

## Relay Protection Sport Systems Based on MATLAB-Based Simulation Technology

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### Abstract

*MATLAB-based simulation technology can support the analysis and design of relay protection sport systems. A simulation model is built for the study of sport system relay protection. As an example, the sport system fault simulation, zero-sequence current protection simulation and transformer differential protection simulation are presented herein. The case studies show that the simulation of sport system relay protection is effective and feasible.*

**Keywords:** Sport system; relay protection; simulation; MATLAB

### 1. Introduction

With the development of power movement system, the scale of power grid has been gradually expanded, plus the network connection is getting more and more complex, coupled with the use of series capacitor, shunt reactors and some other equipment, the probability of occurring fault in power movement system is increased. Moreover, there is a trend that the type of breakdown is complicated [1]. At the same time, the modern power grid is closely linked, once the local accident cannot be handled well and properly, it is very likely to spread to the entire network, which can cause huge losses to the national economy. Therefore, it must put forward higher request to the relay protection device as "the first line of defense" of the power grid, once the breakdown is occurred, people should be able to remove the breakdown quickly and selectively, so as to reduce its influence on the whole power movement system to the minimum [2].

Sport System digital simulation can be divided into two types of simulation study and training simulation. Simulation Study includes a variety of sport system stability and transient electromagnetic transient simulation software, integrated electromagnetic transient stability program, Such as electromagnetic transient software EMTP and widely used in domestic electric sport department comprehensive stability program as well as the Math work company's newly minted MATLAB, etc. [3]. Training simulator including those belonging to the EMS dispatcher training simulator DTS, substation operator training simulator and sport plant unit operation personnel training simulators [4].

Some of DTS has function of studying simulation, so hardware and software are very large and complex, also the equipment's are expensive. Simulation studies can be divided into non-real-time simulation and testing of real-time simulation. Real-time simulation of sport system protection devices currently are used mainly for testing and adjusting the generator excitation system. With physical participation, thus we required simulation system in real time. Real-time simulation software must be finished within a practical step all state variables and state variables to solve the calculation and associated with the physical parameters of the transformation, sport amplifier and connection [5-7].

From the training requirements of the system, taking MATLAB as a development platform, we used the system's sportful, suitable functions for the development of a number of sport system protection simulation modules. Students can construct a

simulation model according to the required imitation really sport topology structure, sport flow calculation, short circuit Calculation, transient simulation calculation and relay protection testing and validation.

## 2. The Overview of MATLAB

MATLAB is high performance numerical software produced by Math works company, it combines numerical analysis, matrix computation, signal processing and graphical display in one body, which has a friendly user interface environment at the same time. MATLAB can solve practical engineering problems, such as automatic control, digital signal processing, control system, statistical signal processing and image processing *etc.* The biggest feature of MATLAB is easy to spread, which allows the user to set up and complete M file with the assigned function.

### 2.1 The Design of System

The module base of power movement system in Simulink of MATLAB is the integration of the various components that power movement system simulation model needs, which can realize the simple simulation of power movement system, but the simulated user interface of the Simulink is not very intuitive, besides, it also needs to understand the simulation before the setting of the element characteristics and simulation performance, which have relatively high requirements on the users; while Qt programming tools have the advantages such as: programming is simple, the development speed of interface is fast. Therefore, by using Qt as a development tool, using MATLAB as the background server simulation, combined with the advantages of these two tools, this interactive method can realize simulation and output.

MATLAB and Qt communication protocol is based on ActiveX technology. It is a component of integrated protocol that is developed by Microsoft, which is a independent programming language without the environmental constraints. Moreover, it can be used in different environments, both MATLAB and Qt can accept this protocol. The platform can mainly realize these two relatively independent functions, namely the protection simulation and fault simulation. The overall design of simulation platform can be shown in Figure 1. Protection simulation can realize the simulation of motion process of each typical devices. First of all, under the Qt, it can complete setting up various modules, including graphic interface, calibration equipment, protective device. Among the protective device, it can be divided into data acquisition, algorithm, logical judgment, process display and other modules. Then after completing the fault models in MATLAB, with the drawing of one and two wiring diagrams, as well as the setting of input and output variables, by using ActiveX technology to send orders to MATLAB from the Qt interface. Then by using Qt to draw the simulation waveform, so as to realize the fault simulation function and help students to improve the ability of analyzing breakdown.

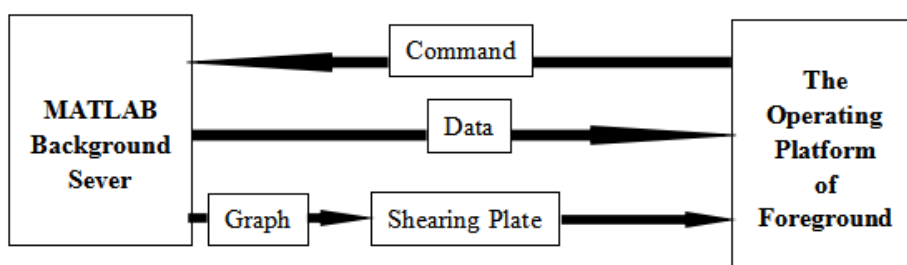


Figure 1. The Overall Designing Diagram

## 2.2 The Set Up of Simulation Model

The relay protection simulation training software in power movement system mainly can realize breakdown simulation, protection simulation and other typical transient simulation. The breakdown simulation can be including the simulation of three -phase fault and two-phase fault, two-phase to ground fault and single-phase to ground fault, which can output the voltage and current wave forms of the breakdown phase, so as to deepen the understanding about the various faults; protective action simulation can be including phase overcurrent, zero sequence overcurrent, the relative distance, grounding distance high frequency and longitudinal differential protection. Based on the fault and protection function, as well as the electrical parameters of waveform with circuit breakers output measurement, it can deepen the understanding about the protection principle; the other typical simulation can carry on with the transient simulation and system oscillation, *etc.*, which can output various transient waveforms.

According to the requirement of simulation, it can establish simulation wiring diagram under the environment of Simulink, by using the measuring element in module base, it can store various parameters of simulation output in the form of variable into MATLAB, waiting for the processing command from the foreground, the drawing of simulation diagram ten can be saved to the MATLAB working directory, so, when the foreground call MATLAB, it can find out the required simulation file directly.

In the constructed fault system MATLAB simulation model, through the fault module, it can set three-phase short-circuit, two-phase short circuit, two-phase short circuit to the ground and single-phase to the ground grounding fault. Taking the single-phase to the ground fault as an example, setting the three-phase short circuit element parameters is the fault with A to the ground, running the simulation model, then it can get the short circuit voltage and current waveforms that obtained by the single line when it is with single-phase to ground fault.

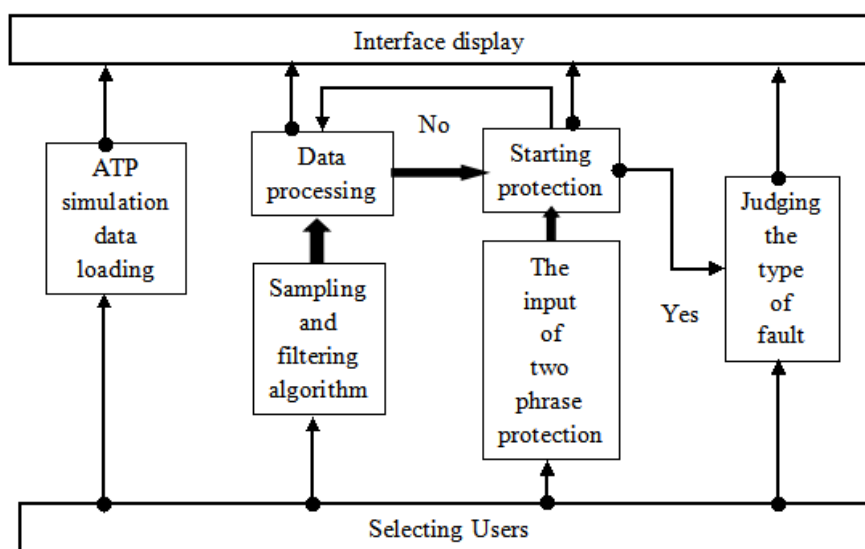


Figure 2. The Diagram of System Structure

## 2.3 The Design of Foreground Operating Interface

The foreground interface is designed by using visual technology, the left side adopts shutters form technology that can realize the various simulation functions, while the right side adopts multi-file technology to realize the corresponding simulation principle

diagram, so as to realize the display of MATLAB diagram and simulation result as well as the output of the stimulation waveform. Taking the single phase to ground fault simulation as an example, selecting the left side of the single phase to ground fault simulation module, while the right side can show the principle diagram and wiring diagram of MATLAB, through the simulation settings, it can choose the fault points, namely the voltage and current waveform of A phase, B phase, C phase.

In this system, the switch of each interface used function Run and Eval. Variable between multiple interfaces can be transferred by using two kinds of methods: one is function global; the other method is saving the variable in a MAT file, when it is used, it can use load command to open, thus, the characteristic of this method is to record the value of the variable in the last run.

If each function design of the system is completed, if it is correctly operated in MATLAB operation, then it can be compiled and executed on any computer. Through inputting the "the file name 1.m of mcc-m, file name 2.m...", file M can be compiled and generate one executable file named exe.

### 3. The Acquisition of Fault Data

By using ATP-EMTP, it can set up line protection system. In the ATP-EMTP window, click the right button, then the shortcut menu can be opened, selecting the required elements to control, so as to connect the elements according to the actual connection and set its parameters at the same time. Taking the established unilateral power supply of 110 KV transmission line as an example, first of all, click the right button, then select the source menu in the shortcut menu, select Ac type 14 as power control. Then, select the power control with the left button and drag it to the appropriate location. After that, double click the control icon by using the left button of the mouse, then set the amplitude, frequency and other parameters in the dialog box. It can use the similar method, select the control and set their parameters. After establishing the system, choose settings to set the size of time step and the length of time in the ATP drop-down menu; set the parameters of output control in the output tab. Finally, run ATP, then it can generate file PL4 as the result data, which can convert it to a MAT file called by MATLAB. The generating process of fault data can be shown in Figure 3:

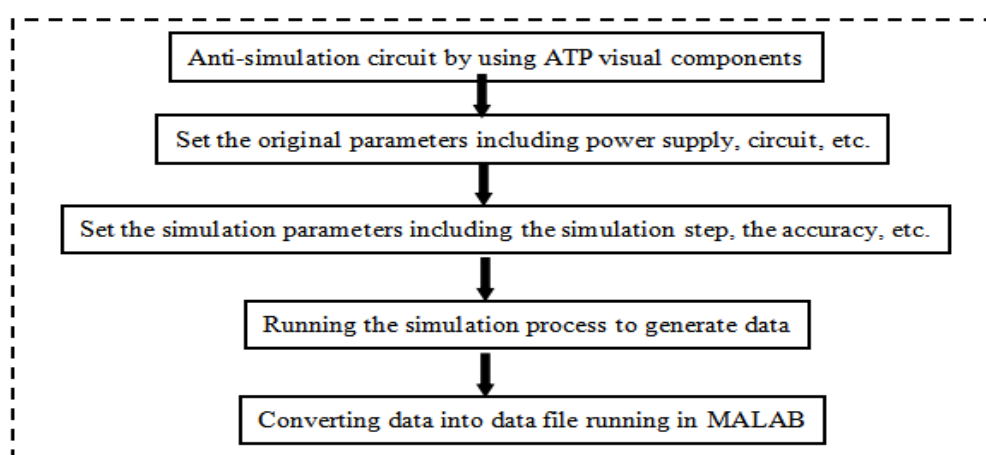
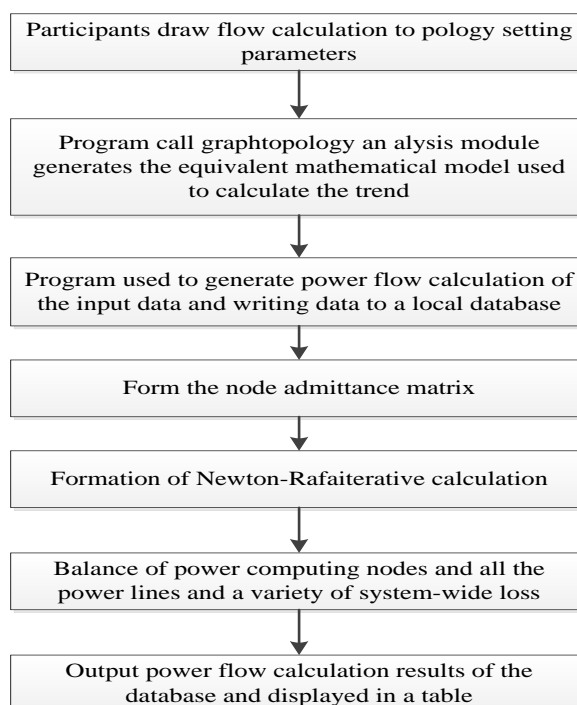


Figure 3. The Generating Process of Fault Data

## 4. Sport Flow Calculation

During systems analysis, it often in need of sport flow calculation. So the system integrates the flow calculation module. Sport flow calculation used a modular programming methods. The calculation module is written in C++ language, so it has fast computing speed. In addition to the core algorithm module used a better convergence of the Newton-Raphson algorithm, to meet the students' purpose of sport flow calculation. Taking advantage of the trend of computing systems provide mapping module, through a simple drag and drop mapping method to draw a trend to be calculated topology, students do sport flow calculation by making convenient graphical parameter settings. Compared with the traditional data card fill in sport flow calculation method, this method has greater convenience, making the students get rid of the traditional calculation method of dry sex, greatly improving the learning interest. Process of sport flow calculation module are shown in Figure4.



**Figure 4. Flow Calculation Flow Chart**

In the process of sport flow calculation, some PV systems in order to maintain a given node voltage, reactive sport of them may exceed the permitted range, especially when the sport system reactive sport is not very abundance more prone to PV node reactive sport of crossing the line. Thus, in an iterative process that must be monitored for reactive sport PV node, when the reactive sport over a given range, the trend of the program should be able to reactive sport control to allow these nodes within range.

If PV node  $i$  reactive sport maximum allowable value  $Q_iM$ , the node is calculated in the iterative process of reactive sport  $Q_i$ , then the reactive sport reserves should be:  $Q_i = Q_iM - Q_i$ .

When  $Q_i$  is negative, indicating that the point has been cross-border reactive sport, in this case, the intervention must be to reduce the reactive sport iteration of this node  $|Q_i|$ , reactive sport to make it back to the upper bound  $Q_iM$ . Consequence of this is bound to bring each node voltage systems change, and change the maximum (or reduce the

maximum) is the voltage cross-border points. In fact, when the PV node by node  $i$  converted to PQ nodes.

Newton's method for flow calculation procedures, the hair in an iterative process PV node reactive sport is now out of range when it should translate into PQ node, ( $Q_iM - Q_i$ ) as the point on the reactive sport error. In this case, the structure of the equation should be modified accordingly changes. When sport is used when the polar coordinate expression, should be increased corresponding to an equation  $Q_i$  in the correction equation, the sport when using a rectangular coordinate type.

A periodic function  $x(t)$  with the angular frequency can be represented by a trigonometric series, such that for any  $t$ :

$$X^{(1)}(k) = \sum_{i=1}^k X^{(0)}(i) = X^{(1)}(k-1) + X^{(0)}(k)$$

And also be represented as:

$$X^{(1)} = \{X^{(1)}(k), k = 1, 2, \dots, n\}$$

The Fourier coefficients can be computed easily in MATLAB using symbolic functions, such as integration function *int* and symbolic substitution function *subs*. The MATLAB code for spectrum analysis of the periodic square pulse signal is as follows

$$Y_n = (X^{(0)}(2), X^{(0)}(3), \dots, X^{(0)}(n))^T$$

The  $K$  layers wavelet decomposition matrix of the graph with height  $h$  and width  $v$  can be converted into the ordered linear list with size of  $v^h$ . In ordered linear list, in the first ( $2 \leq l \leq k$ ) layer the high frequency sub-band coefficients  $X[i]$  have four child coefficients, which are located at  $4i$ ,  $4i+1$ ,  $4i+2$ , and  $4i+3$ ; in the  $k-l$ th layer the low frequency sub-band coefficient  $X[i]$  has three child coefficients, which are located at  $i+u$ ,  $i+2u$ , and  $i+3u$ , here  $u = vh/4k$ .

Proof. The food packaging image with height  $h$  and width  $v$  through the  $k$ -th layer wavelet decomposition, will produce  $3k+1$  sub-bands, the code numbers are LLK, LHK, HLK, HHK, LHK-1, HLK<sup>-1</sup>, HHK<sup>-1</sup>, ..., LH1, HL1, HH1. According to this kind of sub-band order these sub-band coefficients will be stored into an ordered linear list line by line, in the head of ordered linear list to store the coefficient of low frequency sub-band LLK with the  $k$ -th layer, and in the same layer to store the coefficients of three high frequency sub-band LHK, HLK, HHK; then store the coefficients in the next layer which are from three high frequency sub-band LHK-1, HLK<sup>-1</sup>, HHK<sup>-1</sup>; finally store the coefficients of three high frequency sub-band LH1, HL1, HH1 in the first layer, therefore, a linear list with size of  $h^v$  is produced.

For any one coefficient  $X[i]$  in the linear list, if it is located at the  $l$ -th layer ( $2 \leq l \leq k$ ), assuming it is the  $i'$ -th coefficient in the high frequency sub-band, then in front of the first layer of high frequency sub-band coefficients there are  $h^v/4^l$  coefficients, therefore  $i' = i - h^v/4^l$ . Due to  $2 \leq l \leq k$ ,  $X[i]$  has four child coefficients in the No.  $l-1$  layer. If the coefficients of the No.  $l-1$  layer are grouped per four, the four child coefficients of  $X[i]$  happens to be the sub coefficient of the  $i'$ -th group in the No.  $l-1$  layer. Because there are  $h^v/4^{l-1}$  coefficients in front of the No.  $l-1$  layer, the position of the first child coefficient of  $X[i]$  in the No.  $l-1$  layer is  $j = h^v/4^{l-1} + 4i' = 4i$ . Therefore, in the ordered linear list the element  $X[i]$  located at No.  $l$  ( $2 \leq l \leq k$ ) is corresponding to the four child coefficients  $X[4i]$ ,  $X[4i+1]$ ,  $X[4i+2]$ ,  $X[4i+3]$ , if element  $X[i]$  is located at the low frequency sub-band LLK in

the  $k$ -th layer, then  $X[i]$  has a child coefficient respectively in LHK, HLK, and HHK, they are  $X[i+u]$ ,  $X[i+2u]$ , and  $X[i+3u]$ , hereinto,  $u = vh / 4^k$ . removed from the data, the detection procedure should be done again using the remaining data to find another outliers. So the MATLAB code is as follows:

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```
x=[28.53, 28.52, 28.50, 29.52, 28.53, 28.53, 28.50, 28.49, 28.49, 28.51, 28.53, 28.52,
28.49, 28.40, 28.50];
disp('*****Computing results*****')
```

```
void CreateOrder(int order[][W], int width, int dlevel)
/* W is a constant, such as W = 512 */
{ int ScanOrderX[4] = {0, 0, 1, 1};
int ScanOrderY[4] = {0, 1, 1, 0};
int LX[M1], LY[M1];
/* M1 is a constant, while the graph
width = 512, M1 = 512 * 512 / 4 = 65536 */
LX = (int*)calloc(width * width / 4, sizeof(int));
LY = (int*)calloc(width * width / 4, sizeof(int));
w = width; dl = dlevel; s0 = floor(w / pow(2, dl)); k = 0;
for (j = 0; j < s0; j += 2) {
for (i = 0; i < s0; i += 2) {
for (m = 0; m < 4; m++) {
LY[k] = j + ScanOrderY[m];
LX[k] = i + ScanOrderX[m];
order[LY[k]][LX[k]] = k; k++;}}
n = k;
for (i = 0; i < n; i++) { L
Y[k] = LY[i] + s0; LX[k] = LX[i];
order[LY[k]][LX[k]] = k; k++;}
for (i = 0; i < n; i++) {
LY[k] = LY[i]; LX[k] = LX[i] + s0;
order[LY[k]][LX[k]] = k; k++;}
for (i = 0; i < n; i++) {
LY[k] = LY[i] + s0; LX[k] = LX[i] + s0;
order[LY[k]][LX[k]] = k; k++;}
p = n;
while((p < k) && (p < 65536)){
```

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From the training requirements of the system, taking MATLAB as a development platform, we used the system's sportful, suitable functions for the development of a

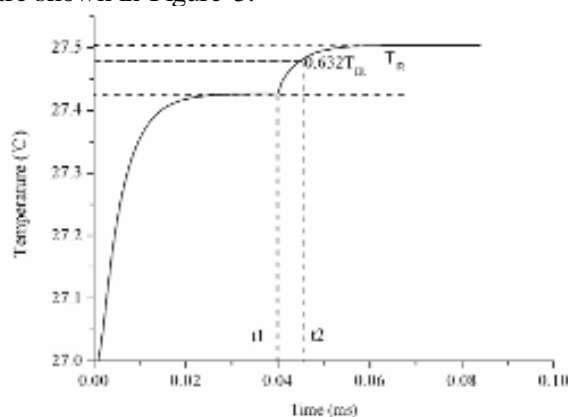
number of sport system protection simulation modules. Students can construct a simulation model according to the required imitation really sport topology structure, sport flow calculation, short circuit Calculation, transient simulation calculation and relay protection testing and validation.

In the calculation process, we used a network node number of the sport network optimization method. Mainly at least the outlet of the dynamic slip numbered, *i.e.* the process of elimination in the node, each node after the erasing, the number of branches at each node occurs with the node connected to the change (increase, decrease or remain the same) occurs. So, in each elimination of a node, the number of branches has not yet appeared immediately corrected number of nodes, and then choose the least number of branches which qualify a node number, you can expect to get better results.

Through the use of flow calculation module of the system to IEEE30, IEEE4, IEEE6 node system simulation, the result is correct.

## 5. Results

While retaining the traditional content and using MATLAB to the fullest extent possible. The Fourier coefficients can be computed easily in MATLAB using symbolic functions, such as integration function `int` and symbolic substitution function `subs`. The MATLAB code for spectrum analysis of the periodic square pulse signal is as follows, and running results are shown in Figure 5.



**Figure 5. Spectrum Analysis Running Results**

The Pulse Generator block was used to generate the periodic signal, so the block parameters are set as follows: Amplitude: 1, Period (seconds): 4, Pulse width (% of period): 25, and Phase delay (seconds): -0.5. The analog filter design block designs and implements a Butterworth, Chebyshev type I, Chebyshev type II, or elliptic filter in a high pass, low pass, band pass or band stop configuration.

## 6. Conclusion

The analysis and design of relay protection simulation system of digital relay protection is based on the power movement system of computer technology, the application of MATLAB simulation technology in the research of relay protection of power movement system has very important practical significance. The core technology of relay protection in power movement system constructs the MATLAB simulation model of the relay protection system. The practice shows that the application of MATLAB in digital relay protection simulation of power movement system is effective and feasible.



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