SIGNATURES OF LOW-LATITUDE GEOMAGNETICALLY INDUCED CURRENTS EFFECTS ON TRANSFORMERS IN NAIROBI, KENYA

Conference Paper · April 2014

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1 INTRODUCTION

In this paper, we focus on the correlation between the calculated GICs and the behaviour of the power grid in Nairobi (a low latitude region) during a geomagnetic storm occurring in the low solar activity period of the year 2009. We also show that there is a correlation between the GICs and the post-sunset east-ward component of the ionospheric electric field enhancements that are usually responsible for plasma bubble development and occurrence of ionospheric scintillations.

2 METHODOLOGY

We considered the geomagnetically disturbed days of 2009: February 4, March 3, April 11, July 22 and August 30. During each of these days the Kp-index reached Kp=5. We also consider three quiet days before and after the storm days. The selected disturbed days are shown in table 1. The geo-magnetic field variations three days before and after the geomagnetic disturbance were also .

Table 1: Details of selected disturbed days

Day	Description
2009-02-04	Kp=5 reached at 11:42UTC.
2009-03-03	Geomagnetic sudden impulse at 06:02UTC
2009-04-11	Kp=4 activity warning at 01:28UTC
2009-07-22	Kp=5 reached at 03:45 UTC
2009-08-30	Kp=5 reached at 16:18 UTC

The ground resistivity data shown in table 2 was provided by the Department of Geology, University of Nairobi and this was used to compute the average ground conductivity a parameter needed for computation of geo-electric fields.

The ground conductivity was computed using the relation $\sigma_G = 1/\rho_G$ where σ_G and ρ_G are the average ground conductivity and resistivity respectively. The average conductivity was found to be 0.022 S/m and this is the value used in the computation of geoelectric fields.

3 GEOELECTRIC FIELDS AND GICs

The plane wave model [1] was used to compute the geo-electric fields . This model assumes a uniform source field, where for the calculation of the electric field it is assumed that the Earth's resistivity structure varies only with depth and that the electric field is spatially constant. From the magnetometer data, we obtained the magnetic field variations

Table 2: Ground resistivity, conductivity values and depth from the surface of Earth

Depth (km)	Resistivity (ohm.m)	Conductivity (S/m)
3.2	78.26	0.0128
4	79.18	0.0126
5	77.26	0.0129
6.4	66.25	0.0151
8	62.91	0.0159
10	52.82	0.0189
12.6	45.13	0.0222
16	38.00	0.0263
20	33.80	0.0296
26	30.74	0.0325
32	30.51	0.0328
40	28.98	0.0345
50	33.32	0.0300
64	32.20	0.0311
64	25.90	0.0386
80	29.74	0.0336
100	15.83	0.0632
126	40.13	0.0249
160	44.55	0.0224
200	46.80	0.0214
260	58.08	0.0172

The graphs of the time derivative of the geo-magnetic field were plotted e.g as for 22 July, 2009 shown in figure 1.

Now, on the assumption that the electric field is spatially constant over a region of constant ground conductivity, we calculated GIC as

$$GIC(t) = aE_x(t) + bE_y(t)$$

where a and b are network coefficients, obtained from Kenya Power company as a=-80Akm/V and b=1Akm/V.

The computed GIC magnitudes are shown in table 3.

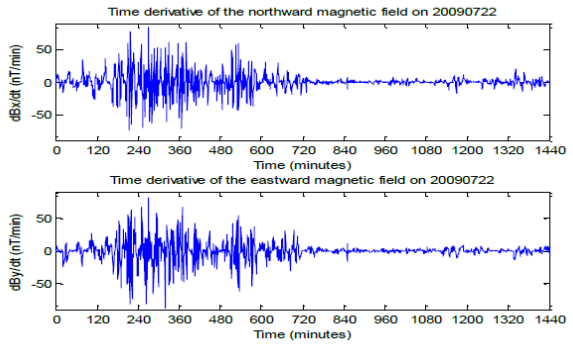

Fig. 1: Time rate of change of Geomagnetic field on 22 July 2009

Table 3: Maximum absolute values of GICs

Day	Kp value /Impulse	Maximum |GIC| (A)
2009-02-04	5	6.1508
2009-03-03	Impulse	7.3153
2009-04-11	4	1.4141
2009-07-22	5	6.2327
2009-08-30	5	7.6439

4 GEOMAGNETIC EVENTS AND POWER OUTAGES.

From the results of GICs obtained using the plane wave model and the power outages/transformer malfunctioning data provided by Kenya Power, it was noted that days that registered geomagnetic disturbances corresponded with recorded power grid problems.

6 TEC AND SCINTILLATIONS

An analysis of GPS data in terms of scintillation indices plots and Total Electron content plots showed that on 3 March 2009 there were post-sunset TEC enhancements arising from pre-reversal enhancement electric fields and some other contributions possibly attributable to atmospheric dust generated electric fields [2].

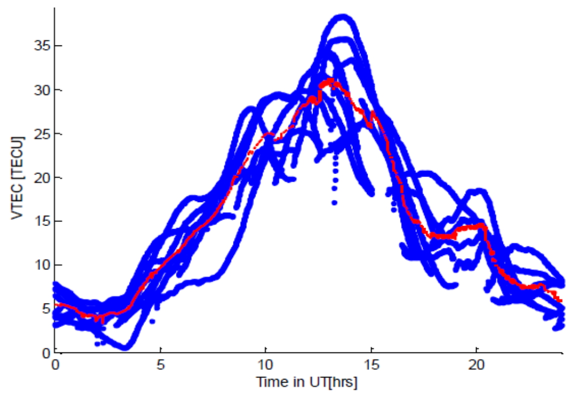

Fig 2: Vertical Total Electron Content, March 3, 2009 (note TEC enhancements after 23:00 LT)

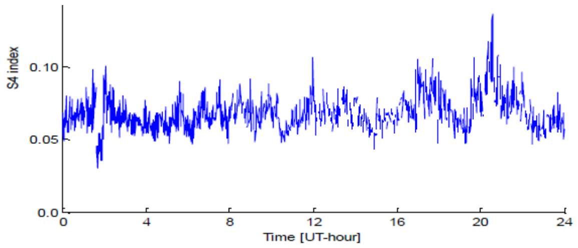

Fig 3: Scintillation Index plots (note weak scintillation at 23:00LT)

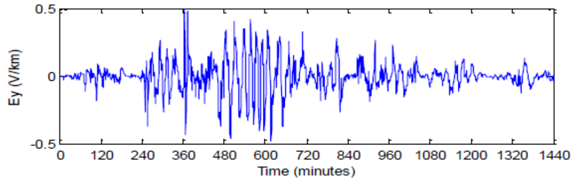

Fig 4: Geo-electric field plot Ey (note weak enhancements at about 23:00LT)

7 CONCLUSION

A study of the effects of Geomagnetically Induced Currents (GICs) on the Power grid in Nairobi, Kenya was conducted using co-located instruments i.e Magnetic Data Acquisition System (MAGDAS) and Scintillation GPS receiver located on Chiromo Campus of the University of Nairobi. The study was conducted for geomagnetically disturbed and quiet days before and after the disturbances in the year 2009. We employed the plane wave model to compute the GICs and observed that transformer malfunctioning occurred around the geomagnetically disturbed days, thus depicting possible GIC effects on power grid. From our observations, we concluded that it is possible that the same mechanisms that are responsible for TEC enhancements and east ward ionospheric electric fields also contribute to geo-electric fields and are therefore responsible for GICs observed in the low latitude region such as Nairobi.

8 ACKNOWLEDGEMENT

We acknowledge Departments of Physics and Geology, University of Nairobi for availing ground resistivity data and allowing us to use all the data. We sincerely appreciate the Boston University for SCINDA-GPS, MAGDAS team in collaboration with Kyushu University, Japan for installing the magnetometer in Nairobi, Kenya that helped in data acquisition.

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