A fault analysis of DC electric arc furnaces with SVC harmonic filters in a mini-mill plant

Byungju Park\textsuperscript{a}, Hansang Lee\textsuperscript{b}, Gilsoo Jang\textsuperscript{b,}\textsuperscript{*}, Byungmoon Han\textsuperscript{c}

\textsuperscript{a} PQ TECH INC., Youngtong-dong, Youngtong-gu, Suwon 443-813, South Korea
\textsuperscript{b} School of Electrical Engineering, Korea University, Anam-dong 5-ga, Seongbuk-gu, Seoul 136-701, South Korea
\textsuperscript{c} Department of Electrical Engineering, Myongji University, Nam-dong, Yongin, Gyeonggi-do, 449-728, South Korea

\textbf{A B S T R A C T}

This paper proposes the most feasible solution to overcome the failure of the 2nd harmonic filter in the static VAR compensator (SVC) which operates with the DC electric arc furnace (EAF) at Gwangyang Steel Mill in Korea. In order to investigate the causes of this failure, various measurements were carried out on the DC EAF and the main transformer at the PCC (point of common connection). It was concluded that the two causes for the failure are: the inrush current in the main transformer, and the parallel resonance between the system impedance and the harmonic filter. Three solutions to suppress the transformer inrush current and another three solutions to avoid the parallel resonance are suggested. The feasibility of these solutions was verified through the computer simulation with PSCAD/EMTDC. The most feasible solution to avoid further failures of the 2nd harmonic filter was selected, based on the estimated result for the six optional solutions in the point of performance and cost.

\section{1. Introduction}

The large-scale steel mill in Gwangyang Korea utilizes a SVC to improve the power quality problem at the interconnected power system caused by the operation of the EAFs. The main objectives for the installation of the SVC are to compensate the reactive power, reduce the harmonic current, and mitigate the flicker level\cite{1-3}. The SVC operated with the EAFs employs a TCR to control the system's leading power factor. The TCR, which is composed of a reactor and an anti-parallel thyristor switch, operates in a discontinuous current mode. Therefore, the EAFs and the TCR are the main sources of the harmonic current\cite{4,5}. The SVC employs several single-tuned harmonic filters to suppress the harmonic current injection into the interconnected power system\cite{6-9}.

The Gwangyang Steel Mill, which has been operated since 1982, is one of the most important plants in the steel industry in Korea. A few years ago, as a step-up in production had been requested, the service substation voltage of the plant had been raised from 154 to 345 kV in order to increase the electrical power capacity. This resulted in a filter capacitor failure in the SVC because the system configuration had been changed. The aim of this paper is to provide an analytical approach to finding the causes of this failure, and to propose the most feasible solution.

In this paper, Section 2 addresses the system configuration for measurement and analysis. The power quality characteristics and the transformer inrush currents are presented in Sections 3 and 4, respectively. In Section 5, six feasible solutions are suggested and the methodologies and details of each solution are described. The feasibility of each case study was carried out using PSCAD/EMTDC, and its results are described in Section 6. The final analysis and subsequent discussion are presented in Section 7.

\section{2. Gwangyang Steel Mill power system}

A simplified single line diagram for the power system of Gwangyang Steel Mill is shown in Fig. 1. The two DC EAFs, which have nominal ratings of 52 MVA, work with a ladle furnace which has a 22 MVA rating. The SVC was designed to regulate the reactive power to the two EAFs and the ladle furnace. The SVC system, which is rated for 83 MVAR at 22 kV, consists of a TCR and five harmonic filters. The TCR is continuously adjusted in response to the arc furnace power fluctuation. The filter capacitor banks provide the leading reactive power to improve the load power factor. Also, they work as harmonic filters to eliminate the harmonics produced by the TCR and the EAFs. These filters are tuned with the 2nd (9.9 MVAR),...