

# Performance evaluation system for partial discharge detector based on Tesla coil structure

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**Abstract.** Partial Discharge (PD) detection aiming at finding the insulation defects make great effort for ensuring the reliability of the electrical equipment. Thus the performances, such as sensitivity and classification and recognition of PD pattern of PD detector need verified. This paper offers an effective tool to evaluate these performances of PD detectors. Design of the system consists of three modules, including PD pattern simulation module, PD pulse sequence generating module, and high voltage simulation module. Example of realization is also given in detail, which takes advantage of Tesla coil structure to generate programmable pulse sequence under the control of embedded system according to PD pattern. After that, the performance analysis of this proposed evaluation system is discussed, the performance evaluation system can simulate PD pulse sequence with controllability of pulse position distribution and randomness of amplitude in a range referring to PRPD pattern from database.

## 1. Introduction

Partial discharge detection is a non-destructive method to effective detect insulation defects of high voltage electrical equipment [1], which take advantage of the characteristics of insulation defects that its exist enhances electric field around and further results in local insulation breakdown with quick charge transfer [2]. Partial discharge detection is based on the evaluation of electrical or non-electrical signals in the discharge process, which is essential part of insulation assessment for high voltage electrical equipment [3].

At present, PD detectors have been developed from analogy type that purely measures apparent charge to digital equipment that can realize partial discharge pattern recognition. The magnitude of apparent charge only indicates the existence and severity, while by analysing Phase Resolved Partial Discharge (PRPD) pattern can we obtain much more detailed information [4]. Therefore, detectors adopt Digital Signal Processing (DSP) method to implement statistical or time-frequency analysis to achieve classification and recognition of PD, also interference elimination and noise suppression [5].

However, most traditional partial discharge calibrator only output magnitude-aware charge pulse with fixed frequency to verify the linearity and influence of polarity, while programmable calibrator can carry out additional test, such as pulse response sequence and pulse resolution time, which mainly focus on calibration and evaluation of apparent charge [6]. This paper aims at providing a reasonable

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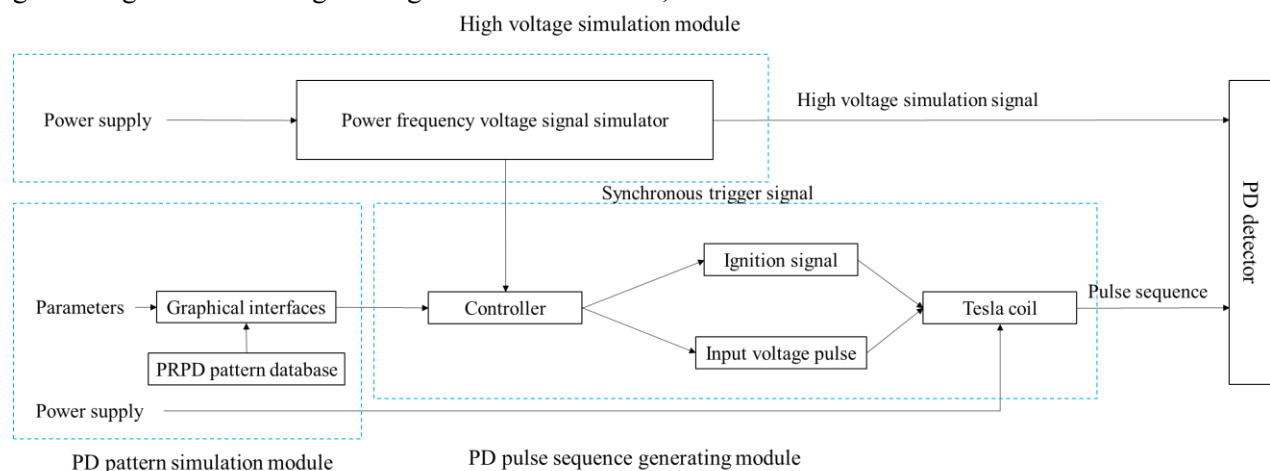


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method to evaluate PD detector, which makes use of Tesla coil to generate PD pulse by referring to high voltage signal and PRPD pattern from simulation module

## 2. Design of the performance evaluation system

According to what's mentioned above, the performance evaluation, which is on the basis of programmable PD calibrator, proposed in this paper have several outstanding advantages. It can miniaturise experimental equipment, also generate various types of PD pulse sequence, including programmable calibration pulse sequence, which therefore can simulate PD by generating pulse sequence according to patterns of different insulation defects. The performance evaluation system is shown in Fig.1, which includes three modules, PD pattern simulation module, PD pulse sequence generating module and high voltage simulation module, as follow.



**Figure 1.** Structure of an evaluation system for PD detector

### 2.1 PD pattern simulation module

PD pattern simulation module, which is used to input power supply and characteristic information of each pulse of PD pulse sequence to be simulated, including amplitude, polarity, pulse phase angle, time-frequency parameters and so on. These information can be referred from PRPD pattern and receive parameters from graphical interfaces by users.

### 2.2 PD pulse sequence generating module

PD pulse sequence generating module, which is composed of control part, Tesla coil circuit and synchronous trigger output circuit. Controller plays a role as receiving information from PD pattern simulation module to provide Tesla coil input voltage and ignition signal to match desired pulse sequence [7]. Tesla coil is triggered by ignition signal and amplitude of pulse is controlled by input voltage. In this way, this module can generate and output pulse sequence to simulate PD signal.

### 2.3 High voltage simulation module

High voltage simulation module, which takes advantage of isolation transformer to couple power supply. The coupled signal generates synchronous sinusoidal signal and then becomes square wave signal through circuit, detailed process is illustrated in Section 3. The rising edge of square wave signal works as synchronous signal that triggers discharge of each cycle of the output.

PD detector serves as a terminal part that receives PD pulse sequence and synchronous trigger signal, after data acquisition, interference recognition, PD classification and recognition are carried out.

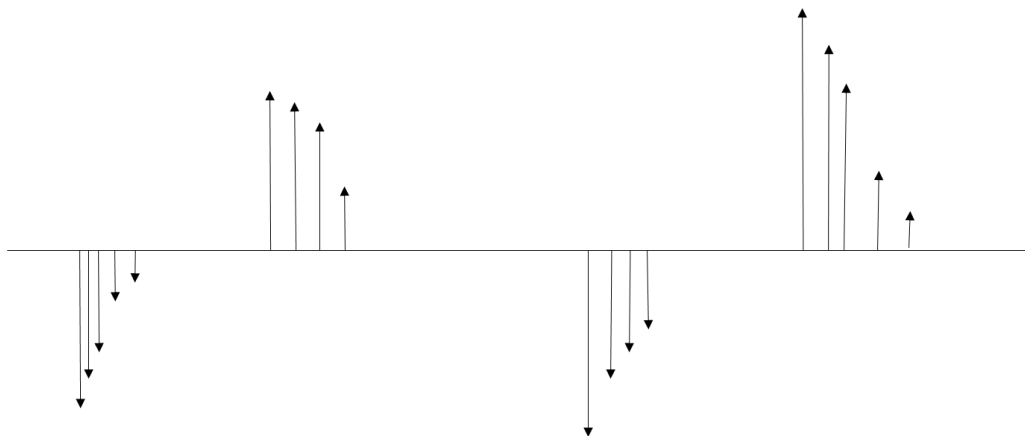
### 3. Realization of performance evaluation system

#### 3.1 Simulation of PD pattern

Different types of defects possess different statistical characteristics of pulse time distribution and amplitude distribution, which is resulted from the mechanism of partial discharge. Such specificity can be used to classify and identify insulation, therefore, the gather of discharge pattern is of great importance, which can be achieved through following three methods: partial discharge on line detection, digital simulation based on mathematical model and experiments based on typical defects. The PD pattern database can be constructed through gathering information to restore waveform of partial discharge, information of PD test, and the characteristics of each pulse in PD pulse sequence, such as amplitude and phase.

When the system generates PRPD pattern, synchronous output is generated by trigger circuit, which is mainly used for simulating high voltage signal. It takes advantage of isolation transformer to couple power supply. The coupled signal generates synchronous sinusoidal signal after low-pass filter, which further generates square wave signal by comparing with referred DC voltage signal in comparator. The rising edge of square wave signal works as synchronous signal that triggers discharge of each cycle of the output. By changing referred DC source, the phase difference between trigger signal and zero point of rising edge ranges from 0 degree to 90 degree. And the high voltage simulating signal comes from amplify of synchronous signal.

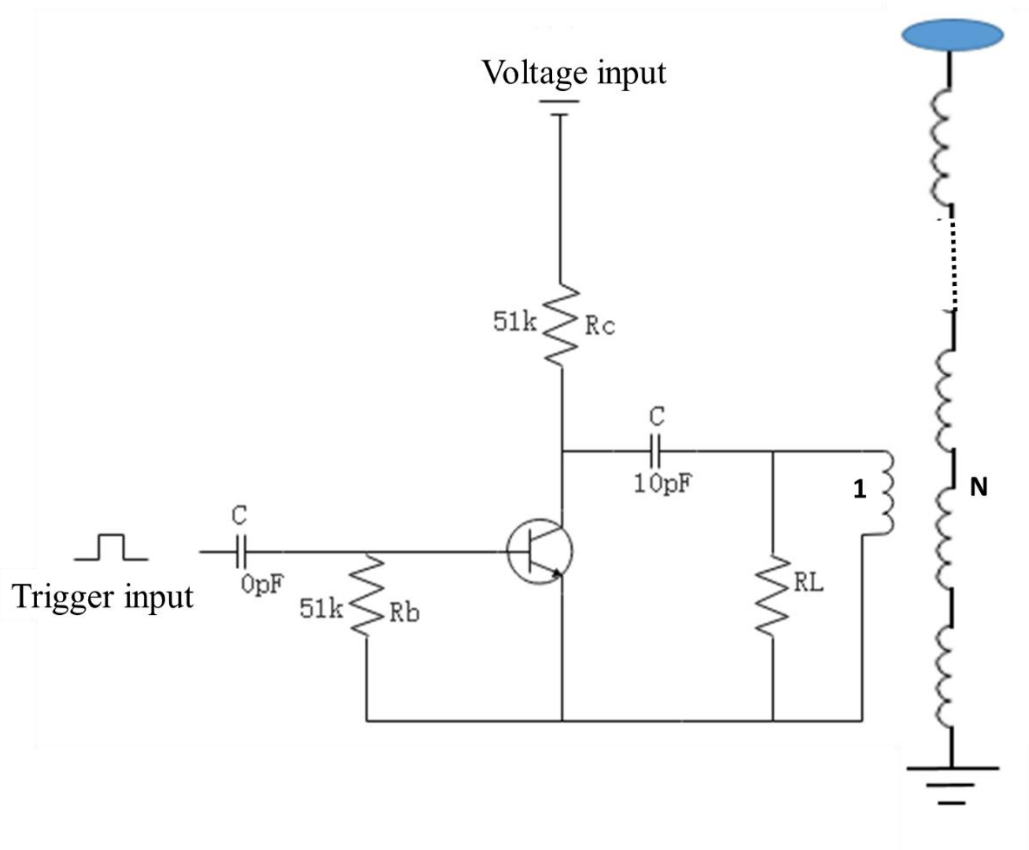
Tesla coil circuit is controlled by embedded system, input trigger signal connects circuit and input controlling voltage to define amplitude of pulse. PRPD pattern pulse sequence is read from database by programming, and this sequence is divided into pulse fragments according to power frequency cycle, these fragments perform as reference source to control trigger circuit. Fig.2 shows an example of pulse sequence, each of pulse contains information of phase position and amplitude.



**Figure 2.** Pulse sequence example

#### 3.2 Programmable pulse sequence

Partial discharge pulse sequence can be reproduced by PD pulse sequence generator, the Tesla coil circuit is shown in Fig.3.



**Figure 3.** Tesla coil circuit

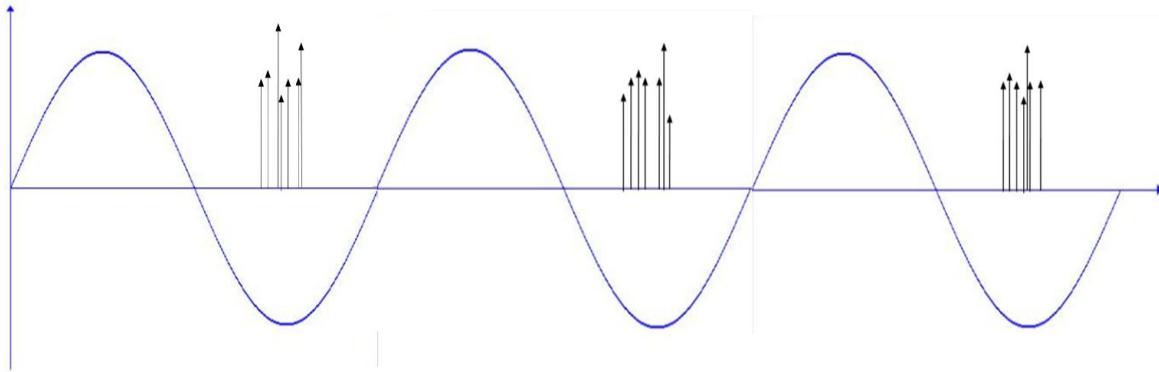
Inside drive circuit, the avalanche tube remains cut off condition until trigger pulse from control circuit arrives, the capacitor  $C$  is charged by input voltage  $V$ . When a trigger pulse that is large enough arrives, the operating point of the transistor is moved to an unstable avalanche negative resistance region. Then avalanche breakdown of transistor produces a rapidly increasing current, which further results in a rapid discharge of capacitor through transistor, then a narrow pulse occurs on load  $RL$ .

The narrow pulse possesses high amplitude because of the high avalanche current. And due to the result that limited charge is stored in capacitor, which is usually not larger than hundreds of picofarad, thus the pulse width is also limited. With the influence of circuit distribution parameters, the avalanche current gradually increases till a certain peak value, then the decrease of charge in capacitor leads to the decrease of discharge current. Former process generates the rising edge of pulse while latter process causes the falling edge. In this way, a sub nanosecond UWB narrow pulse with a very short rising time is obtained on the load. The trigger signal and voltage controlling signal to Tesla coil circuit are controlled by embedded controller, and the generated narrow pulse is output after being boosted through Tesla coil transformer.

#### 4. Performance analysis of the device for partial discharge simulation

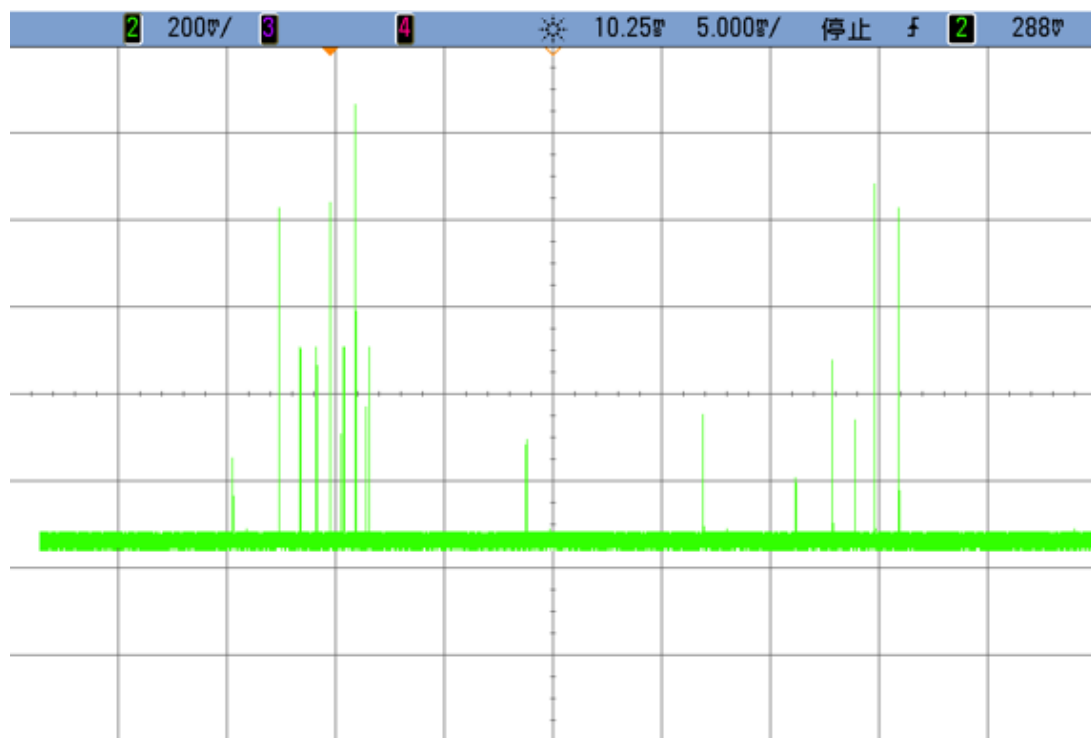
This performance evaluation system can simulate all kinds of PD pattern theoretically, point discharge is taken as an example here.

Point discharge first occurs only around negative half peak of high voltage signal, and the discharge time points symmetrically distribute on both side of peak point, Fig.4 is a typical example of point to plane discharge pulse sequence.



**Figure 4.** Pulse sequence of point discharge

The simulation of performance evaluation system is based on the PRPD pattern stored in database, where program read pulse sequence data including pulse amplitude ( $A_i$ ) and phase angle ( $T_i$ ). Then these sequences are divided into groups according to primitive periods, each pulse is triggered by trigger signal and the amplitude is controlled by input voltage on Tesla coil circuit. Fig.5 is the output PRPD pattern observed in oscilloscope, it can be clearly seen generated PD pulse sequence obeys the distribution characteristics of point discharge. The high comparability verifies the simulation function of evaluation system.



**Figure 5.** PRPD pattern observed in oscilloscope

## 5. Conclusion

In this paper, a method to construct performance evaluation system of partial discharge detector based on Tesla coil is proposed, which can reproduce pulse sequence of various types of partial discharge. The system is a miniaturization and integration of experimental equipment that can satisfy requirement

for verifying the feasibility and accuracy of PD detector. The design and realization details are given, performance analysis of this system is also discussed above.

The most outstanding advantage of this method is that simulation realized by this performance evaluation system possesses high reliability, which can guarantee not only the controllability of discharge process but also the randomness of reality simulation process.

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