Standard Basis for Quoting

Transmission Line Magnetic Fields

March 2006

Standard Basis for Quoting Transmission Line Magnetic Fields

Prepared for the ENA EMF Committee, March 2006

1. Purpose:

To provide guidelines for use by electricity authorities in producing magnetic field profile information for existing or proposed transmission lines.

2. Outcome:

A standardised approach to be used by electricity authorities in calculating and quoting magnetic fields from existing or proposed transmission lines using a set of practical and consistent criteria. A flow chart and work sheet are provided to assist staff to produce this information.

3. Background:

Electricity authorities are often requested to provide details of the magnetic field profile produced from an existing or proposed transmission line. Such requests may come from the public, or be required for an environmental impact assessment or other formal report.

In responding to requests for information regarding magnetic field profiles, utilities need to provide information which is sufficiently accurate for practical purposes and is presented in a simple form which will be readily understood by a non-specialist. Thus it is not always a straightforward matter as the magnetic field strength varies with a number of factors including the line loading, the line design (structures and layout), the weather conditions and the ground profile.

These guidelines provide a standardised approach which authorities may use to produce magnetic field profile information for an existing or proposed transmission line. The process is shown in the attached flowchart and is described in the following sections.

4. Variables Affecting Transmission Line Magnetic Fields:

4.1. Line Loading:

The electrical load and therefore the magnetic field on any power line, whether it is high or low voltage, varies continually with time. Records, if available, may provide useful data regarding a line's historical loading, but long term load projections are required to estimate likely future loading. The situation can be further complicated by changes in load growth patterns or system requirements which may significantly alter future load flows on any line in the transmission network. This means that any reference to a magnetic field level needs to make some assumptions regarding the conditions under which this value occurs.

4.2. Line Design:
There are certain line design details which are required as inputs for magnetic field calculations.

These are:
- structure, conductor and earthwire geometry
- conductor type and parameters
- earthwire type and parameters
- conductor and earthwire stringing data
- minimum design ground clearance
- actual and equivalent span
- soil resistivity

4.3. Wire Height Above Ground:
The vertical position of conductors varies with temperature which in turn, is dependent on a number of factors such as electrical load, ambient temperature and wind velocity as well as line layout /design. These considerations, together with the variable nature of the ground in both longitudinal and transverse directions means that additional assumptions are necessary to allow calculation of magnetic field profiles.

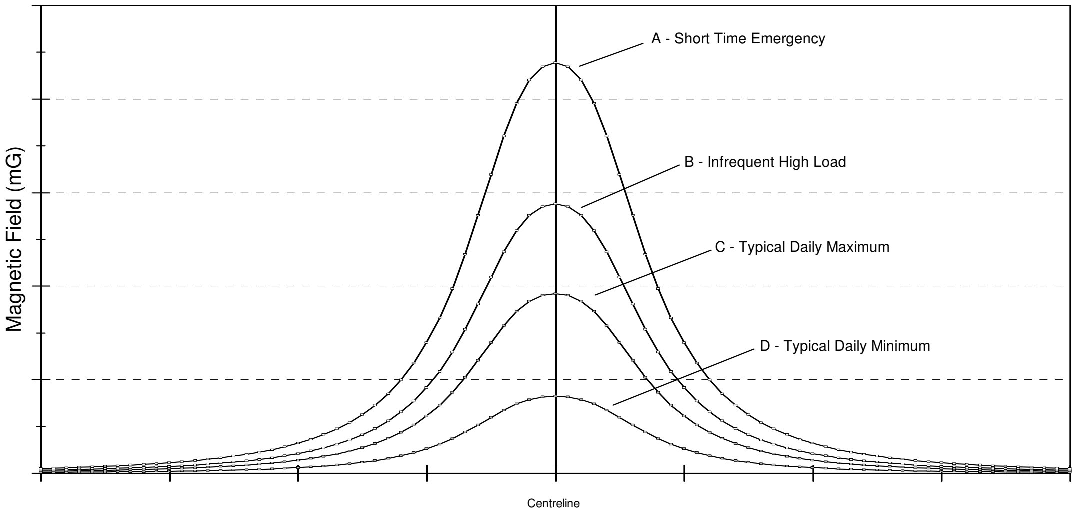
In the case of an existing line, these details are known for any particular point along the line, but for proposed lines, certain assumptions must be made. Likely sources of information for the purpose of such assumptions are detailed in Table 1:

Design Detail	Source - Proposed Line	Source - Existing Line
Structure / Conductor / OHEW Geometry	typical details for existing structure designs	structure design records
Conductor Type and Parameters	planning reports or typical designs / standards / manufacturer's data	design records / standards / manufacturer's data
Earthwire Type and Parameters	planning reports or typical designs / standards / manufacturer's data	design records / standards / manufacturer's data
Conductor and Earthwire Stringing Data	typical designs or practices	line layout records
Minimum Design Ground Clearance	statutory requirements or authority practices	design records
Equivalent and Actual Span	estimated using assessment of typical designs and terrain	line layout records

Table 1 - Line Design Details

5. Full Characterisation Of Fields Associated With A Line

Fields associated with a transmission line may be characterised as shown in Figure 1.



Transmission Line Field Profile
Figure 1

5.1. Loading Conditions:

A Short Time Emergency:
- could be short time thermal limit - may in practice never be reached on a line

B Infrequent High Load:
- for example yearly peak with the system substantially normal

C Typical Daily Maximum:
- the peak value reached for the line on a typical day

D Typical Daily Minimum:
- the value reached for the minimum daily load on a line

For communication purposes, experience has shown that the amount of detail above is confusing to people without a detailed knowledge of transmission systems. Accordingly it is recommended to adopt a simplified but nevertheless honest approach, as follows:

- For general discussion purposes - cite Curve C as this gives a (conservative) value for long term exposure

- In an Environmental Impact Statement, mention A* and B in passing, but base discussion on Curve C as this represents the likely maximum field which would, in practice, be achieved over a sustained period.

In such cases, Curve C should be based on the likely loading regime to be reached during the lifetime of a line, and not necessarily that which occurs upon commissioning.

** if Curve A is so unlikely as to be inconsequential, it could be permissible to ignore it on the basis that, in everyday life, it is not unusual for people to encounter fields of considerable magnitude for brief periods of time.*

For some lines, the daily load profile will vary significantly between seasons. In such cases, the curves relating to the season with the highest loading should be used.

The overall aims are: -

- to acknowledge the highest field which may occur in practice, and
- to focus attention and discussion on reasonably conservative estimates of the actual field levels which would be associated with the line over an extended duration

For proposed lines or line upratings, the currents corresponding to the various load cases should be obtained from system planners. In the case of existing lines, load records should be consulted.

The load corresponding to the typical maximum daily load case (Curve C) is less straightforward. Where load - duration data are available, the current loading for Curve C should normally be taken as the 85% load. i.e. the load which is exceeded for no more than 15% of the time.

In cases where the load duration data are not available, it is necessary to exercise judgement based on the best available information to derive a load which is unlikely to be exceeded for more than 15% of the time.

For each curve, having established the load current, the next step is to translate this to a magnetic field profile.

The magnetic field at a point adjacent to a line is primarily dependent on current, but also on ground clearance which is also influenced by load current.

5.2. Ground Clearance:

In a practical situation, ground clearance varies from span to span and from point to point within a span. Accordingly, a suitable practical (and reasonably conservative) value of ground clearance needs to be selected to enable field calculations to be carried out.

The equivalent and actual spans, conductor conditions and terrain considerations are all required to calculate average height above ground at the point of interest.

Average height above ground = (minimum ground clearance at max design temp) + (additional height due to assumed operating temperature below max design temp) + (1/3 sag at that assumed operating temperature)

The conductor temperature under a given set of conditions may be calculated using the appropriate table in ENA publication D(b)5 -1976 “Current Ratings of Bare Overhead Line Conductors”:

Inputs required are :

- Current = *derived as described previously in section 5*
- Conductor type = known (or nominated), surface condition assumed to be black i.e. *Solar Absorption Coefficient = 1.0 and Emissivity =1.0*
- Solar Radiation intensity = *assumed 1000 W/sq m*
- Lateral Wind Velocity = *assumed 1m/s*

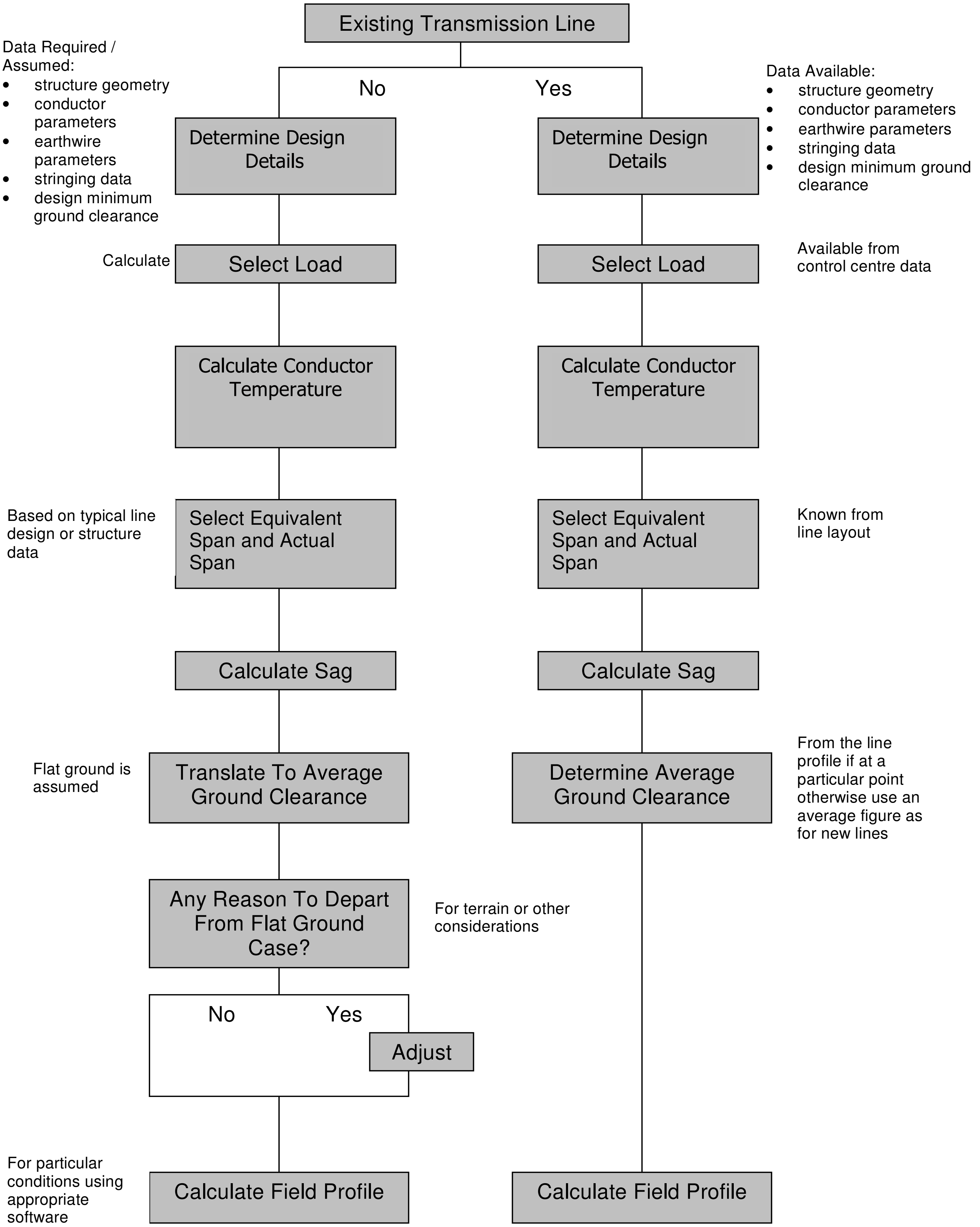
Conductor sag and therefore ground clearance can then be calculated from the appropriate design information for the particular section of line under consideration (i.e span and equivalent span). It is normal practice to assume flat ground in calculations of this type, but if local conditions are known, an appropriate adjustment should be made to the average ground clearance used in the calculation.

6. Magnetic Field Calculation:

The magnetic field profile is produced using standard computer software, such as Power Technologies TLFIELD program, using inputs derived in accordance with Section 5 of these guidelines.

Reference height for calculations should be taken as 1 metre, in accordance with normal practice and the ENA Residential Protocol For The Measurement of Electric and Magnetic Fields.

APPENDIX A


Existing Transmission Line
No
Yes
Data Required / Assumed:
• structure geometry
• conductor parameters
• earthwire parameters
• stringing data
• design minimum ground clearance
Determine Design Details
Determine Design Details
Data Available:
• structure geometry
• conductor parameters
• earthwire parameters
• stringing data
• design minimum ground clearance
Calculate
Select Load
Select Load
Available from control centre data
Calculate Conductor Temperature
Calculate Conductor Temperature
Based on typical line design or structure data
Select Equivalent Span and Actual Span
Select Equivalent Span and Actual Span
Known from line layout
Calculate Sag
Calculate Sag
Flat ground is assumed
Translate To Average Ground Clearance
Determine Average Ground Clearance
From the line profile if at a particular point otherwise use an average figure as for new lines
Any Reason To Depart From Flat Ground Case?
For terrain or other considerations
No
Yes
Adjust
For particular conditions using appropriate software
Calculate Field Profile
Calculate Field Profile

APPENDIX B

Notes on Calculation of Ground Clearance.

The input for field calculation requires an “average conductor height” - which is determined by ground clearance (at certain load conditions) and sag (at the same set of conditions).

It is assumed that the ground is flat unless there is sufficient information available to make an assessment for the case being considered.

It can be shown (using parabolic equations) that the average conductor sag is 2/3 of overall sag when measured from the points of attachment. Alternatively, the average conductor height is equal to ground clearance at the low point of the parabola, plus 1/3 sag.

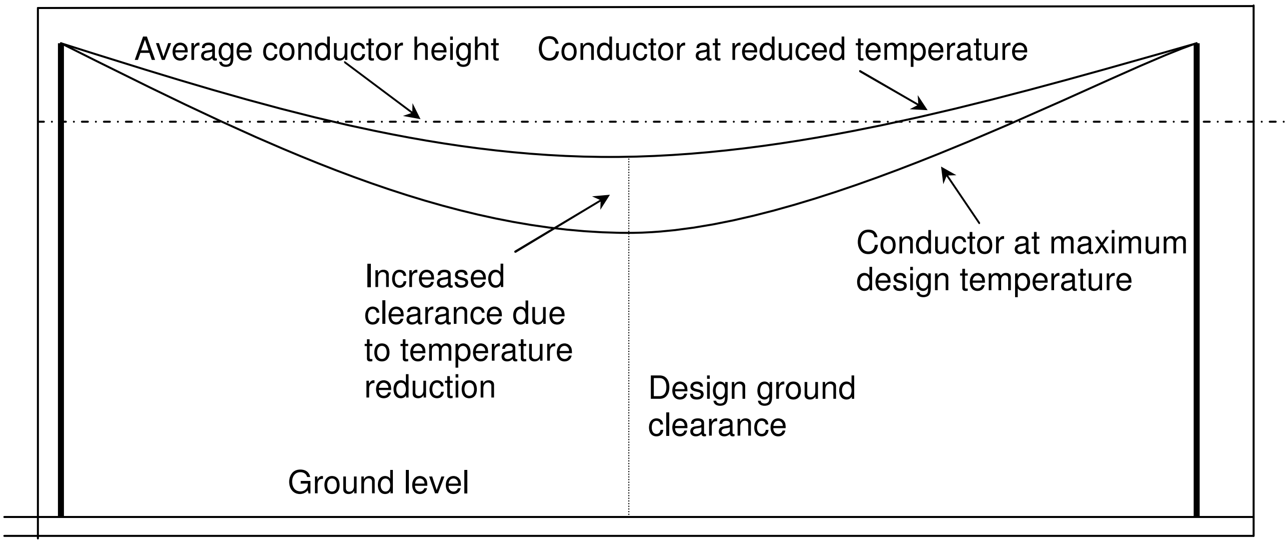
Average height above ground = (minimum ground clearance at max design temperature) + (additional height due to assumed operating temperature below max design temperature) + (1/3 sag at that assumed operating temperature)

Conductor electrical loading (calculated or assumed) causes a conductor temperature rise above ambient but the temperature will normally remain below that corresponding to maximum design load (minimum (design) ground clearance is based on this maximum load).

As the load and therefore conductor temperature is below this design value - the conductors will be higher - and have less sag.

Layout clearances for conductors at maximum design temperature are generally based on individual State Regulations and authority design practices. Typically, minimum layout clearances may be:

- 110 / 132kV = 7.0m
- 220 / 275kV = 8.0m
- 330kV = 8.5m
- 500kV = 9.5m



While this document is directed primarily towards transmission lines, the basic approach may be modified and applied to suit sub-transmission and distribution lines.

APPENDIX C

Typical Inputs - Magnetic Field Calculation Program

Input	Existing Line	Future Line
(a) Reference ht for field calculations:	Known (1m)	Known (1m)
(b) Overhead Earthwire data:		
- No. of wires	Known	Assumed
- X and Y coordinates of each wire	Known / Calculated	Calc (Assumed)
- size (diameter) of wires	Known	Assumed
(c) Phase Conductor data:		
- No. of phase conductors	Known	Assumed
- X ,Y coordinates-bundle/conductor	Calc (Known)	Calc (Assumed)
- size (diameter) of wires	Known	Assumed
- subconductor spacing	Known	Assumed
- phase to phase voltage	Known	Known
- phase angle	Known	Assumed
(d) Grounded horizontal guard wires?	Known	Assumed
(e) Energised E cancellation wires?	Known	Assumed
(f) Currents in Overhead Earthwires:		
- current in each wire	Known	Assumed
- phase angle for each current	Known	Assumed
(g) Current details for Conductors:		
- current and direction in each wire	Calc (Known)	Calc (Assumed)
- phase angle for each current	Assumed	Assumed
(h) Soil Resistivity	Known / Assumed	Assumed
(i) X- Coordinate: both sides of element	Known	Known / Assumed

APPENDIX D

Worksheet - Standard Basis for Quoting Transmission Line Magnetic Fields

1. Design Details	
Line Voltage	
Structure Geometry • *number of circuits* • *horizontal and vertical coordinates of conductors and earthwires* • *conductor phasing*	
Conductor Parameters • *type / diameter / unit weight* • *number and spacing of subconductors*	
Earthwire Parameters • *type / diameter / unit weight*	
Stringing Data • *conductor sag / tension condition* • *earthwire sag / tension condition*	
Design Minimum Ground Clearance • *design minimum ground clearance*	
2. Line Loading	
• *maximum daily load*	
3. Conductor Temperature	
Use appropriate table from ENA D(b)5 - Inputs Required • *conductor type (from Step 1)* • *line loading (from Step 2)*	
Assumed Parameters: • *daytime, black conductor, 1m/s wind*	
4. Equivalent and Actual Span	
To be determined / calculated: • *equivalent (ruling) span* • *span under consideration*	
5. Calculate Sag	
Inputs: • *conductor unit weight, tension (from Step 1)* • *equivalent span, actual span (from Step 3)*	
6. Average Ground Clearance	
Inputs: • *minimum design ground clearance (from Step 1)* • *adjustment (for temperature below max design temp- from Step 4)* • *1/3 sag at assumed operating temperature (from Step 4)*	
7. Adjustment for Departure from Flat Ground Case	
8. Calculate Magnetic Field Profile	