I J C T A, 10(5) 2017, pp. 125-131

Identification of Earthquake Precursors by Comparing Welch and Burg Methods using GPS TEC

K. Uday Kiran[*], S. Koteswara Rao[**] and K.S. Ramesh[**]

Abstract: Sesimogenic ionospheric perturbations due to earthquake occurred on 23rd December 2013 in Indonesia are analyzed. The magnitude of the event is 4.5 as recorded on Richter scale. It occurred at 7:58 hours universal time coordinates i.e. at 1:28 hours local time coordinate. The vertical total electron content (VTEC) data on the earthquake day. In the present work Welch and Burg methods are implemented on the VTEC data of the event. The algorithms are applied for both the disturbed and undisturbed VTEC data. The increment of energy in the ionosphere is observed when the event is occoured. This energy enhancement in the ionosphere is seen at the 13.84 hours LTC in the ionosphere is identified by using these two methods.

Keywords: Ionospheric anomalies, Statistical signal processing algorithms, Earthquakes.

1. INTRODUCTION

Earthquakes are one of the vulnerable natural disasters occurred in nature. Anomalous phenomena of electron density in the ionosphere have been reported well before the occurrence for many earthquakes around the world [1-2]. Seismogenic perturbations in the ionosphere are simple and effective tool to understand the spectral characteristics of earthquakes. The ionosphereis disturbed due to movement of vertical electrical field generated from the ion clusters. [3, 4].

The physical explanation for the coupling of seismicity and ionosphere is explained by Pulinets [2004]. There are various explanations like electromagnetic emissions stress changes in rocks which leads to piezoelectric effects. The investigation began from the Great Alaskan earthquake which was occured on 27th march 1964.The effect of induction is caused due to motion of electric charges in geomagnetic field, ionization of lower atmosphere due to the emission of radioactive gas and metal ions [5, 6].

Anecdotal studies show that ionospheric perturbations may be considered as short term precursors for earthquakes.

The total electrons presented between the line of sight path and satellite receiver is measured as time delay introduced in GPS receiver it is represented as slant total electron content (STEC). The time delay measured in meters called as pseudorange. For single frequency GPS receiver, the pseudorange 'ρ_{L_1}' is given as

$$\rho_{L_1} = (40.3 \times \text{STEC})/f_{L_1}^2 \tag{1}$$

For GPS receiver with two frequencies,

$$\rho_{L_1} - \rho_{L_2} = (40.3 \times \text{STEC}) \times [(1/f_{L_1}^2) - (1/f_{L_2}^2)] \tag{2}$$

where 'f_{L_1}', & 'f_{L_2}', are frequencies for 'L_1' and 'L_2', signals. The STEC for GPS receiver having two frequencies is

[*] Assistant Professor, Department of Electronics and Communication Engineering, K.L. University, Vaddeswaram, Andhra Pradesh. *Email: meemithrudu@gmail.com*

[**] Professor, Department of Electronics and Communication Engineering, K.L. University, Vaddeswaram, Andhra Pradesh. *Email: skrao@kluniversity.in and dr.ramesh@klunivesity.in*

$$\text{STEC} = \left[\frac{(\rho_{L_1} - \rho_{L_2})}{40.3}\right] \times \left[\frac{f_{L_1}^2 \times f_{L_2}^2}{f_{L_1}^2 - f_{L_2}^2}\right] \tag{3}$$

VTEC values are calculated using eq. (4)

$$\text{VTEC} = \text{STEC} \times (\cos(\xi)) \tag{4}$$

Here ξ represents the difference value in between the 90° and zenith angle. The analysis is carried out on the GPS TEC data. This global scale TEC values are obtained from ground based GPS receivers [7].

In the present work, the data of a single ground based GPS receiver is considered. The Stochastic algorithms are applied on GPSTEC.

Spectral estimation techniques give better statistical and accurate estimate of the signal. Parametric methods suppose that the underlying stationary stochastic process has a certain structure which can be outlined with the help of minor amount of parameters. Non parametric methods approximate the covariance without presuming that the process has a certain structure. In this paper one of each of the above methods are used for the detection of the earthquake. Welch and burg methods are applied for the analysis.

2. OCCURRENCE COGITATION

The event has occurred on 23rd December 2013 in Kawalu Java, Indonesia (8.121°S, 108.269°E) at 7:58 hours universal time coordinate (UTC. The magnitude of the earthquake is recorded as 4.5 on Richter scale.

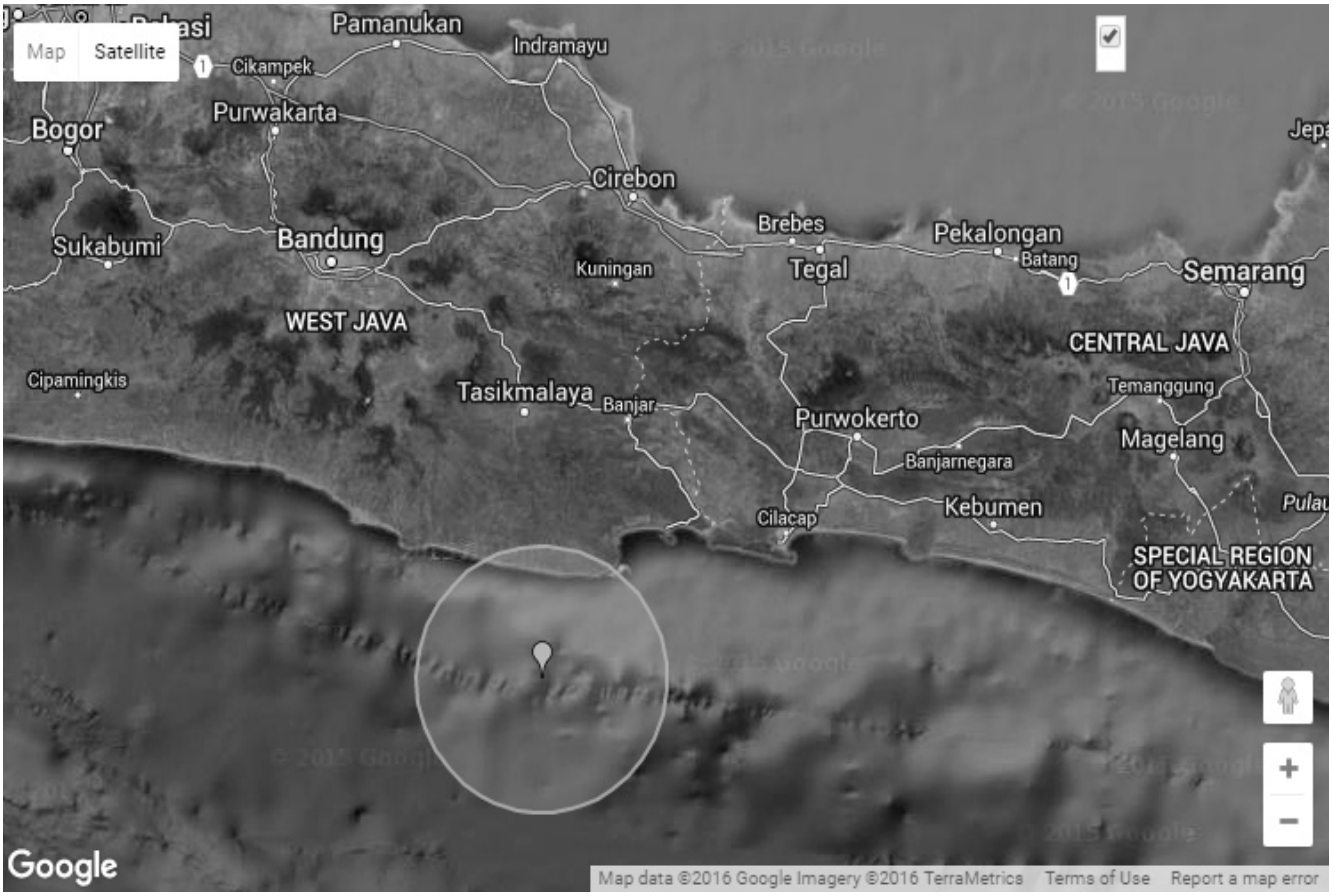

Figure 1: Earthquake Location

The location map of the earthquake is shown in the Figure 1. The location map of earthquake from http://earthquaketrack.com/quakes/2013-12-23-07-58-10-utc-4-5-86.

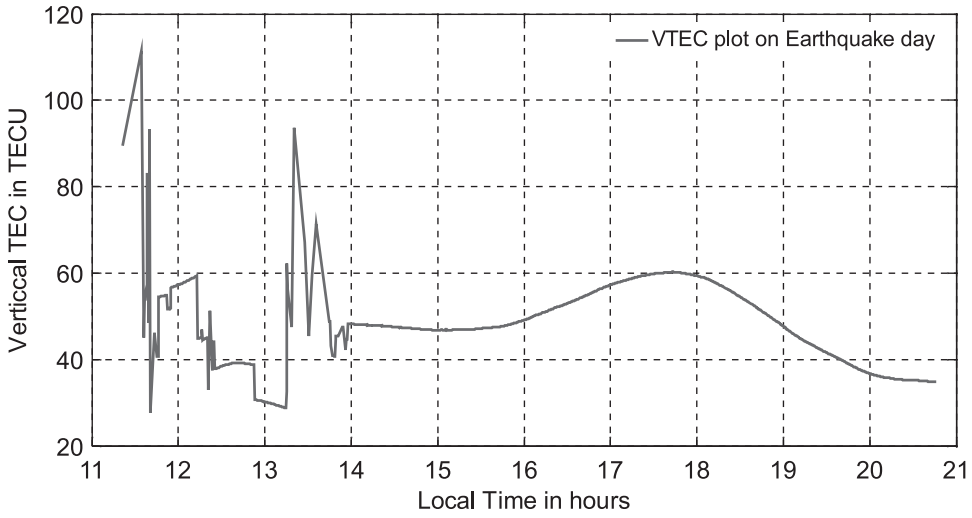

Figure 2: Plot of VTEC

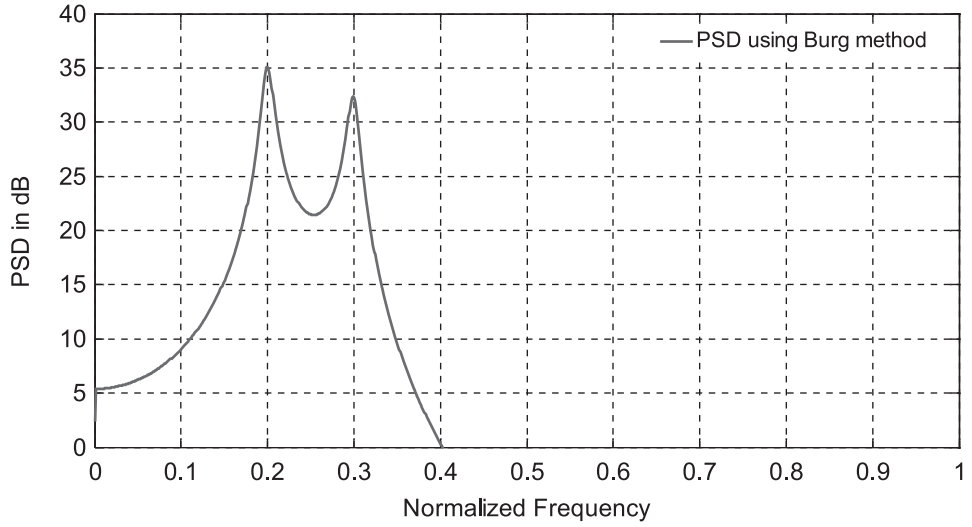

Figure 3: PSD of the synthetic signal using burg method

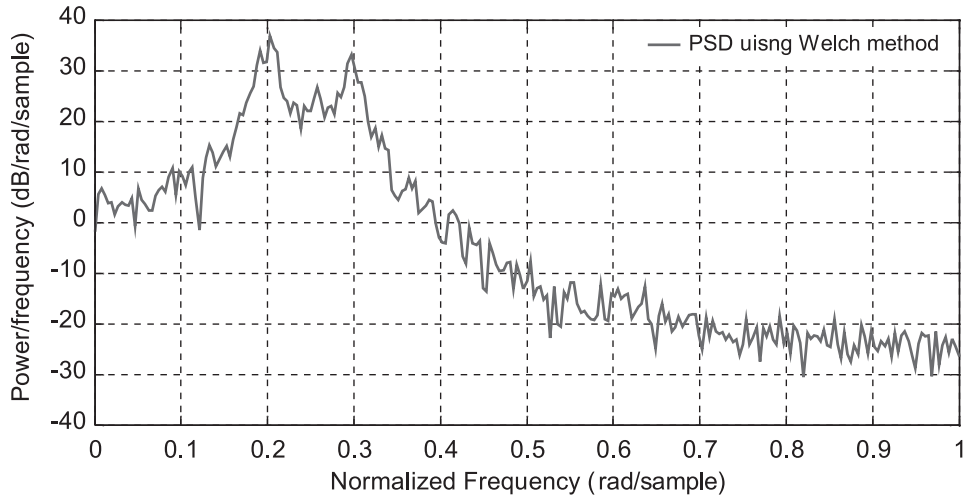

Figure 4: PSD of the synthetic signal using welch method

3. DATA

International GNSS services (IGS) provides GPS VTEC. The event is on 357 day of the year, with respect to the GPS calendar of 2013. The VTEC data was analysed and the VTEC data of the satellite PNR 18 is perturbed. Plot is shown in Figure 2.

4. METHODOLOGY

To find out the perturbations in the signals, there are numerous statistical signal processing methods [8-11]. In this research work, burg a parametric method and a non-parametric method Welch are implemented on VTEC data. With the aid of these two methods, the power spectral density (PSD) for both disturbed and undisturbed VTEC data is estimated. In Welch method, the signal is split into overlapping segments. The data is divided into X data segments having length Y and Z points are overlapped. In this method if Z = Y/2 points, then the overlapping is said to be 50%. The overlapped segments are windowed to calculate the PSD.

Burg method uses auto regressive parameters which are more accurate than the other paramedic methods. This algorithm uses both forward and backward corrections in calculating of auto regressive parameters. This method gives stable results and also produces high resolution PSD for short data records. The synthetic signal is generated in matlab and their frequencies are 0.2 and 0.3. The PSD of the signal using both the methods are represented in the Figure 3 and Figure 4 respectively. The output has exactly represented the normalized frequencies for the synthetic signal. So, these methods are implemented on the VTEC data [12].

The VTEC data has for satellite PRN 18 has 1035 points. The VTEC data is available from 11:00 hours to 21:00 hours LTC. Disturbed VTEC data is considered upto 14:00 hours LTC and the undisturbed VTEC is upto 17:00 hours LTC. The plots of these VTEC data are given in Figure 5 and Figure 6 . The VTEC data after 17:00 hours LTC is ignored because it represents the evening perturbations in that low latitude station. The disturbed data consists of 208 points and the undisturbed data consists of 308 points respectively.

The PSDs of the disturbed data using welch are represented in the Figure 7. The PSDs of the disturbed and undisturbed data using burg are represented in the Figure 8 and Figure 9. The application of Welch method resulted in a peak at a frequency of 0.6085 having PSD of 14.14 dB and for Burg algorithm, the peak frequency of 0.7351with a PSD of 18.03 dB is observed. In the undisturbed parts the PSDs have –ve value. The PSDs of the two methods are tabulated in Table 1.

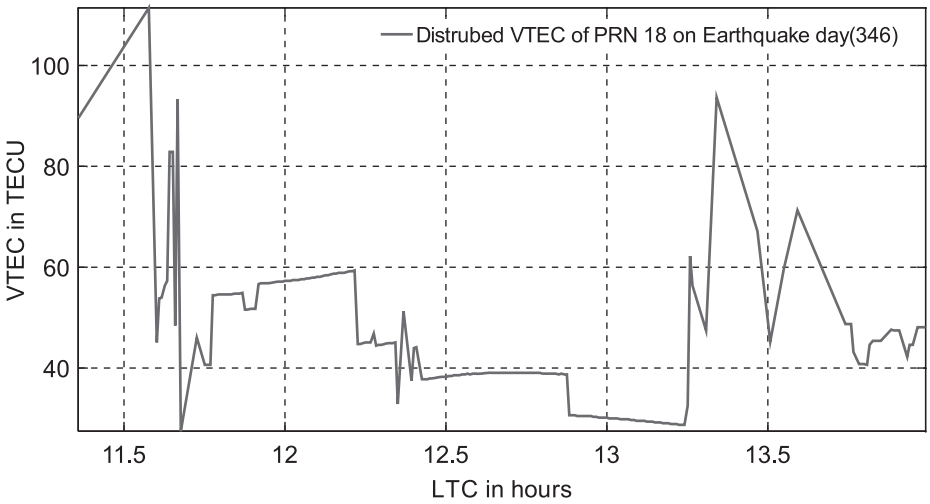

Figure 5: Detrended disturbed VTEC data

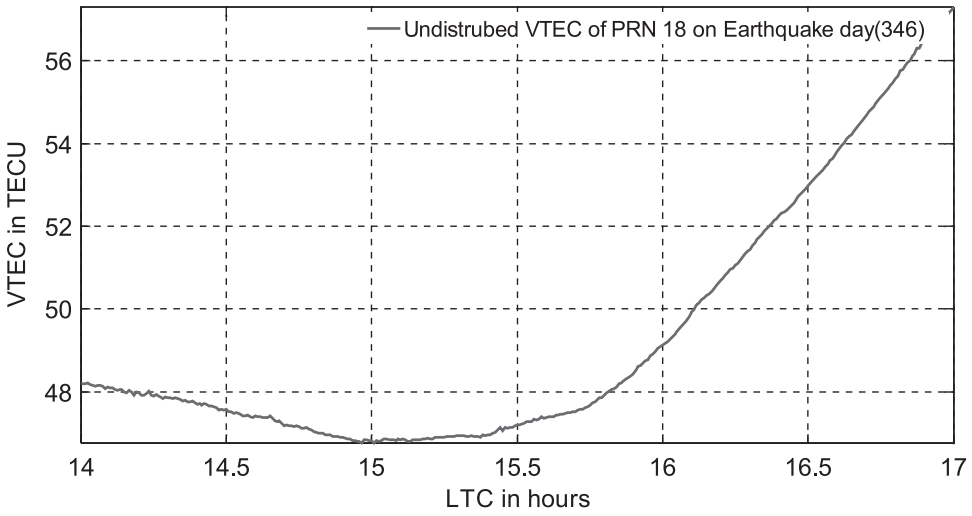

Figure 6: Detrended undisturbed VTEC of PRN 18

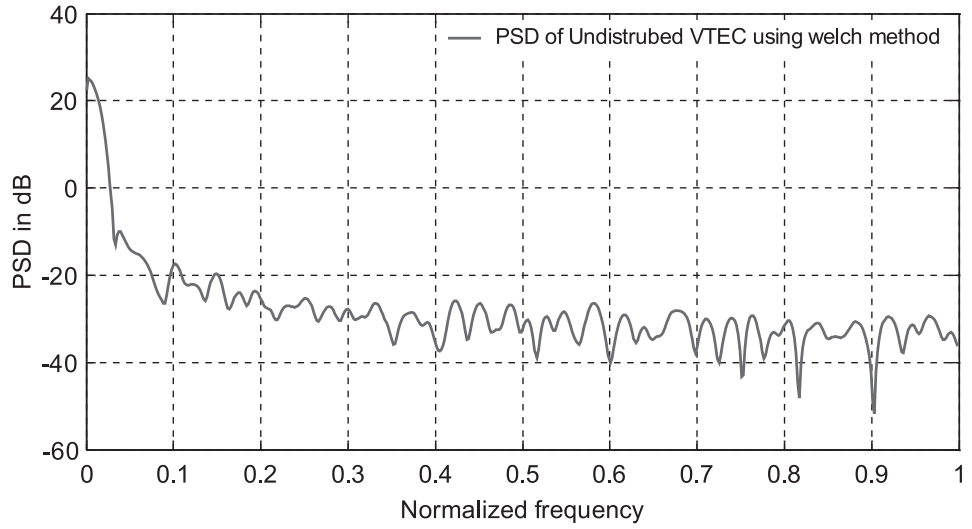

Figure 7: PSD of the disturbed VTEC using welch method

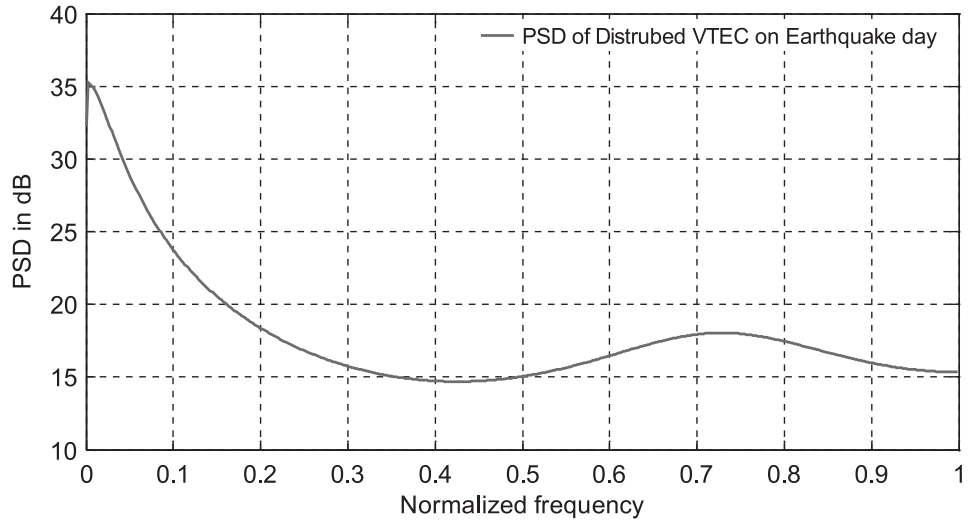

Figure 8: PSD of the disturbed VTEC using Burg method

The application of the algorithms on the first bisection using Welch method resulted in peaks at normalized frequencies at 0.3851 and 0.4555 with PSDs of 4.51dB and 9.15dB in the first and second sets

respectively. In the application of burg method on the first bisection a peak is observed in second set at a frequency of PSD of 19.73dB.

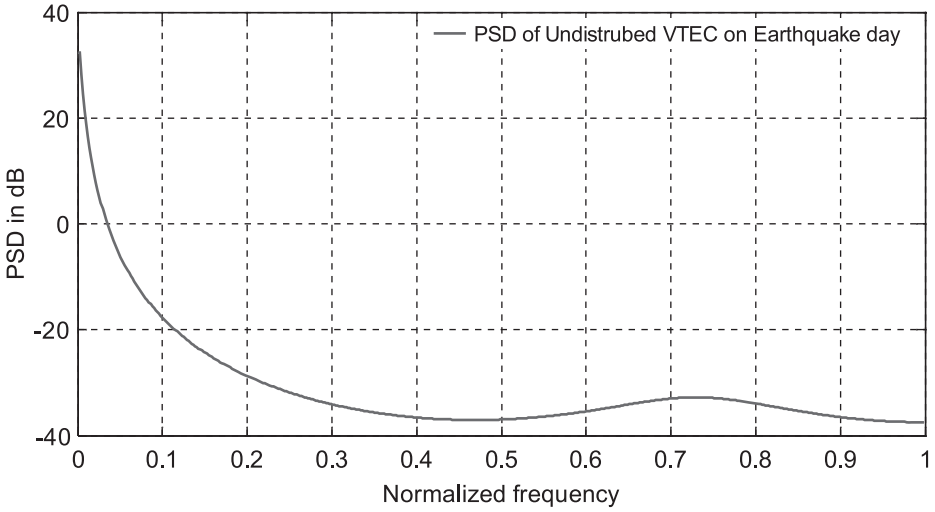

Figure 9: PSD of the undisturbed VTEC using burg method

Finally the data is split into four equal sets & both the algorithms are applied on them. The PSDs of this division for both methods are given in Figure 12 and Figure 13. In the implementation of the Welch method peaks are observed at the first and the fourth sets of 52 data points each at normalized frequencies 0.4457, 0.7683 and 0.3734 with PSDs of 10.67 dB, 14.63 dB and 14.65 dB respectively. In the implementation of Burg algorithm on the VTEC data a peak is observed at the normalized frequency at 0.6315 with PSD of 22.82 dB in the fourth set of 52 data points each. In all the other sets in both the methods, the energy has abated.

Table 1
PSD of disturbed and undisturbed VTEC using Welch and Burg methods

S.No	*Method*	*Disturbed VTEC Undisturbed VTEC* / *Normalized Frequency*	*PSD in dB*	
1	Welch	0.6085	14.14	No peaks are observed
2	Burg	0.7351	18.03	No peaks are observed
		0.7312	–32.7	No peaks are observed

5. DISCUSSION

The analysis of VTEC data using Welch and Burg methods has identified the seismic perturbations in the ionosphere during the earthquake. These perturbations are in accordance with the lithosphere-atmosphere-ionosphere coupling mechanism i.e., the vertical electric field generated in the earthquake zone disturbs the dynamic upper atmosphere. In the analysis the earthquake considered is nearer to the epicentre. Thus it specifies that there is an enhancement of the energy in the ionosphere during the occurrence of the earthquake. The energy enhancement in the ionosphere is seen at the 13.84 hours LTC in the ionosphere in both the methods.

6. CONCLUSIONS

From the analysis of VTEC data on earthquake day it may be concluded that the observed ionospheric perturbations represent the impending earthquake. The distance between the earthquake epicentre and the BAKO IGS station also cornerstone the results obtained in this analysis. Welch and Burg methods can represent the perturbations more precisely.

References

1. Ali Alp Akyol[1], Orhan Arikan[2], Feza Arikan[3], M. Necat Deviren[4], "Investigation on the Reliability of Earthquake Prediction Based on Ionospheric Electron Content Variation", 16th IEEE International Conference on Information Fusion (FUSION), 2013, from 9-12 July 2013, pp: 1658 – 1663,ISBN number: 978-605-86311-1-3.
2. Komjathy, A. (1997). Global Ionospheric Total Electron Content Mapping Using the Global Positioning System. Ph.D. dissertation, Department of Geodesy and Geomatics Engineering Technical Report No. 188, University of New Brunswick, Fredericton, New Brunswick, Canada, 248 pp.
3. Pulinets. Sergey [1], "Ionospheric Precursors of Earthquakes; Recent Advances in Theory and Practical Applications", TAO, Vol. 15, No. 3, 413-435, September 2004.
4. Thanassoulas. C[a] and Tselentis. G[b], "Periodic variations in the Earth's electric field as earthquake precursors: results from recent experiments in Greece", Tectonophysics, 224 (1993) 103-111, Elsevier Science Publishers B.V., Amsterdam.
5. Freund, F. (2005). Cracking the Code of Pre-Earthquake Signals. National Information Service for Earthquake Engineering, University of California, Berkeley (Found at: http://solar-center. stanford. edu/SID/educators/earthquakes. html).
6. Gosh. D, and Midy. S.K, "Associating an ionospheric parameter with major earthquake occurrence throughout the world", Journal of Earth Systems and Science.
7. Prathap Mishra, "Global Positioning Systems", Second edition, Ganga-Jamuna Press.
8. Omkar Lakshmi Jagan[*], Koteswara Rao. S, Jawahar. A, Karishma S.K.B, "Application of Particle Filter using Bearing Measurements", Indian Journal of Science and Technology, Vol. 9(7), DOI: 10.17485/ijst/2016/v9i7/85557, February 2016.
9. Jawahar. A[*], Koteswara Rao. S, "Recursive Multistage Estimator for Bearings only Passive Target Tracking in ESM EW Systems", Indian Journal of Science and Technology, Vol.8(26), 74932, October 2015.
10. Jawahar. Annabattula[1*], Koteswara Rao. S, Sampath Dakshina Murthy. A[2], Srikanth. K.S[1] and Rudra Prathap Das[2], "Multi-Sensor Submarine Surveillance System using MGBEKF", Indian Journal of Science and Technology, Vol. 8(35), DOI: 10.17485/ijst/2015/v8i35/82088, December 2015.
11. Nalini Santhosh. Mylapilli[1*], Koteswara Rao. S[2], Rudra Prathatp Das[1], and Lova Raju[1], "Underwater Target Tracking using Unscented Kalman Filter", Indian Journal of Science and Technology, Vol. 8(31), DOI: 10.17485/ijst/2015/v8i31/77054, November 2015.