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Magnetic Fields Measurement and Evaluation of EHV Transmission Lines in Saudi Arabia

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ABSTRACT

Transmission lines are considered one of the major sources of magnetic field. In recent years great public concern has arisen because of reports on adverse health effects due to Magnetic fields. The rapid increase of electric energy utilization and ascending geographical growth in the Gulf Cooperation Council (GCC) region led to the reality that utilities need to upgrade and develop existing and new transmission and distribution lines which resulted in the transmission lines to become inside the urban areas.

This project is directed to measure magnetic field on existing lines in the Eastern Province of Saudi Arabia. This real measurement have been compared with simulation results and also used to provide a validation of using the simulation software package for design purposes.

Transmission lines towers and conductors models are developed from given electrical and geometrical data and used to compute the magnetic fields under, within the right-of-way (ROW) and outside the ROW. Analysis and comparison of measured and simulated fields are used to verify the transmission line model and identify the important magnetic sources and location.

The 380 and 230 kV transmission lines designs are selected and studied in terms of their measurement and simulated fields. This project is to accumulate and evaluate the EMF data from these transmission lines, and also to introduce and suggests new data for the EHV lines in the GCC utilities that can be utilized during any future expansion to these utilities.

KEYWORDS

Real Electromagnetic Field Measurements, Extra High Voltage Lines, EMF Evaluation, Transmission Lines Configuration, GCC Electrical Utilities.

INTRODUCTION

Electrical power came into use many years before environmental impacts were common, and today our domestic power lines are taken for granted and generally assumed to be harmless. However, this assumption has never been adequately tested. Low-level harmful effects could be missed, yet they might be important for the population as a whole since electric lines are ubiquitous. The environmental effects of electric fields have been studied since the early

1970 s,' but the effects of magnetic fields gained publicity only during the last few years because of the several epidemiological studies. There is no doubt, however, that many people are concerned about the magnetic field effects of power frequency electric current associated with AC Transmission Power Lines [1-8]. While health studies related to the magnetic field management are in progress, it appears desirable to conduct parallel technical studies related to the magnetic field management that serve as a guideline to the utilities in practical implementation [8-12].

The question of weather proximity to high-current power lines might promote cancer-raised more than decades ago by epidemiologist, who said electromagnetic fields from power lines may be a public health hazard and that electric utilities have tried to cover this up.

Electric and magnetic fields are fields of force created by electric voltage and current. Such fields occur in nature, but these are direct current fields whereas power lines and household appliances produce alternating current fields. Interest in potential health effects has focused on these AC fields, and on magnetic fields in particular. Power lines give off both electric fields measured in volts per meter, and magnetic fields measured in milligauss. Stronger current produce stronger magnetic fields both electric fields and magnetic fields decrease with distance.

This investigation was carried out in 1998-1999 in the eastern province of Saudi Arabia high voltage transmission lines. Actual measurement of the magnetic and electric fields on the 230 and 380 KV lines has been done mainly; to have a record of these fields under different current loading, to be used a spot on the results of the computer software package that computes the strength of magnetic fields of such line, and to investigate and evaluate the EMF produced by these lines on the near by objects and humans.

Actual measurement becomes an asset to show and demonstrate to the people who live near by power lines and take off their concern. Also, it can determine where the higher magnetic fields are and using computer simulations of tower configurations to find out ways to reduce magnetic fields. It is known that electric fields can be shielded but it is difficult to shield magnetic fields because they cut through dirt, metal and other non-magnetized material [8].

It is also aimed to develop and initiate a broad database and study of the environmental impact of such lines as the population and cities boundaries growth will make such lines within the urban places. Also, to assist in introducing new designs which reduce the magnetic fields in the planning and construction of new grids all over the GCC countries.

Saudi Arabia is one of the developed countries with high electrical power system growth and increase in population. The huge expansion of transmission system raised the concern of this subject. Different line construction standards were used in the existing transmission systems in Saudi Arabia. Attempts have been made to study EMF of the existing system as well as to introduce some options of management techniques for the most popular (EHV) Transmission Voltage Levels of 230 kV and 380 kV and this is another reason for this investigation.

BACKGROUND

A. Social Reverberation to Magnetic Field Effects

In Australia, farmers in the rural community of Oberon, for example managed to stop a proposed transmission line from passing through their land because they believe it will reduce livestock production and crop yields. Aside from litigation costs, the Electricity Commission of New South Wales has already spent millions of dollars on a new power station for the line. [7]

In the United States, Florida has been a major Electric and Magnetic Field (EMF) battleground. It is one of seven states to set magnetic and electric field limits that apply in, or at the edge of, the right-of-way of new transmission lines. It became the first state to add magnetic field limits ranging from 15 (mT) for lines 230 kV and lower to 20 mT for new 500 kV lines. New-York State is close to setting an interim limit of mT for new transmission lines. Initially, electric fields were the prime concern, but recent research has changed the focus to magnetic fields. Florida's new limits are based on what existing technology can meet, not on health data, according to Buck Oven of Florida's Department of Environmental Regulation Some countries have already adopted national electric and magnetic field exposure standards for extremely low frequency (ELF) fields. The Soviet Union and the United Kingdom derived national magnetic field limits from World Health Organization guidelines drawn up in 1984. In January 1990, the International Radiation Protection Association (IRPA) issued interim standards based on those guidelines. Australia adopted them, and is drafting standards derived from IRPA limits. [8]

The fact that evidence exists suggesting enough of a potential health problem means finding low cost to reduce the field level. On the other hand, until it is established that of magnetic fields cause adverse health effects trying costly field management techniques will not be taken seriously.

The calculation and measurement of electromagnetic fields around transmission and distribution lines has long been understood and practiced by electrical engineers. Such fields are relatively uniform; the ordinary laws of Physics allow reasonably accurate predictions of their strengths and variations. EPRI have spent Millions of dollars in studies & investigation of the possibility of human health effects from exposure electric and magnetic fields (EMF).

Electric and magnetic fields are produced in different degrees by all electrical carrying devices & lines. The strength of these fields varies. The electric field is strongest around high voltage transmission lines, i.e., those line usually supported on steel towers that carry electric power. The magnetic field on the other hand is related to the current being carried and may be higher close to household appliances than near transmission lines. Figure (1) depicted the Magnetic fields sources in perspective. It is clear from the figure that the home appliances constitute the higher mG at short distance as well as the exposure. The effect of transmission EMF from its source is considered high and exposure is common.

PROJECT OBJECTIVES

The investigation is focused on conducting actual measurement of the magnetic field of the existing EHV lines in Saudi Arabia. The validation of the agreement of the measured magnetic field to that obtained by simulation is another important investigation phase. This validation is very important because the management of magnetic fields and the use of mitigation options are dependent on simulation.

The main objectives of this investigation is to conduct detailed measurement of magnetic field for the extra high voltage transmission lines 230 & 380 kV levels in the eastern region of Saudi Arabia, to investigate the magnetic field measured levels as compared to standards, and to compare and analyze measured and simulated fields values, to develop Magnetic field models for the transmission line configuration and geometrical data to compute magnetic fields under and around such lines and to initiate a database of real and simulated measurements for use of GCC utilities.

MAGNETIC FIELDS MEASUREMENT

A. Measurement Procedures

The EMDEX II is a programmable data-acquisition meter, which measures the three orthogonal vector components of the magnetic field through its internal sensors; and, through the use of an optional external sensor, the magnitude of the equivalent electric field is measured. Measurements are stored in the meter's memory and later transferred through a serial communications port to an IBM-compatible Personal Computer (PC for storage, display, and analysis).

Alternating current (AC) magnetic field strength (actually the flux density) is determined by measuring the currents induced in three sensor coils mounted orthogonally along the x, y, and z-axes.

All measurements were taken in an area that can be considered as flat area at a height of one meter above the ground. Measurements of magnetic field were made every specific interval depending on the configuration and the area available. An attempt was made to measure the ground level magnetic field on both sides of the transmission lines. However, such access was not always available. An attempt was made also to select flat area as much as possible. However, some of the measurements were taken over higher ground level, which is considered one of the measurement errors.

A spot measurement, also referred to as a point-in-time measurement, is a measurement that is performed at some instant and does not provide information regarding the temporal or spatial variations of magnetic field. Spot measurements of magnetic field under transmission line represent "snapshot" in the time of field levels and will depend on such things as load in the line, transmission line height and line configuration. [8,10]

Either using cable height meter or telescopic Hot Sticks were used to measure conductor heights. All load conditions were collected from the Power Control Center (PCC) with maximum accuracy as physically possible. In some of the conditions and while doing the measurement, the load was changed due to switching in the system, at that point the data was cancelled and collected again.

B. Line Configurations Included In The Measurement

In Saudi Arabia, many line configurations are installed for different voltage levels. The highest voltage level is 380 kV. For the field measurement, some of these configurations were included in the investigation are as follows:

Case 1: 230 kV Double Circuit Delta Configuration.

This design, shown in Figure 4.1, is a typical Lattice-type structure for most of 230 kV lines that are used in Saudi Arabia. The measured data for this case is tabulated in Table 4.1. The measurement data were collected in relatively flat area with some sand dunes of about 1 m height. The phasing arrangement was confirmed from the substation side. The conductor used is 795 mm^2 bundled with two conductors with spacing of 18 inches, which is the standard conductor for 230 kV lines in SCECO-EAST.

Case 2: 380 kV Single Circuit Horizontal Configuration.

This line is passing in desert area with very high sand dunes. This design, shown in Figure 4.2, is a typical Lattice-type structure for the existing 380 kV single circuit lines in Saudi Arabia. The measured data for this case is tabulated in Table 4.2. The measurement data were collected from one side of the line because of the high sand dunes in the other side. The conductor used is 1080 mm^2 bundled of four conductors with a spacing of 18 inches, which is the standard conductor for all 380 kV lines in Saudi Arabia.

Case 3: 380 kV Double Circuit Vertical Configuration.

This line is passing in relatively flat area. This design, shown in Figure 4.3, is a typical Lattice-type structure for 380 kV double circuit lines in Saudi Arabia. The measured data for this case is tabulated in Table 4.3. The phasing arrangement was confirmed from the substation side. This phasing arrangement is common for all 380 kV lines in SCECO-EAST.

Case 4: Case 2 and Case 3 passing in the same corridor.

Those lines are passing in relatively flat area. As shown in Figure 4.4, it is a combination of 380 kV single-circuit with 380 kV double-circuit lines. The measured data for this case is tabulated in Table 4.4. The phasing arrangement was confirmed from the substation side.

Case 5: Two 230 kV Double Circuit Delta Config. passing in the same corridor.

Those lines are passing in desert area with very high sand dunes. As shown in Figure 4.5, it is a combination of two 230 kV double-circuit delta configuration lines. The measured data for this case is tabulated in Table 4.5. Rough road, which is crossing under the lines, was utilized for the measurement. Sand dunes under the lines were the only obstacle for measuring the magnetic field along the span. The phasing arrangement was also confirmed from the substation side.

Case 6: Case 1 and Case 2 passing in the same corridor.

Those lines are passing in relatively flat area. As shown in Figure 4.6, it is a combination of 380 kV single circuit flat configuration and 230 kV double circuit delta configuration lines. The measured data for this case is tabulated in Table 4.6. Rough road, which is crossing under the lines, was utilized for the measurement. Sand dunes under the lines were the only obstacle for measuring the magnetic field along the span. The phasing arrangement was also confirmed from the substation side.

ANALYSIS AND EVALUATION

Different existing 230 & 380 kV configurations were included in the actual measurement of the magnetic fields. The measurement data for all of the configurations indicate that the magnetic field is decreasing as the distance from the line to the measuring point is increasing. This can prove that there is an inverse proportionality between the magnetic field and the distance between the conductors and the measuring points. The maximum magnetic field was obtained at the minimum conductor clearance point, which is at mid span in most of the measured data.

The measurement data shows also that the maximum magnetic field for 230 kV double circuit delta designs were in range of 20 mG. The minimum conductor clearance points for both circuits were about in the same range. The load transfer for the 230 kV line was about four times the load on lower voltage level line at the measurement time. This can prove that increasing the voltage level and optimizing the phasing arrangement have great affect on the magnetic field. Converting the existing lines to higher operating voltage will reduce phase current and will cause a proportional reduction in magnetic field.

The comparison between the magnetic field produced by 380 kV single circuit flat design and 380 kV double circuit design shows that single circuit flat design was providing higher magnetic field with higher ground clearance. This can prove that double circuit vertical design can provide lower magnetic field with higher power transfer. Utilizing double circuit vertical structure for single circuit flat design by splitting the circuit can be used as one of the approaches to reduce the magnetic field.

The current has great effect on the maximum magnetic field. There is direct relation between the magnetic field and the current in the circuit. This can be seen clearly from the comparison for the magnetic field of line measured in case 6. The maximum magnetic field under the line in case 2 was much higher that the maximum magnetic field under the same line in case 6 even with higher ground clearance in case 2. Reducing the current in the circuit can be used as one of the options for reducing the magnetic field. In practice, current in the circuit cannot be fully controlled as it varies with the load flow.

CONCLUSIONS AND SUGGESTIONS

In this investigation one of the major sources of magnetic field, which is the EHV Transmission Lines, has been considered. Magnetic field simulation package has been used to quantify the field values resulting from the Transmission Lines. Magnetic fields for different existing configurations in Saudi Arabia was measured and compared with the simulated results. Some of the existing line configurations in Saudi Arabia have been modeled and simulated, as well as other configurations were introduced. The selection of the line design for the new lines should be based on which configuration offers the most economy and still meets the necessary requirements. The design selected should not jeopardize the reliability nor downgrade the operating characteristics of the system.

Simulation studies using different tower configurations, which are not in use at the time of measurement showed that some new tower configuration designs can drastically reduce magnetic field, namely standard cruciform design in 230 kV as seen in table 4.7. When the same simulation was done on the existing tower configurations, the results showed that standard vertical design #1 in table 4.8 had less magnetic field measured.

For 230 kV Lines, compact diamond design can provide the lowest magnetic field over all single circuit designs mentioned. The usage of 230 kV double circuit compact vertical design gives the excellent positive sequence current magnetic field reduction with some maintenance constraints. The phasing arrangement is playing major role in magnetic field management. For 380 kV Lines, compact diamond design can provide the lowest magnetic field over all designs mentioned. Diamond conductor arrangement is always providing the lowest magnetic field values comparing with the same line design with different conductor arrangement.

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TABLE 4.1: MAGNETIC FIELD (MG) MEASUREMENT FOR CASE 1

SP*	**DISTANCE (FEET) FROM CENTER OF THE STRUCTURE**												
	95	**75**	**65**	**50**	**25**	**15**	**0**	**-15**	**-25**	**-50**	**-65**	**-75**	**-95**
0	5.72	6.96	8.4	9.88	11.2	11.2	11.2	10.8	9.8	8.6	7.28	6.16	5.2
33	5.4	6.84	8.04	9.84	10.8	10.4	10.4	10.4	9.92	8.44	7	5.76	5.8
66	6.2	7.4	8.84	10.4	11.6	12	12	11.6	10.8	9.2	7.44	6.12	5
100	6.28	7.96	10	12.4	14	14.4	13.6	12.4	11.2	9.6	7.72	6.32	5.12
133	6.4	8.29	10	12.8	14.4	15.2	14.8	14.4	12.8	10.8	8.8	6.96	5.6
166	8.58	10.8	13.6	16.8	18.4	17.6	17.2	16.4	14.4	12	9.68	7.4	6
200	7.26	9.12	12.4	16	19.2	18.4	18.4	18	16.4	12.8	10.4	8.12	6.52
233	6.96	8.92	11.6	16.8	20.8	19.6	19.2	20	17.2	14	10.8	8.52	6.68
266	8.88	11.2	15.2	19.6	24.4	21.6	22.8	22.4	19.6	15.6	12.4	9.6	7.72
300	8.44	10.4	13.6	18.8	25.6	26	26.4	24.8	21.6	17.2	13.2	10.4	8.12
333	8.49	11.6	16	20	26	26.8	27.2	26	21.2	16.4	12.4	9.52	7
366	7.32	9.44	12.8	17.6	26	27.2	27.6	28	24.4	18	13.2	9.44	7.4
400	8.04	10.4	13.6	18.8	26	28.8	29.2	28	26.4	20	14.4	10.8	8.12
433	6.88	8.68	11.6	16	22.4	27.2	28.8	28	24.8	19.6	14.4	10.8	8.2
466	8.04	10.4	14	18.8	24.4	25.2	27.2	27.6	24.4	18	13.2	9.8	7.52
500	7.08	9.26	13.2	18	25.2	22.4	24.4	26	22	16	12.8	9.76	7.8
533	8.02	10.4	13.6	18.4	24	21.6	22.8	22.8	18.4	14.4	11.2	8.48	6.6
566	7.29	9.36	12	16	20	20	21.2	20.4	17.6	14.8	11.2	8.4	6.68
600	7.8	9.84	12.8	16.4	20	19.6	19.6	19.2	18.8	14	10.4	7.92	6.2
633	6.84	8.84	11.6	18.6	18.4	19.2	18.8	18	16.4	12.8	10	7.64	5.88
666	6.84	8.68	11.6	14.4	17.2	18.4	18.4	19.2	17.2	14.4	11.2	8.52	6.6
700	6.04	7.44	9.4	12	14.8	16.8	16.4	16.8	16	13.6	10.8	8.52	6.8
733	7.48	9.2	11.2	13.6	15.2	15.6	15.6	15.6	14.4	12.8	10	8.8	6.4
766	6.84	8	10	12.4	14.9	14.8	14.4	14.8	14	12	9.72	7.8	6.28
800	7	8.52	10.8	12.2	14	15.6	14	14	13.2	11.2	9.1	7.24	5.84

SP* Distance along the span in feet

TABLE 4.2: MAGNETIC FIELD (MG) MEASUREMENT FOR CASE 2

C**	**DISTANCE ALONG THE SPAN (FEET)**																	
	0	**100**	**200**	**300**	**333**	**400**	**500**	**533**	**600**	**700**	**800**	**900**	**933**	**1000**	**1100**	**1200**	**1300**	**1400**
-40	31.6	32.8	44.8	51.6	54.8	60.4	73.2	74.4	85.6	84.6	78.8	70	68.4	60.4	48.4	38	31.2	28.8
0	36	39.2	55.6	61.6	65.8	73.2	85.6	95.3	104	108	97.2	87.2	86.4	72.4	56.2	44.4	34.8	29.2
40	34.8	35.6	51.2	42.1	56.8	64.4	74.8	85.2	91.6	92.4	85.6	79.2	73.6	64.4	52.8	42.4	34	30
75	28.8	32	34.4	50.8	37.6	40	63.2	48.8	53.6	79.2	51.6	66	48.4	44.8	47.6	32.4	30.4	25.2
110	21.2	23.2	21.6	31.6	22.4	22.4	36	26.4	28.8	42.8	28.2	38.8	29.6	26.8	31	23.8	24.4	20.4
145	15.6	16.4	15.2	18.8	14.4	14.4	20.4	16.4	18	24	18.4	23.2	18.4	17.6	21.6	16.4	18.4	15.6
180	12	11.6	10.8	12.8	10.4	10	13.2	11.6	12.4	15.6	12.8	15.6	12.6	12.4	15.2	12.4	14	12

C** Distance from center of measurement in feet

TABLE 4.3: MAGNETIC FIELD MEASUREMENT FOR CASE 3

C**	DISTACE ALONG THE SPAN (FFET)									
	0	**130**	**260**	**390**	**520**	**650**	**780**	**910**	**1040**	**1170**
-190	2.08	1.88	2.12	2.44	2.2	2.6	2.36	2.24	2.2	2.12
-155	3.2	2.8	3.28	3.84	3.4	4.14	3.6	3.4	3.44	3.12
-120	4.76	4.48	5.56	6.24	5.76	7.08	5.84	5.8	5.68	4.72
-90	7.72	7.44	4.48	10.8	10	12.4	10	10	9.72	7.12
-55	11.2	12	16.8	19.2	18.4	23.2	18	18.4	15.2	10.4
-25	12.8	9.6	28.8	35.6	41.2	42	38.8	30.4	20	11.6
0	10.8	22.4	32.2	40.4	48.4	49.2	43.6	34.8	21.6	11.2
25	13.6	24.8	30	37.6	43.2	43.6	37.6	31.6	20	12.4
55	12	15.2	20	24	27.2	26.4	24	20.4	14.4	10.4
80	8.28	9.72	12	13.6	14.8	14.4	13.2	12	9.26	7.64
110	5.44	6.2	7.24	8.04	8.68	8.68	8.04	7.04	6.08	5.2
145	3.84	4.04	4.46	4.88	8.28	5.24	5	4.44	4.2	3.76
175	2.52	2.68	3	3.24	3.44	3.4	3.24	2.92	2.88	2.6

C** Distance from center of measurement in feet

TABLE 4.4: MAGNETIC FIELD (MG) MEASUREMENT FOR CASE 4

C**	DISTANCE ALONG THE SPAN (FEET)																
	65	**130**	**195**	**260**	**325**	**390**	**455**	**520**	**585**	**650**	**715**	**780**	**845**	**910**	**975**	**1040**	**1105**
480	2.04	2.04	2	2.16	2.12	2.36	2.28	2.84	2.8	3.16	2.76	2.6	6.56	5.84	5.4	5.32	5.72
400	3.92	3.84	4.04	4.56	4.56	4.92	5	6.56	6.4	7.12	5.76	15.6	14.4	12	11.4	10	9.88
310	5.48	6.52	7.52	8.88	9.76	11.2	12.4	15.2	16.4	16.8	14.8	30	26.8	22	19.6	17.2	12.8
270	5.48	7.14	8.44	10	11.2	11.2	14.4	18.4	20.4	19.2	17.2	30.8	28	22.4	19.2	16.8	12
225	5.32	6.76	7.6	7.92	9.88	11.6	12.8	16.1	17.2	16.4	14.8	27.6	24.8	20	17.2	14.4	11.2
100	3.8	3.64	4	3.92	4.76	4.4	5.8	5.16	7.32	5.76	6.48	11.6	6.28	8.16	7.32	6.6	5
0	5.2	6.2	6.32	8.96	8.32	11.2	8.2	13.6	9.48	13.2	8.32	5.36	5.88	4.8	4.8	3.92	3.64
-100	11.2	13.6	16	20	24	28	32.4	33.2	34.3	32.8	29.6	13.6	12.4	7.48	8.44	7.62	6.16
-125	12.4	15.2	18.4	22.4	27.2	32	36.8	38	39.2	38	34	15.6	14.4	10.8	9.44	8.6	4.4
-150	13.2	16	18.8	22.4	26.8	30.8	35.2	36.4	38	36.8	32.8	13.2	12.4	9.48	8.44	7.8	4.6
-205	9.76	9.2	11.6	12.4	15.2	15.2	17.6	16.8	18	18.4	18	6.08	4.92	5.66	5.16	4.52	4.2
-270	5.24	4.88	6.04	6.04	7	6.56	7.72	7.16	7.92	7.6	8.04	2.76	2.44	2.6	2.68	2.44	2.44

C** Distance from center of measurement in feet

TABLE 4.5: Magnetic Field (mG) Measurement for Case 5

DISTANCE ALONG THE MID SPAN (FEET)	B MEASURED (mG)
-235	3.44
-215	2.36
-195	2
-180	2.24
-160	1.1
-140	0.94
-120	0.61
-100	0.63
-80	0.52
-60	0.68
-40	1.28
-20	1.56
0	1.88
20	1.88
40	2
60	2.2
80	2.76
100	3.44
120	4.52
140	5.88
160	7.88
180	11.2
200	14.4
220	19.2
240	20.4
260	20
280	16.4

TABLE 4.6: MAGNETIC FIELD (MG) MEASUREMENT FOR CASE 6

DISTANCE ALONG THE MID SPAN (FEET)	B MEASURED (mG)
-235	7.84
-215	14
-200	24.8
-180	26.4
-160	23.6

-145	23.1
-125	20.4
-105	17.6
-90	14.6
-75	14.6
-55	13.8
-40	13.8
-25	14.6
-10	16.2
0	17
10	18.6
25	21.8
40	26.6
55	32.6
75	44
90	54
105	66
125	80
165	88
205	73.2
220	63.2
235	51.2
250	42.4
270	33.6
285	27.6

TABLE 4.7: MAGNETIC FIELD AT DIFFERENT DISTANCES FROM THE 230 KV LINE AXES

TYPE OF DESIGN	**MAGNETIC FIELD AT THE DISTANCE FROM 'THE LINE AXIS (FEET)**					
	0	**50**	**100**	**200**	**400**	**600**
Standard Flat Design	54.795	39.304	19.913	6.461	1.734	0.781
Standard Vertical Design	25.383	16.03	8.732	3.27	0.962	0.446
Standard Delta Design	18.464	12.576	6.42	2.171	0.595	0.269
Standard Cruciform Design	9.059	5.702	2.348	0.505	0.075	0.023

TABLE 4.8: MAGNETIC FIELD AT DIFFERENT DISTANCES FROM THE 380 KV LINE AXES

TYPE OF DESIGN	MAGNETIC FIELD AT THE DISTANCE FROM 'THE LINE AXIS (FEET)					
	0	**50**	**100**	**200**	**400**	**600**
Standard Vertical Design #1	24.11	13.077	4.786	.337	.15	.046
Standard Flat Design	111.87	88.93	39.331	10.962	2.787	1.242

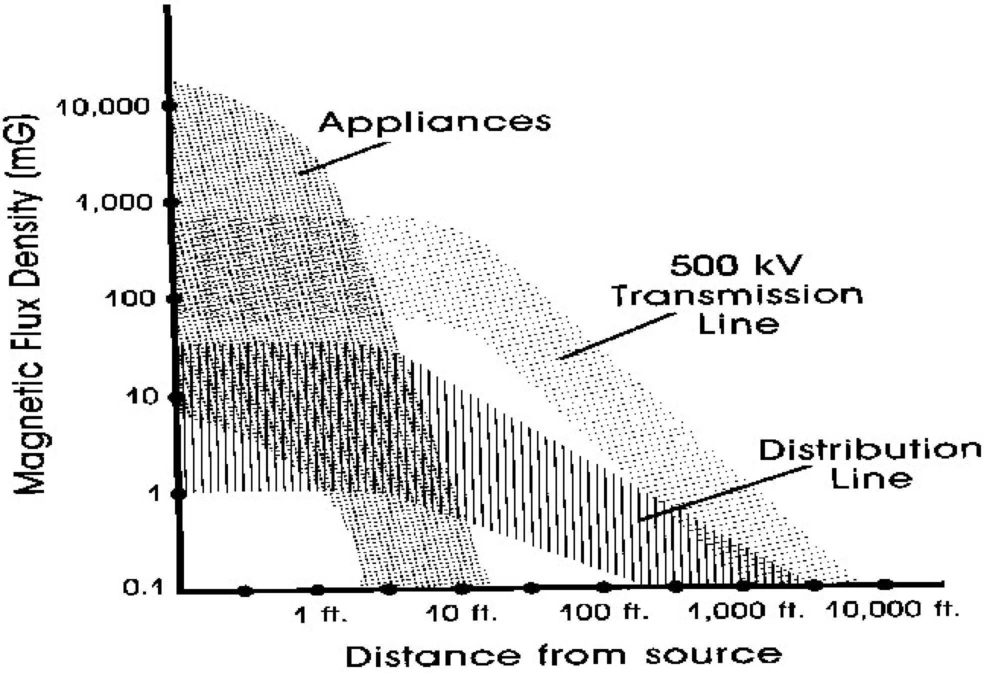

Figure 1 Magnetic field strength of different sources and distances

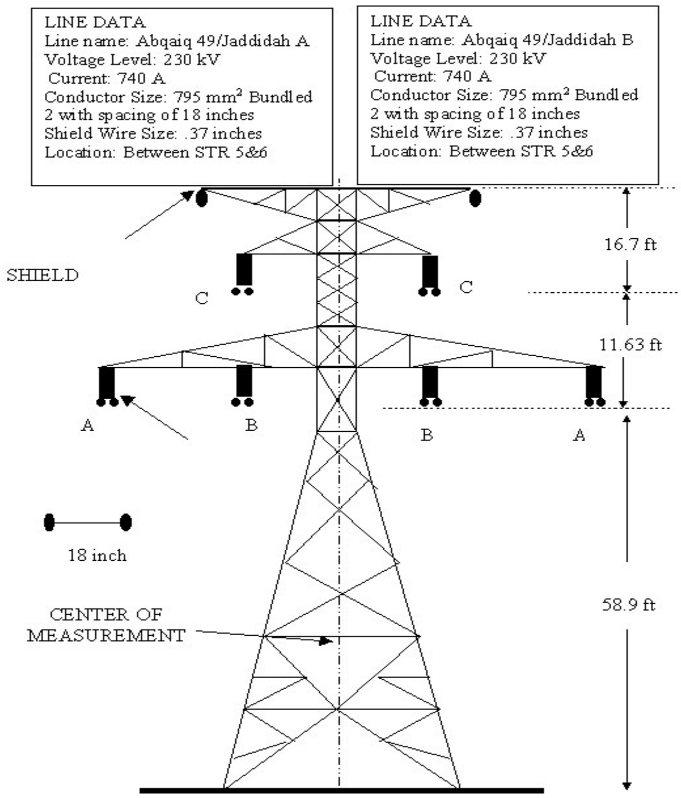

Figure 4.1 Case 1 230 kV Double Circuit Delta Configuration

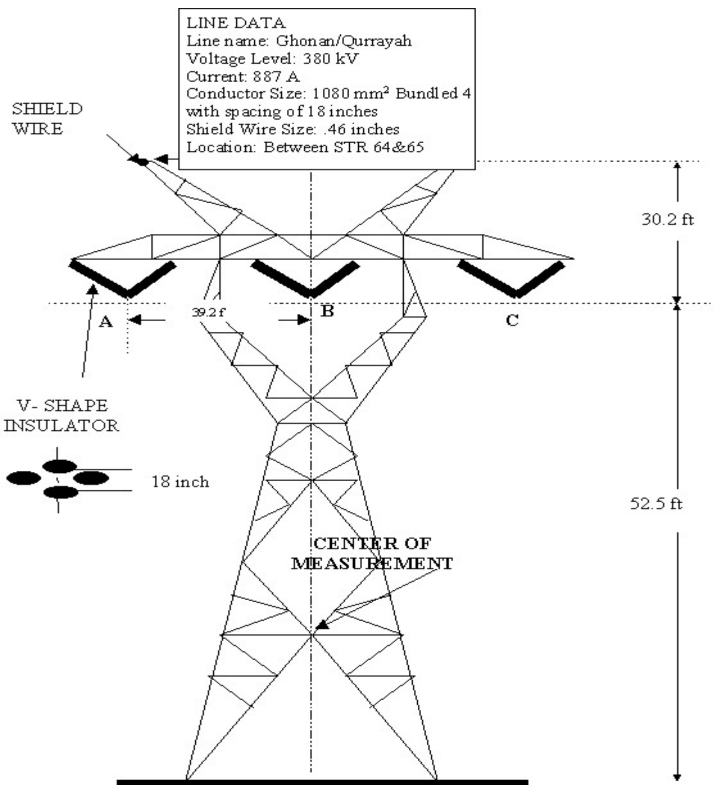

Figure 4.2: Case 2: 380 kV Single Circuit Horizontal Configuration

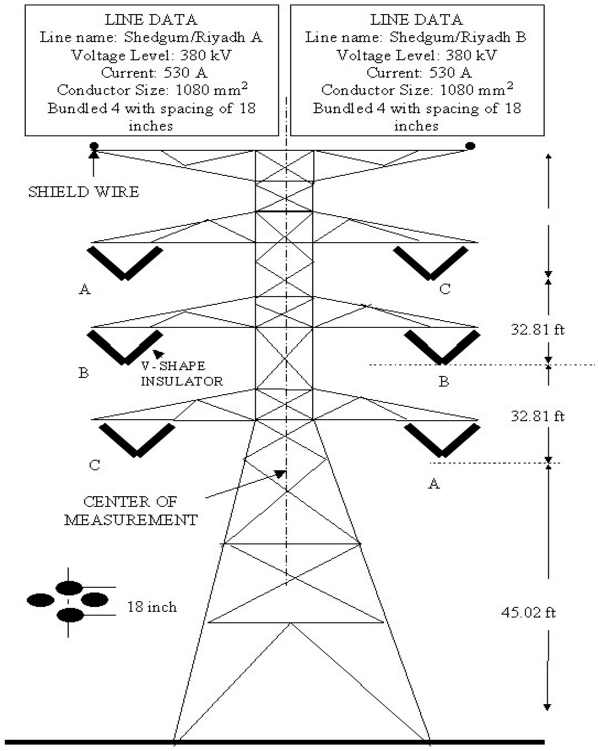

Figure 4.3: Case 3: 380 kV Double Circuit Vertical Configuration

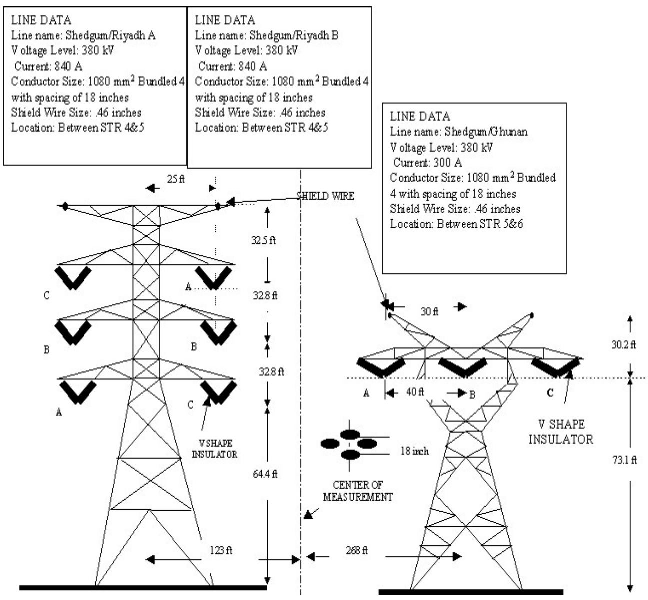

Figure 4.4 Case 4: 380 kV Double Circuit Vertical Configuration With 380 kV Single Circuit Horizontal Configuration

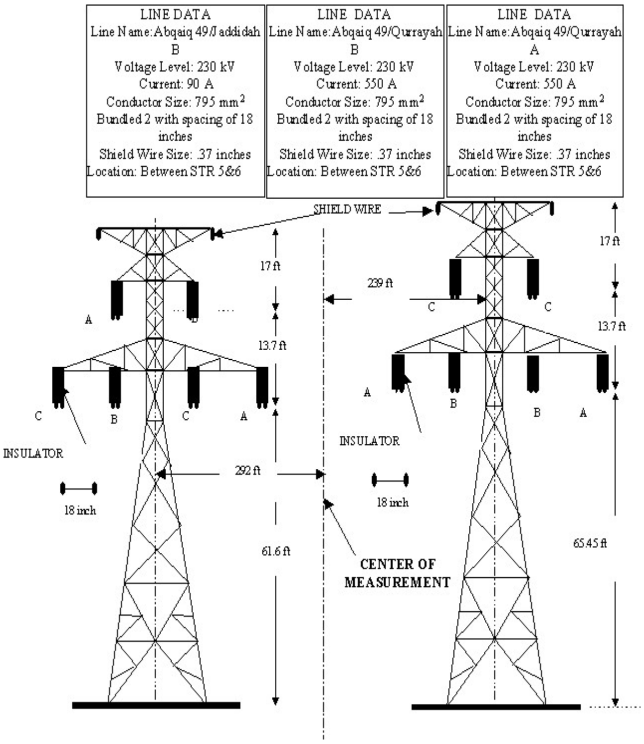

Figure 4.5 Case 5: 230 kV Double Circuit Delta Configuration With 230 kV Double Circuit Delta Configuration

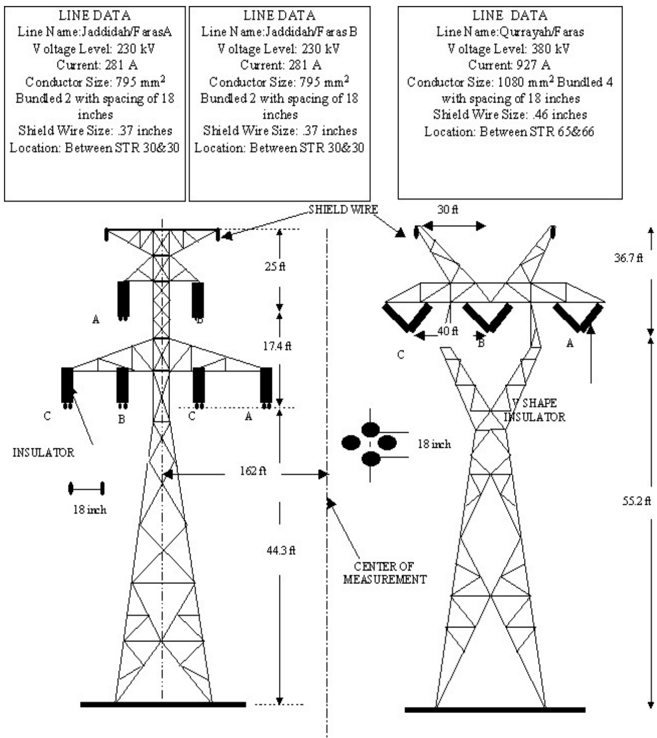

Figure 4.6 Case 6: 230 kV Double Circuit Delta Configuration With 380 kV Single Circuit Horizontal Configuration