Spiral Antenna Design and Analysis As a Tool to Measure Partial Discharge in High Voltage Equipment

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Abstract. The high-voltage equipment often experiences disturbances caused by the age of the equipment, installation errors, partial discharge disturbances. Of these kinds of disturbances, partial discharge is one of the most common disturbances in high-voltage equipment which has a percentage level of 80% due to partial disturbance. In this study, a research related to electrical equipment that can detect partial discharge disturbances in these high-voltage equipment was done. The equipment is a spiral antenna, where the spiral antenna has several advantages in detecting partial discharge. In making the first partial discharge, a literature study will be carried out first, after that designing a spiral antenna using CST 2018 software to get the Return loss and VSWR parameters as desired, namely Return Loss less than -10 and VSWR less than 2. From the results of this study Spiral antenna is measured using VNA, the measurement results show the spiral antenna is in accordance with the parameters that have been determined, namely the return loss value = -30.8 and the VSWR value = between 1 to 1.5.

Keywords: Partial Discharge, High-voltage, Disturbances

1 Introduction

Electricity in this era is a necessary to support human daily activities. The service of electricity must high quality. So to keep the quality of the electrical system, the quality of electricity must be very stable. The Industrial consumers want the electricity supply will continuously and have quality so that industrial productivity is not disturbed.

This requires monitoring and electrical protection technology to be important aspects to maintain the system running properly. The substation is the part that distributes electricity from the power plant to the electrical load with various consumer loads. At substations, there are high voltage equipment will help distribute electricity to customers.

The high-voltage equipment are Transformers, GIS (Gas insulated switchgear) and other high-voltage equipment. It can suddenly disturb, so it must diagnose. Diagnosis is by using fault detection equipment without direct contact between technicians and high-voltage equipment, one way is to use a spiral antenna.[2] Because this type of antenna has several advantages over other types of antennas. Some of the advantages of spiral antennas are broadband (wide bandwidth) where this type of antenna can work at a frequency of 300 MHz to 3 GHz, circular polarization, small size and high efficiency, and is suitable for online partial discharge measurements in high voltage equipment [2]. [3][4].

In this research, a spiral antenna will made which is designed using CST software and with one-sided FR4 epoxy PCB material.

2 Research Method

The steps of this research show in the block diagram

Fig. 1. Research method of this paper conference

2.1 Literature Review

2.1.1 Partial Discharge

That is a partial electrical discharge that event in the insulation it does not fully connected between two conductors and this discharge can occur, both near and

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far from the conductor, and this occurs an inhomogeneous field [2][5][6].

Basically partial discharge can occur in some place for example in the solid insulating materials, the liquid insulating materials and the gas insulating materials. In general, partial discharges are caused by local electrical concentration pressure, in the insulation that occurs inside or on the surface of the insulation itself.

The discharge process can be seen in Fig.2. under. The electrons first emerge from a protrusion of the conductor plate whose electric field is raised to a certain level.

Fig.2. Mekanism of Partial Discharge[2]

There are 3 kinds of partial discharge sources, namely: Internal discharge, Surface discharge, and corona discharge.[8]

Fig.3. Source of partial discharge (a) Internal discharge (b) Surface discharge (c) Corona discharge [2].

2.1.2 High Voltage Equipment

Power Switchgear is equipment that is covered of metal. It design is completely enclosed all of sides using sheet metal materials, (except the ventilation openings and the inspection windows) which have the switching mains electrical circuit equipped with buses and connection equipment.

To get in to interior of the power switchgear which is covered by metal, a door of cover that can be opened flexibly has been provided to make it easier for technicians to carry out inspections and repairs [1].

2.1.3 Antenna

Antenna is a part of a telecommunications equipment system that can convert electromagnetic energy into electrical energy or vice versa that passes through a channel, both medium and vacuum.[3]

Fig.4. Concept of antenna level frequency[3]

2.2 Spiral Antenna Design

In this study, we design a spiral antenna with several advantages such as broadband, circular polarization, minimal size and high efficiency, and is suitable for online partial discharge measurements.

Fig.5. Design antenna spiral using CST software, (a) Tembaga pcb ; (b) Design konektor BNC.

2.3 Manufacturing Spiral Antenna

Spiral antenna is use to detect a partial discharge signal based on electromagnetic waves generated by the needle plate electrode.

The spesification of the spiral planar antenna is inner diameter spiral antenna = 1 cm and has an outer diameter =13.8 cm. Bellow show the manufakturing the antenna using FR4 PCB.

Fig.6. Manufacturing spiral antenna

3 Result and Analysis

3.1 Measurement of Spiral Antenna Characteristics

Measurement of antenna characteristics can be done using a Vector Network Analyzer (VNA) as shown in

Figure 4.1, this tool can measure several antenna parameters like VSWR, Return Loss and antenna impedance.

Type of VNA used is VNA (TR1300/1), which provides basic vector network analysis for various industries and applications such as wireless communication, cable TV, automotive and others.

Fig.7. VNA (TR1300/1)

3.1.1 Result of measurement spiral antenna in Return Loss Parameters

Fig.8. Rectangular spiral antenna RL curve

Table 1. Result of measurement Return Loss

Resonansi (MHz)	Bandwidth (MHz)	Frekuensi Optimum (MHz)	Return Loss (dB)
521 – 527	6	524	-13.313
600 – 608	8	604	-22.47
681 – 694	13	687	-22.313
805 – 815	10	810	-20.476
845 – 861	16	852	-28.329
991 – 1000	9	995	-25.887
1074 – 1079	5	1077	-17.903
1117 – 1121	4	1119	-23.681
1194 – 1200	6	1199	-30.857
1236 – 1250	14	1242	-20.162
1276 – 1291	15	1284	-18.757

The method to read the bandwidth measurement results is in return loss parameters section which has a value is less than -10dB , this value is an antenna parameter which states that the power lost from the signal is $<90\%$. The data from the bandwidth

measurement results on the tested spiral antenna can be seen in Table 1.

3.1.2 Result of measurement spiral antenna in VSWR parameters

The results of measuring the VSWR parameters using VNA on the spiral antenna.

Fig.9. Graph of Rectangular spiral antenna VSWR

The results of the VSWR measurement on the antenna show a VSWR value is more than 1 and the best value is less than 2. From this measurement can be know that antenna can detect the signal from partial discharge.

4 Conclusion

This study discusses the design of a spiral antenna to detect partial discharge in high voltage equipment. The results of this research will show as follows:

1. The spiral antenna has made by FR4 PCB material.
2. The antenna designed using CST 2018 software with several parameters such as return loss, VSWR and BW(Bandwidth) values as a reference to produce an antenna according to the partial discharge frequency.
3. The results of antenna measurements using VNA show that the antenna is in accordance with the partial discharge signal measurement parameters, as evidenced by the Return Loss measurement of less than -10 and the VSWR value of less than 2.

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