Time-Frequency Based Analysis of Wave Propagation Characteristics in Cooling Process of AC 154 kV HTS Cable System

Geon Seok **LEE**, Yeong Ho **LEE**, Su Sik **BANG**, Yong-June **SHIN;** Yonsei University, (Republic of Korea),
seok@yonsei.ac.kr, bang@yonsei.ac.kr, lyh9029@yonsei.ac.kr, yongjune@yonsei.ac.kr
Si-Dole **HWANG**, Hyung Suk **YANG;** KEPRI, (Republic of Korea), sdhwang4527@kepco.co.kr, h.yang@kepco.co.kr

ABSTRACT

In this paper, by using cross Wigner-Ville distribution and scattering parameters, a diagnostic technique to monitor the physical and electrical characteristics of HTS cable systems in a real-time manner is proposed. The proposed technique can diagnose the HTS cable systems and protect the cable systems from failures of the cooling system and degradation of the insulation. In order to validate the efficacy of the proposed time-frequency based technique, the proposed technique is applied to an AC 154 kV 600 MVA HTS cable systems.

KEYWORDS

Cross Wigner-Ville distribution (CWVD), High Temperature Superconducting (HTS) Cable, Scattering Parameter, Time-Frequency Based Analysis, Wave Propagation.

1. INTRODUCTION

Compared to conventional power cables, high temperature superconducting (HTS) cables are expected to provide solutions for a power grid network that needs the high-capacity transmission in densely populated or high-load areas. Moreover, the production of HTS cables, including installation, has increased over the past few years [1]. For instance, in 2016, an AC 154 kV 600 MVA HTS cable systems (1 km) was connected to a real electric power grid and the demonstration was completed in Jeju, South Korea [2]-[4]. Currently, the cryogenic cooling system of the HTS cable systems with a length of 1 km has been extended up to a length of 3 km [3]. Furthermore, new diagnostic technique has been applied for the reliable operation of the 154 kV HTS cable systems. As the part of diagnostic technologies, this paper will examine how the wave propagation characteristic of the HTS cable system changes as a total of 3 km of the cryogenic system is under the cooling process from room temperature to the operating temperature.

In the monitoring of the 154 kV HTS cable systems, time-frequency (TF) based analysis is used. In conventional TF based analysis, typically rectangular signal, sinusoidal signal, or Gaussian enveloped chirp signal is applied to the cable under test and the reflected signal is analyzed in time- and frequency- domain simultaneously. However, in real-world operational conditions, the measured signal is distorted due to the external noise of the measurement environments. Furthermore, in the case of HTS cable systems with joint boxes, additional signal attenuation and reflections occur due to the joint boxes. Hence, additional signal processing is required, and a method is proposed to improve the performance of the wave propagation characteristic monitoring using cross Wigner-Ville distribution (CWVD) and scattering parameter estimation of the 2-port network [5].

In the cooling process of the 154 kV HTS cable systems from room temperature to 80 K, in order to verify the efficacy of the proposed method, temperature and pressure data of the 154 kV HTS cable systems are measured at two terminations and compared with the result of the proposed TF analysis.

In Section 2, the theoretical descriptions of the two proposed TF based analysis and the conventional diagnostic techniques are presented. Section 3 covers the experimental procedure to validate the performance of the proposed analysis. In Section 4, the performance of the proposed analysis is discussed based on experimental results. Finally, the paper is concluded in Section 5.

2. THEORETICAL BACKGROUND

2.1 Transmission Line Theory

As shown in Fig. 1, the 154 kV HTS cable systems consist of three HTS cables which are connected by two joint boxes. An incident signal which is sent through the inlet termination is reflected at the joint box #1 due to insulation change of the joint box, and part of the signal is transmitted through the joint box. Then, the transmitted signal is also reflected at both the joint box #2 and the outlet termination. The proposed TF analysis was conducted on these signals which are reflected from two joint boxes and the termination of 1 km single-phase cable.

The temperature of the cables is one of the dominant factors to affect the impedance of the HTS cable. When the temperature rises and the HTS cable loses its superconductivity, an incident signal which is applied to the HTS cable is transmitted through the copper core or the protective layer of the superconducting wire, not a conductor. The change of the equivalent circuit of the transmission line implies an impedance change of the HTS cable systems, and the change of the impedance affects the results of the TF analysis.

In Section 2.2, the theoretical background of TF analysis to investigate the effects of the impedance change.

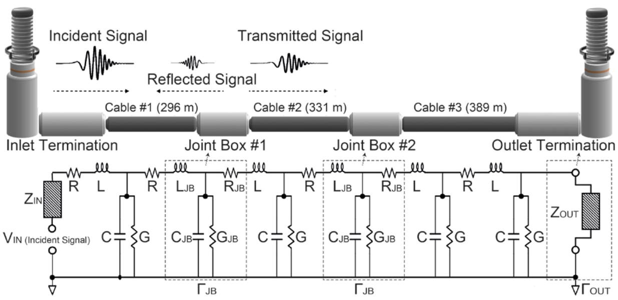

Fig. 1: The configuration of the HTS cable system and reflected signals due to the characteristic impedance change