# *WETC*

# Power Quality Assessment
# Zafarana Wind Farm
## Transformer No. 1 [75 MVA]
## Installed capacity [54.2 MW]

***Conducted By***

Eng. Amagd M. El-Hewehy
Eng. El-Sayed M. Mansour

New and Renewable Energy Authority [NREA]
Hurghada Wind Farm

Wind Energy Technology Center, Test Station for Power Quality, March 2006

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***Abstract***

The report describes power quality assessment performed on transformer substation at Zafarana wind farm regarding the requirements of the standard specification ISO 9001 / 2000.

Overview for Zafarana wind farm

# *Contents*

# 1. Preface

***Reasons for Power Quality Assessment***

Power quality is an issue of increasing importance. The main reason for this is the increasing demands from the customers with respect to security and quality of supply in order for them to rely on the public power supply in such as way that they do not have to take special measures to ensure that they can conduct their business without concern about the availability of computers, machines, appliances etc.

The varying of the power output from wind turbines has an impact on both the operation of the power system and on the power quality of the system. This impact increases as the level of penetration increases.

The influence on power quality is mainly on the level and fluctuations of voltage and frequency, the stability of voltage and frequency should not be degraded significantly, as the controllers of systems are required to be able to prevent instability. Furthermore, the shape of the voltage should not be degraded by the inclusion of wind power in the system. If wind turbines or storage systems applying power electronics are included in the system, it should be ensured that the distortion of the voltage is within required limits.

The voltage level at the point of connection of the wind turbine to the grid will depend on the output from the wind turbines and on the consumer load. Situations where the voltage becomes high due to a high wind power production and a low consumer load will quite often occur. Design should limit maximum voltage to acceptable levels. Normally, nominal voltage ± 10 % as instantaneous value or ± 5 % as 10-minute average value.

Another important aspect is the power fluctuations. The power fluctuations create fluctuations in the voltage and they impose fluctuations in the diesel output. The voltage fluctuations have to be low to avoid disturbances e.g. in the light intensity. The power fluctuations do not only depend on the amount of installed wind power capacity, but also on whether the wind farm consists of a few large wind turbines or correspondingly more, but smaller wind turbines. The relative power fluctuation level basically is decreasing as the number of wind turbines is increasing and as the power output from the wind turbines is increasing.

## 2. Introduction

This wind farm measurements and studies program deals with Power Quality Assessment, the measurements for the study of power quality were carried out at Zafarana wind farm and have been approximately one month from 16/12/2005 to 15/01/2006.

This study should primarily be seen as an initiation and illustration of possibilities for activities and studies regarding wind farms at Zafarana, the main task of this study is to evaluate the wind farm performance and electrical properties, as well as the wind farm impact on power quality.

The installation of equipments has been accomplished with technical support and assist from protection and resident engineers at Zafarana substation.

- **Shaaban Ali Atwa**
- **Ehab El-Sayed Hassan**
- **Abdel-Fattah Helmy**

The CMS engineers at Zafarana wind farm have been checked the measurement system and data files, as well as they participated in installation of equipments, and the required data concerning wind speed, errors list during the measurement period had been compiled and reported by them.

- **Akmal El-Hewehy**
- **Mohamed Heeder**

The analysis of measurements and printout were carried out at Hurghada WETC by:

- **Amgad El-Hewehy**
- **Sayed Mansour**

## 3. Objectives

The power quality is most often described in terms of voltage stability, frequency stability and phase balance. The frequency of larger power systems is normally very stable and therefore no problem. At autonomous grids where for example diesel generators are used, wind turbines may cause frequency variations.

Since wind turbine generators represent balanced three-phase sources, they will actually improve the phase balance of the grid when they are connected. Voltage stability can be subdivided into slow voltage variations, voltage dips, flicker, transient and harmonic voltage distortion.

The objective of Power Quality Assessment task is to:

- Illustrate the wind farm impact on power quality in terms of reactive consumption, voltage and frequency deviations.

- Analyze the measurements taken and relate the results obtained to international standards and theoretical calculations.

# 4. Description of The Site

## 4.1 Zafarana Wind Farm

Zafarana is situated along the coast of Suez Gulf, 250 km north of Hurghada and 110 km south of Suez, the wind farm (total area approx.156 $km^2$, length of 20 km and width of 8 km, annual average wind speed about 9.4 m/s) located 10 km north of Zafarana town towards Suez city. Figure (1) is an overview map of the Suez Gulf.

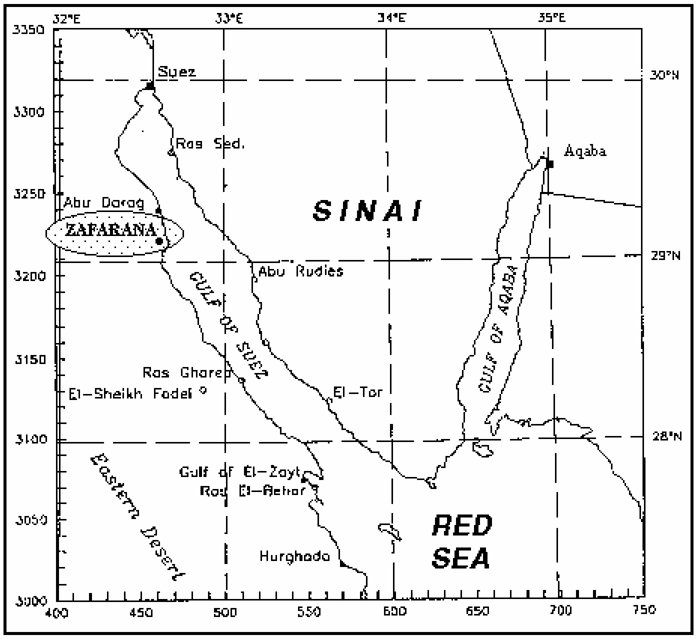



Figure 1

Zafarana wind farm presently consists of:

- Nordex wind turbines [(D1 & KFW1), 63 MW] with total capacity of 105 X 600 kW (N43 - 600 kW, 3 blades, stall regulation), the wind turbine is connected to a 50 Hz, 22 kV medium voltage system by a separate transformer of (800 kVA, 0.69/22 kV).

- Vestas wind turbines [(D2 & KFW2 & KFW3), 77 MW] with total capacity of 117 X 660 kW (V47 - 660 kW, 3 blades, pitch control), the wind turbine is connected to a 50 Hz, 22 kV medium voltage system by a separate transformer of (800 kVA, 0.69/22 kV), Figure (2) is an overview for part of zafarana wind farm.

### 4.2 Zafarana Substation

Zafarana wind farm has been linked to the national grid via a transformer substation located few kilometers north of the site; substation has two stationary transformers and mobile one. The substation has many incoming and outgoing coupling points, as shown in Figure (3).

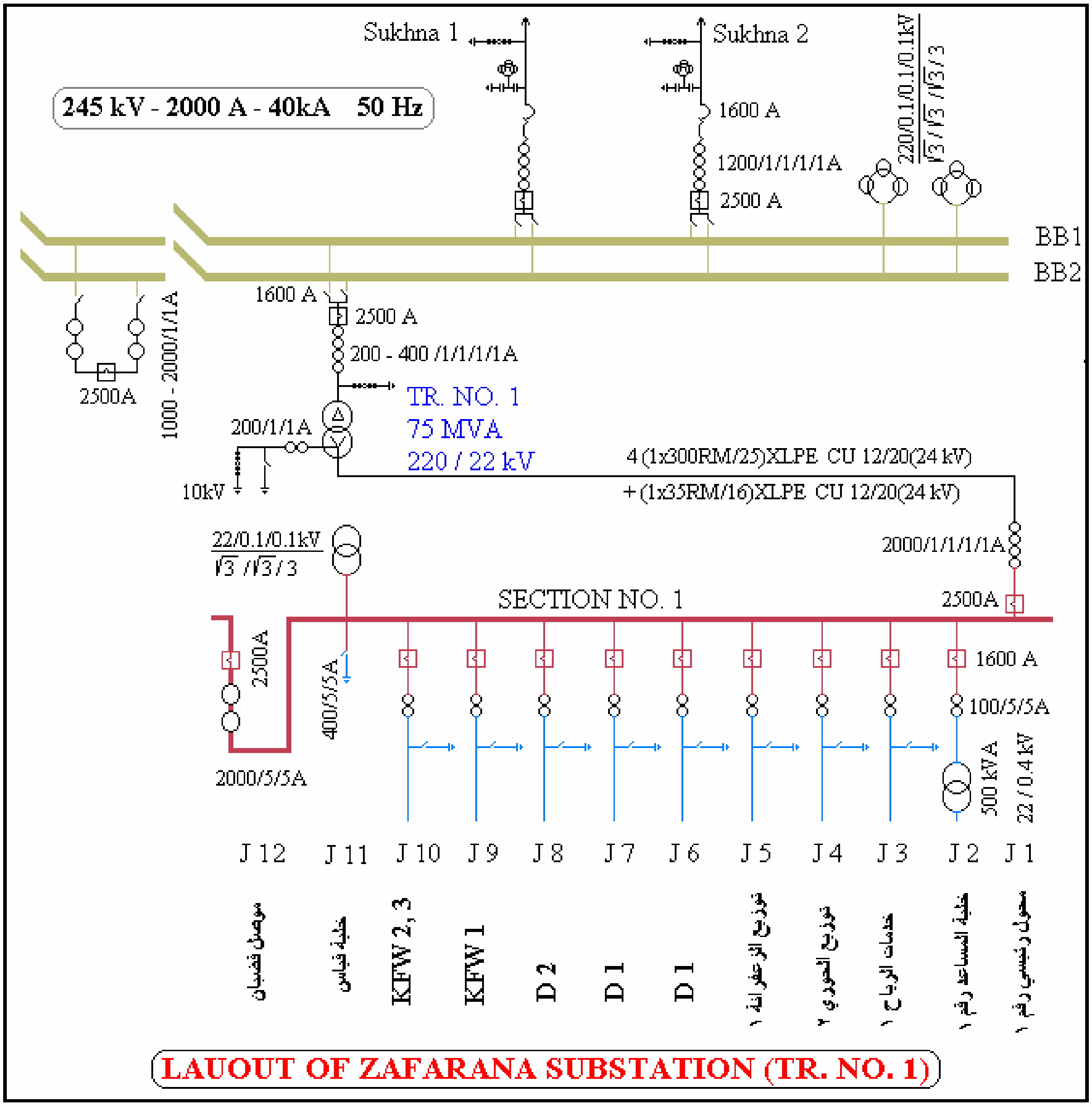



Figure 3

The substation presently consists of two transformers of 75 MVA, 220 kV for each (TR.1 of 54.2 MW and TR. 2 of 64.9 MW installed capacity), and mobile substation (25 KVA - 21.1 MW).

Each wind turbine is connected to a 50 Hz, 22 kV medium voltage system by a separate transformer of 800 kVA, 0.69/22 kV.

The turbines and its feeders connected to transformer No. 1 are shown in figure (4) (schematic diagram of Zafarana Substation, Transformer No. 1), [Appendix 9, Table (1)].

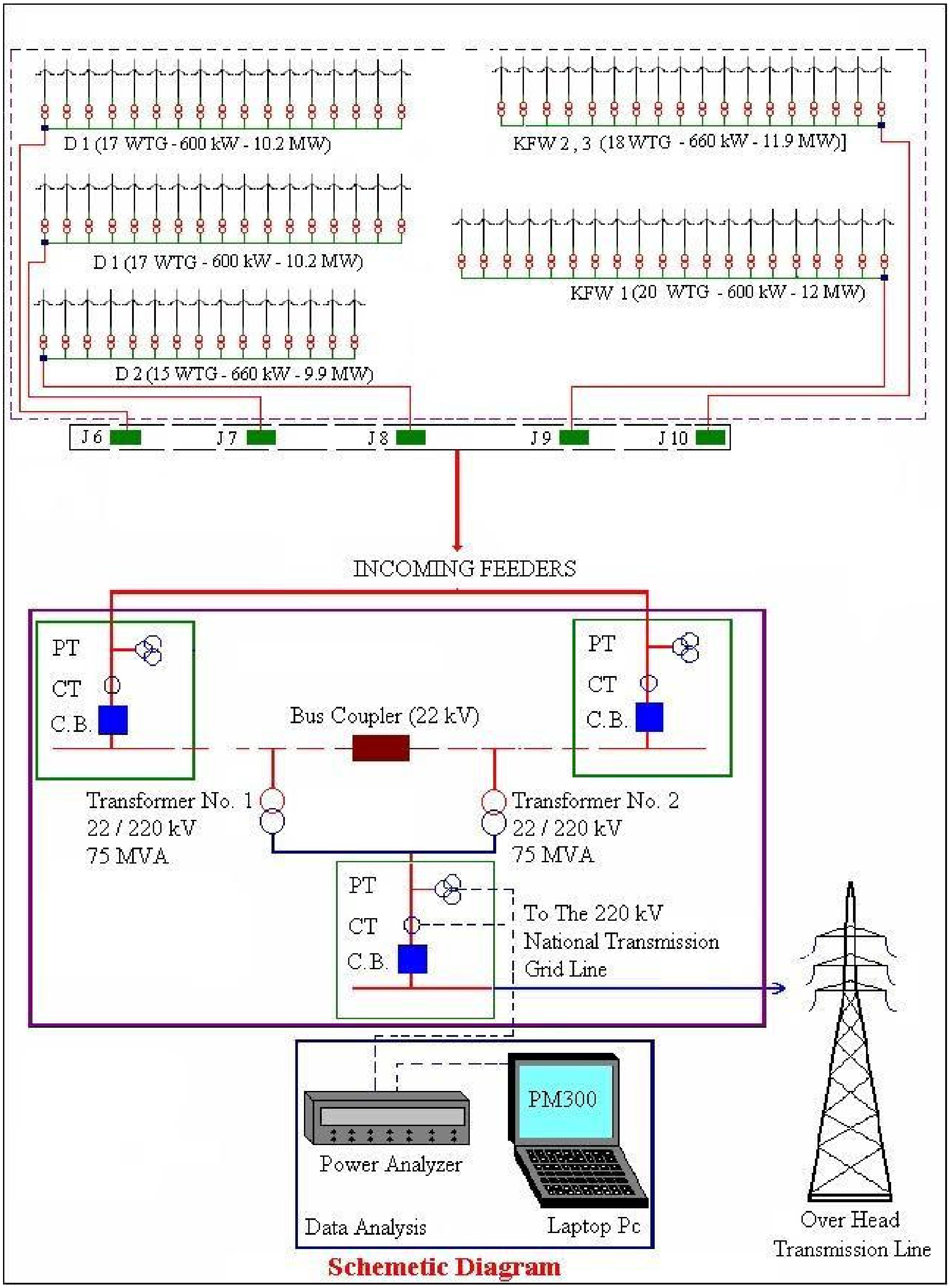



Figure 4

# 5. Data Acquisition and Analysis

## 5.1 Measurement System

The power analyzing system consists of a Voltech PM300 power analyzer, an Olivetti ECHOS 120 laptop PC, and a data logging program called PM300.EXE developed in the programming language Quick Basic 4.5 by Risø National Laboratory. The Voltech PM300 power analyzer performs the actual power measurements, whereas the Basic program PM300.EXE running on the Olivetti laptop computer controls the power analyzer and logs data from it.

The laptop PC running the program PM300.EXE was applied to control the power analyzer and to store data in the hard disk of the PC. The power analyzer was set-up to give total and fundamental values of the three phase active and reactive power, voltage and currents as well as the fundamental frequency, the total harmonic voltage distortion, the odd voltage harmonics up to $11^{th}$ and the total harmonic current distortion, the sampling rate for storing data to the hard disk was set to 10 second, the measurement continued from 16/12/2005 to 15/01/2006.

The logged raw data are stored in ASCII format on files (Time series) named with 8 digits [(00000000.txt), (name)(year)(month)(day).txt], [Appendix 9, Table (2)]

***Voltech PM300 Power Analyzer***

The main specifications:

| | | | |
|---|---|---|---|
| Connection | : three-phase Voltage | Bandwidth | : DC to 250 kHz |
| Current accuracy | : 0.2 % | Current range (direct) | : 20 A rms (200 A peak) |
| Watt accuracy | : 0.4 % | Voltage range | : 1000 V peak |

The power analyzer has a front panel from which it can be controlled manually and a display to show the measured values however, it is not able to store data.

***Laptop CPU***

The main specifications:

| | | | | | |
|---|---|---|---|---|---|
| Processor | : 120 MHz Pentium | Memory | : 16 MB RAM | | |
| Screen | : SVGA Color Screen (600x800) | CD-ROM | : 6X Speed | HD | : 1.2 GB |

## 5.2 Description of Data Handling Routines

***Basic program PM300.EXE***

The Basic software program sets up the power analyzer and logs the measurements, the communication between the laptop computer and the power analyzer is based on RS232. Basic has been chosen as programming language because a simple starter program in Basic is given in the PM300 user manual for RS232 communication (Ref 5).

The first line in the set-up file is the name of the configuration file (Zaf.CFG), the configuration file is an ASCII file, which enables configuration of the PM300 before the data logging starts, the parameters that can be controlled are wiring, current and voltage scaling, range selection etc.

The second line in the input file is the name of the selection file (Zaf.SEL), this file is also an ASCII file. It determines which channels are logged (channel 1, 2, 3, sum, and possibly neutral) and which parameters are logged (power, reactive power, voltage, frequency, current, etc).

The third line in the set-up file is the name of an ASCII output file. As example, Zb060110.txt has been selected. The head of the output file contains copies of the set-up file, the configuration file, and the selection file. Moreover, after setting the specified configuration, the PM300.EXE program gets all configuration codes from the power analyzer and copies them to the output files. This information is useful if the communication between the laptop PC and the power analyzer has failed. The remainder (and main part) of the output file is the logged data in columns with the time as the first column.

The sixth parameter in the set-up file is the sampling time. The PM300 does not specify how fast the sampling time can be, but our experience showed that it should be more than 3 seconds. The minimum sampling time depend on the specified set-up, for instance if specific time consuming calculations such as harmonics have been selected.

The last parameter is the number of measurement channels. This parameter can-in simple cases-be calculated according to the specifications in the selection file using the table (Page 64) in the RS232 manual. If this number is too small, the Basic program will make confusion in the output data file, and if it is too large, it will stop, waiting for data from the PM300.

***The set-up file***

The Basic program PM300.EXE runs from DOS with a single parameter: the set-up file name. The set-up file is an ASCII file. For the power quality measurements described in this report, the set-up file Zaf.sup has been used.

The fourth parameter in the set-up file is the baud rate, this parameter must be the same in the input file as set manually on the PM300, because no communication is possible when the baud rate is conflicting.

The fifth parameter in the set-up file is the measurement time. In the example, it is 360000 second corresponding to 100 hours. This high value has been selected to ensure that the data logging is not interrupted by the program. When the user of the program wants to stop the data logging, the Break key can always be used, which will not be sent. An easy way to determine the number of measurement channels is to specify a very high value, and then run PM300.EXE. Then the program will stop after the first sample of data is send from the power analyzer. The program writes data both to the output file and to the screen. Therefore, the number of channels can be counted either from the screen or from the output file after the program has been interrupted.

Note that parameter 4 to 7 in the set-up file consists of data followed by a comment. The three first parameters, however, have only file names and no comments. Because of the simple reading procedure of the Basic program, this syntax must be followed.

***Configuration file***

The configuration file specifies the configuration such as wiring, scaling etc. A complete list of the available parameters is given in the RS232 manual for the PM300 (Pages 58-63). The first two columns are data used by the PM300.EXE Basic program to configure the power analyzer. The following text is only for comments to the user. Note that the user must specify a comment, because PM300.EXE reads it from the file.

The frequency source (configuration parameter 14 and 15) can cause problems with keeping a fixed sampling time if the frequency of the current shall be calculated but the current is approximately zero. Therefore, the frequency source has been selected to voltage.

***Selection file***

The original purpose of the selection file was only to enable the specification of selection commands such as: SEL: SUM and: SEL: WAT as described in the RS232 manual for the PM300 (Pages 64-66). However, the PM300.EXE Basic program has implemented this task simply by sending the contents of the selection file to the Power Analyzer. Consequently, the selection file can also be used to specify other commands than selection commands to the power analyzer. As an example of that, the command: HMX : ODD 11 is added to the configuration file below, specifying odd harmonic orders up to 11 the harmonic [RS232 manual (Page 40)].

***Data Analysis files***

A software program called PM300sta.EXE developed by Risø were used to generate statistical file (STA, 10-minute Average) [Appendix 9, Table (3)]. from time series file (TXT, 10-sec)

As well as another software program (Consolstanal.EXE, input, listfile) developed by Risø were used for generate two output files, the first is statistical file (the mean value for continuously 10 minute, daily "measurement period") and the second is diurnal file (the mean value as 10-minute over 24 hour throughout measurement period from midnight to midnight), [Appendix 9, Table (4)].

The data analysis were performed using Microsoft Excel.

## 5.3 The Measurements

The measurements were carried out at Zafarana substation on 22 kV Bus Bar, the substation has no single feeder with the total output power of the wind farm, thereby a direct measurements of the total output power is not possible. At substation there are two permanent transformer and mobile one, in order to measure the total power, the currents of the three transformers (TR. 1, TR. 2 and mobile one) must be summed simultaneously using summation transformer where it was not available during the measurements period.

According to the situation at zafarana substation, it is decided to achieve the measurements individually on transformer No. 2 and transformer No. 1, thereby the measurement equipments had been connected to the secondary side of the potential transformer (22000/100 V) to measure the voltage, as well as the current measured using current clamps (1 mV: 1 mA) on the secondary side of the existing current transformer (2000:1 A) of transformer No. 1.

# 6. Measurements Analysis and Results

Key data for Zafarana wind farm measurements

| ITEM | DESCRIPTION |
|---|---|
| Start Date | 16/12/2005 |
| Stop Date | 15/01/2006 |
| Nominal power | 54.2 MW |
| Max. output power (10-minute average) | 46.14 MW |
| Min. output power (10-minute average) | 0.12 MW |
| Mean. output power (10-minute average) | 12.44 MW |
| Mean PF (10-minute average) | 76.1 |
| Mean CF (10-minute average) | 22.95 |
| Mean Bus-Bar Voltage (10-minute average) | 22.87 kV |

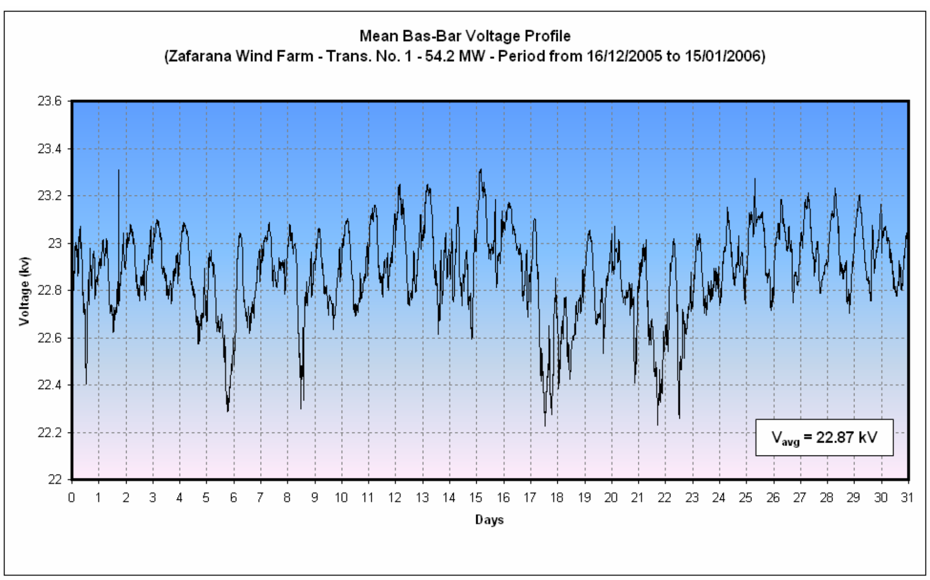
### 6.1 Bus-Bar Voltage

The valid measurement with the power analyzer on 22 kV Bus-Bar give basis for assessing the voltage quality and to analyze the impact of the wind farm on the voltage quality.

Plot (1) is the statistical data of the mean value of the Bus-Bar voltage, the voltage level during the measurement period between 22.25 kV and 23.31 kV, or in other words 22 kV **+ 5.97 %** and – 1.03 %.

International standard (IEC - Ref 3) specifies that the voltage level should be within ± 5 % of its nominal value measured as 10-minute average data or ± 10 % of its measured instantaneous values.

From the results obtained, it could be stated that the voltage level when reaches to its minimum value still within the required limit, meanwhile it is out of range when reaches to its maximum value.

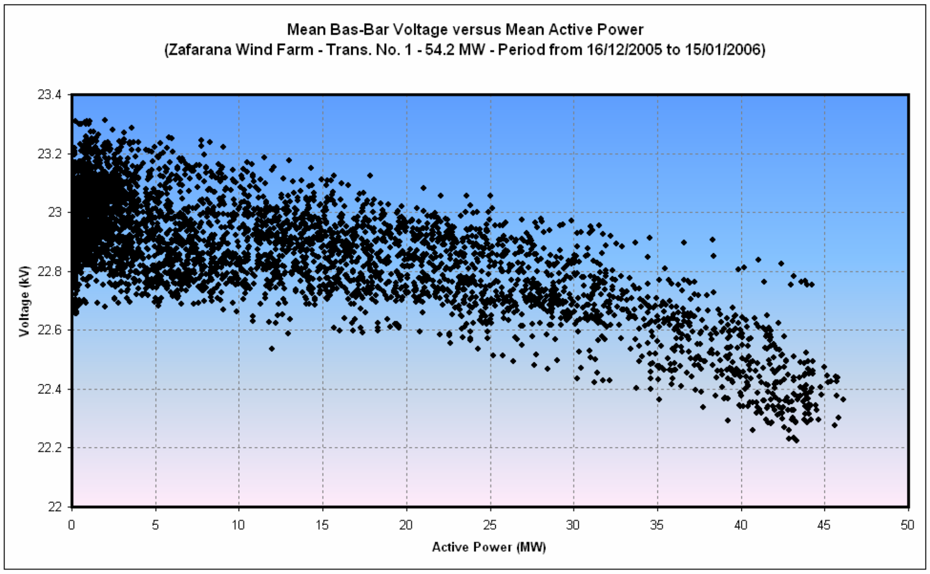



Plot 1

Plot (2) is the statistical data as 10-minute average values of the Bus-Bar voltage plotted versus the 10-minute average values of the output active power from the wind turbines.

In this plot, the voltage level decreases for increasing the active power from the wind turbines, as well as the voltage level seems to be extremely high at low power generated from the wind turbines (cloudy points seen in the plot).

The situation is predicted, since the nominal power of the wind turbine connected to transformer no.1 is 54.2 MW, which is significantly high-generated power.




Plot 2

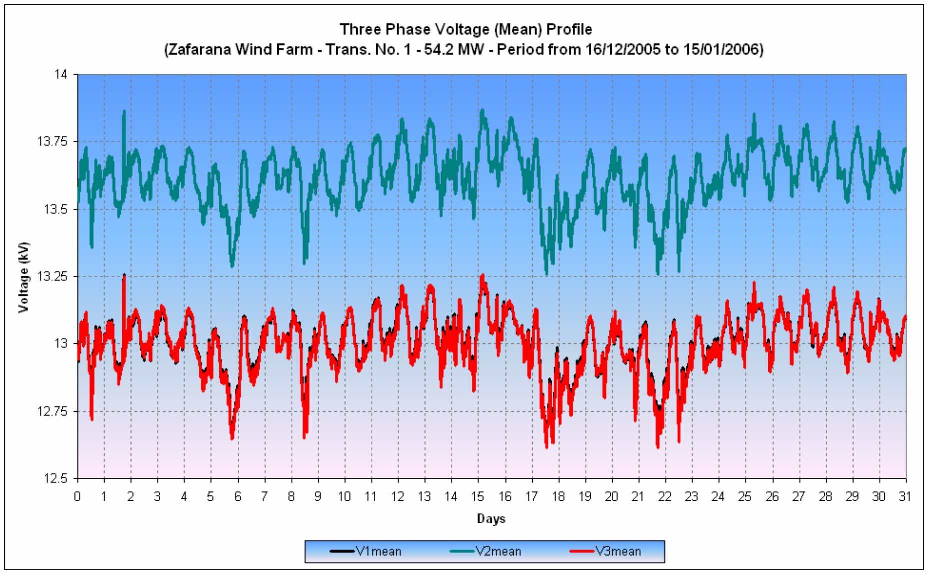
Plot (3) is the statistical data of the three phase voltages as 10-minute average during the measurement period, the limits of the three phase voltages are shown below:

Phase No. 1 varies from 12.62 kV to 13.26 kV, or 12.7 kV + 4.39% and – 0.6 %.
Phase No. 2 varies from 13.26 kV to 13.87 kV, or 12.7 kV **+ 9.21 %** and -4.38 %.
Phase No. 3 varies from 12.62 kV to 13.26 kV, or 12.7 kV + 4.39% and – 0.6 %.

The international standard specifies that the voltage level should be within ± 5 % of its nominal value measured as 10-minute average data.

From the results obtained, it could be stated that the maximum and minimum values of phase No. 2 and phase No. 3 respectively, are critically out of range.

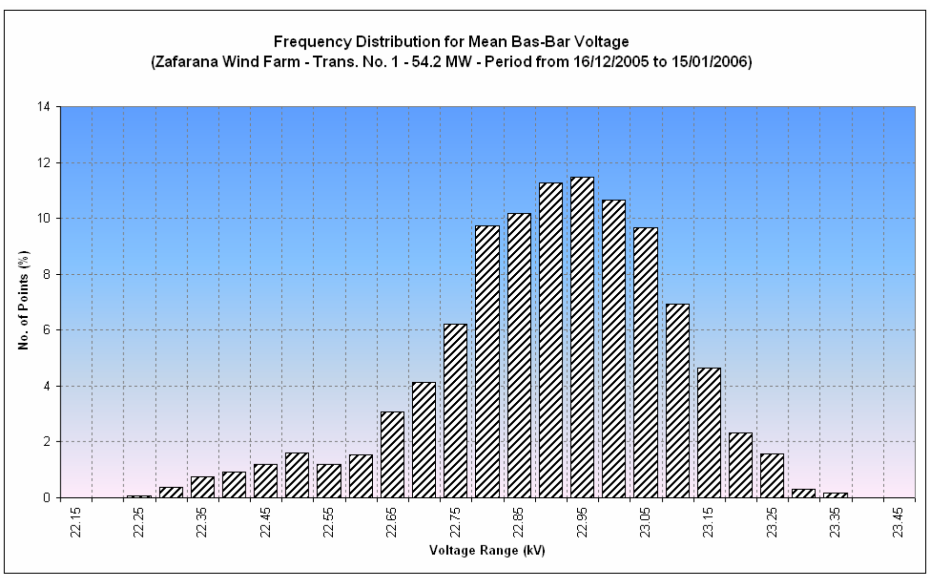
***note*****:** The amplitude of the resulting voltage, drop or rise will depend on the impedance of the feeder between the wind turbine and the substation. The stability of the grid will be sensitive to the ratio of X/R where (X) is the source impedance's reactance and (R) is the source impedance's resistance.




Plot 3

Plot (4) is the absolute value of the frequency distribution as 10-minute average value of the Bus-Bar voltage, there are two different situations are clearly observable in the plot, the first is the distribution is not symmetrical around the nominal value (22 kV) ($Z_0$).

The second is that two peaks are noticed at 22.1 kV and 22.2 kV, as well as the voltage range is quite narrow due to the wind farm connected to a large network. The voltage varies almost from 21.3 kV ($Z_1$) to 22.7 kV ($Z_2$) during the measurement period.

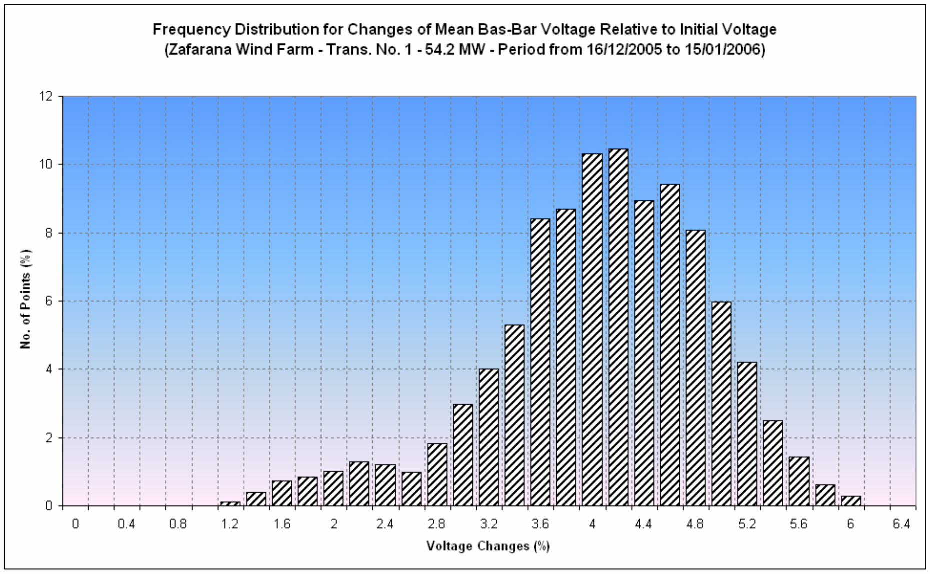



Plot 4

***Hint*: for a given set of values and a given set of bins (intervals), a frequency distribution counts how many of the values occur in each interval.**

Plot (5) is the voltage change relative to the initial (nominal) value "22 kV" from one 10-minute value to the next, the majority of the relative voltage changes are between +2.2 % and -2.6 % as magnitude (bin).

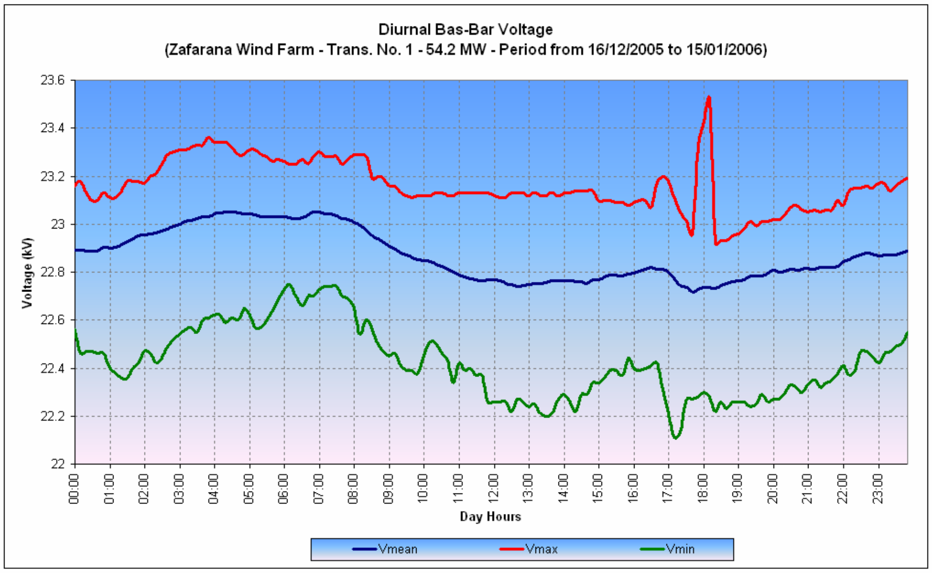
The plot shows that voltage varies in a small range and very few values above +3 % occur. No significant peaks are noticed in the plot, as well as the distribution is not symmetrical around $Z_O$ (when $V_{mean} = V_{initial}$).




Plot 5

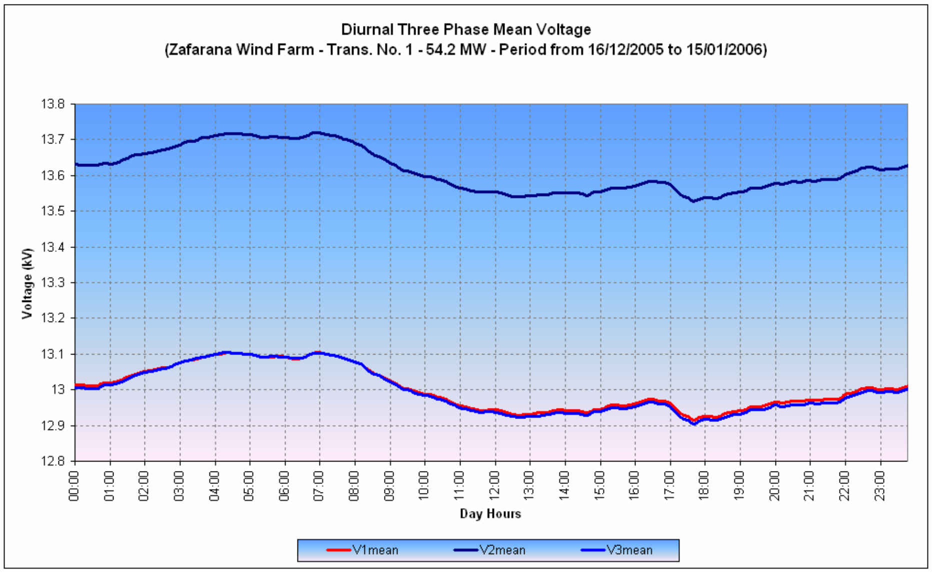
$$V_{relative} = [\frac{V_{mean} - V_{initial}}{V_{initial}}] * 100$$

Plot (6) is the diurnal pattern for the mean, maximum and minimum value of the Bus-Bar voltage, the plot is the typical value of the Bus-Bar voltage profile, since the plot is the average value throughout the measurement period.



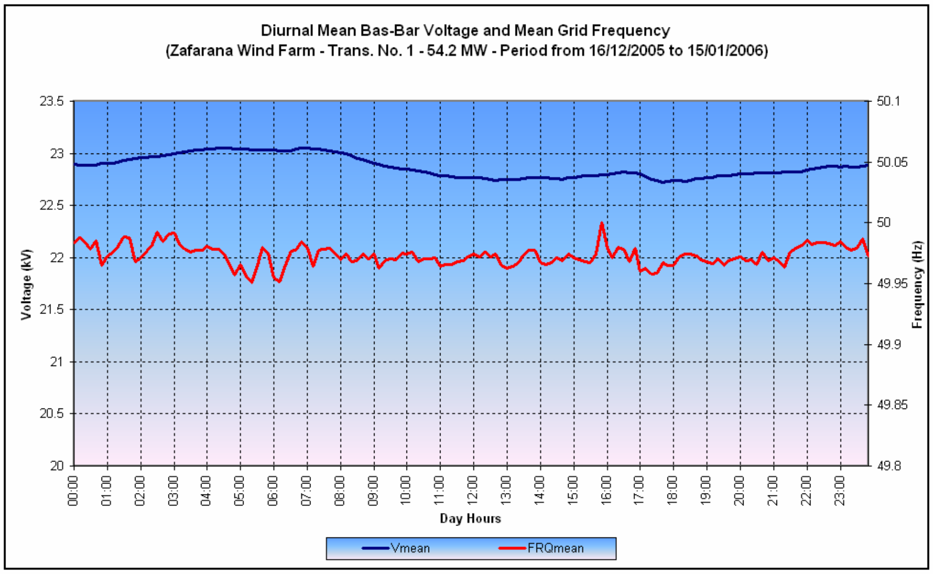

Plot 6

Plot (7) is the diurnal pattern of the three phase voltages as 10-minute average, it is clearly seen in the plot that phase No. 1 and phase No. 3 are slightly lower than phase No. 2.



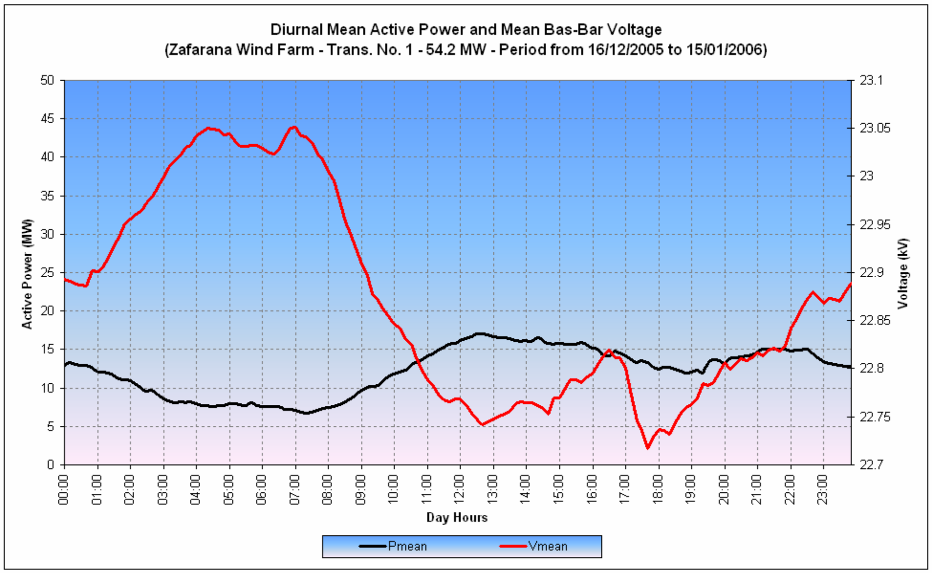

Plot 7

Plot (8) is the diurnal pattern of the grid voltage and grid frequency, the plot shows that the grid frequency is almost constant independent of the Bus-Bar voltage level.



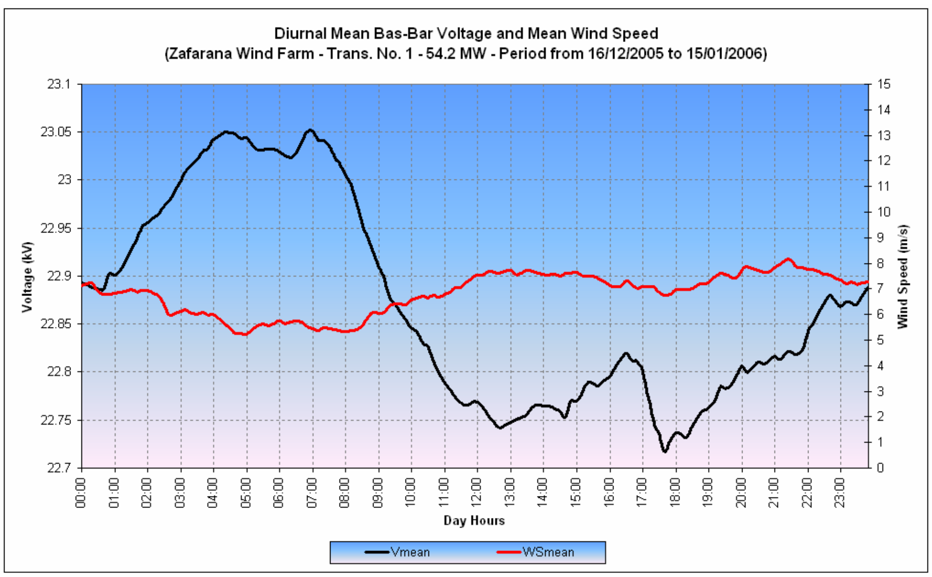

Plot 8

Plot (9) illustrates the diurnal pattern of the Bus-Bar voltage and active power, the plot shows that the voltage varies reversely to the active power. Assuming a fairly relation between the voltage and the output power, it is obviously seen in the plot that the maximum value of active power (50.9 MW) corresponds to minimum value of voltage (21.5 kV) as 10-minute average value.




Plot 9

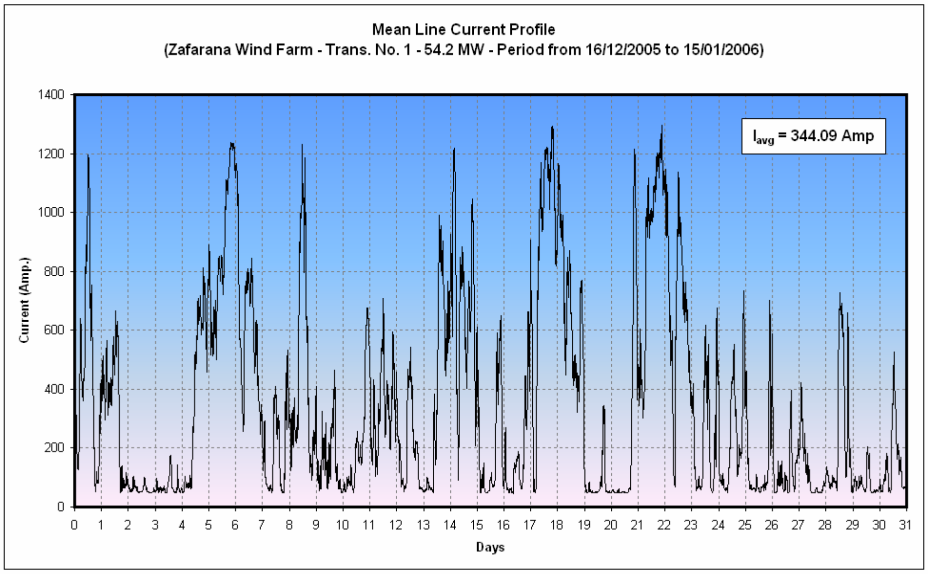
Plot (10) is the diurnal pattern of the Bus-Bar voltage and mean wind speed, the plot indicates that the voltage values seem to vary reversely to the wind speed values. The plot corresponds with voltage-power correlation as shown in Plot (9).




Plot 10

## 6.2 Line Current

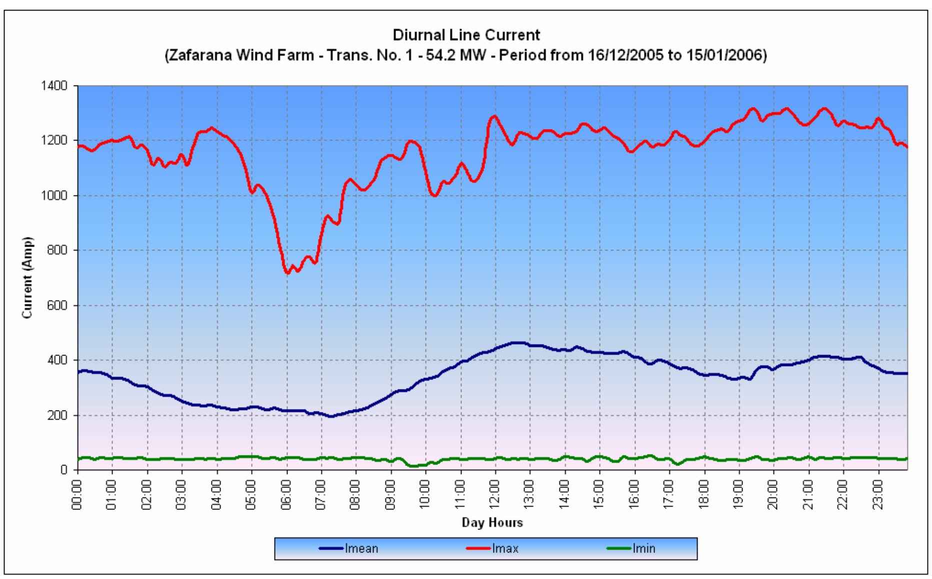
Plot (11) is the statistical data of the line current as 10-minute average during the measurement period.




Plot 11

Plot (12) is the diurnal pattern of mean, maximum and minimum values of line current. The plot is the typical value of the line current profile as the plot is the average of the measurement period.

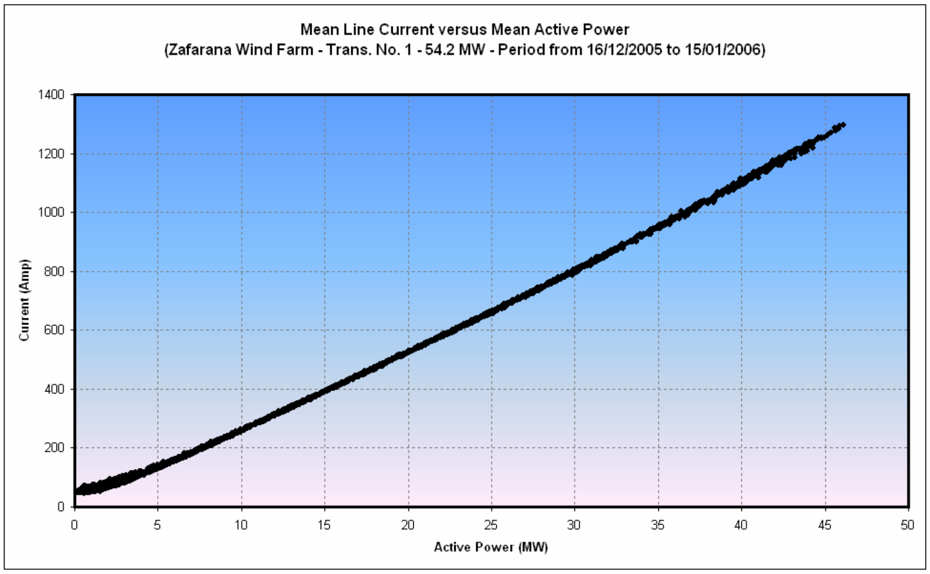
The maximum value looks constant; meanwhile, the mean and minimum values look fluctuated very much.




Plot 12

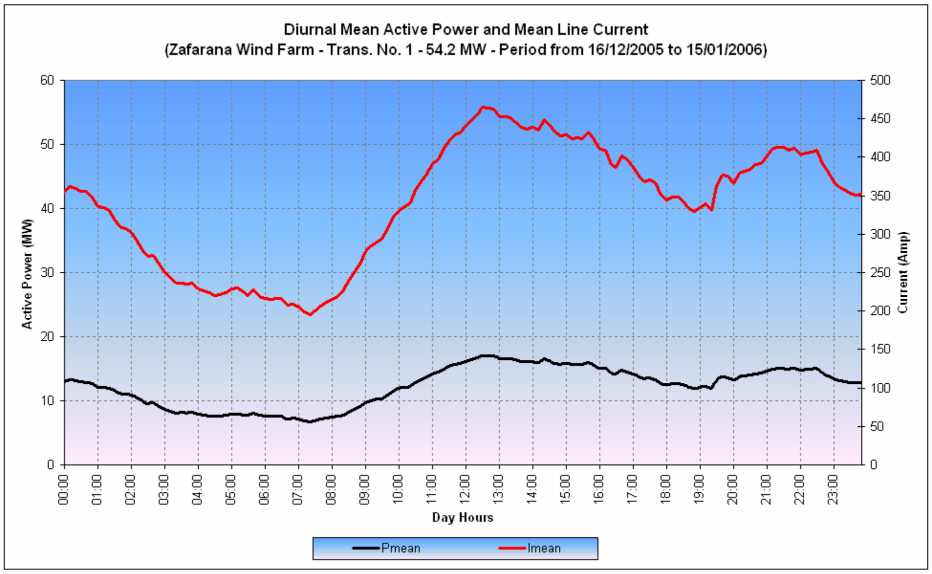
Plot (13) is the statistical data of a correlation between the output active power and line current as 10-minute average value, the plot shows that the power varies proportionally to the line current; however, there is a situation where, a small deviation has been occurred.

The raw data (Time series as 10-sec.) has been investigated carefully, and it is concluded that the current reading of phase No.1 was not match (lower than) with the other two phases, only on day 7/9/2005. The reason for this still unknown.



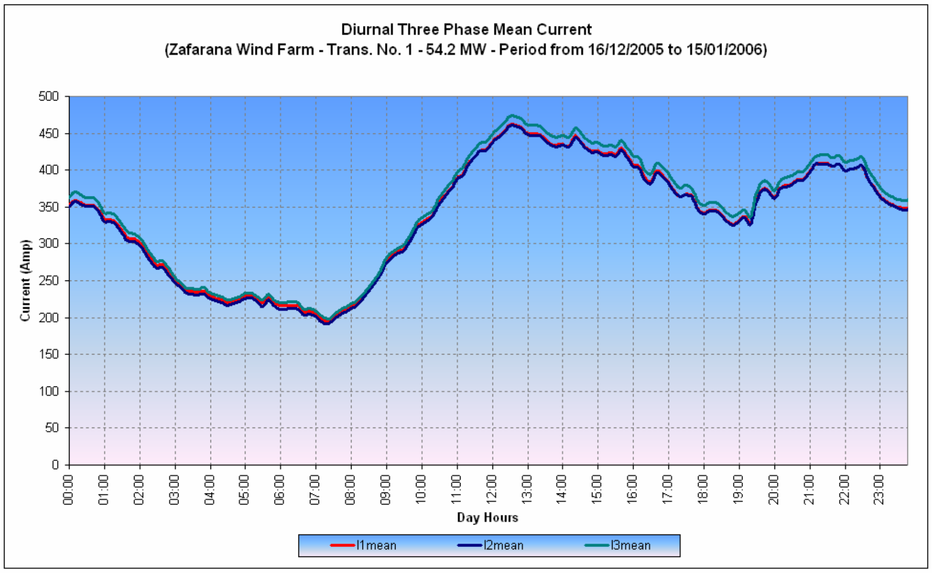

Plot 13

Plot (14) illustrates the diurnal pattern of active power and line current as 10-minute average, the plot shows that the output power varies proportionally to the line current.



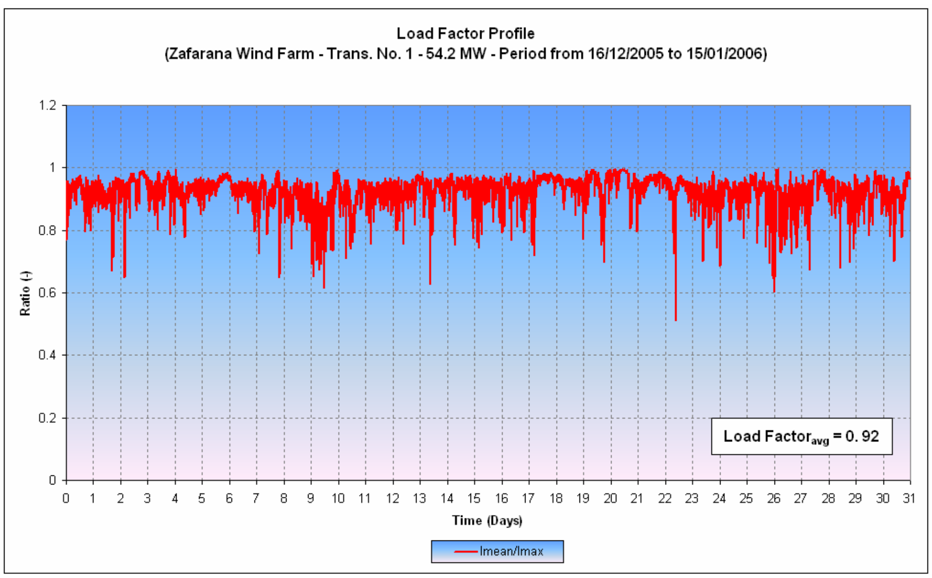

Plot 14

Plot (15) is the diurnal pattern of three phase line currents as mean value. The plot is the typical values of the three-phase currents profile as the plot is the average throughout the measurement period




Plot 15

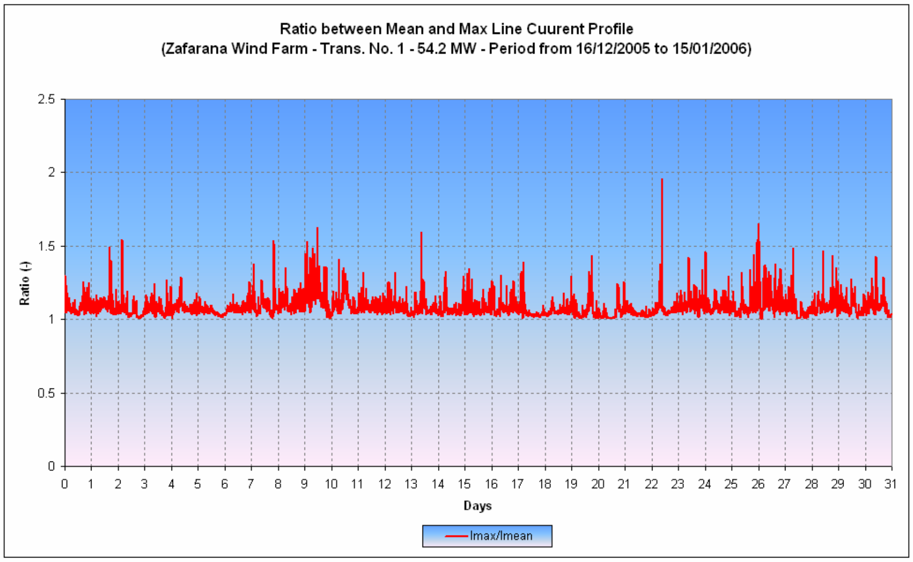
Plot (16) is the statistical data of the load factor as 10-minute average value; the load factor is 0.96 as an average value as shown in the plot.



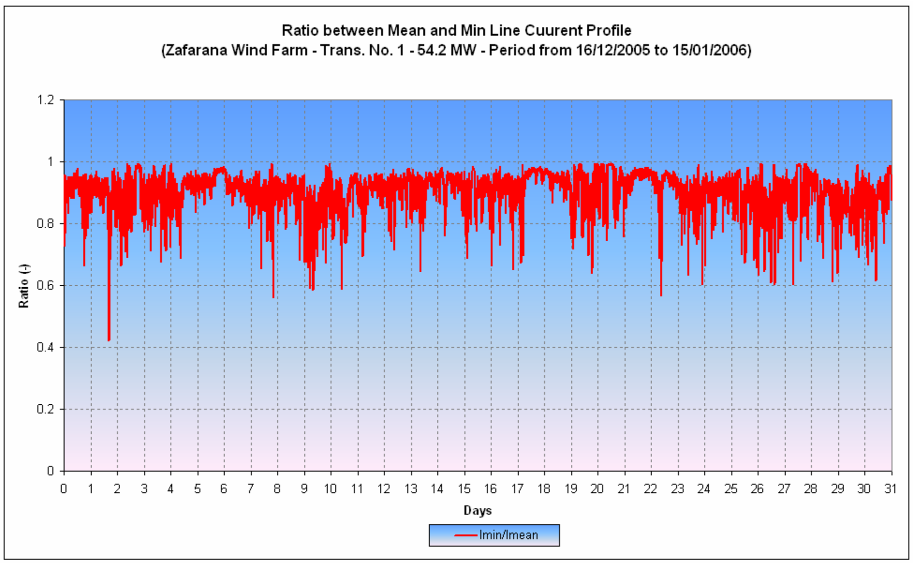

Plot 16

Plot (17), (18) and (19) illustrate the ratio between max, min and mean values of the statistical data as 10-minute average value respectively.

The ratio looks constant even though the two peaks and drops seen in the plots. The interpretation for the two peaks and drops are related to low power production at low wind speed.




Plot 17




Plot 18

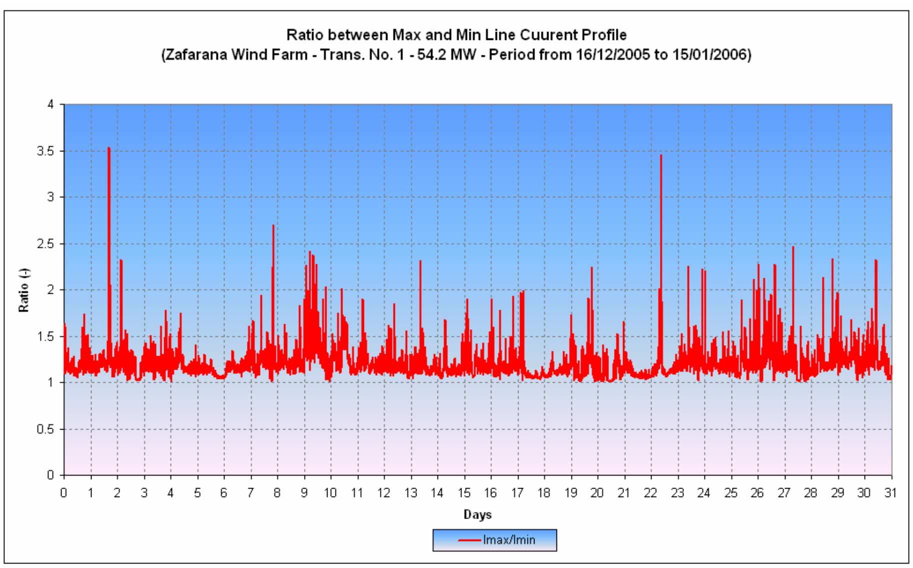
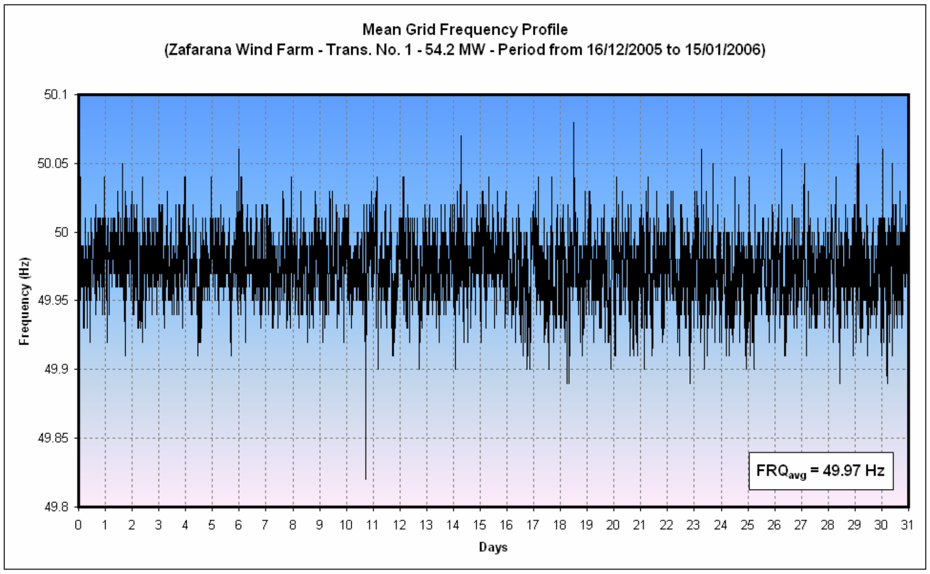



Fig 19

## 6.3 Grid Frequency

Plot (20) is the statistical data of the grid frequency profile as 10-minute average values. It is seen from the plot that the grid frequency is very stable independent of other grid parameters; the average value is 49.96 Hz during the measurement period.

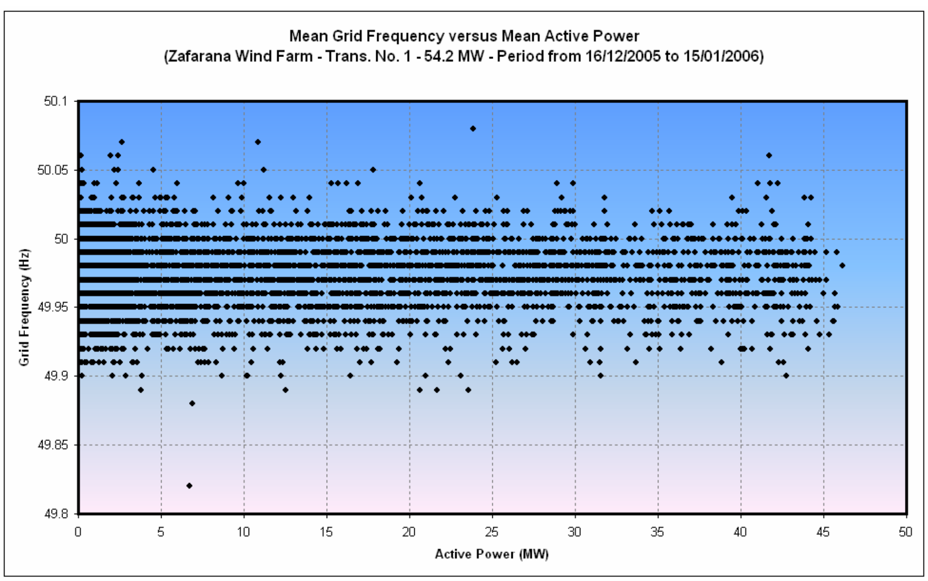
The plot shows that the frequency lays within a narrow band between 49.86 Hz and 50.13 Hz that comply with the international standards (50 Hz ± 1 %).




Plot 20

Plot (21) is the statistical data of a correlation between the grid frequency and active power, the grid frequency remains constant independent of the produced power from the wind turbines.

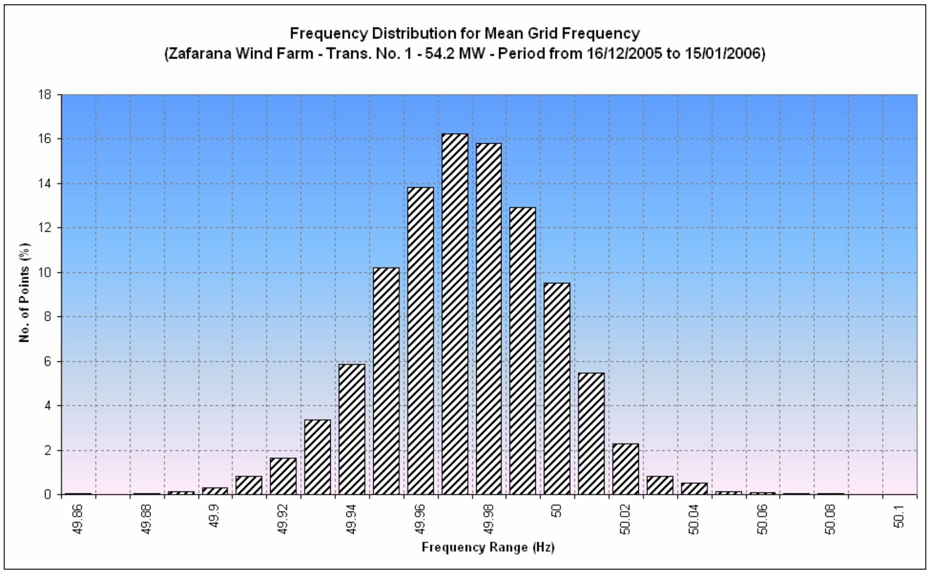
It is noticed also that the cloudy points in the plot is quit wide at high output power from the farm, however, the changes in the frequency still in a very small range.




Plot 21

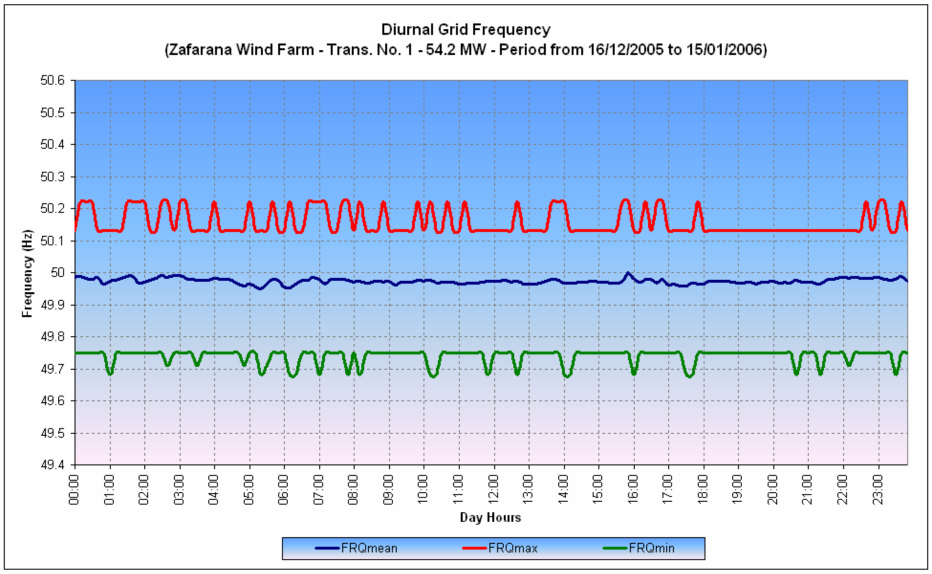
Plot (22) is the absolute change of the frequency distribution as 10–minute average values of the grid frequency, it is obviously seen in the plot that, the frequency is well controlled with only small deviations from the 50 Hz nominal setting, these small deviations are slightly above 50 Hz.

The grid frequency is quite symmetrical and triangular around 49.98 Hz, varying from 49.92 Hz to 50.03 Hz.



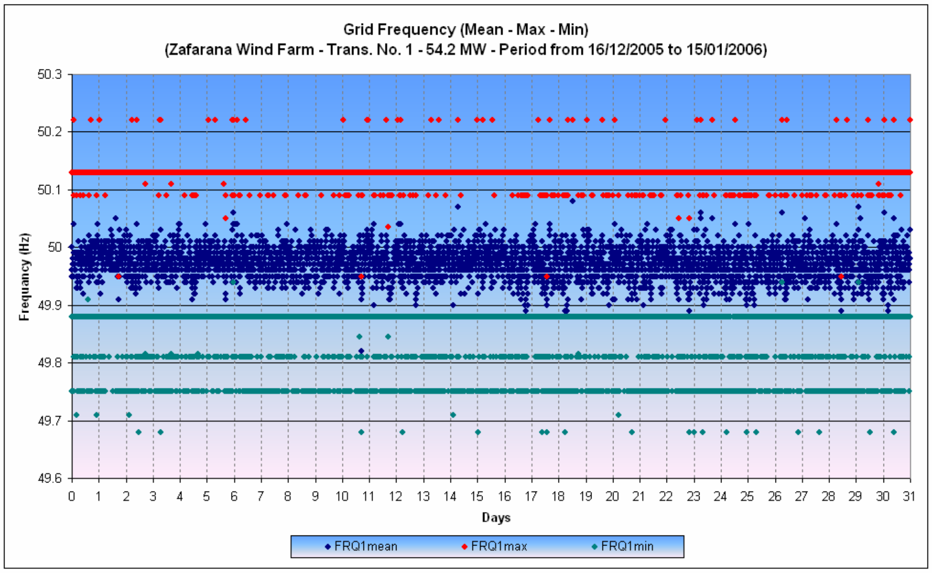

Plot 22

Plot (23) is the diurnal pattern of the mean, maximum and minimum values of the grid frequency, the plot emphasis the result obtained in Plot (22).




Plot 23

Plot (24) is the statistical data of mean, maximum and minimum values of grid frequency as 10-minute average value.

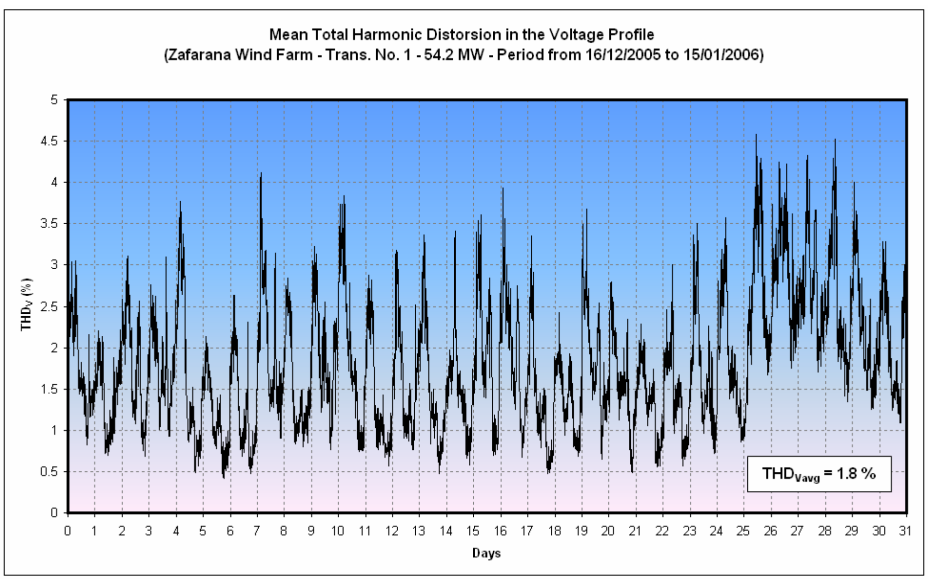



Plot 24

## 6.4 Voltage Harmonics

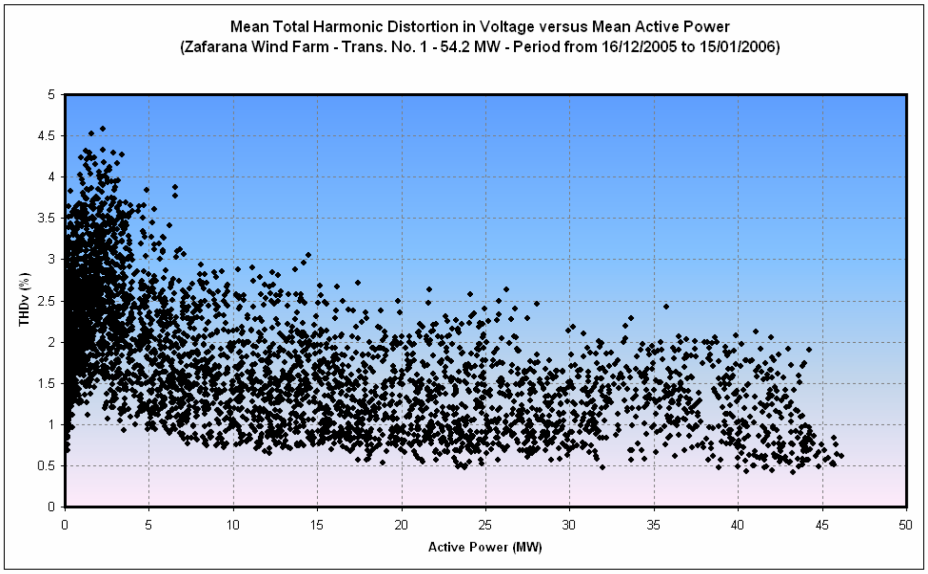
Plot (25) is the statistical data as 10-minutes average value of the Total Harmonic Distortion (THD) of the Bus-Bar voltage.

It can be seen from the plot that the measured THD within the measurement period are between 0.3 % and 3.11 %, which comply with the international standards (Voltage THD should less than 5% measured as 10-minute average) for supply voltage characteristics.



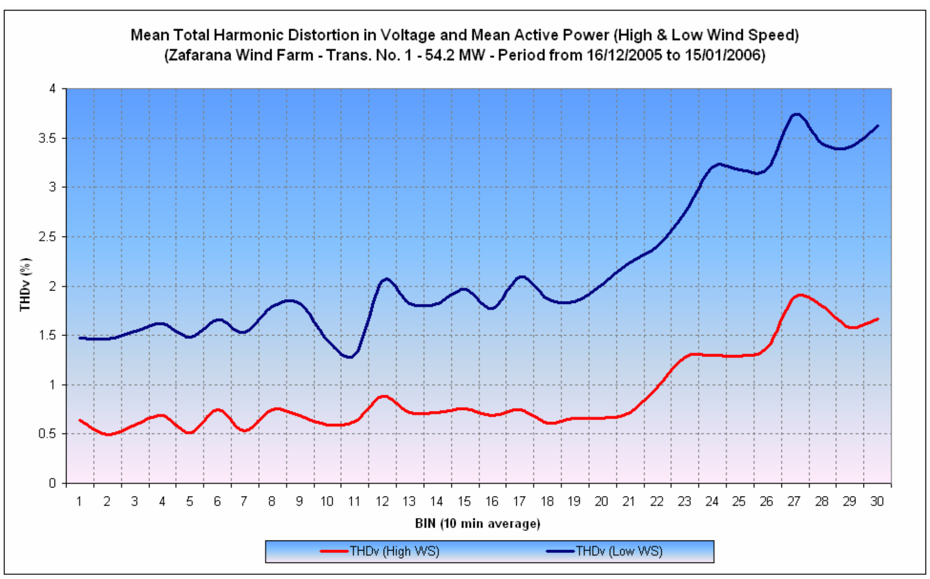

Plot 25

Plot (26) is the statistical data of a correlation between voltage THD and active power as 10-minute average value, the maximum value (3.11%) of THD occurred at 0.5 MW, indicating no particular relation between the output active power and the voltage THD, but the voltage THD follows the daily load pattern.

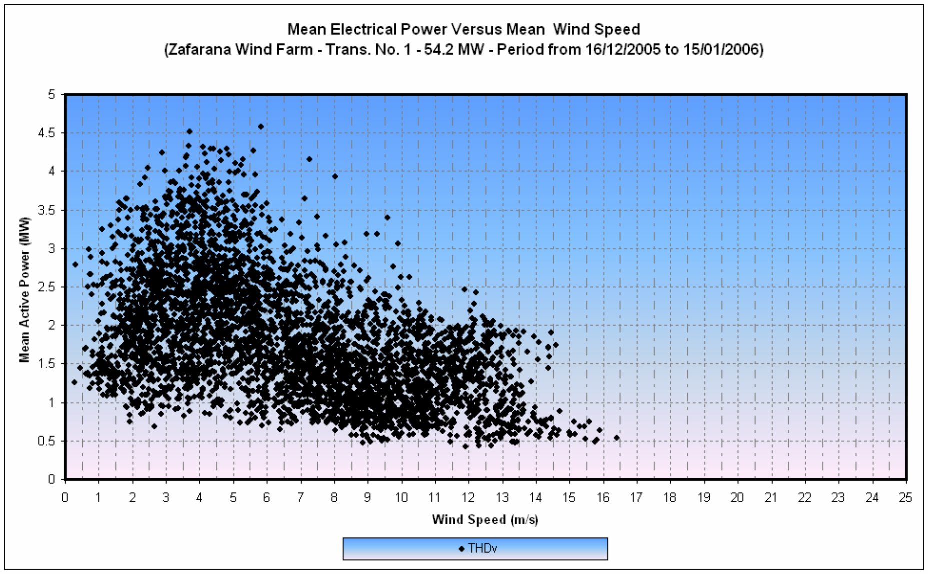



Plot 26

Plot (27) is the voltage THD in case of high and low wind speed, the plot emphasizes the fact that the wind turbines are not responsible for causing any significant harmonic distortion, in particular, the wind turbines at the site are fixed-speed with induction generator (without a power electronic converter).

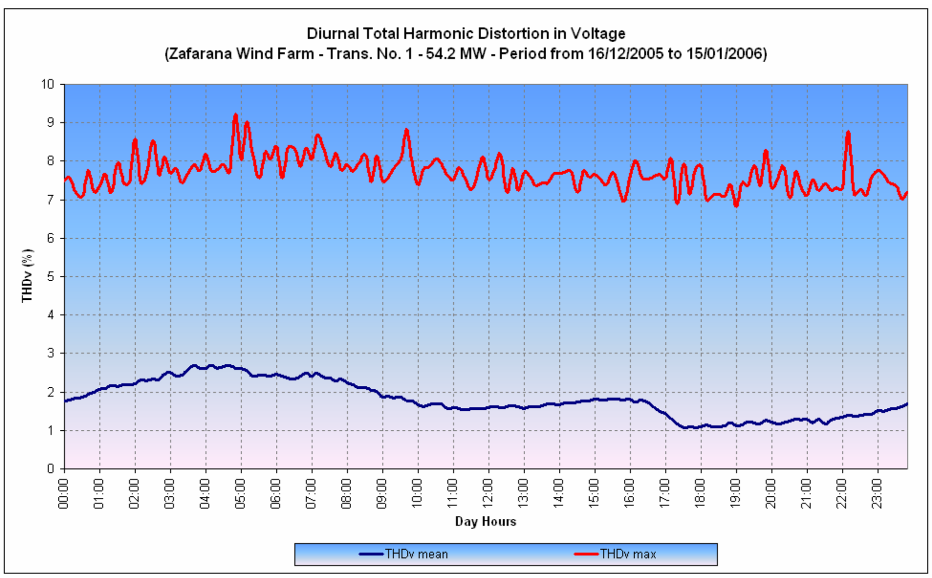



Plot 27



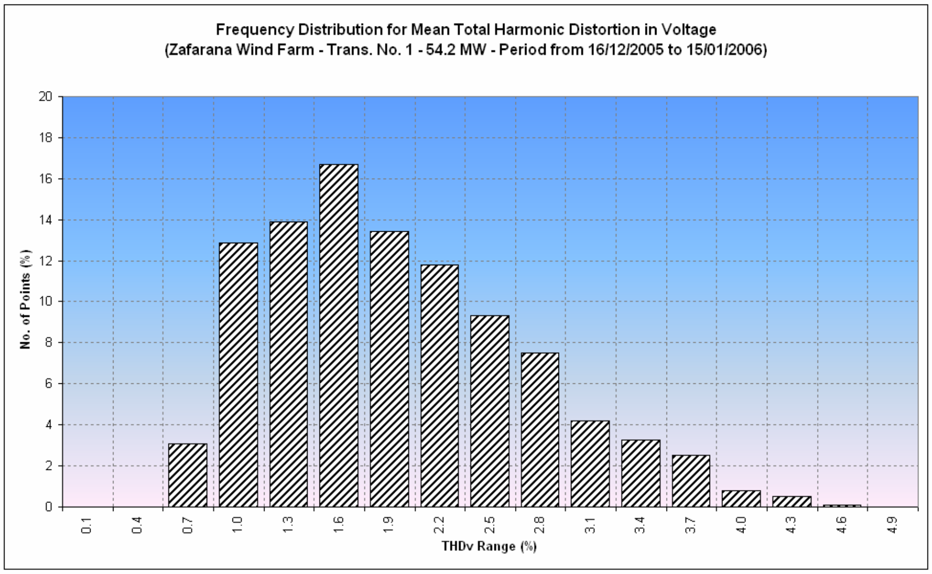

Plot (28) is the diurnal pattern of the mean and maximum values of the total harmonic distortion of the Bus-Bar voltage.

The plot is the typical voltage THD profile since the plot is the average value throughout the measurement period.




Plot 28

Plot (29) illustrate the absolute value of the frequency distribution of the voltage THD, the plot does not show any particular features except for a low mean value of THD.

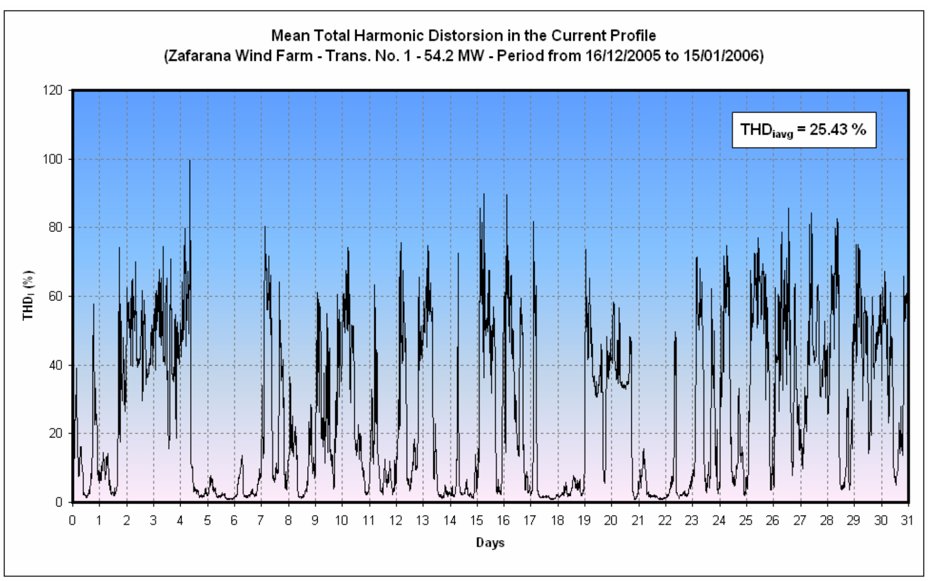



Plot 29

## 6.5 Current Harmonics

Plot (30) is the statistical data as 10-minute average value of the line current THD, it is clearly seen from the plot that there is a peak of 70 % of THD, and it is clarified that the peak corresponds with low wind speed during the measurement period.

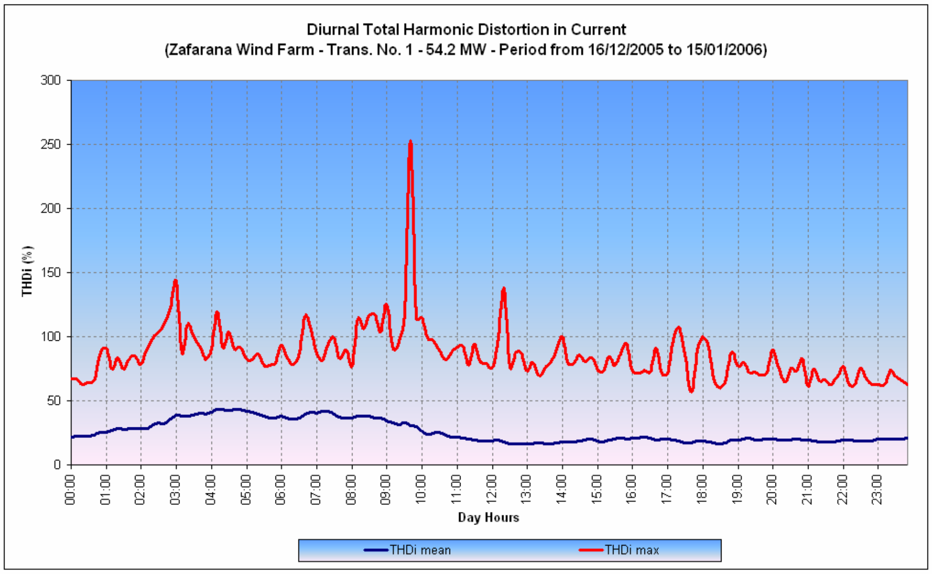
However, the other situations in the plot show very low line THD which comply with the IEC.




Plot 30

Plot (31) is the diurnal pattern of the mean and maximum values of the line current THD, the plot shows that the line current THD follows load pattern except for the situation of low wind speed.

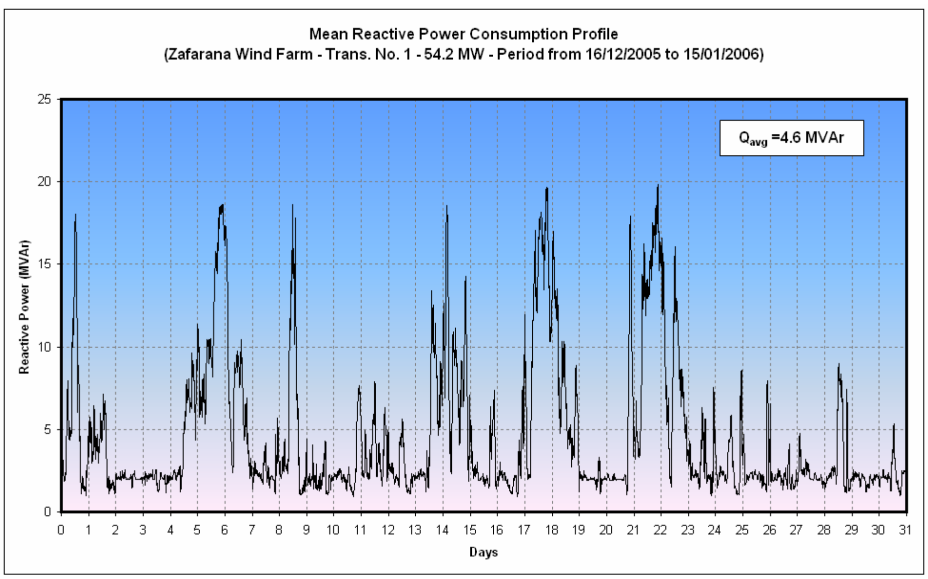
The plot corresponds with the diurnal line current plot (Plot 12), i.e. maximum current THD occurred at minimum line current.




Plot 31

### 6.6 Consumed Reactive Power

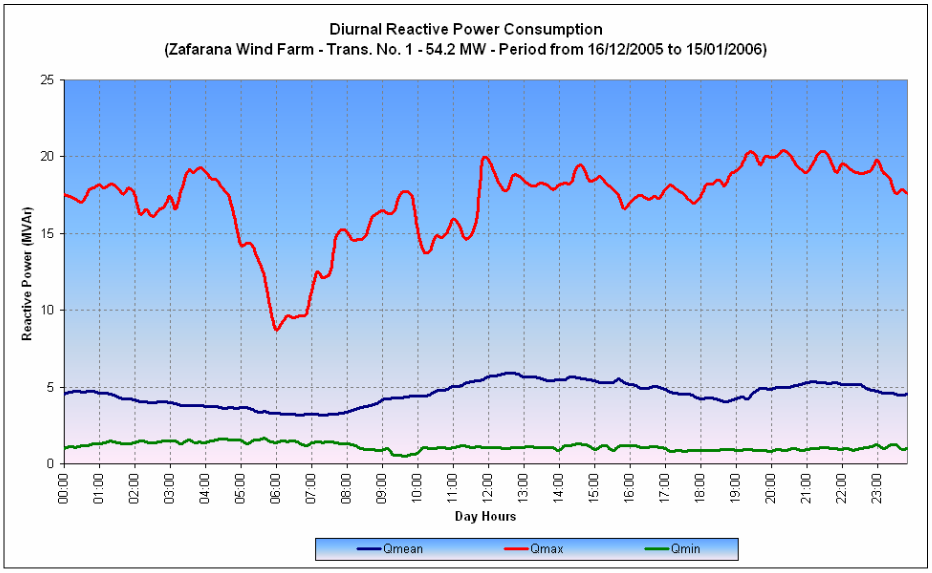
Plot (32) is the statistical data as 10-minute average values of the consumed reactive power by the wind turbines. The mean value of the consumed reactive power is 17.22 kVAr during the measurement period.




Plot 32

Plot (33) is the diurnal pattern of the mean, maximum and minimum values of the consumed reactive power.

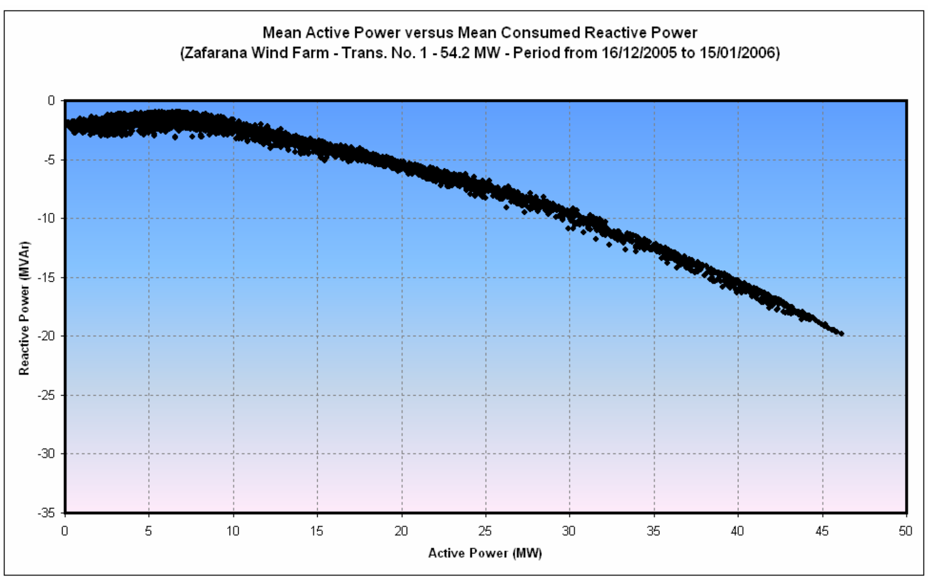
The plot is the typical consumed reactive power profile since the graph is the average values of the measurements period.




Plot 33

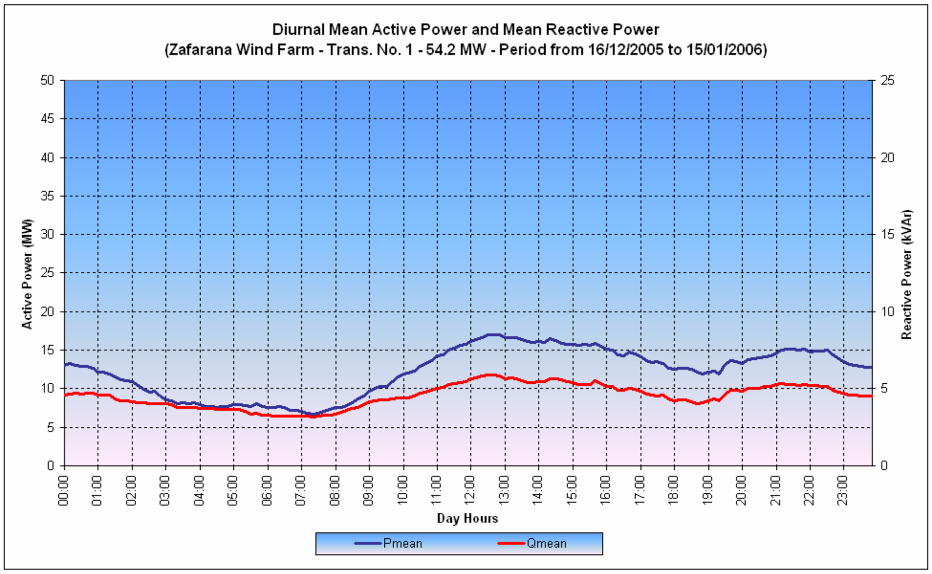
Plot (34) is the statistical data of the reactive power consumption as a function of active power production, the plot shows that the reactive power varies proportionally to the active power, even though the values are scattered when the active power is high.

The vague correlation between active and reactive power on day 7/9/2005 still needs for an interpretation, the consumed reactive power on that day looks higher than the active power.




Plot 34

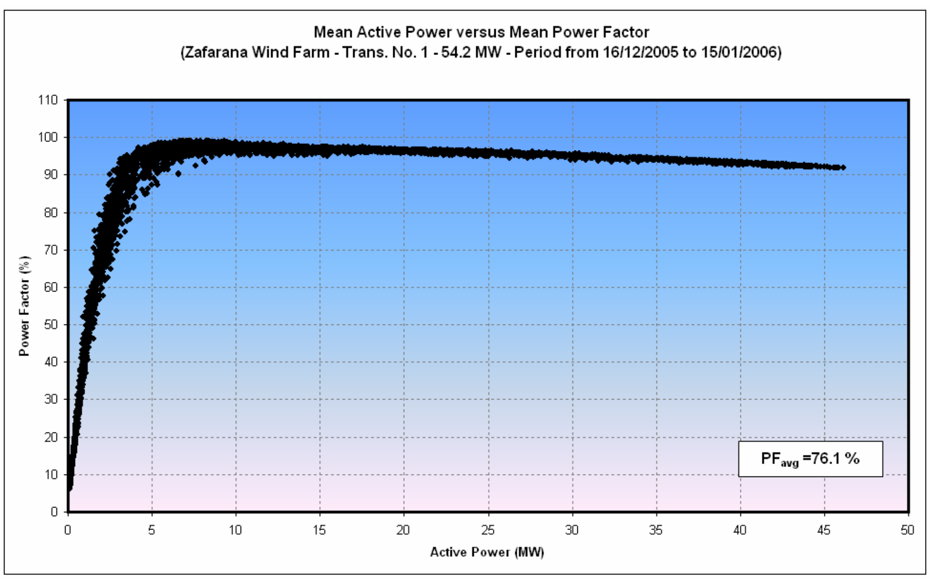
Plot (35) is the diurnal pattern of the consumed reactive power and the active power as mean value, the plot shows that the reactive power varies proportionally to the active power.




Plot 35

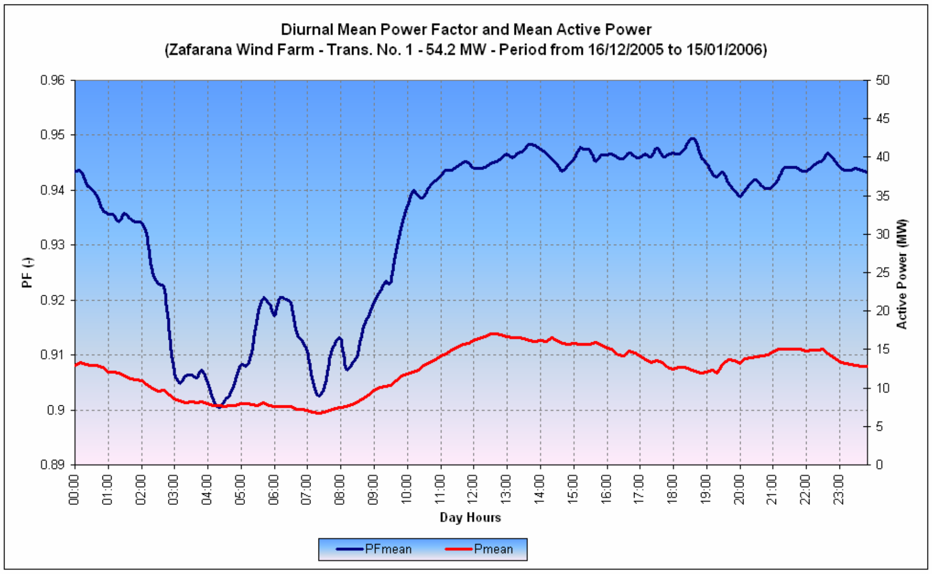
Plot (36) is the statistical data of a correlation between power factor and output power, the power factor looks reasonable at a value above 0.90 due to the two types of the wind turbines (Nordex – Vestas) are regulated by 200 kVAr and 250 kVAr of capacitor banks respectively.

The power factor “cos (φ)” has its maximum value of about 0.99 around 4.41 MW output power from the wind turbines.




Plot 36

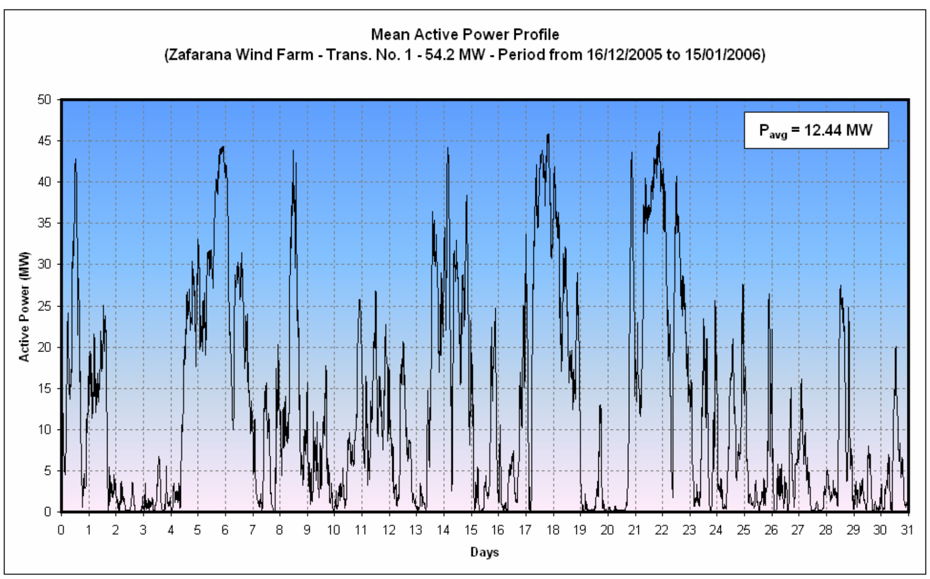
Plot (37) is the diurnal pattern of the power factor and active power as mean value, the plot shows that the power factor decreases for increasing the active power.




Plot 37

### 6.7 Produced Active Power

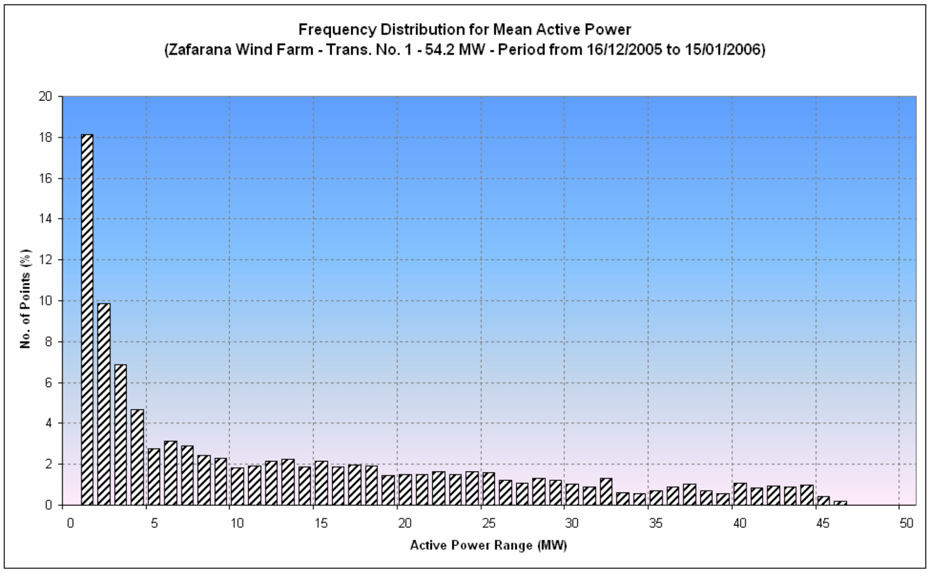
Plot (38) is the statistical data as 10-minute average of the output active power from the wind turbines, from the plot it is seen that the average value of the output active power is 42.12 MW during the measurement period, the plot corresponds with the line current plot (Plot 11).




Plot 38

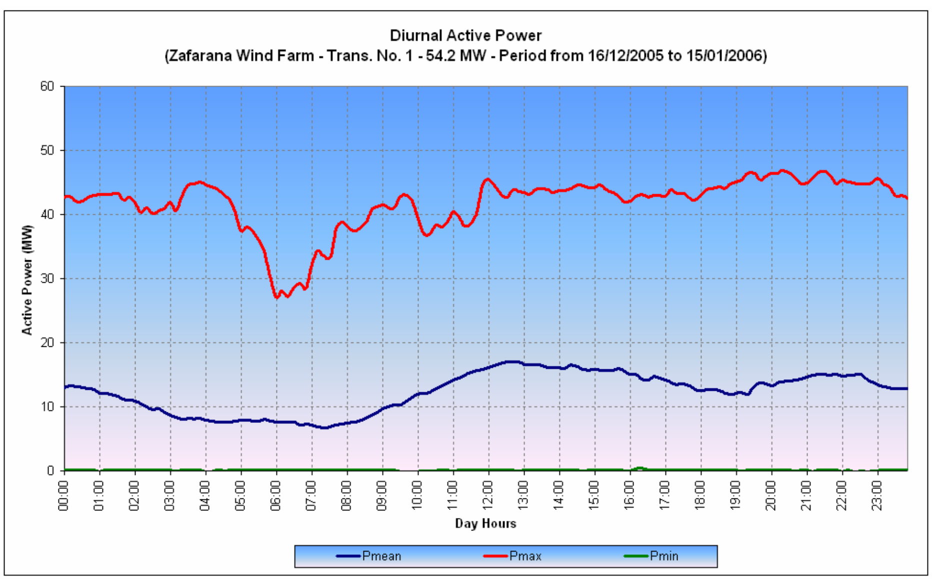
Plot (39) is the absolute value of the frequency distribution of statistical data as 10–minute average of the output active power from the wind turbines.

The distribution has a tail towards low production as well as the output active power varies from Zero MW to 55.06 MW as mean value and the majority of high active power data represent more than 60 % of the full data.



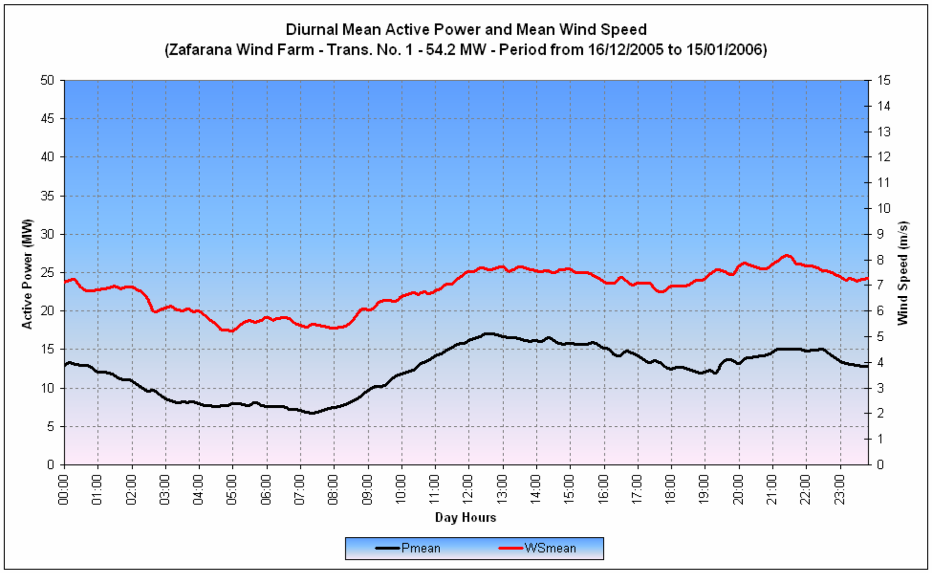

Plot 39

Plot (40) is the diurnal pattern of the mean, maximum and minimum of the active power value. The maximum value looks constant meanwhile the minimum value is somewhat does not show any particular features. The plot corresponds with the diurnal line current profile plot (Plot 12).




Plot 40

Plot (41) is the diurnal pattern of the active power and wind speed as mean value, it is observed that the wind speed is rather high during the measurement period, [Appendix 9, Table (5)].



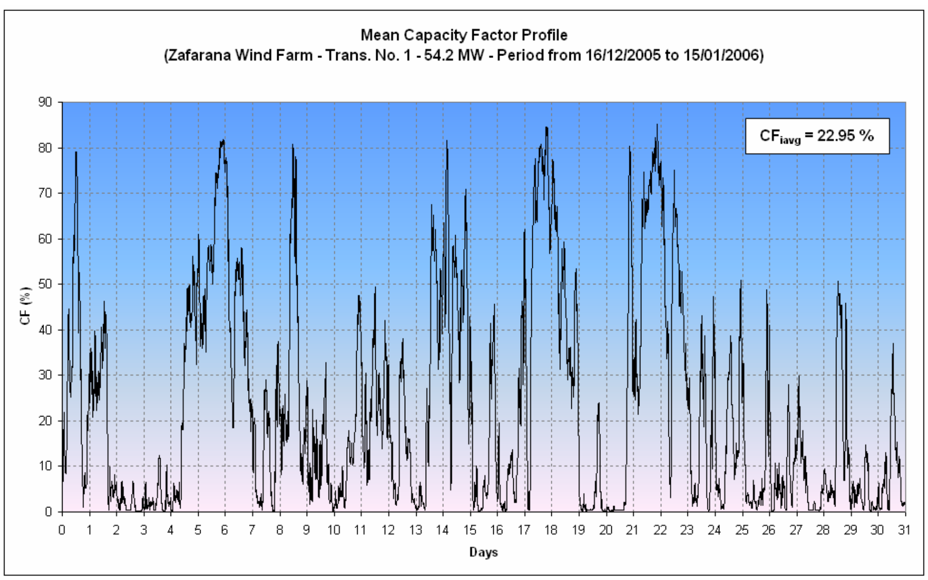

Plot 41

### 6.8 Capacity Factor

Plot (43) is the statistical data of the capacity factor (CF) as 10-minute average values, the average capacity factor during the measurement period is 64.94 %, which is quite high.

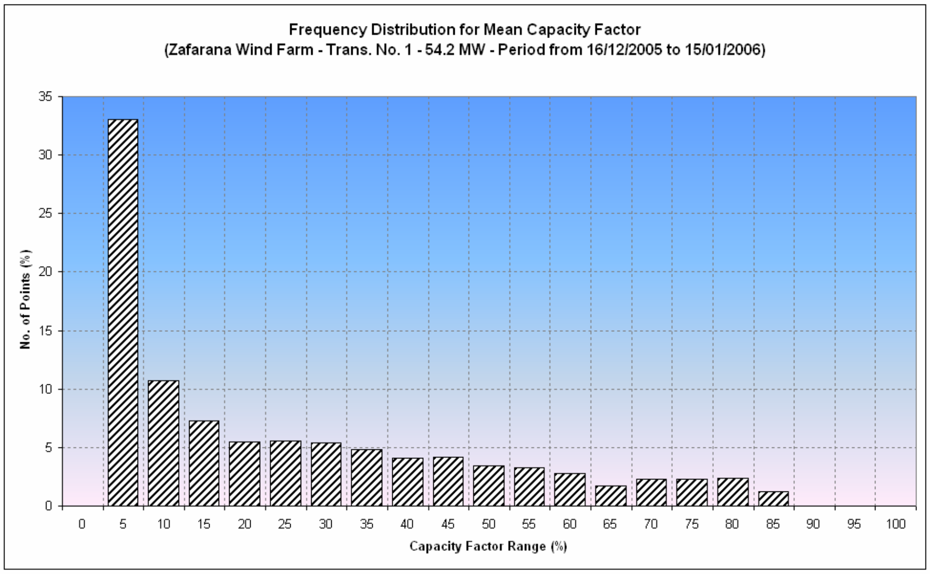
The capacity factor is determined according to the following equation:-

$$CF = [\frac{Power_{act}}{Power_{theo}}] * 100$$




Plot 43

Plot (44) is the absolute value of the frequency distribution of statistical data as 10–minute average of the capacity factor, the capacity factor varies from zero to 85 % as mean value, and the majority of high values of CF represent more than 60 % of the full data.


Frequency Distribution for Mean Capacity Factor
(Zafarana Wind Farm - Trans. No. 1 - 54.2 MW - Period from 16/12/2005 to 15/01/2006)
No. of Points (%)
35
30
25
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Capacity Factor Range (%)

Plot 44

## 7. Conclusion and Recommendations

- During the measurement period the voltage level at Zafarana substation was between 21.06 kV and 22.73 kV, or in other words 22 kV +3.3 % and –4.27 %, International standard IEC (Ref 3) specifies that the voltage level should be within ± 5 % of its nominal value measured as 10-minute average data or ± 10 % of its measured instantaneous values. From the results obtained it could be stated that the voltage level when reaches to its maximum value still within the required limit, meanwhile it is critical when reaches to its minimum value.
- The voltage level at substation (point of connection of the wind turbines to the grid) depends on the output power from the wind turbines.
- The absolute value of the voltage changes lays in a narrow range and non-symmetrical around the nominal value, considering the wind farm connected to the 220 kV national grid.
- The maximum value of phase No.2 is 13.40 kV (12.7 kV + 5.50 % ) and minimum value of phase No.3 is 11.98 kV (12.7 kV -5.70 % ) , the two voltage limits are out of range.
- In case of adding more wind turbines, a through analysis must be executed, in particular voltage level.
- During the measurement period, the grid frequency was between 49.86 Hz and 50.13 Hz being within the required limits to comply with international standards on supply voltage characteristics.
- The load factor (mean / max ) is 96 % which is quite reasonable.
- During the measurement period, the measured total harmonic distortion THD of the voltage on day 7/9/2005 reached to 3.11% being within the required limit to comply with international standards on supply voltage characteristics.
- The total harmonic distortion in voltage is not due to the output power from the wind turbines, but follows the daily load pattern.
- No correspondence between harmonic amplitude and overall power output level.
- Fixed-speed wind turbines do not produce any harmonics; meanwhile variable-speed wind turbines may be produce different amounts and orders of harmonics depending on the type of inverter used.
- The maximum current THD occurred at minimum line current.
- The reactive power consumption of the wind farm increases for increasing output power.
- The maximum value of the power factor is 0.99 at output power 4.41 MW.
- The average capacity factor of the wind farm is 64.9 % during the measurement period.
- The majority of high active power data represent more than 60 % of the full data.
- The average wind speed throughout the measurement period is 12.69 m/s.
- No measurements were performed regarding power fluctuations, flicker, and transient since this kind of measurements requires specific instruments that were not available.

## 8. References


1. ***Isolated System with Wind Power, Results of Measurements in Egypt***.
   Henrik Bindner, Risø National Laboratory, Laila Saleh, Salah Abdel-Hafiez and El-Sayed Mansour, New and Renewable Energy Authority**.**

2. ***Hurghada Wind Energy Center (WETC), Demonstration Wind Farm Studies, Power Quality Assessment***.
   Jhon Tande, Poul Sorensen, Risø National Laboratory, Denmark, Mohamed Galal, Usama Naoman, El-Sayed Mansour, Amgad El-Hewehy, Ahmed El-Maghawry and Ibrahim Darweesh, New and Renewable Energy Authority.

3. ***Grid Interaction and power Quality of Wind Turbine Generator Systems***.
   Ake Larsson, Chalmers University of Technology.

4. ***The International Energy Community standard (IEC)***.

5. ***The PM300 User Manual of RS232***

# 9. Appendix

Table (1) Wind Turbines and its Feeders connected to TR 1

| **Project** | D 1<br>F 1 | | | D 1<br>F 2 | | | D 2<br>LOT 1 | | | KFW 1<br>F 3 | | | KFW 2, 3<br>LOT 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Feeders** | J 6 | | | J 7 | | | J 8 | | | J 9 | | | J 10 | | |
| **Number of WTGs** | 17 | | | 17 | | | 15 | | | 20 | | | 18 | | |
| **WTG capacity (kW)** | 600 | | | 600 | | | 660 | | | 600 | | | 660 | | |
| **Total capacity (MW)** | 10.2 | | | 10.2 | | | 9.9 | | | 12.0 | | | 11.9 | | |
| **WTG no.** | 1 | 2 | 3 | 11 | 12 | 13 | 1 | 2 | 3 | 24 | 25 | 26 | 22 | 23 | 24 |
| | 4 | 5 | 6 | 14 | 15 | 16 | 4 | 5 | 6 | 27 | 28 | 29 | 25 | 26 | 27 |
| | 7 | 8 | 9 | 17 | 18 | 33 | 7 | 8 | 24 | 30 | 31 | 32 | 28 | 29 | 30 |
| | 10 | 26 | 27 | 34 | 35 | 36 | 25 | 26 | 27 | 33 | 34 | 35 | 31 | 32 | 33 |
| | 28 | 29 | 30 | 37 | 38 | 39 | 28 | 29 | 30 | 36 | 37 | 38 | 34 | 35 | 36 |
| | 31 | 32 | | 40 | 41 | | | | | 39 | 40 | 41 | 37 | 38 | 39 |
| | | | | | | | | | | 42 | 43 | | | | |

Table 1

Table (2) The Output Text File (Time series) from PM300.EXE program

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE: 08-17-2005 | | | | | | | | | | | | | | | | | | | | | | | | | |
| SETUP FILE ZAF.SUP: | | | | | | | | | | | | | | | | | | | | | | | | | |
| ZAF.CFG | | | | | | | | | | | | | | | | | | | | | | | | | |
| ZAF.SEL | | | | | | | | | | | | | | | | | | | | | | | | | |
| ZA050817.txt | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19200 BAUD RATE | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1000000 MEASUREMENT TIME (SEC) | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 SAMPLE TIME (SEC) | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 NUMBER OF MEASUREMENTS (CHANNELS) CORRESP TO SPECIF IN SELECTION FILE | | | | | | | | | | | | | | | | | | | | | | | | | |
| CONFIGURATION FILE ZAF.CFG: | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 4 FAST OPERATING | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 0 3 PHASE 4 WIRE | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 1 FIXED AVERAGING | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 1 AVERAGING DEPTH | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 1 EXTERINAL CURRENT SHUNT | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 0 FIXED VOLTAGE RANGING | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 0 FIXED CURRENT RANGING | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 1 MANUAL FREQ SOURCE | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 1 FREQ SOURCE IS VOLTAGE | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 1 VOLTAGE HARM ENAB | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 11 HARMONIC ORDER | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 1 ODD HARMONICS | | | | | | | | | | | | | | | | | | | | | | | | | |
| 38 220 VOLTAGE SCALING | | | | | | | | | | | | | | | | | | | | | | | | | |
| 39 25 CURRENT SCALING | | | | | | | | | | | | | | | | | | | | | | | | | |
| SELECTION FILE ZAF.SEL: | | | | | | | | | | | | | | | | | | | | | | | | | |
| :SEL:CLR | | | | | | | | | | | | | | | | | | | | | | | | | |
| :SEL:CH1;:SEL:CH2;:SEL:CH3;:SEL:SUM; | | | | | | | | | | | | | | | | | | | | | | | | | |
| :SEL:WAT;:SEL:VAR;:SEL:VLT;:SEL:AMP;:SEL:VDF;:SEL:ADF | | | | | | | | | | | | | | | | | | | | | | | | | |
| :SEL:FRQ | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14:17:39 | 14181000 | 15964000 | 15417000 | 45560000 | 7039000 | 6407000 | 6505000 | 20020000 | 12342 | 12757 | 12276 | 21580 | 1282.8 | 1348.4 | 1363 | 1331.4 | 49.94 | 49.94 | 49.94 | 0.72 | 0.69 | 0.74 | 1.25 | 1.31 | 1.26 |
| 14:17:49 | 14449000 | 16247000 | 15659000 | 46360000 | 7210000 | 6605000 | 6682000 | 20560000 | 12312 | 12740 | 12253 | 21540 | 1311.5 | 1376.6 | 1389.4 | 1359.2 | 49.88 | 49.88 | 49.88 | 0.51 | 0.86 | 1.08 | 0 | 1.15 | 0.98 |
| 14:17:59 | 14391000 | 16020000 | 15457000 | 45870000 | 6907000 | 6332000 | 6418000 | 19714000 | 12388 | 12774 | 12290 | 21620 | 1288.6 | 1348.5 | 1361.8 | 1333 | 49.94 | 49.94 | 49.94 | 0.48 | 0.72 | 0.98 | 1.28 | 1.04 | 0.85 |
| 14:18:09 | 14287000 | 15846000 | 15343000 | 45480000 | 6915000 | 6365000 | 6452000 | 19783000 | 12427 | 12747 | 12273 | 21620 | 1277.2 | 1339.7 | 1356.2 | 1324.4 | 50.05 | 50.05 | 50.05 | 0.64 | 0.55 | 0.62 | 1.03 | 0.98 | 0.99 |
| 14:18:19 | 14267000 | 15967000 | 15404000 | 45640000 | 6988000 | 6413000 | 6498000 | 19959000 | 12398 | 12762 | 12276 | 21610 | 1281.4 | 1348.4 | 1361.9 | 1330.5 | 49.94 | 49.94 | 49.94 | 0.63 | 0.58 | 0.61 | 1.09 | 1.02 | 0.95 |
| 14:18:29 | 14459000 | 16130000 | 15557000 | 46150000 | 7055000 | 6479000 | 6559000 | 20150000 | 12390 | 12750 | 12267 | 21600 | 1298.5 | 1363.3 | 1376.3 | 1346 | 49.95 | 49.95 | 49.95 | 0 | 0.49 | 0.69 | 0 | 0 | 0.98 |
| 14:18:39 | 14378000 | 16183000 | 15609000 | 46170000 | 7063000 | 6431000 | 6512000 | 20080000 | 12340 | 12754 | 12271 | 21570 | 1298.2 | 1365.4 | 1378.2 | 1347.3 | 49.94 | 49.94 | 49.94 | 0 | 0 | 0.57 | 0 | 0 | 0 |

Table 2

Table (3) The Output Statistical File (10-minute average) generated by using PM300STA.EXE program

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE: 08-17-2005 | | | | | | | | | | | | | | | | | | |
| SETUP FILE ZAF.SUP: | | | | | | | | | | | | | | | | | | |
| ZAF.CFG | | | | | | | | | | | | | | | | | | |
| ZAF.SEL | | | | | | | | | | | | | | | | | | |
| ZA050817.txt | | | | | | | | | | | | | | | | | | |
| 19200 BAUD RATE | | | | | | | | | | | | | | | | | | |
| 1000000 MEASUREMENT TIME (SEC) | | | | | | | | | | | | | | | | | | |
| 10 SAMPLE TIME (SEC) | | | | | | | | | | | | | | | | | | |
| 25 NUMBER OF MEASUREMENTS (CHANNELS) CORRESP TO SPECIF IN SELECTION FILE | | | | | | | | | | | | | | | | | | |
| CONFIGURATION FILE ZAF.CFG: | | | | | | | | | | | | | | | | | | |
| 1 4 FAST OPERATING | | | | | | | | | | | | | | | | | | |
| 2 0 3 PHASE 4 WIRE | | | | | | | | | | | | | | | | | | |
| 4 1 FIXED AVERAGING | | | | | | | | | | | | | | | | | | |
| 5 1 AVERAGING DEPTH | | | | | | | | | | | | | | | | | | |
| 6 1 EXTERINAL CURRENT SHUNT | | | | | | | | | | | | | | | | | | |
| 10 0 FIXED VOLTAGE RANGING | | | | | | | | | | | | | | | | | | |
| 11 0 FIXED CURRENT RANGING | | | | | | | | | | | | | | | | | | |
| 14 1 MANUAL FREQ SOURCE | | | | | | | | | | | | | | | | | | |
| 15 1 FREQ SOURCE IS VOLTAGE | | | | | | | | | | | | | | | | | | |
| 19 1 VOLTAGE HARM ENAB | | | | | | | | | | | | | | | | | | |
| 23 11 HARMONIC ORDER | | | | | | | | | | | | | | | | | | |
| 24 1 ODD HARMONICS | | | | | | | | | | | | | | | | | | |
| 38 220 VOLTAGE SCALING | | | | | | | | | | | | | | | | | | |
| 39 25 CURRENT SCALING | | | | | | | | | | | | | | | | | | |
| SELECTION FILE ZAF.SEL: | | | | | | | | | | | | | | | | | | |
| :SEL:CLR | | | | | | | | | | | | | | | | | | |
| :SEL:CH1;:SEL:CH2;:SEL:CH3;:SEL:SUM; | | | | | | | | | | | | | | | | | | |
| :SEL:WAT;:SEL:VAR;:SEL:VLT;:SEL:AMP;:SEL:VDF;:SEL:ADF | | | | | | | | | | | | | | | | | | |
| :SEL:FRQ | | | | | | | | | | | | | | | | | | |
| Number of channels | | | | 25 | | | | | | | | | | | | | | |
| 141000 | 19750200 | 15 | 14359467 | 133935 | 14654000 | 14173000 | 16019002 | 138924 | 16247000 | 15703000 | 15480866 | 120275 | 15659000 | 15221000 | 45860668 | 371927 | 46480000 | 45100000 |
| 142000 | 19750800 | 60 | 14843550 | 280991 | 15491000 | 14271000 | 16571886 | 318644 | 17202000 | 15945000 | 16010284 | 301280 | 16591000 | 15393000 | 47426330 | 892502 | 49200000 | 45700000 |
| 143000 | 19751400 | 60 | 14842849 | 183489 | 15280000 | 14454000 | 16528596 | 200685 | 16966000 | 16113000 | 15985852 | 191028 | 16401000 | 15637000 | 47357670 | 561379 | 48560000 | 46200000 |
| 144000 | 19752000 | 60 | 14710833 | 193369 | 15198000 | 14343000 | 16419083 | 199864 | 16867000 | 15956000 | 15857301 | 206120 | 16308000 | 15455000 | 46988164 | 588205 | 48350000 | 45870000 |
| 145000 | 19752600 | 60 | 14671218 | 215820 | 15128000 | 14175000 | 16350198 | 225484 | 16742000 | 15783000 | 15777753 | 214815 | 16137000 | 15275000 | 46799164 | 644503 | 47950000 | 45320000 |
| 150000 | 19753200 | 60 | 14803333 | 323210 | 15525000 | 14147000 | 16481184 | 345180 | 17209000 | 15802000 | 15923453 | 337013 | 16622000 | 15260000 | 47207825 | 997943 | 49350000 | 45210000 |
| 141000 | 19750200 | 15 | 6985533 | 94461 | 7210000 | 6775000 | 6399333 | 89867 | 6605000 | 6198000 | 6468800 | 85503.9 | 6682000 | 6303000 | 19914534 | 265796 | 20560000 | 19332000 |
| 142000 | 19750800 | 60 | 7256652 | 185742 | 7633000 | 6922000 | 6680016 | 183062 | 7063000 | 6355000 | 6760749 | 176794 | 7138000 | 6443000 | 20757700 | 545873 | 21900000 | 19779000 |
| 143000 | 19751400 | 60 | 7104884 | 140054 | 7392000 | 6863000 | 6526851 | 131285 | 6833000 | 6296000 | 6621349 | 128437 | 6918000 | 6405000 | 20312668 | 399336 | 21200000 | 19639000 |
| 144000 | 19752000 | 60 | 7228334 | 136180 | 7457000 | 6891000 | 6658749 | 130149 | 6876000 | 6352000 | 6757169 | 129504 | 6983000 | 6452000 | 20703046 | 393385 | 21350000 | 19745000 |
| 145000 | 19752600 | 60 | 7143616 | 194956 | 7491000 | 6682000 | 6559381 | 194982 | 6927000 | 6097000 | 6663401 | 196365 | 6985000 | 6211000 | 20425882 | 580580 | 21460000 | 19050000 |
| 150000 | 19753200 | 60 | 7128665 | 233542 | 7626000 | 6680000 | 6553399 | 228801 | 7014000 | 6112000 | 6654483 | 224433 | 7182000 | 6223000 | 20394767 | 685160 | 21880000 | 19083000 |
| 141000 | 19750200 | 15 | 12371.87 | 31.09 | 12427 | 12312 | 12750.47 | 15.56 | 12774 | 12707 | 12273.67 | 13.5 | 12290 | 12240 | 21589.33 | 26.13 | 21620 | 21540 |
| 142000 | 19750800 | 60 | 12366.42 | 34.78 | 12434 | 12298 | 12741 | 15.04 | 12777 | 12709 | 12265.15 | 9.69 | 12293 | 12243 | 21577 | 25.6 | 21620 | 21520 |
| 143000 | 19751400 | 60 | 12376.48 | 34.92 | 12441 | 12317 | 12747.33 | 15.29 | 12784 | 12719 | 12274.45 | 9.54 | 12301 | 12255 | 21591.83 | 27.62 | 21660 | 21540 |
| 144000 | 19752000 | 60 | 12355.52 | 31.7 | 12413 | 12295 | 12732.28 | 15.76 | 12766 | 12700 | 12256.87 | 12.64 | 12280 | 12225 | 21560.5 | 27.3 | 21620 | 21500 |
| 145000 | 19752600 | 60 | 12355.87 | 34.39 | 12414 | 12286 | 12722.7 | 24.96 | 12769 | 12648 | 12251.15 | 22.21 | 12293 | 12177 | 21552.67 | 38.01 | 21630 | 21440 |
| 150000 | 19753200 | 60 | 12375.03 | 32.58 | 12443 | 12320 | 12742.77 | 18.19 | 12775 | 12707 | 12269.07 | 14.43 | 12294 | 12241 | 21585.17 | 30.04 | 21650 | 21530 |
| 141000 | 19750200 | 15 | 1290.75 | 11.93 | 1311.5 | 1268.2 | 1352.91 | 12.34 | 1376.6 | 1324.3 | 1366.98 | 11.66 | 1389.4 | 1340.8 | 1336.89 | 11.84 | 1359.2 | 1311.1 |
| 142000 | 19750800 | 60 | 1336.14 | 27.34 | 1390.9 | 1286.4 | 1402.42 | 28.69 | 1458.2 | 1348.5 | 1416.98 | 28.6 | 1470.9 | 1361.9 | 1385.17 | 28.16 | 1438.6 | 1332.3 |
| 143000 | 19751400 | 60 | 1329.63 | 17.76 | 1369.7 | 1294 | 1394.11 | 19.14 | 1433.7 | 1356.3 | 1409.68 | 19.13 | 1449.2 | 1374.3 | 1377.81 | 18.62 | 1416.9 | 1341.5 |
| 144000 | 19752000 | 60 | 1326.64 | 18.05 | 1363.6 | 1288.2 | 1391.62 | 18.69 | 1430.5 | 1350.2 | 1406.33 | 19.66 | 1447.3 | 1364.9 | 1374.87 | 18.72 | 1413.8 | 1336.4 |
| 145000 | 19752600 | 60 | 1320.74 | 23.07 | 1360.4 | 1264.8 | 1384.76 | 23.34 | 1421.3 | 1329.7 | 1398.06 | 23.51 | 1434.3 | 1342 | 1367.85 | 23.2 | 1405.2 | 1312.3 |
| 150000 | 19753200 | 60 | 1327.77 | 32.13 | 1397 | 1262.7 | 1391.94 | 32.96 | 1459.6 | 1328.1 | 1406.67 | 33.47 | 1477.2 | 1341.8 | 1375.46 | 32.8 | 1444 | 1310.9 |
| 141000 | 19750200 | 15 | 50.01 | 0.08 | 50.13 | 49.88 | 50.01 | 0.08 | 50.13 | 49.88 | 50.01 | 0.08 | 50.13 | 49.88 | 0.57 | 0.25 | 0.89 | 0 |
| 142000 | 19750800 | 60 | 49.97 | 0.08 | 50.13 | 49.88 | 49.97 | 0.08 | 50.13 | 49.88 | 49.97 | 0.08 | 50.13 | 49.88 | 0.65 | 1.14 | 6.61 | 0 |
| 143000 | 19751400 | 60 | 49.99 | 0.09 | 50.13 | 49.88 | 49.99 | 0.09 | 50.13 | 49.88 | 49.99 | 0.09 | 50.13 | 49.88 | 0.51 | 0.2 | 0.89 | 0 |
| 144000 | 19752000 | 60 | 49.95 | 0.09 | 50.13 | 49.75 | 49.95 | 0.09 | 50.13 | 49.75 | 49.95 | 0.09 | 50.13 | 49.75 | 0.45 | 0.26 | 0.78 | 0 |
| 145000 | 19752600 | 60 | 49.96 | 0.08 | 50.13 | 49.75 | 49.96 | 0.08 | 50.13 | 49.75 | 49.96 | 0.08 | 50.13 | 49.75 | 0.68 | 1.29 | 6.33 | 0 |
| 150000 | 19753200 | 60 | 49.98 | 0.09 | 50.13 | 49.88 | 49.98 | 0.09 | 50.13 | 49.88 | 49.98 | 0.09 | 50.13 | 49.88 | 0.61 | 1.13 | 6.5 | 0 |
| 141000 | 19750200 | 15 | 0.66 | 0.32 | 1.51 | 0 | 0.72 | 0.14 | 1.08 | 0.57 | 0.68 | 0.58 | 1.28 | 0 | 1.06 | 0.48 | 1.86 | 0 |
| 142000 | 19750800 | 60 | 1.09 | 1.51 | 7.13 | 0 | 0.74 | 0.25 | 1.62 | 0 | 0.76 | 0.57 | 1.59 | 0 | 1.45 | 1.83 | 7.34 | 0 |
| 143000 | 19751400 | 60 | 0.71 | 0.76 | 6.09 | 0.44 | 0.61 | 0.13 | 1.12 | 0.45 | 0.87 | 0.39 | 1.25 | 0 | 1.12 | 1.04 | 6.5 | 0 |
| 144000 | 19752000 | 60 | 0.66 | 0.77 | 6.17 | 0 | 0.64 | 0.28 | 1.54 | 0 | 0.77 | 0.48 | 1.41 | 0 | 1.07 | 1.29 | 6.72 | 0 |
| 145000 | 19752600 | 60 | 0.71 | 1.05 | 6.17 | 0 | 0.57 | 0.21 | 1.34 | 0 | 0.63 | 0.49 | 1.32 | 0 | 1.18 | 1.65 | 6.55 | 0 |
| 150000 | 19753200 | 60 | 0.84 | 1.38 | 7.14 | 0 | 0.6 | 0.26 | 1.64 | 0 | 0.69 | 0.5 | 1.58 | 0 | 1.16 | 1.6 | 7.34 | 0 |
| 141000 | 19750200 | 15 | 0.98 | 0.3 | 1.3 | 0 | | | | | | | | | | | | |
| 142000 | 19750800 | 60 | 1.21 | 0.98 | 6.4 | 0 | | | | | | | | | | | | |
| 143000 | 19751400 | 60 | 0.99 | 0.16 | 1.33 | 0.59 | | | | | | | | | | | | |
| 144000 | 19752000 | 60 | 0.86 | 0.28 | 1.27 | 0 | | | | | | | | | | | | |
| 145000 | 19752600 | 60 | 0.79 | 0.34 | 1.24 | 0 | | | | | | | | | | | | |
| 150000 | 19753200 | 60 | 1.05 | 1.01 | 6.29 | 0 | | | | | | | | | | | | |

Table 3

Table (4) The Diurnal file (10-minute average) generated by PM300STA.EXE program

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1413 | 12593.9 | 146.59 | 12899 | 12250 | 12968.6 | 145.304 | 13268 | 12607 | 12484.7 | 144.205 | 12775 | 12140 | 21965.3 | 251.181 | 22470 | 21370 |
| 10 | 1389 | 12584.4 | 145.778 | 12876 | 12284 | 12957.5 | 144.981 | 13258 | 12643 | 12475.3 | 143.093 | 12761 | 12183 | 21949.1 | 250.021 | 22450 | 21430 |
| 20 | 1440 | 12597.6 | 138.352 | 12865 | 12297 | 12980.9 | 137.545 | 13253 | 12670 | 12478.8 | 136.114 | 12746 | 12196 | 21955.1 | 237.317 | 22420 | 21470 |
| 30 | 1440 | 12591.3 | 128.736 | 12896 | 12214 | 12983 | 127.597 | 13250 | 12591 | 12481.9 | 128.258 | 12763 | 12118 | 21980.3 | 220.328 | 22480 | 21330 |
| 40 | 1440 | 12594.4 | 124.796 | 12884 | 12227 | 12967 | 122.541 | 13254 | 12595 | 12485.8 | 122.137 | 12761 | 12127 | 21968.8 | 212.688 | 22450 | 21340 |
| 50 | 1424 | 12611.8 | 129.493 | 12879 | 12206 | 12981.4 | 128.002 | 13250 | 12613 | 12500.6 | 127.488 | 12760 | 12153 | 21995.1 | 221.748 | 22440 | 21370 |
| 100 | 1394 | 12599.2 | 128.632 | 12807 | 12217 | 12967.4 | 126.423 | 13209 | 12617 | 12490.8 | 126.199 | 12729 | 12147 | 21974.2 | 219.423 | 22390 | 21360 |
| 110 | 1441 | 12586 | 131.259 | 12858 | 12216 | 12954.1 | 128.123 | 13227 | 12619 | 12481.6 | 128.778 | 12738 | 12147 | 21951.8 | 223.457 | 22400 | 21370 |
| 120 | 1500 | 12601.5 | 139.325 | 12922 | 12209 | 12967.4 | 136.746 | 13268 | 12615 | 12495.6 | 136.904 | 12804 | 12140 | 21976.5 | 237.758 | 22510 | 21350 |
| 130 | 1500 | 12613.3 | 137.984 | 12924 | 12234 | 12990.1 | 134.65 | 13287 | 12660 | 12508.6 | 135.273 | 12803 | 12188 | 21998.1 | 234.853 | 22510 | 21420 |
| 140 | 1500 | 12619.7 | 140.178 | 12942 | 12229 | 12986.7 | 136.427 | 13296 | 12638 | 12515.1 | 137.108 | 12819 | 12178 | 22009.3 | 238.299 | 22540 | 21400 |
| 150 | 1500 | 12625.3 | 137.905 | 12921 | 12251 | 12990.3 | 132.696 | 13282 | 12661 | 12520.7 | 134.894 | 12806 | 12197 | 22018 | 230.579 | 22520 | 21440 |
| 200 | 1500 | 12607.6 | 143.058 | 12890 | 12261 | 12970.9 | 138.447 | 13253 | 12663 | 12505 | 140.147 | 12774 | 12189 | 21987.4 | 242.981 | 22480 | 21440 |
| 210 | 1560 | 12598.1 | 143.574 | 12843 | 12239 | 12962 | 138.457 | 13195 | 12669 | 12496.5 | 140.115 | 12727 | 12188 | 21971.8 | 242.986 | 22380 | 21420 |
| 220 | 1560 | 12600.7 | 139.305 | 12841 | 12273 | 12963.3 | 136.194 | 13209 | 12671 | 12499.2 | 136.682 | 12735 | 12209 | 21975.8 | 237.225 | 22390 | 21450 |
| 230 | 1560 | 12611.6 | 139.687 | 12885 | 12239 | 12974.6 | 136.278 | 13208 | 12601 | 12509.6 | 137.031 | 12739 | 12156 | 21994.6 | 237.826 | 22400 | 21370 |
| 240 | 1560 | 12620 | 144.806 | 12907 | 12259 | 12982.9 | 141.432 | 13280 | 12614 | 12517.9 | 141.628 | 12778 | 12170 | 22009 | 246.508 | 22470 | 21400 |
| 250 | 1536 | 12631.2 | 138.393 | 12901 | 12312 | 12993.2 | 135.532 | 13235 | 12663 | 12528.5 | 135.995 | 12775 | 12218 | 22027.6 | 236.05 | 22480 | 21490 |
| 300 | 1500 | 12647 | 137.057 | 12909 | 12324 | 13009.5 | 134.53 | 13276 | 12696 | 12544.5 | 135.246 | 12787 | 12241 | 22055.2 | 234.423 | 22500 | 21520 |
| 310 | 1500 | 12652.7 | 140.472 | 12905 | 12333 | 13014.9 | 137.377 | 13241 | 12698 | 12550.1 | 138.025 | 12772 | 12248 | 22065 | 239.553 | 22450 | 21540 |
| 320 | 1500 | 12658.3 | 142.244 | 12917 | 12319 | 13019.6 | 139.598 | 13273 | 12697 | 12554.9 | 139.24 | 12780 | 12233 | 22072.5 | 241.969 | 22490 | 21510 |
| 330 | 1500 | 12656.5 | 141.658 | 12908 | 12315 | 13019.6 | 136.705 | 13273 | 12691 | 12554.5 | 138.087 | 12796 | 12225 | 22072.4 | 239.79 | 22510 | 21500 |
| 340 | 1500 | 12654.5 | 138.378 | 12926 | 12319 | 13018.8 | 133.332 | 13309 | 12713 | 12553 | 135.095 | 12821 | 12232 | 22069.9 | 234.288 | 22550 | 21510 |
| 350 | 1500 | 12657.1 | 138.758 | 12941 | 12324 | 13020 | 135.678 | 13319 | 12698 | 12554.7 | 136.319 | 12827 | 12243 | 22073 | 236.6 | 22580 | 21530 |
| 400 | 1500 | 12655.6 | 141.306 | 12951 | 12340 | 13019.4 | 136.796 | 13320 | 12706 | 12553.8 | 138.642 | 12805 | 12254 | 22071.4 | 240.078 | 22570 | 21540 |
| 410 | 1500 | 12684.8 | 148.217 | 12987 | 12332 | 13028.9 | 143.412 | 13304 | 12707 | 12582.7 | 145.491 | 12846 | 12250 | 22087.3 | 251.826 | 22590 | 21530 |
| 420 | 1500 | 12672 | 151.482 | 12991 | 12371 | 13035.9 | 147.529 | 13348 | 12735 | 12570.2 | 148.734 | 12870 | 12285 | 22099.7 | 257.891 | 22630 | 21600 |
| 430 | 1500 | 12673.2 | 152.591 | 12980 | 12379 | 13037.8 | 148.79 | 13347 | 12741 | 12571.4 | 149.755 | 12868 | 12286 | 22102.3 | 259.867 | 22620 | 21600 |
| 440 | 1440 | 12672.2 | 151.309 | 13004 | 12373 | 13037.4 | 147.405 | 13365 | 12745 | 12570.5 | 148.597 | 12876 | 12280 | 22100.9 | 257.778 | 22640 | 21600 |
| 450 | 1441 | 12674.6 | 154.549 | 13021 | 12376 | 13039.8 | 151.177 | 13375 | 12741 | 12572 | 152.275 | 12895 | 12284 | 22104.6 | 264.002 | 22670 | 21610 |
| 500 | 1440 | 12675.3 | 149.904 | 13045 | 12407 | 13041.1 | 147.638 | 13408 | 12751 | 12573.1 | 148.13 | 12906 | 12316 | 22106.4 | 256.873 | 22740 | 21650 |
| 510 | 1440 | 12675.5 | 148.221 | 13044 | 12409 | 13041.1 | 144.319 | 13405 | 12777 | 12573.4 | 145.800 | 12925 | 12317 | 22106.7 | 252.495 | 22730 | 21680 |
| 520 | 1440 | 12681.6 | 148.481 | 13067 | 12438 | 13047 | 144.465 | 13414 | 12800 | 12579.3 | 145.401 | 12958 | 12329 | 22117 | 252.497 | 22780 | 21700 |
| 530 | 1440 | 12687 | 144.307 | 13009 | 12441 | 13053 | 139.884 | 13397 | 12815 | 12585.6 | 141.432 | 12919 | 12344 | 22127.2 | 245.345 | 22720 | 21720 |
| 540 | 1441 | 12698.9 | 147.749 | 13033 | 12399 | 13064.4 | 143.847 | 13398 | 12792 | 12596.7 | 145.03 | 12917 | 12323 | 22147.1 | 251.671 | 22710 | 21670 |
| 550 | 1500 | 12693.8 | 153.898 | 13049 | 12421 | 13058.6 | 148.576 | 13406 | 12788 | 12592 | 150.671 | 12926 | 12326 | 22138.1 | 261.029 | 22730 | 21680 |
| 600 | 1500 | 12698.2 | 145.917 | 13005 | 12445 | 13062.1 | 141.169 | 13374 | 12808 | 12596.3 | 143.395 | 12910 | 12349 | 22145 | 249.098 | 22690 | 21720 |
| 610 | 1500 | 12696.9 | 148.101 | 13011 | 12402 | 13060.2 | 144.002 | 13359 | 12754 | 12594.8 | 146.354 | 12890 | 12300 | 22142.3 | 252.562 | 22650 | 21640 |
| 620 | 1500 | 12700.6 | 152.974 | 13030 | 12380 | 13065.1 | 148.226 | 13368 | 12745 | 12598.2 | 150.488 | 12900 | 12287 | 22149.5 | 260.33 | 22680 | 21610 |
| 630 | 1500 | 12710.8 | 155.348 | 13032 | 12379 | 13075.8 | 150.751 | 13390 | 12753 | 12608.6 | 152.506 | 12906 | 12297 | 22167.4 | 264.443 | 22690 | 21620 |
| 640 | 1500 | 12716.7 | 160.727 | 13043 | 12417 | 13081.2 | 155.123 | 13410 | 12779 | 12615 | 157.47 | 12900 | 12329 | 22177.7 | 272.868 | 22730 | 21680 |
| 650 | 1500 | 12717.5 | 165.706 | 13045 | 12409 | 13082.6 | 161.476 | 13397 | 12779 | 12616.3 | 163.35 | 12926 | 12312 | 22179.6 | 282.888 | 22720 | 21670 |
| 700 | 1500 | 12705.6 | 173.418 | 13084 | 12368 | 13070 | 168.158 | 13433 | 12717 | 12604.6 | 170.316 | 12957 | 12267 | 22158.6 | 294.995 | 22780 | 21570 |
| 710 | 1500 | 12691.9 | 178.331 | 13076 | 12358 | 13057.2 | 172.976 | 13430 | 12725 | 12591.4 | 174.79 | 12951 | 12257 | 22135.8 | 300.471 | 22770 | 21580 |
| 720 | 1500 | 12679.2 | 180.139 | 13067 | 12352 | 13044 | 174.434 | 13422 | 12719 | 12577.6 | 176.578 | 12953 | 12256 | 22112.8 | 306.352 | 22780 | 21550 |
| 730 | 1440 | 12674.7 | 180.897 | 13064 | 12328 | 13039.8 | 177.182 | 13421 | 12702 | 12573.2 | 178.028 | 12943 | 12232 | 22105.5 | 309.169 | 22750 | 21520 |
| 740 | 1440 | 12659.8 | 182.897 | 13058 | 12287 | 13024.6 | 178.465 | 13407 | 12663 | 12558.6 | 179.361 | 12940 | 12202 | 22079.7 | 311.741 | 22740 | 21450 |
| 750 | 1440 | 12645.9 | 181.880 | 13055 | 12280 | 13009.8 | 176.305 | 13403 | 12670 | 12543.1 | 178.371 | 12941 | 12181 | 22054.2 | 309.271 | 22730 | 21440 |
| 800 | 1440 | 12616.9 | 184.658 | 13027 | 12248 | 12980.6 | 180.304 | 13354 | 12652 | 12514.6 | 181.01 | 12893 | 12171 | 22004 | 314.715 | 22670 | 21410 |
| 810 | 1381 | 12585.9 | 186.242 | 12995 | 12256 | 12949.9 | 183.82 | 13347 | 12630 | 12483.8 | 183.684 | 12875 | 12156 | 21950.5 | 319.358 | 22630 | 21400 |
| 820 | 1380 | 12554.9 | 187.885 | 12982 | 12209 | 12919.4 | 184.82 | 13310 | 12603 | 12453.6 | 185.171 | 12844 | 12139 | 21897.7 | 321.802 | 22590 | 21350 |
| 830 | 1380 | 12532 | 188.891 | 12912 | 12229 | 12896.5 | 187.963 | 13288 | 12589 | 12430.1 | 186.892 | 12796 | 12135 | 21857.6 | 325.053 | 22490 | 21350 |
| 840 | 1320 | 12517.5 | 189.903 | 12891 | 12189 | 12882.7 | 189.727 | 13263 | 12567 | 12415.7 | 188.307 | 12781 | 12092 | 21832.9 | 327.658 | 22470 | 21270 |
| 850 | 1320 | 12504 | 186.498 | 12878 | 12218 | 12868.6 | 184.95 | 13229 | 12573 | 12400.1 | 183.565 | 12758 | 12121 | 21808.2 | 319.991 | 22420 | 21320 |
| 900 | 1286 | 12503.7 | 185.777 | 12850 | 12187 | 12870.3 | 184.358 | 13207 | 12541 | 12399.5 | 183.372 | 12735 | 12087 | 21808.6 | 319.022 | 22380 | 21260 |
| 910 | 1320 | 12511.4 | 195.67 | 12857 | 12162 | 12876 | 193.577 | 13218 | 12536 | 12405.4 | 193.315 | 12738 | 12049 | 21819.7 | 336.174 | 22400 | 21230 |
| 920 | 1260 | 12523.5 | 184.539 | 12820 | 12147 | 12889.9 | 183.036 | 13191 | 12520 | 12417.5 | 182.406 | 12725 | 12036 | 21841.6 | 317.2 | 22350 | 21200 |
| 930 | 1260 | 12521.2 | 177.609 | 12778 | 12154 | 12886.7 | 175.343 | 13149 | 12535 | 12415.6 | 175.177 | 12684 | 12039 | 21837.3 | 304.626 | 22270 | 21200 |
| 940 | 1260 | 12524.6 | 177.278 | 12800 | 12159 | 12890.5 | 176.582 | 13168 | 12539 | 12419.2 | 175.17 | 12696 | 12048 | 21843.5 | 305.078 | 22310 | 21220 |
| 950 | 1260 | 12533.8 | 180.613 | 12883 | 12145 | 12899.8 | 179.137 | 13238 | 12512 | 12428.3 | 177.811 | 12781 | 12001 | 21859.6 | 310.078 | 22440 | 21190 |
| 1000 | 1260 | 12538 | 180.815 | 12885 | 12143 | 12903 | 182.137 | 13240 | 12529 | 12431.6 | 181.199 | 12762 | 12042 | 21865.7 | 315.649 | 22450 | 21210 |
| 1010 | 1260 | 12531.6 | 185.778 | 12879 | 12148 | 12896.3 | 183.802 | 13229 | 12534 | 12425.1 | 183.202 | 12757 | 12044 | 21854.4 | 318.857 | 22430 | 21210 |
| 1020 | 1223 | 12529.7 | 183.51 | 12866 | 12122 | 12893.7 | 180.518 | 13227 | 12499 | 12423.1 | 180.897 | 12751 | 12010 | 21850.6 | 314.198 | 22420 | 21150 |
| 1030 | 1200 | 12534.6 | 180.86 | 12840 | 12133 | 12899.4 | 178.242 | 13189 | 12505 | 12428.7 | 178.457 | 12710 | 12020 | 21859.9 | 309.882 | 22360 | 21170 |
| 1040 | 1140 | 12535.2 | 191.399 | 12805 | 12091 | 12898.2 | 188.655 | 13194 | 12482 | 12428.5 | 188.74 | 12714 | 11986 | 21859.5 | 328.033 | 22360 | 21110 |
| 1050 | 1080 | 12550.1 | 187.344 | 12830 | 12106 | 12912.4 | 183.683 | 13191 | 12477 | 12442.5 | 184.52 | 12711 | 12000 | 21884.4 | 320.358 | 22350 | 21130 |
| 1100 | 1080 | 12553.6 | 181.555 | 12825 | 12110 | 12916.6 | 178.715 | 13194 | 12488 | 12446.4 | 179.512 | 12716 | 12000 | 21891.1 | 311.441 | 22360 | 21140 |
| 1110 | 1080 | 12544.8 | 172.424 | 12817 | 12147 | 12907.6 | 169.601 | 13175 | 12518 | 12437.8 | 170.068 | 12698 | 12004 | 21875.9 | 295.097 | 22320 | 21190 |
| 1120 | 1080 | 12539.9 | 171.601 | 12811 | 12146 | 12900.8 | 168.54 | 13170 | 12523 | 12431.8 | 169.392 | 12679 | 12008 | 21865.7 | 293.84 | 22310 | 21200 |
| 1130 | 1080 | 12539.7 | 173.058 | 12815 | 12125 | 12901.9 | 170.504 | 13170 | 12498 | 12432.7 | 171.139 | 12680 | 12013 | 21868.7 | 296.772 | 22320 | 21150 |
| 1140 | 1088 | 12535.1 | 167.164 | 12795 | 12129 | 12896.9 | 164.362 | 13157 | 12489 | 12427.2 | 165.301 | 12670 | 12008 | 21858 | 288.371 | 22290 | 21160 |
| 1150 | 1091 | 12520.3 | 411.595 | 12802 | 12128 | 12881.9 | 420.75 | 13172 | 12485 | 12413.1 | 407.558 | 12677 | 12010 | 21832.7 | 715.614 | 22310 | 21152 |
| 1200 | 1140 | 12532.2 | 154.737 | 12790 | 12190 | 12894 | 152.283 | 13148 | 12576 | 12424.3 | 151.828 | 12665 | 12077 | 21853 | 264.495 | 22280 | 21270 |

Table (4)

Table (5) The Average Wind Speed (Daily – Hourly) during measurement period from 16/12/2005 to 15/01/2006

| Day Hours | Days | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 00:00 | 4.0 | 4.8 | 3.5 | 1.8 | 3.9 | 10.9 | 12.4 | 7.5 | 4.2 | 5.2 | 4.3 | 8.3 | 8.4 | 2.2 | 11.1 | 9.0 |
| 01:00 | 3.9 | 6.0 | 2.4 | 3.1 | 2.9 | 10.7 | 12.3 | 7.5 | 5.1 | 3.0 | 4.6 | 6.5 | 7.5 | 2.6 | 11.7 | 10.0 |
| 02:00 | 3.6 | 7.1 | 2.3 | 4.3 | 2.7 | 10.4 | 11.2 | 7.6 | 7.3 | 4.6 | 4.5 | 6.9 | 7.4 | 4.6 | 11.3 | 8.6 |
| 03:00 | 4.5 | 8.2 | 1.7 | 2.7 | 3.8 | 10.0 | 10.0 | 4.7 | 6.0 | 6.0 | 4.3 | 8.5 | 8.5 | 3.0 | 14.3 | 4.5 |
| 04:00 | 5.0 | 7.1 | 1.4 | 3.0 | 3.6 | 9.1 | 9.9 | 4.0 | 5.0 | 3.0 | 4.4 | 8.5 | 4.9 | 2.4 | 13.9 | 4.8 |
| 05:00 | 7.0 | 7.9 | 2.1 | 2.3 | 3.5 | 9.8 | 8.7 | 2.7 | 4.7 | 3.5 | 3.7 | 7.1 | 3.4 | 1.2 | 12.6 | 6.3 |
| 06:00 | 8.0 | 8.8 | 2.4 | 1.9 | 3.7 | 9.6 | 8.0 | 3.5 | 5.2 | 5.6 | 2.9 | 7.7 | 3.4 | 1.8 | 9.0 | 4.5 |
| 07:00 | 6.1 | 6.9 | 2.3 | 2.4 | 1.9 | 9.9 | 8.0 | 3.3 | 6.1 | 4.8 | 3.2 | 8.0 | 3.1 | 2.0 | 7.7 | 3.3 |
| 08:00 | 6.0 | 7.1 | 1.9 | 2.2 | 3.0 | 10.4 | 9.9 | 4.8 | 6.8 | 3.8 | 3.5 | 7.7 | 5.7 | 4.4 | 9.8 | 1.7 |
| 09:00 | 5.5 | 6.1 | 1.6 | 1.7 | 7.9 | 10.7 | 10.5 | 7.1 | 7.8 | 4.3 | 4.6 | 7.9 | 8.5 | 8.4 | 11.1 | 3.3 |
| 10:00 | 6.2 | 5.6 | 2.3 | 3.5 | 8.1 | 10.6 | 10.5 | 8.0 | 7.9 | 4.1 | 5.1 | 8.9 | 9.2 | 7.0 | 10.8 | 3.1 |
| 11:00 | 7.8 | 6.0 | 1.9 | 3.4 | 8.8 | 10.7 | 10.6 | 8.4 | 8.6 | 3.8 | 6.6 | 8.9 | 8.8 | 7.2 | 10.9 | 4.8 |
| 12:00 | 9.4 | 6.4 | 3.3 | 5.0 | 9.0 | 10.5 | 10.5 | 8.4 | 9.2 | 5.0 | 7.0 | 9.2 | 9.0 | 8.0 | 10.3 | 5.7 |
| 13:00 | 8.4 | 5.8 | 4.2 | 6.2 | 9.4 | 10.6 | 10.1 | 7.3 | 9.4 | 7.4 | 6.9 | 7.7 | 8.4 | 9.9 | 9.6 | 5.4 |
| 14:00 | 6.1 | 5.7 | 5.7 | 5.7 | 10.2 | 11.4 | 10.1 | 6.9 | 8.0 | 7.4 | 6.5 | 7.7 | 7.9 | 11.2 | 9.1 | 5.4 |
| 15:00 | 6.6 | 5.2 | 4.7 | 4.5 | 10.2 | 12.4 | 9.7 | 5.8 | 5.8 | 7.8 | 7.2 | 8.8 | 7.6 | 11.5 | 9.9 | 5.9 |
| 16:00 | 4.5 | 3.3 | 4.1 | 3.4 | 9.9 | 12.5 | 9.0 | 5.1 | 5.4 | 8.8 | 6.5 | 8.4 | 7.2 | 10.9 | 11.1 | 7.4 |
| 17:00 | 3.8 | 1.6 | 3.4 | 2.5 | 9.2 | 12.0 | 8.9 | 3.4 | 5.9 | 6.3 | 7.1 | 8.2 | 8.0 | 11.1 | 11.1 | 9.3 |
| 18:00 | 3.9 | 1.1 | 2.3 | 2.1 | 10.2 | 12.4 | 9.6 | 2.0 | 4.5 | 5.9 | 7.4 | 7.7 | 8.0 | 10.1 | 10.7 | 9.7 |
| 19:00 | 3.7 | 2.8 | 2.1 | 2.5 | 10.9 | 12.5 | 9.2 | 2.1 | 4.1 | 5.8 | 7.9 | 8.8 | 8.0 | 9.2 | 11.7 | 10.0 |
| 20:00 | 3.9 | 4.3 | 2.1 | 3.1 | 10.9 | 13.0 | 8.2 | 3.7 | 3.7 | 4.6 | 9.7 | 9.9 | 5.7 | 9.8 | 12.8 | 10.6 |
| 21:00 | 4.9 | 4.7 | 1.1 | 3.8 | 10.5 | 13.0 | 8.3 | 4.3 | 3.9 | 5.1 | 10.3 | 8.9 | 5.2 | 10.5 | 12.0 | 10.0 |
| 22:00 | 4.0 | 3.2 | 1.3 | 5.4 | 9.5 | 13.1 | 8.5 | 5.8 | 3.8 | 3.4 | 10.6 | 9.1 | 3.8 | 11.1 | 9.2 | 8.3 |
| 23:00 | 6.2 | 3.4 | 1.5 | 5.1 | 10.8 | 12.8 | 8.4 | 4.5 | 4.4 | 2.8 | 9.6 | 8.0 | 1.9 | 9.8 | 8.3 | 7.9 |
| $AVG_{day}$ | 5.5 | 5.4 | 2.6 | 3.4 | 7.3 | 11.2 | 9.7 | 5.3 | 6.0 | 5.1 | 6.2 | 8.2 | 6.6 | 7.1 | 10.8 | 6.6 |

| Day Hours | Days | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | $AVG_{hour}$ |
| 00:00 | 7.7 | 11.3 | 11.8 | 7.4 | 1.7 | 10.4 | 12.4 | 8.6 | 6.0 | 9.3 | 8.3 | 5.3 | 6.5 | 2.1 | 5.4 | 7.0 |
| 01:00 | 9.9 | 10.9 | 13.0 | 4.8 | 3.0 | 10.9 | 11.9 | 8.3 | 5.8 | 8.9 | 5.2 | 4.7 | 6.8 | 2.9 | 3.7 | 6.7 |
| 02:00 | 4.7 | 6.9 | 12.9 | 2.6 | 1.9 | 12.6 | 12.0 | 6.0 | 5.5 | 8.5 | 1.5 | 5.7 | 6.4 | 2.7 | 2.4 | 6.3 |
| 03:00 | 4.7 | 4.2 | 12.0 | 4.2 | 1.2 | 11.2 | 11.8 | 3.0 | 5.9 | 7.0 | 2.6 | 5.7 | 6.1 | 1.8 | 3.5 | 6.0 |
| 04:00 | 5.2 | 2.5 | 12.7 | 4.4 | 2.1 | 10.6 | 10.7 | 2.6 | 5.5 | 4.5 | 3.4 | 5.2 | 5.1 | 2.8 | 4.1 | 5.6 |
| 05:00 | 3.7 | 9.0 | 12.0 | 2.3 | 2.4 | 10.6 | 10.4 | 2.9 | 4.2 | 4.5 | 4.1 | 5.2 | 3.9 | 3.1 | 3.1 | 5.4 |
| 06:00 | 5.3 | 11.9 | 11.2 | 2.2 | 1.9 | 10.4 | 10.7 | 3.8 | 5.2 | 5.0 | 4.3 | 5.0 | 3.5 | 3.9 | 2.5 | 5.6 |
| 07:00 | 3.8 | 11.8 | 11.1 | 3.4 | 1.1 | 12.1 | 9.0 | 3.2 | 4.8 | 4.2 | 5.6 | 4.8 | 4.1 | 4.3 | 2.3 | 5.4 |
| 08:00 | 5.8 | 12.9 | 11.6 | 2.9 | 1.0 | 11.8 | 3.7 | 4.7 | 5.6 | 4.6 | 4.4 | 3.7 | 3.4 | 3.1 | 2.1 | 5.6 |
| 09:00 | 7.1 | 11.8 | 11.4 | 1.2 | 1.4 | 12.2 | 7.6 | 5.1 | 6.3 | 5.4 | 3.0 | 3.3 | 3.1 | 2.4 | 3 | 6.3 |
| 10:00 | 6.8 | 11.7 | 11.1 | 3.2 | 1.9 | 11.9 | 10.2 | 7.0 | 7.0 | 5.3 | 1.6 | 2.3 | 6.8 | 2.2 | 5.9 | 6.8 |
| 11:00 | 6.9 | 12.6 | 11.0 | 2.8 | 2.2 | 11.7 | 11.4 | 8.2 | 8.2 | 3.9 | 3.2 | 1.8 | 8.7 | 2.7 | 7.3 | 7.2 |
| 12:00 | 7.0 | 13.0 | 9.9 | 2.2 | 2.3 | 12.0 | 11.8 | 9.5 | 8.3 | 3.4 | 5.4 | 2.6 | 9.4 | 5.8 | 7.6 | 7.7 |
| 13:00 | 6.7 | 13.2 | 9.1 | 2.8 | 2.9 | 12.1 | 11.7 | 8.8 | 9.0 | 2.6 | 4.7 | 2.3 | 9.7 | 7.1 | 8.5 | 7.8 |
| 14:00 | 5.9 | 13.4 | 9.1 | 3.7 | 2.7 | 12.4 | 12.0 | 8.5 | 8.5 | 4.6 | 2.3 | 3.5 | 9.6 | 5.8 | 7.8 | 7.6 |
| 15:00 | 5.7 | 13.1 | 9.2 | 3.3 | 4.3 | 12.9 | 11.2 | 7.4 | 8.0 | 5.0 | 2.9 | 3.7 | 8.9 | 5 | 6.7 | 7.5 |
| 16:00 | 6.1 | 13.2 | 9.5 | 4.7 | 5.2 | 12.6 | 10.6 | 5.3 | 7.1 | 5.5 | 4.2 | 2.6 | 7.8 | 1.7 | 7.4 | 7.1 |
| 17:00 | 7.1 | 13.4 | 8.9 | 6.7 | 7.3 | 13.0 | 10.5 | 3.4 | 6.0 | 5.6 | 4.4 | 2.2 | 6.8 | 1.5 | 6.8 | 6.9 |
| 18:00 | 8.6 | 14.7 | 9.2 | 6.4 | 8.6 | 12.9 | 10.0 | 2.7 | 7.2 | 5.8 | 4.6 | 1.9 | 7.0 | 4.2 | 6.4 | 6.9 |
| 19:00 | 9.3 | 15.6 | 8.5 | 4.4 | 10.5 | 13.6 | 9.9 | 5.7 | 7.4 | 6.6 | 4.0 | 2.7 | 9.6 | 4.8 | 4.6 | 7.3 |
| 20:00 | 9.4 | 15.1 | 9.7 | 2.4 | 12.8 | 13.5 | 10.0 | 8.2 | 7.3 | 7.3 | 5.1 | 3.8 | 7.6 | 4.3 | 4.5 | 7.5 |
| 21:00 | 9.7 | 14.1 | 11.2 | 2.1 | 13.4 | 14.1 | 8.3 | 7.2 | 8.6 | 9.5 | 6.3 | 5.7 | 7.0 | 4.9 | 4.5 | 7.8 |
| 22:00 | 10.1 | 13.0 | 10.6 | 1.4 | 11.6 | 13.6 | 8.9 | 9.5 | 10.1 | 7.8 | 5.1 | 6.6 | 6.1 | 4 | 4.6 | 7.5 |
| 23:00 | 11.3 | 11.9 | 10.7 | 1.2 | 10.5 | 13.1 | 9.0 | 8.9 | 8.6 | 7.3 | 3.6 | 6.2 | 4.3 | 5.7 | 4.1 | 7.1 |
| $AVG_{day}$ | 7.0 | 11.7 | 10.7 | 3.4 | 4.7 | 12.2 | 10.2 | 6.2 | 6.9 | 5.9 | 4.2 | 4.0 | 6.6 | 3.7 | 4.9 | 6.8 |

Hourly Average | Daily Average | Period Average

Table (5)