Electromechanical Transient Simulator of Electric Power System Based on Object-oriented Design Patterns

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ABSTRACT

Studying the electromechanical transient of electric power system is very necessary for dispatchers to understand the electromechanical transient process and remove or avoid faults in time. Electromechanical transient simulation system based on traditional dispatcher training simulator (DTS) is developed. System framework of the electromechanical transient simulator is introduced firstly, and then modeling electromechanical transient of electric power system with class inheritance. Singleton and factory method are used to instantiate models in the end. The demonstration is performed on a modified IEEE 11-node grid and compared with BPA. Keywords: Electromechanical transient, object-oriented technology, design pattern, dispatcher training, simulator

INTRODUCTION

With the fast development of AC-DC hybrid grid, physical topology and operating characteristics of grid change dramatically. The operating characteristics of grid changes from regional pattern to integration pattern. Then, the impacts of local faults expand. Therefore, in order to improve the capability of keeping the AC-DC hybrid grid operate safely and steadily, it is urgent for dispatchers to grasp the integrated dynamic characteristics of grid when there is DC bipolar block, low frequency oscillation, and so on. Electromechanical transient simulation of electric power system mainly researches on the transient stability of electric power system after large disturbance and the static stability after small disturbance. At present, PSASP and BPA are usually be used to simulate the electromechanical transient process in China, and PSS/E of PTI company, ETMSP of EPRI, SIMPOW of ABB, NETOMAC of SIMENS are usually be used in the international. These programs are good at grid analyzing, planning and evaluating, not dispatcher training [1-3]. As to dispatcher training simulator (DTS), there have been many researches until now. Wei Wenhui [4] researches the key technologies and architecture of both software and hardware adopted in the DTS, and then he [5] proposes the new standard of smart

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grid dispatching control system dispatcher and operator training simulator according to the standard writing requirement of state, trade and corporation. Meanwhile, he [6] builds steady-state simulation model of multi-terminal VSC-HVDC and proposes hybrid solution algorithm of AC/DC system based on the DTS. These traditional dispatcher training simulator systems can only calculate dynamic electric power flow [7-9], which cannot help dispatchers to understand the electromechanical transient process much better. Therefore, electromechanical transient simulation system based on DTS is developed in this paper.

SYSTEM FRAME OF ELECTROMECHANICAL TRANSIENT SIMULATOR BASED ON OBJECT-ORIENTED DESIGN PATTERN

Object-oriented Design Pattern Introduction

Object-oriented technology is a software development method to construct system with object, class, inheritance, polymorphism, encapsulation, aggregation, message, etc. Being of polymorphism, inheritance and encapsulation characteristics, it allows abstract and modular hierarchy.

Design pattern is used to describe class and objects that communicate with each other to solve general design problems in specific scenarios. Essentials of a design pattern includes name, problem, solution and result. According to different objects, design patterns are divided into creational, structural, behavioral. Creational patterns are in connection with creating objects, such as singleton, factory method, builder, and so on; Structural patterns are related with the combination of class or objects, for example adapter, proxy; Behavioral patterns describe how class or objects to communicate and assign responsibilities, taking observer, iterator as example.

System Framework of Electromechanical Transient Simulator

The system framework of electromechanical transient simulator is shown in Figure 1. There is fast electromechanical transient simulation of large power grid, interactive and visualized trainer support, data manager center, in which fast electromechanical transient simulation of large power grid is the core of this simulator. It is composed of electromechanical transient model of electrical equipment, detail simulation of secondary system and system solution algorithm.

Figure 1. System framework of electromechanical transient simulator.
MODELING ELECTROMECHANICAL TRANSIENT WITH OBJECT-ORIENTED TECHNOLOGY

Designing classes with good inheritance and encapsulation characteristics is the key of developing a system based on object-oriented technology. Simulating mechanical motion of generators is the key point in electromechanical transient simulation. Therefore, electromechanical transient model of generator is needed to build, including motor and governor system, excitation system, power system stabilizer (PSS), shown in Figure 2.

![Electromechanical transient model framework](image)

Figure 2. Electromechanical transient model framework of electric power system.

Fundamental circuit elements and control elements are encapsulated into base classes independently. Every kind of electrical equipment inherit these base classes. Class design and inheritance of electromechanical transient model of electric power system is shown in Figure 3.

![Class design and inheritance](image)

Figure 3. Class design and inheritance of electromechanical transient model.

a. Fundamental circuit element class design
   Build fundamental circuit element classes for the essential electrical equipment. They are composed by resistance, capacitor, inductor, controlled source, voltage source, current source. Equivalent model for kinds of electrical primary equipment can be built by these fundamental circuit element classes.

b. Fundamental control element class design
   Build fundamental control element classes for generator control systems. There are
proportional element, inertial element, integrating element, oscillating element, differentiation element, time delay, etc. By these fundamental control element classes, model of control systems can be built easily.

c. Electrical primary equipment class design

Inherited from fundamental circuit element classes, electrical primary equipment classes are built. There are bus class, line class, transformer winding class, generator class, breaker class, etc. Then physical equipment classes are built by inheriting from these electrical primary equipment classes. For example, two-winding transformer class and three-winding transformer class are derived from the transformer winding class.

d. Dynamical model class of generator design

Dynamical model of generator is composed by prime mover, motor, governor, excitation system and PSS normally. Build general classes for these parts inherited from fundamental control element classes. Then physical control system classes are built by inheriting from these general classes. For example, steam turbine class and hydro turbine class are derived from motor class; E-type, F-type, M-type, N-type excitation classes are derived from the excitation class.

Moreover, matrix class and simulation flow control class are built in order to form and resolve equations conveniently. Matrix class includes linear matrix class and linear matrix management class. Simulation flow control class is designed for controlling the overall process of electromechanical transient simulation including memory allocation, initialization, event handling, topology analysis, data access, simulation clock control, etc.

DESIGN PATTERNS USED IN ELECTROMECHANICAL TRANSIENT SIMULATOR

How to create objects is the core issue of object-oriented technology. Design pattern describes class and objects communicated with each other for problems under a certain scenario, that is design pattern is a way to create objects.

In electromechanical transient simulation, the grid model and parameters are unique and global, there are many common properties among different type of models, and so on. According to these characteristics, main design patterns used in this system are shown as follows.

a. Singleton

Singleton ensures that one class has only one instance and provides a global point of access to it. In electromechanical transient simulation, the global and stable objects are created with singleton. For example, the way of creating object of a grid topology model is as follows:

```cpp
CIMEDIORtdbBuf * CIMEDIORtdbBuf::Instance ()
{
    if ( m_pInstance == NULL)
    {
        m_pInstance = new CIMEDIORtdbBuf();
    }
    return m_pInstance;
}
```

b. Factory method

Factory method, also known as virtual constructor, defines an interface for creating objects and which class to be instanced is up to subclass. In electromechanical transient simulation, there are many common properties among different type of electrical equipment. For example, models of continuous rotation DC excitation system (EA) and brushless rotation AC excitation system (EB) are the same except one feedback loop. Therefore, E-type excitation class is defined
abstractly and EA type –EK type excitation systems are created by factory method. Take EA type as an example:

```cpp
class CTRM_ExcitorEA: public CTRM_Excitor
{
    public:
        CREATOR (CTRM_ExcitorEA);
}
```

CASE STUDIES

Test the validity of this proposed electromechanical transient simulator with the modified IEEE 11-node grid and compare with BPA. The wiring diagram of IEEE 11-node grid is shown as Figure 4. Generators on node 1, 3, 4 adopt classic second-order model; Pure resistance loads are on node 7 and 9; simulation step is set to be 0.02s.

In order to test the validity of electromechanical transient model of a generator, two scenarios are designed.

![Figure 4. The wiring diagram of IEEE 11-node grid.](image)

**a. Scenario A.** Generator on node 2 adopts classic second-order model

BC interphase short circuit happens on bus 7. The swing angle of generator on node 2 relatives to which of generator on node 4 is shown in Figure 5.

![Figure 5. Simulation results of the relative swing angle of generators.](image)

It is shown in Figure 5 that the maximum error of the relative swing angle between the proposed simulator and BPA is 0.86%.

**b. Scenario B.** Generator on node 2 adopts four-order model with EA-type excitation system

BC interphase short circuit happens on bus 7. The swing angle of generator on node 2 relatives to which of generator on node 4 is shown in Figure 6.
Figure 6. Simulation results of the relative swing angle of generators.

It is shown in Figure 6 that the maximum error of the relative swing angle between the proposed simulator and BPA is 0.58%.

From above case studies, it is proved that models in this proposed electromechanical transient simulator is right and reliable.

CONCLUSION

In this paper, electromechanical transient simulation system based on traditional dispatcher training simulator is developed. Firstly, electromechanical transient modeling methods of electric power system is introduced. Then, the methods of how to instantiate models are proposed, including singleton and factory method. In the end, the demonstration is performed on a modified IEEE 11-node grid and compared with BPA to prove that the electromechanical transient simulator developed in this paper is right and reliable.

REFERENCES

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