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Design and development of a portable partial discharge generator

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Abstract. Intensive study of Partial Discharge (PD) phenomenon is of great importance for detecting and distinguishing different types of partial discharge. A portable device for partial discharge generation is designed and developed in this paper, which possesses advantage of miniaturization, dependability and flexibility. Such device is composed of power supply module, PD generating module and PD output interface. An implementing example of the partial discharge generator is given here in detail. Simulated high voltage signal is generated by a waveform generator and applied on physical PD generating model after being amplified by power amplifier and being boosted by a high voltage transformer with high transformation ratio. The generated PD pulse sequence are acquired and further analysed by MATLAB. Point to plane discharge is used as an example and verifies the performances of this device.

1. Introduction

Partial Discharge (PD) is a main cause of insulation fault in electrical equipment. Intensive study of PD phenomenon is of great significance for PD detection in order to ensure safety, reliability and stability of electrical equipment [1]. Due to the randomness and uncontrollability of PD in practical operation of electrical equipment [2], PD generator becomes a vital tool for PD research, especially for experimental study [3].

At present, the simulation of PD aiming at obtaining discharge pattern in lab mainly take advantage of high voltage experimental system combined with various real PD test model [4]. However, such method has many limitations: the hugeness results in immovability which restrict simulation in specific environment such as high-voltage testing hall, the long period for constructing experimental equipment and single form of experimental power source such as power frequency voltage or DC voltage.

A portable device for partial discharge generating is proposed to avoid these shortages mentioned above, which possesses advantages of miniaturization, dependability and flexibility. Miniaturization means that the experimental device is portable and movable, the test is not limited in specific environment any more. Dependability possesses great importance in experiments, proposed method can veritably simulate partial discharge. What's more, flexibility not only refers to various kinds of partial discharge, but also the diversity of power source and physical models.

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In this paper, the fundamental of this portal PD generator is described in detail in second part, constructing method and details are illustrated as well. Result obtained from generator, is also analyzed. Finally, a brief conclusion is drawn in the last part.

2. Design of a partial discharge generator

The device comprises of three parts: power supply module, PD generating module and PD output interface. The structure of it is shown in Fig.1.

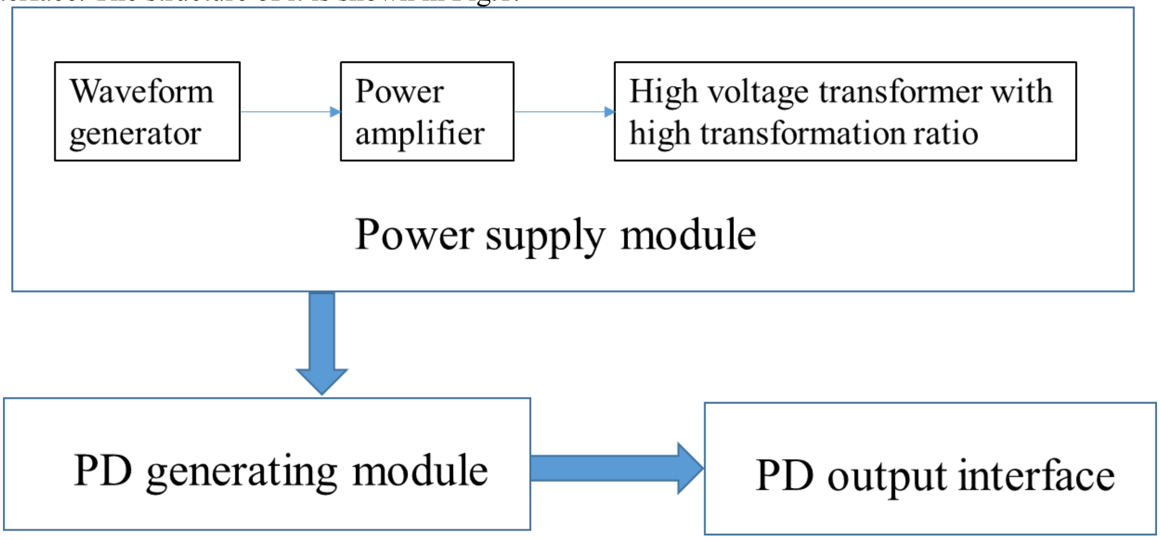

Figure 1. Functional structure of a portable partial discharge generator

2.1 Power supply module

Power supply module plays a role as generating various forms of high voltage signal on partial discharge physical models, which can be divided into three components.

The first component is waveform generator, which generates programmable and amplitude adjustable voltage waveform, such as power frequency signals, shockwave signal, and other programmable signals. The signal is then sent to power amplifier to ensure that the generated partial discharge current by PD generating as supposed. After being amplified, such signal is handled by the last component named high voltage transformer. The amplitude of voltage is raised to high enough to reach boundary of partial discharge generation.

2.2 PD generating module

PD generating module includes three major typical kinds of physical models for surface discharge, air-gap discharge and point to plane discharge, respectively. Specific types can be determined according to different discharge types in different electrical equipment. Physical model is a reduced version of the practical model to decrease required PD voltage on physical models, so that the experiments can be carried under relatively low voltage. This module includes protective resistance in series, which can limit maximum current generated during PD to protect power module and guarantee safety of users.

2.3 PD output interface

PD output interface including serial interface for common detection resistance, current detection port for high frequency pulse and detection for electromagnetic wave signal and ultrasonic signal, mainly deals with detection problem.

3. Implementation of the partial discharge generator

An example of the implementation of the partial discharge generator is given in this section.

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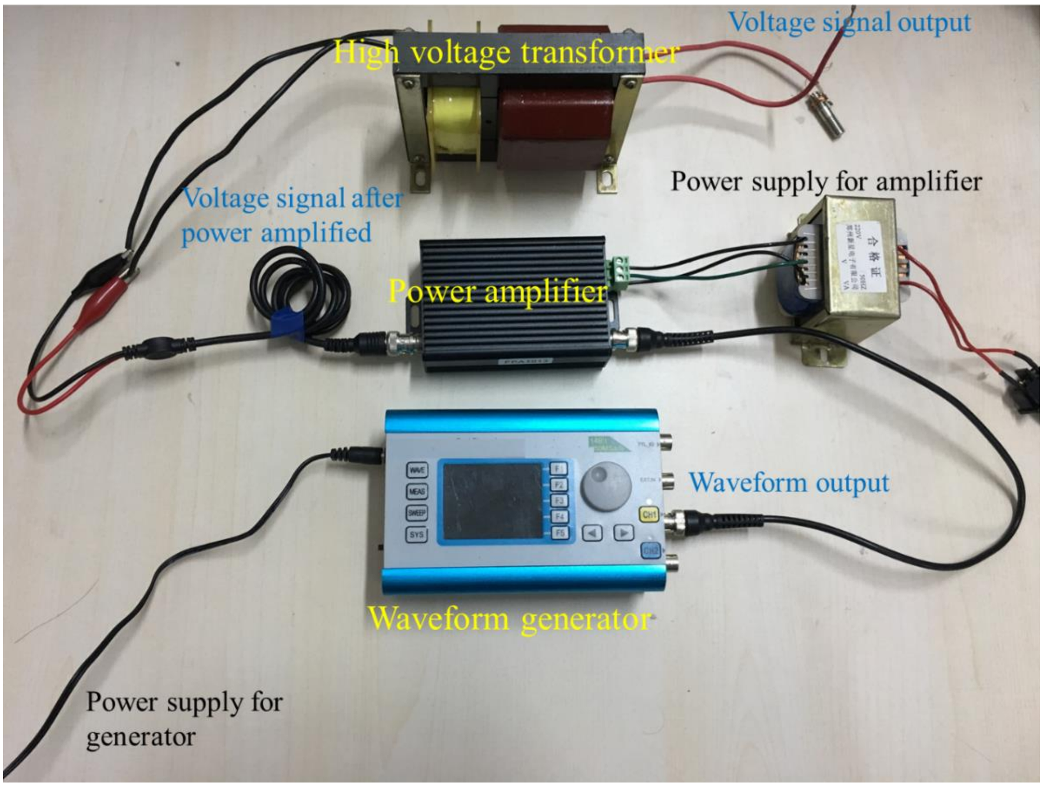

Figure 2. An example of power supply module

Fig.2 shows power supply module of the device, where FPA performs as power amplifier and self-defined 1:1000 ratio transformer works as high voltage transformer. Circuit in this example can generate square wave, triangle wave and sinusoidal wave with adjustable frequency. In this way, the frequency, amplitude and waveform can be decided according to requirement. FPA owns output overcurrent protection and internal temperature abnormal protection, which provides maximum 2A output current, 50V voltage and 30W power. High voltage transformer with high transformation ratio is used to boost voltage from 10V to 10kV to meet requirement of generating partial discharge on test model. The performance parameters of it are listed as follows. Transformation ratio is 1:1000 as described before, working frequency ranges in low band, which is 50Hz here. The size is 125mm*96mm*75mm, which take advantage of epoxy potting syrups technology to guarantee dampproof property.

After constructing reasonable power supply module, the generating type of partial discharge is closely related with spatial electric field distribution and electrode shape. Therefore, reasonable partial discharge generating model is of great importance for generating desired partial discharge phenomenon.

In this example, we design physical PD generating model for point to plane discharge, surface discharge and air-gap discharge, respectively. The structure of point to plane discharge is shown in Fig.3 filled with air, where left side is iron probe with 7kV voltage of 50Hz, right side is copper rivets with ground connection, insulation shell is made of acrylic.

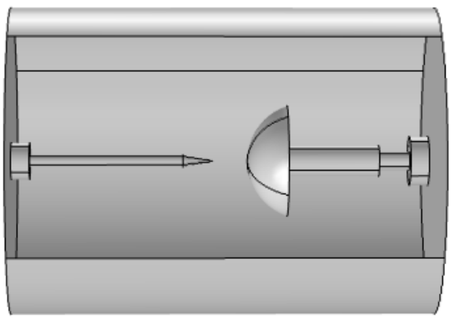

Figure 3. Model for point to plane discharge

Fig.4 shows the model for surface discharge, left side of the geometric model is an iron screw model with a diameter of 3mm, with an acrylic plate with a thickness of 5mm in the middle. Right side is an aluminium plate electrode and the insulating shell around is made of acrylic as well. The AC potential on left side is 7.5kV with frequency of 50Hz, right side is grounded.

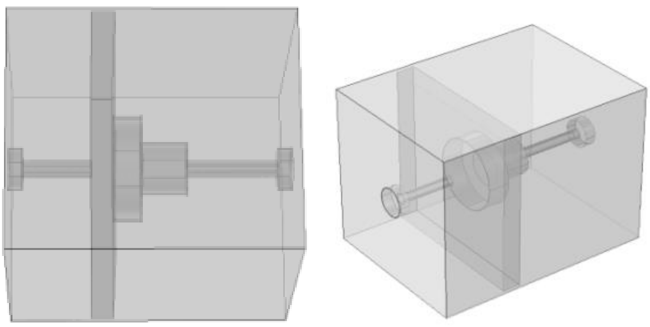

Figure 4. Model for surface discharge

The air-gap model is shown as Fig.5 that left side is a smaller iron plate electrode while right side is a larger plate electrode, middle of them is an organic glass plate with the exist of an air-filled circular hole with a diameter of 2mm. The AC potential on left side is 5kV with frequency of 50Hz, right side is grounded.

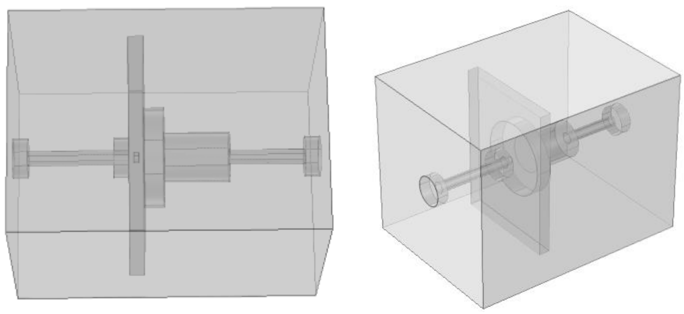

Figure 5. Model for air-gap discharge

All parts described above are integrated into Pelican1500 safety box, whose outer size is 47cm*35.7cm*17.6cm and inner size is 42.5cm*28.4cm*15.5cm. The width of box cover is 4.6cm and depth of box is 10.9cm. There are three bending strips with width of 2cm and thickness of 3mm aluminium that build a frame shaped working as bearing and fixed fulcrum of PD generator equipment platform. At the bottom of aluminium frame, epoxy resin plate, which works as insulating substrate and supporting system for components, is fixed on the punch with aluminium screws.

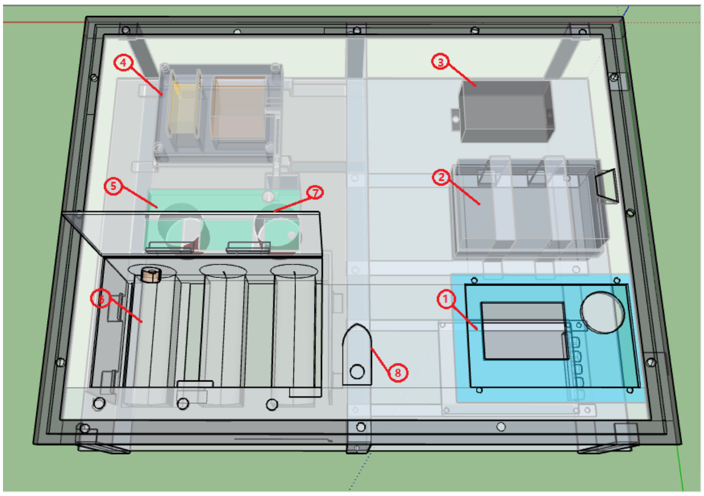

Figure 6. An example of PD generator platform

The integrated platform is shown in Fig.6, where the components are introduced as follow: (1) Waveform generator; (2) Rechargeable battery: power supply for waveform generator and power amplifier; (3) Power amplifier: input port receives waveform signal from waveform generator and output port is connected to high voltage transformer; (4) High voltage transformer: boost voltage signal from power amplifier; (5) High voltage bus: insulation supported by insulators; (6) Exchangeable PD model groove; (7) Glass retainer; (8) Slot for glass retainer

In this way, the PD simulation platform can integrate all required devices in a portable safety box.

4. Performance analysis of the partial discharge generator

Here oscilloscope is used to acquire output of PD simulation (Fig. 7), point to plane discharge is considered here as an example of assessing the performance of this device.

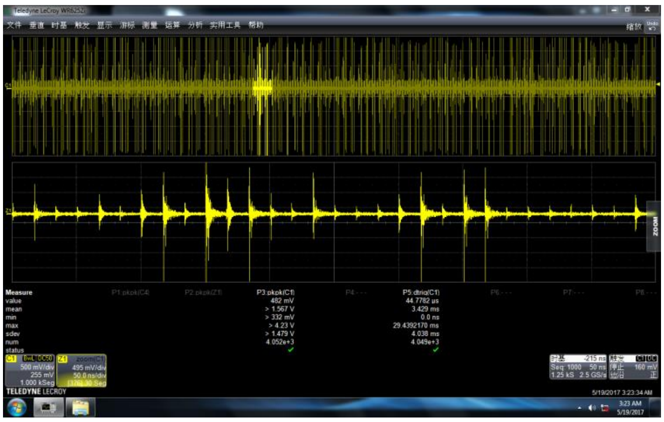

Figure 7. Waveform of point to plane discharge recorded by oscilloscope

The voltage on point to plane discharge model is adjusted to 7kV with frequency of 50Hz, simulation is repeated until obtaining current pulse data of 1000 times. The waveform acquired by MATLAB is shown as Fig.8, we can further get waveform after filtering and generate Phase Resolved Partial Discharge (PRPD) pattern, Phase Resolved Pulse Sequence (PRPS) pattern by using dlmread function of MATLAB.

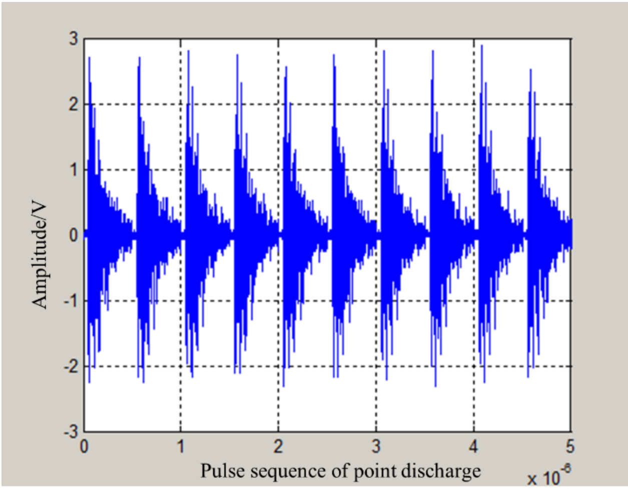

Figure 8. Waveform sequence of point to plane discharge

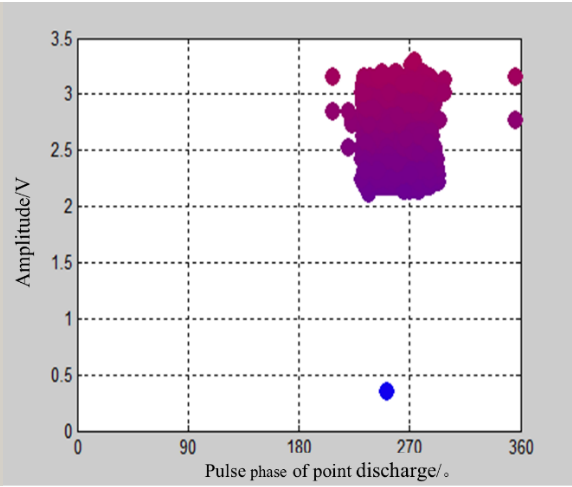

Figure 9. Flame grey pattern

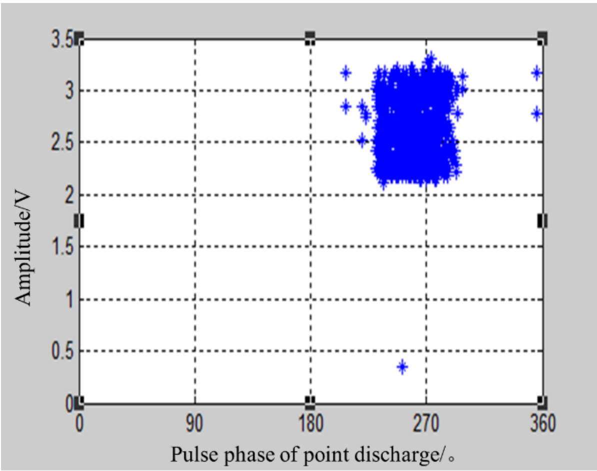

Figure 10. PRPD pattern

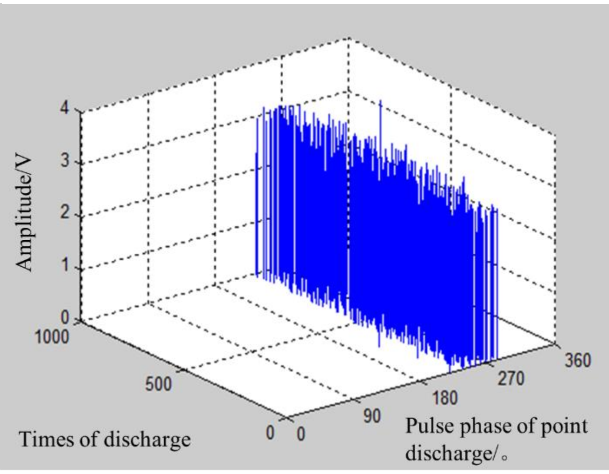

Figure 11. PRPS pattern

By referring to related papers about partial discharge [5][6], large amount of experimental data indicates that point to plane discharge first occurs only around negative half peak of test voltage, and the discharge time points symmetrically distribute on both side of peak point [7]. Only when test voltage is too high can second group discharge with similar distribution appear near the positive peak of test voltage waveform.

Compared with what's described above, it's obvious that the distribution characteristics obey characteristics of point to plane discharge well. In flame grey pattern (Fig.9), PRPD pattern (Fig.10) and PRPS pattern (Fig.11), most occurrences of discharge are distributed symmetrically around phase of 270 degree, and their amplitude is close.

It is reasonable to reach the conclusion that the generator platform of partial discharge can accurately simulate the occurrence of point to plane discharge with little interference and obvious discharge characteristics. These characteristics obtained from generator mean a lot for detecting and distinguishing different types of partial discharge.

5. Conclusion
In this paper, a method to completely integrate modules into a portable partial discharge generator is proposed, which can generate multiple types of partial discharge under different types of power sources.

It's noteworthy that the greatest advantage is the simplification, mobility and reliability of such platform. Its environmental dependence to external equipment is low while the operability is quite strong, which means that the test can be carried out anytime and anywhere by any method. The reliability is also verified through comparing simulation results and known partial discharge characteristics, the point to plane discharge is taken as an example here.

References
[1] Li J, Si W, Yao X, et al. Measurement and simulation of partial discharge in oil impregnated pressboard with an electrical aging process[J]. Measurement Science & Technology, 2009, 20(10):105701.

[2] Noskov M D, Sack M, Malinovski A S, et al. Measurement and simulation of electrical tree growth and partial discharge activity in epoxy resin[J]. Journal of Physics D Applied Physics, 2001,34(9):1389-1398(10).

[3] Champion J V, Dodd S J. Simulation of partial discharges in conducting and non-conducting electrical tree structures[J]. Journal of Physics D Applied Physics, 2001, 34(8):1235-1242.

[4] Pu L, Ni H, Zhao X F, Ju Z L, Study on partial discharge characteristic in XLPE accessory based on pulse sequence analysis[J]. Insulation Materials, 2016,49(12) :45-51.

[5] Li H J, Si W R, Yao X, Guo Z F, Li Y M. Measurement and simulation of partial discharge in disc-void of oil-pressboard insulation with electrical degradation process[J]. Proceedings of the CSEE, 2009,29(31):128-134.

[6] Yu H, Research on GIS defects recognition based on partial discharge pattern[A]. CSEE. 2013 Proceedings of the annual meeting of CSEE[C]. 2013:8

[7] Zhou Y J, Zhang J X, Di S G. Study on Insulation Defects in GIS Partial Discharge[J]. Inner mongolia electric power, 2013,31(5):106-110.