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GEOINDUCED CURRENTS DURING MODERATE GEOMAGNETIC STORM 12-13 SEPTEMBER 2017

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Abstract. The complex space weather events of September 2017 included interplanetary coronal mass ejections (ICMEs), magnetic clouds (MCs), Sheaths, Corotating Interaction Regions (CIRs), solar wind high-speed streams (HSSs), fast forward shocks. In this report we will consider the geomagnetic activity and appearance of geoinduced currents (GICs) during moderate magnetic storm (SYM/H ~ −65 nT) occurring on September 12-13 caused by Sheath southward IMF. It is known that one of the important sources of GIC in the auroral zone is the amplification and motion of electrojets during substorms. At the background on the storm on 12-13 September 2017 two intense substorms (SML~1070 and~ 1540 nT) were registered. We analyzed the fine spatiotemporal structure of electrojet development during substorms using the latitudinal profiles of the equivalent currents of the MIRACLE system and IMAGE magnetometers data. The appearance of GICs were controlled by data from Vykhodnoy (VKH) and Kondopoga (KND) stations in the North-West of Russia (PGI, EURISGIC, eurisgic.ru), and from gas pipeline near Mantsala (MAN) in the South of Finland. It was shown that the appearance of GIC at different latitudes is associated with the movement of the westward electrojet to the pole during expansion phase of substorm. Besides, it was found that the source of one of the GIC bursts was a short pulse of Pc5 pulsations at the recovery phase of intense substorm. The paper also shows a relationship between an increase in the geomagnetic indices IL and Wp and the appearance of GIC, which also indicates the dependence of the appearance of GIC on substorm activity.

Introduction

Geoinduced currents (GIC), which occur both on power lines and pipelines, can have a negative impact on technological networks up to blackouts [1]. Along with studies of the causes of GICs, an important item of the protection from adverse effects of space weather is the monitoring geomagnetic field disturbances and recording of the development of GICs in actual power systems. The excitation of GICs in power transmission lines is controlled in many countries located in both high and middle geomagnetic latitudes [2], [3]. The European Risk from Geomagnetically Induced Currents (EURISGIC) project organized a system of continuous GIC observations at three to five nodes of the operating power transmission line, which runs from south to north across Karelia and the Kola Peninsula, from 2011 to the present [4-6]. It should be noted that this system is located precisely in the auroral latitudes, where substorms are usually observed, therefore it is possible to study the relationship between auroral electojets enhancement and moving and appearance of GICs. Recently, it was shown, that one of the source of GIC in auroral zone is the movement and the enhancement of the westward electrojet during substorms [7], [8], [9].

September 2017 was an extremely active space-weather period with multiple events leading to varying impacts on the Earth's magnetosphere. A large number of space-weather events took place during a period of only one month and resulted in several geomagnetic effects such as magnetic storms (of varying intensity), substorms, and HILDCAAs [10]. Appearance of intense GICs during the first space-weather event on September 7-8, 2017, associated with the development of two strong substorms (supersubstorms), which were observed against the background of two magnetic storms caused by two successive CMEs, was discussed in our previous work [9]. In this work we considered following event of space weather registered in September 2017, the event on 12-13 September, when a moderate magnetic storm (SYM-H ~ −65 нТл) developed, caused by Coronal Mass Ejection, and when GICs appear on Karelian-Kola power line (Vykhodnoy and Revda stations) and Finland gas pipeline near Mantsala.

Solar wind and interplanetary magnetic field (IMF) parameters on 12-13 September 2017 are shown in Figure 1. The fast shock (IS) occurred at ∼19:55 UT on September 12. It was associated with CME on September 10 [10]. The moment of IS registration is marked by red vertical line and inscription – IS. Then the plasma compressed region SHEATH was registered after IS, from ∼20 UT on September 12 to ∼04 UT on September 13. The boundaries of the SHEATHs are marked by the red rectangle and inscription: SHEATH. It is seen that some discrete southward Bz periods were observed (∼ −10 nT). They led to a moderate magnetic storm (SYM/H ~ −65 nT) at ∼00:10 UT on September 13. It should be noted that only the SHEATH was detected in this case, not MC or EJECTA [10]. At the background of the storm two intense substorms (SML ~ 1070 and ~ 1540 nT) were registered. We analyzed the fine spatio-temporal structure of the westward electrojet development during these substorms and magnetic pulsations registered at the substorm recovery phase.

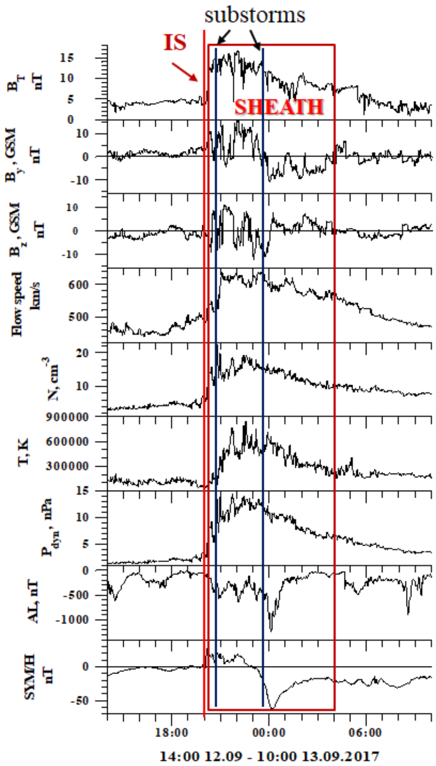

Figure 1. Variations of the solar wind and IMF parameters (B_T, By, Bz, V, N, T, Pdyn) and some geomagnetic indexes (AL, SYM/H) from 14 on 12 September to 10 UT on 13 September 2017. The boundaries of the solar wind types are marked by the red rectangle and inscription: SHEATH or IS. Moment of shock wave (IS) is marked by red vertical line, moments of the substorm onsets are shown by the vertical blue lines.

Data

To analyze the GIC appearance, data from two recording systems were used: 1) EURISGIC (http://eurisgic.ru/), located in the North-West of Russia in auroral zone; the points of registration of the GIC and the location of magnetometers can be found in previous works [4], [5], [6]. 2) GIC registration system in Finland obtained from gas pipeline near Mantsala is the subauroral zone (https://space.fmi.fi/gic/index.php) The geographic coordinates of substations, whose data are used in the work: Vykhodnoy (VKH) (68.8° N, 33.1° E), Revda (RVD) (67.9° N, 34.1° E) and Mantsala (MAN) (60.6° N, 25.2° E). The spatial distribution of the substorm was determined using the magnetometers of the IMAGE (http://space.fmi.fi/image/) and SuperMAG (http://supermag.jhuapl.edu/) networks. The IL- and SML- indexes are also taken from IMAGE and SuperMAG networks, correspondingly. Note, that the IL index shows the variation of the magnetic field at the selected IMAGE stations, that is, in essence, it is similar to the AL index, which is associated with the auroral electrojet. To study the spatial distribution of magnetic disturbances on the IMAGE profile, instant maps of the distribution of ionospheric equivalent electric currents MIRACLE (https://space.fmi.fi/MIRACLE/) were analyzed. We used also the Wp (wave and planetary) index is related to the power of the Pi2 pulsation wave at low latitudes and associated with onset of substorm. The solar wind and IMF parameters are taken from OMNI database ftp://ftp.iki.rssi.ru/omni/ and the catalog of large-scale solar wind types ftp://ftp.iki.rssi.ru/pub/omni/catalog.

Results

1. *First substorm at 20:20 UT on 12 September 2017*

First substorm began at ~20:25 UT on September 12 on OUJ station, spread rapidly to SOR station and then to NAL station. This substorm consists of 3 activations, which marked as 1, 2, 3 in the Fig. 2: at ~20:25, ~20:45 ~21:10 UT. We can see these activations in the profile of Wp index. Accordingly SuperMAG maps at 20:40 UT GIC registration stations were around midnight sector. More details the thin spatio-temporal picture can be considered on the MIRACLE map (Fig. 3b). It is seen that the westward electrojet start moving from auroral latitudes (~67° N) to high latitudes (~ 78º N geographical latitude). After ~21:20 UT recovery phase began: disturbances moved back from the pole to the auroral latitudes (~64° N). So, we observed first pick of GICs during first substorm activation on Mantsala station, second peak of GIC (corresponds to second substorm activation) was registered at all stations (VKH, RVD and MAN), and third peak - during third substorm activation - was observed only on VKH, because disturbances were at high latitudes in this moment, where VKH station is located.

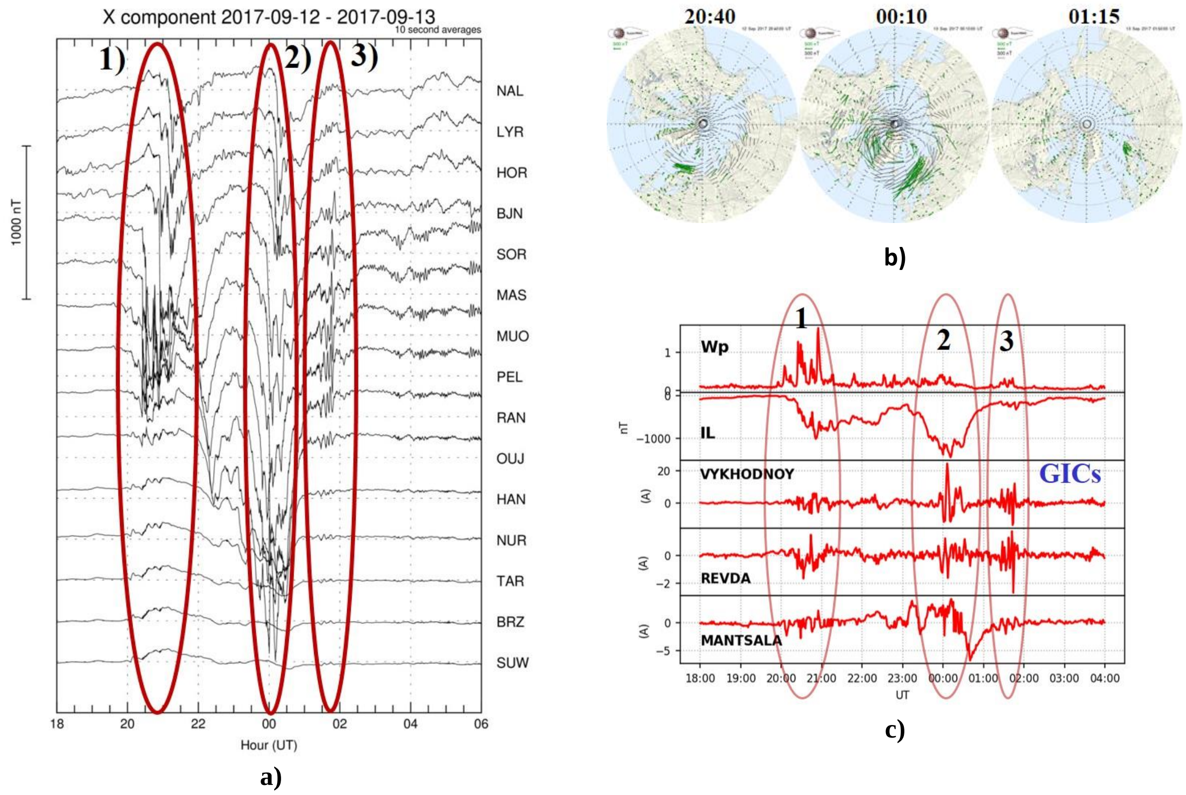

Figure 2. September 12-13, 2017 from 18 to 06 UT, red ovals shown three periods for the study: X-components of geomagnetic field from IMAGE magnetometers (chain SUW-NAL) (a); three maps of magnetic vectors from SuperMag network (b) Wp and IL indexes and GIC registration on Mäntsälä, Revda and Vykhodnoy stations (c).

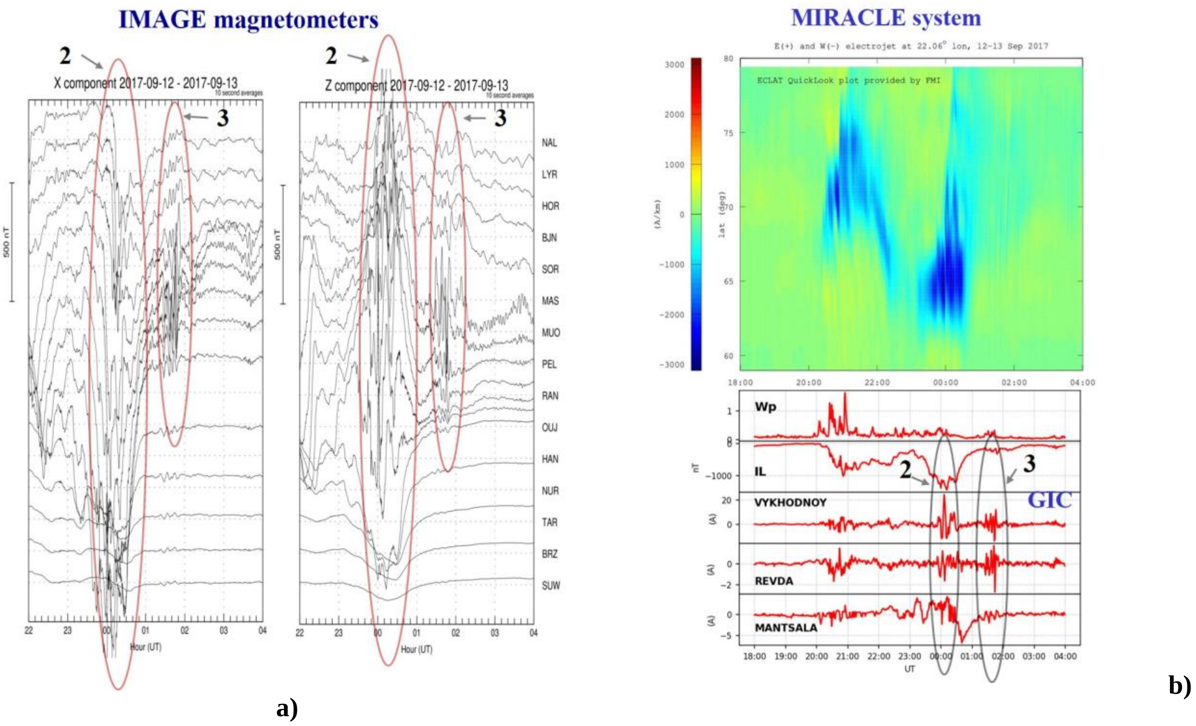

Figure 3. Second and third periods in more details, from 22 to 04 UT 12-13 September 2017. Format Fig.3 is the same as Fig.2. But additional are presented the latitudinal profile of the electrojets, obtained using the MIRACLE system (b) and Z-components of geomagnetic field (a).

2. ***Second substorm at 23:20 UT on 12 September 2017***

Second substorm began at ∼23:30 UT on September 12 on HAN station and spread to NAL station, where start of disturbance was ~ 00:10 UT on September 13. Note, this substrom belong to the "high-latitude" ones, since, according to Z-component variations, center of westward electrojet moved from OUJ to LYR. According to the data from MIRACLE system, the disturbances began at geographic latitude ~63-64° N, and then we see the expansion of westward electrojet to the pole to the latitude ~78° N (to the NAL station). As seen from SuperMAG maps, disturbance developed in the morning sector around 2-3 MLT, GIC registration stations were after midnight sector. And at this time in the GICs profile data we can see the most intense GICs on Vykhodnoy (>20A) and Revda (~2A) stations during an expansion phase of a substorm. So, we also see the spatiotemporal development of this substorm, the rapid expansion of the electrojet to the west, which corresponds to the almost simultaneous appearance of GIC peaks from Mantsala station to Vykhodnoy station.

3. ***Magnetic pulsation Pc5 at 01:30UT on 13 September 2017***

On the recovery phase of second intense substorm there were magnetic pulsation Pc5 at ~01:30 UT (Fig. 2 and Fig. 3). It is a short burst of Pc5 at a frequency of ~ 3MHz with an amplitude maximum at auroral latitudes. This is a typical event for the early morning during the recovery phase of a substorm. At this time in the GICs profile data we can see the most intense GICs on Vykhodnoy (~14A), Revda (~3A), Mantsala (~2.5A) stations. So, the magnetic pulsations Pc5 are also seen in the GICs data at all stations, but with a difference in amplitude depending on latitude.

Conclusions

Three events of GIC occurrence during moderate storm on 12-13 September 2017 were connected with the westward electrojet increasing and expansion during two substorms and with a short burst of Pc5 pulsations.

1) During first event it was possible to trace the appearance of GICs on the meridional profile (from Mäntsälä to Vykhodnoy) in accordance with the thin spatial - temporal structure of the substorm.

2) The most intense GICs (> 20A) were recorded in the expansion phase of the midnight intense substorm almost simultaneously at all observation latitudes.

3) The source of the third GIC burst was a short pulse of Pc5 pulsations at the recovery phase of intense substorm.

4) As in our earlier cases [9], there is a good accordance between the appearance of GICs and the increase in geomagnetic IL index, demonstrating the intensity of the westward electrojet on the IMAGE meridian, and Wp index, characterizing the onset of a substorm.

Asknowlegments

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