Field Measurements and Calculations of 220 KV Overhead Transmission Line.

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OF 220 KV OVERHEAD TRANSMISSION LINE

By

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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

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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 connec-
tions. 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 diffe-
rent 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 pre-
pared 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-vol-
tage 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 ca-
librated 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 consi-
dered to have a uniformly distributed electric field,
neglecting the end effect.

Calibration is also carried out for the magnetic mea-
suring 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
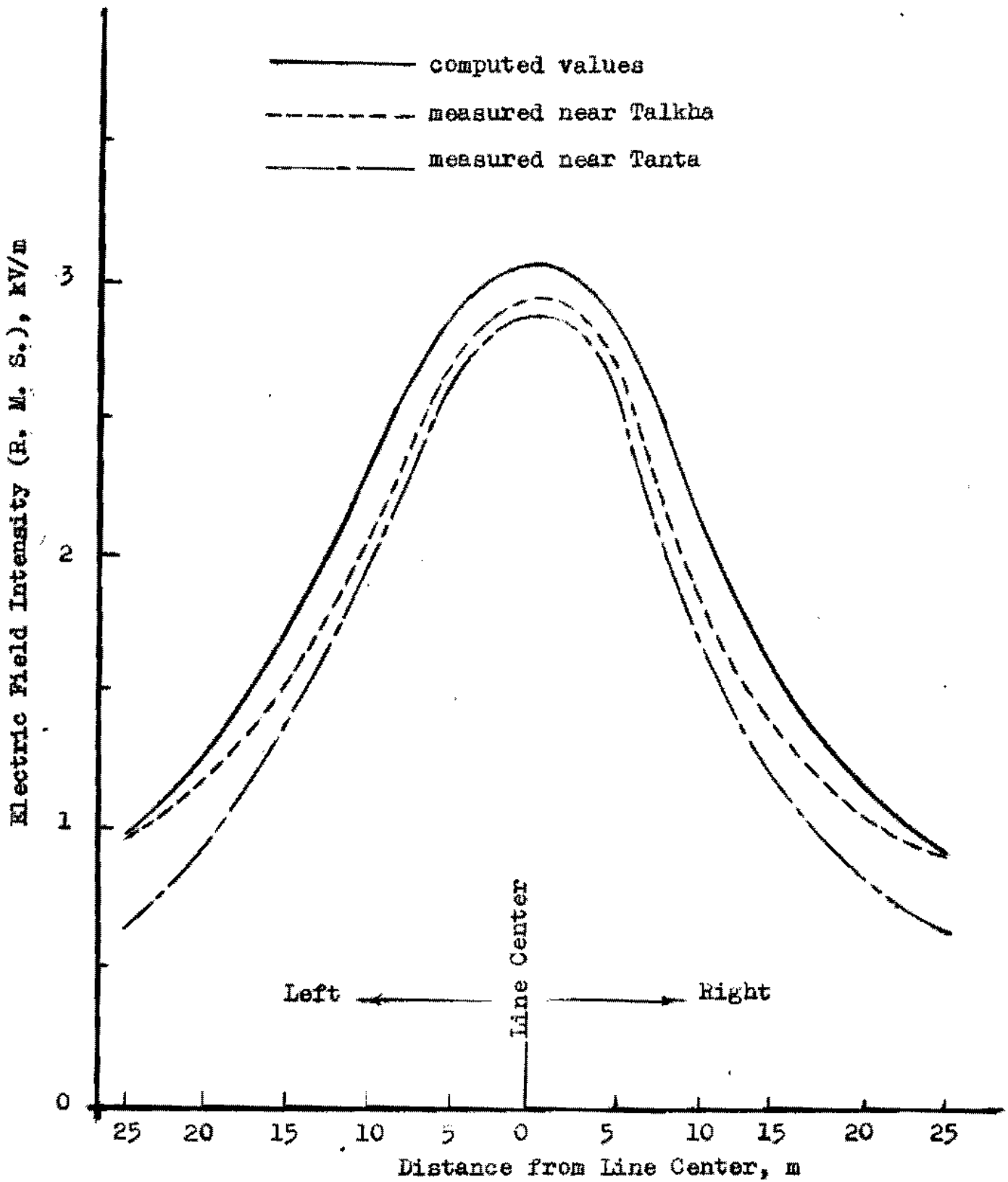
Fig. 1: Computed and measured values of electric field under 220 kV
overhead transmission line at 1 m above ground against   the
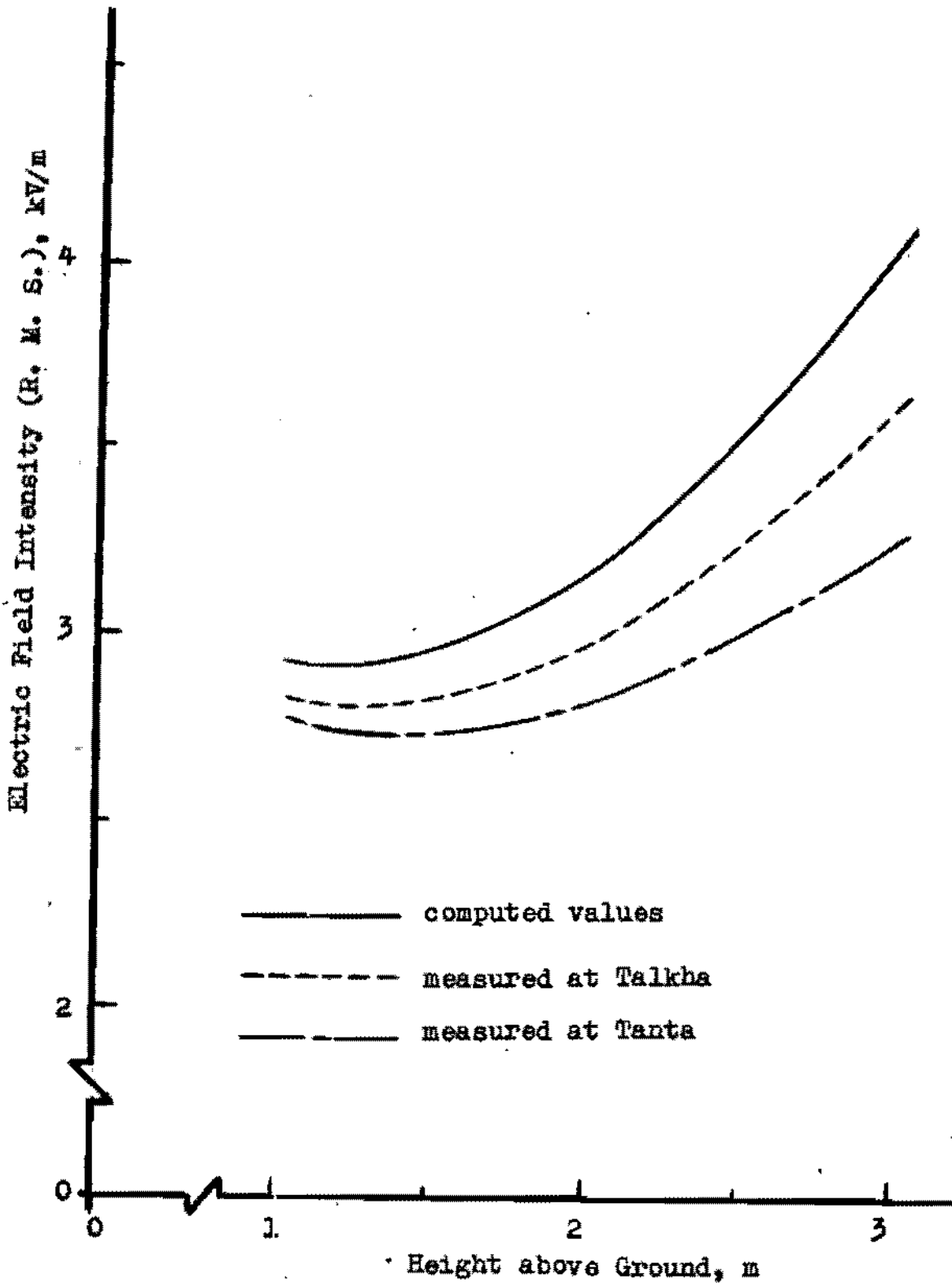distance from the center of the line.

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 rea-
dings. 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 af-
fected. 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 trans-
mission line can be briefly explained as follows. If the
currents of the conductors are A. C., a time-dependent ma-
gnetic 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.
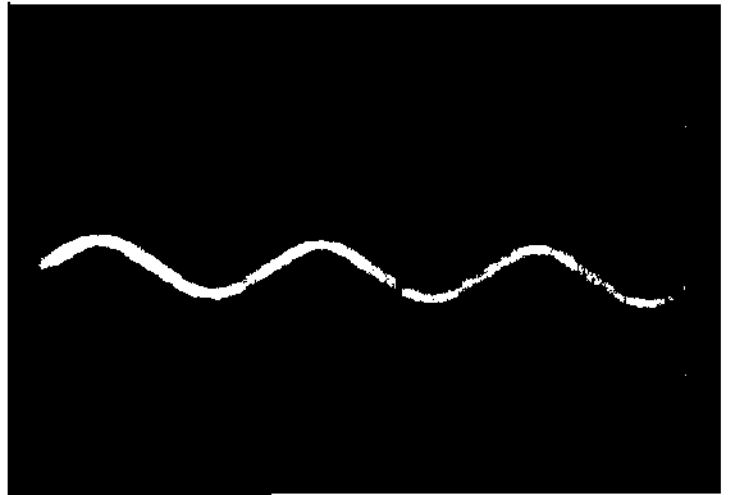
b) Vertical component of
electric field under
220 kV line at 1 m above
ground.
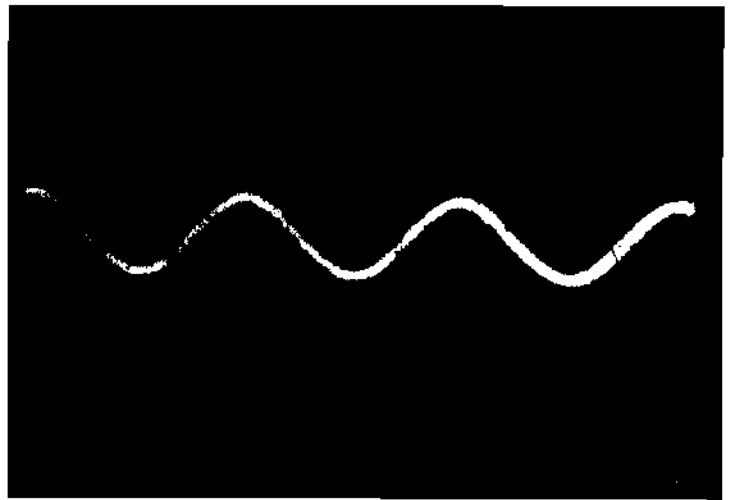
c) Horizontal component of
electric field under 220
kV line at 2.4 m above
ground.

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 varia-
tion 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 pro-
portional 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 dis-
tances from line center. Figures (4) and (5) shows the ex-
perimental 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 pro-
duced by a high-voltage line depends also on the height of
the measuring point above the ground level. This is illu-
strated in Fig. (5), which shows the variation of the mag-
netic 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 sub-
station are higher than those recorded near Talkha substa-
tion 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 oscillo-
scope 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-

Magnetic Flux Density, 10^{-4} Wb/m^2

0.15 ——————— computed values

———·——— measured at Talkha

———·——— measured at Tanta

0.10

0.05

Left ◄———— Line Center ————► Right

0

25   20   15   10   5   0   5   10   15   20   25

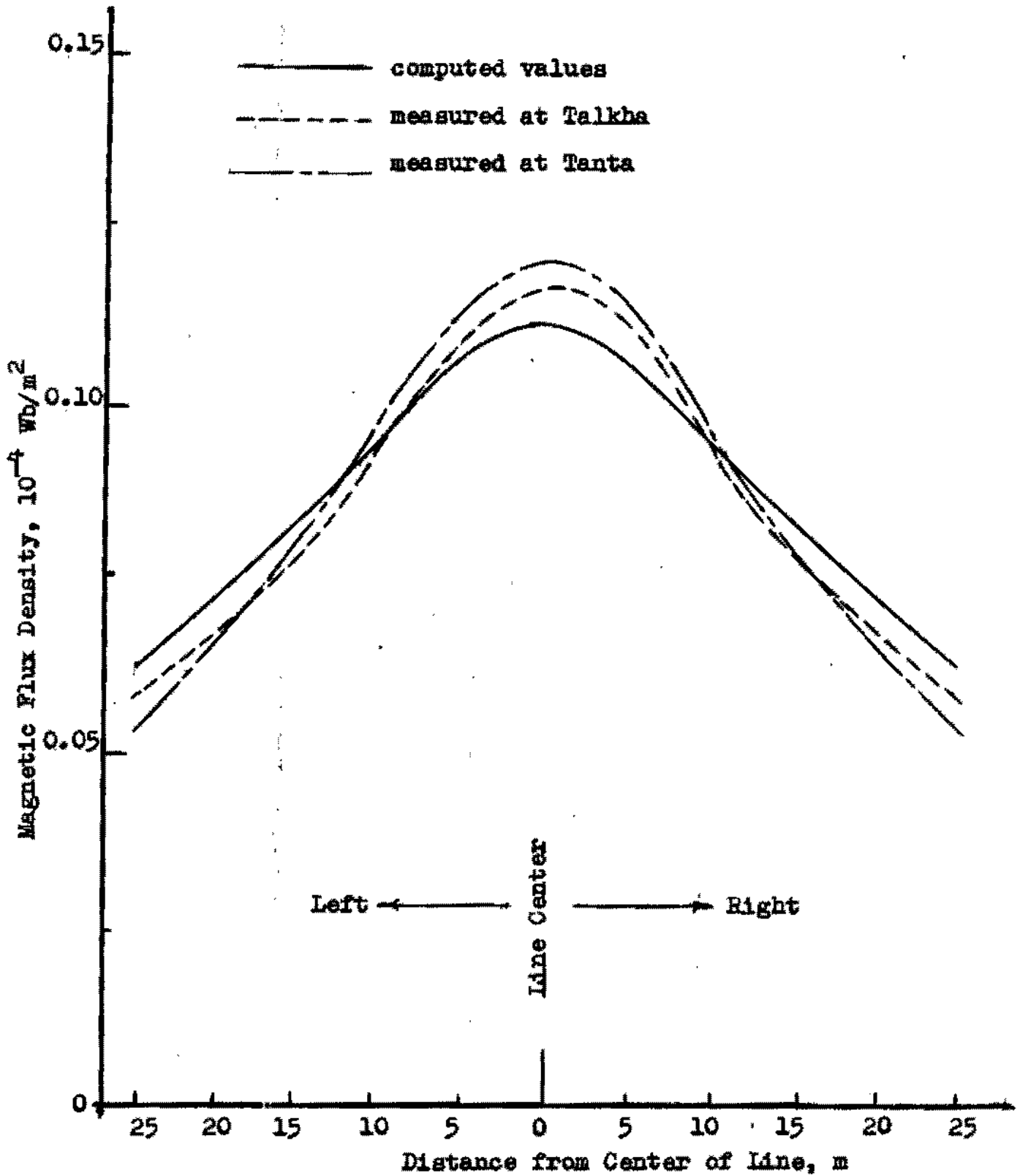Distance from Center of Line, m

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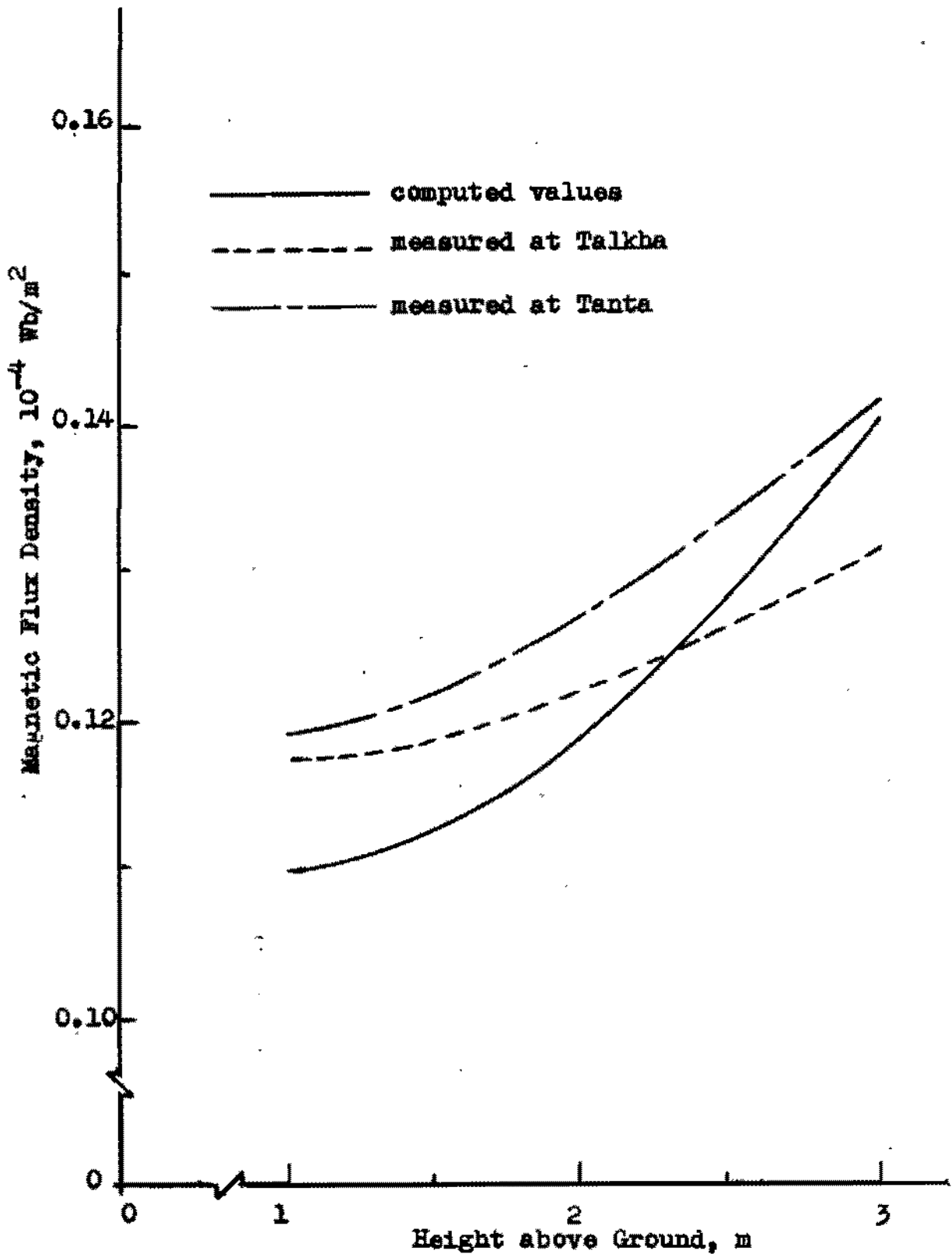against the distance from the center of the line.

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 corre-
sponding 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 trans-
mission line are measured by means of a new simplified
experimental technique at two measuring sites in the area

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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.

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