Mansoura Bulletin, Vol. 6, No. 2, December 1981.

FIELD MEASUREMENTS AND CALCULATIONS OF 220 KV OVERHEAD TRANSMISSION LINE

By

Y. Abed K. M. Shebl S. A. Farghal *

ABSTRACT:

The present paper reports experimental results of both electric and magnetic fields produced under a 220 kV overhead transmission line at different heights above ground and at varied transverse distances from line center. A simplified experimental technique is used for this purpose. The indirect effects of both fields are appeared on the oscilloscope in the form of current traces which are recorded by a photographic camera. Some of the reproduced photographs are also contained here. The values of both fields are also computed at two selected sites in the area between Talkha and Tanta substations. These values are estimated by using the moment techniaue and compared with the corresponding experimental results.

INTRODUCTION:

The rapid advancement in the increase of transmission voltages has led to intensive research in the accompanied high-voltage phenomena. It is well known for electrical engineers that there are many reasons for the ever-rising characteristic of the operating voltage of electrical power systems. As the voltage level is increased many performances are considerably improved. In Egypt, the transmission voltage is not increased continuously but at irregular intervals in the successive fashion 11 kV, 22 kV, 33 kV, 66 kV, 132 kV, 220 kV and 500 kV. Higher transmission voltages are used in other countries, namely 750 kV and 1000 kV

---

* Faculty of Engineering, Mansoura University.

The ever-rising characteristics of the operating voltage of overhead transmission lines put forth many problems before the electrical power-system engineers. These problems are so many that it is very difficult to encompass them within the framework of a single research work. One of these problems is the formation of electromagnetic field around the high-voltage energized transmission lines. It is very important to study the influence of this field on the surrounding life forms and objects. To have a clear idea, the value of both electric and magnetic fields under the high-voltage transmission lines must be determined. Therefore, this work is aimed to determine the value of the two fields at different levels and transverse distances under a 220 kV energized overhead transmission line interconnecting the two substations at Talkha and Tanta. These values are determined by measuring using a simplified experimental technique and numerically by applying the moment technique.

MEASURING TECHNIQUE AND SITES:

Measuring Sites:

The measurements are carried out at two places under 220 kV single-circuit overhead transmission line interconnecting the two substations at Talkha and Tanta. The first place is chosen under the begin of the line near Talkha substation, while the second at Toukh-Mazied village near Tanta. Both sites are selected away from any disturbing object to avoid its effect on the measured fields. The two substations have many lines having different operating voltages ranged from 11 kV to 220 kV of both types of transmission lines namely underground cables and overhead lines. Measurements are performed under the line away from any parallel line while it is operated under 210 kV and 300 A as loading current.

Field Measurements:

To avoid any disturbing effect on the measured values of both the electric and magnetic fields, a simplified experimental system is used here. When measuring the electric field, the system consists mainly of an oscilloscope, a parallel-plates condenser, a wooden cage and shield cables for all connections. The magnetic field is measured by the same system after replacing the condenser and the cage by a search coil and high-voltage sticks. The oscilloscope differs from all field measuring instruments since it has no moving parts when it is in operation. The used oscilloscope (Advance Electronic, LTD, UK) is supplied from a portable generating unit of Hunda type, 3 kVA, 50 Hz and 220 V placed at least 100 m away from the measuring site. The condenser can be considered here as a gradient meter and consists of two similar aluminium plates, each of 28 x 28 cm and 1 mm thickness isolated from each other at 10 mm spacing. The wooden cage is used here to support the condenser at different levels under the line to avoid the proximity effect of the researcher and his co-workers. It is about 3 m high and has a square cross-section of 30 x 30 cm. The cage is prepared to enable the condenser mounting during test either horizontally or vertically at heights of 1 m, 1.5 m, 2 m, 2.5 m and 3 m to measure both the horizontal and vertical components of the electric field at these heights. The same components of the magnetic field at the before-mentioned heights are also measured by the search coil and high-voltage sticks. The coil has 2500 turns and is of 5 cm long and square cross-sectional area of 1.8 x 1.8 cm.

Calibration of the Measuring System:

The measuring arrangement of the electric field is calibrated in the high-voltage laboratory by measuring a known electric field between two parallel plates each of 60 x 100 sq. cm and spaced 50 cm apart from each other. The calibrating condenser is supplied from A. C. high-voltage generating circuit having output voltage of up to 80 kV (R. M. S.). The condenser is placed between the two plates of the calibrating condenser, which can be considered to have a uniformly distributed electric field, neglecting the end effect.

Calibration is also carried out for the magnetic measuring arrangement by using a standard solenoid of 450 turns, 1 m long and 10 cm mean diameter. The search coil is placed inside the calibrating solenoid where the magnetic field is uniformly distributed. The value of the magnetic field inside the solenoid can be theoretically calculated and measured by the search coil and the oscilloscope.

RESULTS AND DISCUSSIONS:

Field measurements were carried out at two places in the area between the two substations at Talkha and Tanta under 220 kV energized overhead transmission line, interconnecting the two substations. This line is a single-circuit line and has three SCA - stranded conductors each of 400 sq. mm area. The three conductors are supported by steel towers each of about 36 m height and three cross-arms each of 5.3 m long. The heights of the three conductors are 19.87 m, 23.28 m and 29.96 m above ground. Measurements are carried out away from the nearest tower by at least 50 m to avoid any disturbing effect on the field values.

Measured Fields:

Electromagnetic field is measured under 220 kV overhead transmission line at the two selected sites between Talkha and Tanta substations. The line is located above a flat homogenous ground surface. The weather during all experiments was fair with temperature of about 25°C. Field measurements were performed under the 220 kV line away from any other parallel operating line to avoid any disturbing effect on the measured fields. These fields are measured by the simplified experimental arrangements described before. The field at any selected point is estimated by ten successive measurements. The operating voltage and current are recorded during the measurements and all results reported here are related to 210 kV and 300 A recorded at Talkha substation.

The electric field is measured separately at each of the two selected sites at different distances from line center and at various heights above ground under the line. The obtained results are illustrated in Figs. (1) and (2). Figure (1) shows the experimental results of the electric field near the two substations at 1 m above ground. Each

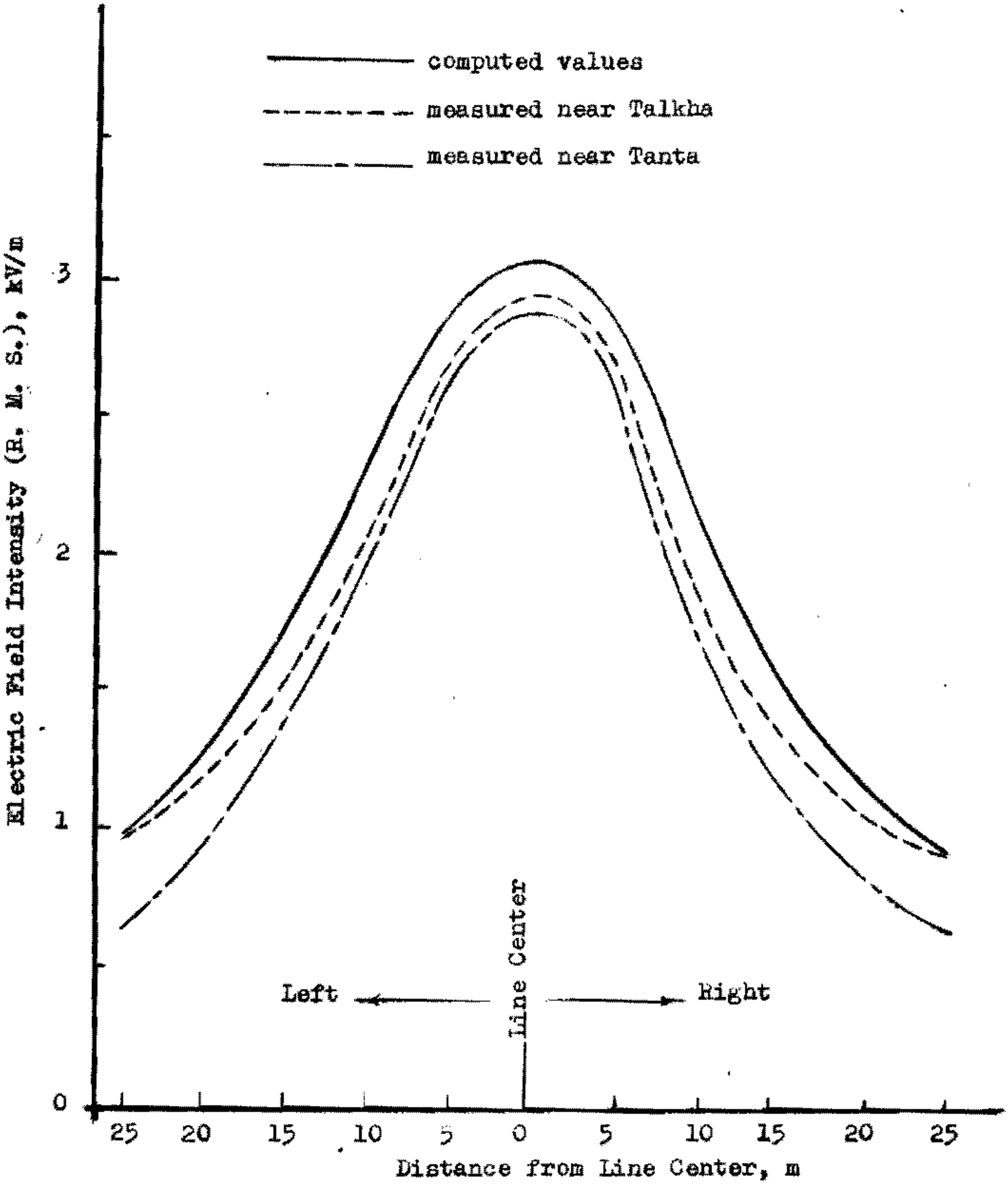


Fig. 1: Computed and measured values of electric field under 220 kV overhead transmission line at 1 m above ground against the distance from the center of the line.

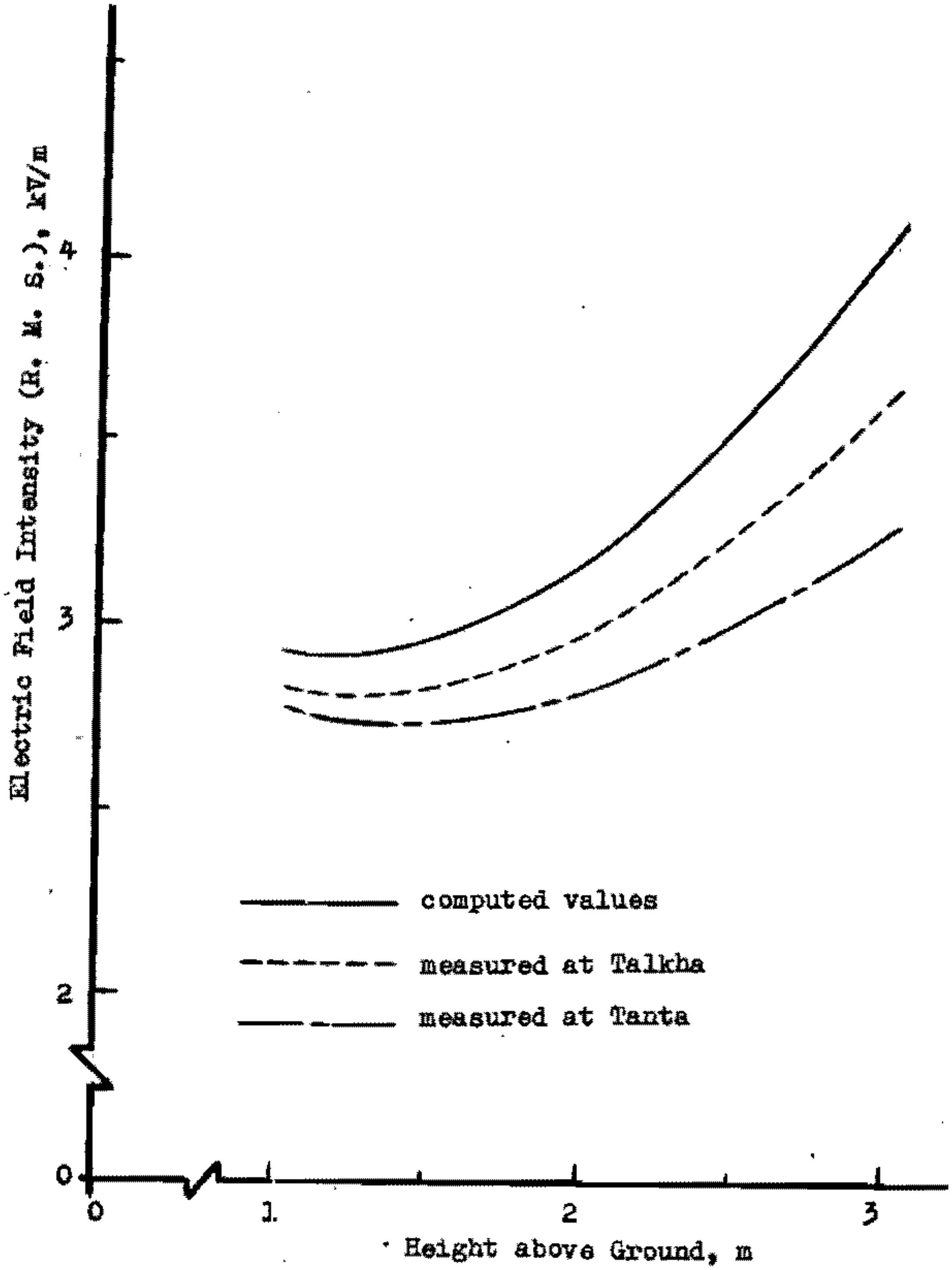
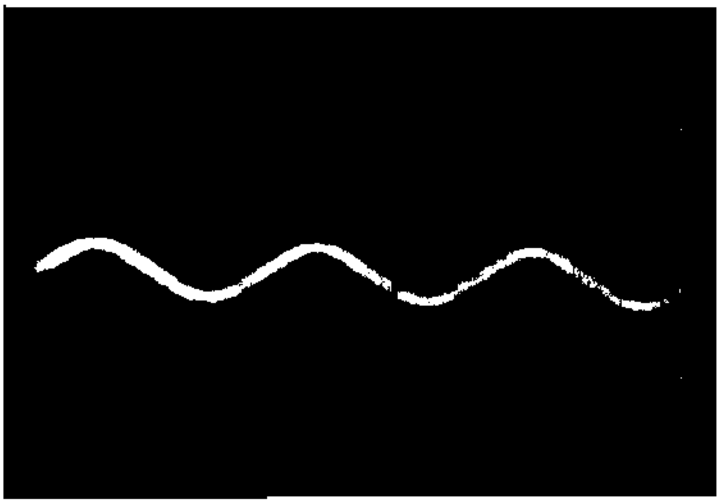


Fig. 2: Comparison between the computed and measured values of the electric field under the center of 220 kV overhead transmission line as function of the height above ground.

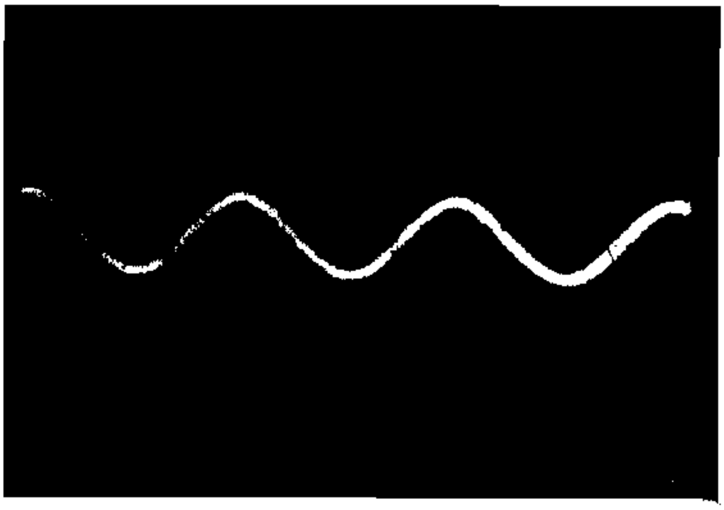
value given here represents the mean of 10 successive readings. It is clearly seen that the electric field has its highest value just at the line center. It decreses as the distance from line center is increased either to the left or to the right. The electric field measured near Talkha is higher than that at Tanta at the same distance from line center. The electric field intensity depends of course on the height of the measuring point above ground. This is clearly illustrated in Fig. (2), which shows the dependence of the electric field on the height above ground. As this height is increased, the electric field increases also at the same distance from line center at the two measuring sites. Here also, the values of the electric field measured near Talkha substation are higher than the corresponding values measured near Tanta substation. This may be explained to be due that the operating voltage at Talkha is higher than that at Tanta. Not only the value of the electric field under high-voltage lines is affected by the height above ground but also the wave shape and frequency are affected. This is also investigated by the oscilloscope and by many photographs recorded for the current traces on the oscilloscope. As example, Fig. (3) shows some reproduced photographs of the oscilloscope current traces formed as indirect effect of the electric field under the line. It is clearly illustrated that the electric field has horizontal component differing from the vertical at the same measuring point (Ph. a and b). The two components are affected by the height above ground (Ph. a and c).

The magnetic field produced under a high-voltage transmission line can be briefly explained as follows. If the currents of the conductors are A. C., a time-dependent magnetic flux density will be produced inside and around the conductors in the form of ellipses. The value and direction of its vectors are time-varying. The summation of these vectors forms an elliptic rotating-field.

The magnetic flux density is also measured at the two measuring sites by using the search coil and high-voltage sticks of different heights as described before. When this coil is placed in the time-varying magnetic field produced



a) Horizontal component of of electric field under 220 kV line at 1 m above ground.



b) Vertical component of electric field under 220 kV line at 1 m above ground.

c) Horizontal component of electric field under 220 kV line at 2.4 m above ground.

Fig. 3: Oscilloscope current traces produced by the electric field under 220 kV transmission line at differnt heights above ground level (1 msec, 5 V/div.).

by the high-voltage line, a time-varying potential will be induced. This potential is proportional to the flux variation in the coil according to Farday's law. The indirect effect of the time-varying magnetic field is measured by an oscilloscope. The electric current flowing from the coil to the oscilloscope can be considered to be directly proportional to the magnetic flux density under the line. This arrangement is calibrated by measuring a known magnetic flux density as described in the foregoing section.

The magnetic flux density is measured under the 220 kV line at different heights above ground and at varied distances from line center. Figures (4) and (5) shows the experimental results of the magnetic flux density recorded at the two selected measuring sites. Figure (4) shows the variation of the magnetic flux density with the distance from line center at 1 m above ground at the two sites. The highest value of the magnetic flux density is also at the line center and is of about 0.12×10^{-4} Wb/m^2 measured near Tanta substation. The magnetic flux density decreases as the distance from line center is increased either to the left or to the right. The magnetic flux density produced by a high-voltage line depends also on the height of the measuring point above the ground level. This is illustrated in Fig. (5), which shows the variation of the magnetic flux density at the line center at different heights above ground. The magnetic flux density increases as the height is increased. The measured values near Tanta substation are higher than those recorded near Talkha substation because of higher current at the former. The magnetic flux density increases from about 0.12×10^{-4} Wb/m^2 to about 0.14×10^{-4} Wb/m^2 as the height of the search coil is increased from 1 m to 3 m above ground.

The magnetic flux density under the high-voltage line has a character differing from that of the electric field. This is observed during all measurements on the oscilloscope and recorded by a photographic camera. Figure (6) shows some reproduced photographs of oscilloscope current traces produced by the magnetic flux density formed under 220 kV line. The amplitude of the current on the oscillo-

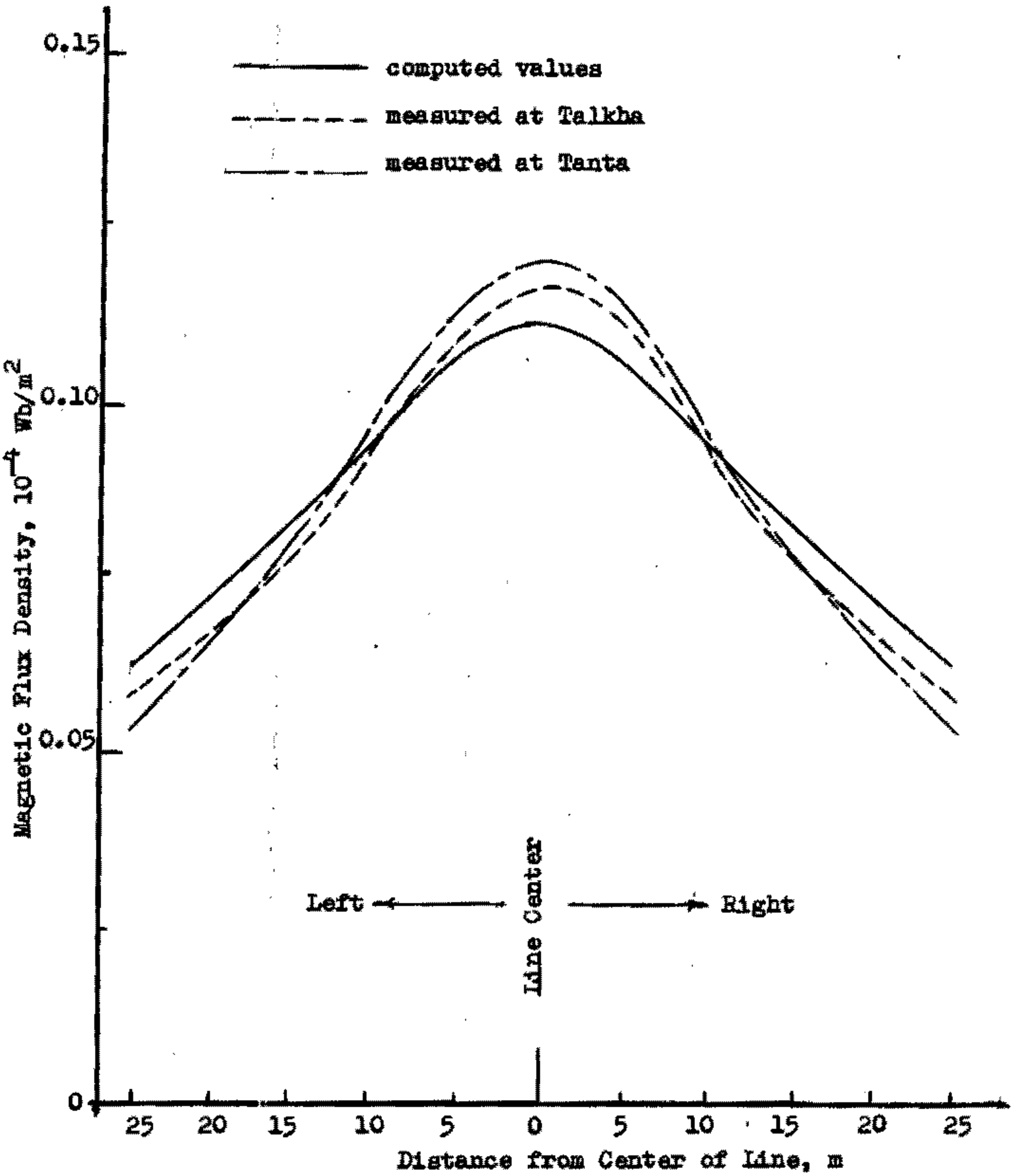


Fig. 4: Computed and measured values of the magnetic flux density under 220 kV overhead transmission line at 1 m above ground against the distance from the center of the line.

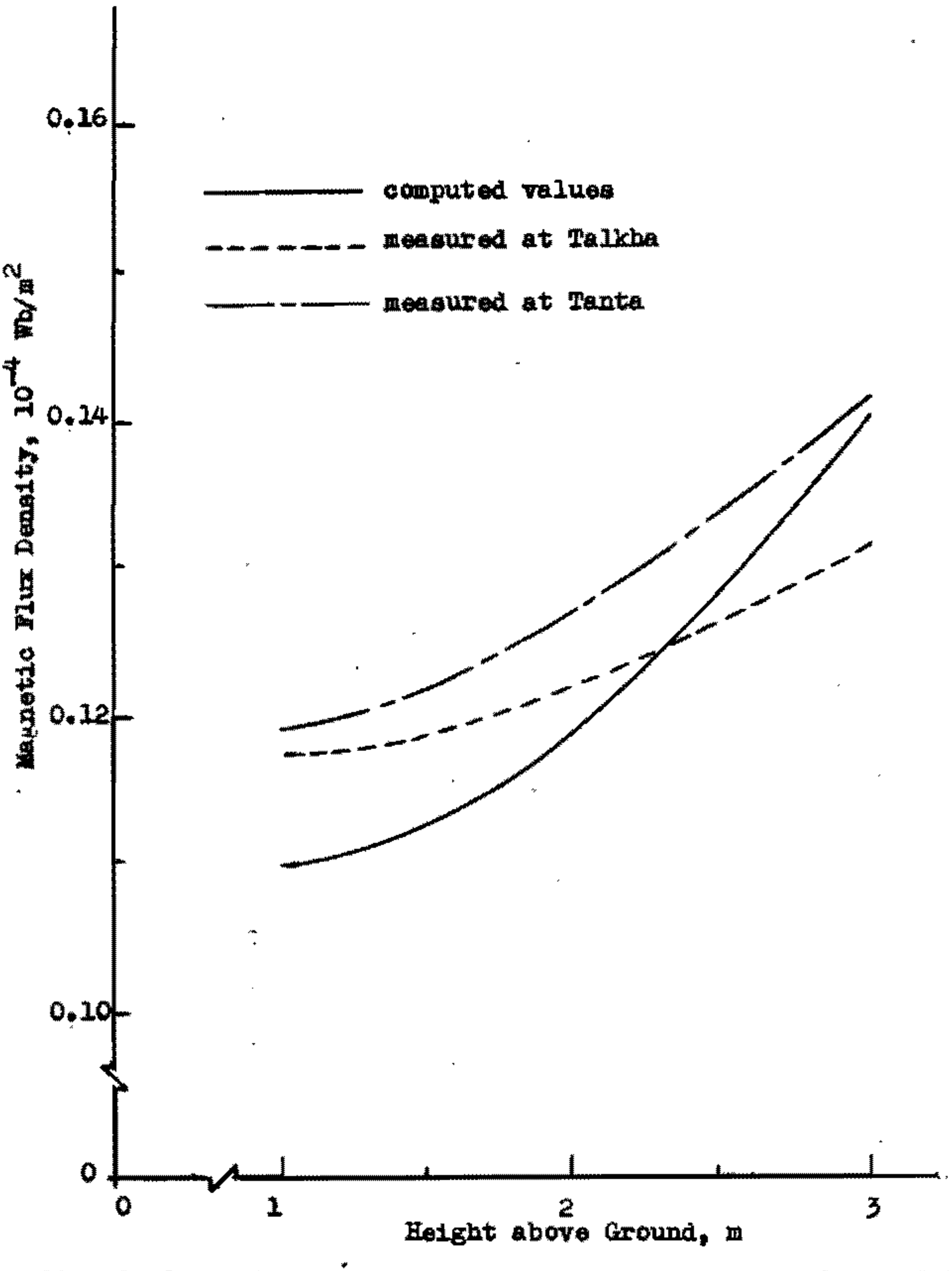
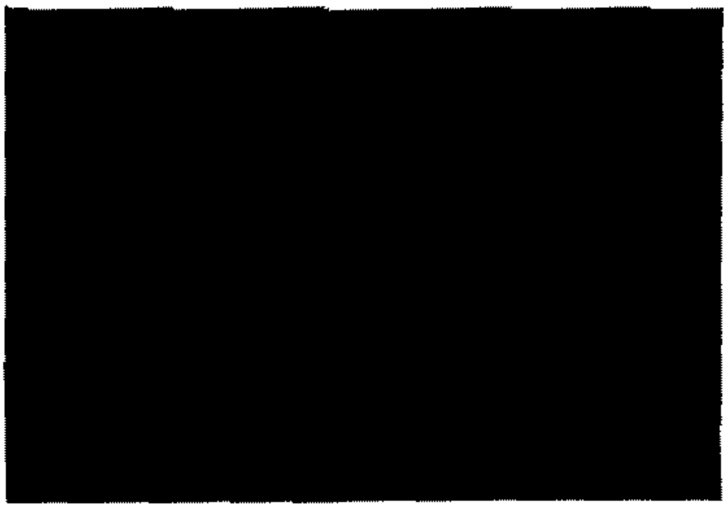


Fig. 5: Comparison between computed and measured values of the magnetic flux density under the center of 220 kV line as a function of the height above ground.



a) Horizontal component of the magnetic field under 220 kV line at 2.2 m above ground.

b) Magnetic field at 1.8 m above ground.

c) The magnetic field under 220 kV transmission line at 1 m above ground.

Fig. 6: Oscilloscope current traces produced by the magnetic field under 220 kV overhead transmission line (0.1 msec., 20 mV/div.).

scope depends on the position of the search coil and its height above ground. The magnetic field produced by high-voltage transmission lines having time-varying currents has a comparatively high longtudinal component parallel to the transmission line. The oscilloscope current trace of this component is shown in Fig. (6, Ph. a). The traces of the magnetic field at different heights are shown by Ph. b and Ph. c in Fig. (6).

Computed Fields:

The computation of the electric and magnetic fields is performed using the moment technique suggested by Spiegel (Ref. 3). This technique depends mainly on the estimation of both the current and charge induced on an object by the electromagnetic field produced by the transmission line by using the image theory and quasi-static approximations. The induced conductor charge can be calculated by Matrix Algebra in terms of the conductor line-to-ground voltage and the coordinates of each conductor and its image and the observation point with respect to the ground level. The electric field is estimated in terms of this charge, while the magnetic field is determined in terms of the conductor currents which are time-varying and produce a time-varying rotating field.

Computations are performed for each observation point under the load conditions mentioned before, namely 210 kV and 300 A. The computer results are also shown in Figures (1), (2), (4) and (5) represented by the solid curves. The computed values of both fields are higher than the corresponding experimental values. The latter can be considered as more accurate than the computed values because of many approximations in the computation technique and neglecting the proximity effect of all surrounding objects and life forms.

CONCLUSIONS:

The electric and magnetic fields under a 220 kV transmission line are measured by means of a new simplified experimental technique at two measuring sites in the area between Talkba and Tanta substations. Measurements are performed at different heights above ground and at varied transverse distances from the line center. The indirect effect of both fields is appeared on the oscilloscope in the form of current traces of amplitude depending on the height above ground. This effect increases as the height above ground is increased at the same transverse distance under the line. The highest value of both fields is obtained under the line center. Some reproduced photographs of the oscilloscope current traces formed by both fields are given and illustrating that the amplitude and frequency of them depend on both the height above ground and the transverse distance from line center. The two fields are also computed using the moment technique and found to be higher than the corresponding experimental values due to both the approximation in this technique and neglecting the proximity effect of the surrounding objects and life forms near the high-voltage line.

REFERENCES:

(1) W. Hadrian und H. Hofschneider, "Die Messung transienter magnetischer Fielder von Hochspannungsfreileitungen", Elektrie 34, H. 10, S. 540-543, 1980

(2) T. Takashima and R. Ishibashi, "Electric Fields in dielectric Multi-Layers calculated by Digital Computer", IEEE Trans., Vol. EI-13, no. 1, pp. 37-44, 1978

(3) R. J. Spiegel, "Electromagnetic Fields in the near Vicinity of Transmission Line Towers", IEEE Trans., Vol. PAS-95, no. 6, pp. 1863-1871, 1976

(4) D. W. Deno, "Transmission Line Fields", IEEE Trans., Vol. PAS-95, no. 5, pp. 1600-1611, 1976

(5) T. D. Bracken, "Field Measurements and Calculations of Electrostatic Effects of overhead Transmission Lines", IEEE Trans., Vol. PAS-95, no. 2, pp. 494-504, 1976

(6) T. M. McCauley, "EHV and UHV electrostatic Effects: simplified Design Calculations and preventive Measures", IEEE Trans., Vol. PAS-94, no. 6, pp. 2057-2065, 1975

(7) D. W. Deno, "Electrostatic Effect Induction Formulae", IEEE Trans., vol. PAS-94, no. 5, pp. 1524-1536, 1975

(8) D. W. Deno, "Calculating Electrostatic Effects of overhead Transmission Lines", Paper T74-086-5 presented at IEEE PAS Winter Meeting, New York N. Y. January 27-February 1, pp. 1458-1471, 1974

(9) Working Group on Electrostatic Effects of Overhead Transmission Lines, Parts I and II, IEEE Trans., vol. PAS-91, no. 2, pp. 422-444, 1972