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The Analysis of the Geomagnetic Data during the installation of the First MAGDAS System at the Malaysian Space Agency

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***Abstract*— Magnetic Data Acquisition System (MAGDAS) is a system of the real-time magnetometer deploy by Kyushu University of Fukuoka, Japan as a part of the contribution to the International Heliophysical Year of United Nations[1]. The magnetometer used for real-time data acquisition is YU-8T SN-59, which is a part of the first model of the MAGDAS magnetometer. This paper discussed the characteristic of the magnetic data from the MAGDAS BTG and the possibility of the data to be used for further research study in the field of space and weather. There is 3 main magnetic field component from YU-8T magnetometer that describes the magnetic field which is Horizontal Intensity (H-component), Declination (D-component) and Vertical Component (Z-component). The installation of the MAGDAS system is located at Malaysian Space Agency (MYSA), Banting (BTG), Malaysia (geographic latitude and longitude: 2.78^{o}, 101.51^{o}, and geomagnetic latitude and longitude: 6.86^{o}, 174.10^{o}). The YU-8T magnetometer measures the earth's magnetic field in horizontal intensity(H), declination(D), and field down(Z). The magnetic field data were collected, analyze, and compared with the MAGDAS LKW, USM, and the World Magnetic Model (WMM) to verify the performance of the MAGDAS BTG. The importance of the study is to identify the reliability and characteristic of the magnetic data from the MAGDAS BTG in response to the solar event and GIC formation.**

***Index Terms*— BTG, MAGDAS, YU-8T, H, D, Z, WMM.**

I. Introduction

IN CONJUNCTION with the International Heliophysical Year (IHY; 2007-2009), the real-time Magnetic Data Acquisition System (MAGDAS) of Circum-pan Pacific Magnetometer Network (CPMN) was introduced by the International Centre for Space Weather Science and Education (ICSWSE), Kyushu University, Japan [1]–[3].

Based on space weather studies, the observation from space and ground is essential due to the importance of the data from both sources in the study of solar-terrestrial activity. In general, MAGDAS is the largest network of magnetometers that existed worldwide. There are more than 80 active stations of MAGDAS in the world [2], with seven MAGDAS stations present in Malaysia alone. Furthermore, the MAGDAS stations installed in Malaysia are classified into MAGDAS-II (MAG-II) and MAGDAS-9 (MAG-9).

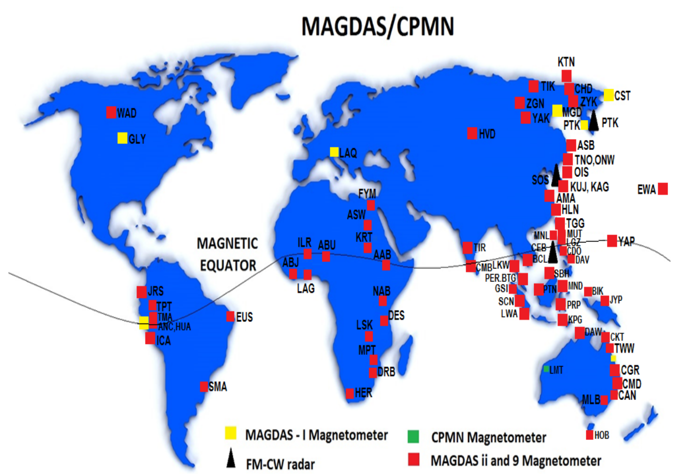

Fig. 1. MAGDAS Station around the world

MAGDAS system provides the ability to monitor the level of the surrounding magnetic field. From a scientific standpoint, the installation of the MAGDAS system allows for the monitoring and modeling of (1) the global three-dimensional current system, (2) plasma mass density, and (3) the penetrating process of polar electric fields into the equatorial ionosphere, allowing for a better understanding of the Sun-Earth coupling system and electromagnetic/plasma environment changes[4][5]. The influence of the solar storm will change the magnetic field level and trigger the formation of the GIC underground, which is dangerous and causes electrical appliance breakdown[6][7][8].

The activity of the magnetic field in MAGDAS station facilitates the estimation of the severity of the solar storm when

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an impact takes place[2]. Figure 1 presents the availability of MAGDAS networks worldwide. This paper discussed the characteristic of the magnetic data from the new MAGDAS station at BTG. The availability of the MADGAS system at BTG provides the possibility of conducting more research studies in the field of Space Weather in the area which is closed to the MAGDAS system including the study on GIC in Power Network and electrical equipment failure [1], [9]. Due to the relationship between Magnetic data and the formation of an underground geoelectric field[10], [11], the underground geoelectric field can be calculated based on the data from the magnetic field[11]. The installation of the MAGDAS system provides current trend observation of the magnetic field data and allows the study of the solar event and underground

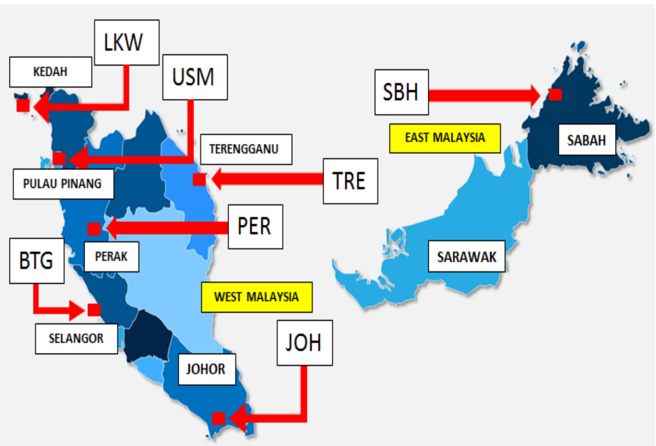

Fig. 2. The MAGDAS network throughout Malaysia.

geoelectric field[1], [2].

The deployment of the IoT data logger for MAGDAS system is to localize the process of data gathering locally in Malaysia without relying on the MAGDAS data gathered by ICSWSE. The data collected by ICSWSE is through a GPS antenna which is a link through the satellite system[1], [2], [4]. The data from the BTG MAGDAS will be compared with the MAGDAS from LKW, USM, and World Magnetic Map (WMM 2015-2019) to confirm the variance and reliability of the system. The first installed MAGDAS and the pioneer of all MAGDAS stations are the LKW located at Langkawi National Observatory (LNO), Kedah [2], [4], the installation of the MAGDAS LKW is on 4th September 2006 [4]. The selection of LNO as the pioneer station was based on its location, which was the nearest to the magnetic equator[2], [4].

TABLE I
GEOGRAPHIC AND GEOMAGNETIC LATITUDE/LONGITUDE OF MAGDAS STATION IN MALAYSIA

Station	GG.LAT(°)	GG.LON(°)	GM.LAT(°)	GM.LON(°)
LKW	6.30	99.78	3.30	172.44
SBH	6.02	116.07	3.56	188.66
BTG	2.78	101.51	6.86	174.10
PER	3.72	101.53	5.92	174.14
TRE	5.23	103.04	4.21	175.91
JOH	1.53	103.88	8.04	176.69
USM	5.12	100.00	4.32	173.07

GG.LAT(°) = Geographic Latitude, **GG.LON(°)** = Geographic Longitude, **GM.LAT(°)** = Geomagnetic Latitude, **GM.LON(°)** = Geomagnetic Longitude.

Seven magnetometer networks are present in Malaysia alone as a result of the collaboration between the International Center for Space Weather, Science and Education, Kyushu University, Fukuoka, Japan (ICSWSE), Malaysian Space Agency (MYSA) previously known as National Space Agency (ANGKASA), Universiti Teknologi MARA (UiTM) Shah Alam, and

Universiti Kebangsaan Malaysia (UKM). Figure 2 presents the availability of MAGDAS networks all around Malaysia.The coordinate of the MAGDAS station should be identified to determine the absolute value of the magnetic field based on the World Magnetic Map (WMM) [1], [4] and the location of the MAGDAS installation [4]. Table I presents the coordinate of each MAGDAS station in Malaysia.

II. METHODOLOGY

This section discussed the Magnetic Field component of the MAGDAS system, the installation of MADGAS at the ground station, the relationship of the solar event with MAGDAS data, and the relationship of the magnetic data with the formation of GIC. IEEE will do the final formatting of your paper. If your paper is intended for a conference, please observe the conference page limits.

A. Magnetic field Component of MAGDAS system

The YU-8T MAGDAS magnetometer is a three-component fluxgate magnetometer, with a sensitivity accurate to approximately 0.1nT[4]. The magnetometer measures the earth's magnetic field in terms of voltage. It also consists of three different devices, namely the sensor, pre-amplifier, and filter box. The sensor connects with the pre-amplifier in the middle of the filter box as a medium to filter noise[2], [4]. The signals from the pre-amplifier, namely the H, D, and Z components are then digitized to ADC form for analysis purposes[4]. To identify the real value and variance of the H,

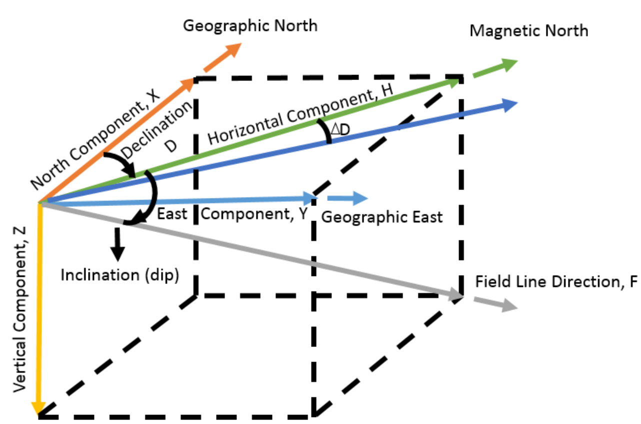

Fig. 3. Direction of the H, D and Z-component of the Earth's Magnetic Field

D, and Z of the magnetic field, the MAGDAS station needs to be installed. The H, D, and Z of a magnetic field represented the three-dimensional vector with geographic direction northward (X), eastward (Y), and vertical field (Z) [12]. Figure 3 shows the direction of H, D, and Z-component.

The formula (1) and (2)[7] can be used to calculate the value of the geomagnetic element. WMM gives you a thorough picture of the strength of the magnetic field in the world. In the presence of North Component (X-component), East Component (Y-component), and West Component (Z-component), the magnetic field strength direction of H and D-component can be calculated using formulas (1),(2), and (3).

$$H = \sqrt{X^2 + Y^2} \quad (1)$$

$$X = H\ COS\ D \quad (2)$$

$$Y = H\ SIN\ D \quad (3)$$

The magnetic field components of the X, Y, and Z components are 90 degrees apart vertically. The H-component is located between the X and Y-components. The angle between the X-component and the H-component determines the value of the D-component. The direction of the H-component determines the value of the D-component. The value of the D-component in degrees is converted to nanoTesla (nT) using the formula in (4).

$$D(nT) = H\ TAN\ D° \quad (4)$$

The intensity of a magnetic field can be measured in nanoTesla(nT)[7]. The following formula, stated in degrees, can be used to calculate the inclination or dip angle (5).

$$\frac{Z}{H} = TAN\ (I) \quad (5)$$

The magnetic field in the north-south direction is represented by the H-component value. The magnetic field's north pole is naturally drawn to the northern arctic area by the Earth's dipole field. Delta H (dH), delta D (dD), and delta Z (dZ) were used to represent fluctuations in the magnetic field in the H, D, and Z-components, respectively. The overall field (F + dF) was calculated using the components (H + dH), (D + dD), and (Z + dZ)[2].

B. Installation of MAGDAS at BTG ground station

On 19th October 2019, an installation of the MAGDAS system has been deployed at the MYSA/BTG. The installation of MAGDAS at MYSA/BTG is conducted to study the variation of the Magnetic field at the Selangor area, which differed at each location due to the H, D, and Z-components of the magnetic field. MYSA/BTG was selected as the new location of MAGDAS installation due to the location is far from human activities. Noise from the surrounding area causes the fluctuation of the magnetic field to become higher and unstable. The criteria of the location for MAGDAS installation are 1) the distance from the sea is more than 1000 meters 2) the distance from the building and road is more than 100 meters. During the installation of the MAGDAS system at the MYSA/BTG, the nearest housing area is 513 meters to the northeast and the nearest road to the area is 635 meters to the west-south from the location where the MAGDAS system is deployed. Figure 4 shows the location of the deployed MAGDAS system in MYSA/BTG. World Magnetic Model (WMM) is the standard model of the geomagnetic field, which is produced at a five-year interval, with the current model expiring at the end of 2019. The WMM is changed two times in a decade due to the unpredictable non-linear changes in the earth's magnetic field. The range of the magnetic field based on the WMM in Malaysia is illustrated in **Appendices**. The source of the magnetic data is taken from the National Oceanic and Atmospheric Administration (NOAA)[2]. Based on the magnetic data from WMM, the value of the H-component in Malaysia is normally in the range of 40000 nT and above [4], while the declination intensity, which is the D is near 0 nT. The value of Z which is field down varies from -10000 nT to 10000 nT.

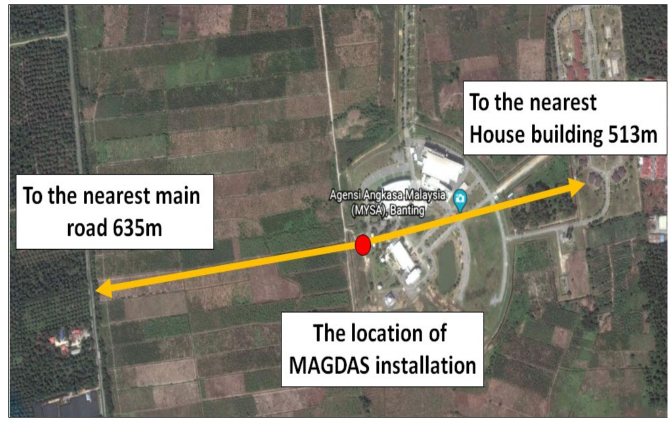

Fig. 4. Location of the deployed MAGDAS system at BTG/MYSA

The YU-8T MAGDAS system consists of a sensor, the pre-amplifier, and a data logger with a filter box and cloud-based data gathering system [1], [2], [4]. The data logger and cloud server were self-developed to facilitate the data gathering method from the ground station. During the MAGDAS deployment, the pre-amplifier and the data logger are placed inside the small building as illustrated in Figure 5. This helps prevent the data logger from being exposed to the water which might limit the lifespan[4]. The small building is equipped with the light main DB, power source, light switch, internet (LAN) socket, and ventilation system. The sensor of the MAGDAS places 50 meters away from the small building to prevent more noise which might interfere with the magnetic field reading[4]. The sensor is placed inside a one-meter underground Hut. This helps to provide a more reliable MAGDAS study on the

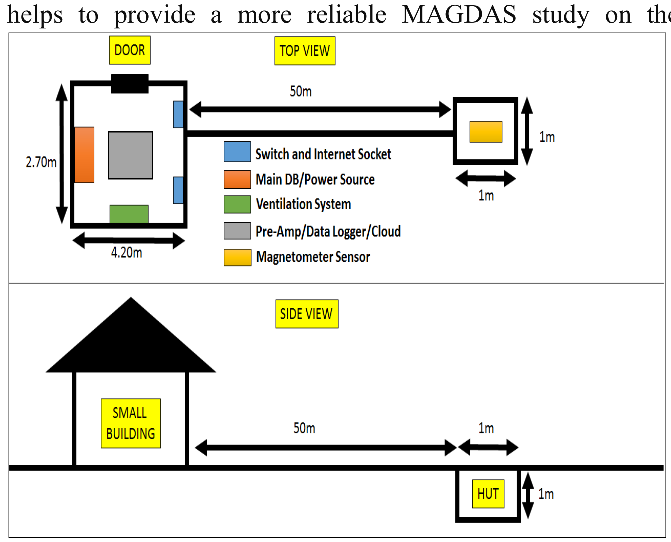

Fig. 5. The architecture of the MAGDAS system deploy at BTG/MYSA

penetration process of polar electrical fields into the equatorial ionosphere, real-time modeling and monitoring of global 3D current systems, and the plasma mass density[4]. Figure 5 is the architecture diagram of the YU-8T MAGDAS system deploys at MYSA/BTG.

A suitable location near the station should be identified within the cable length of the sensor to place the YU-8T sensor. This location must be free from all ferromagnetic objects, vehicle traffic, and other sources of magnetic disturbances[1][2][4].

C. The Relationship of MAGDAS and Solar Event

Solar activities, such as solar storms are natural phenomena of the sun with significant impacts on the earth including magnetic fields, underground pipeline systems, and electrical equipment among others [1], [9]. The main attribute of the solar storm is the solar wind, which impacts the earth through a collision with the earth's magnetic field [13]. The solar wind consists of electrons and protons in the plasma state, which consistently flows out from the sun in a similar way as the solar magnetic field [14], [15]. The production of the densities and speed from the solar wind varies based on the regions of the sun. Specifically, the speed of the solar wind could consist of two ranges, namely below 400 kms^{-1} and between 400 and 800 kms^{-1}[2].

The solar wind with a speed below 400 kms^{-1} is known as the low-speed solar wind, while the speed range of 750 to 800 kms^{-1} is known as high-speed solar wind [2]. The geomagnetic activity at high latitudes is significantly efficient at high-speed solar wind streams (HSSs). Figure 6 illustrates the solar phenomenon on the 26th of October 2019 during the MAGDAS installation. Figure 6 above shows large corona holes from the sun, which are naturally produced from solar activities. As a result of the solar wind plasma, the interplanetary magnetic field (IMF) lines across the sun are solidified [15]. Similar to the phenomenon of the solar wind, which flows out of the sun in a swirling pattern with low and high speed due to different densities, the IMF is normally present due to the sun pivot [2], [9], [16].

Additionally, the IMF is formed in an open magnetic field spot, where field lines rise in one area. However, it would never return to that particular area. The fast solar wind, which flows at 750 to 800 km s along open magnetic field lines anchored in polar coronal holes, occupies most of the heliosphere, according to Feldman et al.[17], whereas the slow wind is confined to the low-latitude belt 15[17]. Then, Sheeley et al. found that coronal holes are unmistakably linked to high-speed streams and the periodic geomagnetic disturbances they cause[17]. The findings substantially support the theory that high-speed streams seen in the solar wind near the ecliptic plane are caused by coronal holes.

Antonucci (2000) investigated the outflow velocity of high winds during minimum in the northern polar coronal[17]. The solar wind is thought to originate near the sun's surface. Its speed, however, cannot correspond to faraway impressions of its origin because it is fundamentally faster over the solar surface[17]. Even though the stream of kinetic characteristics

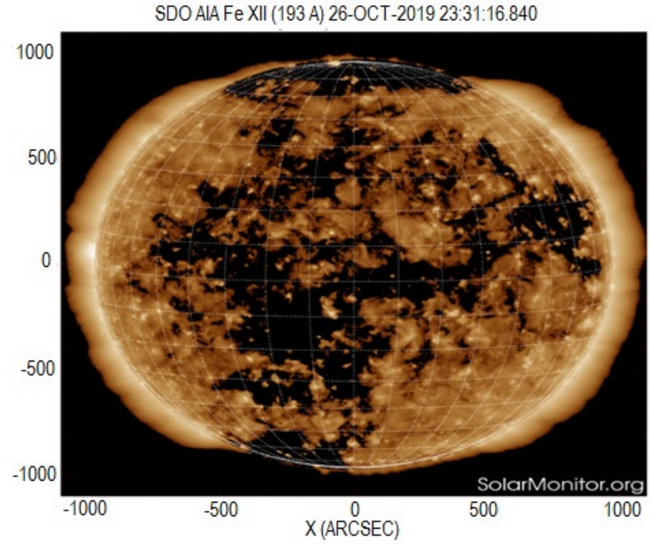

Fig. 6. The solar phenomenon from the sun. (Source of Phenomenon: https://www.solarmonitor.org/full_disk.php?date=20191026&type=saia_00193&region=%29)

may change as the result of the dynamic collaboration between the high and moderate solar wind, basic and charge synthesis remains unaffected. It transmits essential information regarding small-scale features of coronal gap boundaries near the Sun.

D. The Relationship of MAGDAS and Solar Event

The activity from the solar event will affect the magnetic field as well as the geoelectric field formation of the earth. This is due to the Sun-Earth coupling system and electromagnetic/plasma environment changes[4], [5]. The formation of Geomagnetic Induced Current (GIC) from the underground will move towards the grounded electrical equipment and pipeline system[1], [9]. In the power network, the formation of GIC moved between the earth and the network through the grounding system[11], [18], [19]. By deploying the MAGDAS system, the horizontal component of the geoelectric field can be identified by applying the plane wave assumption. Based on plane wave assumption, the value of the horizontal component of the geoelectric field can be determined from the perpendicular geomagnetic field component[11], [20]. The GIC formula in the time domain can be expressed as shown in (6).

$$GIC(t) = \alpha E_x(t) + bE_y(t) \tag{6}$$

Based on the given GIC expression, the E_x is north component of the geoelectric field and E_y is the east component of the geoelectric field. While α and b is the constant coefficient which depends on the electrical parameter and topology of the power system[11], [20]. The coefficient determination required information from network geometry, station coordinate, transformer resistance, transmission line resistance, and station earthing system[11], [20]. The study on GIC in Malaysia is in the early stage and the research on GIC formation in various fields including in power networks will provide information on the threshold limit of GIC in Malaysia. The author has conducted measurement at the neutral cable of the 33kV transformer to identify the possible GIC formation and

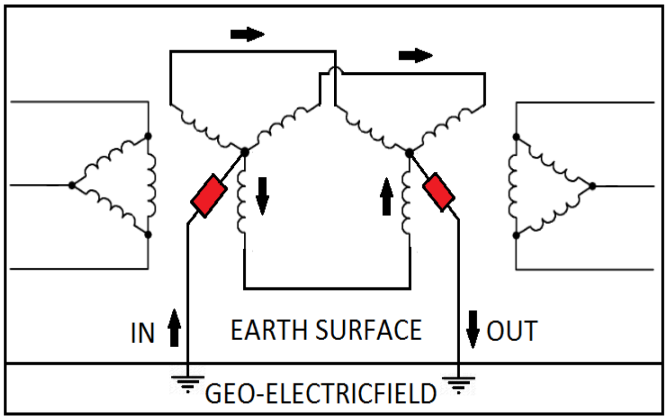

Fig. 7. The illustration of geoelectric flow from the underground to the three-phase transformer

comparing with geomagnetic perturbation data. Figure 7 shows the illustration of the geoelectric flow from the underground to the three-phase transformer.

The location of GIC measurement is located at Hotel UiTM Shah Alam having geographic latitude and longitude: 3.117N, 101.00E and geomagnetic latitude and longitude: 6.26S, 173.65E. The distance between BTG MAGDAS station (geographic latitude and longitude: 5.117N, 100.00E and geomagnetic latitude and longitude: 4.32S, 173.07E) and GIC measurement location is 31.35 KM. The result from the measurement is discussed in the result and discussion section

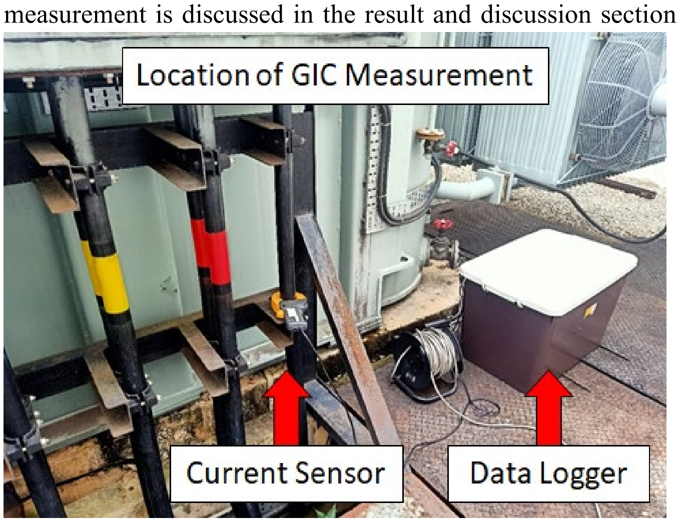

Fig. 8. The Location of GIC measurement at the three phase transformer

which comparing the data from the GIC measurement and BTG MAGDAS data. Figure 8 shows the location of the GIC measurement at the TNB substation 33KV three-phase transformer.

III. Result and Discussion

The result discussed in this section is based on the data of the magnetic field parameter collected from MAGDAS BTG, LKW and USM. It is followed by a discussion, which compares the variation of the magnetic field parameters with the solar event data due to the correlation between both data. The geomagnetic disturbance resulted in a high fluctuating current in the ionosphere and magnetosphere, which altered the level of the geoelectric field underground [1]. The high level of the geoelectric field would cause a formation of geomagnetic-induced current, which harmed electrical appliances [21].

A. Comparison of MAGDAS data from BTG, LKW, and USM

The magnetic field parameter data from BTG was compared with the data from MAGDAS LKW and USM. There was a difference in the actual absolute values due to the location of the installation, which was BTG at a geographic and geomagnetic latitude/longitude of 2.78°, 101.51°; 6.86°, and 174.10°**,** LKW was located at the geographic and geomagnetic latitude/longitude of 6.30°, 99.78°, 3.30°, and 172.44°**,** and USM was located at the geographic and geomagnetic latitude/longitude of 5.12°, 100.00°, 4.32°, and 173.07°. It was observed that the magnetic field variation of MAGDAS BTG, LKW, and USM were similar in pattern, the similarities in the magnetic variation of MAGDAS BTG and LKW H(nT) is 74.49% while D(nT) at 35.35% and 35.94% for Z(nT).

The magnetic variation similarities of MAGDAS BTG and USM H(nT) is 85.38%, 52.24% for D(nT) and 52.87% for Z(nT). Based on Figure 9, the average H(nT) BTG amounted to 41237.3 nT, 41665.2 nT at LKW, and 41566.1 nT at USM. The H(nT) was based on the location of the deployment of the MAGDAS system. Although a similar pattern was observed from both BTG, USM, and LKW H(nT), several differences were present in the plotted graph, such as the peak value of H(nT) during daytime and the minimum value at nighttime. Based on Figure 9, the average reading of D(nT) BTG amounted to 2.308 nT, while the reading for D(nT) LKW was 6.528 nT and D(nT) USM at 4.418 nT.

Notably, the pattern of the MAGDAS D(nT) was almost similar although higher spikes were seen from LKW D(nT) compared to BTG and USM D(nT). All three MAGDAS station average D(nT) is near to zero due to the location is closed to the equator region[4]. Based on Figure 9, the D(nT) from BTG, LKW, and USM are similar in pattern from 19th to 27th October 2019. The pattern of the H, D, and Z(nT) produce more fluctuation from 24th to 27th October 2019. During a geomagnetic disturbance, the sun and magnetosphere/ionosphere coupling gives rise to rapid magnetic field changes[9]. Based on Figure 9, the value of Z(nT) BTG amounted to -7624.35nT, while the value of Z(nT) LKW amounted to -1586.7nT and USM Z(nT) at -3611.64 nT. The pattern of the Z(nT) from BTG, LKW, and USM is similar unless on the small segment such as on noon 21st October 2019 and on 24th to 27th October 2019.

The noise level from MAGDAS BTG is higher compare to the LKW and USM which might be due to the location of the installation which is closer to the human civilization[2][4]. The variance value of the BTG Z(nT) during peak daytime was higher compare to the LKW and USM Z(nT) from 19th to 22nd October 2019. The value of H, D, and Z(nT) were based on the location of the deployment of the MAGDAS system, the reading of the H, D, and Z(nT) was within the range of the absolute value provided by WMM. Figure 9 shows the level of H, D, and Z(nT) from MAGDAS BTG, LKW, and USM from

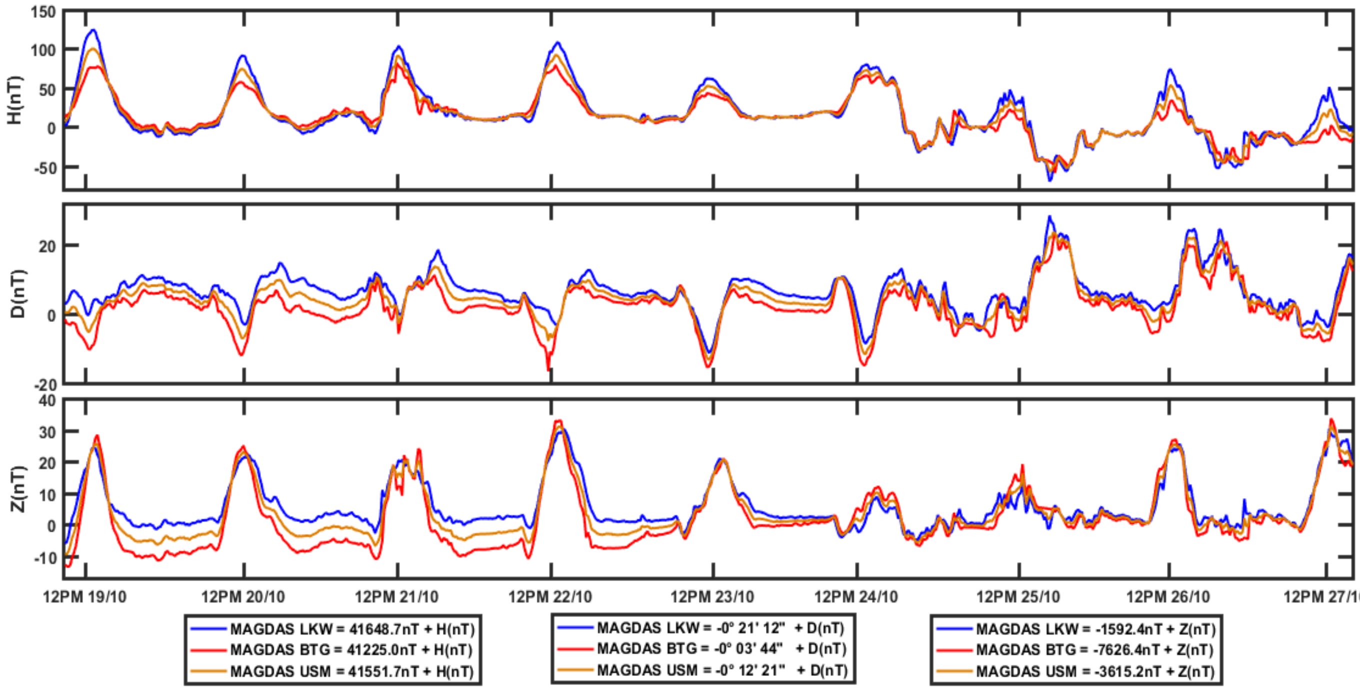

Fig. 9. The Level of H, D and Z(nT) from MAGDAS BTG, USM and LKW MAGDAS station from 19th to 27th October 2019

19th to 27th October 2019. Despite the similarity between the patterns from magnetic field parameters, a difference was also present in the plotted graph, such as spikes, peak, and minimum reading. The location of the MAGDAS installation from MAGDAS BTG is more exposed to noise from buildings, roads, and human activity compare to the MAGDAS USM. This pattern might change due to interference by human activities. It was indicated from the MAGDAS data observation that the data from MAGDAS BTG exhibited a similar feature in magnetic field variance compared to the MAGDAS data from USM and LKW. The identification of an accurate value from the MAGDAS data, a comparison of the data with WMM should be performed. WMM consist of the earth's magnetic field pattern illustrated on the World Map. Table II summarises the geomagnetic data H, D, and Z-component values collected from MAGDAS station BTG, LKW, and USM plotted in result and discussion and from WMM.

TABLE II
SUMMARY ON THE H, D, AND Z-COMPONENT MAGNETIC FIELD VALUE FROM BTG, LKW, USM AND WMM

MAGDAS Station/ WMM	Horizontal Intensity, H	Declination, D	Vertical Down, Z
BTG (nT)	41237.29	93.11	-7624.36
LKW (nT)	41665.21	264.68	-1586.72
USM (nT)	41566.10	162.31	-3611.64
WMM (BTG coordinate)	41225.0	90.80	-7626.40
Similarities of BTG H(nT) and WMM (%)	99.97	97.52	99.97
Similarities in Variance of BTG H(nT) and LKW (%)	74.49	35.36	35.94
Similarities in Variance of BTG H(nT) and USM (%)	85.38	52.24	52.88

BTG = Banting, LKW = Langkawi, USM = University Sains Malaysia; WMM = World Magnetic Map.

B. Analysis on MAGDAS data with Solar Event data

The fluctuation of the solar event parameter could be observed from the plotted graph of the interplanetary magnetic field (Bz), solar wind speed, and solar flow pressure. Due to the coupling between solar storm, interplanetary magnetic field, ionospheric and magnetic field parameters[22], the interplanetary magnetic field is said to be solidified into the sun based on the solar wind plasma. The sun pivot causes IMF, similar to the solar wind[2]. Moreover, MAGDAS was performed for a scientific purpose, which was to study the real-time monitoring of geomagnetic data, plasma mass density, and penetration process of the polar electric field into the equatorial ionosphere [23], [24]. The Bz recorded from the previous measurement conducted at the TRE MAGDAS station is between -12 to 11nT[2].

The value of Solar wind speed was recorded between 373Km/s to 667Km/s. A speed below 400Km/s is considered low-speed solar wind while more than 400Km/s is considered as high-speed solar wind[2], [25], [26]. The value of solar wind flow pressure from 19th to 23rd October 2019 is from 1.28 to 5 nPa. However, from 24th to 27th October 2019 the flow pressure fluctuated more and produce the highest flow pressure reading on 24th October which is 10.02 nPa. The previous solar wind flow pressure recorded at TRE MAGDAS station is around 1.28 to 10.02 nPa[2]. According to the symmetrical index data (SYM/H) from the solar event, the plotted graph was stable from the 19th to 23rd of October 2019. However, a fluctuation of the

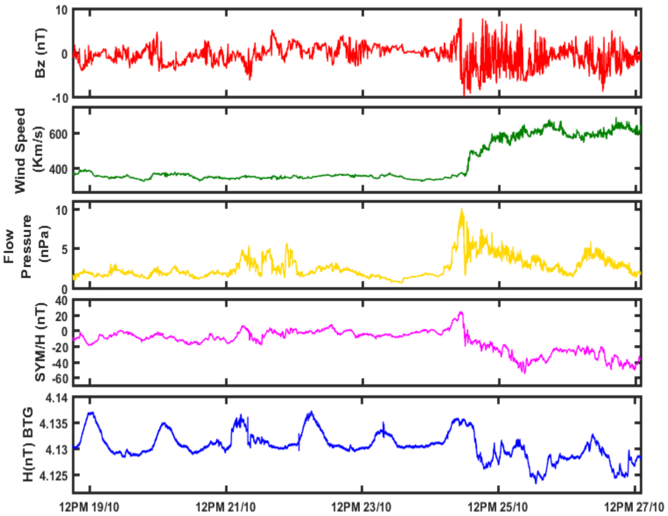

Fig. 10. The plotted data of Interplanetary Magnetic Field(Bz), Solar Wind Speed and Flow Pressure from solar event

data from the symmetrical index began from the 24th to 27th of October 2019. Figure 10 presents the plotted data of the interplanetary magnetic field (Bz), solar wind speed, and solar flow pressure. Based on Bz measured on 19th to 23rd October 2019, the reading in between -5.8 to 5.1nT and from 24th to 27th October 2019 is between -9.2 to 9.43nT.

Furthermore, the reading from the symmetrical index was nearly from the 19th to 23rd of October 2019, followed by its fluctuation from the 24th to 27th of October 2019. SYM/H was a part of the solar event parameters, which were influenced by solar activities [27], [28]. Based on Figure 10, which presents the comparison between the SYM/H index and H(nT) from the BTG MAGDAS station, the highest reading of SYM/H was present from the 24th to 25th of October 2019. In this case, the reading of the solar wind abruptly increased, as shown in Figure 10. After the decrease in the SYM/H, a uniform increase in it took place until the 1st of November 2019.

The fluctuation of the data from MAGDAS BTG increased from the 24th to 27th of October 2019, leading to an unstable reading of the H(nT). Therefore, it was clear that the reading of H(nT) was lower compared to the normal H(nT) reading. Based on the data collected from the solar event, there is a significant impact of the solar storm towards the variation of the magnetic field reading collected from the MAGDAS BTG. This was followed by further fluctuation from 24 October 2019 until 27th October 2019, which ranged from -9.2nT to 9.43nT. However, the speed of the solar wind from the 19th until the 23rd of October 2019 was lower than 400 km/s and higher than 600 km/s on the 24th and 25th of October 2019. Solar flow pressure also fluctuated further from the 24th of October 2019 until the 1st of November 2019.

C. Analysis of MAGDAS data with GIC formation

Based on the graph plotted on MAGDAS BTG and GIC data in Figure 11. It is observed that the measurement consists of positive and negative values. The data was acquired via the 33KV transformer's neutral cable. There was a variation on both the positive and negative sides of the statistics based on the data collected. The GIC value is the highest during the daytime following the increment of the magnetic field variance value. This is due to the higher number of electrically charged particles in the ionosphere and magnetosphere. The highest GIC data is on

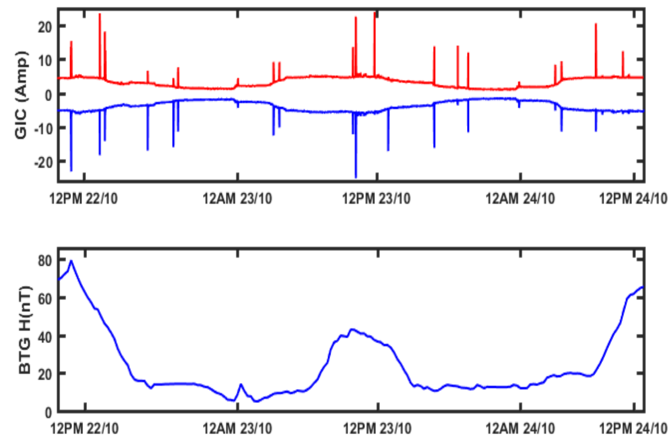

Fig. 11. Comparison between GIC measurement and MAGDAS BTG data

12 PM 22nd, 23rd, and 24th October 2019. There are small spikes existed on the measurement data of the GIC. On 12 PM 23rd October 2019, the bigger spikes existed which happen on both GIC measurement and MAGDAS data. Figure 11 compares the data from GIC measurement with the data from MAGDAS BTG.

This phenomenon causes a sudden increase in GIC value which is harmful to the transformer. According to T.J. Overbye and K. S. Shetye, the quasi-dc GIC causes an offset on the regular AC current in high voltage transformers, which can lead to half-cycle saturation[3]. As a result, the existence of the GIC is due to a mixing of AC current and the GIC. The positive current spikes as high as 24 Amps and the negative current spikes as high as -25.2 Amps, according to the data gathered. According to C. Barbosa and L. Alves, GIC data from solar cycles 23 and 24, which include 270658 data points, only 219 of which exceed 10A, the GIC values vary from 1 to 30A [11].

The research was carried out in a low-latitude zone, and the readings were in the form of a spike, as well as readings taken from the GIC measurement. The whole data gathered from positive current is 190107, and the total data that exceeds 10Amps is roughly 17 data, while the total data collected from negative current is 190107, and the value that is less than -10A is 22 data. As a result, the measurement data produces spikes that are damaging to the transformer's operating system. This spike could result in transformer saturation, heating, missed operations, and transformer core winding burn[17].

The presence of the MADGAS system at BTG allows further research in the subject of Space Weather to be conducted in the area surrounding the MAGDAS system, such as studies on GIC in Power Networks transformer and electrical equipment failure[1], [9] . The subsurface conductivity can be determined using data from the magnetic field because of the link between magnetic data and the production of underground conductivity[10], [11]. The study related to the application of magnetic field data is suitable for the location of which is near to the MAGDAS station[4], [17]. The variance of the magnetic field is almost similar in MAGDAS system Malaysia, there are small differences in variance value of the MAGDAS system. This causes differences in underground geoelectric field calculation from each MAGDAS station. The differences in the earth crust cause differences in underground conductivity value[11].

IV. Conclusion

The MAGDAS station at BTG was successfully deployed and the MAGDAS data can be collected for the research related to the space and weather study. As a result, stable readings of H, D, and Z were obtained, which were within the range of WMM and able to produce magnetic variation according to the real reading of the magnetic field value. Therefore, the reading from the MAGDAS BTG is suitable for magnetic field data observations and studies related to the space weather perturbation such as the study related to underground current and solar event data. For future research, the author attempts for a measurement of the possible backflow current at a 275KV high voltage transformer.

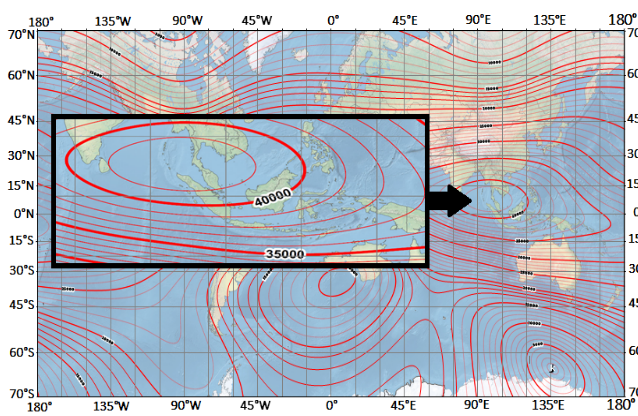

Fig. 12. The Mercator Projection for Horizontal Intensity (H)

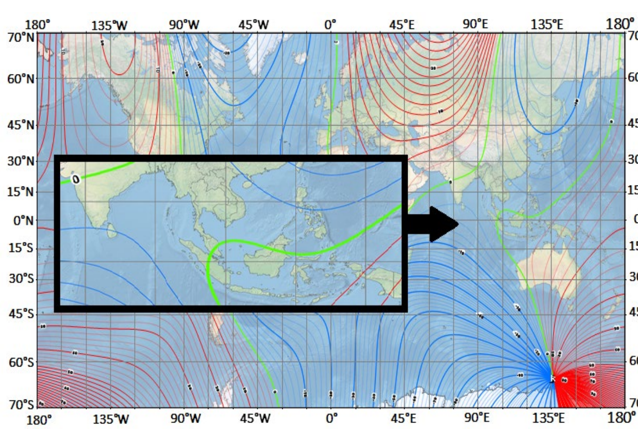

Fig. 13. The Mercator Projection for Declination (D)

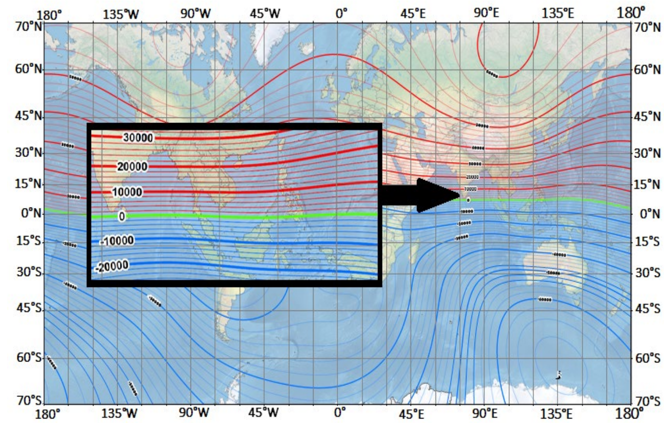

Fig. 14. The Mercator Projection for Vertical Down (Z)

Appendix

The Mercator projection of World Magnetic Model 2015-2020 (WMM2015) of H, D, and Z presented in Figure 12, 13 and 14. The Mercator projection of the WMM2015 map is in the range of 70^{O}S to 70^{O}N of geomagnetic latitude and longitude.(Source:https//www.ngdc.noaa.gov/geomag/WMM/image.shtml)

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MAGDAS/CPMN (Magnetic Data Acquisition System/Circum-pan Pacific Magnetometer Network) system of the SERC, Kyushu University deploying the largest Magnetometer network worldwide. The importance of the MAGDAS system is to study the activities and the physics of the Earth's magnetosphere and several types of measurements made with different instruments both on earth’s and space.