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Online Diagnostic Ultra-Wideband Antenna System in High Voltage Polymeric Insulator

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Abstract—A novel ultra-wideband (UWB) antenna system is proposed for fault inspection and online diagnoses on high voltage polymeric insulators. This technique makes use of the multimode transferring theory on dielectric waveguides, where the transmission signal level difference can be employed to detect internal defects in the core rod. An investigation by simulation is performed with regard to the interfacial mm-ordered cracks in transverse and longitudinal orientations, and roughly 30~50 dB and 20~40 dB differences have been observed over the same band 3~10 GHz, respectively.

Keywords—online diagnosis; ultra-wideband (UWB) antenna; polymeric insulators; internal defects

I. INTRODUCTION

Nowadays, polymeric insulators are widely applied in power systems due to their superior anti-pollution properties, excellent high-dielectric strength, low volume and light weight [1]. Tens of million pieces of polymeric insulators have currently been operating over the world, making up a huge portion of power grid insulators that consist of three categories by materials, i.e., porcelain, glass and polymeric insulators. As time goes by, some internal defects such as interfacial air voids, micro-crack, erosion defect and chemical degradation could gradually appear in polymeric insulators due to various complex circumstances, which will result in severe deterioration on insulation performance [2]-[6]. However, it is of great difficulty to make real time monitoring and diagnoses on the internal defects of polymeric insulators in operation, particularly of outdoor types. An efficient online detection technique is thus called in order to secure reliable operation of polymeric insulators in a smart power grid.

II. MULTIMODE TRANSFERRING THEORY

A piece of polymeric insulator is generally composed of a polymeric core rod (mainly fiber glass plus epoxy resin), a polymeric (mainly silicon rubber) housing and a number of polymeric (mainly silicon rubber) sheds.

The core rod can be considered as a cylindrical dielectric waveguide. According to the guided wave theory, as illustrated in Fig.1, when a microwave at a proper frequency propagates end-to-end through a normal core rod without any internal defects, the dominant mode TM_{01} (mode 1) and other higher ordered mode, for example, mode HE_{11} (mode 2), can be excited within the cylinder, without mutual couplings between the

orthogonal modes. However, if there exist some defects inside or on the surface of the core rod, the mutual couplings between the dominate mode and the higher ordered modes will appear with significant values. This is basically the physical principle of the proposed online diagnosis technique.

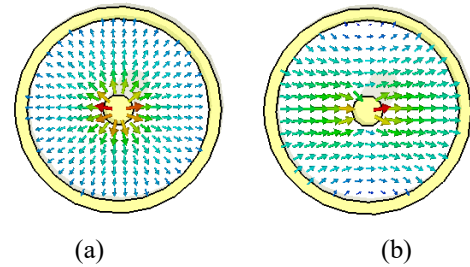


Fig. 1. Transverse E-field distribution of (a) mode 1 (b) mode 2 in core rod.

III. SYSTEM DESIGN AND ANALYSES

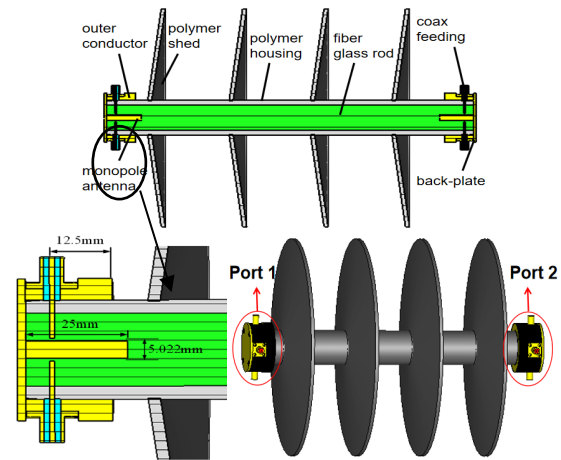


Fig. 2. Geometry and parameters of online diagnostic UWB antenna system.

As shown in Fig. 2, the proposed online diagnostic system mainly consists of two identical antennas that can respectively be integrated in metal (typically aluminum) fittings at the cable end and the ground end, as a transmitter (port 1) and a receiver (port 2), or vice versa. A single antenna is composed of four monopole probes inside the core rod covered by an outer cylindrical conductor that is analogous to a metal cavity with one open aperture.

Fig. 3 shows how to excite mode 1 and mode 2 microwaves at both ports. Mode 1 can be generated by simultaneously exciting all the four feed probes with equal amplitude and same phase, while mode 2 by exciting two probes for one polarization with equal amplitude but opposite phase

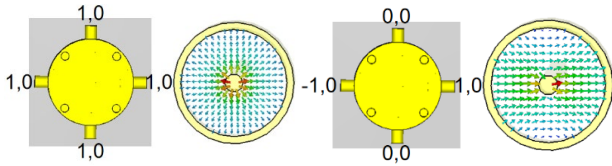


Fig. 3. Port excitations of mode 1 and mode 2 signals within core rod.

IV. SIMULATION RESULTS

Detection of internal defects in the core rod is investigated by simulation in *CST MWS*. As depicted in Fig. 4, both transverse (perpendicular to z-axis) and longitudinal (parallel to z-axis) conformal cracks on the interface between the core rod and the polymer housing are modelled by air slots, whose volume dimensions are 5.878mm*1.0mm*1.0mm, and 0.5mm*1.0mm*10.0mm, respectively.

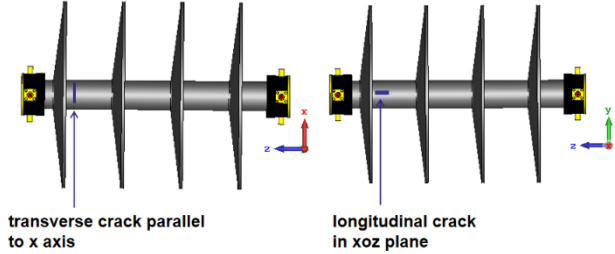


Fig. 4. Transverse and longitudinal cracks on insulator inter-surface.

The simulated transmission S-parameters are exhibited in Fig. 5. As for the transverse cracks, significant difference up to 30~50 dB can be observed on the transmission curves ($S_{2(1),1(2)}$ and $S_{2(2),1(1)}$) between the reference model and the defect model over 3~10 GHz. As for the longitudinal cracks, 20~40 dB difference can be observed on the transmission curves between the reference model and the defect model over the same band.

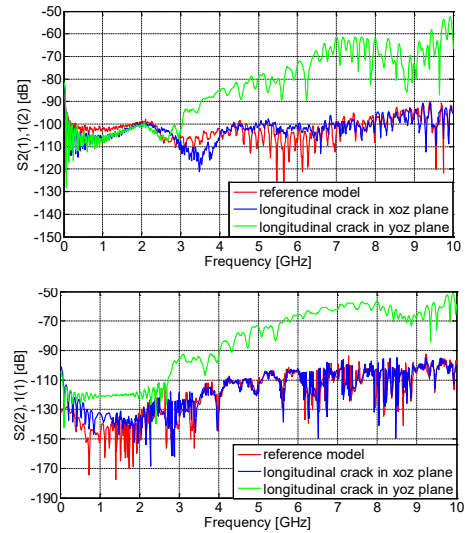
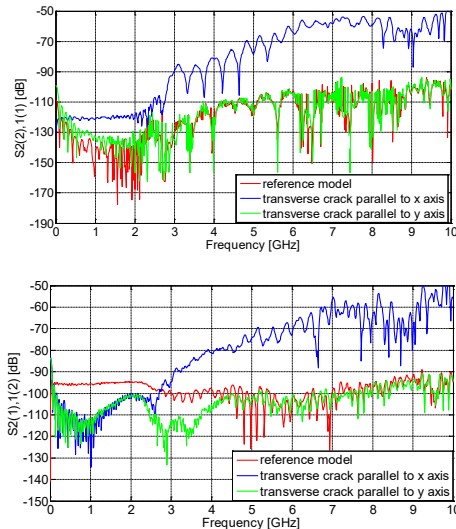


Fig. 5. Simulated S-parameters of reference model and defect model.

V. CONCLUSION

A novel online diagnostic UWB antenna system for polymeric insulators is presented in this paper. Detection of interfacial cracks in a dielectric core rod is investigated by simulations. The simulation results show that air cracks in the order of millimeters could successfully be detected by the proposed technique, which may open up a grand new path to fault inspection and online diagnoses on high voltage polymeric outdoor insulators. By the way, an intensive experimental study will be carried out on a manufactured prototype in the near future.

ACKNOWLEDGMENT

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