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THE BEHAVIOR OF SOLAR WIND PARAMETERS AND GEOMAGNETIC ACTIVITY INDICES FOR GEOMAGNETICALLY INDUCED CURRENT OBSERVATIONS

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ABSTRACT

The main objective of the current work is to investigate the behavior of space weather parameter as well as geomagnetic activity indices to observe the Geomagnetically Induced Current (GIC). Subsequently, solar wind parameter and geomagnetic activity indices provided an evidence that GIC formed during quiet days. The result revealed that the solar wind parameter and geomagnetic activity indices reflect the GIC. However, the solar wind parameter gave the best representation on GIC.

Keywords: coronal mass ejection; geomagnetic indices; solar wind parameters.

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1. INTRODUCTION

Space weather refers to the conditions at interplanetary space, produced by the sun that can disrupt modern technologies and affect human life or health [1]. Space weather is driven by solar activities which embraces a wide variety of phenomena such as solar flares, geomagnetic storms and solar energetic particles. Over the past 100 years, space weather study have attracted increasing attention and have been considered for abundant of application such as high-frequency radio communications, Global Positioning System (GPS) navigation, spacecraft measurements and development of space climatology. Previous researched on space weather covered from severe to extreme scenario event. In [2] declared that the extreme space weather condition is due to powerful Coronal Mass Ejection (CME) and detected the CME arrived to Earth only about 19h later. In [3] explained the extreme space weather data have been used for probabilistic forecasting ultimately, but not for event prediction. The energetic particle from space directly will affect atmosphere, ionosphere and lithosphere [4]. Among them, previous researchers found that the Geomagnetically Induced Current (GIC) are the ground end of space weather chain [5].

Space weather effect on underground based technology system discussed by [6-10]. Authors come out with no contradict conclusion that the occurrence of GIC is very harmful for underground [22] equipment. In power network, GIC may cause the transformer saturated and may led the whole system collapse and damage [6-11]. GIC study have been widely explored at high latitude region since north region facing a direct geophysical effect from the space precisely due to penetration of energetic particle into the Earth. In [7] discussed the risk of GIC at high latitude, meanwhile in [8] discussed the possible occurrence of GIC at four station located at low latitude region. The evidence occurrence of GIC at low latitude region have been investigate and prove based on [12]. The value of time derivation horizontal component, dH/dt exceed 30 nT/min, it indicates the occurrence of GIC. In [8-9] have been explained and clearly analyzed the results in order to validate that low latitude region also experience on GIC.

The main objective of this research was to observe the behavior of solar wind parameter and geomagnetic activity indices based on space weather condition and the most parameter influenced will be identified. In order to observe the occurrence of GIC, geomagnetic field component which is horizontal (H) and the time derivative of horizontal component (dH/dt) also being analyzed. The possibility of GIC occur was observed at different latitude region in order to identify the most affected region during space weather perturbation. Finally, the conclusions are summarized and some finding remarks made.

2. METHODOLOGY

2.1. Solar Wind Parameter and Geomagnetic Indices

The solar wind parameters are supplied by the satellites at the geostationary orbit in the near-Earth space, whereas the magnetic field variation are recorded by a network of observatories well located all over the world. In this study, all the data for the solar wind parameters and the geomagnetic activity indices are real-time data that were obtained from The Space Physics Data Facility (SPDF) based at NASA's Goddard Space Flight Center in Greenbelt, MD U.S.A. The Space Physics Data Facility (SPDF) was constructed to monitor the electromagnetic and plasma environment in the geo-space in real-time. The input data for this database system are supplied from several satellites system such as Interplanetary Monitoring Platform-8 (IMP 8), Interplanetary Physics Laboratory (Wind), Advanced Composition Explorer (ACE) and Geomagnetic Tail Laboratory (Geotail). The OMNI data were retrieved from the GSFC/SPDF OMNIWeb interface at http://omniweb.gsfc.nasa.gov. Data obtained from the OMNI database are the hourly values and the gaps in the data were filled by interpolation. The data is plotted using MATLAB software. For each event, the energy transfer to the magnetosphere is estimated by using the original Akasofu parameter. Akasofu's epsilon parameter is defined as Equation (1) [9].

$$\varepsilon = \frac{4\pi}{\mu_0} VB^2 \sin^4\left(\frac{\theta}{2}\right) l_o^2 \text{ [ergs/s]} \quad (1)$$

with V = the solar wind speed (km/s), B = the magnitude of the IMF (nT)

= the polar angle of the IMF vector in the y-z plane in solar-magnetospheric coordinate

$= \tan^{-1} (|B_y|)/B_z$ for $B_z > 0$

$= - \tan^{-1} (|By|)/ B_z$ for $B_z < 0$ $l_0 = 7$

Earth radii.

2.2. Geomagnetic Field, Horizontal Component

The analysis of horizontal geomagnetic field was extracted based on H-direction geomagnetic field data from three INTERMAGNET stations of different latitudes. The INTERMAGNET stations that are involved in this research are Cambridge Bay-CBB (Canada) for high latitude station, Cheongyang-CYG (Republic of Korea) for mid-latitude station and two station at low latitude which is Apia- API (Western Samoa) and Guam-GUA (United States of America) he details of the stations can be referred at the map.

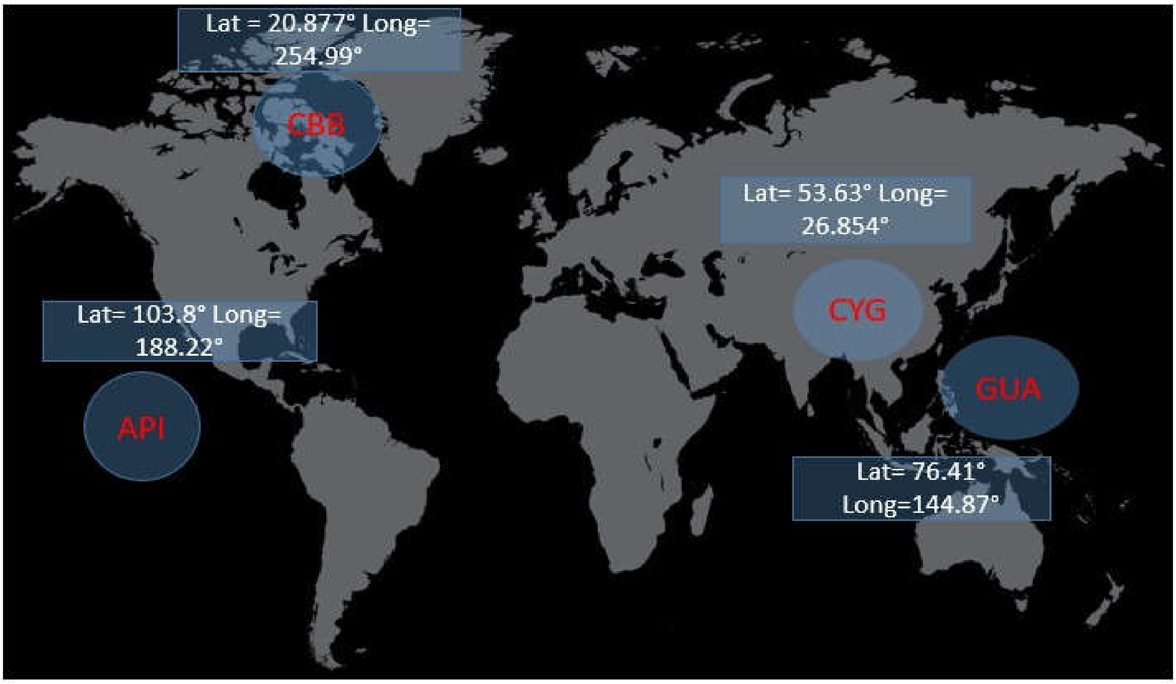

Fig.1. INTERMAGNET station map. The marked stations are the geomagnetic observatories involved in this study, CBB, CYG, API and GUA and the coordinates respectively

In this work, 3 cases study were conducted which refers to the different events that occurred during period of 2014-2015 as given below:

a) Case Study 1-Coronal holes event at 17 March 2015
b) Case Study 2-Coronal mass ejection event at 22 June 2015
c) Case Study 3-Quiet day with sudden impulse at 23 December 2014

3. RESULTS AND DISCUSSION

3.1. Case Study 1: Coronal Holes Event

During period of case study 1, the event of CH occurred on 17 March 2015. CH event was identified through the trend of proton density, N and Vsw where N will rises first and followed by Vsw with density start to drop. Based on Fig. 1, the sudden impulse occurred at

1000 UT. All solar wind parameters shows increment at the same time. IMF Bz points southward and the reading of solar wind input energy, IE tend to increase and may lead the penetration of IE into the earth from north to south. Over that situation, PC and AE shows high reading where both parameter classified as great storm [19] and it may cause a great impact at high latitude region. Kp index also shows high reading classified as large disturbance level occurred in the earth magnetic field. Even though Dst index continuously dropped, the reading remain as moderate storm classification and only related with low latitude region.

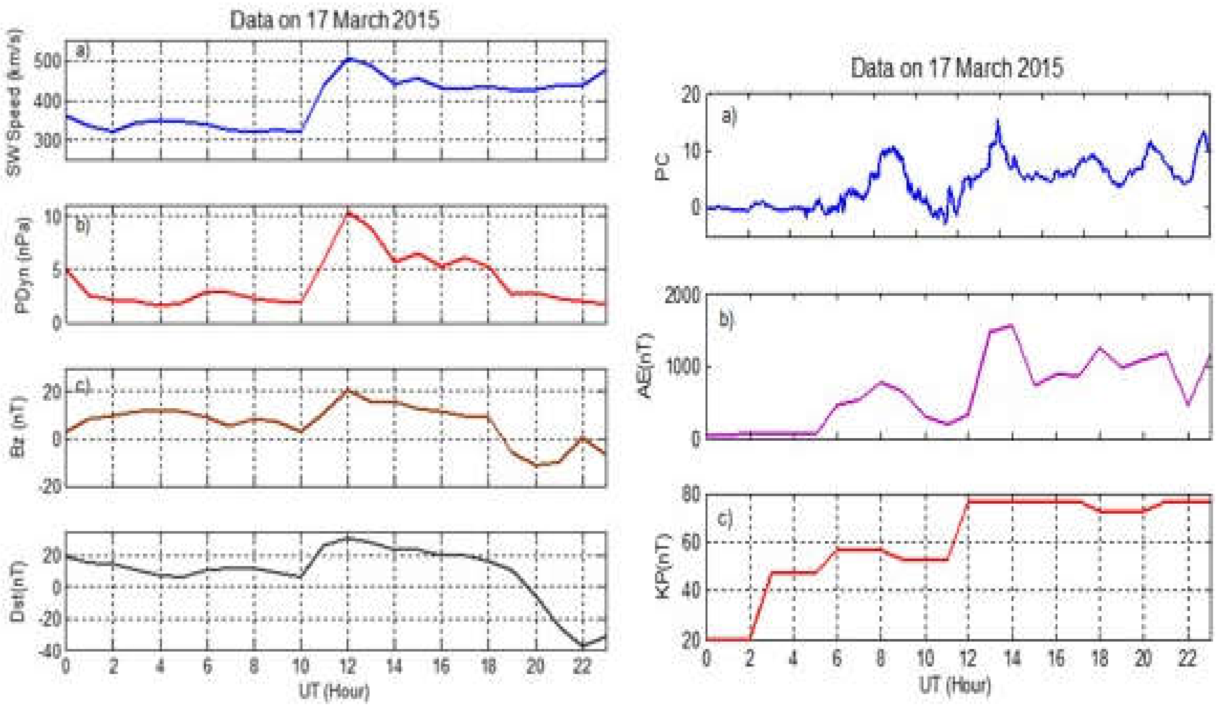

Fig.2. Solar wind parameter and geomagnetic indices parameter at 17 March 2015

The variation of H component at different region are based on the intensity of the region. GIC observation at CBB station shows highest reading since the Bz direction facing antiparallel to the earth and the energy transfer can be larger from solar wind to magnetosphere and ionosphere. A little increment of SW Pdyn may cause CYG station be the lowest reading of dH/dt. SW Pdyn are depend on N and Vsw, where the low pressure indicate a low momentum energy transfer from magnetosphere-ionosphere system and apparently does not affect mid-latitude region. Related to CH event, CBB station was more affected due to Bz direction. Meanwhile, API and GUA were affected due to Dst index continuously dropped of Dst index which represents the intensification of ring current after sudden impulse at 1000 UT. For case study 1, it can be concluded that the observation on GIC reveals that CBB station was significantly affected compared to CYG, API and GUA station due to huge penetration of input energy during CH event where high latitude has a direct geophysical effect from the space.

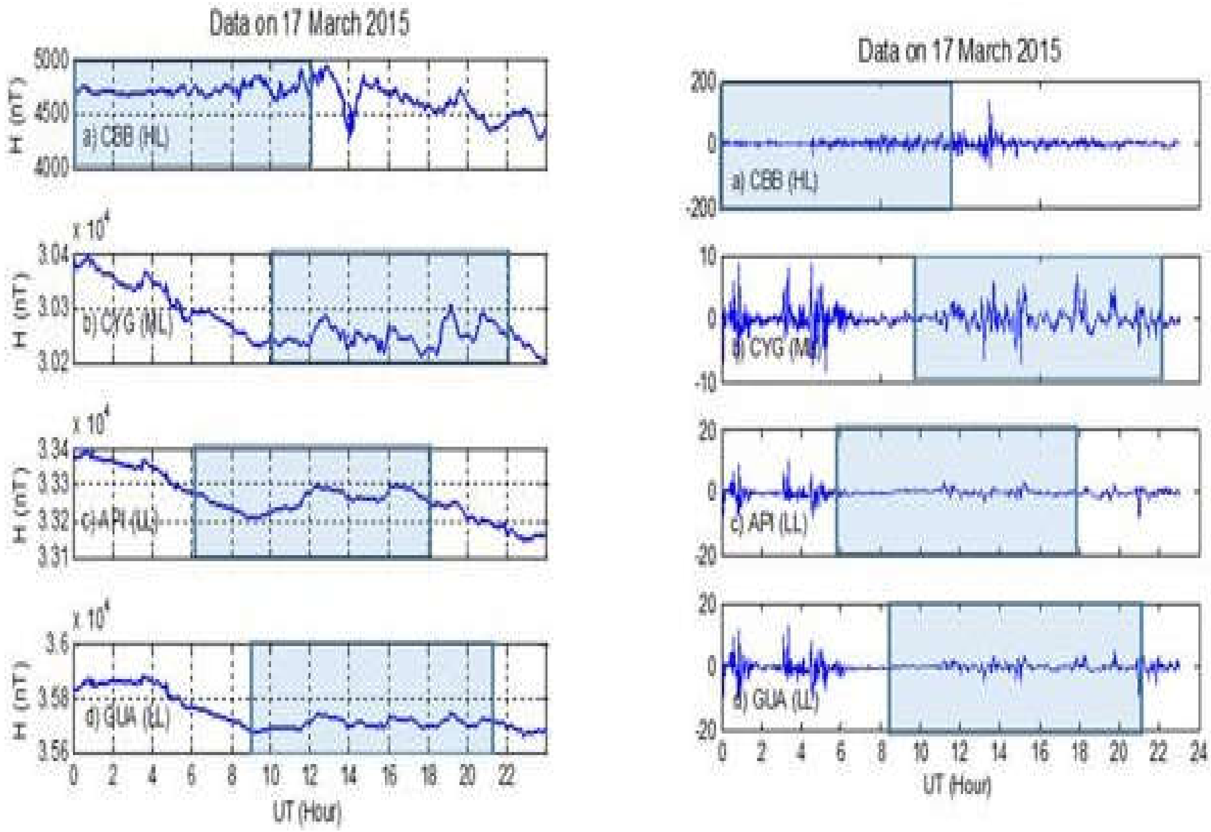

Fig.3. H component and time derivative of horizontal component dH/dt at 17 March 2015

3.2. Case Study 2: Coronal Mass Ejection Event

During period of case study 2, CME event occurred on 22 June 2015 [12]. The CME event is identified by rapidly rise trend of N, Vsw, B and T. The IMF Bz pointed southward, which made the high energy of charged particle to penetrate into the earth and the geomagnetic disturbance became more severe. The increment of PC index and AE index indicates high latitude region was significantly affected by the penetration of input energy. Since SW Pdyn is directly proportional with N and Vsw, the reading started to shot up at 1900 UT. SW Pdyn indicates a high energy of momentum along the interplanetary to magnetosphere and ionospheric in this case. Kp index and Dst index shows a reading that indicates the large disturbance and great storm respectively occurred during CME event.

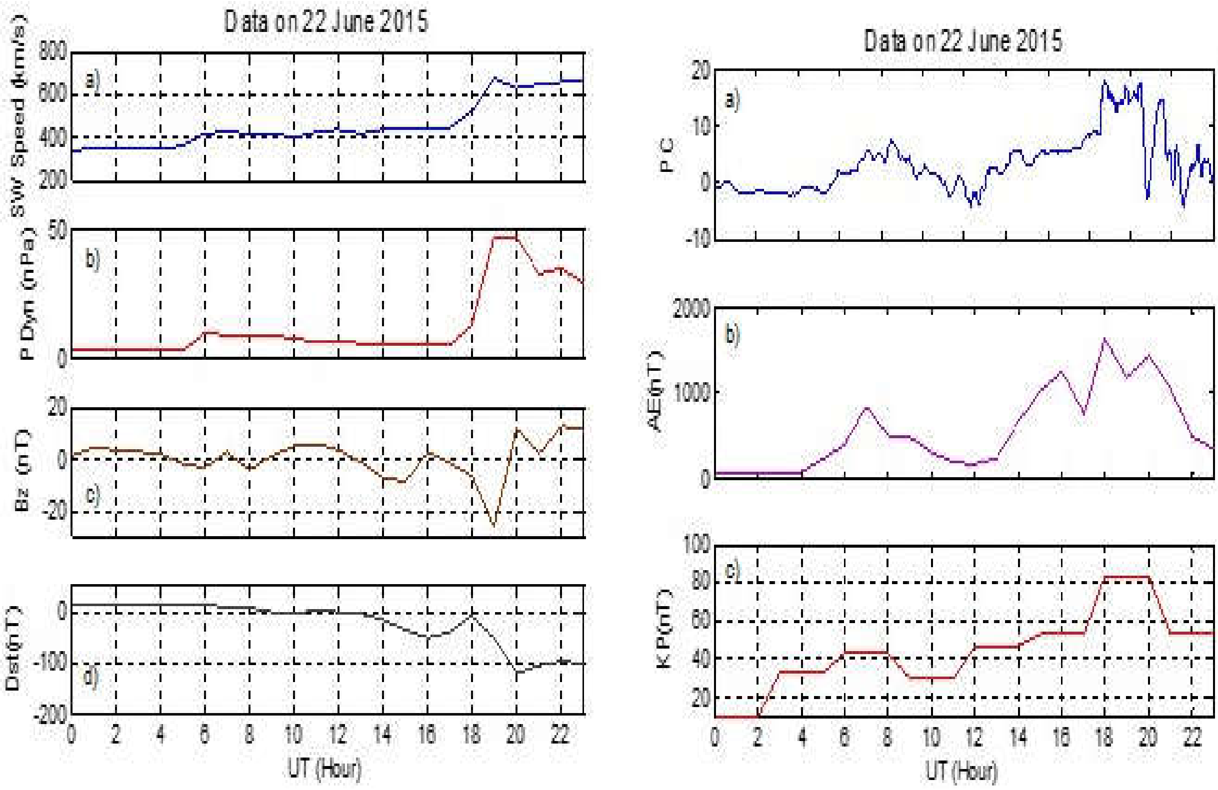

Fig.4. Solar wind parameter and geomagnetic indices parameter at 22 June 2015

H component reading varies due to the earth magnetic field intensity of the region. CBB station shows the highest reading of dH/dt due to SW Pdyn and Bz parameter. A very high energy of momentum transfer from solar wind into the earth affected the high latitude and mid latitude region instantly. Nevertheless, the reading of dH/dt at CYG station is lower than CBB station. API and GUA station, which are located at low latitude, also were significantly affected by the great storm occurred during CME event and it is represented by Dst index. According to case study 2, CBB station experience the highest reading of dH/dt due to high penetration of input energy where the penetration occurred from north to south. CBB station extremely affected by the penetration since the station located at north region. Powerful SW Pdyn that carry the momentum of input energy allowing the penetration occurred in great distance and also affected CYG station where the reading of dH/dt more than 30 nT. Meanwhile, Dst index declined to negative value and classified as great storm directly affected GUA station rather than API station due to location of GUA station nearest to equatorial region. Dst index is the parameter indicate storm at equatorial specifically may lead a little changes of dH/dt at low latitude region. The observation on GIC can be concluded the penetration of input energy together with a powerful SW Pdyn may allow a great penetration and may affected two region instantly.

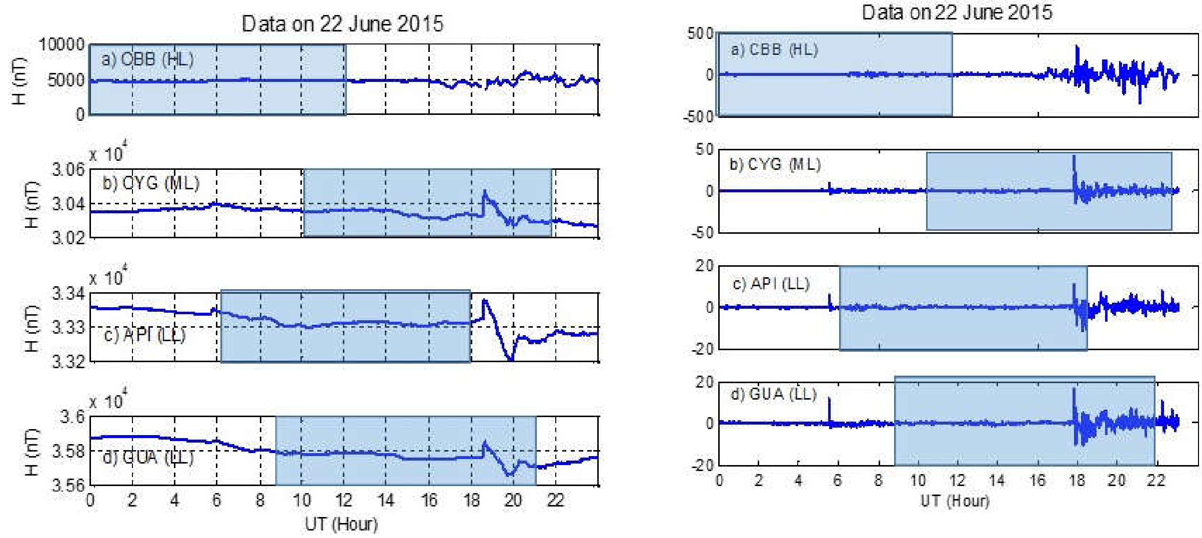

Fig.5. H component and time derivative of horizontal component dH/dt at 22 June 2015

3.3. Quiet Day (Sudden Impulse)

Case study 3 refers to a quiet day with a sudden impulse occurred at 23 December 2014. During solar quiet [23], the changes of solar wind parameter shows sudden impulse occurred at 1200 UT. On the same time, Vsw, SW Pdyn, Bz and Dst shows an increment and the direction of Bz facing north. Since Bz point northward, analogy said it is a closed system [24] with no penetration of input energy into the earth. Due to that, PC and AE index varies but it was considered as moderate storm at high latitude region. Kp index shows increment before occurrence of sudden impulse where it may affect mid-latitude region. Dst index shows a decrement starting 1200 UT and indicates a weak storm during that period.

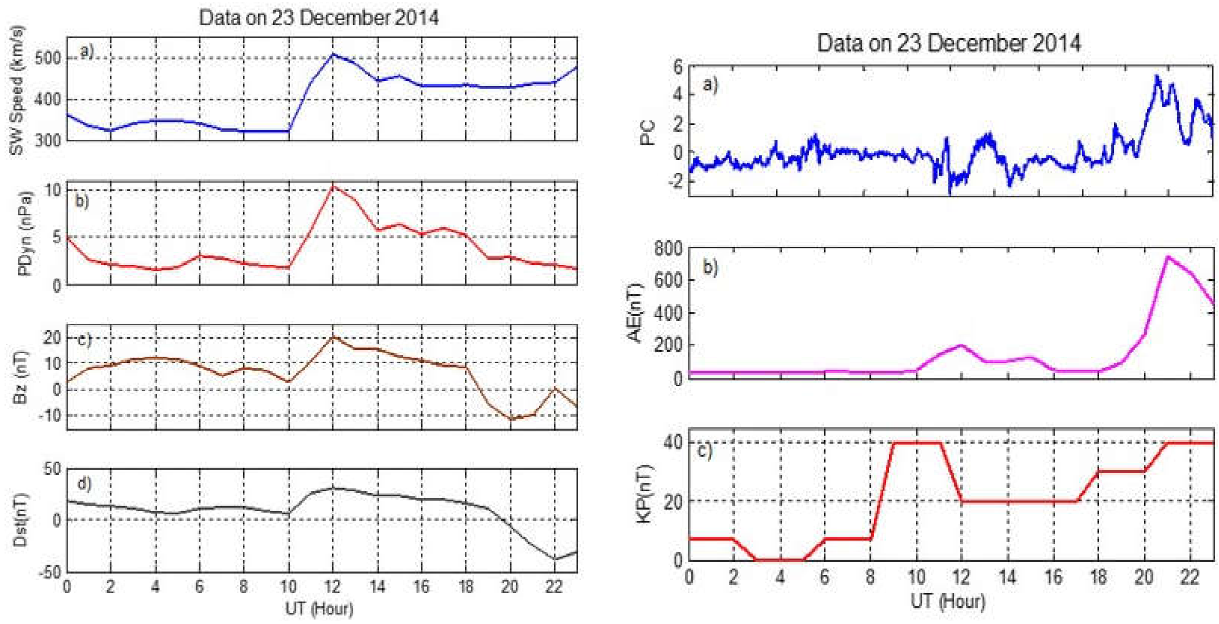

Fig.6. Solar wind parameter and geomagnetic indices parameter at 23 December 2014

The intensity of region make the reading of H component always varies in that proportion. As usual, CBB station shows the high reading of dH/dt since the moderate geomagnetic disturbance represented by PC and AE index. Kp index indicates warning storm at mid-latitude and lead to high reading of dH/dt at CYG station. However, at API and GUA station shows a relatively high reading even though the disturbance occurred was classified as weak storm. Related to observation on GIC purposes, low latitude reveal that the region could be influenced where the ground sudden increased associated to space weather [21] event can lead to high magnetic changes of dH/dt and increases the possibility of GIC on that particular region.

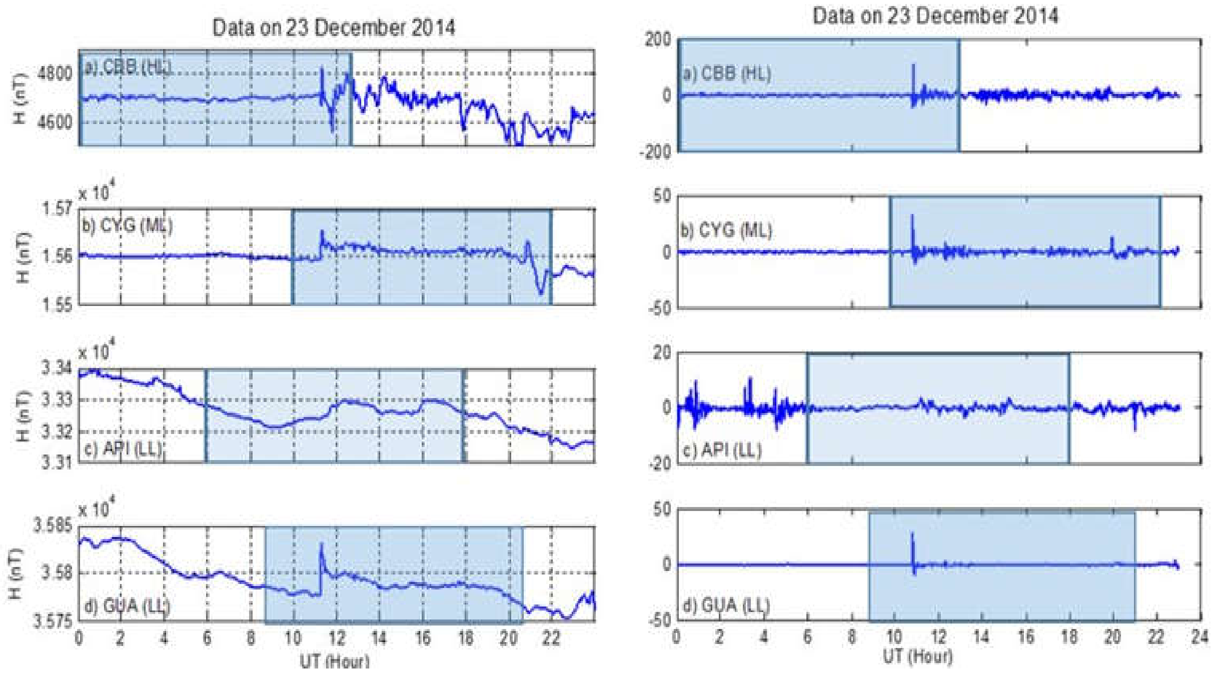

Fig.7. H component and time derivative of horizontal component dH/dt at 23 December 2014

4. CONCLUSION

The present work has been made to achieve a better understanding of solar wind parameters and their relationships with various geomagnetic indices during disturbed and quiet period. The variation of H component at different latitudes varies based on the intensity at particular region. Observation on GIC at different latitudes was done by referring the time derivation of horizontal geomagnetic field where the reading of dH/dt exceeding 30 nT indicates an occurrence of GIC [18]. Two events and single quiet day were investigated in a time interval of 1-hour data [20] for each event to examine the variations of solar wind parameters, geomagnetic indices and geomagnetic field, H component. Table 1 was represented a summary of result.

Table 1. Observation on GIC related to space weather event

Event	Maximum of dH/dt	Time
Coronal Holes (17 March 2014)	High latitude (CBB) = 134.4 nT	Morning
	Mid Latitude (CYG) = 08.60 nT	Noon
	Low Latitude (API) =10.570 nT	Noon
	Low Latitude (GUA) =13. 01 nT	Noon

Coronal Mass Ejection (22 June 2014)	High latitude (CBB) =343.7 nT	Noon
	Mid Latitude (CYG) =42.90 nT	Midnight
	Low Latitude (API) =10.77 nT	Noon
	Low Latitude (GUA)=16.99 nT	Noon
Quiet Day (23 December 2014)	High latitude (CBB) =105.7 nT	Dawn
	Mid Latitude (CYG) =32.36 nT	Dusk
	Low Latitude (API) =10.570 nT	Noon
	Low Latitude (GUA)=29.09 *nT*	Dusk

On the basis of observational results and discussions, important conclusions can be summarized. Higher variations of solar wind parameters and geomagnetic indices are due to the activities of CH and CME. A few parameter was highlighted in this study that play an important role related to GIC observational purposes. A huge solar wind input energy together with high solar wind dynamic pressure be the main cause toward the disturbance at geomagnetic indices parameter henceforth allowed the variation of dH/dt at high and mid-latitude. Another solar wind parameter that affect low latitude region represented by Dst index. High-speed solar wind together with great geomagnetic storm may cause low latitude region experienced disruption may increase the reading of dH/dt. As concluded, if Vsw and Dst index continuously increased, low latitude region will facing a risk where the reading of dH/dt also increase and may allow the penetration of geomagnetic current toward the region.

5. ACKNOWLEDGEMENTS

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