

Effect of Switching Method in Polarization and Depolarization Current (PDC) Measurement Technique

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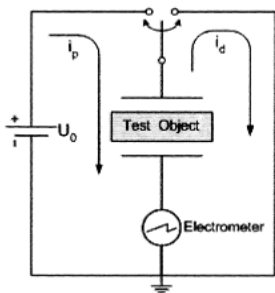
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Graphical abstract



Abstract

Switching method in Polarization and Depolarization Current (PDC) measurement technique is an appealing area to look at, especially in terms of its behavior over time based monitoring. Previous researches on this technique did not deliberate the effect of switching method in its measurement analysis. Most of the researchers use a conventional HV relay that acts as a switching component. This paper studies the behavior of PDC measurement results and its relationship between the types of switching methods used. It is due to the research hypothesis where different switching method produces distinctive PDC measurement results. Determination of which optimal method that suit with this technique can be made by comparing PDC measurement results; the result which analogous to the reference is considered as the finest method. Two different switching methods were applied in this research, which are HV relays and series-connected of 600V, 30A, Insulated Gate Bipolar Transistor (IGBT).

Keywords: PDC; high-voltage (HV) switching; HV relay; series-connected IGBTs

Abstrak

Kaedah pensuisan dalam Polarisasi dan Depolarization Current (PDC) teknik pengukuran adalah satu kawasan yang menarik untuk dilihat, terutama dari segi tingkah lakunya ke atas pemantauan berasaskan masa. Kajian terdahulu pada teknik ini tidak membincangkan kesan kaedah pensuisan dalam analisis pengukurannya. Kebanyakan penyelidik menggunakan konvensional geganti Voltan Tinggi (VT) yang bertindak sebagai satu komponen pensuisan. Kertas kajian ini mengkaji tingkah laku keputusan pengukuran PDC dan hubungan antara jenis kaedah pensuisan yang digunakan. Ia adalah disebabkan oleh hipotesis penyelidikan di mana kaedah pensuisan yang berbeza menghasilkan keputusan pengukuran PDC yang berbeza. Penentuan kaedah optimum yang sesuai dengan teknik ini boleh dibuat dengan membandingkan keputusan ukuran PDC; di mana hasil yang lebih serupa dengan rujukan dianggap sebagai kaedah terbaik. Dua kaedah pensuisan yang berbeza digunakan dalam kajian ini, dan ia merupakan geganti VT dan 600V/30A, Insulated Gate Bipolar Transistor (IGBT) yang disambungkan secara siri.

Kata kunci: PDC; voltan tinggi (VT) suis; geganti VT; IGBTs bersambung siri

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1.0 INTRODUCTION

PDC measurement is time domain measurement in appraising the condition of the high-voltage electrical apparatus. PDC measurement technique has gained its popularity around the globe due to the significant importance which can evaluate the condition of the electric equipment such as transformer, cable and rotating machine as they are the substantial units in the power system [1, 2]. The basic circuit for this measurement technique presented by the previous researchers is shown in Figure 1.

The circuit diagram (Figure 1) denotes the path for PDC and represented as i_p and i_d ; the current path also indicates the concept of PDC measurement where it is actually a process of charging and discharging the capacitor for a long time period (e.g. 10, 000

seconds). The leakage current from the test object is measured and analyzed for both processes to ascertain the condition of the test object.

Previous studies emphasize the PDC measurement results regardless of the switching method. In this paper, the method of switching is a key topic to be discussed at the same time, finding an attempt to introduce a new IGBT switching component in the measurement of the PDC.

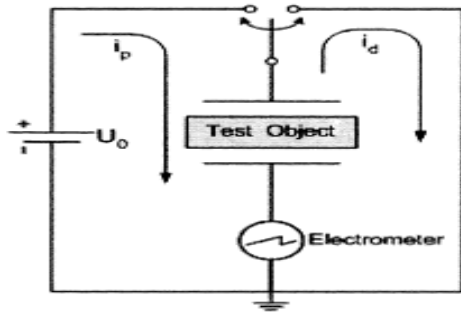


Figure 1 Circuit diagram for PDC measurement technique

2.0 MATERIALS AND METHODS

There are two switching methods proposed in this paper and specially designed to befit the PDC measurement purpose. These two switching methods are HV relay and series-connected IGBTs.

2.1 Switching Method: High Voltage (HV) Relay

This method is well-known and common in the field of PDC measurement [1-3]. The fundamental concept of PDC measurement is preserved when implementing this method except for the 2kΩ resistor. The reason of putting the resistor before the electrometer is to protect the measuring device from damage due to instantaneous high current through the electrometer during a possible low impedance faulty connection [3]. The measurement circuit used in this research is as shown in Figure 2.

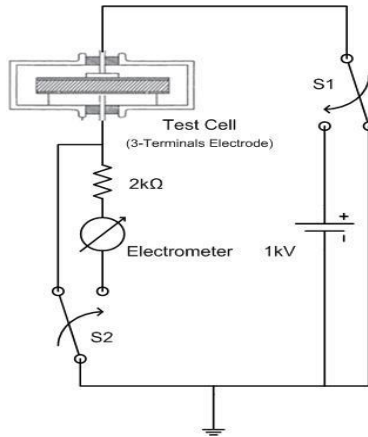


Figure 2 Circuit diagram by using HV relay

2.2 Switching Method: Series-connected IGBTs

Series-connected IGBT is not a new method in an electric field. Most of its applications are implemented in power conversion system, high-power modulator, processing technology, high-voltage dc transmission system (HVDC) and flexible ac transmission system (FACTS) as mention in [4-6].

In this research, this method will be introduced for the first time in the field of PDC measurement due to its function that can act like a switch. The aim is to find an alternative way to replace the old HV relay component by monitoring its switching characteristic. The proposed circuit diagram for this method is as shown in Figure 3.

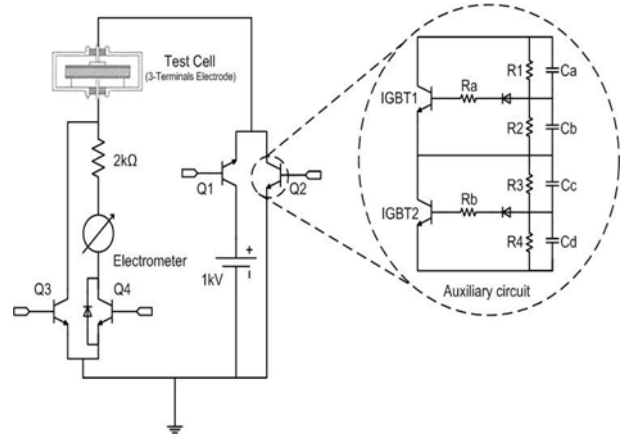


Figure 3 Circuit diagram for series-connected IGBTs

The main problem associated with series-connected devices is how to guarantee the voltage balance between the devices both at static and dynamic transient states and the same problem also being reported in [4-10]. If no action taken to overcome this problem, it will damage the device as its consequences. One of the ways to terminate this problem is by using auxiliary circuit as proposed by J. W. Baek, et al. and G. Busatto, et al. in [4, 9]. The purpose of putting the diode in parallel with Q4 is to make the switching action like a two-way switch.

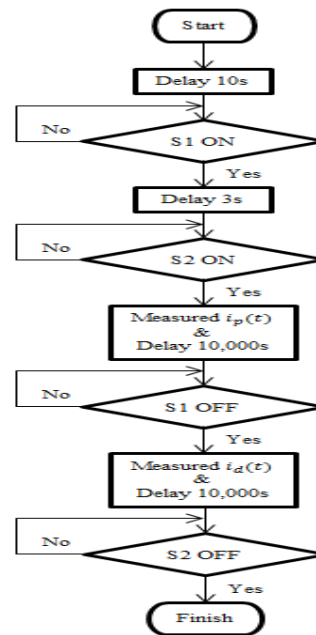


Figure 4 Flow chart of PDC measurement technique process

Figure 4 shows the flow chart of the PDC measurement process for HV relay switching method. Similar process is used in another switching method by replacing the HV relay with series-connected IGBT. Before begin the process, delay 100s is needed to verify all the dielectric memory of the test object is being cleared first.

The purpose of 3s delay after S1 activated is to bypass the electrometer; delay 10,000s for polarization and depolarization

process is needed to get the tail part of PDC measurement's results in order to determine the moisture content of the test object.

3.0 RESULTS AND DISCUSSION

The proposed switching methods were tested by simulation using NI Multisim 10 software. By setting the input voltage equal to 1 kV_{dc} for each test, the result confirmed that both methods can function according to the flow chart (Figure 4) and the captured data for switching activity are shown in Figure 5 and Figure 6.

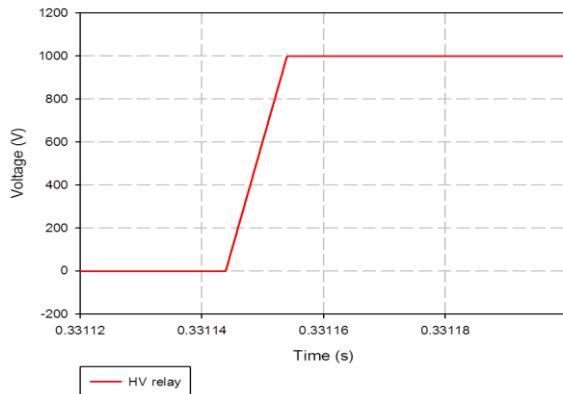


Figure 5 Ideal relay during transition from NC to NO

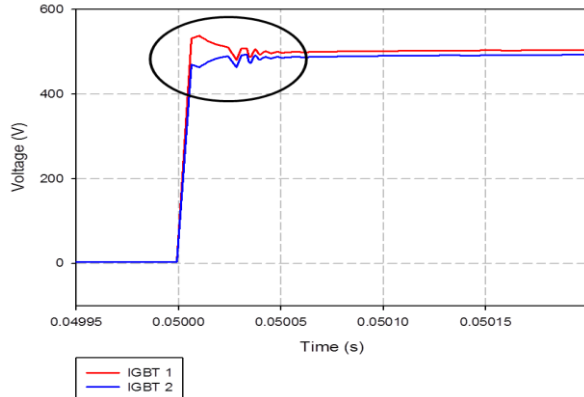


Figure 6 Balanced voltage during turn-off transient

In Figure 5, no overvoltage spike has been recorded for HV relay test during transition from NC (normally closed) to NO (normally open). The characteristic of the relay which has been tested in simulation is an ideal relay. Hence, it produces a perfect switching result. However, in practical, there is no “ideal” characteristic for every electric / electronic component.

The voltage balancing in dynamic and static transient are well achieved as shown in Figure 6. Each device shares the same voltage value which is 500V_{dc} and still operates under Safety Operation Area (SOA) [11]. The result shows an auxiliary circuit plays an important role to overcome the major problem in series-connected devices. Hence, this is another proof that this method can be implemented in PDC measurement technique without facing any problem.

Nevertheless, the overvoltage spike as recorded in Figure 6 (in circle) is the main subject that needs to be discussed and monitored. Due to the hypothesis of the research, the different of PDC measurement results with respect to different switching method probably caused by this phenomenon.

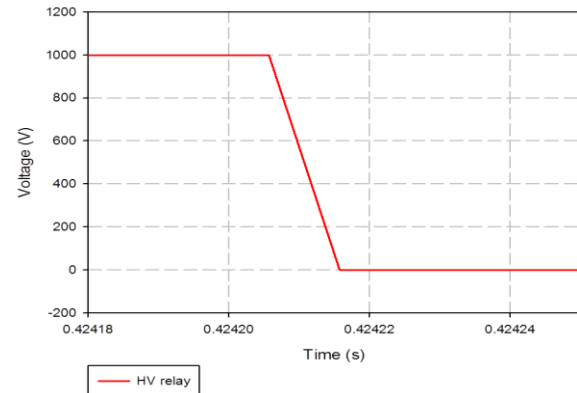


Figure 7 Ideal relay during transition from NO to NC

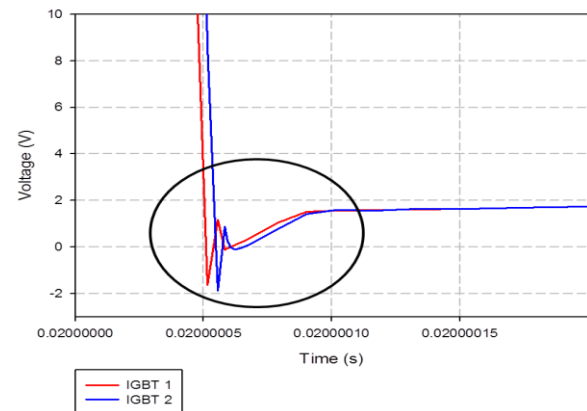


Figure 8 Balanced voltage during turn-on transient

Figure 7 shows the transition of HV relay from NO to NC. The results indicate no overvoltage spike occurred (due to ideal characteristic). Again, for series-connected IGBTs (Figure 8), during turn-on transient the presence of overvoltage spike has been recorded (in circle).

4.0 CONCLUSION

Basically, the simulation results show that HV relay is the suitable switching component and can perform well in order to get an accurate result for PDC measurement if compared to series-connected IGBTs. However, no ideal characteristic for electric / electronic components exist in the practical world. So, an over voltage spike could happen in HV relay.

The major problem that associated with series-connected devices is successfully terminated by using auxiliary circuit, and has been demonstrated by simulation results. Another problem that has been traced in this method is an overvoltage spike event. Simulation results show it occurred for both transient states.

The correlation of an overvoltage spike phenomenon and its effect towards PDC measurement results is still under research. So, it needs to be practically tested to confirm the hypothesis of the study either it is true or not and observe the effect of switching method in producing PDC measurement results. After analyzed every obtained data, a further conclusion can be made regarding to this matter.

Acknowledgement

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