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Right of Way Survey of Electric Power Lines and Tower Spotting: Route and Techniques

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ABSTRACT

This paper examines right of way survey of electric power lines and tower spotting including the underlying principles of route profile in electrical power systems. The techniques and procedures of carrying-out the practical implementation of route surveying in relation to transmission and distribution power lines are outlined in details in this work taking standard regulations into consideration. The method of data acquisition, data processing, storage and display of information were dealt with in this article. Consequently, the paper exposes the techniques for implementing Right-of-Way (ROW) in electrical networks and the tolerance limits of conductors sagging and power lines crossing buildings, hills etc. both for vertical and horizontal distances for the 330kV, 132kV and 33kV power lines.

Keywords: Engineering, Surveying, Route Profile, Right-of-Way, Tower Spotting, Power Lines, Data cquisition

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1. INTRODUCTION

Electrical Power Systems are one of the most complex system ever built by man. Its complexity and reliability cannot be overemphasized, if power supply from it to consumers must be reliable. It is worth knowing that a good power system design will give a reliable power output to its consumers. Hence, a reliable supply is a hallmark of a good design. Then a reliable and good surveying during electric power design cannot be underestimated. Presently, the Nigeria complex transmission and distribution systems supply the vast needs of electrical power to their citizenry (Akpojedje, et al., 2016) and in Nigeria today, the power system is characterized with erratic, inadequate and inefficient power supply, voltage drop, undervoltage and high-power losses, especially in the distribution network (Akpojedje, et al., 2014; Akpojedje, et al., 2017) which is due to long distribution and transmission lines which may be caused by non-optimal route profile selection during design. It is worthwhile knowing that the existing utility facilities are ageing and they are being overstretched due to increase in loads and high losses in the system without commensurate improvement and overhauling of the power network facilities to match the increasing loads for several past decades to improve consumers' satisfaction and reliability (Akpojedje, 2017). One of the ways to minimize high losses in the network is optimal route selection for power lines and a good design should do so.

"A good design involves a good Right-of Way (ROW) survey and effective management of the electric power lines (transmission and distribution lines). Right-of Way (ROW) is a corridor of land over which electric power lines are located. Electric power lines owners might own the land in fee, own an easement; or have certain license or franchise rights to construct and maintain power lines". The importance of ROW in electric power lines design cannot be overemphasized, since "utility companies seek to locate power line in sites that are technically optimal, economically and environmentally acceptable to accommodate required facilities." Designing the Right-of Way is a significant factor when developing an electrical power system" (Ahmed and Hafeez, 2012) because it gives the various optimal route profiles and locations that should be harness.

Hence, "Power Systems is an interconnected network of generating plants, transmission lines and distribution facilities." The transmission lines evacuate (transport) the generated electric energy to the consumers at the point of utilization. The path the electric power lines follow to transport the energy generated to consumer is known as the power line route or Right-of Way (ROW); an adequate route survey is a key to a good Plan and Profile of electric power lines and subsequently tower spotting. Consequently, this paper x-ray survey of electric power lines, tower spotting and route profile plotting in electric power systems.

1.1 Surveying

Surveying is defined as (1) The science and art of making all essential measurements in space to determine the relative positions of points and/or physical and cultural details above, on, or beneath the earth's surface and to depict them in usable forms, or to establish the position of points and/or details. Also, the actual making of a survey and recording and/or delineation of dimensions and details for subsequent use, (2) The acquiring and/or accumulation of qualitative information and quantitative data by observing, counting, classifying and recording according to need" (ASCE, 1978).

Recently, the term Surveying is referred to as Geomatics due to drastic change in manner and scope of practice in Surveying. The development of sophisticated equipment and modern technology in their operation have greatly created a paradigm shift in the traditional method of surveying to the era of electronic/digital collection of data, storage, processing, management, display and dissemination of spatial related information. It has increasingly driven concerns about the environments, locally, regionally and globally.

Surveying as defined, is the bedrock of any meaningful development. The planning and design of all civil engineering projects such as construction of highways, bridges, tunnels, dams etc are preceded and based upon surveying measurements. Not only do Surveyors determine preliminary survey of engineering projects, but they also engage in layout out optimal route (plan and profile) and every other feature on map to designed accuracy

1.1.1 Engineering Survey

Engineering surveying may be regarded as a specialty within the broader professional practice of engineering and, it includes all surveying activities required to support the conception, planning, design, construction, maintenance and operation of engineered projects (ASCE, 1978). Furthermore, engineering surveying can be broadly described as a term used to describe the work of surveyors on engineering projects or works. The engineering surveys are broadly divided into two categories namely: i. design-data surveys and ii. construction surveys.

1.1.2 Construction Surveys

"Construction surveying is further divided into two categories: (1) the layout, or stakeout survey and (2) the as-built survey. The layout, or stakeout survey consists of locating and marking (staking) horizontal and vertical control points to guide construction crews and giving line and grade as needed to establish additional control points and to reestablish disturbed stakes. The as-built survey includes making measurements to verify the locations and dimensions of completed elements of a new structure and to determine the amount of work accomplished up to a given date" (ASCE, 1978).

1.2 Route Surveys

Route surveying is an aspect of surveying made along a defined belt of a territory for location, design and eventual construction of routes for transportation and infrastructures such as highways, railways, canal, pipeline for water, sewage and transmission lines for power systems and telephone. A Route Survey is also referred to as the required service and product that adequately locates the planned path of a linear project or right of way, which crosses a prescribed area of real estate, extending from at least one known point or turning and terminating at another known point. It supplies the data necessary to determine alignment, grading, and earthwork quantities for the design and construction of various engineering projects such as roads, railroads, pipelines, and utilities. A Route Survey is usually required for the planning of a right of way (ROW). The location of the facilities within the right of way, are often held in respect to the centerline or a right of way line. A Route Survey is done on the ground to provide for the location of right of way lines, a centerline, or reference lines in relation to property lines and terrain features.
The method of surveying as applied to transmission lines can be divided into the followings:

1. Recconnaisance and route alignment survey.
2. Detailed survey.
3. Tower spotting.

1.2.1 Recconnaisance and Route Alignment Survey: a provisional route of transmission line is initially spotted on survey maps and a recconnaisance and walkover survey is carried out. This is essential to fix up angle tower position tentatively since many of the physical features on the ground may not be clearly available on the survey maps due to the development that might have taken place subsequent to the preparation of the map.The recconnaisance survey is essential to be carried out, to collect the first hand information of various important field data required for transmission line work. The general consideration to be kept in view while establishing the preliminary route at the time of recconnaisance survey are as follows:-

a. The route should be as short and straight as much as posible.
b. Crossing of permanent objects such as railway lines, roads, rocks, buildings etc should be minimal and preferably these are to be at right angle to the route. (reference shall be made to the appropriate railway regulations and electrification rules as well as civil authorities for protection to be provided for railway and road crossing respectively)
c. In case of hilly terrain having sharp rise and falls in the ground profile, it is necessary to conduct detail survey and locate the lower positions. The proposition should be most economical and save. The following areas should be avoided while selecting route:-
    a. Marshy areas, low lying land, river beds, earth slippery zones e.t.c. involving risk to stability of foundation.
    b. Areas subject to flood, ponds, lakes, hurricane or having extreme climatic condition that can subject it to natural hazards.
    c. Areas which will create problems for right of way and wayleaves.

1.2.2 Detailed Survey: the objective of carrying out detailed survey is to prepare longitudinal and cross section profiles on the approved allignment and to prepare the route plans showing details of deviation angles along with important objects falling within the right of way (ROW). In total length of a long transmission line there may be several deviation points. According to the angle of deviation there are four (4) **types of transmission tower**:

1. A – Type tower – angle of deviation 0° to 2°.
2. B – Type tower – angle of deviation 2° to 15°.
3. C – Type tower – angle of deviation 15° to 30°.
4. D – Type tower – angle of deviation 30° to 60°.

Work of detailed survey is distinctly done in two stages:-

i. Actual field observations for Cadastral and Topographical data acquisition.
ii. Plotting of profile.

1.2.3 Tower Spotting: the work of tower spotting is clearly divided into the following six operations:-

i. Sag tension calculation.
ii. Preparation of sag template
iii. Application of sag template to decide the optimum tower position on survey charts.
iv. Preparation of structure limitation charts.
v. Deciding tower types and preparation of tower schedule
vi. Setting out the positions of the tower legs on ground.

The right of way survey and tower spotting begins with the establishment of control points with equipment of high accuracy along the Transmission Line Route, Setting out the center of Tower positions and Provision of three Pegs at ten meters interval longitudinal to the Transmission Line at every Tower position preferably using Total station instrument. The center peg serves as the Tower Position. The recommended right of way width for transmission line should also be determined in the course of the operation.

In designing an overhead transmission line, attention is paid to the tension force in order not to exceed in any case the limit of the mechanical strength of the conductor. For distibution lines, poles are placed by the sides of the streets that is most free of other lines and trees. The transmission lines are kept on the same side of the road of the entire length of the power line if possible. The span of the line supports of transmission lines is dependent on the type of the supporting structure for the overhead conductors. There are various types of line support such as wooden poles, steel poles, Reinforced Concrete Cement (RCC) and the Towers. Wooden poles are limited to low voltage up to 11kV and suitable for lines of relatively short spans up to 38.10m meters (30.48m minimum and 45.72m maximum). Steel poles are used in place of wooden poles with span of 50 meters.

The RCC poles usually refer to concrete poles are used for low voltage and high voltage distribution lines up to 33kV. It has a greater mechanical strength, durable and permit longer span than steel poles. It can be used for longer span between 50 to 80 meters. Steel towers also known as Lattice steel towers has a greater mechanical strength and are used for higher voltage transmission lines. It allows a longer span from 80 to 200 meters. They are of two types, The Narrow base lattice steel tower used for distribution lines between 11kV and 33kV, and the broad base lattice steel tower used for transmission lines of 132kV and 330kV.

Whenever the line support comes in line with property or fences alongside with road, the span is adjusted. The poles should be place at safety distance from ground to transmission line and scissors crossing as follows:
Where the transmission line crosses a railway

1) There should be no joints in the conductor or ground wire within the crossing span length
2) The minimum vertical distance from the tread to the conductor should be not less than 7.6 meters and 8.5 meters for 33kV to 132kV and 330kV respectively.

Where the transmission line crosses a public road, there should be no joints in the conductor within the crossing span length and second-class circuit. The minimum vertical distance from the ground to the conductor should be 7 meters for 33kV to 132kV and 8 meters for 330kV. The minimum horizontal distance from railway or a public road to the conductor should not be less than as stated below:

a. from the pole to the railway edge, where the transmission lines are at right angle with the railway; the 33kV to 132kV = Pole height + 3 meters and where the transmission lines are crossing the railway, 33kV to 330kV lines support should be place at 5 meters to the edge of railway.
b. from pole to roadbed edge, it should be place at 5 meters for 33kV to 330kV.

Where the transmission lines cross low current circuit, there should be no joints in the conductor within the crossing length of first class and second-class low current circuit and a minimum vertical and horizontal distances are stated in Table 1:

Table 1a: Minimum Vertical of Power Line Crossing

Voltage	Distance in Meters
33kV to 132kV	3m
330kV	4m

Table 1b: Minimum Horizontal Distance of Power Line Crossing

Voltage	Distance in Meters
33kV to 132kV	4m
330kV	5m

Where the transmission lines cross a low current circuit, the crossing angle to the ground and second-class low current circuit should be more than 45^0 and 30^0 respectively. The minimum height from the ground to conductor at maximum sag should not be less than as listed in Table 2:

Table 2: Minimum Height from the Ground to Conductor at Maximum Sag

Voltage	33kV to 132kV	330kV
Residential area	7 Meters	7.5 meters
Non-Residential Area	6 Meters	6.5 Meter
Road-Block Area	5 Meters	5.5 Meters

Minimum space distance from hillside, precipice or rock to the conductor should be as stated in Table 3:

Table 3: Minimum Space Distance on Hillsides

Voltage	33kV to 132kV	330kV
Hillsides which can be access by foot	5 Meters	5.5 Meters
Hillsides, precipice of rock that cannot be access by foot	3 Meters	4 meters

The supposed vertical distance from building to the conductor at maximum sag should not be less than the values stated in Table 4:

Table 4: Vertical Distance from Buildings to Conductor at Maximum Sag

Voltage	**Distance in Meters**
33kV	4
132kV	5
330kV	6

The horizontal distance from building to the conductor at maximum sag calculated or windage yaw should not be less than the value in Table 5:

Table 5: Horizontal Distance from Buildings to Conductor at Maximum Sag

Voltage	**Distance in Meters**
33kV	3
132kV	4
330kV	5

Where the transmission line crosses a bush/forest, a path should be cut out to give way to every tree and plants at distance between the phases conductors of the sides of the transmission line. The high trees around the path should also be cleared. Safety distance to be adopted from the plants/trees/crops to the conductor at maximal sag or maximum windage yaw shall be as stated in Table 6:

Table 6: Safety Distance to be adopted from Plants to Conductor at Maximum Sag

Voltage	**33kV to 132kV**	**330kV**
Vertical Distance at Maximum Sag	4 Meters	4.5 Meters
Space Distance at Maximum Sag or Calculated Windage Yaw	3.5 Meters	4 meters

Note that the flashover often accompanies strong wind and rain that makes the rate of re-closure low when the transmission lines trip and is caused by windage yaw which affects the security and reliability of the power system. However, in open roadways or highways, poles should place at 46cm from the outside of the fence. For transmission lines, poles should be positioned on elevated areas so that the shorter poles may be used and keeps the proper ground clearance at the middle of the span. Locating of poles at the edges of embankments and streams where there is possibility of washout should be avoided. Tower spotting commence with the establishment of control points along the proposed transmission lines followed by Line Route using differential GPS or Total station and lastly the Setting out the center of line supports / tower positions.

In the course of tower spotting, it is also imperative to provide the three Pegs at ten meters interval longitudinal to the Transmission line at every Tower position using Total station instrument with the center peg indicating the Tower Position and other pegs showing the Right of Way. For example, the recommended right of way for 132kV/dc transmission line is not less than 27 meters.

2. PROJECT PLANNING AND PREPARATION

This constitutes the first thing to do in the course of executing any survey job, as it is widely believed that success of any project depends on the proper, effective and adequate planning.

2.1 Recconnaisance Survey

Recconnaissance is usually an essential aspect of any survey operation, it help in decision making and it facilitates proper planning vis a vis:

- Accuracy specified
- Determining the most suitable and profitable points and methodology in data acquisition.
- Type of instrument that will be used for the project
- Cost of project
- Personnel to execute the project
- Type of vehicle to be used
- Type of safety equipment needed to use during the execution of the job.
- Duration of the field work

Both **data search** and **field reconnaisance** are required in Right of Way survey and tower spotting.

2.1.1 Data Search

This entailed all office preparations made which included but not limited to getting all necessary information about the control pillars near the project site, type of instrument needed to execute the job, the right personnel and all other documents which would assist in a thorough and acceptable result. Below are examples of controls data and the coordinates of the Tower Center Points contained in the Tower Schedule that will be made available by Client.

Table 7: Co-ordinates of Control Points

Points	Nothings (m)	Eastings (m)	Height (m)
ATCS 5S	790058.499	537164.785	44.082
ATCS 14S	788647.517	534027.11	38.257
ATCS 16S	785236.244	543691.095	125.904

Table 8: Tower Schedule

1	LAGA CE POWER LTD															
2	132 KV D/C TRANSMISSION LINE															
3	Section : ABEOKUTA-IGBOORA (50.595 Kms.)															
4																
5	TOWER SCHEDULE															
6–7	Sr No	Prov. No.	Tower Type	Basic Span(m)	Deviation Angle (deg)	SectionNo	Sect. Length (m)	Rulling. Span (m)	Section Chainage (m)	Cum. Chainage (m)	X Easting (m)	Y Northing (m)	Z Ground Elevation (m)	Vind Span (m)	Veight Span (m)	Remarks
8	1	1	dd90	142.8	0	1	143	144.5	0.0	0.0	543444.6	785042.2	115.2	72	73	DEAD END TOWER / AP0
9	2	2	dd60	256.8	57.74				142.8	142.8	543440.7	784899.4	115.2	202	275	AP1
10	3	3	dd2	121.0	0	2	378	223.7	256.8	399.6	543219.8	784768.5	104.9	190	256	
11	4	4	dd30	329.6	14.35				377.7	520.6	543115.7	784706.8	96.0	226	104	AP2
12	5	5	dd2	325.8	0				329.6	850.2	542799.4	784614.1	92.5	328	296	
13	6	6	dd2	304.0	0				655.4	1176.0	542486.7	784522.6	94.9	315	326	
14	7	7	dd2	349.0	0				959.4	1480.0	542195.0	784437.1	95.3	327	296	
15	8	8	dd2 +6	367.0	0				1308.4	1829.0	541860.0	784339.1	95.6	358	395	
16	9	9	dd2	279.2	0	3	2855	322.2	1675.4	2196.0	541507.8	784235.9	101.1	323	265	
17	10	10	dd2	324.8	0				1954.7	2475.2	541239.9	784157.5	109.5	302	407	
18	11	11	dd2 +3	324.0	0				2279.4	2800.0	540928.2	784066.2	98.1	325	334	
19	12	12	dd2	251.2	0				2603.4	3124.0	540617.2	783975.1	91.0	288	315	
20	13	13	dd10	295.8	5.91				2854.6	3375.2	540376.2	783904.6	80.0	274	119	AP3
21	14	14	dd2	329.5	0				295.8	3671.0	540085.2	783851.1	90.9	313	370	
22	15	15	dd2 +3	381.5	0				625.3	4000.5	539761.2	783791.6	90.3	356	506	
23	16	16	dd2	241.0	0				1006.8	4382.0	539385.9	783722.6	65.5	312	236	
24	17	17	dd2	313.0	0				1247.8	4623.0	539148.9	783679.1	57.8	277	192	
25	18	18	dd2 +3	339.7	0	4	2917	332.2	1560.8	4936.0	538841.0	783622.5	59.1	326	370	
26	19	19	dd2	285.3	0				1900.5	5275.7	538507.0	783561.2	58.8	313	323	
27	20	20	dd2	366.7	0				2185.8	5561.0	538226.3	783509.6	54.5	326	310	
28	21	21	dd2 +6	364.4	0				2552.5	5927.7	537865.6	783443.3	46.2	366	368	
29	22	22	dd30	270.8	21.61				2917.0	6292.2	537507.2	783377.5	49.9	318	259	AP4

Source: (Laga Ce Power Limited, Abuja)

The satellite imagery of the project area should also be downloaded from goggle map, imagery or any reliable source. This is to get the required information about the area and the route of the project.

Fig 1: Satellite Imagery of Part of the Project Area

2.1.2 Detailed Survey

With the tentative route(s) selected, a preliminary or detailed survey is carried out to prepare Plan and Profile design showing details of deviation angles along with important objects falling within the right of way (ROW). In the course of detailing, all pertinent topographic information and overheads and underground lines should be captured indicating individual properties whether it's of power or communication lines.

Work of the detailed survey is distinctly done in two stages:

i. actual field observations for Cadastral and Topographical data acquisition.
ii. plotting of plan and profile on which the plan depicts the route the transmission or distribution line will pass through with the significant topography adjacent to the route and the profile exhibiting the existing ground elevations along the route and the top elevations of the poles/towers which are set in accordance with the minimum allowable clearance specified in the National Electrical Safety Code (NESC).

2.2 Equipment to be used

It should be noted that in surveying practice, the nature of survey project that is to be executed and the accuracy required of such project determines the kind of instruments to be used.

Hence, the equipment recommended for the purpose of this operation comprised of both hardware and software.

2.3 Hardware Requirements

These are categorized into the following:

- **i.** Data Acquisition Equipment.
- **ii.** Data Processing and Plan Production Equipment.

2.4 Data Acquisition Equipment

1. Differential GPS with its accessories
2. Total Station with its accessories.
3. Steel tape (100 meters)
4. Ranging poles
5. Cutlasses
6. Hammers.
7. Brushes and Paints
8. Sets of Motorola Radio.

2.5 Data Processing and Information Presentation Equipment

1. *Computer*
2. *Printer*
3. *Scientific calculator*

2.6 Software Requirements

The software seemly for this kind of operation are listed below:

1. *ArcGIS 9.3*
2. *AutoCAD Civil 3D*
3. *GPSpro*
4. *Total station downloading/uploading software*
5. *Google Earth*
6. *Microsoft Word*
7. *Microsoft Excel*

2.7 Logistics

1. Safety Boots
2. Rain Boots
3. Helmets
4. Vehicles
5. First Aid Kits

2.8 Monumentation

The beacons should be casted in-situ. Holes with dimensions 30cm x 30cm must be dug into the ground to a depth of 75cm and $3^{1/4}$-inch galvanized pipe cut to a length of 1.2 metres should be driven into each at centers and further driven into the ground to a depth of 15cm. The concrete mixed at a ratio 3:2:1 of sharp sand, gravel and cement are respectively poured in the hole with the mold (30cm x 30cm) as a guide. The pipe should be filled with the concrete and a nail inserted in the middle of the pipe as the center point.

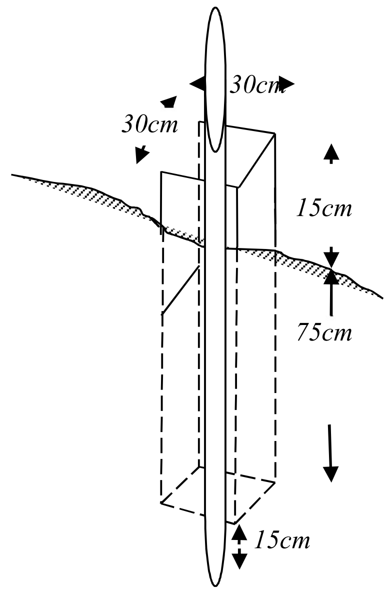


Figure 2: Schematic diagram showing its dimension. (not drawn to scale*)*

2.8.1 Data Acquisition

The data acquisition involves the following: -

1. *Acquisition of satellite imagery and attribute data.*
2. *Geometric or Locational data acquisition with Differential Global Positioning System (DGPS) and Total Station Equipment.*

2.8.2 Data Acquisition from Satellite Imagery

This involves the following:-

i. *Extraction of the satellite imagery of the study area.*
ii. *Geo-referencing and digitizing of map features.*
iii. *Attribute data acquisition.*

2.8.3 Acquisition of Imagery of Study Area

Satellite imagery of the study area is extracted in portions (in slides if the study is large), in such a way that all the portions are having a common overlapping area using Google Earth or any other source of high accuracy. This method of data acquisition is employed to fix landmark features that are closer to the route. Any other prominent features such as highway, access roads, rivers and streams are also fixed using this method. The images extracted can be saved between EMF, EPS, AI, PDF, SVG, BMP, JPEG, PNG, TIFF, and GIF formats. The resolution and additional parameters can be configured in each format for the purpose of digitizing.

2.9 Georeferencing

It is operation of obtaining and assigning geographical coordinates to information (usually a layer) that lacks it. Usually applied to place Earth images or events associated with postal addresses (Moreno, 2008). Georeferencing is a technique of spatial positioning by means of which a digital image is assigned a reference system based on known coordinates. Some raster information is not associated with a reference system, such as maps, scanned topographic maps, aerial images, etc. To link an image to a known coordinate system, you must perform the georeferencing process, as explained below.

In the georeferencing of an aerial image, once the ArcMap application is executed, click on the **Add Data** icon in the **Standard** bar load the image.

Standard Toolbar

Fig 3: Standard Toolbar

The directory is scanned and the raster file that is to be georeferenced is selected, ignoring the unknown spatial reference message to load the image. In topographic maps, several control points can generally be identified through the coordinates shown on the X and Y axes. Activate the **Georeferencing** toolbar. If not found use the ***Customize > Toolbars*** menu.

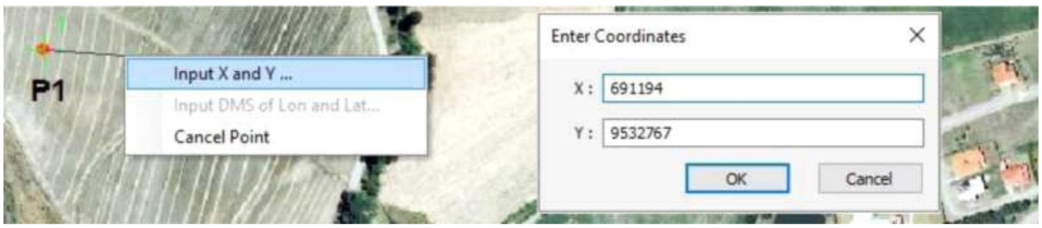
Georeferencing toolbar

Fig 4: Geoconferencing Toolbar

Make sure that the added image (georeference_image.jpg) is inside the bar. If you cannot see the image in the current screen view, click ***Georeferencing > Fit To Display.***

Now click on **the Add Control Points** icon; this tool allows you to adjust the image spatially by means of known points. The first step is to mark a known point on the image (P1). Once the cursor is positioned, it turns green, then right-click and select **Input X and Y** to enter the XY coordinates. The process is repeated for the second point (P2) and for the other points that need to be added.

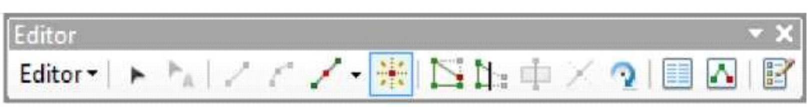
To finish with georeferencing after acceptable adjustment of the control points, go to ***Georeferencing > Update Georeferencing.*** This will create auxiliary files to the current image containing the transformations made.
The number of control points is not strictly reflected in the quality of the result, and the important thing is to make an adequate distribution. Try not to concentrate the control points in a single sector but distribute them homogeneously within the image. The more points you can apply, the more complicated the transformations (polynomial, spline, adjustment or projective) you can use to determine the proper location of the coordinates for each cell of the raster image.**Shapefiles Editior**



Enter XY coordinates

Fig 5: Enter XY Coordinates

To create new elements or edit existing ones within a shapefile, return to the ArcMap application and add the shapefiles generated as layers using the ***Add Data*** icon in the ***Standard*** toolbar. To start editing, activate the Editor Toolbar. Go to ***Editor > Start*** editing to enable editing in the workspace (in shapefile). In the next dialog box that appears, select the layer or workspace to edit. In case of warnings, omit them and click continue. The Create Features panel (left) then appears with a list of the current layers sorted by their geometry (points, lines and polygons), and in Construction Tools select the feature you want to edit. The central idea of editing a shapefile is to map the elements present in an image (to maintain an order, start first to work with the points, then with the lines and finally with the polygons). All required changes can then be made to the selected shapefile. To finish editing, go to ***Editor > Stop editing*** and save the modifications. Changes only affect the selected vector entity.



Toolbar Editor

Fig 6: Toolbar Editor

2.10 Data Acquisition using Differential Global Positioning System (DGPS) and Total Station

Differential Global Positioning System (DGPS) and Total Station are used to acquire data if necessary. The following observations are carried out;

1. GPS observation for control establishment.
2. Traversing, detailing and setting out of Tower points with its directional pegs.

The observational procedure for the field observations always commence on a known control or with the establishment of three-dimensional coordinates using DGPS if none is found within 5 kilometers to the study area. The traversing, detailing and setting out of the Tower Center Points are out carried out with Total Station. However, the setting-out points are later re-coordinated to check the accuracy of the work at every point.

2.11 DGPS Field Procedure for Control Establishment

The Base/master receiver is set up on control pillar (base station), centered and levelled accordingly. The mode of operation is set to static survey. The receivers (rovers), is set up as on any other control station. The necessary information such as point Identification, Antenna height, mask angle, record interval, track times are keyed-in at each receiver's station. The receivers are then activated for satellite tracking thereby simultaneously collecting or receiving ephemeris data (satellite orbital information) for a minimum of preset observation time of 30 minutes for the ambiguity resolution of the GPS.

This duration is adopted considering the baselength of the two receivers since the longer the baseline, the longer the observation time and vice versa. At the expiration of the preset observation time, the rover is stopped from collecting data. The data already collected are stored in the internal memory of the receivers. The roving unit is subsequently transferred to the other established points in turn for data collection following the same procedures. The GPS master receiver maintained its original position throughout the period of the observation. Ensured that the correct antenna height reading was entered and also, the Geometric Dilution of Precision (GDOP), a function of the satellite vector (arrangement) is good throughout the observations so as to obtain a reliable point positioning.

2.12 Setting out of Tower Center Points and Offsets Points.

In order to carry out a setting out operation there must be a setting out data. The setting out data are obtained from the Tower Schedule. Setting out of points are carried out using the setting out program of a Total Station. The program computes setting out elements for polar, cartesian or orthogonal, setting out of points using coordinates or angle, horizontal distance and height that had been stored in the instrument. The setting out data may be typed manually or uploaded into the Total Station through the computer.

The following procedures should be followed in setting out of the Tower points; (using Leica TC 407 Total station)

- The instrument is set on a known control point**,** switched on and all temporary adjustment duly carried out.
- **PROG** button is pressed and **SETTING OUT** is selected from the Program list while the following settings are carried out.

i. **JOB – TOWER SPOTTING** is entered
ii. **OPERATOR** – Surv. Samuel
iii. **DATE** and **TIME** the Job is created will automatically be registered by the instrument.
iv. **SET** is selected by pressing Enter button.
    - Under **SET STATION**, Station ID **must be** inputed into the Total Station. The instrument will request for the station information if not found in the internal memory but if stored, automatically recalled the uploaded coordinates of the point.
    - Height of Instrument is measured from the trunion axis of the instrument to the tip of the nail on the pillar and input into the instrument.
    - Enter button is pressed on **SET** to save.

- The reflector at the back-sight station is bisected.
- **SET ORIENTATION** is activated, and orientation by **COORD** is selected and the backsight point Id is inputted, the instrument will request for the station parameters if not found in the internal memory but if stored, automatically recalled the uploaded coordinate of the orientation point and displayed the backsight bearing.

PRECAUTION: Ensure that enter button was pressed when the cross hair was accurately bisecting the reflector on the back sight point.

- The **START** button is initiated to begin Setting Out operation
- From the 2D Set out screen, **Pt ID** is inputted
- The instrument displayed the distance from the control to the station selected with zero (0) degree bearing.
- Tracking pole is aligned along the direction as indicated by the Total Station, and then tracked until the instrument reads zero in distance with zero-degree bearing indicating the initiated station).

The above procedures constituted a typical setting out process using Leica TC 407 Total Station in a setting out operation; the procedures are repeatedly followed till all the Tower points and offset positions are set out. The pegging are often done with a quarter inch pipe of 70cm length, painted yellow and 40cm driven to the ground with pure concrete. Every Tower Pegs has the company name, tower number and tower type inscribed on it. The Right of Way (ROW) of 15m from the center line are also established using concrete pillars.

2.13 Electromagnetic Locating Survey

"Electromagnetic location instruments (Cable/Pipe Locator) is used to locate metallic pipes and trace wires that laid for non-metallic pipes and drains where there is an access point within a reasonable distance from the site or on the route being surveyed. All surface features relating to underground utilities, such as manholes, draw pits, inspection chambers and gullies, including all street furniture connected to pipes and cables such as lamp posts, illuminated road signs and bollards, telephone kiosks, will be recorded during the survey process. Underground utilities will be located continuously and recorded in three dimensions at reasonable intervals and at each surface feature, change of direction. Where bands of cables/ducts are identified, the upper and lower outer cables/ducts will be traced in order to provide a cross section of the cable/duct band" (HKIUS-UTMS, 2011).

Direct connections will be made to gas and water valves without any damage to the utilities. All electrical utilities (lampposts, traffic lights, low / medium / high voltage electric cables and telecom cables) will be located by either inductive methods or where necessary the use of a signal clamp which makes no contact with any conducting material. Sewer manholes will never be accessed internally but rather examined by use of torches thus not requiring confined space entry and greatly reducing any chance of injury from harmful gases, rats, snakes, etc. All known and all other recordable underground services within the site will be surveyed. However, the condition of services should not be surveyed. Information about the terrain is obtained. This is essential and informative for proper description of observed entity.

2.13.1 Data Downloading and Processing

This involves various computations and methods in which useful information that can aid decision making which are derived from the data acquired.

2.13.2 Data Downloading and Storage

The data stored in the internal memory of total station are downloaded from total station through Leica Geo-Office Software. The instrument downloading cable (an accessory accompanying the total station) is connected from the total station to the computer. "Leica Survey Office" (Leica downloading software) short cut on the computer's screen should be double checked and which will display a dialogue box. In the dialogue box, Data Exchange Manager is clicked on the computer with automatically recognize the instrument by putting it on and depicting the jobs contained in the total station folder. The job name (when observed data are stored) is selected, two files with be displayed namely fixed points and measurements point. Measurement points stands for stored data in the field observation while the fixed points are data typed manually or uploaded from computer into the internal memory of the total station. The measurement point should be highlighted and copied and paste into the local disk 'C' at right side of the window. The data will automatically download at the pasting of copied selected items. It should be saved with file extension 'IDX' into the computer 'C' drive. The computer will return to the dialogue box and 'coordinate data editor' is now clicked. The saved file downloaded should be located to be open and data are copy into MS-excel file. From the MS-excel the data are process and save to format that will be recognize by the drafting software or draft man. The data in this case should be save as CSV (comma delimited) or PRN as preparation for further use in AutoCad application.

2.13.3 Techniques in Plotting of Route Profile

From the data obtained during the survey, the route profile is plotted to show the route(s) taking all angle points and topography into cognizance. According to Pandey (Pandey, 2007), stated in his company manual "construction manual for transmission line" that, "the line as surveyed is plotted on the G.T sheet maps indicating all the angle points". Furthermore, Pandey (Pandey, 2007) in his text, construction manual for transmission lines outlined the techniques and guidelines as follows:

i. From the field book entries, route plan and longitudinal profile, commonly referred to as 'Route Profile' or simply 'Profile', is prepared. The profile is prepared and plotted on 1mm /5mm / 1cm square paper rolls of graphed tracing paper. The profile is plotted to a scale of 1cm = 20 m horizontal and 1 cm = 2 m vertical. The profile shall progress from left to right. The height of the sheet shall be taken so that the ground profile and the towers, including extensions can be fully shown. For hilly terrain, greater height of the sheet may be taken, or the sections may be plotted on separate sheets.
ii. The length of each sheet may be taken so that approximately 5 km of the line route can be plotted. A gap of 5 to 10 cm shall be kept between sections.
iii. The profile shall show the longitudinal profiles along the centre line of the transmission and distribution lines route and also the cross-section profile wherever appreciable difference in level exists with reference to the centre line level.
iv. The angle of line deviation, duly marked left (L) or right (R) as the case may be, shall also be shown.
v. The profile shall show the route plan giving details of all objects lying within 50 metres on both sides of the centre line of the route.
vi. Objects and their distances along the route within 50 metres on both sides of the centre line, nearby villages, important roads or rivers shall be marked on the route profile.
vii. Crossing details of any other power or telecommunication lines, roads, railway lines, canals or rivers shall be marked as clearly as possible.
viii. Readings shall be taken of the levels of roads, canal and river embankments, maximum water / flood levels, railway top levels and heights of supports / lines being crossed, and shall be shown in the offsets part of the profile. All trees coming within the zone of the right of way and which need to be cut / trimmed shall also be indicated.
ix. A typical profile is depicted in Figure 1.

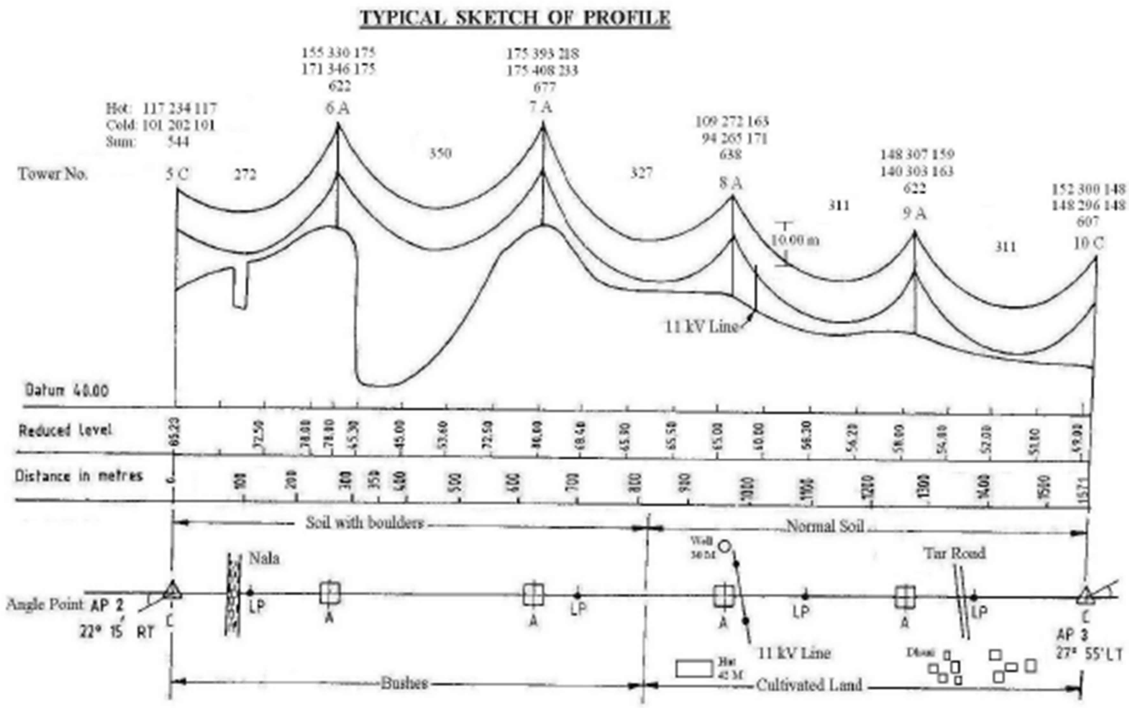


Figure 7: Typical Sample of 11kV Line Route Profile Plotted, Source (Pandey, 2007).

3. CONCLUSION

Having encapsulate the important of this paper and the underlying principles of engineering survey of electric power lines in electrical power systems as a critical aspect of electrical power design and development when carrying-out electrical power systems construction for a particular location or area. It is imperative to note that engineering survey in the area of electric power lines is of a great importance in locating the optimal route for the electrical networks. The transmission and distribution systems are very important to utility companies because its optimal routing minimize the length of conductors and power losses, hence save cost in the network. Consequently, the accurate route line surveying in electrical power systems is a key to designing and developing optimal electrical power network or overhauling existing once. The work intended to meet the needs of diverse range of groups interested in understanding engineering survey especially the areas of Right of Way and Route Profile plotting in electrical power systems and also, to provide reference point for educational purposes and educational advancement in engineering survey as an area of specialty for engineers and surveyors and, to stimulate further research interest.

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