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GEOMAGNETICALLY INDUCED CURRENTS MEASURED IN BRAZIL: 5 YEARS OF MONITORING DURING SOLAR CYCLE 24

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ABSTRACT

This paper presents a summary of five years of monitoring geomagnetically induced currents (GIC) at low latitude measured at a 500 kV transformer in a substation. Measurement system is based on a miniaturized Hall sensor properly mounted in a pair configuration to avoid electromagnetic noise. GIC has been investigated in the Furnas-Inpe scope cooperation since 2001. During a five years period (2009-2014), it was recorded the GIC occurrence and magnitude in events at transformers and also power line cable placed at low latitude.

Keywords: GIC, space weather, geomagnetic storm, geomagnetism, Hall sensor

RESUMO

O presente trabalho apresenta os resultados das correntes induzidas geomagneticamente medidas em um transformador de 500 kV operando em uma subestação de Furnas, situada em Itumbiara. O sistema de medição utilizado é baseado em um sensor Hall miniaturizado, disposto em uma configuração tal que minimize o ruído eletromagnético presente no local. As GIC tem sido investigada pela cooperação entre INPE e Furnas desde 2001, a instalação de um sensor dedicado está em operação desde 2009. No período de 2009 a 2014 foram registrados GIC relacionadas a eventos de tempestade geomagnética.

Palavras Chave: GIC, Clima Espacial, Tempestade geomagnética, geomagnetismo, sensor Hall

Introduction

The proposed physical mechanism for GIC generation at mid and low latitudes are the equatorial electrojet (EEJ) currents (Pulkkinen *et al*., 2012) nearby EEJ, the ring current enhancement (Erinmez *et al*., 2002), usually associated with prolonged GIC, SI and the propagation of SI wave modes in the Earth (Kappenman, 2003). Actually, GIC occurrence due to SI is a function of the local Earth's conductivity and it can be observed at any latitude, including the equatorial zone (Kappenman 2003). As a consequence, some studies have observed high intensity GIC in different countries (Trivedi *et al*., 2007; Marshall *et al*., 2012; Ngwira *et al*., 2008). We discuss the procedure to choose the power grid to be monitored, the details of the sensor applied during this monitoring. We analyze the geomagnetically induced currents measured from 2009 until 2014 by a Hall sensor placed at the ground cable of the transformer in a low latitude power network. We provide a calculation of GIC from a magnetic field temporal variation measured for the most intense storm is this solar cycle (March 17, 2012).

Description of instruments, measurements and methodology

Measured GIC was done at the neutral of the Itumbiara 500 kV transformer. The power network is located in a central territory of Brazil (see Trivedi *et al*., 2005, Trivedi *et al*., 2007 and Barbosa *et al*., 2015). The Hall sensor was mounted in a pair configuration with the aim of eliminating room-temperature and electromagnetic noise originating from the electrical plant. The sampling rate of the GIC data was six samples per minute, and the measurements were continuous during the period from 2009 until 2013, except for certain periods of maintenance. Around 30 geomagnetic storms were identified by the Dst index, most

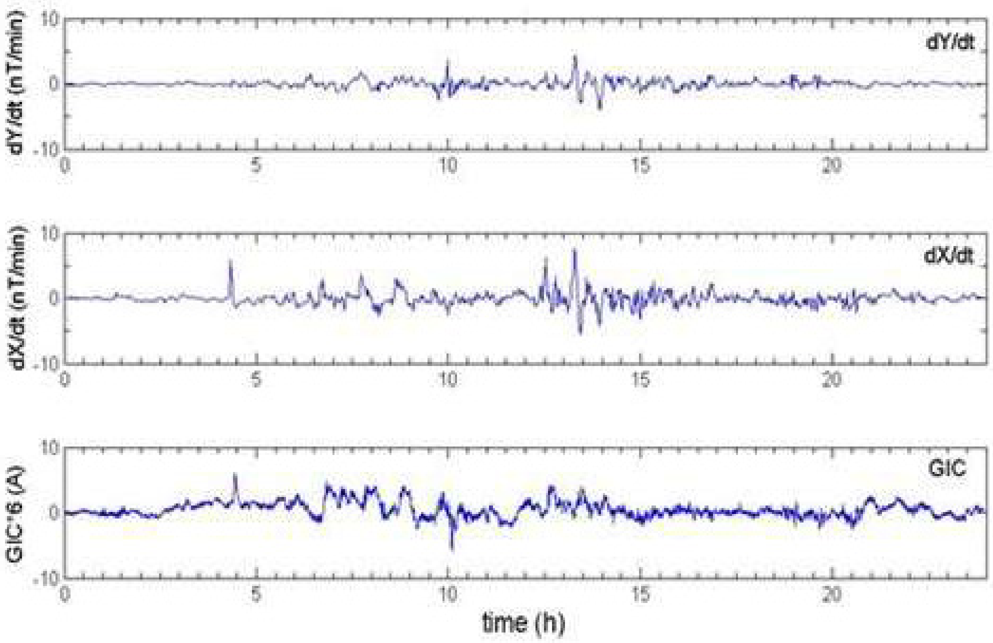

Figure 1. Comparison between the time derivatives of the geomagnetic field X and Y components measured at CXP and GIC measured at ITB on March 7, 2012.

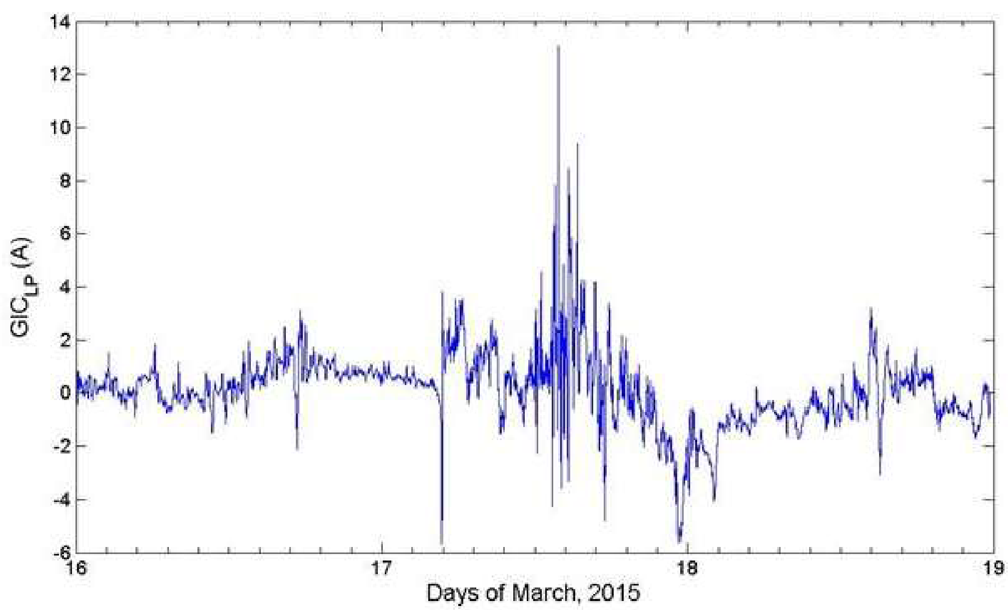

Figure 2. Calculated GIC on March 17, 2015.

of the storms registered were considered moderate (-100 < Dst < -50 nT), as a consequence, in only four of those events GIC intensity was higher than 4 A.

On March 17, 2015, the most intense geomagnetic storm (Dst = -228 nT) during solar cycle 24 hit the Earth, as the Hall sensor was not operating, we chose to calculate GIC during such event. The model we apply to perform the calculation was the LP-method proposed by Lethinen and Pirjola (1985). The GIC is calculated from the geoelectric field variation obtained from the JAT station magnetometer (Embrace/INPE magnetometer array) 270 km far from the substation.

Results and Discussion

Table 1 presents the parameters of the peak of the storm. Eventually the peak of the storm occurs on the day after SI, in this case the storms are identified by (*). The geomagnetic indices are presented to indicate the strength of the geomagnetic storm.

The inspection of the GIC plot compared to magnetograms from Embrace/INPE magnetometer array (Fig. 1), show that the sharp changes in GIC intensity is usually related with the following events: SI ongoing, the North-South geomagnetic component sharp decline, ring current enhancement (DRC) and, other disturbances mainly related with variations on solar wind (DSW). In other words, all these phenomena can contribute to bring on relevant GIC at low latitudes.

GIC calculated for the geomagnetic storm on March 17, 2015 was performed according Barbosa *et al*. (2015), the result is on Figure 2. GIC amplitude was as high as 13 A around 14:00 UT.

Table 1. Magnetic storms dates and times of SI occurrence. The geomagnetic indices from the peak of the storms and substorms are shown. Dates marked with (*) indicates that the peak of the storm occurs on the subsequent days.

Year	Day/Month	NOAA's Storm Level	Dst (nT)
2010	20/01	> G1	-34
	04-05/04	G4	-61
	01-02/05	G2	-71
	28-29/05	G1	-80
	03-05/08	G2	-74
	23-25/08	> G1	44
	11/10	> G1	-75
2011	06-07/01	G1	-42
	04-05/02	G2	-63
	26-28/05	G2	-80
	05-06/08	G4	-115
	09/09	G2	-72
	17/09	G2	-69
	26/09	G2	-118
	24-25/10	G3	-147

2012	22-24/01	G1	-67
	07/03	G2	-74
	08-09/03	G4	-131
	12/03	G2	-40
	15/03	G2	-72
	23/04	G2	-95
	16/06	**G2**	**95**
	15/07	G3	-127
	03-04/09	G2	-74
	30/09	> G1	-41
	08-09/10	G3	-105
	12-14/11	G2	-108
2013	17/03	G3	-131
	01/06	G3	-119
	29/06	G2	-98
	02/10	**G4**	**-67**
	08/10	**G2**	**-61**

Conclusions

In this paper we present a survey on moderate geomagnetic storms that occurred in 2012. The data investigated were measured at South American medium and low latitudes, aiming to provide information about specific characteristics related with these locations. The study was carried out by using a dedicated magnetometer array and a Hall sensor for monitoring GIC in a power network. Storm characteristics were analysed by means of the time derivative of north-south magnetic field component (dtX).

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