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AutoCAD and Line Design

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ABSTRACT:

To adequately and economically design an overhead power line it is necessary, as a first step, to produce a scaled plan and profile drawing of the proposed line route. This paper describes how Spreadsheets and AutoCAD can be combined to transform raw survey data into the required drawings, without the need for a calculator, a drawing board, or expensive line design software.

INTRODUCTION:

Computer hardware and software represent a major investment within our organisation. To obtain the maximum return from this investment it must be used at every opportunity to contribute to the economic efficiency of operations.

The formal design of overhead lines is one way in which economic efficiencies can be maximised. To date all but three aspects of line design have been improved by the use of computers. Presently non-computerised are

i) the theodolite survey
ii) the calculation of survey points from survey data
iii) the production of the plan and profile drawings.

AutoCAD software and associated hardware represents a major chunk of the computer investment. AutoCAD has been used to design lines using CAD based profile and plan drawings supplied by contractors. AutoCAD based design allows the effect of a wide variety of pole heights and placements to be considered, by simply erasing and redrawing entities on the screen. The use of a plotter significantly reduces the time taken to draw up construction plans. Updates can easily be performed, and drawings easily altered at any time to reflect "as built" configurations. Disk based drawings are easily stored, and easily backed-up to provide complete drawing security.

This paper presents an overview of the line design process, then describes the program developed to enhance it. The FBK field-book program brings together spreadsheets and AutoCAD to calculate survey data and produce plan and profile drawings. The computerisation of ii) and iii) is completed by AutoLISP routines to place poles and catenaries on the drawing. The flexibility of AutoLISP programming within AutoCAD will soon see further automation of design, with the production of materials lists from the finished drawings.

The computerisation of i) remains a subject for future consideration.

1.0 LINE DESIGN

1.1 Reasons for Line Design

A line can be built without design by an experienced line overseer and line gang. The line overseer will take account of rises, hollows and natural obstacles. Observations and line construction experience will be used to choose poles and crossarms, pole locations, and conductor tension. The line overseer must rely on experience to ensure that; the conductor maintains minimum clearances in its final state, a minimum of poles are used, conductors will not clash, and no overloading occurs.

Optimised line construction is not this simple. There are a large number of interactions that occur and trade-offs to be made that can only be properly addressed by a formal design;

> Minimum clearance must be maintained, despite the temperature, over the length of the design, considering also road and rail crossings, and other obstacles.

The final tension of the conductor may not be the same as the stringing tension.

Pole height and strength must be traded–off against the cost of the poles, the number used, and any clearance considerations.

Crossarm length and insulator size must be traded–off against the need to withstand maximum loading and prevent conductor clashing.

Tensions from existing lines must be taken up.

Loading due to conductor uplift, angles, temperature changes and wind must be considered.

1.2 Savings to be made from accurate Line Design.

Taranaki Electricity has developed software to take account of all mechanical loadings over a range of extreme temperatures.

The possible savings to be made from an accurate line design come from;

a line that is mechanically sound in all weather conditions,

use of fewer poles,

determination of minimum strength components,

optimum conductor tension.

2.0 THE PLAN AND PROFILE DRAWING

2.1 Formal Line Design and the Plan and Profile Drawing.

The design begins with an overview of the approximate line route. Features that may require special attention are identified. A potential line route is determined (or a number of possible alternatives).

Following a survey of the area, survey field–book data is processed to provide the horizontal and vertical displacements of survey points. These are then used to produce a drawing showing a plan of the area and a profile of the possible line route(s). The drawing is scaled 1:2000 in the horizontal and 1:500 in the vertical, to show in detail the clearances which must be made.

Poles are drawn to scale at locations which take advantage of rise and fall, and minimise angle loadings. Under the manual system the sag that will give minimum clearance is determined using plastic curves. A PC based sag–tension program developed by Taranaki Electricity is used to determine the corresponding conductor tension.

The tension calculated will determine whether the poles may be shifted further apart or closer together. The design is a trial and error process of pole selection, pole placement, and tension calculation. It relies on the experience and judgement of the designer to determine the most cost effective design which maintains clearances and doesn't overload supports or conductor.

2.2 Processing of Survey Data to produce a Plan and Profile Drawing.

An optical theodolite is used to perform the survey. The tacheometrical method of surveying is employed, using the stadia system to determine the horizontal and vertical displacement of the surveyed points.

At the point being surveyed a graduated staff is held perpendicular. The angle of the theodolite is adjusted so that the cross–hairs of the telescope are focused on the staff. The stadia hair intersections with the staff markings are then recorded in the field–book.

The stadia readings are used to calculate the distance from the theodolite to the staff,

$$D = (f/i) * s * \cos\Theta + (f+c)$$

where f/i = theodolite multiplication constant
$(f+c)$ = theodolite additive constant
s = distance between the stadia hairs.

Also recorded are the horizontal and vertical angle of the theodolite. The vertical angle, Θ, is used to calculate the horizontal and vertical distance to the survey point,

$$H = D\cos\Theta \quad \text{and} \quad V = D\sin\Theta + \text{instrument height}$$

3.0 LINE DESIGN, THE PLAN AND PROFILE DRAWING, AND AUTOCAD

3.1 Transferring Survey Data to AutoCAD.

Line design on AutoCAD was kicked off by a magazine article which presented a simple AutoLISP[1] routine for drawing catenary curves with unequal x–y scales.

A line survey conducted by contractors was supplied as an AutoCAD file with the required 1:2000, 1:500 scaling. This drawing was used to design a line, using appropriately scaled poles and catenaries. The final design was then plotted to produce the construction drawings.

Following this successful design, another design was performed on AutoCAD using a profile produced from field–book data. The survey points were first calculated using a programmable calculator. To obtain the scales required for the AutoCAD drawing a further calculation had to be made for each point. This process was very time consuming.

AutoCAD had been used for line design, but the transferring of survey data to AutoCAD had proved to be a problem.

[1] AutoLISP is the programming language which comes with AutoCAD. AutoLISP programs are run within AutoCAD to perform any of AutoCAD's drawing commands, as well as being able to perform calculations, read and write files.

3.2 Commercially available Line Design Software.

There are programs which will accept field–book data, produce a profile, and then, to a greater or lesser extent, assist with the line design. There are a few things to bear in mind about such programs;

Flexibility – In most cases these programs have evolved from the needs of a major user. They tend to reflect the requirements and preferences of this user; in terms of the information required, the detail of the design, and the construction practices.

Training and support – Owing to the foreign supplier and specialised nature of such programs New Zealand support is seldom available. Anyone who has used any software will know how important software support can be.

Cost – The high cost of some of these programs must be carefully justified, possibly by

a) improved economics of design
b) savings in design time
c) lack of viable alternatives.

Given the already rigorous approach, improved economics of design are unlikely. The programs will provide savings in design time. Most of this saving would come from the production of a scaled drawing from survey data.

Possible viable alternatives must then be considered. Savings in design time can be made by developing software to produce plan and profile drawings. This can be achieved in a reasonable time, utilising existing investment in spreadsheet software and AutoCAD.

4.0 THE "FBK" FIELD–BOOK PROCESSING PROGRAM

4.1 Objectives of the program;

To allow field–book data to be entered into a spreadsheet with a similar layout.

To use the spreadsheet to mark points that are to be included on the profile, and to allow these points to be sorted so that the order of the points on the profile need not be dependant on the order of the survey.

To calculate the survey points using the spreadsheet and then transfer these points to a file that can be read by AutoCAD.

To be able to enter AutoCAD directly upon leaving the spreadsheet, and have the plan and profile plotted.

Survey points to be marked on the drawing, accompanied by a reference.

The plan part of the drawing to include all points.

The profile plotted to include only those points selected in the spreadsheet, in the order determined in the spreadsheet, and joined by a profile line.

The profile points to be drawn directly below the corresponding plan points. Plan and profile drawings labelled as such.

All distances are scaled 1:2000 in the horizontal and 1:500 in the vertical.

As few files as possible created in the process.

4.2 Achievements to date.

For a relatively small time investment all the above objectives have been achieved.

Figure 4.1 shows a typical page from a survey field-book.

Figure 4.2 shows the entry screen of the spreadsheet[2] used to input field-book data (calculated cells are off screen to the right). When all the data has been entered and sorted, ALT–T[3] transfers the calculated cells to AutoCAD for drawing.

Figure 4.3 shows the drawing produced on AutoCAD. Figure 4.4 shows the drawing with poles, conductors, fences, gates and hedges added.

4.3 Files involved in the FBK programme.

FBK is more a programme than a program[4], as it is divided between programs from 3 software packages;

1) FBK.EXE, a compiled QuickBASIC program which is run to start the field-book transformation process. This program is used to run Framework and AutoCAD with options to ensure that the necessary files are loaded. FBK.EXE also performs data manipulation and file management functions.

2) Two Framework spreadsheets,

   i) FBKBLANK.FW3 (which is renamed when used) acts as a field–book entry screen, and contains the stadia calculations.

   ii) FBKLOAD.FW3 which is executed when Framework is run. FBKLOAD.FW3 loads from within itself the macros ALT–S (sort) which allows survey points to be ordered, and ALT–T (transfer) which will recalculate the spreadsheet, export the

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[2]All spreadsheets mentioned are running under Ashton Tate's Framework III.

[3]ALT–T is a spreadsheet macro which executes a series of functions. The macro is run by holding down the ALT key and the T key simultaneously.

[4]A program being a series of coded instructions to control a computer, and a programme a list of a series of events, in this case a series of programs.

calculated survey points and other information to a comma delimited text file[5], then exit Framework.

3) Two files associated with AutoCAD,

i) FBKCAD.SCR, an ASCII text file which is created by FBK.EXE. It is an AutoCAD "script" file which is executed when AutoCAD is run. It loads the plan and profile drawing, passes to AutoLISP the name of the file containing the calculated survey points, loads the AutoLISP routine FBK.LSP and then executes it.

ii) FBK.LSP, an ASCII text file containing the AutoLISP code necessary to read the data from the file containing the calculated survey points and draw it onto the screen, label the points with their reference, draw the profile line, and label "PLAN" and "PROFILE".

None of these files is particularly large or complex, approximate sizes in bytes are;

FBK	.EXE	47 000	(an executable file)
FBKBLANK	.FW3	33 000	(a spreadsheet file)
FBKLOAD	.FW3	2 000	(a spreadsheet file)
FBKCAD	.SCR	75	(an ASCII text file)
FBK	.LSP	3000	(an ASCII text file)

4.4 Operation of the FBK programme.

The FBK.EXE program controls the flow of the programme;

The user enters FBK to start.
The name of their field–book file is requested (.fbk extension is assumed).
User enters "fbkname".

If "fbkname".fbk is found FBK.EXE renames it "fbkname".fw3. If it's not found then FBK.EXE creates it by copying FBKBLANK.FW3 to "fbkname".fw3.

FBK.EXE runs the Framework spreadsheet program, setting the command line options so that "fbkname".fw3 is loaded, and FBKLOAD.FW3 is loaded and executed.

Framework runs, and FBKLOAD.FW3 loads its macros (ALT–S and ALT–T), then opens "fbkname".fw3.

The user enters into the spreadsheet; the jobname, the degree of rotation to be applied to the drawing, and the data from their survey field–book. If a survey

[5] In comma delimited format (CDF) blocks of data are enclosed in quotes and separated by commas, e.g. 1.0 2.0 would appear as "1.0","2.0" in CDF.

point is to be included in the profile, the user types a "p" (or a "P") in the "prof" column. If the survey points need to be re-ordered, the user numbers them in order in the "SORT" column then presses ALT-S to perform the sort.

When all data is entered the user presses ALT-T. The ALT-T macro recalculates the "fbkname".fw3 spreadsheet and saves it. Jobname, rotation and all the calculated cells (hidden from the users view: horizontal azimuth in radians, horizontal, and vertical displacement) are copied to a temporary spreadsheet. This is exported as a comma delimited file, fbktemp.txt, then deleted. Framework is exited.

FBK.EXE renames "fieldbook".fw3 to be "fieldbook".fbk so that it is readily identifiable as a field-book file.

FBK.EXE converts the comma delimited file fbktemp.txt to a single column of data[6] in a file named "fieldbook".cad. Fbktemp.txt is then deleted.

FBK.EXE writes the script file FBKCAD.SCR, so that when AutoCAD is run the drawing "fbkname".dwg will be used.

FBK.EXE runs AutoCAD, with FBKCAD.SCR to take over as soon as AutoCAD begins.

AutoCAD runs, and FBKCAD.SCR loads "fbkname".dwg (as a new drawing if necessary). FBKCAD.SCR then enters the filename "fbkname".cad as an AutoCAD variable. It then loads and executes FBK.LSP.

FBK.LSP gets the variable "fbkname", then opens the "fbkname".cad file, reads the data line by line, plots the survey points, draws the profile, and enters the survey point identifiers. The file "fbkname".cad is then deleted, as all of its information is stored in the drawing.

The user is now free to use the plan and profile drawing for design.

The only files created are the "fbkname".fbk spreadsheet, which is left available for future alteration or addition, and the "fbkname".dwg AutoCAD drawing file.

5.0 FUTURE PLANS FOR AUTOCAD AND LINE DESIGN

At the time of writing the FBK programme can be used to produce a plan and profile drawing. Poles of various types can be selected from the AutoCAD tablet menu and placed on the drawing. Catenaries of a selected sag can be strung between these poles.

Menu macros and AutoLISP routines are being developed to automate the drawing of fence

[6]AutoLISP can read data from files either line by line, or character by character. Data is easily extracted from a single column file by reading it line by line. QuickBASIC can easily produce such a file as it recognises the comma delimited format.

lines, hedges, gates and trees. About to be added are poles with attributes that record their type, and their crossarm and insulator info. Once this is done these attributes can be exported from the drawing to produce a materials list text file that can be read by a word processor, or a spreadsheet, or a database.

Other future plans include anything suggested by the end users of the software.

6.0 RECOMMENDATIONS

There are many good reasons to rigorously design overhead power lines, not the least of them being economic optimisation.

The design process can be improved in terms of speed, accuracy and flexibility by the use of AutoCAD.

Much of what can be done by expensive programs developed for large organisations can be performed on a smaller scale by using existing programmable software.

Software developed in–house can be flexible to the needs of its users; in terms of formats, design criteria, support, and upgrades. If the right software is used for the job (in this case spreadsheets for data input and calculations, AutoCAD for graphics, QuickBASIC as an organiser) then the costs of such developments can be minimised.

7.0 ACKNOWLEDGEMENTS

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8.0 REFERENCES

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Advanced Techniques in AutoCAD, 2nd Edition R.M.Thomas, Sybex, 1989.

AutoCAD Release 11 and associated manuals Autodesk, 1990.

QuickBASIC 4.0 and associated manuals Microsoft, 1987.

Framework III and associated manuals Ashton Tate, 1988.

Figure 4.1 Typical page from survey field-book

Eng. Form 105

JOB S/C FOR SLATTERY SOUL ROAD

F.B. & Page No. 1

Date 7/10/91

Station/ Location	Azimuth	Slope	Stadia Wires			Red. Dist.	Rise Fall	Inst. Hgt	Remarks
			B	C	T				
AT INST A ON PP1	0°0'0"							1.60	
H1	21°29'51"	97°58'51"	0.66	1.0	1.34	66.7	-8.75		
H2	0°07'21"	97°27'00"	0.68	1.0	1.32	62.9	-7.628		
F1	356°25'21"	97°02'21"	0.675	1.0	1.325	64.0	-7.306		
PP1	359°43'51"	96°55'39"	0	1.0	1.355	70.0	-7.961		
F2	346°29'06"	96°34'27"	1.175	1.5	1.825	64.1	-7.293		
F3	255°49'30"	98°27'12"	1.165	1.8	1.995	38.2	-5.58		
PP3	181°24'45"	92°09'00"	0.70	1.0	1.30	59.9	-1.649		REPLACE CE. POLE
A1	105°10'36"	91°30'18"	0.44	0.5	0.56	12.0	+0.755		
A2	111°16'54"	87°53'36"	0.84	1.0	1.16	32.0	+1.776		
A3	112°35'12"	87°01'27"	0.70	1.0	1.30	59.8	+3.711		
A4	117°24'30"	84°01'15"	0.70	1.0	1.30	59.3	+6.815		
A5	115°37'12"	84°8'27	0.56	1.0	1.44	87.1	+9.536		
A6	111°51'00"	86°42'30"	0.56	1.0	1.44	87.7	+5.642		
A7	111°23'12"	85°44'30"	0.44	1.0	1.56	111.4	+8.590		
A8	108°58'42"	85°01'54"	0.36	1.0	1.64	146.9	+13.269		
A9	112°46'36"	83°50'41"	0.52	1.20	1.88	134.4	+14.593		E/LOV
(H3?) A10	114°36'45"	43°09'37"	0.35	1.00	1.65	125.2	+15.974		
F4 PIN	122°26'22"	79°59'33"	1.49	2.00	2.51	98.9	+17.056		
(H2) A11	119°09'00"	81°54'00"	3.34	4.00	4.66	129.4	+15.829		

THEODOLITE CONSTANTS printed 16/10/91
stadia additive
ratio (mm)
100 0

Figure 4.2 FBK spreadsheet entry screen

Use: ALT-S to sort stations
ALT-T to transfer data to AutoCAD

JOB>solerd

The Rotate> entry: determines rotation of plan profile dwg

ROTATE> -90

Put "P" in the Prof column to include pt in profile
Use # in front of the stn to indicate an inst pt

Prof SORT	inst	stn	Azmth	dd.mmss Slope	BW	Stadia Wires CW	TW	remarks
====								
	1.600	H1	21.2851	97.5851	.66	1	1.340	
	1.600	H2	.0721	97.2700	.68	1	1.320	
	1.600	F1	356.2521	97.0221	.675	1	1.325	
	1.600	PP1	359.4351	96.5839	.645	1	1.355	
	1.600	F2	346.2906	96.3427	1.175	1.50	1.825	
	1.600	F3	355.4930	98.2712	1.615	1.80	1.985	
	1.600	PP3	181.2445	92.0900	.700	1	1.300	
p	1.600	A1	105.1036	91.3018	.440	.50	.560	
p	1.600	A2	111.1654	87.5336	.840	1	1.160	
p	1.600	A3	112.3512	87.0127	.700	1	1.300	
	1.600	A4	117.2430	84.0118	.700	1	1.300	
	1.600	A5	115.3712	84.0827	.560	1	1.440	
p	1.600	A6	111.5900	86.4236	.560	1	1.440	
p	1.600	A7	111.2312	85.4436	.440	1	1.560	
	1.600	A8	108.5842	85.0154	.360	1.10	1.840	
	1.600	A9	112.4636	83.5041	.520	1.20	1.880	
p	1.600	A10	114.3648	83.0933	.350	1	1.650	
	1.600	F4	122.2622	79.5933	1.490	2	2.510	
	1.600	#A11	115.0900	81.5900	3.340	4	4.660	
	1.500	H4	248.4400	94.0421	.710	.800	.890	
p	1.500	B1	165.0100	100.4124	.925	1	1.075	
p	1.500	B2	167.5018	102.1127	.810	1	1.190	
p	1.500	B3	167.1255	101.5936	.640	1	1.360	
p	1.500	H5	166.3327	100.0948	1.440	2	2.560	
	1.500	H6	156.4148	99.4706	1.440	2	2.560	
p	1.500	F5	168.5009	98.5851	3.390	4	4.610	
p	1.500	B3a	168.0124	98.5742	3.340	4	4.660	
p	1.500	B4	166.2242	98.4958	3.180	4	4.820	
p	1.500	B5	165.1313	97.5509	.960	2	3.040	
p	1.500	#F7	164.0606	95.2133	.680	2	3.320	
	1.390	F8	256.1718	95.0806	.935	1	1.065	
p	1.390	C1	181.3600	80.3145	.395	.500	.605	
p	1.390	#F9	183.4621	79.2915	.760	1	1.240	
	1.550	F10	168.4810	91.0342	.440	.500	.560	
	1.550	F11	346.1621	104.0933	.905	1	1.095	
	1.550	F12	339.0018	102.5400	.775	1	1.225	
	1.550	F13	348.3212	100.5522	.680	1	1.320	
	1.550	F14	324.0442	107.2112	.895	1	1.105	
	1.550	D1	256.5845	103.2809	.900	1	1.100	
	1.550	F15	221.1651	106.4309	.940	1	1.060	
p	1.550	D2	197.2418	100.1439	.900	1	1.100	
p	1.550	D3	194.5631	100.2134	.810	1	1.190	
p	1.550	F15A	194.5542	101.2137	.660	1	1.340	
	1.550	F16	184.1524	97.1415	4.180	4.500	4.820	
p	1.550	D4	194.5545	100.1122	.570	1	1.430	
p	1.550	D5	195.5409	98.2324	.400	1	1.600	

Figure 4.3 Drawing produced on AutoCAD (reduced)