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Research Article

THE USE OF HORIZONTAL GEOMAGNETIC FIELD COMPONENTS FOR ESTIMATION OF GEOMAGNETICALLY INDUCED CURRENT OVER TURKEY DURING SPACE WEATHER EVENTS

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ABSTRACT
In this study, the time derivatives of the horizontal geomagnetic field components were computed to estimate the geomagnetically induced current (GIC) over Turkey during space weather events and the results were compared with the geomagnetic activity indices. The interplanetary magnetic field (IMF) index, disturbance storm time (D_{st}) index, global geomagnetic activity indices (a_p and K_p) were used as indicator of space weather events. The changes because of solar flares and coronal mass ejections in the space environment between the Sun and Earth are defined as space weather events. Such events' effects on the Earth's magnetosphere are called geomagnetic storms. In this study, two different space weather events that occurred on 20-26 June 2015 and 06-10 September 2017 are analyzed. The data of the horizontal magnetic field components used in the analysis are obtained from İznik magnetic observatory (40.5°N, 29.7°E). During space weather event on 20-26 June 2015, the maximum (max.) value of time derivative of (dX/dt and dH/dt) X and H horizontal magnetic field components were calculated as 72,22 nT/min. and 74,40 nT/min., respectively, while during space weather event on 06-10 September 2017, the max. value of the time derivative of the X and H horizontal magnetic field components are calculated and the results are 36,90 nT/min. and 38,12 nT/min., respectively. Also, it was observed that the strength of the local geomagnetic disturbance and amplitude of dX/dt and dH/dt at the observatory station depend strongly on the characteristics of geomagnetic activity indices during the space weather events. The southward IMF B_z component induces larger amplitude of dX/dt and dH/dt. The results indicate that the possibility of GIC occurrence over Turkey is quite high. Therefore, we strongly believe that further research and experiment on GIC for Turkey is important.

Keywords: *Space Weather Events, Horizontal Components of Magnetic Field, Geomagnetically Induced Current, Magnetometer*

1. INTRODUCTION

The coronal mass ejections and solar flares, occurring as a result of the changes in solar activity, cause space weather events. During such events, an interaction occurs between space weather and the magnetic field of Earth. This interaction causes to sudden and dramatic changes in the components of Earth's magnetic field (Prölss, 2004; Schunk and Nagy, 2000; Timoçin *et al*., 2018; Timoçin, 2019). The changes in Earth's magnetic field caused by space weather events induce an electrical current that flow on the technological conductor systems, for instance electric power transmission networks, telecommunication cables, railway equipment, oil and gas pipelines. These currents are called geomagnetically induced currents (GIC) that flow on the technological conductor systems can cause great damages in the system attached to that conductor (Boteler *et al*., 1998; Pirjola *et al*., 2000; Pirjola, 2007; Schrijver *et al.*, 2014).

Large GICs are usually observed at high latitudes in or near the auroral regions where strong auroral electrojet currents that are one of the principal causes of the geomagnetic disturbances leading to GICs occur. (Pirjola, 2005; Wik *et al*., 2009; Eroshenko *et al*., 2010; Falayi and Beloff, 2012; Stauning, 2013; Myllys *et al*., 2014). It was believed that mid- and low-latitude regions are not affected by GICs. However, numerous GIC studies that were performed in mid- and low- latitude regions proved that strong space weather events can induce intense GICs also at mid- and low-latitudes (Kappenman, 2003; Trivedi *et al*., 2007; Liu *et al*., 2009; Watari *et al*., 2009; Caraballo *et al*., 2013; Liu*et al*., 2014; Viljanen *et al*., 2014; Doumbia *et al*., 2017; Tozzi *et al*., 2018).

During the last decades, the increasing dependence on technology of society has increased the interest in the investigation of the mechanisms of GICs that cause great damages on the man-made infrastructures. To the best of our knowledge, there are no studies about the geomagnetically induced currents and their effects on power systems in Turkey.

In this study, the horizontal magnetic field components measured over İznik/Turkey magnetic observatory were examined to the estimate the GIC over Turkey during two space weather events that occurred on 20-26 June 2015 and 06-10 September 2017. This study can be pioneer and basic research about estimating the geomagnetic induced currents over Turkey.

The results can provide important contributes to expand awareness about GICs over Turkey and to efforts to understanding GIC activity. Also, the results can encourage researchers to do further investigation and experimentation on GIC activity over Turkey.

2. DATA AND ANALYSIS METHOD

In this study, the data of the horizontal magnetic field components were examined to the estimate the GICs over Turkey during two space weather events that occurred on 20-26 June 2015 and 06-10 September 2017. The data of the horizontal magnetic field components were obtained from İznik magnetic observatory (40.5°N, 29.7°E). The time derivatives of the horizontal magnetic field components were computed to estimate the GICs over Turkey during two space weather events.

Several methods are used in the GICs research, such as calculation of the magnetospheric, ionospheric parameters, and technological conductor parameters. The most widely used of these methods is the method that calculates the horizontal components of the Earth's magnetic field with respect to time. Since the rate of change at the horizontal component of the Earth's magnetic field cause the GICs, the time derivative of the horizontal magnetic field components is directly related to the GICs (Pirjola *et al*., 2000; Pirjola, 2007;Trivedi *et al*., 2007; Watari *et al*., 2009; Wik *et al*., 2009; Eroshenko *et al*., 2010; Caraballo *et al*., 2013; Stauning, 2013; Myllys *et al*., 2014; Liu*et al*., 2014; Viljanen *et al*., 2014; Doumbia *et al*., 2017; Kalafatoğlu and Kaymaz, 2017; Tozzi *et al*., 2018). The electric field induced on the Earth's surface is determined using the rate of change of the Earth's magnetic field during geomagnetic storms using the following Eq. 1.

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \tag{1}$$

It is obvious that the effects of GICs over the world particularly on the technological systems can be observed once the derivative of horizontal magnetic field components with respect to 1 min. is higher than 30 nT/min. In other words, the value of derivative, dX/dt > 30nT/min. and dH/dt > 30nT/min. indicate the possibility of the GIC occurrence at Earth's surface particularly on the technological systems (Viljanen, 1997; Viljanen *et al*., 2001; Ngwira *et al*., 2011). In this study, we use the time derivatives of horizontal magnetic field components obtained from Eq.2 to prediction the GIC.

$$\frac{dH}{dt} = \sqrt{\left(\frac{dX}{dt}\right)^2 + \left(\frac{dY}{dt}\right)^2} \tag{2}$$

In addition to data of horizontal magnetic field components, interplanetary magnetic field (IMF) index, disturbance storm time (D_{st}) index, and global geomagnetic activity indices (a_p and K_p) were used as indicator of space weather events. The interplanetary magnetic field is the magnetic field of sun that is carried into space environment by the solar winds. This field has three components, B_x, B_y and B_z, of which B_z is responsible for energy input into the Earth's magnetosphere during space weather events. The D_{st} index is a measure of changes in the horizontal component of the Earth's magnetic field in the equatorial region during geomagnetic storms. This index is measured by magnetometer stations located in the equatorial region. Large negative values of the D_{st} index are indicative of a severe storm. K_p and a_p indices are obtained from changes in the horizontal component values of the Earth's magnetic field. These indices are used as a global indicator of the level of geomagnetic activity and are not dependent on local time, latitude and seasons. The time derivatives of horizontal magnetic field components were compared with these indices.

3. RESULTS AND DISCUSSION

The daily changes of dX/dt, dH/dt, IMF B_z, D_{st}, a_p, and K_p on 20-26 June 2015 are shown in Fig. 1a-1f, respectively. The IMF B_z presents three mainly rapid and severe southward turnings on 21-23 June 2015. Upon the first southward turning of IMF B_z, the D_{st} started to decrease slowly and the global geomagnetic indices (a_p and K_p) increase drastically and reach to the max. values.

Upon the second southward turning of IMF B_z, the value of the D_{st} reduces rapidly and finally reaches to the min. value. Next, the D_{st}, a_p, and K_p indices turn back to recovery phase. The first southward turning of IMF B_z disturb the regular pattern which is tend to about 0 nT/min. of the dX/dt and dH/dt values. The southward turning of IMF B_z results in the dX/dt and dH/dt values to reach the max. value of 72,22 nT/min. and 74,40 nT/min., respectively. That is, the first southward turning of IMF B_z has induced the highest dX/dt and dH/dt. It is easy to see in Fig. 1a-1f that the behaviors of geomagnetic activity indices are strongly related to dX/dt and dH/dt patterns.

Figures 2a-2f show the daily changes of dX/dt, dH/dt, IMF B_z, D_{st}, a_p, and K_p on 6-10 September 2017, respectively. The IMF B_z presents two mainly rapid and severe southward turnings on 7-8 June 2015. The first southward turning of IMF B_z cause a sudden decrease in the D_{st} and an increase in the global geomagnetic indices (a_p and K_p). With the intensification of the southward IMF B_z, the D_{st} reaches the min. value and the global geomagnetic indices experience first peaks. Next, the D_{st} turns back to recovery phase. The space weather event intensifies again due to the second large southward turning. The second southward turning of IMF B_z cause again a sudden decrease in the D_{st} and the global geomagnetic indices (a_p and K_p) reach the max. value. Then, the space weather event turns back to recovery phase.

The first southward turning of IMF B_z disturb the regular pattern which is tend to about 0 nT/min. of the dX/dt and dH/dt values. With southward turning of IMF B_z, the dX/dt and dH/dt values reach the max. value of 36,90 nT/min. and 38,12 nT/min., respectively. That is, the first southward turning of IMF B_z has induced the highest value dX/dt and dH/dt. As it is shown in Fig. 2a-2f, the behaviors of geomagnetic activity indices are strongly related to dX/dt and dH/dt patterns.

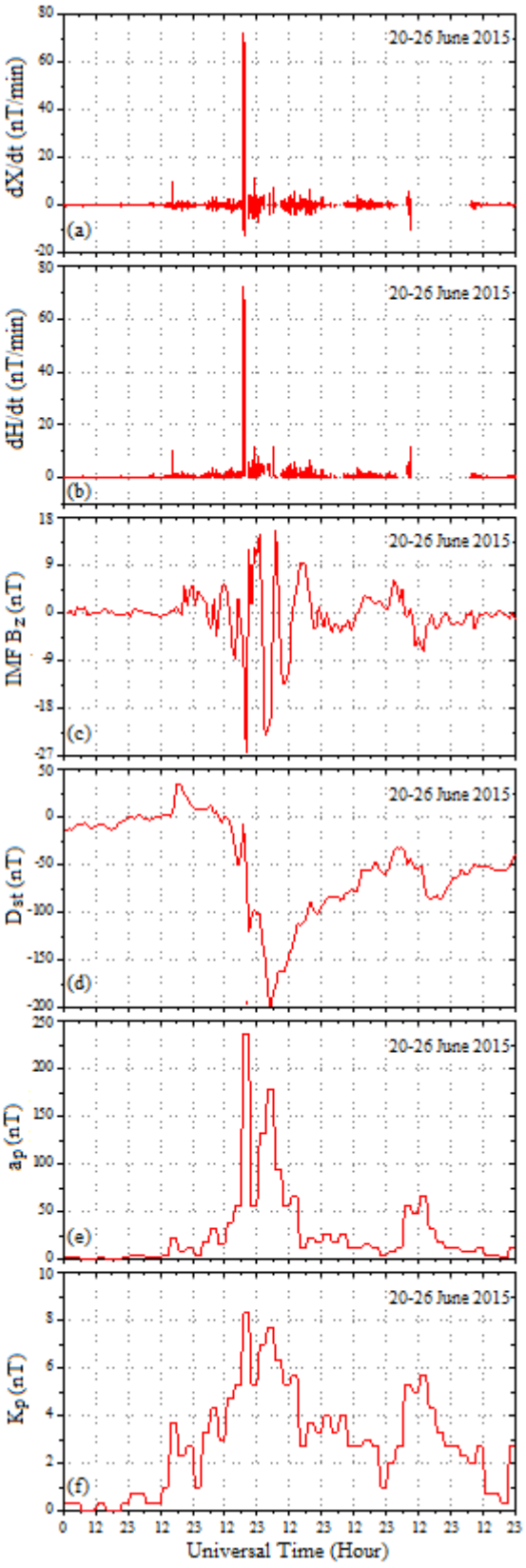

Fig. 1. The daily changes of (a) dX/dt, (b) dH/dt, (c) IMF B_z, (d) D_{st}, (e) a_p, (f) K_p, during 20-26 June 2015.

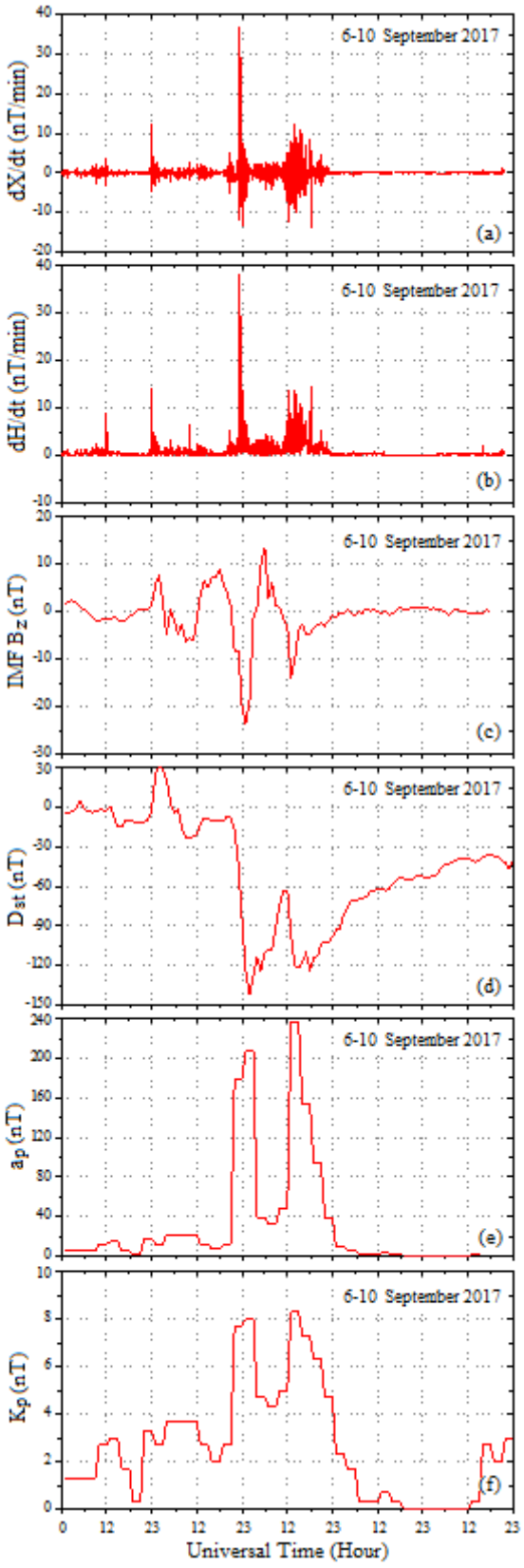

Fig. 2. The daily changes of (a) dX/dt, (b) dH/dt, (c) IMF B_z, (d) D_{st}, (e) a_p, (f) K_p, during 6-10 September 2017.

4. CONCLUSIONS

The results show that the effects of two space weather events cause large amplitude in the horizontal magnetic field components' time dependent derivatives measured at İznik magnetic observatory. For two different space weather events (20-26 June 2015 and 6-10 September 2017), the strength of the local geomagnetic disturbance and amplitude of dX/dt and dH/dt depend strongly on the characteristics of the IMF B_z component, disturbance storm time (D_{st}) index, and global geomagnetic activity indices (a_p and K_p). A strong correlation between the fluctuations in the dX/dt and dH/dt values and the geomagnetic indices is observed once the matching one to one is applied. We can conclude that it is possible that a large geomagnetic disturbance with dH/dt exceeding 30 nT/min. may occur.

The results indicate that the possibility of GIC occurrence over Turkey is quite high. Therefore, more detailed research for determination and experimentation about GIC event over Turkey is quite important. Further studies will be carried out about GIC event over Turkey.

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