequency transform, load control module(PLC) are realized by RS485, as Fig.4 shown below.

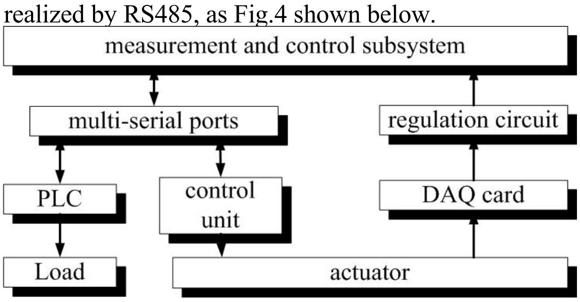


fig.4. Multi-communication mode in control network

In order to achieve an effective data communication between these subsystems and control modules made up of MCU and its peripheral circuit, proper serial communication protocol should be set. Taking communication between subsystem of the main generator and its voltage regulator as an example, as a core part for controlling the generator, the regulator needs upload operation status, operation parameters and built-in self-diagnostic data of the generator periodically. The asynchronous serial communication model, which baud rate is fixed in 9600bps, with 12 bytes in each data frame is adopted. The detailed content of the data frame is illustrated in Fig.5.

'@'	alert	reserve	output voltage		output current		excitation voltage		reserve		'#'
1	2	3	4	5	6	7	8	9	10	11	12

Fig.5. Data frame format for communication between between the subsystem and a control module

In Fig.5, the first byte of the frame is '@' and the last one is '#', both are ASCII code. Each data, such as output voltage, is hex and occupies two bytes. The length of a data in the frame is 16 bit, high 8 bit will be uploaded first. After receiving the whole frame, it still needs a simple conversion so as to get actual values which displayed on the virtual control panel.

For example, if a data sent from the regulator is'00000001 00001101', the actual value of output voltage is:

$$0x01*(256)+0x0d*(1)=27V \qquad (1)$$

According to practical requirements, communication protocols are set between other control modules in EL and subsystems.

B. Subsystem for smart power distribution

CAN bus is adopted to built a smart power distribution network, and 10 smart distribution boxes act as CAN node for the purpose of simulating actual power distribution condition when a vehicle is running. CAN communication protocol is used to diagnose the status of these intelligent distribution nodes, which accept control command from CL.

.Take 28V main distribution box as example, as Fig.6 illustrating below. By operating the 'virtual' button in the panel, the control command can be transmitted to this main distribution box, and make a corresponding action to turn on/off switch in the box. On the other hand, subsystems in CL collect data through CAN bus and display them on the virtual panel. By doing this, real time current, voltage and temperature of all loops in the distribution box can be monitored easily and intuitively when the whole DTCS is running. Furthermore, after obtaining running condition of the distribution box, alarm records can be displayed in time, some simple classified query can be achieved.

V. CONCLUSION

By optimizing network architecture of the control system, and combining a variety of communication mode organically, a novel DTCS based on new power supply system is established. The new system avoids shortcomings of previous TCS such as poorly adaptability by using single-communication mode and low degree of autonomy of the subsystems in previous TCS because of obsolete construction technology. As proof-tested, it can fully meet testing and certification requirements of new power supply system. The design concept and idea proposed in the paper used for establishing the new DTCS has reference value to some extent.

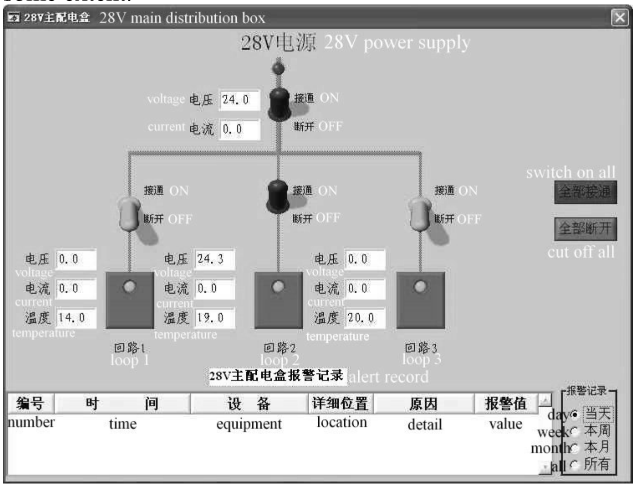


Fig.6. operation state of 28V main distribution box(Annotate:The Engish words in Fig.6 are added designedly in order to avoid confusing the reader)

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