THE EFFECT OF TIME DURATION IN THE NETWORK AND RADIAL METHOD TOWARD THE ACCURACY IN MEASURING THE DEFORMATION AT MURIA

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ABSTRACT
THE EFFECT OF TIME DURATION IN THE NETWORK AND RADIAL METHOD TOWARD THE ACCURACY IN MEASURING THE DEFORMATION AT MURIA. *The Deformation monitoring activities in the vicinity of Mount Muria are recommended by the IAEA (International Atomic Energy Agency) to be done for 5 years. The purpose of these activities is to determine the rate of the deformation caused by the volcanic activity of Mount Muria, as a basic study in analyzing the volcanic hazard toward the NPP (Nuclear Power Plant). The whole coordinate points measured encompass the district of Jepara, Pati, Demak, and Kudus. In 2010 deformation measurements were periodically conducted for 4 times a year using two geodetic GPS units of Trimble R7 GNSS type through the network method. The measurements were carried out at seven points of interest and at one reference point in March, April, May and December. Each session of the measurements was performed for 2.5 hours. In 2011 the deformation measurements were periodically conducted for 4 times a year by means of the radial method. The measurements were made at eight points of interest and at one reference point in April and May, June and July. Each session of measurements was performed for 10 hours. Based on the results of the measurements by means of the network method in 2010, it was concluded that the range of horizontal and vertical accuracy is between 6-10 mm and 25-46 mm., while the results of the measurements of the radial method in 2011 is 4-7 mm, and 16-28 mm respectively. Furthermore, it provides the evidence that the radial method tends to has better result than the network method if it is applied 4 times longer than the network method, resulting the accuracy below 7 mm and 28 mm for horizontal and vertical respectively.*
Keyword: *deformation, global positioning system, differential method*

ABSTRAK
PENGARUH WAKTU PENGUKURAN PADA METODE JARING DAN RADIAL TERHADAP AKURASI DATA DEFORMASI DI MURIA. *Kegiatan monitoring deformasi di sekitar Gunung Muria, Jawa Tengah direkomendasikan oleh IAEA (International Atomic Energy Agency) untuk dilakukan paling kurang selama 5 tahun. Tujuan kegiatan ini untuk mengetahui besarnya nilai deformasi yang disebabkan oleh aktivitas vulkanik Gunung Muria, sebagai dasar untuk analisis bahaya Gunung Muria terhadap tapak PLTN (Pembangkit Listrik Tenaga Nuklir). Titik koordinat yang diukur meliputi Kabupaten Jepara, Pati, Demak dan Kudus. Pada tahun 2010 telah dilakukan pengukuran deformasi secara periodik selama 4 kali dalam setahun menggunakan 2 unit GPS geodetik jenis Trimble R7 GNSS dengan metode jaring. Pengukuran dilakukan di 7 titik pengamatan dan satu titik referensi di Bulan Maret, April, Mei dan Desember. Setiap sesi dari pengukuran dilakukan selama 2,5 jam. Pada tahun 2011 telah dilakukan pengukuran deformasi secara periodik selama 4 kali dalam setahun dengan metode radial. Pengukuran dilakukan di 8 titik pengamatan dan 1 titik referensi di Bulan April dan Mei, Juni, serta Juli. Setiap sesi dari pengukuran dilakukan selama 10 jam. Berdasarkan hasil pengukuran dengan metode jaring pada tahun 2010 diperoleh kesimpulan bahwa keakurasian horizontalnya berkisar dalam rentang 6 – 10 mm dan keakurasian vertikalnya adalah 25 – 46 mm. Sedangkan hasil pengukuran dengan metode radial pada tahun 2011 diperoleh kesimpulan bahwa keakurasian pengukuran horisontalnya berkisar dalam rentang 4 – 7 mm, dan keakurasian vertikalnya adalah 16 – 28 mm. Hal ini membuktikan bahwa jika dilakukan 4 kali lebih lama dari metode jaringan, maka metode radial cenderung memberikan akurasi yang lebih baik yaitu di bawah 7 mm untuk akurasi horizontal dan dibawah 28 mm untuk akurasi vertikal.*
Kata kunci: *deformasi, global positioning system, metode diferensial.*

1. INTRODUCTION

In an effort to support the government to meet the increasing electricity demand, BATAN (The National Nuclear Energy Agency) has carried out a preparatory study to select a feasible and safe candidate site for NPP (Nuclear Power Plant). One of the activities undertaken was a study of the safety aspects for locating the prospective nuclear power plants free from any volcanic activity of a volcano.

The purpose of this activity is to support the safety and reliability aspect of the candidate site for the planned construction of NPP in Muria Peninsula, Central Java. By knowing the rate of local deformation caused by volcanic activity of Mount Muria, it is expected to obtain some information about the capable status of the Mountain, as a basic study for analyzing the volcanic hazard toward the NPP's site.

This paper describes one of the deformation observation techniques by analyzing the surface deformation through monitoring of a shift in the coordinate points due to some volcanic activities. The study was conducted at some coordinate points in the vicinity of Mount Muria, the candidate site of the NPP which will be built.

The deformation monitoring activities were based on the recommendation from IAEA (*International Atomic Energy Agency*) in 2006 entitled "*Review of Status Evaluation Studies At Site Of Muria Peninsula NPP Site*", which states that it is necessary to monitor the surface deformation using geodetic GPS. The deformation monitoring activities began in 2010, with local scope in the vicinity of Mount Muria, and the equipment was Geodetic GPS *Trimble R7 GNSS*. Monitoring will be periodically done every year over the next 5 years with the differential method. The monitoring data of each year will be summarized in a single project file.

In principle, an indication of the surface deformation is indicated by the presence of the shift of the coordinate points on the x-axis direction. Globally, the deformation may have caused by the movement of the continental plates, while on a regional basis it may have caused by a fault movement either offshore or onshore, and by some volcanic activities as well. However, monitoring the deformation in this activity is focused on the local deformation caused by some magma activities of the volcanoes. Thus, in addition to the monitoring activities, further studies are also required to determine whether the deformation that occurs comes from the presence of some magmatic activity of Mount Muria.

The measurements are planned to be conducted every year within a period of 5 years. The results of the deformation measurements, in the form of raw data, will be downloaded and post processed using a commercial or scientific software such as Trimble Business Center or Bernese, and will be stored in a project file. This Project file will be compared with the other one in the next 5 years to monitor the rate of deformation.

2. METHODOLOGY

2.1. GPS (*Global Positioning System*)

GPS is a system of satellite navigation and positioning that is owned and managed by the United States. The system is designed to provide three-dimensional position and velocity as well as information regarding the time continuously throughout the world regardless of time and weather to many people simultaneously[1]. Today, the GPS has been very widely used around the world in the various fields of application. GPS in Indonesia has already been widely applied, particularly in relation to the applications requiring information about the position, velocity, acceleration or accurate time. GPS can provide position information with an accuracy varying from a few millimeters up to tens of meters. In principle, the GPS works as follows: the signals from GPS satellites are received by a GPS receiver whose distance is equal to difference of travel time multiplied by light speed. The time taken by the signal from the satellite to the receiver is processed mathematically by the receiver and then translated into a position which its coordinates on the surface of the earth.

The instruments used in this study are a hand-held GPS Garmin of *GPS map 76CS* type (Figure 1), a Zephyr Geodetic antenna and a tripod (Figure 2), *Trimble geodetic GPS of R7 GNSS* type (Figure 3), *Trimble Bussiness Center (TBC) and Bernese* 5.0 software, and *ArcGIS 9.2*.

Fig.1. GPS Garmin 76CS

Fig.2. Zephyr Antenna

Fig.3. GPS Trimble R7

The Garmin GPS is used to determine the initial location of the BM, while the Trimble GPS and the antenna are used for the measurement of the coordinates. TBC and the Bernese softwares are used for post processing raw data from Trimble GPS and *ArcGIS 9.2* software is used to visualize the data into the map.

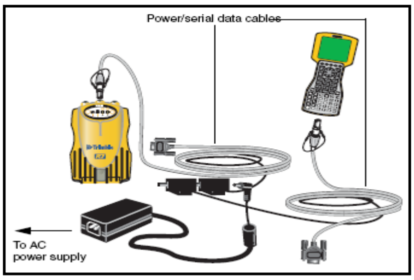

Fig.4. Connectivity

Fig.5. TSC2 Controller

The connectivity between the receiver, the battery and the controller is simply described in Figure 4. As the power consumption of the GPS is of the DC type, and the configuration that can use electricity directly from the source of AC is not available, it is recommended to always fully charge the battery after the completion of the measurement. Trimble R7 GNSS geodetic GPS is also equipped with a controller (Figure 5), one of whose activity serves as an electronic data recorder. The other function is as a visual indicator to see the number of satellites, the satellite configuration and the use of batteries; it is quite helpful, because geodetic GPS is not equipped with visual indicators such as those available on the type of handheld GPS.

2.2. Binding To The Fixed Point

In a GPS survey area, the baselines observed must be bound directly or indirectly with the existing frame work points of higher order. It is important to define the datum of the basic framework concerned, as well as to maintain the consistency and homogeneity of the accuracy of the points corresponding to the frame work of the other points.

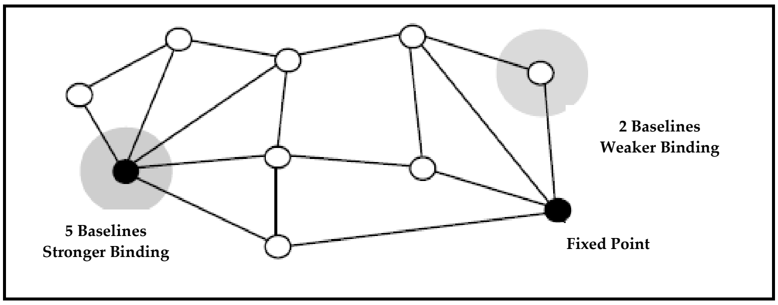

Figure 6. The Connectivity of the Network

In general, a network of GPS points should be tied to at least one fixed point of known coordinates, namely a fixed point of having a higher order of accuracy, at least of the same order, not the one that having a lower order of accuracy. The fixed and used points are evenly distributed over the whole network, and the number of the fixed points must be accorded with the network size[2]. The connectivity of a point in the network to a fixed point should be better made relatively stronger than that between one point and another point in the network, as shown in Figure 6.

The measurement of deformation are conducted by using two methods, namely the network and radial method. The basic principle of the network method is to bind 3 points to be measured into an enclosed triangle. The GPS survey network is the connection between the reference point, which is has been identified, and the interest points that will be monitored. The whole points are then connected by a connecting baseline that will be observed in the dX, dY and dZ component[5].

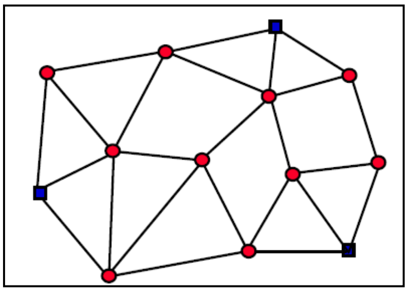

Fig.7. Network Method

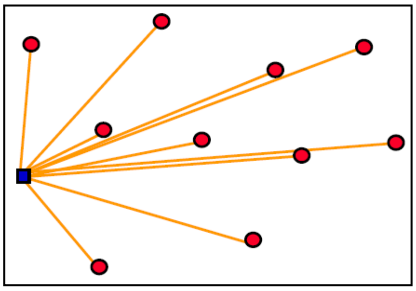

Fig.8. Radial Method

The network method is illustrated on Figure 7. The blue squares shape are the reference points that have zero orde, this points are possessed by BAKOSURTANAL (Coordinating Agency for National Surveys and Mapping). The red circulars shape represent the points that plan to be monitored, whereas the straight lines represent the baseline that plan to be observed. The radial method has the similar principal to the network method, that is to determine a relative coordinate position against the other points of known coordinates. However, there is no connection among the baselines. Figure 8 illustrates the measurement of several points of interest (red circles) relatively monitored against the reference point (blue squares). In the radial measurements, a GPS is usually used in accordance with the number of GPS coordinates to be monitored, so that more receivers are needed when compared to the network method. But on the other hand, the radial method can cut the operating costs significantly, because the completion time will be shorter, which is due to the simultaneous measurements. It will finally save the time and the cost of activities as well[5].

2.3. Deformation

Deformation is defined as the change in shape, position and dimension of a material or a change in position (movement) of a material both absolutely and relatively in a particular reference frame work due to a force acting on the material[3].

There are two deformation properties, namely elastic property, a deformed material will return to its original shape after the deformation force does not work anymore on it, and plastic property - a deformed material will not return to its original form after being deformed as the effects that occur stick to it[4].

The deformation analysis aims to determine the shift quantity and the deformation parameters which have characteristics in the space and time. The deformation parameters are obtained from the result of the shift of the coordinates of the object either periodically or continuously observed. Broadly speaking, the stages performed in the analysis of deformation are the implementation of the basic framework, the data processing, the analysis of the shift value that happens to a deformed body and the determination of an appropriate deformation model[4].

The deformation analysis can be geometrically done, viz. strain analysis by simply observing the status of the geometry (size and dimension) of the object being observed. The data of the geodetic observation result on the response effects of a material towards the force acting on it can help to construct a mathematical model that represents the type of deformation. This geometric analysis can be grouped into two types, namely the shift: it is the analysis that shows a position change of an object by using the position difference data obtained from smoothing the observational data at the different time and strain, it is the analysis that shows a change in position, shape and size of an object by using direct geodetic observation data or strain data obtained from the geodetic observation data of position changes.

The deformation monitoring using GPS surveys can be either episodic or continuous. In the episodic method, the deformation monitoring is done by carefully observing the changes in the coordinates of several points at the location monitored by the specified intervals, like once a year. Whereas in the continuous method, GPS observations are carried out continuously. In the deformation monitoring, it needs high level of accuracy of position shift, which is generally at the level of mm / year, so far this purpose it is usually necessary to have two-frequency geodetic receivers and a relatively long observation time even better continuously. During any data processing it needs scientific software as well as rigorous use of the orbit (*precise ephemeris*).

2.4. BM Equipment (Benchmark)

One of the facilities to support the monitoring of deformation is a benchmark, which is useful as a procedure for positioning coordinates to be monitored. According to BAKOSURTANAL, the specification for normal BM repeatedly measured is that a BM is made from concrete, iron frame, iron rods of 8 mm in size, 60x60x30 cm pillar base, shaft pillars measuring 140x30x30 cm (Figure 9). A BM foundation is planted in the ground and emerges at ground level as high as 30 cm (Figure 10), a metal mark is planted on the surface of the pillars made by stainless steel, brass, or copper[2].

In order to prevent the poor quality of the raw data that may have caused by the noise, the location of the BM must be an open area and there are no obstacles (buildings, large trees, high voltage power) in all directions so that the GPS satellite signals can be received by the GPS antenna without any interference.

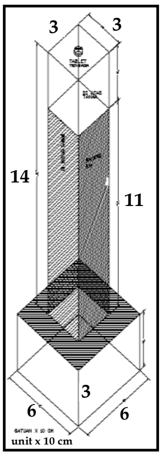

Fig.9. BM Specification

Fig.10. BM Foundation

The angle of view is 15 degrees above the horizon of the GPS antenna, the ground condition is stable and not mushy, and the environment is safe from any destruction and building development or plant growth.

2.5. Location Of The Study

As of the end of 2011, 9 pieces of BM have been successfully built, 5 of which are BM_RTW (Rahtawu), PDP (Perdopo), RGG (Rengging), KTP (Ketek Putih), UJW (Ujung Watu), located near BATAN seismograph. The placement of BM adjacent to the seismograph is based on the idea that position of seismograph is a part of sensitive position to magma movement, which can be assumed to be sensitive to a deformation shift (Figure 11). The position adjacent to the seismograph equipment also gives some other advantages such as ease of supervision, security, and maintenance of the BM.

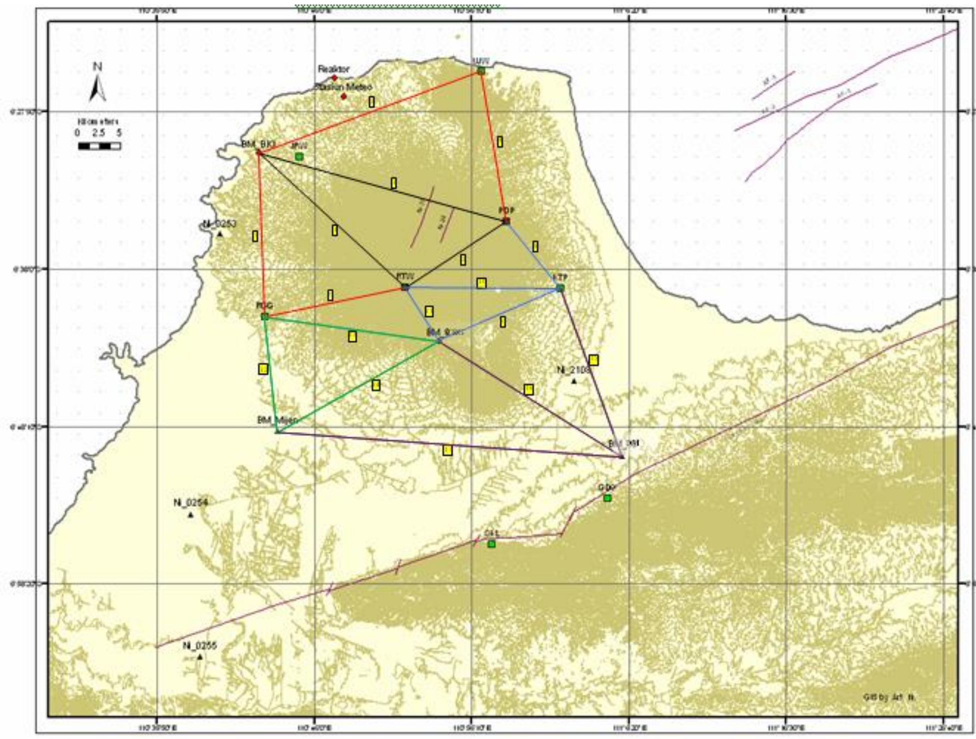

Figure 11. The Position Of GPS Geodetik For Monitoring The Muria Deformation[7]

The distribution of the BM position and formation encircling the mountain is based on its usefulness which aims to monitor the deformation caused by a magma activity of a volcano. Eight of the BM serve as a coordinate whose deformation movement will be monitored against the reference point, the BM_Mijen. The location of the reference point is determined on the basis that the location is considered stable as it is located outside the complex of Mount Muria.

GPS observations at Mount Muria are processed by using TBC software (Trimble Business Center), facilitated by Trimble. Before data processing, the raw data acquired by the GPS receiver will be first downloaded and converted from the format with the extension *To to *DAT, or converted to RINEX format (format for global GPS) so that they can be processed by the other software like Bernese and Gamit. The stages of post processing with TBC consists of the download processing, baseline processing, network adjustment and report.

3. RESULTS

In 2010 some deformation measurements were periodically done for four times a year in March, April, May and December. The measurement were conducted for 2.5 hours per session with 2 units of geodetic GPS of Trimble R7 GNSS type using the net method. The measurements were made on 7 points of interest, namely in BM_BKI (Bopkri), UJW (Ujung Watu), PDP (Perdopo), RTW (Rahtawu), RGG (Rengging), KTP (Ketek Putih), CRG (Cranggang), and a reference point called BM_Mijen.

From Figure 12 some information is obtained that a network has been formed consisting of 9 BM and 14 baselines. The superiority of the net method is its ability to reduce the error and the noise between the baselines during the measurement, so that the resulting data will be more accurate.

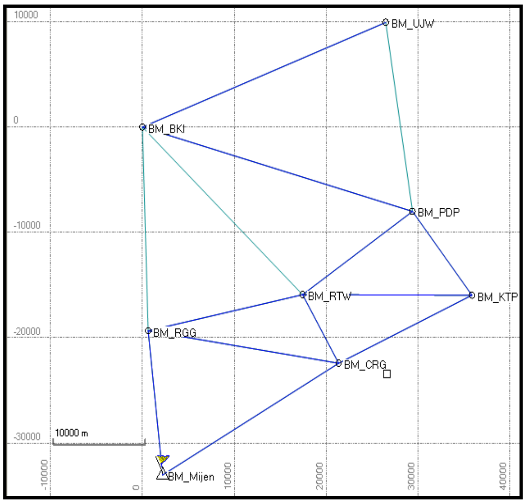

Fig.12. Network Baseline Processing[7]

Table 1. The Result of Network Processing

From	To	Solution Type	H.Precision (m)	V.Precision (m)
BM_PDP	BM_RTW	Fixed	0.007	0.032
BM_BKI	BM_PDP	Fixed	0.008	0.035
BM_BKI	BM_UJW	Fixed	0.009	0.034
BM_RTW	BM_RGG	Fixed	0.007	0.046
BM_KTP	BM_PDP	Fixed	0.006	0.029
BM_CRG	BM_KTP	Fixed	0.008	0.037
BM_RTW	BM_KTP	Fixed	0.007	0.042
BM_CRG	BM_RTW	Fixed	0.006	0.025
BM_RGG	BM_Mijen	Fixed	0.008	0.038
BM_CRG	BM_RGG	Fixed	0.01	0.044
BM_Mijen	BM_CRG	Fixed	0.009	0.041

However, the disadvantage is that if there are errors and noise in the baseline, it will affect the accuracy of the other baseline. Moreover, as the network method requires a high mobilization it will require more time and cost when compared to the radial method. Table 1 shows that based on the results of measurements by the network method in 2010. It was concluded that the horizontal accuracy ranged in 6-10 mm whereas the vertical accuracy was

25-46 mm. Furthermore, the data in Table 2 shows that the horizontal accuracy is more precise than the vertical accuracy[7]. It is closed to the characteristics of the GPS devices, that the horizontal accuracy is better than the vertical one[6].

Table 1 informs about the process of primary data, namely the information about the horizontal and vertical accuracy. The horizontal accuracy is needed to determine the deformation changes on the ground surface due to a volcanic activity of a volcano in the direction of axis X, while the vertical accuracy is required to find out the existence of high and low changes in the ground surface that occurs because of the inflation (raising of the ground surface) and deflation (lowering of the ground surface) caused by magma movement within the volcano in the direction of Y axis. In 2011 by radial method also applied to measure the deformation periodically 4 times a year in April and May, June and July by the radial method. The measurements were performed for 10 hours per session using the radial method. They were conducted in BM_BKI, UJW, PDP, RTW, RGG, ID, CRG, DM and 1 reference point namely BM_Mijen.

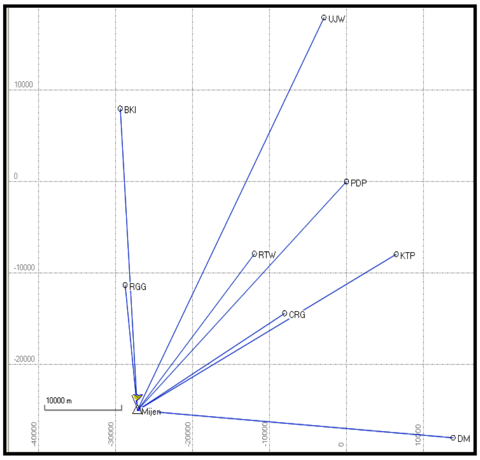

Fig.13. Radial Baseline Processing[8]

Table 2. The Result Of Radial Processing

From	To	Solution Type	H.Precision (m)	V.Precision (m)
BM_Mijen	BM_RGG	Fixed	0.005	0.016
BM_Mijen	BM_CRG	Fixed	0.004	0.028
BM_Mijen	BM_BKI	Fixed	0.006	0.022
BM_Mijen	BM_PDP	Fixed	0.005	0.019
BM_Mijen	BM_KTP	Fixed	0.005	0.022
BM_Mijen	BM_RTW	Fixed	0.007	0.026
BM_Mijen	BM_DM	Fixed	0.005	0.018
BM_Mijen	BM_UJW	Fixed	0.005	0.017

Figure 13 shows the results of the baseline processing using the radial method. The advantages of this method lie in the practicality of doing the mobilization, so that no much time and cost are needed during the measurements. There are 8 points of interest represented by a circle and a point of reference represented by a triangle. The points of interest are BKI, RGG, UJW, RTW, PDP, KTP, CRG, and DM (Danyang Mulyo) spreading in Pati regency, Jepara and Kudus. The reference point called BM_Mijen is a point which is considered stationary, located in the Regency of Demak. Since the reference point is not of 0 order, it must be connected to the global network of 0 order belonging to BAKOSURTANAL. Figure 13 also shows the clear characteristics, viz. the direct monitoring of deformation between each point of interest and a reference point, and one baseline is not connected to the other, while Table 3 indicates the measurement result. From Figure 14 it can be concluded that the horizontal accuracy of the measurement ranges between 4-7 mm, while the vertical accuracy is between 16-28 mm[8].

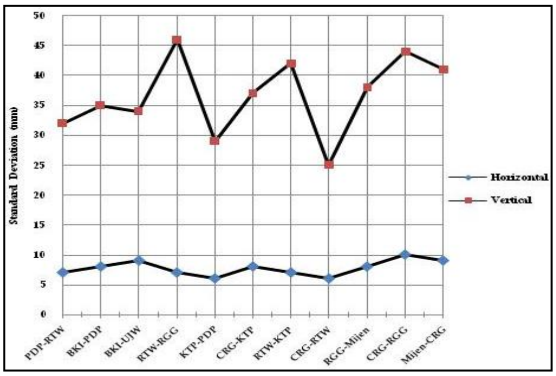

Fig.14. Accuracy Of Measurement By Network Method In 2.5 Hours

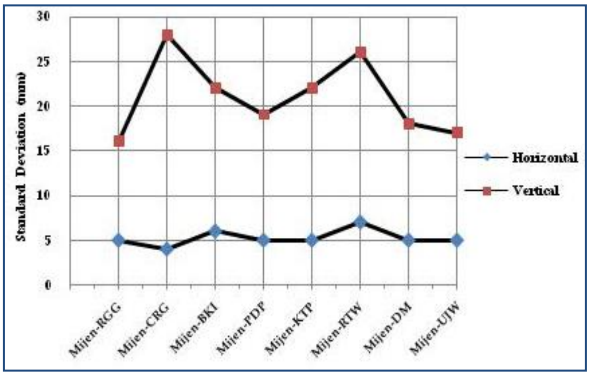

Fig.15. Accuracy Of Measurement By Radial Method In 10 Hours

Furthermore, Figure 14 and 15 show the comparison between the accuracy value between horizontal and vertical. According to the curve of standard deviation, it can be concluded that the horizontal accuracy performs better than the vertical accuracy. This result is due to the characterization of the GPS device provided by the manufacture. This difference may also due to the difference of time duration of the measurement. The measurement in 2010 was performed for 2.5 hours, whereas in 2011 was performed in 10 hours. Based on the processing data, it can be deduced that the radial method tend to perform better result than the network method if it is applied 4 times longer than the network method, resulting the accuracy below 7 mm and 28 mm for horizontal and vertical respectively.

4. CONCLUSION

In 2010 and 2011 the deformation measurements were episodically carried out using two different methods, namely the network and the radial method. The measurements were performed by using two geodetic GPS receivers.

Based on the measurement results by the network method in 2010 it was concluded that the horizontal accuracy ranged in 6-10 mm and the vertical accuracy in 25-46 mm. While those by the radial method in 2011 concluded that the horizontal measurement accuracy ranged in 4-7 mm, and the vertical accuracy in 16-28 mm.

Therefore, it can be concluded that the measurement accuracy by the radial method produces higher accuracy than that by the network method as it applied 4 times longer than network method, resulting the accuracy below 7 mm and 28 mm for horizontal and vertical respectively.

It is conceded that both measurements were not done in the apple to apple way because it was done with the different methods and at different time, and therefore further studies are needed on this issue. Nevertheless, the results of these studies may provide some input and early consideration in conducting further deformation measurements, especially in terms of accuracy, time saving as well as the cost of the activities.

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REFERENCES

[1]. ABIDIN, HASANUDDIN Z, "Penentuan Posisi Dengan GPS Dan Aplikasinya", PT. Pradnya Paramita , Cetakan Ketiga, Jakarta, 2006.

[2]. _______, "Jaring Kontrol Horizontal, Standard Nasional Indonesia", SNI 19-6724-2002", Badan Standardisasi Nasional, Jakarta, 2002.

[3]. KUANG S, "Geodetic Network Analysis and Optimal Design : Concept and Applications", Ann Arbor Press Inc., Chelsea, Michigan, 1996.

[4]. _______,"Pengukuran Global Positioning System Untuk Pemantauan Deformasi Gunung Muria Dalam Rangka Pembangunan Pembangkit Listrik Tenaga Nuklir", Institut Teknologi Bandung, Bandung, 2011.

[5]. ABIDIN, HASANUDDIN Z, "Modul 7 Pendahuluan Metode Survey GPS", Jakarta, 2007.

[6]. _______, "Petunjuk Singkat Pengoperasian Trimble R7 GNSS", PT Hydronav Teknikatama, Jakarta, 2008.

[7]. NUGROHO A, "Laporan Teknis Pengukuran Deformasi Muria", BATAN, Jakarta, 2010.

[8]. NUGROHO A, "Laporan Teknis Pengukuran Deformasi Muria", BATAN, Jakarta, 2011.