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An Experimental Magnetotelluric Short Sounding During High Sun Spot Activity Cycle in 2013

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ABSTRACT

Sun spot activities during the last decades reached their maximum in 2001 and the next peak is predicted in 2014. Year 2013 was a good time to run magnetotelluric (MT) surveys. An experimental MT short sounding was carried out in Waypanas, Ulubelu, Lampung, Indonesia. Phoenix system MTU-5A recorders, high gain MTC-80H magnetic coils, and non-polarized porous pot were used. A three-hour MT sounding was run in the afternoons in March-April 2013. The time series data are transformed into the frequency domain to produce MT impedance directly in the field. An MT record with frequencies ranging from 320 down to 0.0013 Hz was successfully obtained. The high frequency data set easily collected a large number of excellent cross-powers while the low frequency data set contained a rather limited amount of cross-powers, however most of them were good. With only a few bad cross-power rejections, excellent MT curves was produced. The data shows continuous curves of rho-xy, rho-yx, phase-xy phase-yx. The error bars of the curves are negligible or very small. This experiment shows that conducting a cost effective MT survey is possible when MT signals are strong.

1. INTRODUCTION

Magnetotellurics (MT) is a passive geophysics exploration technique that utilizes a broad spectrum of naturally occuring geomagnetic variation as a power source for electromagnetic induction in the earth. The penetration depths of electromagnetic fields within the Earth depend on the electromagnetic sounding period on the Earth conductivity structure. MT technique involves the measurement of fluctuations in the natural electric **(E)**, and magnetic **(B)**, fields in orthogonal settings at the surface of the Earth as a means of determining of conductivity structure of the Earth at depths ranging from a few ten meters to several hundred of kilometers (Simpson and Bahr, 2005).

There are two kind of signal sources in MT technique, i.e. sources with frequencies higher than 1 Hz comes from meteorological activities such as lighting discharge and sources with frequencies lower than 1 Hz comes from solar wind activities. Interaction between the solar wind (Parker, 1958) and the Earth's magnetosphere-ionosphere generate electromagnetic fluctuations with frequencies lower than 1 Hz. Solar wind is a continual stream of plasma, radiating mainly protons and electrons from the Sun. On encountering the terrestial magnetic field at the magnetopause, these protons and electrons are deflected in opposite directions, thereby establishing an electric field (Figure 1).

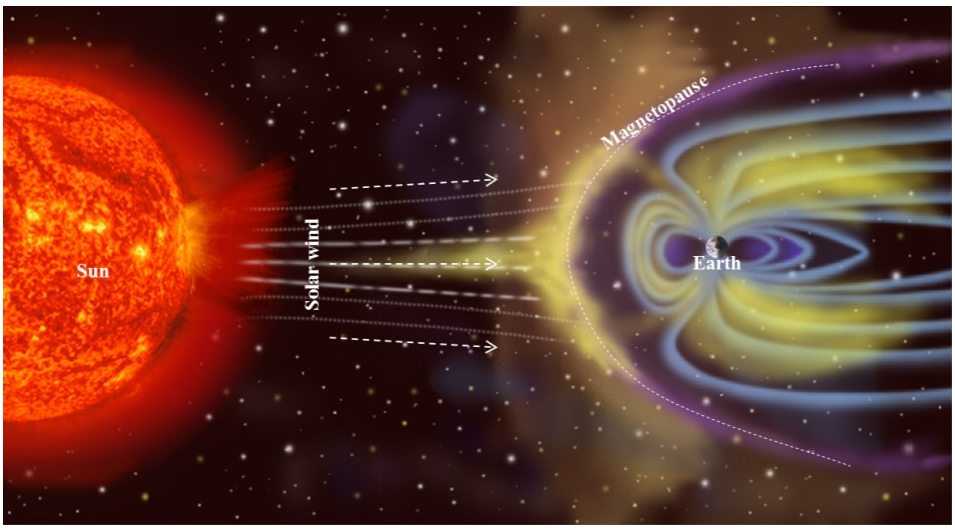


Figure 1. Solar particel from Sun interact with Earth magnetosphere (modified from www.wikipedia.org/wiki/file:magnetosphere_rendition.jpg)

Variations in density, velocity and magnetic field intensity of solar wind produce rapidly varying distortions in the Earth magnetosphere. Increasing in solar wind pressure causes rapid compression of magnetosphere, and therefore compaction of magnetic lines, affecting an increase in the horizontal geomagnetic field. In MT measurement with increasing horizontal magnetic field, makes the signal to noise ratio in magnetic variation value in MT measurement increase. This allows for higher possibilities to get good quality data in MT results. Solar magnetic/solar radiation activity periodicly change in the Sun, and its appearance displays visible changes due to the number of sunspots activities. Solar cycles have an average period of about 11 years. NASA periodicly observed sunspot activity for hundreds of years. In this decade, NASA observed and predicted peaks of Sun spot activity in 1990, 2001, and 2014 as shown in Figure 2.

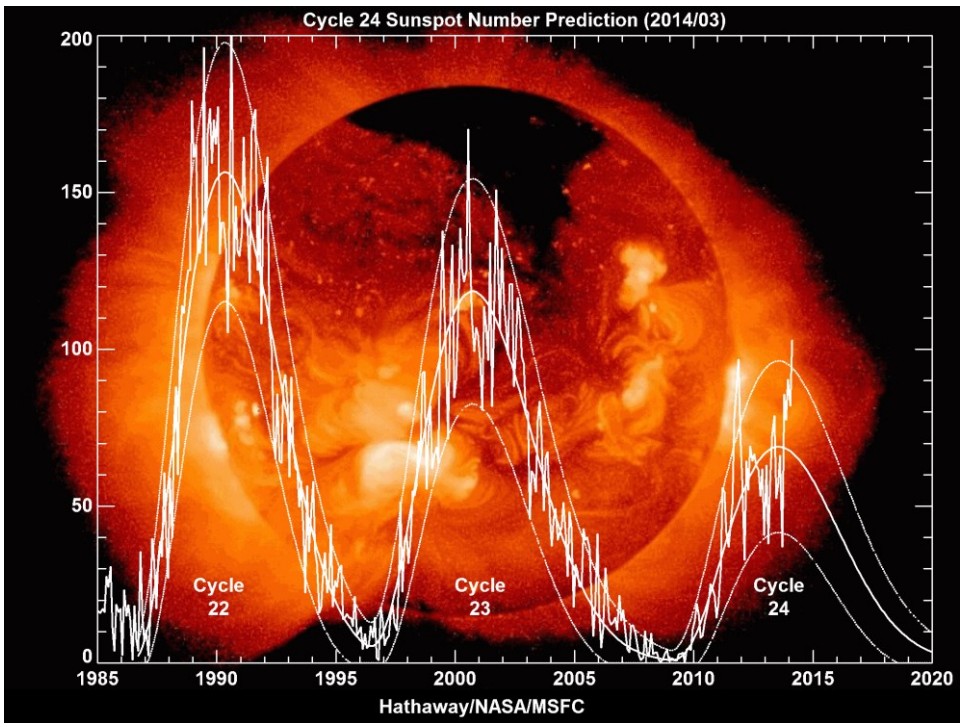


Figure 2. Observed and prediction Sun spot activity (http://solarscience.msfc.nasa.gov/predict.shtml)

Based on this data, the authors tried to conduct a study for the possibility of short duration MT measurements when Sun spot activity are at its peak condition. In Geothermal exploration, the duration of MT measurements lasts commonly about 10-18 hours, in this study authors tried to cut time duration of MT measurement to only 3-4 hours since the horizontal magnetic fields are in a good condition. At the end, authors compared between normal duration MT measurement results with short duration MT sounding, and also compared between short sounding MT results at the peak sun spot activities (2013) with short sounding MT results at low sun spot activities (2009) in Waypanas-Lampung Geothermal Prospect (in the same area).

2. FIELD DATA ACQUISITION

A short MT sounding experiment was carried out at Waypanas-Lampung-Indonesia in March-April 2013. The instruments consisted of a MTU-5A Phoenix system recorder, three channel high gain MTC-80H magnetic coils, and two channel PbCl non-polarized porous pots. In order to perform comparisons for the results, experiment were made with two types of MT measurement, i.e full time sounding MT measurement (fifteen hours), and short duration sounding (three hours) as shown in Figure 3.

Figure 3. MT full-time and short-time field data acquisition

Three MT instruments owned by PT. Pertamina Geothermal Energy were used in this study. This experiment combined between short and full time MT measurement, all data measurement were performed with single site method, and without remote reference sites due to a low noise environment.

3. MT DATA PROCESSING

MT data processing used Time Series View Syncro software from Phoenix to perform quick check data quality from raw time series data. SSMT2000 software was used to perform Fourier Transforms and Robust processing techniques, and Mteditor software for selecting crosspower and visualizing MT data results.

3.1 Time-series and spectrogram analysis

The first steps of MT data processing are time series and spectrogram analysis. Raw data analysis is effective to identify noise content on time series data during the measurements in the field. From the observations of the full sounding time series and spectrogram result, it is shown that generally several hours in the beginning of the MT measurement the data contain higher noise levels compared to entire remaining data set.

Data MT station conducted in 2013 (WYP-04) were compared with the MT station were conducted in 2009 (J-5). Both MT stations located in Waypanas-Ulubelu area with distances of around 400 m, assuming that the area has similiar resistivity structures. In order to extract the relation between high sun spot activity in 2013 and low sun spot activity in 2009, time series and spectrograms were analyzed using horizontal magnetic fields caused by sun spot activity during 2009 to 2013 as shown in Figure 4.

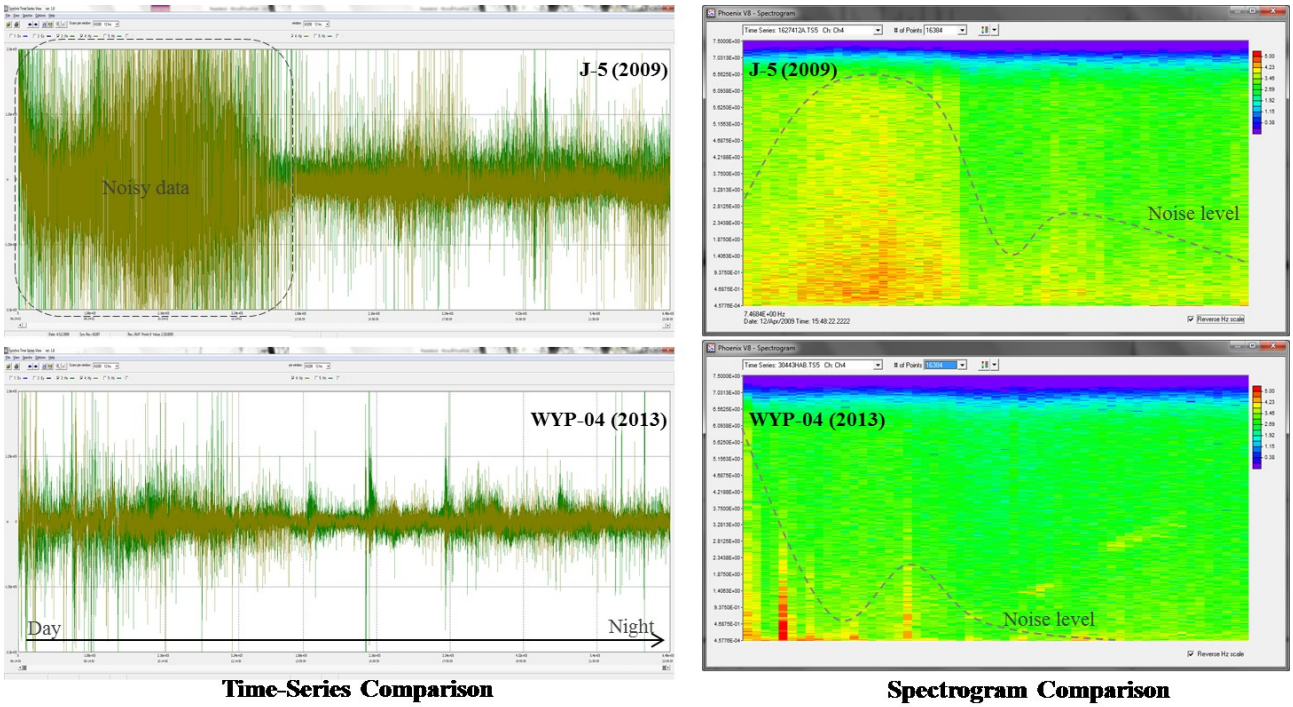


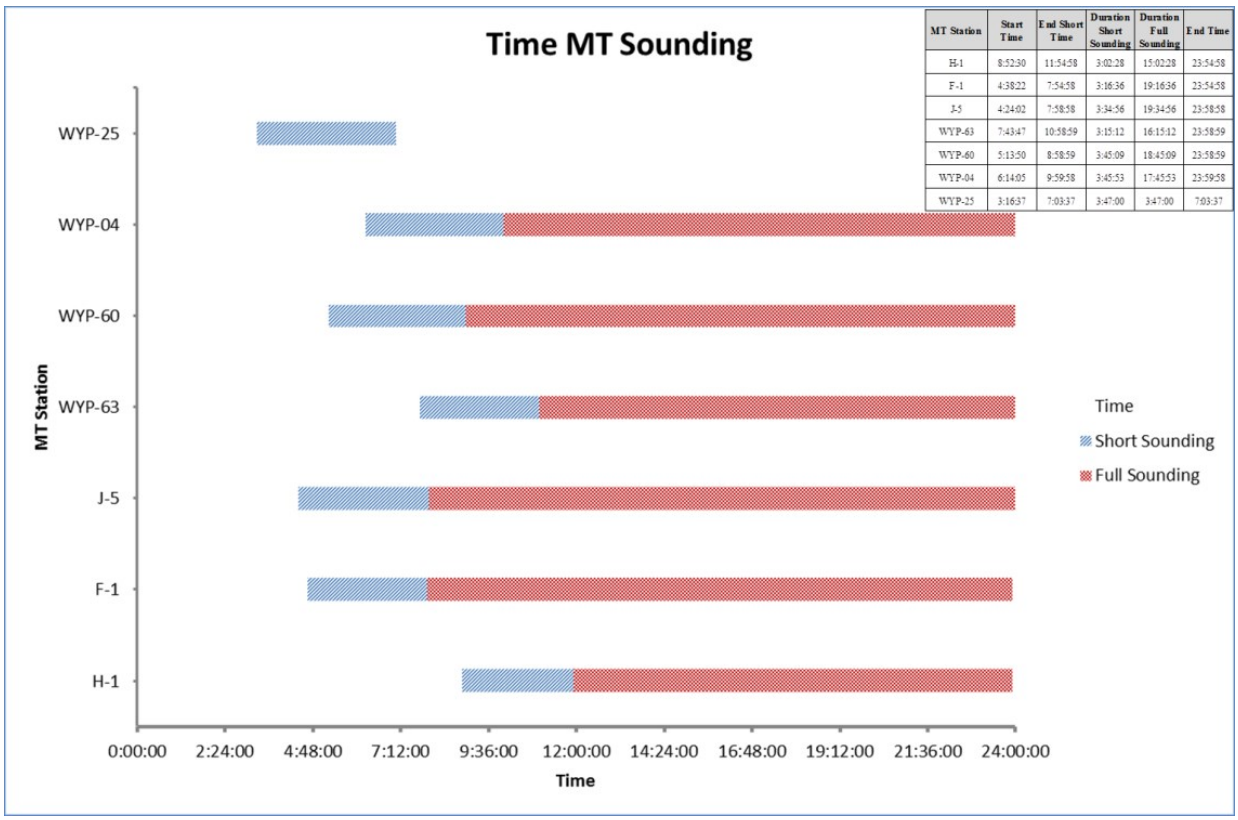
Figure 4. MT data comparison horizontal magnetic fields between 2009 and 2013

The comparisons are shown in Figure 4 . The upper panel shows the comparison time series data (left) and comparison spectrogram (right) in 2013. A noisy record is shows within the first few hours. While the lower panels show the record with from the data in 2013 more clear of noise than in 2009.

3.2 Short dan Full Sounding processing

After the time series and spectrogram data were analyzed, a Fourier transform was performed to translate the time series domain to a frequency domain, and then robust processing techniques were used until impedance value from each MT station were produced. A comparison between full length sounding and short sounding were performed for all obtained data.

In this research the author used seven MT samples, three data sets from MT measurement in 2009 (J-5, F-1, and H-1), and four data sets from MT measurements in 2013 (WYP-04, WYP25, WYP-60, and WYP-63). These data sets were chosen since the stations are close to each other, with the distance for each station are generally around 300-500 meters. All data are time sounding measurements with average 15 hours recording duration, in the part of processing authors separates with two different type of processing, full time sounding processing from all time recording data, and short time sounding processing from 3-4 hour time series at the beginning of recording.



MT Station	Start Time	End Short Time	Duration Short Sounding	Duration Full Sounding	End Time
H-1	8:52:30	11:54:58	3:02:28	15:02:28	23:54:58
F-1	4:38:22	7:54:58	3:16:36	19:16:36	23:54:58
J-5	4:24:02	7:58:58	3:34:56	19:34:56	23:58:58
WYP-63	7:43:47	10:58:59	3:15:12	16:15:12	23:58:59
WYP-60	5:13:50	8:58:59	3:45:09	18:45:09	23:58:59
WYP-04	6:14:05	9:59:58	3:45:53	17:45:53	23:59:58
WYP-25	3:16:37	7:03:37	3:47:00	3:47:00	7:03:37

Figure 5. Time duration of MT measurement for selecting time on data processing, short sounding processing used from about 3 hours in the beginning of MT recording, full sounding used from all recording duration.

Figure 5 shows recording time for analysis on the MT data, average full time sounding process is about 15 hours, and short time sounding process about 3 hours at the beginning of all full time measurements. For MT station WYP-25 only has short time MT sounding (3 hours and 47 minutes).

4. RESULT

Based on MT data processing results from each MT sample between MT short sounding and full sounding results, the authors produced MT curves to be analyzed.

Figure 6 shows that the MT curve results. The results shows excellent quality data for all samples, it has a good continuous trend curve of apparent resistivity and phase data, and the error bars for both curves are negligible or very small.

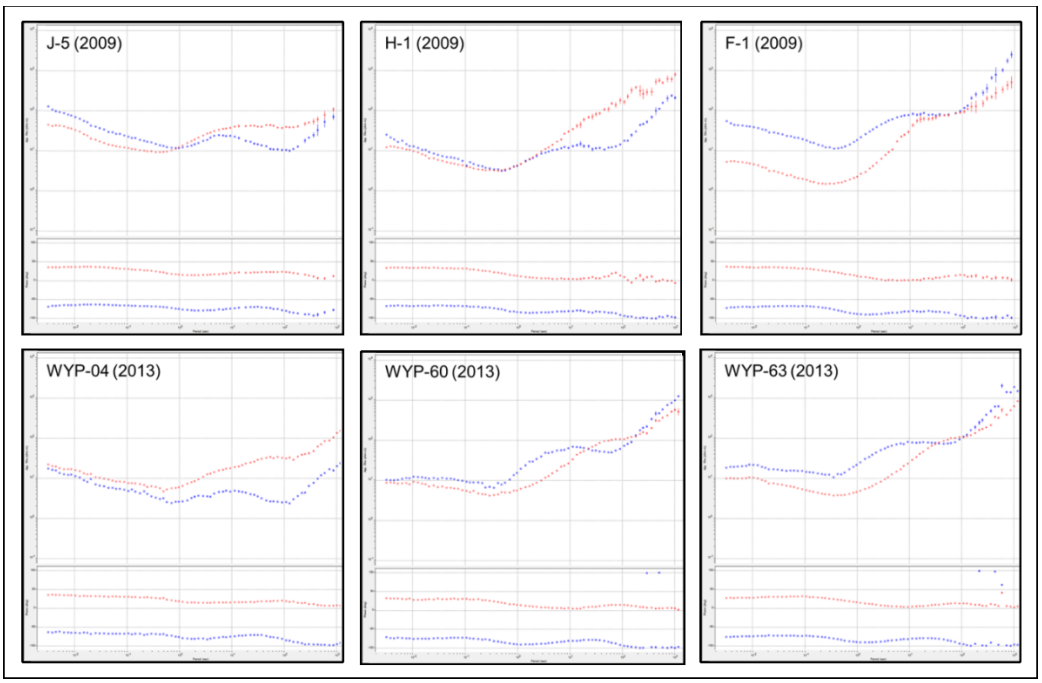


Figure 6. MT curve results from all full time sounding samples in 2009 and 2013

After processing the full time sounding data, the authors tried to process short sounding data. This produced very different results from short sounding when compared with the full sounding results. The main difference lies in the frequency range. From full time sounding results with time duration of about 15 hours, the frequency of the data sets obtained ranged from 320 Hz to 0.00084 Hz, and from short time sounding result frequency of the data sets obtained is only from 320 Hz to 0.0013 Hz. But in geothermal exploration these frequencies ranges still qualify as good data sets because the depth of the target area in geothermal reservoirs is about 2-4 km. The other consequences of short time MT data measurement is decreasing data quality in lower frequencies, because of number of data in the lower frequencies are decreased so that cross power at the end of frequency data is very low, but lower cross power does not mean it is data of a lower quality; good quality data can even come from ones cross power data.

From that short sounding data processing, it obtained quite interesting results. Short sounding processing results from data sets in 2013 has better quality than that in 2009 on locations near each other. Short sounding MT curve results in 2013 has a good trend of apparent resistivity of rho-xy rho-yx and phase of phase-xy phase-yx. This curve trend in short sounding is not too much different compared to full time sounding measurements that carried out across 15 hours. However if we see short sounding curve results from data sets in 2009, the apparent resistivity and phase curve trend results when processed from short time sounding is not clear on three hours measurements, even based on full time sounding curve the data has an excellent quality as shown in figure 7.

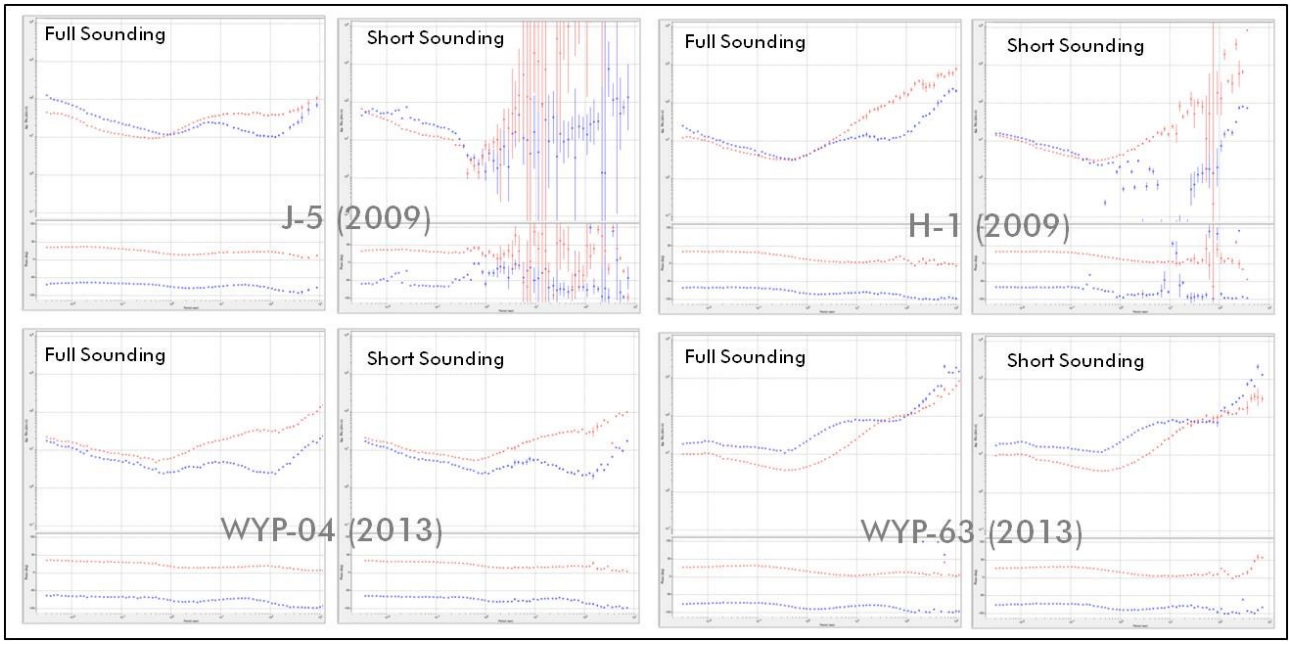


Figure 7. Full and short sounding MT curve result in 2009 on Waypanas-Ulubelu Area

The difference between results from short time sounding and full sounding in 2009 and 2013, may be caused by the difference in intensity of horizontal magnetic fields from solar wind activity on the sun. The indication of sun spot activity effect can be seen clearly from the result of time series and spectrogram analysis, difference results are derived from the same place but at a diffrent time. In 2009 it is known that the sun spot activity is at the lowest condition, so that even in remote areas, the posibility to get a good quality data is not high. Whereas in 2013 with sun spot activities in the highest peak of its cycle, there is increased signal to noise ration especially in the horizontal magnetic field. A good quality horizontal magnetic field allows for easier impedance, because impedance is the ratio between the electric field and the magnetic field. Higher magnetic intensities also produces a lower error bar as shown on the MT curves. The fluctuation values produced from noise in the measured impedance also become lower.

Quality measurements based on short sounding are relativly similiar compare to full sounding measurement in 2013, the time is a peak cycle of sun spot activities period, it possible to reduce the duration of MT measurements. When sun spot activity is at its lowest, MT measurements should be conducted with a longer duration (about 15 hours per station), but when MT measurements are conducted at the peak of spun spot activity period, recording MT duration should be performed shorter with only 3-4 hours recording, which means it can reduce operating cost and improve data acqusition.

5. CONCLUSIONS

Increasing sun spot activity was predicted to occur in 2013-2014, this results in high sun spot activities, causing an increased horizontal magnetic field. The high intensity of magnetic field can improve signal to noise ratio in MT data, so that 2013 was a good time to carried out MT data acqusition. Short time MT measurement were conducted in Waypanas-Ulubelu area with the duration of MT recording of about 3 hours to analyze the results of MT data

By using MT Phoenix instruments in Waypanas-Indonesia in 2013, this study concluded that short duration of MT measurements are possible to performed when sun spot activity in the solar wind are at a peak of its cycle. The MT curves from full time sounding result compared with short time sounding MT measurement in the high sun spot activity shows excellent quality results. When signal in the horizontal magnetic fields are strong, short sounding MT measurements can be performed to reduce cost and increase time effective production of MT surveys in the field. Short sounding MT duration should not be performed when sun spot activity is low. The knowledge of sun spot activity can help to determine the type of method of MT measurement in the field.

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