A New Frame Work for Protective Relay Tester

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Summary
Appropriate relay testing provides a first defense against relay mal-operations and hence improves power grid reliabilityby preventingblack out.
In this work, a new PC based tester framework using acquisition card for generating wave form signal from power grid Simulink model under different conditions has developed. But, one problem may be encountered such this signal may be distorted during its amplification. This paper proposes an amplifier class D for overcoming this problem. The generated signals displayed on the scope are satisfactory.

Key words:
WSWAN, Protectionrelay,Reliability, tester, DC offset, Amplifier class D.

1. Introduction

The reliability of the power systemdepends upon the performance of the thousands of relaysthat may be used in protective and control system.The failure of a relay to operate as intended mayaffect on the stability of the whole power grid andits bulk elements. In fact, major system failures during adisturbance are more likely to be caused by unnecessary tripping of relays rather than by the failure of arelay itself to take an action. In other words, theperformance of protection relay is measured by severalcriteria including reliability, selectivity, speed ofoperation, etc. Reliability has two aspects: dependabilityand security. Dependability is known as the degree ofcertainty that a relaying system will operate correctly as intended. Security is the degree ofcertainty that a relay will operate unnecessary during any transient disturbance [1].

Appropriate relay testing provides first line ofdefense against relay mal-operations. Relay testing canhelp to validate the design of relay logic, compare theperformance of different relays, verify relay settings,identify system conditions that might cause unintendedrelay operation, and carry out post-event analysis tounderstand the causes of unintended or unnecessary relayactions. Relay testing system improvements need tocontinue because of the use of relays in smart powergrids where the conditions that are not the same as in theconventional one. This leads to new relay technologies [2].

Disturbances include transient distortion in the voltage due to post fault,potential transformer saturation or FACTs switching may affecton transmission line relays and relaying systems in various ways. The mal-operation of this relay is generally unnecessary tripping during post fault or FACTs connection which produces DC offset and harmonics. This may reduce the security of protection system and hence its reliability.

This work focuses mainly on the design and the implementation of the PC based Testing system associated with Class D amplifier. The Class D amplifier has been used in this work to amplify the simulated disturbance signals that are generated using software Matlab and outputs via AD 622 Board and then injected to the protective relay.

2. Testability

Protection System Reliability and Testability require in part that the protection system be designed for high functional reliability and in-service testability commensurate with the safety function to be performed. They also require a design that permits on-line periodic testing of the functioning of the protective system.

The testing of protection schemes faces a number of problems. This is because the main function of protection equipment is solely concerned with operation under system fault conditions, and cannot readily be tested under normal system operating conditions. This situation is aggravated by increasing the complexity of protection schemes and use of relays containing software.

Type tests are required to prove that a relay meets the published specification and complies with all relevant standards. Since the principle function of the protection relay is to operate correctly under abnormal power conditions, it is essential that the performance be assessed under such conditions. Comprehensive type tests simulating the operational conditions are therefore conducted at the manufacturer's works during the development and certification of the equipment.

Types of testing that can be performed by the developed relay tester are as follows [3]:

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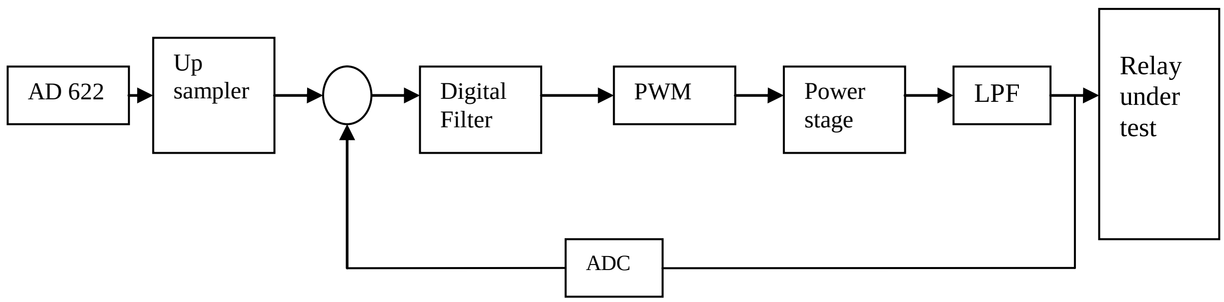

Fig. 2 Overall schematic of the amplifier.

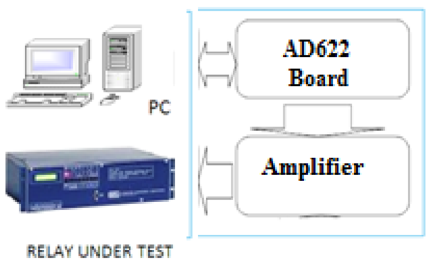

Fig.1 Block diagram of PC based relay tester.

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 automatic system. This type is of less use in commissioning, due to the injected signal does not represent the real power system signal during faults or abnormal condition.

2.2 Dynamic state test:

Dynamicstate test is investigated by simultaneously applying fundamental frequency components of voltage & 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.

2.3 Transient Test:

Transient testing may be investigated by applying simultaneouslyfundamental and non-fundamental frequency components of voltage and current those representreal power system conditions.This type of test may be used for testing a security of the protective relay. The signal that may be used in this type for testing may be obtained from digital fault recorders (DFR) real-time Simulatorusing Simulink/Matlab or electromagnetic transient programs (EMTP).

The increasing use of digital technology in devices such as protection, 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, real-time system simulators may be used to generate digital data. The users of these data are faced the problem of how to convert it to real-time signal by amplifying it without distortion as the signals outputted from instrument transformers.

3. Tester Implementation

PC based relay tester has been implemented using the acquisition card as shown in Fig.1. It consists of three main parts which are computer, AD622 board and amplifier.

Application development for relays tester has been investigated using SIMULINK development tool and HUMOSOFT driver and AD622 board. PC outputs the signals generated by Transient simulator through the acquisition card AD622, where the DAC converts the data from digital form into analog form, and then to the relay under test using the amplifier[4, 5].

Figure 2 shows an overall block diagram of the (class D) amplifier with feedback. In the feedback the output signal of the amplifier is sampled by an analogue-to-digital converter and subtracted from an up sampled version of the 24-bit digital input signal in the considered Bandwidth (0-5Khz). The resulting signal serves as input to a digital loop filter which drives a digital pulse width modulator.The power stage, which can be a half-bridge converter, is followed by a low pass filter to recover the original analog signal[6].

3.1 Amplifier development

The final circuit design of this class D amplifier is shown in Figure 3. The first stage of this class D amplifier is the control circuit where the PWM signal generator is fed to

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the two gate drives that have as main role to create dead-time for avoiding shoot-through current that can damage the output stage.Then, the power stage which consists of H-Bridge and low pass filteris the final stage.

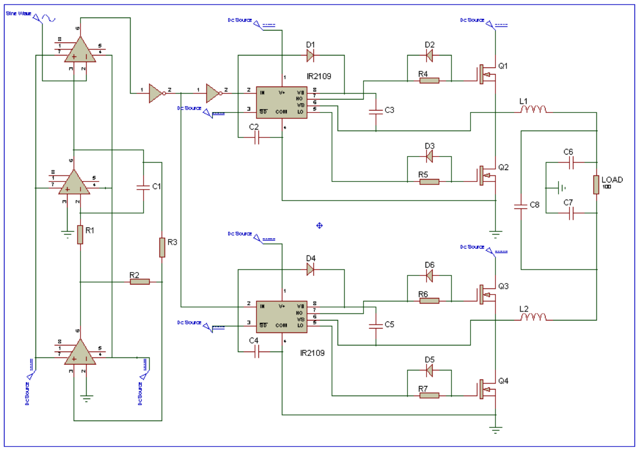

Fig.3 Design of Class D Amplifier using Proteus

The implementation circuit of the Class D amplifier is shown in figure 4.

This circuit was implemented on two printed circuit board (PCB) to separate the control side from the power side.

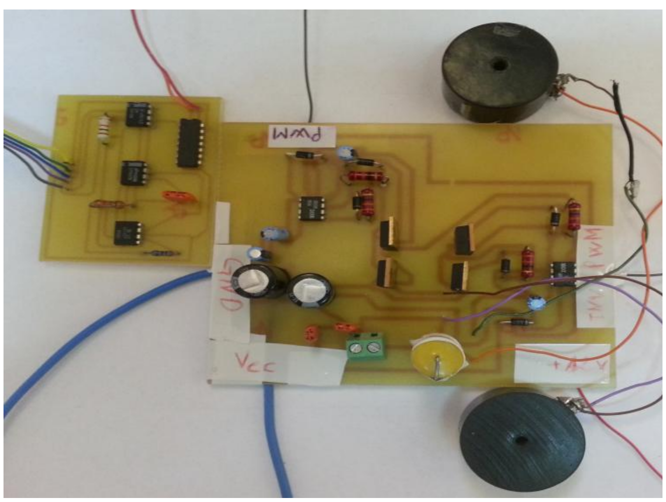

Fig. 4. PCB of Class D amplifier

The output signal of the PWM generator is shown in Fig.5.

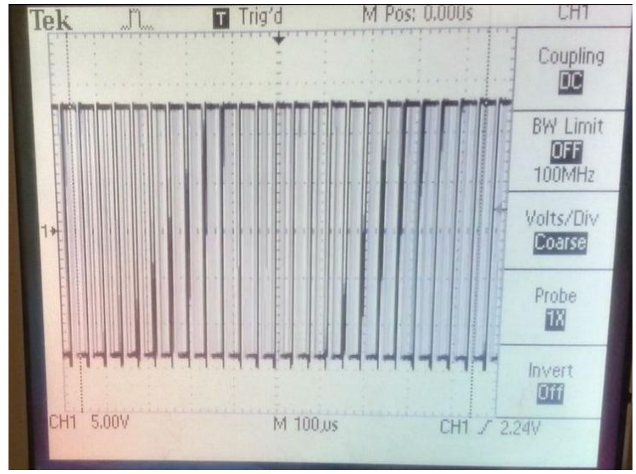

Fig.5 PWM generator signal

Figure 6 shows the shifted PWM signal with zero volt reference, the level shift is needed to inject the signal into the gate driver.

The output PWM signal of the H-bridge before the using the low passive filter is shown in Fig.7 where the H-bridge is fed with 12V.

The output signal of the H-Bridge fed with 18.73V and a load of 100Ω is shown in figures8 and 9, the input signal is a sine wave of 10V peek to peek and frequency of 50Hz.

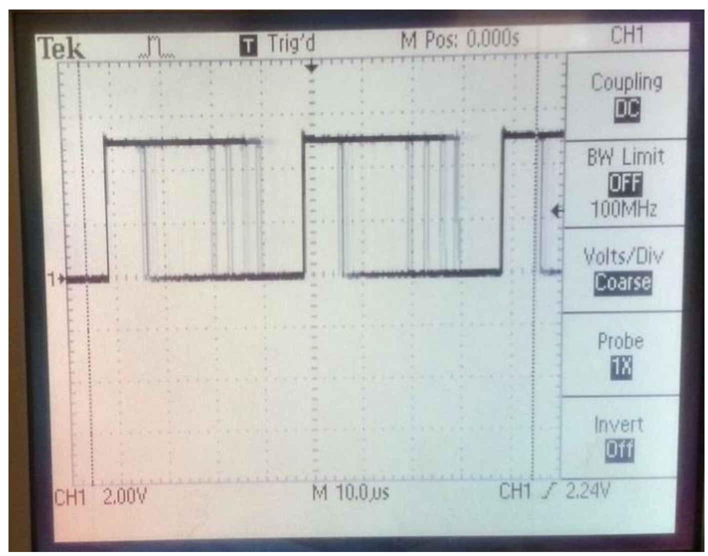

Fig.6 Level shift of the PWM signal

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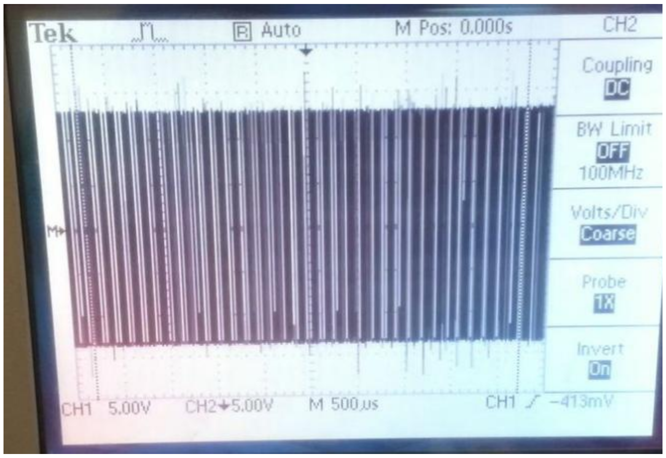

Figure.7 H-bridge output PWM signal

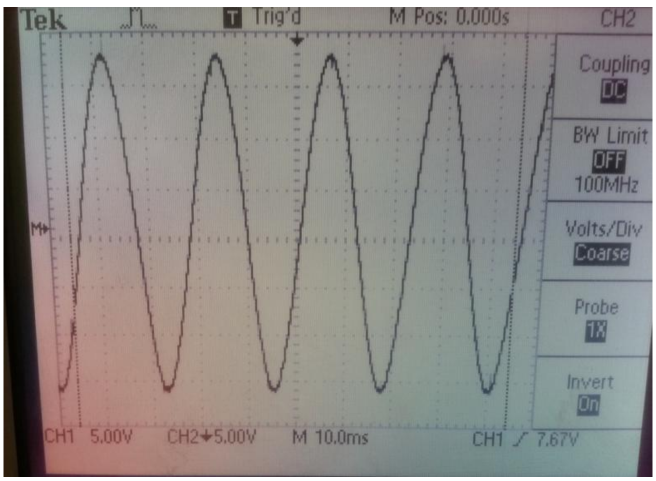

Fig.8 Output signal of class D amplifier

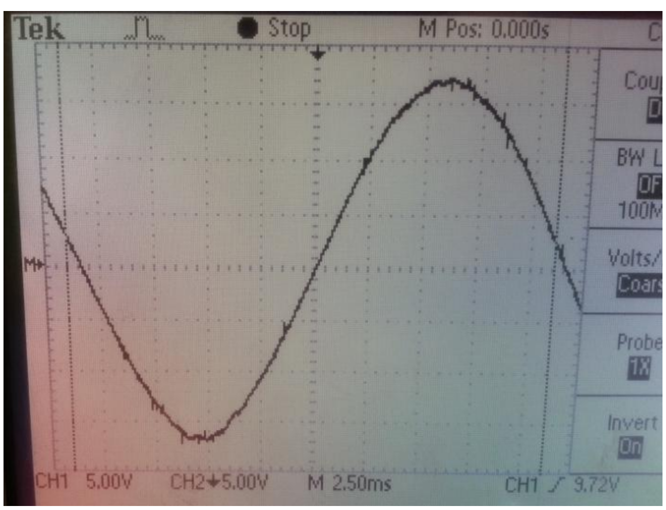

Fig.9Amplified sine wave using Class D amplifier

3.2 Performance Evaluation of the Tester

The testing signal is voltage sag signal that was obtained from Matlab (Simulink) software and converted to analogue signal using the AD 622 card and DAC. The output signal of the DAC is 10V peak to peak and frequency of 50 Hz. Figure 10 shows the output signal of the DAC:

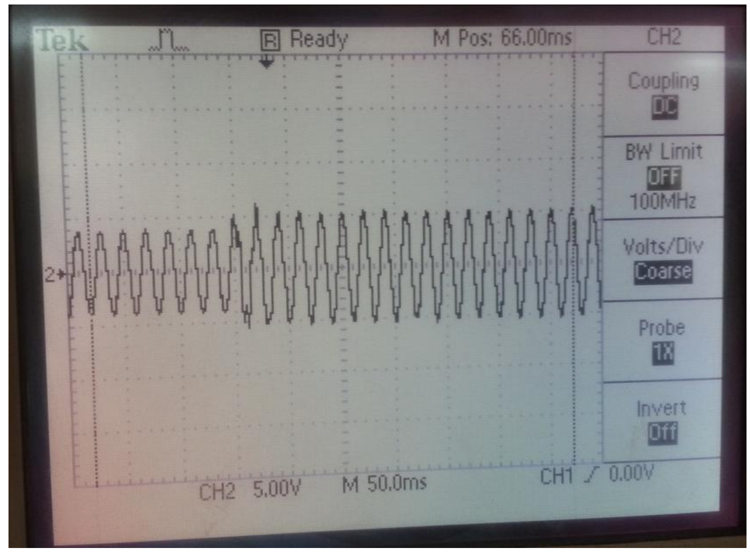

Fig.10 Voltage sag generated from Disturbances generator

This signal has been taken and injected to the Class D amplifier but the voltage of the H-bridge has been changed to 38.8V and the probes were changed to X10 to decrease the scale of the oscilloscope so that each division is 20V. Figures 11 and 12 show the amplifier voltage sag signal using the Class D amplifier.

The amplified output signal is 80V peak to peak and a frequency of 50 Hz the efficiency is approximately 100%. From figure 12 some distortions are appearing in the output amplified signal, these distortions are not due to the class D amplifier, they are part of the disturbance input signal.

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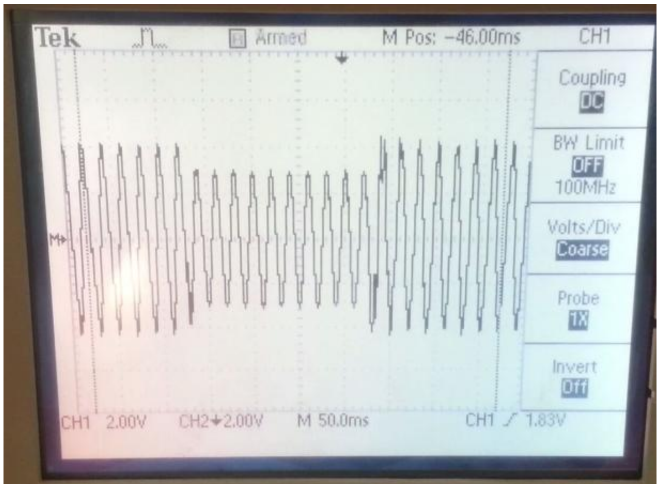

Fig.11 Amplified Voltage sag signal

Fig.12 In sight of the amplified voltage sag signal

The theoretical efficiency of a Class D amplifier is 100% but this is unachievable in practice. However, this efficiency can approach significantly this value by making a good design to minimize switching losses that lead to high power loss.

The formula to calculate the efficiency is:

$$\eta = \frac{P_{OUT}}{P_{in}} * 100$$

The efficiency and the gain are calculated with respect to a sine wave input of 10V and the voltage of the source that feed the H-bridge is of 18.73V whose efficiency is $\eta =$ 90.76%

The gain of this amplifier is simply calculated using this formula:

$$\text{Gain } = \frac{V_{Out(RMS)}}{V_{in(RMS)}}$$

In this case the gain is 3.4.

Whereas, if the H-bridge is fed with 40V the gain is

Gain= 8.

The total harmonic distortion (THD) is very important parameter to evaluate the performance of the Class D amplifier to have a clean signal, we don't have the proper means to do the calculation to have the exact value but it appears that the THD is less than 1%.

4. Conclusions

The PC based relay testing system has beensuccessfully implemented.Simulator is used to generate three phase voltages andcurrents presented the actual power grid eventsmainly the fault and other abnormal conditions to test the relay performance. In fact, implementation is used to generate one of these signals and output them to external environment using the acquisition card AD 622. User Interface (GUI) has been developed to include some parameters of the relay, to control the generated data of waveform signals and to display the generated signals.The Class D amplifier has been chosen in this work to amplify the simulated disturbances signals. Design and implementation of the Class D amplifier which is the amplification part of the testing system have been investigated successfully.

The test results of the performance of this tester using Class D amplifier are very satisfying. This is clearly proven by its high efficiency, very low THD and the gain that depends on the input voltage of the H-bridge. This Class D amplifier can amplify any disturbance signal with the same performance results even if the frequency of these disturbances is changing. This ability is possible because the cut-off frequency of its filter can attain 1.1 kHz.

In this work, we have used new technologiesthat allow designing an enhanced relay testing systemwhich in turn can be used for improving the performanceof protective relay.In order to test both security and dependability and hence the reliability, this work proposesa new frame work of tester based on PC associated with acquisition card.

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