# INVESTIGATION OF HARMONIC LEVELS FOR THE POWER NETWORK OF EGYPT

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## ABSTRACT

*Voltage and current harmonics seriously affect the supply power quality. Voltage and current harmonic measurements are the tools used for determination of harmonic levels.*
*The harmonic measurements in the distribution system of Egypt are planned to cover a wide area, in different atmospheric conditions and at different measurement sites.*
*The sites are chosen in the various cities in Egypt, where high voltage substations 66, 33/11 KV, are installed.*
*The system consists of 200 high voltage substations.*
*The number of consumers fed at high voltage are 30, while several hundreds of consumers are fed at medium voltage.*
*The paper reviews the overall scheme of harmonic presence in the power network of Egypt, its levels and main sources. Also the paper describes the present measurement methodology. Measurement results for the first phase of the plan are given.*

## INTRODUCTION

As the number and power rating of non-linear loads (static power converters..) connected to the utility electric system increases, so does the concern over harmonic distortions. This concern is with the effect of harmonics on the quality of power, and on the operation of the systems.
These concerns have lead to the formulation of guideline for the current and voltage waveform distortions. A measure of the quality of a waveform (either voltage or current) is the current or voltage distortions factor.
Harmonic measurements must continue to specify the existing harmonic limitations, to determine harmonic sources, and to evaluate a system problem that may be related to harmonics.

## HIGH VOLTAGE NETWORK OF EGYPT

The Electric Network of Egypt is divided into 7 zones.
Table (1) summarizes some characteristics of high voltage network of the 7 zones.
Table (2) represents the percentage consumption pattern in different categories of the 7 zones.
In table (2) it is noticed that:

- The Agricultural loads predominate on the W.Delta zone loads
- The Industrial loads predominate on Cairo, Alexandria and Canal zones loads.
- The Residential loads predominate on Cairo M.Delta , North Upper E and South Upper E zone loads

**Table (1) Substation Capacity in MVA and length of electric circuits Km (96/97)**

| Item / Zone | MVA | | Length Km | | |
|---|---|---|---|---|---|
| | 66/11KV | 33/11KV | 66KV | 33KV | 11KV |
| Cairo | 7090 | - | 1815 | - | 18422 |
| M.Delta | 3175 | 34 | 270 | 375 | 18873 |
| W.Delta | 1224 | 13 | 1295 | 204 | 9992 |
| Alexandria | 2618 | 182 | 1112 | 97 | 6420 |
| Canal | 2374 | - | 1847 | - | 13053 |
| North Upper E | 661 | 694 | 876 | 1092 | 13014 |
| South Upper E | 707 | 701 | 816 | 1431 | 9802 |

**Table (2) % Consumption Pattern in Different Categories**

| Item / Zone | Resi-dential | Com-mercial | Indus-trial | Agricul-tural | Other |
|---|---|---|---|---|---|
| Cairo | 45.1 | 3.5 | 30.9 | 1 | 17.7 |
| M.Delta | 53 | 2.85 | 14.1 | 1.1 | 15.7 |
| W.Delta | 34.7 | 1.1 | 25.3 | 15.5 | 15.6 |
| Alexandria | 38.1 | 8.2 | 32.8 | 0.8 | 17.2 |
| Canal | 35.3 | 3.9 | 31.9 | 3.4 | 16.9 |
| North Upper E | 59.3 | 1.4 | 7.3 | 3.2 | 14 |
| South Upper E | 52.4 | 1.2 | 11.8 | 4.6 | 13.4 |

These Zones cover the whole of Egypt with different atmospheric conditions regarding temperature and humidity. In Alexandria, Delta, and Canal the climate is moderate and in Cairo and Upper Egypt it is continental.

### Measurements

Figure (1) is the normal one line diagram of 66/11 kV substation in Egyptian Networks. The busbar where the measurements were made are indicated by symbol X.
The monitoring program was based on the use of the following equipment:

- Energy and harmonic Analyzer : VIP system 3
- BMI 80/v PQ Node and PQ Node Application and system software program.

These instruments are storage systems, which allow for long period monitoring. Using these instruments, measurements were performed in order to obtain information concerning: voltage, current, power and

harmonics. The results represent the electrical supply behaviour for the different busbars.
This paper presents preliminary results from a monitoring program which presently involves 40 sites across Egypt.
The total harmonic distortion of the current voltage (THDI & THDV) are compared to the specified IEEE Std. 519 – 1992.

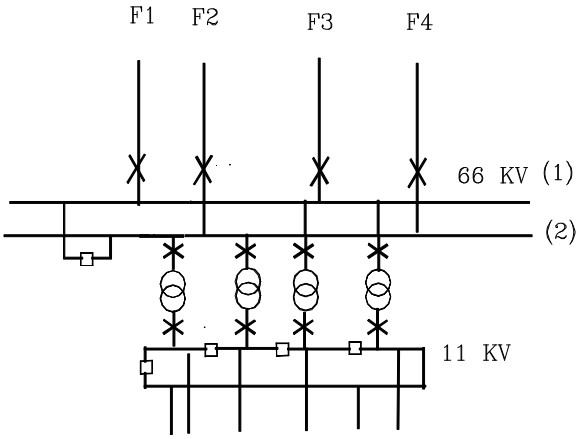


**Fig ( 1 ) Typical 66 /11 KV Substation**

## VOLTAGE POWER QUALITY CHARACTERISTICS

The voltage power quality were discussed and analyzed using all data recorded at the monitored sides during the monitoring periods. An important figure of quality is the statical distribution of the harmonic voltage distribution.
The results are presented in this section for the 7 Egyptian Electric Zones.

### Alexandria Network

Harmonic recording took place on all high and medium voltage buses of 22 high voltage substations, which is presented in Figure (2).

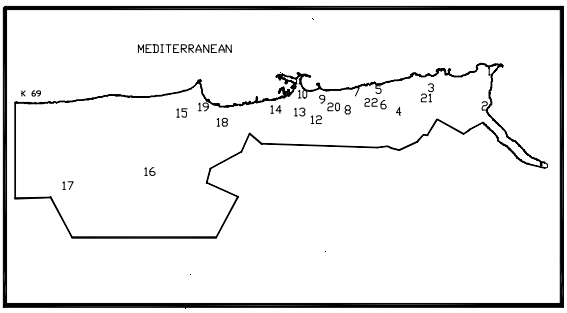


**Fig (2) The Alexandria substations 66,33 KV/11KV**

Figure (3) illustrates a scatter plot of all THDV at 66 kV buses where data points were plotted vs. the time of day. An analysis of the THDV reveals that the peak and the peak of the average THD values are around 7.0 % and 3.78 %respectively.
Figure (4) illustrates a scatter plot of all THDV at 33 kV buses, the peak and the peak of the average THD values are around 4.5 % and 3.13% respectively.
Figure (5) illustrates a scatter plot of all THDV at 11 kV buses, the peak and the peak of the average THD values are around7.7 % and 4.13 % respectively.
The maximum peak of the average THDV occurred mainly during the light load period from 4 AM to 7 AM.
However, the average THDV measured at 66, 33, 11 kV buses were found to be within the IEEE 519 limit.

### Middle Delta Network

Figure (6) illustrates a scatter plot of all THDV at 66 kV buses, the peak and the peak of the average THD are around 4.45 % and 3.38 % respectively.
Figure (7) illustrates a scatter plot of all THDV at 11 kV buses the peak and the peak of the average THD are around 5.1 % and 4.66 % respectively.
The maximum peak of the average THDV occurred mainly during the Light load period from 12 PM to 3 PM.

### The Other Networks

For Cairo,West Delta,Canal,North and South Upper Egypt networks, the results are summarized in table (3) and Figures from (8) to (17) represent a scatter plot of all THDV at 66 kV and 11 kV buses for these networks.

**Table (3)**

| Zone | 66 KV THDV% | | 11 KV THDV% | |
|---|---|---|---|---|
| | Peak | Peak of average | Peak | Peak of average |
| Cairo | 4.6 | 2.87 | 7.29 | 3.45 |
| West Delta | 3.92 | 1.24 | 3.63 | 2.82 |
| Canal | 2.8 | 2.4 | 5.6 | 3.56 |
| North Upper E | 6.5 | 3.74 | 4.3 | 3.66 |
| South Upper E | 2.5 | 1.92 | 4.5 | 3.01 |

## CONSUMERS IN ALEXANDRIA ZONE :

### A – Medium Voltage Consumers Causing Harmonics

Various loads cause harmonics. This paper focuses on two types of loads namely the electric stations of the tram way and the central telephone exchanges . The following section represents the results.

### Electric Stations of the Tram Way

There are six medium voltage stations. A six-pulse AC/DC diode bridge rectifier is used. The harmonic content of the input current was basically monitorized at these stations. Figure (18) is the one line diagram of one of these six stations. Figure (19) gives the results of 24 hours

recording on the medium bus bars. The results clearly indicate the following:

- The THDI exceeds the IEEE limit over all the time
- The THDV exceeds the IEEE in early morning hours
- The fifth harmonic component is dominant.

Figure (20) illustrate a scatter plot of all THDV at 11 KV buses of six stations of the tram way , the peak and the peak of the average THD values are around 5.7% and 5.16% respectively. However the average THDV measured is to be close to IEEE limit inspite of the very high value of THDI

**Central Telephone Exchanges**

There are twelve exchanges. Capacitor banks are installed to improve power factor. The load variation during the day is clearly constant. They generate harmonic currents that produce excessive harmonic distortion on the power system. Figure (21) gives the results of 24 hours scatter plot of all THDV at 11 KV buses of exchanges , the peak and the peak of the average THD values are around 8.1% and 5.4% respectively. The maximum peak of all the average THDV occurred mainly during night hours.

**B - High Voltage Consumers Causing Harmonics**

In Alexandria zone, the 66 KV network are extended and serves 7 main large consumers : Chemical , Petrochemical , Fertilizer , 2 Cement and 2 petroleum companies.

**Fertilizer Company**

The fertilizer company load consists mainly of induction motors, cooling tower and automatic electronic control systems.
The system characteristics were recorded on the 66 Kv side of the two 66/6.6 Kv transformers. Most of the loads operate three shifts. Capacitor banks are installed on medium and low voltage sides for reactive power compensation. Figures (22) & (23) show the THDV and THDI on two 66 Kv feeders. The current harmonic distortion is very high and exceeds the IEEE limit, with the fifth and seventh harmonic components being dominant. The THDV was found to be within the limit.

**Chemicals Company**

The Chemicals Company load consists mainly of electrolysis system. The network consists of three 66/0.446KV , 11.5 MVA transformers, huge rectifying banks and filters.
The system characteristics were recorded on the 66 KV side of one transformer. Figure (24) shows the TDHV and THDI. The THDI is very high and exceeds the IEEE limit, with $5^{th}$, $7^{th}$, $11^{th}$, $13^{th}$ .. harmonic components being dominant. The filter keeps the THDV within standard limit.

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Fig (25) illustrates a scatter plot of all THDV at 66 Kv & 11Kv buses, the peak of the average THD are 2.31% &3.24 % respectively.
Fig (26) shows the number of measurements in each 1% THD interval. The sample standard deviation of the 66 Kv &11Kv THDV measurements are 1.4% &4% of the measurements above the IEEE limit respectively.
Fig (27) shows the number of measurements in each 1% spectrum distortion interval. The sample standard deviation of the 11Kv spectrum $V_5$ & $V_7$ measurements are 22% &4.7 % and of the 66Kv are 2.7% & 5% of the measurements above the IEEE limit respectively.
The fifth harmonic is pronounced in the bus voltage.

**CONCLUSION**

Electricity companies will have to report power quality performance statistics and make sure that the performance does not significantly deteriorate over time.
AEC recently completed a 2-year monitoring project to provide benchmark indices describing THDV levels on power systems in Egypt.
This survey is voltage characterstistics for Egyptian network. Results show that levels of harmonics at most sites meet the standard IEEE 519 – 1992 limit.
In some HV&MV sites the analysis results showed that the current harmonic distortion exceeds the IEEE limit, with the fifth and seventh harmonic components being dominant, but the THDV is within the limit.
Finally, the concept of measured level, provides a very helpful and flexible tool for electric power companies to define emission limits for the connection of distorting loads to MV and HV power systems.

**REFERENCES**

[1] IEEE “Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems” ANSI/IEEE std. 519 - 1992
[2] IEC “ Assessment of Emission Limits for Distributing Loads in MV and HV Power Systems” Technical Report type 3,IEC 1000-3-3,1996.