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Power Frequency Magnetic Field Survey in Indoor Power Distribution Substation in Egypt

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***Abstract*—**In our modern society electricity is vital to our health, safety, comfort and well-being. While our daily use of electricity is often taken for granted, public concern has arisen about potential adverse health effects from electric and magnetic – electromagnetic – fields (EMFs) produced by our use of electricity.

This paper aims to compare between the measured magnetic field values and the simulated models for the indoor medium to low voltage (MV/LV) distribution substations.

To calculate the magnetic flux density in the substations, interactive software SUBCALC is used which is based on closed form solution of the Biot-Savart law with 3D conductor model.

The comparison between the measured values and the simulated models was acceptable. However there were some discrepancies, as expected, may be due to the current variation during measurements.

***Keywords*—**Distribution substation, magnetic field, measurement, simulation.

I. INTRODUCTION

ELECTRIC and magnetic fields, known as electromagnetic fields (EMFs), are produced wherever electricity is used. In recent times, magnetic fields emissions from various electrical components have induced more than one debate whether they represent a harmful influence to our health.

In addition, interferences caused by power frequency (PF) magnetic fields on electronic equipments in industrial systems (e.g. cathode ray tubes found in TV screens and computer monitors, electron microscopes) become evident at levels over 1 one (μT). Nevertheless these issues have caused some concern with the general public but also to the utilities, their customers and the International agencies which tried to establish guidelines for PFMF exposure.

There are two international exposure limit guidelines. The first one is the International Committee of Non Ionizing Radiation Protection 1998 (ICNIRP), and the second one is the Institute of Electrical and Electronics Engineering 2002 (IEEE).[1-2]

These limits are issued to protect living organisms against these effects as shown in TABLE I.

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TABLE I
MAGNETIC FIELD EXPOSURE LIMITS GUIDELINES

Authority / Type of Exposure	ICNIRP	IEEE
Occupational Exposure	500 μT	2.71 mT
General Exposure	100 μT	904 μT

For utilities awareness, they recognized and took seriously their responsibilities to resolve the public concerns. Utilities believe that their responsibilities are:

1- To provide safe and reliable electricity for their customers.
2- To provide balanced and accurate information, derived from all sources, to their employees, customers and regulators. This will include providing EMF measurements and calculation to their customers upon request.
3- To support all necessary researches to resolve unanswered scientific questions.
4- To conduct the required research to develop and evaluate the engineering designs and find ways to reduce the fields generated by electric facilities.
5- To take reasonable low-cost steps to reduce field exposures from new facilities and continue to consult and advise their customers regarding existing facilities.[3]

Utilities have been carrying out extensive projects to characterize and manage the magnetic field emission. For this reason this study focuses on the fields originating from the distribution stages of the power network before reaching the customers, in particular the components of in-house secondary substations. This research examines the magnetic field level according to the guidelines, compares between the measured and simulated magnetic field values, and applies the simulation program on different load cases.

II. INDOOR POWER DISTRIBUTION SUBSTATION

In the big cities where many building are near to each other, the load density is high. Therefore, indoor power distribution substations, which usually have high nominal power, are located in the ground floor of the buildings. It is regular to find these rooms in the buildings in Egypt.

The standardized indoor power distribution substations in Egypt have nominal powers of 300, 500, 800, and 1000kVA. So these indoor substations may effect on the occupants health in these building, especially for town like Alexandria the number of the inhabitants are above 4 millions, and the number of installed transformer substation are about 5000 rooms.

Their number and their proximity to homes and workplaces may raise the concerns of the people over health hazards from the fields caused by the operation of these substations.

III. Magnetic Field Measurement

On site measurements of magnetic fields are done using the magnetic field meter, the more precisely PMM 8053 which works together with a PMM EHP-50 probe supplied by Italy, which are connected through fiber optics wire used to avoid interference as shown in Fig.1. The meter supports recording, storage, and evaluation functions for sequences of results and can measure electric and magnetic fields.

These measurements were performed on a 0.5m×0.5m grid at a height of one meter above the ground and around the distribution transformer. The spot measurements were taken by the meter, at the same time the line currents and the neutral current were measured by a precise clamp ammeter. This measurement was taken at 11am for one hour, where the load was quite small. The readings can then be presented in a two dimensional magnetic field versus distance plot or three-dimensional graphs and contour plots. [4-7]

Fig. 1 View of the probe and meter

A typical distribution substation for residential area consists of a building which houses a transformer rated at 500kVA with their associated 11kV circuit breakers and the 3phase, 4 wire 380/220 V distribution panel as shown in Fig.2.

Power is fed to the substation via 3 phases, 11kV underground cables and distributed to consumers through the 3 phase, 4 wire 380/220 V distribution board through underground cables as shown in Fig.3. The magnetic field measurements were conducted at these substations and the results are indicated in the measuring grid shown Fig.4 with a grid of 0.5m.The 3D plot for the measured values shown in Fig.5, and the contour plot for measured values is shown in Fig.6 Some measurement points were not available to be measured because due to the place circumstance. The magnetic field was measured over the cables of the low tension side and the maximum values were approximately 0.659 mT at the transformer low tension side and 193µT at the low tension panel. At the same time, the load currents were measured during the magnetic field measurement and were found to be 89.7A, and the neutral current was 29.8 A

Fig. 2 Magnetic field measurement at distribution substation

Fig. 3 Low voltage panel view

IV. Magnetic Field Simulation

Modelling and Simulation in and around the distribution substation and its facilities for the magnetic field emission can be used to determine the magnetic field level. Modelling and Simulation studies are useful for the following purposes [8-9]:

- It allows an environmental effects related evaluation of substation design.
- It is good complement to full scale studies for both measurement and analysis techniques.
- It can be used as a design tool that can save money in the development stages of substations
- Ground level magnetic field strength or magnetic flux density mapping can be obtained.
- Easy change of operating and geometric conditions
- Development of mitigation techniques

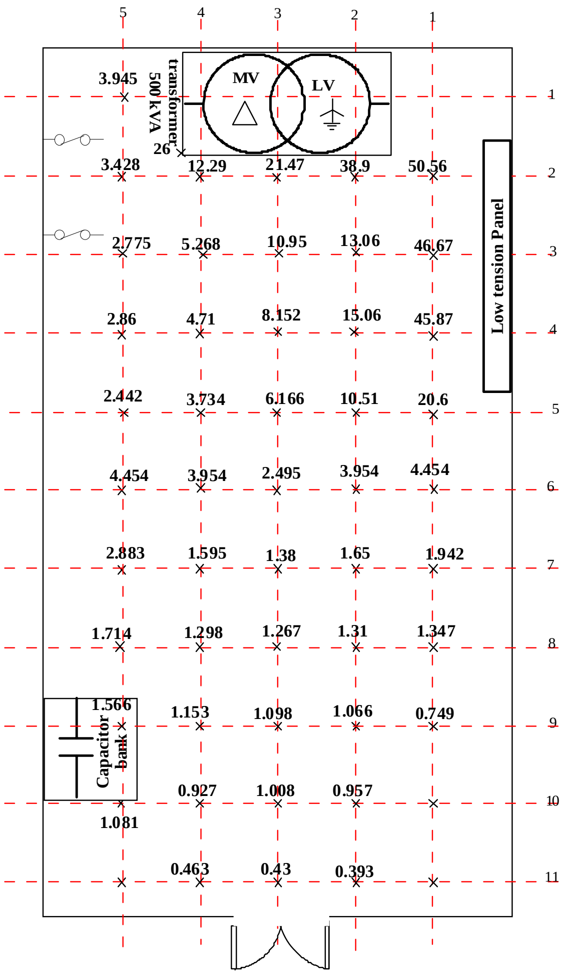

Fig. 4 Measured results

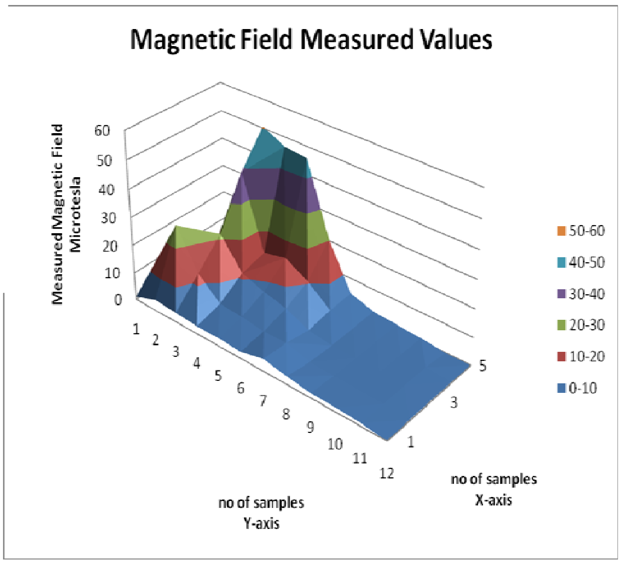

Fig. 5 3D plot for the measured values in substation

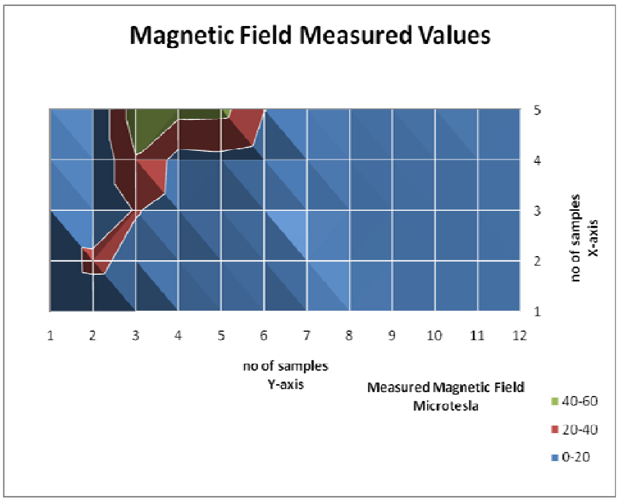

Fig. 6 Contour Plot for the Measured Magnetic Field

The following assumptions were taken into consideration in calculating the magnetic fields in the substation:

1. Source currents are confined to the measured values and current path (earth currents are neglected regardless of their origin).
2. The earth is non-magnetic.
3. Induced current on the wires and the ground wires are ignored.

In this research, the SUBCALC program is used to model the magnetic fields in 11/0.38 kV distribution substation. The magnetic field output of the SUBCALC simulation program for the same measured substation and for the same loading conditions is also presented in two different formats. The 3D representation for simulated output of the substation model as shown in Fig.7, and the contour representation of the same results of the program is shown in Fig.8

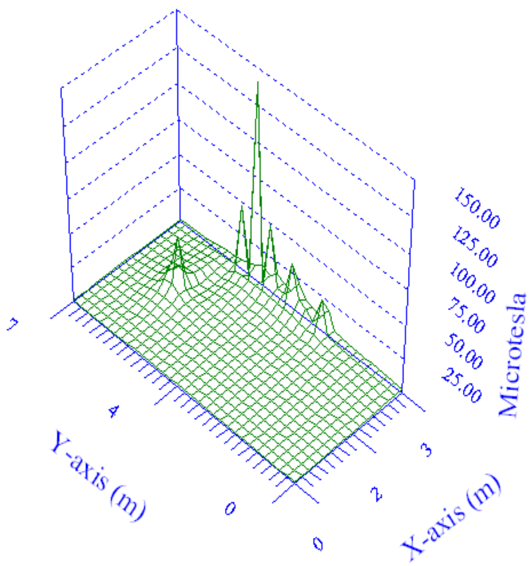

Fig.7. 3D presentation of simulated magnetic field

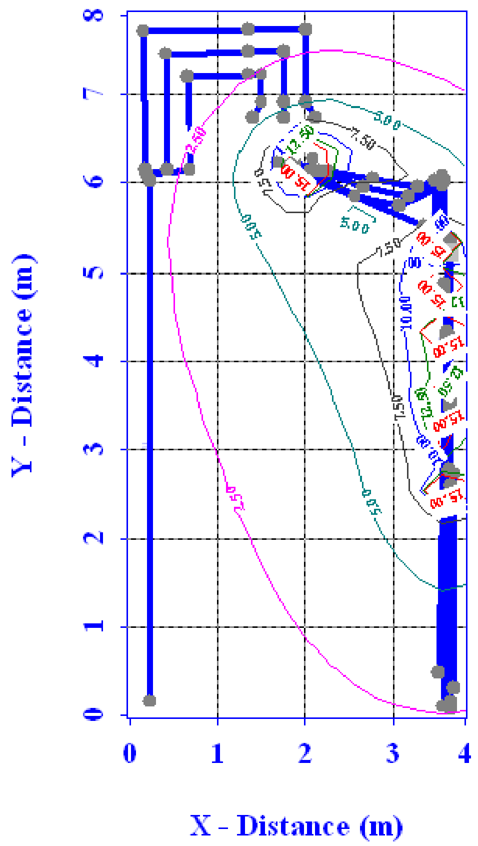

Fig. 8. Contour presentation of simulated magnetic field

V. Comparison Between Measurement And Simulation

The SUBCALC program and the measuring meter are used to provide closer look at the variation of magnetic field density within some specified location inside the field density within some specified locations inside the substation and to present direct comparison between measured and calculated magnetic fields at that defined location inside substation.Fig. 9 shows the field profile inside the substation at Y=4.5meter, while varying the X-axis.

It can be observed that the simulation profile agrees with the measurements profile in the overall distribution of the magnetic field. Except in some points where some difficulties where faced during taking the measurements (ex. an object like the transformer may block the path of the measurements or in some locations when it was impossible to measure there for safety reasons).

VI. Application

The good agreement between the measured and simulated values encouraged us to find the magnetic field exposure from this power distribution room at the peak load. The transformer load was assumed to be about 720 A, and neutral current was 25A.

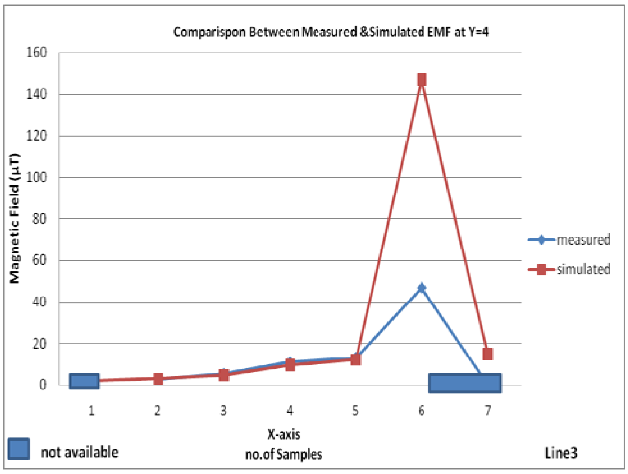

Fig. 9 Simulated and measured magnetic field Profiles at Y=3

The 3D representation for simulated output of the substation model as shown in Fig.10 . The maximum magnetic field value was approximately 350 μT

Also, The SUBCALC program enable us to simulate the magnetic field exposure at 5m height which is 1m from the ground of the first floor. So ,the program represent the magnetic field level for the general people who live in the first floor as shown in Fig. 11. The maximum magnetic field level in that floor at height 1 m was 5μT.

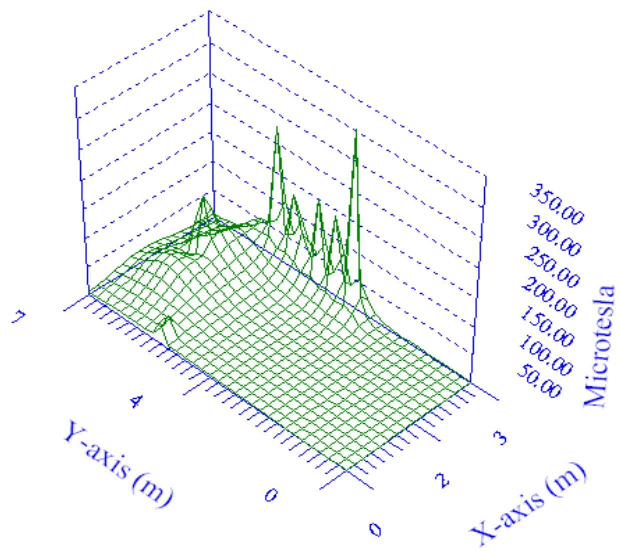

Fig. 10. 3D presentation of simulated magnetic field at peak load

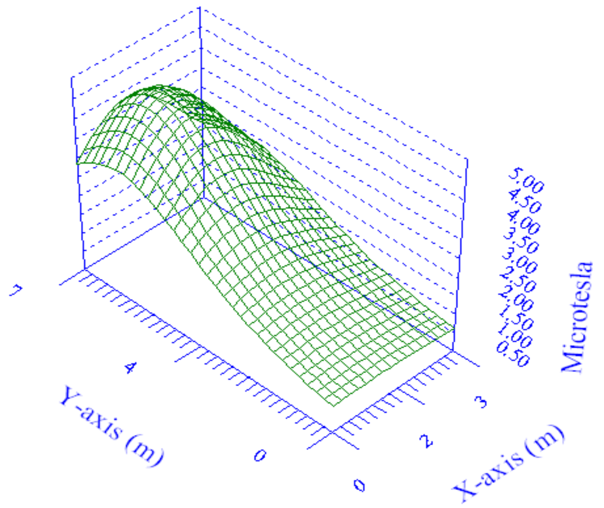

Fig. 11 3D presentation of simulated magnetic field at height 1m above the first floor

VII. Conclusion

This paper presents the results of measurement and simulation of the magnetic field on 11/0.38 kV distribution substation in Egypt. The distribution substation includes transformer, cables which feed the transformers, low voltage panels, low voltage cables which feed the different customers. The resulting magnetic field environments has been presented in a variety of graphical formats including contour and three-dimensional maps. The attainable measured and modelling results were coordinated and showed almost full agreements. This may conclude that the modelling and simulation program is capable to determine the magnetic field distribution inside and outside the distribution substations. The comparison agreement between the measured and simulated values was motive to apply the simulation at the peak load and at distance 1m above the ground of the first floor to study the magnetic field exposure level. If the magnetic fields exceed the guidelines limit value, the utility must find solution to reduce the magnetic field level emission. This would have a great benefit to electrical utilities in choosing the substation location and to take the proper measures in designing these substations.

The measured and simulated results were within the guidelines limits of ICNIRP for occupational exposure where the maximum value was 350 µT and for general exposure was 5 µT. But the substation need many modification in the cables arrangement to reduce the magnetic field level because the scientific researches still investigate the health effect due to magnetic field exposure for longer period.

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