Electric Power Systems Research xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Investigation of diode rectifier trouble by lightning in D.C. traction substation

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ARTICLE INFO

Article history:
Received 18 February 2017
Received in revised form 3 May 2017
Accepted 26 October 2017
Available online xxx

Keywords:
Traction substation
Diode rectifier
Railway
Lightning flash
Grounding
FDTD
VSTL

ABSTRACT

On August 17th, 2012, a diode rectifier at Nagano Traction Substation was broken. The broken rectifier was dismantled and investigated in detail and, as a result, it was estimated that the overvoltage caused by the lightning flash caused the dielectric breakdown in the rectifier. To confirm the assumption of the broken process, the field measurement at Nagano Traction Substation and FDTD (finite-difference time-domain) calculation analysis at Nagoya Institute of Technology were carried out. As a result, it was indicated that the direct lightning to the elevated bridge over the substation caused the transient overvoltage of the grounding system of the substation and resulted in the breakdown within the rectifier. Because the concrete bridge pier is located adjacent to the substation, the surge voltage from the elevated bridge is able to influence the potential of the substation mesh. In this paper, the investigation process to determine the cause of the trouble will be shown in detail.

1. Introduction

In August and September, 2008, we experienced severe lightning around Tokyo area and public services such as power supply and railway transportation were severely influenced by them. Based on our experiences, the troubles in traction power supply system and railway signaling system caused by thunder lightning were investigated and evaluated [1], and some countermeasures against lightning flash have been carried out since 2009 [2]. For example, the grounding system was improved mainly at traction substations of D.C. electric railway around Tokyo metropolitan area. More specifically, the length of grounding wires of surge arresters were made to be as short as possible to make surge impedance of the grounding wire small, as one of the countermeasures in traction substations [3,4]. In catenaries system which is the overhead power supply system for railway operation above the railroad tracks, the most important issue caused by the lightning flash is the continuous D.C. grounding fault current at the flashover point which results in the breaking of wire in some cases [5]. Because the grounding fault current in D.C. traction power supply system is much smaller than that of the nominal load current, the detection of the grounding faults is very difficult. Some new approaches to detect the D.C. grounding fault is investigated and tested [6,7,12].

Since 2009, the number of severe lightning troubles in East Japan Railway Company tends to be decreased. It is difficult, however, to say that it is by virtue of the countermeasures we had carried out, because only 7 years has passed and it is too short to evaluate the effect of the countermeasures statistically. We hope, however, that our countermeasures contribute to enhance reliability of traction power supply system.

In this paper, one of the major lightning troubles which happened on August 17th in 2012 at Nagano traction substation is discussed. Nagano Substation located far from Tokyo and the countermeasures of grounding system improvement was not applied.

In this trouble, a diode rectifier was broken by lightning. The outline of the trouble, the results of dismantle at the factory, the assumption of the cause of the trouble, the confirmation test to check the validity of the assumption at the field and the evalua-

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https://doi.org/10.1016/j.epsr.2017.10.026
0378-7796/

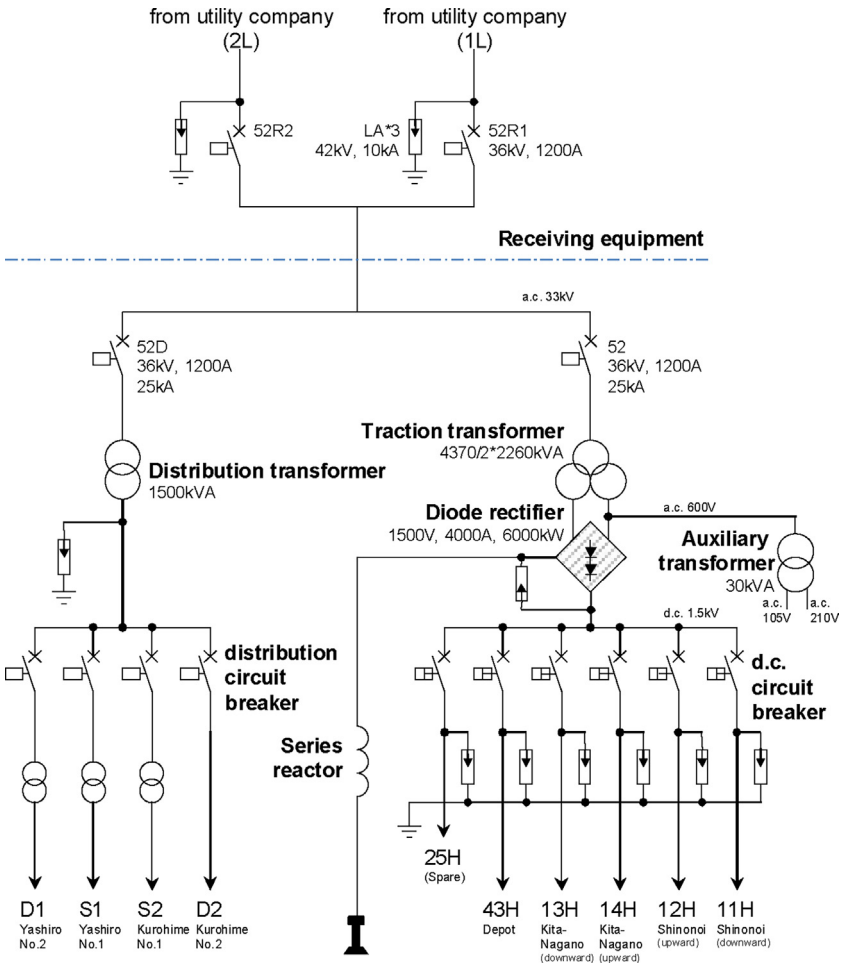

Fig. 1. Skeleton diagram of Nagano SS.

tion of the phenomena by computer simulation based on the FDTD method will be shown in this paper.

2. Outline of the event and initial investigations

2.1. Outline of the event

About the lightning troubles in traction substation, two major troubles happened after 2008. One is a trouble of rectifier at Sakaori traction substation on July 25th in 2010 which was already reported in Ref. [8], and another is a trouble of rectifier at Nagano Substation on August 17th in 2012 which was firstly reported in Ref. [9]. In this paper, the procedure of cause investigation and dedicated assumption will be discussed (Fig. 1).

Fig. 2 shows the skeleton diagram of Nagano Substation and the broken rectifier is indicated as a shadow hatching box in this figure [9]. When the rectifier was broken, a lot of lightning flash strokes were observed around the substation and it was estimated that the breakdown of the rectifier was caused by lightning. The location of the rectifier was, however, under the elevated bridge for the high speed railway and the electric machines of Nagano Substation for conventional railway was completely shielded from lightning as shown in Fig. 2 [10], and the electric machines of Nagano Substation are electrically independent from the catenaries system for high speed railway on the elevated bridge. The grounding down conductor of grounding wire on the elevated bridge, however, leads to the ground along the pier adjacent to the Nagano Substation.

Fig. 2. Installation condition of rectifier.

Judging from such a location of the broken rectifier, the procedure of the breakdown was estimated as follows:

- A lightning flash hit the overhead grounding wire of the catenaries for high speed railway on the elevated bridge.
- The lightning surge went through the down conductor in the bridge pier and was released to the ground.

Please cite this article in press as: H. Hayashiya, et al., Investigation of diode rectifier trouble by lightning in D.C. traction substation, Electr. Power Syst. Res. (2017), https://doi.org/10.1016/j.epsr.2017.10.026