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RESEARCH ON EXCITATION CONTROLLER AND RELAY PROTECTION OF THE REAL-TIME HYBRID SIMULATION PLATFORM

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ABSTRACT
This paper discusses the configuration and principle of the power system hybrid simulation platform. Two experiments based on a typical power system are carried out to test this platform and the results are given. It also researches the feature of real-time simulation on this platform. This platform is a foundation of a more advanced hybrid simulation platform in the future.

KEY WORDS
Hybrid simulation, real-time, electromechanical transient software, physical devices

1. Introduction

Simulation is an important tool to research in the field of modern science and engineering of power system. Many popular simulation tools used today are off-line, such as EMTP, EMTDC and NETOMAC [1]. They are widely used in planning, designing and validating power system. However, with the continuing involvement of HVDC and FACTS technologies, the off-line simulation has more and more difficulties in satisfying the requirement of scientific research and engineering application [2][3]. So, on-line real-time simulation has been becoming the focus of research nowadays. The real-time simulation often involves physical devices and leads to a software and physical hybrid simulation [4][5].

2. Configuration and Principle of the Real-time Hybrid Simulation Platform

2.1 Basic Configuration of the Real-time Hybrid Simulation Platform

The basic configuration of the simulation platform is shown in Fig.1.

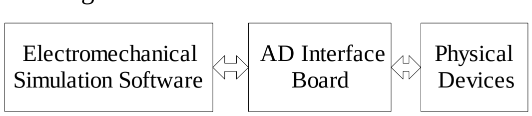

Fig. 1 Basic Configuration of the Real-time Hybrid Simulation Platform

This platform performs real-time hybrid simulation of electromechanical transient software simulation and physical devices. The platform consists three parts. They are 1) electromechanical transient simulation software 2) Analog and digital (AD) interface board 3) physical devices. The details of the three parts will be described in next three sections separately.

2.2 Electromechanical Transient Simulation Software

This electromechanical transient simulation software is developed by Tsinghua University which matches the requirement of analyzing the large-scale power grid nationwide. It is designed to achieve the goal of hybrid simulation involving physical devices, so real-time simulation is an important feature of this software.

This software consists two parts. They are called Client and Server.

Client: this part provides graphic interface on which users can set parameters and faults. The simulation results are also illustrated on this graphic interface. Besides this function, client also completes the calculation of power flow.

Server: this part completes the calculation of electromechanical transient simulation. The communication between AD interface board and software is also one of the tasks of this part.

Because the focus of this paper is to build a hybrid simulation platform, we have to pay much attention to the communication process between the software and AD interface board. In this electromechanical transient simulation software, the communication program controls the reading and writing process of the serial port of computer.

2.3 AD Interface Board

This part is an interface between software simulation and physical devices. Signals are processed and transferred between the two parts through this interface board. Here, digital signal processor (DSP) which is good at both calculation and communication is chosen as the main part of the AD interface board. The type chosen has good capacity of analog-to-digital (AD) and digital-to-analog

(DA) conversion. Such a capacity is quite vital in the real-time hybrid simulation platform. For the important role the DSP has played in this platform, it is necessary to introduce the features of the DSP, especially the features related to communication.

1) Model: TMS320LF2407 (Texas Instruments)
2) Channels of AD and DA conversion:
    AD—16 channels; DA— 4 channels
3) Conversion time of AD and DA:
    AD—500ns; DA—10us
4) I/O voltage range of AD and DA:
    Input voltage range of AD—0~3.3V;
    Output voltage range of DA— -10~+10V
5) Conversion resolution:
    AD—10bits; DA—12bits

The communication part with software is a universal asynchronous receiver and transmitter (UART) which is a TL16C752B model. The communication protocol is RS-232. The UART has 64 bits FIFO and the highest baud rate is 1.5Mbps.

2.4 Physical Devices

This part should be many kinds of physical devices, such as excitation controller, relay protector [6]. Here, we use them as the physical devices in the testing experiments. The physical devices are simulated by analog circuits to achieve the function of PI regulation. This PI controller is involved in the platform to complete the closed-loop simulation. The scheme of PI controller and its input and output are shown in Fig.2. The scheme of relay protector and its input and output are shown in Fig.3.

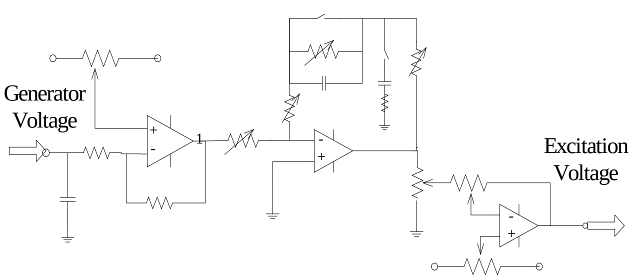

Fig. 2 Physical Devices (excitation controller) on the Simulation Platform

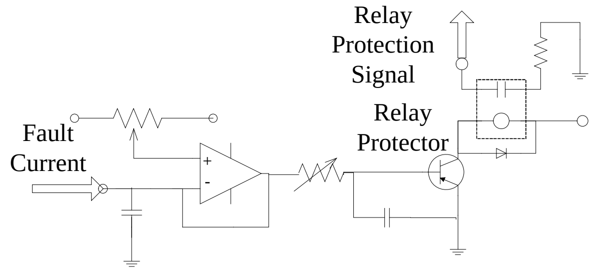

Fig. 3 Physical Devices (relay protector) on the Simulation Platform

As described above, the software simulation runs in computer to carry out the electromechanical transient calculation. When one step of calculation is completed, the result is sent to AD interface board. The AD interface board converts this digital result to analog signal and sends it to physical devices. The physical devices then send an analog signal back to the AD interface board. The board converts the analog signal to digital signal and then sends it to software through serial port in computer. This feedback result is used to calculate in the next step. This process can be described in another way that parts of the model of power system is taken out from the software and constructed as physical devices.

3. Testing Experiments on the Real-time Hybrid Simulation Platform

In order to test this platform, two testing experiments are carried out on it. A typical 36-node power system model was chosen to complete the testing experiments. Most part of this model is constructed in software, while a small part of it is constructed implementing hardware devices. There are two experiments to test this platform involving different physical devices. One is excitation controller, the other is relay protector. The configuration of these two testing experiments is shown in Fig.4.

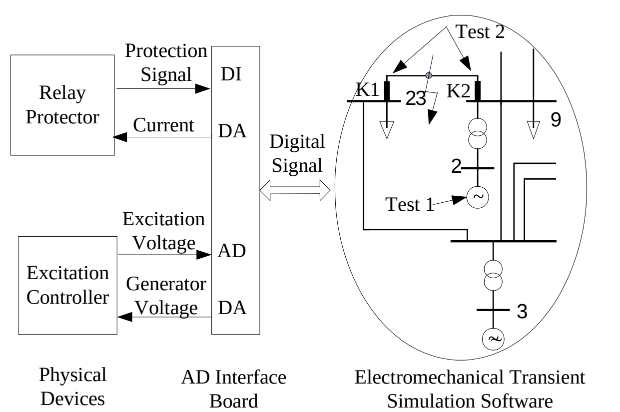

Fig. 4 Example of Simulation and the Digital/analog Simulation Task Assignment

The fault which is a three-phase short circuit fault is set to occur at 0.50s. In the excitation controller experiment, the fault is removed at 0.53s by cutting off the fault circuit. In the relay protection experiment, the fault will be removed by the feedback signal from the physical relay protector.

3.1 Hybrid Simulation Experiment (Excitation Controller as the Physical Device)

In this experiment, physical device is excitation controller of the generator at BUS2 (Test 1 in Fig.4). The signal transferred from software to physical device is the generator voltage. And the feedback signal from physical device to software is excitation voltage. The result of the generator voltage on the hybrid platform is shown in Fig.5. To test the accuracy of the hybrid simulation platform, a comparison between hybrid simulation and software simulation is presented in Fig.5.

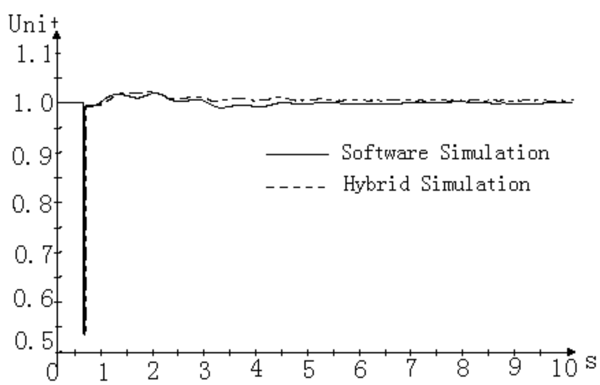

Fig. 5 Generator Voltage (BUS2) on the Hybrid Simulation Platform and Software Simulation

From the comparison of these two results, we can conclude that the result of hybrid simulation is almost coincided with the one of software simulation. The static error is less than 3%.

The error mainly results from two aspects. One is the inevitable difference between physical model and digital model. The other is the bandwidth restriction of serial communication.

3.2 Hybrid Simulation Experiment (Relay Protector as the Physical Device)

As described above, a three-phase short circuit fault occurs at 0.5s. The short circuit current is sent to physical device from software. The relay protector will operate according to this signal and a given reference value. When the protector sends back a signal to cut off the fault circuit, the software simulation will calculate according to the new structure of power grid.

The results of generator voltage and relay protection wsignal are shown in Fig.6. The response time *t* is 30ms.

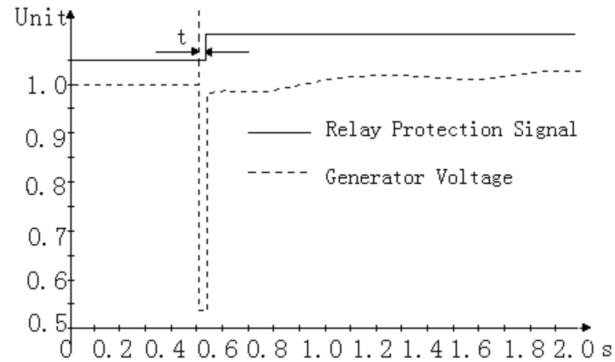

Fig. 6 Results of Relay Protection on Hybrid Simulation Platform

4. Analysis of the Feature of Real-time on This Simulation Platform

In the research field of power system simulation, the concept of simulation step is important, especially in real-time simulation. The typical step in electromechanical transient simulation is 10ms. So we have to guarantee that the total time in one step including the calculation time *tcal* and the communication time *tcom* is less than 10ms to achieve the purpose of real-time. This focus is also a critical technology in constructing such a real-time hybrid simulation platform.

The calculation time *tcal* is determined by the scale of the power grid. The larger the grid is, the more calculation time could be spent. In this testing experiment, the *tcal* of the typical 36-node model is less than 1ms. With the enlargement of the scale of power grid, the *tcal* will be more and more. However, there must have a maximum calculation time to satisfy the time limit of 10ms. How to determine this amount of calculation time? We should determine the communication time *tcom* first, because when the interface configuration is determined, *tcom* is fixed. To determine the communication time *tcom*, the protocol and configuration of serial communication have to be depicted first. On this platform, the protocol is RS232. Every frame has 8 data bits, 2 stop bits. Baud rate is 115.2Kbps, so in theory, it transfers one byte in 0.086ms. In Linux OS, there is a 10ms delay when sends a byte outside through serial port under default configuration. This period of time is called latency. On such a real-time simulation platform, the 10ms delay cannot be tolerated. So the configuration has to be reset. In Linux OS, the critical configuration related to this delay is the attribute of a flag. We should set the attribute of this flag to ss.flags |= ASYNC_LOW_LATENCY. After such a change, the communication time *tcom* is shorten dramatically.

To test the accurate *tcom*, a specific program is designed. The flow chart of this testing program is shown in Fig.7.

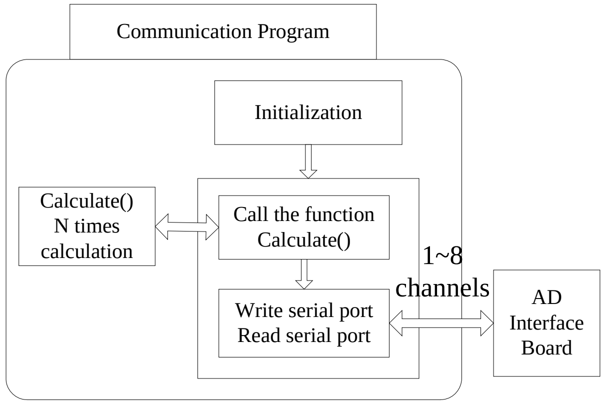

Fig. 7 Testing Program of Real-time Simulation

The number of channels in this program should range from one to eight. That means the communication signals between software and physical device should have 8 channels in maximum. The testing result is shown in Table.1.

Table.1 Communication Time *tcom*

Channel number	one	two	three	four
Communication time/ms	1.0	1.2	1.4	1.6
Channel number	five	six	seven	eight
Communication time/ms	1.8	2.0	2.1	2.0

The data in this table is an average of 100 times measurement. From this table, a conclusion can be driven that, because the communication time *tcom* can be controlled in 1~2ms, so the calculation time *tcal* can reach to 8~9ms long.

5. Conclusion

This real-time hybrid simulation platform realizes the interactive simulation between electromechanical transient software and physical devices. The results of testing experiments demonstrate that the accuracy of hybrid simulation can be satisfied. The analysis of chapter 4 shows that the simulation on this platform is real-time.

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