Microcontroller Based Protective Relay Testing System

ABDERRAHMANE OUADI, HAMID BENTARZI, MAHFOUD CHAFAI, and ABDELKADER ZITOUNI

Signals and Systems Laboratory (SiSyLAB)
IGEE, Boumerdes University
E-mail: sisylab@yahoo.com
ALGERIA

Abstract: - The functional security of the power grid depends upon the successful operation of thousands of relays that may be used in protective scheme for preventing the power system from cascading failures. The failure of one relay of the protective scheme to operate as intended may jeopardize the stability of the entire power grid and hence it may lead the whole system to blackout. In fact, major power system failures during a transient disturbance are more likely to be caused by unnecessary protective relay tripping rather than by the failure of a relay to take action. In other words, the performance of protective relay or system is very important to be known especially in smart power grid.
Appropriate relay testing provides a first defense against relay mal-operations and hence improves power grid stability and prevents catastrophic bulk power system failures.
In this work, new technologies that allow designing an enhanced relay testing system that can be used for improving the performance of protective relay have been used. We have designed and implemented microcontroller based relay testing system as well as tested its performance for showing its experimental evaluation.

Key-Words: - Power system, transient disturbance, reliability, protective relay tester.

1 Introduction

The operational security of the power system depends upon the performance of the thousands of relays that protect the power system from cascading failures. The failure of a relay to operate as intended may jeopardize the stability of the entire system and equipment in it. In fact, major system failures during a disturbance are more likely to be caused by unintended protective relay operation rather than by the failure of a relay to take an action at all. In other words, the performance of protection system is measured by several criteria including reliability, selectivity, speed of operation, etc. Reliability has two aspects: dependability and security. Dependability is known as the degree of certainty that a relay system will operate correctly when there is a fault on the system. Security is the degree of certainty that a relay will operate unnecessary even when there is no fault on the system [1, 2].

Appropriate relay testing provides one line of defense against relay mal-operations. Relay testing can help to validate the design of relay logic, compare the performance of different relays, verify relay settings, identify system conditions that might cause unintended relay operation, and carry out post-event analysis to understand the causes of unintended or incorrect relay actions. Relay testing system improvements need to continue because of the use of relays in smart power grids where the conditions that are not the same as in the conventional one. This leads to new relay technologies.

In this work, we have used new technologies that allow designing an enhanced relay testing system which in turn can be used for improving the performance of protective relay. We have designed and implemented microprocessor based relay testing system through the use of the new technologies such as microcontroller.

The protective relays that may be tested by our developed relay testing system are:

- Over-current relays,
- Undercurrent relays,
- Frequency relays,
- Ground fault relays,
- Directional ground fault relays,
- Differential protective relays,
- Automatic reclosing devices,
- Tripping relays,
- Thermal relays,
- Time-delay relays,

2 Types of testing

Types of testing that can be performed by our relay tester are as follows:

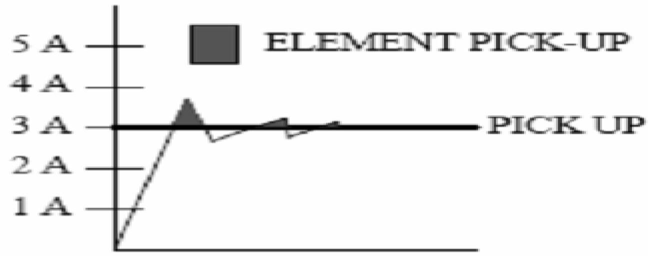

Figure 1 Steady State Pick-up Test

2.1 Steady State test

Usually steady state testing is used for checking the relay pick up by injecting current or voltage at predetermined value for duration longer than the setting time of relay. Then, the injected signal is varied gradually at a rate much smaller than resolution of relay, either manually turning a knob or by an automated system. Figure 1 indicates how relay picks when the current is raised and then fluctuated around pick up. This type is of less use in commissioning, due to the injected signal does not represent the actual power system faults.

2.2 Dynamic state test

Dynamic-state test is investigated by simultaneously applying fundamental frequency components of voltage and current which represent power system states of pre-fault, fault and post fault. Time for relay operation is measured. This type of test can be used in commissioning and troubleshooting. Figure 2 shows simple dynamic state test waveforms.

2.3 Transient Test

Transient testing may be investigated by applying simultaneously fundamental and non-fundamental frequency components of voltage and current that represent power system conditions (see Fig.3).

3 Transient Data Sources

The signal that may used in the above mentioned types of testing may be obtained from digital fault recorders (DFR) or Simulator such as Simulink / Matlab or electromagnetic transient programs (EMTP) especially for the last type of test [3].

The increasing use of digital technology in devices such as protection, oscillograph, measurement, and control apparatus in electric power substations has created the potential for accumulating large numbers of digital recording of power system transient events. In addition to these sources of digital data, analog and digital power system simulators may be used to generate digital data. The users of these data are faced with the problem of having to manage with different formats used by each system to generate, store, and transmit data [4].

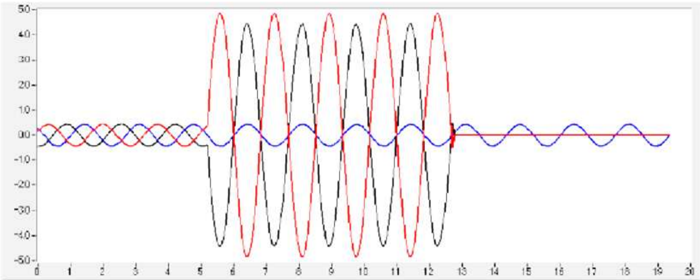
Figure 2 Dynamic State Test

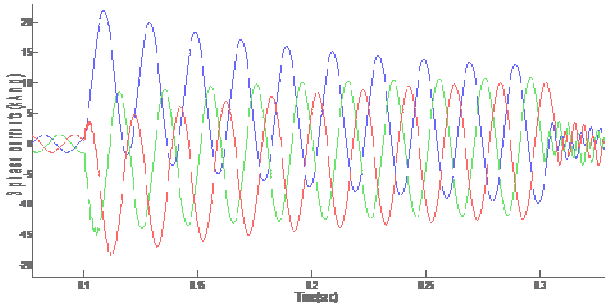
Fig.3 Current transient waveforms (transient test).

The common standard format that has been used in the power system applications is IEEE Standard Common Format for Transient Data Exchange "COMTRADE". Each COMTRADE record has a set of up to four files, each one carries a different class of information. The four files are as follows:

a) header,
b) configuration,
c) Data and
d) Information.

All files in the set must have the same file name, differing only by the extensions that indicate the type of files. File names are in the form xxxxxxxx.yyy. The xxxxxxxx portion is the name used to identify the record (e.g., FAULT1 or TEST_1). The .yyy portion of the file name is used to identify the type of file and is known as the extension: .HDR for the header, .CFG for the configuration, .DAT for data, and .INF for the information file. The file names are limited to eight characters and their extensions are limited to three characters.

There are many sources of transient data given in the COMTRADE standard in the power grid applications [5]. Some data sources are: digital fault recorder, digital relay and transient simulator.

3.1 Digital fault recorders

Digital fault recorders that may be used for monitoring power system dynamics such as voltages and currents are supplied by several manufacturers. These devices record analog signals by periodically sampling them and converting the measured signals to digital values. Typical recorders monitor 16–128 analog channels and a comparable number of event (contact status) inputs.

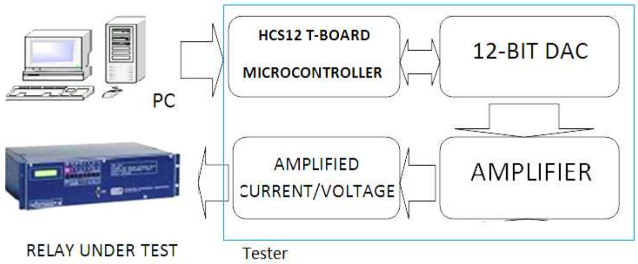

Fig.4 Block diagram of microcontroller based relay tester.

Sampling rates, analog-to-digital converter resolution, record format, and other parameters have not been standardized [6].

3.2 Digital protective relays

New relay designs based on microprocessors are currently being developed and marketed. Some of these relays have the ability to extract and store relay input signals in digital form and transmit this data to another device. For performing this function, the relay is like digital fault recorder, except that the nature of the recorded data may be affected by the needs of the relaying algorithm. As the digital fault recorders, record format and other parameters have been standardized [7].

3.3 Transient simulator

Unlike the above mentioned devices that record actual power system dynamics, transient simulation programs produce transient data by analyzing mathematical models of the power system. Since this analysis is carried out by a digital computer, the results are inherently in digital form suitable for digital data distribution. While they have originally developed for the evaluation of transient overvoltage in power systems [8]. these programs are finding increased usage in other types of studies, including test cases for digital relaying algorithms. Because of the ease with which the input conditions of the study can be changed, transient simulation programs can provide all the different test cases for a relay.

4 Tester Design and Implementation

Figure 4 shows the general block diagram of microcontroller based relay testing system that has been implemented. Digital data that may represent the signals of all conditions of power system may be produced by simulators (EMTP or SIMULINK / MATLAB.) using PC. Then, the generated signal with different waveforms (see Fig.3) that may be injected to the relay under test has been converted and amplified. Microcontroller (HCS12) [9, 10] receives the data from the PC through RS232 port. Then, the executed program transfers the data generated by PC to the device “digital to analog converter” (DAC). Where, the DAC converts the data from digital form to analog form.

The flow chart of software program that has been implemented in the microcontroller is shown in Fig.4. This software program has been used to process the data flow starting from the HEX data obtained from MATLAB and converted it to the analog signal, and finally used for the relay tester. The developed program includes also some adjustments required by the DAC.

The data used in our system are generated by MATLAB by following the steps as mentioned below:

Declaring (dt):

The time measured between two successive samples,

dt = (period / # points per cycle)

Where period=0.02 sec & #of points =200 samples.

Specifying the simulation Time:

We are using the range of one second starting from zero up to (1-dt), with step change of (dt).

Describing of the scenario of our testing signal:

Many parameters can be varied in the scenario: Amplitude, Frequency, Phase shift.

In this case, divide our scenario into nine different portions, each one differs from the others by its phase shift. Then, by adding a DC offset (depending on minimum Amplitude) to get a positive discrete data in order to be understood by the DAC.

Normalizing and Rounding off:

Since the system deals with 12-bit DAC [11], and in order to occupy the full range, the data have to be normalized by multiplying with 4096, and then rounded off to get the decimal values ignoring the fractional part.

In order to take the sign bit into account, we have to apply the following formula to our data: data=int16(test21_11(1:200)).

The last step, is to convert data from decimal form to HEX file to be ready for transferring it to the DAC, as follows:

dac_data=dec2hex(data)

5 Performance Evaluation of the Developed Tester

The developed simulator using Simulink is shown in Fig.6. The power system includes two three phase power generator 300 Km far from each other, linking both generators by three phase transmission line characterized by: Impedance and Length. Each side is provided by protective equipment (circuit breaker). Three phase series compensation modules are Fault (short circuit) of ground resistance equal to 0.01 ohm is applied within the transmission line during time from 0.1sec to 0.33 sec.

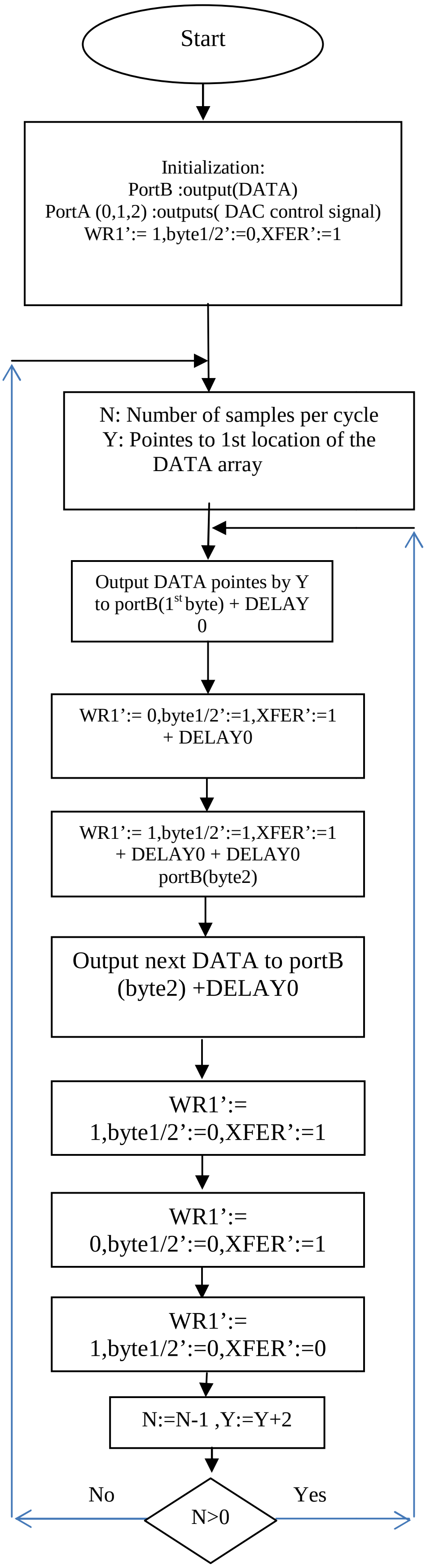

Fig.5 Flow chart of software program implemented in microcontroller.

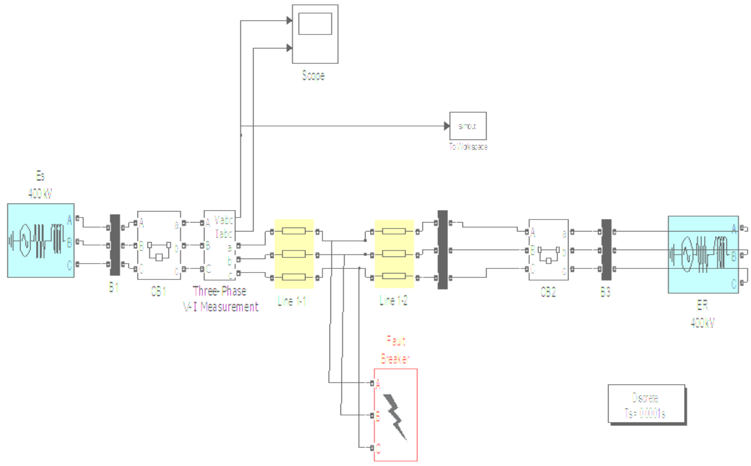

Fig.6 Source of generated data.

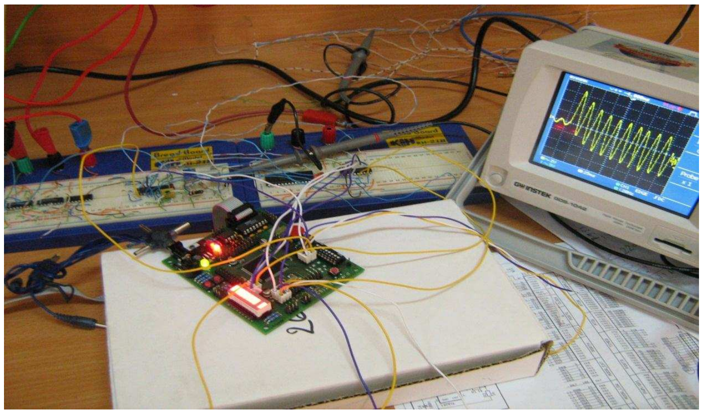

Fig.7 Relay tester hardware with output signal
Displayed on the scope.

Figure 3 shows the distortion of the signals (three phase currents) before and after the fault:

The fault simulator is to take any part from the obtained fault signal then sampled, in order to be injected it to the relay tester for examining the relay performance.

In our design implementation DAC has been used. Its output signal for one waveform (the blue curve (a) of Fig.3) was viewed on the scope as shown in Fig.7. To achieve that, we have converted this signal into HEXA file data as explained in the previous section.

6 Conclusion

The microcontroller based relay testing system has been successfully implemented. In this work, the software simulator is used to generate three phase voltages and currents presented the actual power grid events including mainly the fault to test the relay performance. In fact, our implementation is used to generate one of these signals using the microcontroller HCS12 kit. Besides, Graphical User Interface (GUI) has been developed for controlling some parameters that included in the relay, and also to send the data of waveform signals.

References:

[1] J. Seymour and T. Horsley, ’’The seven types of power problems’’, APC, USA, 2005.

[2] K.C.A. Dierks, *Relay Specific Computer Aided Testing for Protective Relays* , Eskom, South Africa, 2003.

[3] M. Kezunovic, “Transient Testing of Protective Relays: Study of Benefits and Methodology”, PSERC Publication, March 2008.

[4] T.L. Floyd, *Digital Fundamentals*, 9th edition, USA, 2006.

[5] Power Systems Relay Committee of the IEEE Power Engineering Society, ”IEEE Standard Common Format for Transient Data Exchange for Power Systems”, IEEEStd C37.111-1999, USA, 18 March 1999.

[6] IEEE Power System Relaying Committee, *Application of Fault and Disturbance Recording Devices for Protective System Analysis*, IEEE special publication 87TH0195-8-PWR, 1987

[7] A.G Phadke,. and J. S. Thorp, *Computer Relaying for Power Systems*, Research Studies Press/John Wiley & Sons, 1988.

[8] A.G. Phadke, “Protection System Representation in the Electromagnetic transients program”, IEEE transaction on power delivery, vol.9,No.2, April 1994.

[9] T. Almy, *Designing with Microcontrollers-The 68HCS12*, 2008.

[10] “HCS12 T-Board Hardware User Manual”, Version 1.00, December 16th , 2005.

[11] National Semiconductor corporation, “MICRO-DAC Double Buffered D to A converters”, DATA Sheet, February,1995.

.

.