Tennessee Valley Authority

Thermal Assessment of Existing 161kv & 500kv Transmission Lines

TVA Power Service Area



Why are we gathering aerial laser survey & doing thermal assessments?

- Before 1977; NESC ground clearance requirements @ 120°F (49°C)
- 1977 NESC code required clearances at maximum operating temperature
- Have generally designed new lines for 100°C since 1977

Transmission Line Assessment and Up-Rate Program

Background

- NESC Code for Lines Built Before 1977 Required Clearance be Maintained for a Conductor Temperature of 49 Degrees C
- 1977 NESC Code Revision Required Clearances be Maintained Based on Actual Operating Temperatures
- Peak Conditions Typically Require Operation between 80 100 Degrees C
- Transmission Line Operation and Clearance Requirements are a Matter of NERC Compliance. The scope includes 8,137 Miles of Transmission Line
 - 2,405 Miles of 500-kV Transmission Lines
 - 5,662 Miles of 161-kV Transmission Lines
 - 70 Miles of 46/69-kV Transmission Lines
- Current Asset Condition Could Impact Reputation and Cost
 - Assumed Rating Could Lead to NERC Reportable Flashover Events
 - Increased Risk of Public Contact Events
 - NESC or NERC Violations Receive More Scrutiny Since Blackout of 2003

TVA in-house engineering assessed about 30% of our lines

> Burns & McDonnell Mesa Associates Sargent & Lundy

Aerotec LLC Optimal Geomatics Geodigital Network Mapping Terrapoint USA Inc Tuck Engineering

MESA coupled with Optimal Geomatics S&L coupled with Geodigital Burns & Mac and Network Mapping Vertical clearance of conductors above roads, driveways, parking lots, areas subject to truck traffic, unpaved land subject to cultivating.

	<u>69kV</u>	<u>161kV</u>	<u>230kV</u>	<u>500kV</u>
TVA	22.1	24.1	25.5	29.8
NESC	19.1	21.1	22.5	26.8
delta	3.0	3.0	3.0	3.0

Lidar NESC + 1 ft. 20.1 22.1 23.5 27.8

- Buffer is 1ft.
- Need to model as accurate as possible with lidar
- Why?- affects the sag/clearance (long spans could change sag several feet)
- If there is a violation, could be significat cost for modification

Graphical Sag Options			?
Snap Mode			
 Fit to survey point closest to mouse Fit to mouse cool 	rdinates		
Fit Mode			
 1) Ruling Span Horizontal tension is always the same for all spans in section. Sagging tension and condition will be changed. Display condition will be changed. 			
2) Finite Element Insulators Plumb at Sagging Condition. Horizontal tension constant throughout section at sagging condition but may vary at Sagging tension will be changed. Display condition will be changed.	other conditions.		
3) Finite Element Selected Spans Wire Length Adjustment Adjust length of wire in selected spans without regard for effects on other spans. Wire lengths for selected spans will be changed. Display condition will be changed.			
4) Finite Element All Spans Wire Length Adjustment Adjust wire length in all spans to fit selected point(s) without changing mid span wire Wire length for all spans in section will be changed. Display condition will be change	elevation in other spa d.	ns.	
Tip: There can be a delay after each left click while wire is fit to the selected point(s) points without a fit delay. When done selecting points use a left click to perform the	Use middle clicks o iit.	r the Enter key to) select
5) Finite Element Manual Length Adjust Manually enter change in unstressed wire length for a span. Unstressed wire length for selected spans is changed. Display condition will be char	nged.		
 6) Finite Element Multiple Point Fit Calculate catenary constant and required wire & insulator attachment points required May change wire lengths, structure locations and display condition. 	to fit through three po	pints in each spa	n.
🚽 🔲 Adjust wire length in each span to fit calculated catenary and wire attachment po	ints		
Adjust structure stations, height and offset adjustments to match calculated insula	tor attachment points	:	
🚽 🔲 Follow up with a Finite Element All Spans Wire Length Adjustment (option 4) after	adjustments above		
Version of the second secon	ve Maxidistand	e from 3 point	(ft) 3.000
Generate report showing attachment point locations and tensions	Wire attach featur	e 17	D2 cond mid EE6
🗹 Draw markers showing fit results (fit points, catenary curve, attachment points)	Insulator attack fr	abura 17	
Create survey points at calculated mid span and wire/insulator attachment points	Mid an an animt for		J2 cona mia FE6 💙
	Mid span point rea	iture 17	J2 cond mid FE6 🚩
Feature code for structure points (may be used to help refine attachment point calcul	ation)	99999 Substati	on Data 🛛 😽 😽
Automatically select fit points in each span (for fit mode 4 and 6) Feature code	e for wire fit	1701 Conducto	or (OH)-Transmis: 🔽
Use single point closest to current wire position (old way)			
O Use centroid of all points within 1m of current wire position (tends to err on high	side for bundles)		
OUse center of rectangle encompassing all points within 1m of current wire posit	ion (acod for bundles	but sensitive to	outliers)
Ollse lowest of all points within 1m of current wire position (good for bundles but	sensitive to outliers)		,
Ollise center of smallest circle enclosing all points within 1 m of current wire food	d for bundles but mai	the sensitive to a	outliers)
Les bunde, aware centroid: centroid of coch wich controids using asiste with	in 1m of our ont posit	ion (less consitiu	e to outliere)
Enter either the bundle diameter : (in) 13.000 or the bundle s	pacing: (in)	13.000	e to outliers)
Show web technical note "Graphical Sag Uptions: Making the Wire System Match	n As-Built Survey Po	lints"	UK Cancel

With lidar

Structure location +- 0.2 ft Wire tension +- 20 lbs Ground/obstacles +- 0.2ft

However,

Temperature not directly measured.

Derived from IEEE 738

As Captured Match Lidar 110.3deg Creep FE



:ion): Section #8, phase 1, 161kV, 'rail acsr 954 45_7', from Str. #74B Set 9 'Mahead' to Str. #E216A Set 4 'MID Back', Section at cond (74B-E216A) 110.3deg 'Creep FE', S=34710.86

212 deg F creep FE



Steps to get FE sag

- Alignment
- Structure locations (station/offset)
- Conductor temperature (weather data)
- Assume sagging temperature (plumb INS)
- As captured least square best fit Tension (FE6)
 Used to get tension not move structures
- Adjust each span at mid span (non-plumb INS)FE3

First locate structures (cross section view)

📴 PLS-CADD - springfield-logan aluminum.xyz - tva tower - [Cross Section View]		
🌃 File Edit View Terrain Criteria Structures Sections Lines Drafting Window Help		_ @ ×
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x]		
x		~
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Reauy		NUM

Example of locating structures to match the lidar ghost



ucture): Struct #87 'g:\common\civil\pls\jld (unchecked)\tower\a24\2-cond bundle\a24 48body 28leg 2-cond bundle.tow' 5=34337.75 Strengt

Present Location (hgt=4.0 offset 0.0)

Structure Modify				? 🛛
Structure #87 Line angle (deg) 0.00		Structure Comments		Set Counter 🛕
(1	87		Weight(lbs)
18body 28leg 2-cond bundle	2	A24 82	1	Ξ
Station (ft) 34337.75	3		2	
Height adjust. (ft) 4.00	4		3	
Urrset adjust. (rt) 0.00	5		4	
		Y	_	V
<u>Prev</u> <u>N</u> ext <u>V</u>	iew	<u>E</u> dit <u>Material</u> Google Earth		<u>D</u> K <u>C</u> ancel

Adjust Height & Offset (hgt=4.4 offset 0.5)

Structure Modify				? 🗙
Structure #87 Line angle (deg) 0.00		Structure Comments		Set Counter 🛕
	1	87		Weight(lbs)
18body 28leg 2-cond bundle	2	A24 82	1	=
Station (ft) 34337.75	3		2	
Height adjust. (ft) 4.40	4		3	
Uttset adjust. (tt) 0.50	5		4	
oneritation (dey) o		V		<u> </u>
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:ructure): Struct #87 'g:\common\civil\pls\jld (unchecked)\tower\a24\2-cond bundle\a24 48body 28leg 2-cond bundle.tow' S=34337.75 Strength=Pending



Adjust Station (37337.75 to 37337.4)

Structure Modify									
Structure #87 Line angle (deg) 0.00		Structure Comments	^		Set Counter 🛕				
·····	1	87			Weight(lbs)				
\$8body 28leg 2-cond bundle	2	A24 82		1	=				
Station (ft) 34337.40	3			2					
Height adjust. (ft) 4.50	4			3					
Offset adjust. (ft) 0.50	5			4					
Orientation (deg) 0			Y	_	<u> </u>				
<u>Prev</u> <u>N</u> ext <u>V</u>	iew (<u>E</u> dit <u>M</u> aterial Google Earth			<u>D</u> K <u>C</u> ancel				





ucture): Struct #89 'g:\common\civil\pls\jid (unchecked)\tower\161kv\geometry only\c24\2-cond bundle\c24 48body 16ext 28leg 2-cond bundle.tow' S=36930.37 Stre













Example of As built not on Drawing E.C. tr 154 no special conductor spacing NEI 700 1335 1205 1265 E1 600 1338 9 EI. 500 153 155 156 754

74.4





Eit to survey point closest to mouse		P 1			4
	Fit to mouse coor	dinates			
Fit Mode			Before	you car	do graphic
 1) Ruling Span Horizontal tension is always the same for all spa Sagging tension and condition will be changed. 	ns in section. Display condition will be changed.		sag you	i must o	letermine a
2) Finite Element Insulators Plumb at Sagging C Horizontal tension constant throughout section Spacing tension will be alwayed. Display and the section of the section o	ondition. at sagging condition but may vary at c	ther conditions.	capture	condu	ctor
 3) Finite Element Selected Spans Wire Length A Adjust length of wire in selected spans without r Wire lengths for selected spans will be changed 	Adjustment egard for effects on other spans. I. Display condition will be changed.		tempera	ature	
4) Finite Element All Spans Wire Length Adjustr Adjust wire length in all spans to fit selected poir Wire length for all spans in section will be chang	nent nt(s) without changing mid span wire e ged. Display condition will be change	levation in other spans d.	5.		
Tip: There can be a delay after each left click w points without a fit delay. When done selecting	while wire is fit to the selected point(s). points use a left click to perform the fi	Use middle clicks or ti t.	he Enter key to sele	ct	
5) Finite Element Manual Length Adjust Manually enter change in unstressed wire length Unstressed wire length for selected spans is cha	n for a span. anged. Display condition will be chan	ged.			
 6) Finite Element Multiple Point Fit Calculate catenary constant and required wire 8 May change wire lengths, structure locations ar 	insulator attachment points required l d display condition.	o fit through three poir	nts in each span.		
Adjust wire length in each span to fit calcula	ted catenary and wire attachment poi	nts			
Adjust structure stations, height and offset a	djustments to match calculated insulat	or attachment points			
📃 🔲 Follow up with a Finite Element All Spans Wi	re Length Adjustment (option 4) after	adjustments above			
🛛 🔽 Least squares fit to all wire points within spec	cified distance of 3 point catenary cur	ve Max distance	from 3 point (i	it) 3.000	
Generate report showing attachment point lo	cations and tensions	Wire attach feature	1702.00	nd mid EE 6 🔽	
🚽 🗹 Draw markers showing fit results (fit points, c	atenary curve, attachment points)	Insulator attach fea	1702 co		
🔽 Create survey points at calculated mid span	and wire/insulator attachment points	Mid apap point feature			
		······································	" ^e 1702 co	nd mid FE6 🎽	
Feature code for structure points (may be used t	o help refine attachment point calcula	tion)	99999 Substation Da	ata 🔽	
Automatically select fit points in each span (for f	it mode 4 and 6) Feature code	for wire fit	1701 Conductor (OH)-Transmis: 🔽	
O Use single point closest to current wire po	sition (old way)				
OUse centroid of all points within 1m of curr	ent wire position (tends to err on high	side for bundles)			
O Use center of rectangle encompassing all	points within 1m of current wire positi	on (good for bundles b	ut sensitive to outlie	rsì	
OUse lowest of all points within 1 m of curren	nt wire position (acod for bundles but :	sensitive to outliers)		·	
O Use center of smallest circle enclosing all	points within 1 m of current wire (good	for bundles but may b	e sensitive to outlier	sì	
A Lies hundle suure controld control of or	ach wire's centroids using points withi	n 1m of current position	n (less sensitive to o	utliers)	
		or contoric position			4

IEEE Std 738-2006 Steady-State Conductor Temperature		? 🗙
THERMAL CALCULATIONS METHOD IEEE Standard 738-2006	CIGRE Brochure 207	
SOLAR HEATING DATA Day of Year ● Use day of year producing maximum solar heating ● Use specified day of year O7/08/2009 ▼ Line Direction ● Line perpendicular to solar azimuth (maximum solar heating) ● Use specified line azimuth ●	WEATHER DATA (deg F) 104 Air temperature (deg F) 104 Wind Speed (ft/s) 2 Wind to conductor angle (0=parallel) (deg) 90 Conductor elevation (ft) CONDUCTOR DATA Cable file name goes here	
Steady-state ac current (Amps) 100		
Provide a name for the graph:	OK Car	ncel





		GMT	CDT	deg C	m/s				
				Temp	Wind	Wind			
	Date	Time		Out	Speed	Dir			
	01/05/2005	22:51	5:51 PM	18.9	1.3	NNW	337.5		
	01/05/2005	22:52	5:52 PM	18.9	0.9	W	270		
	01/05/2005	22:53	5:53 PM	18.9	1.3	W	270		
	01/05/2005	22:54	5:54 PM	19.1	0.9	W	270		
	01/05/2005	22:55	5:55 PM	19.1	1.8	WSW	247.5		
	01/05/2005	22:56	5:56 PM	18.9	2.2	WNW	292.5		
	01/05/2005	22:57	5:57 PM	18.9	3.1	WNW	292.5		
	01/05/2005	22:58	5:58 PM	18.9	1.3	NW	315		
	01/05/2005	22:59	5:59 PM	18.9	1.3	NW	315		
	01/05/2005	23:00	6:00 PM	18.9	1.8	NNE	382.5	Not us	e 22.5
	01/05/2005	23:01	6:01 PM	18.9	1.3	W	270		
	01/05/2005	23:02	6:02 PM	18.9	0.9	N	360		
	01/05/2005	23:03	6:03 PM	18.9	2.2	NW	315		
	01/05/2005	23:04	6:04 PM	18.9	2.2	WSW	247.5		
				ave	ave				
				18.9	1.61				
				deg F	ft/s		ave /	Average a	about WNW
				66.1	5.27		298.93		
						max	382.5	NNE	
							83.57		
	Use average	e for flight ti	me + 5min						
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~									
						min	247.5	WSW	
Temp not va	riable bu	t wind sp	beed and	directic	n are		-51.43		
•									

#### Easting & Northing from PI report gives Azimuth

Convert Flight Time to Sun Time

Using difference between Azimuth and wind direction gives wind angle, for example from str 124 to Colbert AZ=59deg Wind Dir = 298.9deg

121	05/0	1/2005										
STR #	STR TYPE	EASTING	NORTHING	FLIGHT TIME	SUN TIME	AVERAGE SUN TIME	AZIMUTH (MATCH) (PLS)	TEMP (°F)	WIND (fps)	WIND DIRECTION (DEG)	WIND ANGLE	USE WIND Angle
Oakland	PULL-OFF	1884910.98	1768918.28	17:09CDT	16.3446	16.35	96	66.9	8.67	296.3	19.8	45
66	H20 80	1885455.9	1768856.85	17:10CDT	16.3613	16.42	314	66.7	8.88	303.8	10.7	30
74	H20 56	1880219.14	1773986.5	17:17CDT	16.4780	16.49	220	66.5	8.10	308.1	88.0	90
77	H20 72	1878180.74	1771560.55	17:19CDT	16.5113	16.59	191	66.5	8.26	313.9	57.1	75
89	H20 60	1875709.96	1758881.66	17:29CDT	16.6780	16.70	183	66.4	8.65	308.6	54.3	75
93	G20 68	1875515.79	1754977.75	17:32CDT	16.7280	16.83	199	66.3	8.19	301.3	77.5	90
109	G20 84	1869634.3	1737708.284	17:44CDT	16.9280	16.95	216	66.1	6.56	303.8	87.7	90
112/72	G20 76	1867851.79	1735256.66	17:47CDT	16.9780	16.99	228	66.2	5.93	296.0	68.1	90
115/69	M21 80	1865148.42	1732812.296	17:49CDT	17.0113	17.03	228	66.2	5.70	289.0	61.2	90
118/66	M21 80	1860347.73	1728470.06	17:51CDT	17.0446	17.05	211	66.2	6.53	283.1	72.4	90
119/65	H20 92	1859934.45	1727774.05	17:52CDT	17.0613	17.09	149	66.1	6.21	295.7	33.7	60
122/62	H20 92	1861123.3	1725760.41	17:55CDT	17.1113	17.11	140	66.1	5.40	296.6	23.6	45
123/61	H20 92	1861703.3	1725065.52	17:55CDT	17.1113	17.12	55	66.1	5.30	294.4	59.4	75
124	H20 60	1862397.32	1725552.74	17:56CDT	17.1280	17.15	59	66.1	5.27	298.9	60.1	75
Colbert	Pulloff	1862890.59	1725850.63	17:59CDT	17.1780							
#### IEEE uses cond elev, Latitude, and Amps Longitude is used for Sun Time

STR #	STR TYPE	COND ELEVATION	LATITUDE (DEG)	LONGITUDE (DEG)	COND AMPS	COND
Oakland	PULL-OFF	668	34.862053	87.778484	211.6	636 26/7
66	H20 80	627			211.6	636 26/7
74	H20 56	631			211.6	795 26/7
77	H20 72	632			219.8	795 26/7
89	H20 60	577			211.6	795 26/7
93	G20 68	578			221.0	795 26/7
109	G20 84	557			122.5	795 26/7
112/72	G20 76	579			122.5	795 26/7
115/69	M21 80	656			122.5	795 30/19
118/66	M21 80	549			122.5	795 26/7
119/65	H20 92	525			122.5	795 26/7
122/62	H20 92	546			122.5	795 26/7
123/61	H20 92	525			122.5	795 26/7
124	H20 60	506			118.5	795 26/7
Colbert	Pulloff		34.74356	87.85167		
			AVG LAT	AVG LONG		
			34.8028	87.8151		





To Demonstrate Graphically Using F7 (measure) azi 298.9 line shows angle between conductor & wind Angle = 60.1deg But from the weather data variance in wind direction +-

Therefore, use 75deg (more cooling)

NUM

- Weather instruments:
- Multiple Davis Instruments Weather Wizard III portable weather stations with recording equipment in vinyl container and with weather probes mounted on telescopic masts.
- Temperature accuracy: +/- 1 degree F
- Temperature range: -50 degrees F to 140 degrees F
- Wind speed accuracy: +/- 5%
- Wind speed range: 2 mph to 150 mph (2.9 ft/sec to 220 ft/sec)
- Wind direction accuracy: +/- 7 degrees

$$LST = CT + \left(\frac{1}{15}\right) \left(L_{std} - L_{loc}\right) + E - DT \quad [hr]$$

Equation 2

#### **Equation for Sun Time**

Where:

- LST = Local Solar Time [hr]
- CT = Clock Time [hr]
- Lstd = Standard Meridian for the local time zone [degrees west]
- Lloc = Longitude of actual location [degrees west]
- E = Equation of Time [hr]
- DT = Daylight Savings Time correction (DT = 0 if not on Daylight Savings Time, otherwise DT is equal to the number of hours that the time is advanced for Daylight Savings Time, usually 1hr)

In using Equation 2, all of the times must first be converted to decimal format from zero to 24, (e.g., a clock time of 3:45 p.m. is expressed as CT = 15.75 hr). Values of the Equation of Time, E, are calculated by:

$$E = 0.165 \sin 2B - 0.126 \cos B - 0.025 \sin B$$
 [hr] Equation 3a

where: 
$$B = \frac{360(n-81)}{364}$$
 [degrees]

and n is the day of the year.

#### =CT+(1/15)*(IF(OR(C8="CST",C8="CDT"),90,IF(OR(C8="EST",C8="E DT"),75,"Check"))-A8)+(0.165*SIN(2*RADIANS(360*(n-81)/364))-0.126*COS(RADIANS(360*(n-81)/364))-0.025*SIN(RADIANS(360*(n-81)/364)))-IF(OR(C8="CST",C8="EST"),0,IF(OR(C8="CDT",C8="EDT"),1,"Check" ))

# **Equation in EXCEL**

## Also, use website

http://aa.usno.navy.mil

#### U.S. Naval Observatory Astronomical Applications Department

#### Sun and Moon Data for One Day

The following information is provided for Sheffield, Colbert County, Alabama (longitude W87.7, latitude N34.8):

s 1	unday . May 2005	Central Da	aylight	Time
	SUN			
В	egin civil twilight	5:33	a.m.	
3	Sunrise	6:00	a.m.	
S	Sun transit	12:48	p.m.	
3	Sunset	7:36	p.m.	
Е	nd civil twilight	8:03	p.m.	
	MOON			
М	loonset	11:26	a.m. or	n preceding
day				
М	loonrise	2:22	a.m.	
М	loon transit	7:27	a.m.	
М	loonset	12:39	p.m.	
М	loonrise	2:59	a.m. or	n following
day				

-48/60 = -0.80 17:59 =17.98 -0.80 = 17.18 (matches spreadsheet)

IEEE Std. 738-2006 method of calculation

Air temperature is 66.10 (deg F) Wind speed is 5.27 (ft/s) Angle between wind and conductor is 75 (deg) Conductor elevation above sea level is 506 (ft) Conductor bearing is 59 (deg) (user specified bearing, may not be value producing maximum solar heating) Sun time is 17.15 hours (solar altitude is 19 deg. and solar azimuth is -85 deg.) Conductor latitude is 34.8 (deg) Atmosphere is CLEAR Day of year is 121 (corresponds to May 1 in year 2009) (user specified day, may not be day producing maximum solar heating)

Conductor description: 795 kcmil 26/7 Strands DRAKE ACSR - Adapted from 1970's Publicly Available Data Conductor diameter is 1.108 (in)

Conductor resistance is 0.1166 (Ohm/mile) at 77.0 (deg F)

and 0.1390 (Ohm/mile) at 167.0 (deg F) Emissivity is 0.7 and solar absorptivity is 0.9

Solar heat input is 3.396 (Watt/ft) (corresponds to Global Solar Radiation of 40.865 (Watt/ft^2) - which was calculated)

Radiation cooling is 0.514 (Watt/ft)

```
Convective cooling is 3.190 (Watt/ft)
```

Given a constant ac current of 118.5 amperes, The conductor surface temperature is <u>74.6 (deg F)</u>

Surface? Change in PLS 10.002

# Range Ambient <u>66.1</u> to Only Uncertain Variable No Wind <u>90.7</u> previous 74.6

Lower Bound Ambient too Conservative

Upper Bound No wind not realistic 2fps min

IEEE Std. 738-2006 method of calculation

Air temperature is 66.10 (deg F)

Wind speed is 0.00 (ft/s)

Angle between wind and conductor is 75 (deg)

Conductor elevation above sea level is 506 (ft)

Conductor bearing is 59 (deg) (user specified bearing, may not be value producing maximum solar heating)

Sun time is 17.15 hours (solar altitude is 19 deg. and solar azimuth is -85 deg.)

Conductor latitude is 34.8 (deg)

Atmosphere is CLEAR

Day of year is 121 (corresponds to May 1 in year 2009) (user specified day, may not be day producing maximum solar heating)

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Emissivity is 0.7 and solar absorptivity is 0.9
```

Solar heat input is3.396 (Watt/ft) (corresponds to Global Solar Radiation of 40.865 (Watt/ft^2) - which was<br/>calculated)Radiation cooling is1.559 (Watt/ft)Convective cooling is2.157 (Watt/ft)

Given a constant ac current of 118.5 amperes, The conductor surface temperature s 90.7 (deg F)

IEEE Std 738-2006 Steady-State Conductor Tempera	ture 🦳 🔀
THERMAL CALCULATIONS METHOD	
⊙ IEEE Standard 738-2006	CIGRE Brochure 207
Day of Year	WEATHER DATA Air temperature (deg F) 104
<ul> <li>Use day of year producing maximum solar heating</li> </ul>	Wind Speed (ft/s) 2
OUse specified day of year	Wind to conductor angle (0=parallel) (deg) 90
C Line Direction	Conductor elevation (ft)
O Line perpendicular to solar azimuth (maximum solar heating)	CONDUCTOR DATA
Use specified line azimuth     (deg)	Cable file name Cable file name goes here
Latitude (deg) 30 Sun time (10=10am, 14=2pm,99= no sun) 11 Atmosphere CLEAR CLEAR INDUSTRIAL	Clear is clean air and industrial is dirty air, Particulates increase conductivity
CALCULATION DATA	
Steady-state ac current (Amps)	
Provide a name for the graph:	OK Cancel

# Sky Not Always Clear

**History : Weather Underground** 

Time: Temp.: DewPoint: Humidity: Sea Visibility: WindDir:Wind:Gust										
(CDT)			Level:		SpeedSpeed: Precip: Eve	nts:Conditions:				
			Pressure							
8:53 AM	53.1 °F	41.0 °F	64% 30.20 in	10.0 miles	Calm Calm - N/A	Clear				
9:53 AM	59.0 °F	37.0 °F	44% 30.21 in	10.0 miles	Calm Calm - N/A	Clear				
10:53 AM	61.0 °F	33.1 °F	35% 30.21 in	10.0 miles	WNW 9.2 mph - N/A	Clear				
11:53 AM	63.0 °F	33.1 °F	33% 30.21 in	10.0 miles	WNW 10.4 mph 16.1 mph N/	A Clear				
12:53 PM	64.0 °F	34.0 °F	33% 30.18 in	10.0 miles	Variable 6.9 mph - N/A	Clear				
1:53 PM	64.0 °F	35.1 °F	34% 30.17 in	10.0 miles	Variable 4.6 mph - N/A	Partly Cloudy				
2:53 PM	64.9 °F	37.0 °F	36% 30.16 in	10.0 miles	Variable 4.6 mph - N/A	Clear				
3:53 PM	66.0 °F	39.0 °F	37% 30.14 in	10.0 miles	WNW 6.9 mph - N/A S	catteredClouds				
4:53 PM	66.0 °F	37.0 °F	34% 30.13 in	10.0 miles	WNW 13.8 mph - N/A	Partly Cloudy				
5:53 PM	6.0 °F	36.0 °F	33% 30.12 in	10.0 miles	NW 10.4 mph - N/A	Clear				
6:53 PM	63.0 °F	35.1 °F	35% 30.12 in	10.0 miles	NW 6.9 mph - N/A	Clear				
7:53 PM	55.9 °F	39.9 °F	55% 30.12 in	10.0 miles	Calm Calm - N/A	Clear				
8:53 PM	51.1 °F	43.0 °F	74% 30.12 in	10.0 miles	South 3.5 mph - N/A	Partly Cloudy				
9:53 PM	48.0 °F	43.0 °F	83% 30.13 in	10.0 miles	SSW 3.5 mph - N/A	Partly Cloudy				
10:53 PM	46.0 °F	41.0 °F	83% 30.14 in	10.0 miles	Calm Calm - N/A	Clear				
11:53 PM	45.0 °F	42.1 °F	90% 30.14 in	10.0 miles	Calm Calm - N/A	Clear				

	GMT	CDT	deg C	m/s			Watts/m ²	Watts/ft ²			
			Temp	Wind	Wind		Solar		Drake 795	26/7	
Date	Time		Out	Speed	Dir		Rad.		dia		
01/05/2005	22:51	5:51 PM	18.9	1.3	NNW	337.5	275	25.55	1.108	2.359	
01/05/2005	22:52	5:52 PM	18.9	0.9	W	270	271	25.18	1.108	2.325	
01/05/2005	22:53	5:53 PM	18.9	1.3	W	270	262	24.34	1.108	2.247	
01/05/2005	22:54	5:54 PM	19.1	0.9	W	270	243	22.58	1.108	2.084	
01/05/2005	22:55	5:55 PM	19.1	1.8	WSW	247.5	257	23.88	1.108	2.205	
01/05/2005	22:56	5:56 PM	18.9	2.2	WNW	292.5	251	23.32	1.108	2.153	
01/05/2005	22:57	5:57 PM	18.9	3.1	WNW	292.5	250	23.23	1.108	2.145	
01/05/2005	22:58	5:58 PM	18.9	1.3	NW	315	248	23.04	1.108	2.127	
01/05/2005	22:59	5:59 PM	18.9	1.3	NW	315	245	22.76	1.108	2.102	
01/05/2005	23:00	6:00 PM	18.9	1.8	NNE	382.5	243	22.58	1.108	2.084	
01/05/2005	23:01	6:01 PM	18.9	1.3	W	270	239	22.20	1.108	2.050	
01/05/2005	23:02	6:02 PM	18.9	0.9	N	360	236	21.93	1.108	2.024	
01/05/2005	23:03	6:03 PM	18.9	2.2	NW	315	232	21.55	1.108	1.990	
01/05/2005	23:04	6:04 PM	18.9	2.2	WSW	247.5	225	20.90	1.108	1.930	
			ave	ave				ave			
			18.9	1.61				23.073		2.130	
			deg F	ft/s		ave					
			66.1	5.27		298.93					D
								NO			R
					max	382.5	NNE	DAT	A REP	ORTS	
						83.57		GΔ		۵R	
Use average	e for flight ti	me + 5min									
								RAL	JATION	N I	
					min	247.5	WSW				
						-51.43					

IEEE Std. 738-2006 method of calculation

Air temperature is 66.10 (deg F) Wind speed is 5.27 (ft/s) Angle between wind and conductor is 75 (deg) Conductor elevation above sea level is 506 (ft) Conductor bearing is 59 (deg) (user specified bearing, may not be value producing maximum solar heating) Sun time is <u>18.063</u> hours (solar altitude is 8 deg. and solar azimuth is -77 deg.) Conductor latitude is 34.8 (deg) Atmosphere is CLEAR Day of year is 121 (corresponds to May 1 in year 2009) (user specified day, may not be day producing maximum solar heating)

Conductor description: 795 kcmil 26/7 Strands DRAKE ACSR - Adapted from 1970's Publicly Available Data Conductor diameter is 1.108 (in) Conductor resistance is 0.1166 (Ohm/mile) at 77.0 (deg F) and 0.1390 (Ohm/mile) at 167.0 (deg F)

Emissivity is 0.7 and solar absorptivity is 0.9

Solar heat input is 1.918 (Watt/ft) (corresponds to Global Solar Radiation of **23.081** (Watt/ft^2) - which was calculated) Radiation cooling is 0.306 (Watt/ft)

Convective cooling is 1.919 (Watt/ft)

Given a constant ac current of 118.5 amperes, The conductor surface temperature is 71.2 (deg F) Changed conductor temp from 74.6 to 71.2 (Very Cloudy would be significant)

Iterate on Sun time

## Steps to get FE sag

- Alignment
- Structure locations (station/offset)
- Conductor temperature (weather data)
- Assume sagging temperature (plumb INS)
- <u>As captured least square best fit Tension (FE6)</u>
   <u>Used to get tension not move structures</u>
- Adjust each span at mid span (non-plumb INS)FE3

## Assumed stringing condition 60deg Initial insulators plumb



# Least Square Best Fit

- FE gives a different tension in each span
- FE gives insulator swing at every condition besides Sagging Condition
- Thus, FE gives insulator swings at As Captured Temperature
- Must determine if swing/sag is due to FE or insulator installed out of plumb initially
- Input Sagging condition Tension(60deg Initial) is one value
- Determine outliers (spans that do not match FE tension)



## Least Square Best Fit

<ul> <li>6) Finite Element Multiple Point Fit Calculate catenary constant and required wire &amp; insulator attachment points required to fit thro May change wire lengths, structure locations and display condition.</li> </ul>	ough three poi	nts in each s	pan.	
Adjust wire length in each span to fit calculated catenary and wire attachment points				
Adjust structure stations, height and offset adjustments to match calculated insulator attac	chment points			
📃 🔲 Follow up with a Finite Element All Spans Wire Length Adjustment (option 4) after adjustm	ients above			
Least squares fit to all wire points within specified distance of 3 point catenary curve	Max distance	from 3 point	(ft) 3.000	5
Generate report showing attachment point locations and tensions	attach feature		1702 cond mid I	EEG V
Draw markers showing fit results (fit points, catenary curve, attachment points)	ator attach for	huro	1702 cond mid 1	
Create survey points at calculated mid span and wire/insulator attachment points	ator attacht red		1702 cona mia i	E6 V
	span point reat		1702 cond mid I	-E6 📉
Feature code for structure points (may be used to help refine attachment point calculation)		99999 Subs	tation Data	*
Automatically select fit points in each span (for fit mode 4 and 6) Feature code for wire	e fit	1701 Condu	ctor (OH)-Trans	mis: 🔽
<ul> <li>Use single point closest to current wire position (old way)</li> </ul>				
O Use centroid of all points within 1m of current wire position (tends to err on high side for	r bundles)			
O Use center of rectangle encompassing all points within 1m of current wire position (goo	d for bundles b	out sensitive	to outliers)	
O Use lowest of all points within 1m of current wire position (good for bundles but sensitive	e to outliers)			
O Use center of smallest circle enclosing all points within 1 m of current wire (good for bur	ndles but may l	be sensitive	to outliers)	
O Use bundle-aware centroid: centroid of each wire's centroids, using points within 1m of	f current positic	n (less sensi	tive to outliers)	
Enter either the bundle diameter : (in) 13.000 or the bundle spacing :	: (in)	13.000		
Show Web technical note "Graphical Sag Options: Making the Wire System Match 'As-Bu	uilt' Survey Poir	nts''	ОК	Cancel

# Least Square Answers do not change with Sagging input

#### Based on lidar points only

Structure Set Phase Number Tension Tension Tension Three Least Number No. Point Squares Points Before After Number Error Calc Calc. Least (lbs) (lbs)-Tension Tension Tension Squares Before (lbs (lbs) Fit (lbs) 74B 1 2124.17 2991.69 225 4891.16 6005.32 3013.63 9 75 1 4927.85 4907.70 2031 4906.58 6005.56 1097.87 4 76 4 1 4954.27 4937.14 1826 4887.36 6007.43 1070.29 77 4 1 4970.02 4959.16 1520 4907.58 6004.48 1045.32 1151 4951.95 6002.76 78 4 1 4970.25 5007.41 995.35 79 4 1 4971.11 5024.33 1126 4955.94 6002.20 977.88 1 4936.19 5041.59 80 816 5004.34 6002.03 960.44 4 4 1 5102.22 5106.94 1335 5108.82 6002.31 895.38 81 82 4 1 4859.67 4973.88 865 5030.29 6003.36 1029.48 1 5017.29 969.66 83 4 5036.29 1506 4989.98 6005.95 84 4 1 5039.66 5034.95 1211 4959.21 6006.30 971.34 1 4966.74 5020.04 986 4956.82 6004.68 85 984.64 4 86 1 4997.25 5063.62 818 4928.81 6004.25 4 940.62 87 4 1 5042.49 5017.46 914 4924.90 6004.65 987.18 88 4 1 4969.19 4972.16 901 4887.46 6006.45 1034.30 89 4 1 5035.10 4950.09 1133 4830.23 6007.69 1057.59 1 4806.83 4861.13 90 1311 4768.40 6008.11 1146.98 4 4 1 4839.69 4870.14 1057 4743.14 6009.36 1139.22 91 92 4 1 4770.34 4901.51 780 4724.05 6012.02 1110.51 1 4838.02 4856.39 820 4700.56 6011.30 1154.91 93 4 94 4 1 4768.98 4875.28 822 4699.75 6009.28 1134.00

Graphical Sag Tension Report

Structure Number         Structure Set         Phase Phase         Fension Tension Tension         Calc. Calc.         Least Least Tension         Tension Tension         Difference Phase         red > 6%         2%         4%         6%           1         748         9         1         2124.17         2991.69         228         4891.16         -1899.47         -63.5%         -         -           2         75         4         1         4972.85         497.7         2014         4906.58         1.12         0.0%         1.12         1.12         1.12           3         76         4         1         4970.02         4997.8         51.58         51.58         51.58         51.58         51.58         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46         55.46 <t< th=""><th></th><th></th><th></th><th></th><th></th><th>Th</th><th>iree</th><th>Least</th><th></th><th>Number</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></t<>						Th	iree	Least		Number							
Number         Set         Phase         Tension         Tension         Tension         Fit         (lbs)         Difference         red > 6%         2%         4%         6%           1         748         9         1         2124.17         2931.69         225         4891.16         -1899.47         -63.5%			Structure			Po	oint	Square	es	Points							
Number         No.         (lbs)         Fit         (lbs)         Difference         res > 6%         2%         4%         6%           1         746         9         1         2124.17         291.16         -1899.47         -63.5%         -63.5%         -         -           2         75         4         1         4927.85         4907.7         2031         4905.85         1.12         0.0%         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.15         1.55         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58         51.58			Number			Ca	lc.	Calc.		Least	Tension						
Row #         Number         No.         (lbs)         Fit         (lbs)         Difference         red > 6%         2%         4%         6%           1         748         9         1         2124.17         2991.69         225         4891.16         -1899.47         -63.5%         -         -         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12         1.12			Number	Set	Phase	Te	ension	Tensio	n	Squares	Before						
1       748       9       1       2124.17       2991.69       225       4991.65		Row #		Number	No.	(Ik	os)	(lbs)		Fit	(lbs)	Difference	red > 6%	2%	4%	6%	
2       75       4       1       4927.85       4907.7       2031       4906.58       1.12       0.0%       1.12       1.12       1.12         3       76       4       1       4954.27       4937.14       1826       4867.36       49.78       1.0%       49.78       49.78       49.78         4       77       4       1       4970.22       4937.14       150       4907.58       51.58       1.0%       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       55.46       55.46       55.46       55.46       68.39       68.39       68.39       68.39       68.39       68.39       68.39       68.39       68.39       68.39       68.91       68.61       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       68.91       69.91       69.93 <td< td=""><td></td><td>1</td><td>74B</td><td>9</td><td></td><td>1</td><td>2124.17</td><td>2991</td><td>L.69</td><td>225</td><td>4891.16</td><td>-1899.47</td><td>-63.5%</td><td></td><td></td><td></td><td></td></td<>		1	74B	9		1	2124.17	2991	L.69	225	4891.16	-1899.47	-63.5%				
3       76       4       1       4954.27       4937.14       1826       4897.36       49.78       10%       49.78       49.78       49.78       49.78       49.78       49.78       49.78       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.58       51.55       51.55       51.55       51.55       51.57       51.55       51.55		2	75	4		1	4927.85	490	)7.7	2031	4906.58	1.12	0.0%	1.12	1.12	1.12	
4       77       4       1       4970.02       4959.16       1520       4907.58       51.58       1.0%       51.58       51.58       51.58       51.58       51.58       51.58       51.58       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       57.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25 <td></td> <td>3</td> <td>76</td> <td>4</td> <td></td> <td>1</td> <td>4954.27</td> <td>4937</td> <td>7.14</td> <td>1826</td> <td>4887.36</td> <td>49.78</td> <td>1.0%</td> <td>49.78</td> <td>49.78</td> <td>49.78</td> <td></td>		3	76	4		1	4954.27	4937	7.14	1826	4887.36	49.78	1.0%	49.78	49.78	49.78	
5       78       4       1       4970.25       5007.41       1151       4951.95       55.46       1.1%       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       55.46       56.83       68.39       68.39       68.39       68.39       68.39       68.39       68.39       68.39       68.39       68.39       68.39       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25 <td></td> <td>4</td> <td>77</td> <td>4</td> <td></td> <td>1</td> <td>4970.02</td> <td>4959</td> <td>9.16</td> <td>1520</td> <td>4907.58</td> <td>51.58</td> <td>1.0%</td> <td>51.58</td> <td>51.58</td> <td>51.58</td> <td></td>		4	77	4		1	4970.02	4959	9.16	1520	4907.58	51.58	1.0%	51.58	51.58	51.58	
6       79       4       1       4971.11       5024.33       1126       4955.94       68.39       1.4%       68.39       68.39       68.39         7       80       4       1       4936.19       5041.59       816       5004.34       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.25       37.35       53.2       11.01       110.17       110.17       110.17       110.17       110.17       110.10       110.10       110.10       110.10       110.10		5	78	4		1	4970.25	5007	7.41	1151	4951.95	55.46	1.1%	55.46	55.46	55.46	
7       80       4       1       4936.19       5041.59       816       5004.34       37.25       0.7%       37.25       37.25       37.25         Section Modify       1.88       1.88       -1.88       0.0%       -1.88       0.0%       -1.88       0.0%       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.88       -1.83       -1.83       -1.51       -1.51       -1.51       -1.51       -1.51       -1.51       -1.51       -1.51       -1.51       <		6	79	4		1	4971.11	5024	1.33	1126	4955.94	68.39	1.4%	68.39	68.39	68.39	
8         81         4         1         5102.22         5106.94         1335         5108.82         -1.88         0.0%         -1.88         -1.88         -1.88           Section Modify         ?         94.13         667         4813.16         80.97         1.7%         80.97         80.97         80.97           Section Modify         ?         94.13         667         479.38         68.91         1.4%         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         68.91         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.17         61.82         63.93         63.03         4736.3         309.23         61.17         61.82         61.17         61.82         61.17         61.82         61.17         61.82         61.17         61.17         61.17         61.18 <td></td> <td>7</td> <td>80</td> <td>4</td> <td></td> <td>1</td> <td>4936.19</td> <td>5041</td> <td>L.59</td> <td>816</td> <td>5004.34</td> <td>37.25</td> <td>0.7%</td> <td>37.25</td> <td>37.25</td> <td>37.25</td> <td></td>		7	80	4		1	4936.19	5041	L.59	816	5004.34	37.25	0.7%	37.25	37.25	37.25	
Section Modify         ?         94.13         667         4813.16         80.97         1.7%         80.97         80.97         80.97           Section 8 from structure #74B to structure #E21EA         68.29         571         4799.38         68.91         1.4%         66.91         66.91         66.91         66.91         66.91         66.91         72.84         593         4811.67         61.17         1.3%         61.17         61.17         63.3         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2         53.2		8	81	4		1	5102.22	5106	5.94	1335	5108.82	-1.88	0.0%	-1.88	-1.88	-1.88	
Section 8 from structure #74B to structure #E216A         68.29         571         4799.38         68.91         1.4%         68.91         68.91         68.91           Type         civit/pls/vead-only/pls/pls_cadd/cables/acst/vail acsr 954 45_7         789.5         633         4736.3         53.2         1.1%         53.2         53.2         53.2           Voltage         (kV) 161         Conductors per phase         2         62.08         745         4751.98         110.1         2.3%         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1         110.1	Sectio	n Modify					?	× 894	1.13	687	4813.16	80.97	1.7%	80.97	80.97	80.97	
Type       72.84       593       4811.67       61.17       1.3%       61.17       61.17       61.17         Voltage       (kV) 161       Conductors per phase       2       62.08       745       4751.98       110.1       2.3%       110.1       110.1         Sagging       Condition       Initial RS       72.86       61.17       4751.98       110.1       2.3%       110.1       110.1         Sagging       Condition       Initial RS       72.36       1498       4763.13       309.23       6.1%       110.2       198.56         Querride calculated ruling span       Temperature       (deg F) 60.0       72.36       1162       4827.89       328.37       6.4%       273.53         Automatic Sagging       Horiz. Tension       (ft 5581.4)       59.88       664       4877.45       273.53       5.3%       273.53         Color       Color       59.84       5201       4771.56       168.28       3.4%       168.28       168.28         V Show selected weather case       Wind from       Both<	Section	8 from structu	ire #74B to stru	icture #E216	A			868	3.29	571	4799.38	68.91	1.4%	68.91	68.91	68.91	
VoikipleStread-only/bl/spls_cadd/cables/acst/rail acst 954 45_7         7789.5         633         4736.3         53.2         1.1%         53.2         53.2         53.2           Voltage         (kV)         161         Conductors per phase         2         62.08         745         4751.98         110.1         2.3%         110.1         110.1         110.1           Sagging         Condution         Initial RS         72.36         1498         4763.13         309.23         6.4%           10.1         110.1         110.1           Sagging         Condition         Initial RS         72.36         1498         4763.13         309.23         6.4%           10.1         110.1         110.1           Querride calculated ruling span         Temperature         (deg F) 60.0         56.66         1162         4827.79         32.37         6.4%          273.53         5.3%         273.53         5.3%         273.53         5.3%         273.53         5.3%         273.53         5.3%         273.55         165.55         165.55         165.55         165.55         165.55         165.55         165.55         165.55         165.55         165.55         165.55         165.55	_ Туре-	C						<mark>;72</mark>	2.84	593	4811.67	61.17	1.3%	61.17	61.17	61.17	
Voltage         (kV)         161         Conductors per phase         2         62.08         745         4751.98         110.1         2.3%         110.1         110.1           Sagging         Condition         Initial RS         72.36         1498         4763.13         309.23         6.1%         0         198.56           Override calculated ruling span         Temperature         (deg F)         60.0         56.26         1162         4827.89         328.37         6.4%         0         273.53           Automatic Sagging         Horiz. Tension         18)         50000         56.26         1162         4827.89         328.37         6.4%         0         273.53           Object         Color         Catenary         (f)         5581.4         753.3         747         4961.69         213.63         4.1%         213.63           Display         Color         Sagging         Wind from         Both<         Y         33.26         537         4798.04         165.55         3.3%         165.28         3.4%         168.28         3.4%         168.28         3.4%         168.28         3.4%         168.28         3.4%         168.28         3.6%         165.55         3.3%         165.55		\civil\pls	\read-only\pls\	pls_cadd\ca	bles\acsr\r	ail ac	sr 954 45	<b>三</b> 178	39.5	633	4736.3	53.2	1.1%	53.2	53.2	53.2	
Sagging       Condition       Initial RS       1077       4762.64       198.56       4.0%       198.56         Override calculated ruling span       Temperature       (deg F) 60.0       56.26       1162       4827.89       328.37       6.4%       273.53         Automatic Sagging       Horiz. Tension       198.56       168.4       4877.45       273.53       5.3%       273.53         Display       Horiz. Tension       198.56       664       4877.45       273.53       5.3%       273.53         Or Or       V Show selected weather case       63.57       657       4798.04       165.55       3.3%       165.55       165.55         WC cond (74B-£216A) 110.3dec v       Wind from       Both v       39.92       618       4826.6       313.32       6.1%       168.28       168.28         VC cond (74B-£216A) 110.3dec v       Wind from       Both v       39.92       618       4826.6       313.32       6.1%       260.96       170.71       1037       4951       219.71       4.2%       219.71         CRI Notes:       TVA Single Circuit       Edit Stringing       Edit Cancel       599       4827.91       -158.46       -3.4%       -158.46       -158.46         Sizabled.       SAPS	Voltag	е	(kV) 161	Conduc	tors per pha	ase	2	<mark>862</mark>	2.08	745	4751.98	110.1	2.3%		110.1	110.1	
Condition       Initial RS       72.36       1498       4763.13       309.23       6.1%       Image: Condition         Diverride calculated ruling span       Temperature       (deg F 60.0)       56.26       1162       4827.89       328.37       6.4%       Image: Condition       273.53         Automatic Sagging       Horiz. Tension       105.55       1162       4827.45       273.53       5.3%       Image: Condition       213.63         Display       Color       105.55       165.55       3.3%       165.55       165.55       165.55       165.55       165.55       165.55       165.55       165.26       1162       4827.39       345.87       6.7%       Image: Condition       Image: Condition<	Saggi	ng							51.2	1077	4762.64	198.56	4.0%			198.56	
Override calculated ruling span       Temperature       (deg F) 60.0       156.26       1162       4827.89       328.37       6.4%         Ruling Span       (ft) 1223.91       Catenary       (ft) 5581.4       58,98       684       4877.45       273.53       5.3%       273.53         Automatic Sagging       Horiz. Tension       (ft) 5581.4       58,98       684       4877.45       273.63       4.1%       213.63         Display       Color       97,84       521       4771.56       168.28       3.4%       165.55       165.55         Y Show selected weather case       97,84       521       4771.56       168.28       3.4%       168.28       168.28         V C cond (74B-E216A) 110.3deg ∨ Wind from       Both ∨       .39.92       618       4826.6       313.32       6.1%        260.96         Condition       Creep FE       Phase       1       ∨       260.96       5.1%       219.71         Cold Totes:       TVA Single Circuit       Edit Stringing       DK cancel       599       4827.91       -158.46       -158.46       -158.46         Displayed Phase will not take effect until override in Section/Display-Options is disabled.       14537.37       3366.19       1101.604       14827.15 <td></td> <td></td> <td></td> <td>Conditio</td> <td>n</td> <td>Ir</td> <td>nitial RS</td> <td><u>×</u> 072</td> <td>2.36</td> <td>1498</td> <td>4763.13</td> <td>309.23</td> <td>6.1%</td> <td></td> <td></td> <td></td> <td></td>				Conditio	n	Ir	nitial RS	<u>×</u> 072	2.36	1498	4763.13	309.23	6.1%				
Ruling Span       (ft) 1223.91       Cetenary       (ft) 5581.4       58,88       684       4877.45       273.53       5.3%       273.53         Automatic Sagging       Horiz. Tension       (ft) 5581.4       (ft) 5581.5       (ft) 5591.5       (ft) 5591.5       (ft) 5591.5       (ft) 5591.5       (ft) 5591.5       (ft) 5591.5 <td< td=""><td>00</td><td>erride calcula</td><td>ted ruling span</td><td>Temper</td><td>ature</td><td>(deg</td><td>F) 60.0</td><td>.56</td><td>5.26</td><td>1162</td><td>4827.89</td><td>328.37</td><td>6.4%</td><td></td><td></td><td></td><td></td></td<>	00	erride calcula	ted ruling span	Temper	ature	(deg	F) 60.0	.56	5.26	1162	4827.89	328.37	6.4%				
Automatic Sagging       Horiz. Tension       Ibs       500000       75.32       747       4961.69       213.63       4.1%       213.63         Display       63.5%       657       4798.04       165.55       3.3%       165.55       165.55         Color       97.84       521       4771.56       168.28       3.4%       168.28       168.28         Show selected weather case       33.26       594       4787.39       345.87       6.7%       6.1%       6.1%         WC cond (748-E216A) 110.3deg       Wind from       Both       39.92       618       4826.6       313.32       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1% </td <td>Ruling</td> <td>Span</td> <td>(ft) 1223.91</td> <td>Catenar</td> <td>y.</td> <td></td> <td>(ft) 5581</td> <td>4 .50</td> <td>98</td> <td>684</td> <td>4877.45</td> <td>273.53</td> <td>5.3%</td> <td></td> <td></td> <td>273.53</td> <td></td>	Ruling	Span	(ft) 1223.91	Catenar	y.		(ft) 5581	4 .50	98	684	4877.45	273.53	5.3%			273.53	
Display       63.58       657       4798.04       165.55       3.3%       165.55       165.55         Color       95.84       521       4771.56       168.28       3.4%       168.28       168.28         Show selected weather case       33.26       594       4787.39       345.87       6.7%       6.1%       6.1%         WC cond (74B-E216A) 110.3deg V Mind from       Both V       39.92       618       4826.6       313.32       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1%       6.1% <td></td> <td>Automatic</td> <td>Sagging</td> <td>🔄 Horiz. T</td> <td>ension</td> <td>(IE</td> <td>os) <mark>6000.</mark></td> <td>.75</td> <td>5.32</td> <td>747</td> <td>4961.69</td> <td>213.63</td> <td>4.1%</td> <td></td> <td></td> <td>213.63</td> <td></td>		Automatic	Sagging	🔄 Horiz. T	ension	(IE	os) <mark>6000.</mark>	.75	5.32	747	4961.69	213.63	4.1%			213.63	
Color       39.54       521       4771.56       168.28       3.4%       168.28       168.28         Show selected weather case       .33.26       594       4787.39       345.87       6.7%           WC cond (74B-E216A) 110.3deg V Wind from Condition Creep FE       Phase       1       .39.92       618       4826.6       313.32       6.1%         260.96         CRI Notes:       TVA Single Circuit       Edit Stringing OK Cancel disabled.       .70.71       1037       4951       219.71       4.2%        219.71         SAPS Finite Element Sag-Tension Options       Sag-Tension Options	Displa	y .						<mark>)63</mark>	3.59	657	4798.04	165.55	3.3%		165.55	165.55	
Show selected weather case       33.26       594       4787.39       345.87       6.7%       Image: Condition Creep FE       Wind from Phase       Both Image: Condition Creep FE       Phase       1mm       39.92       618       482.66       313.32       6.1%       Image: Condition Creep FE       Phase       1mm       39.92       618       482.66       313.32       6.1%       Image: Condition Creep FE       Phase       1mm       1mm       1mm       260.96       5.1%       Image: Condition Creep FE       Phase       1mm       1mm       1mm       260.96       5.1%       Image: Condition Creep FE       Phase       1mm       1mm       260.96       5.1%       Image: Condition Creep FE       219.71       4.2%       Image: Condition Creep FE       219.71       1037       4951       219.71       4.2%       Image: Condition Creep FE       219.71       1037       4.2%       Image: Condition Creep FE       219.71       219.71       4.2%       Image: Condition Creep FE       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       219.71       210.71		Cole	or					- 39	9.84	521	4771.56	168.28	3.4%		168.28	168.28	
WC       cond (748-E216A) 110.3deg v       Wind from       Both v       39.92       618       4826.6       313.32       6.1%         260.96         Condition       Creep FE       Phase       1       1       70.71       1029       4880.61       260.96       5.1%        260.96         CRI Notes:       TVA Single Circuit       Edit Stringing       OK       Cancel       70.71       1037       4951       219.71       4.2%        219.71         Displayed Phase will not take effect until override in Section/Display-Options is disabled.       SAPS Finite Element Sag-Tension Options       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -168.5       121.137       -158.46	🗹 Shi	ow selected <u>v</u>	yeather case					.33	3.26	594	4787.39	345.87	6.7%				
Condition       Creep FE       Phase       1       41.57       1029       4880.61       260.96       5.1%       2219.71         CRI Notes:       TVA Single Circuit       Edit Stringing       QK       Cancel       399       4827.91       -158.46       -3.4%       -158.46       -158.46         Displayed Phase will not take effect until override in Section/Display-Options is disabled.       Image: Condition Section Section/Display-Options is disabled.       Image: Condition Section Sectio	WC a	ond (748-E2	16A) 110.3dec	Vind fro	om		Both	✓ .39	9.92	618	4826.6	313.32	6.1%				
CRI Notes:TVA Single CircuitEdit StringingDKCancelDisplayed Phase will not take effect until override in Section/Display-Options is disabled.3994827.91-158.46-3.4%-158.46-158.46SAPS Finite Element Sag-Tension Options Clip Insulators (lock unstressed length, force finite element sag-tension) Edit Lengths/Stiffnesses-14537.373366.1911016.0414827.15Graph Tension vs. ElongationEdit Lengths/Stiffnesses-1101.6599351.7875491.04165108.2274	Condit	ion Creep F	FE	V Phase			1	<ul> <li>✓</li> <li>.41</li> </ul>	1.57	1029	4880.61	260.96	5.1%			260.96	
CRI Notes:       TVA Single Circuit       Edit Stringing       UK       Lancel       69.45       399       4827.91       -158.46       -3.4%       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46       -158.46	COL N				<u></u>			70	).71	1037	4951	219.71	4.2%			219.71	
Displayed Phase will not take effect until override in Section/Display-Options is disabled.       Image: Constraint of the section	CRENC	otes: TVA S	lingle Circuit	Edit	Stringing	Ľ		icel i69	9.45	399	4827.91	-158.46	-3.4%		-158.46	-158.46	
SAPS Finite Element Sag-Tension Options       14537.37       3366.19       11016.04       14827.15         Clip Insulators (lock unstressed length, force finite element sag-tension)       143       65       121       137         Graph Tension vs. Elongation       Edit Lengths/Stiffnesses       101.65993       51.78754       91.04165       108.2274	Display disable	ed Phase will d.	not take effect	until override	e in Section	/Disp	olay-Optio	ns is									
Clip Insulators (lock unstressed length, force finite element sag-tension)       143       65       121       137         Graph Tension vs. Elongation       Edit Lengths/Stiffnesses       101.65993       51.78754       91.04165       108.2274	CSAPS Finite Element Sag-Tension Options											14537.37		3366.19	11016.04	14827.15	
Graph Tension vs. Elongation         Edit Lengths/Stiffnesses         0.45         0.85         0.96           101.65993         51.78754         91.04165         108.2274	Clip Insulators (lock unstressed length, force finite element sag-tension)											143		65	121	137	
101.65993 51.78754 91.04165 108.2274	Gra	aph Tension v	s. Elongation		Edit Leng	ths/9	Stiffnesse	s				1-10		0.45	0.85	0.96	
												101,65993		51,78754	91.04165	108,2274	

					Three	Least	Number						
					Point	Squares	Points						
					Calc.	Calc.	Least	Tension					
			Set	Phase	Tension	Tension	Squares	Before	D:///	1. 50/	-01/	•0/	c0/
	Row #	Structure	Number	NO.	(Ibs)	(Ibs)	Fit	(Ibs)	Difference	red > 6%	2%	4%	6%
	1	748	9	1	2124.17	2991.69	225	5010.5	-2018.81	-67.5%			
	2	75	4	1	4935.39	4907.7	2031	5026.01	-118.31	-2.4%		-118.31	-118.31
	3	76	4	1	4954.27	4937.14	1826	5007.54	-70.4	-1.4%	-70.4	-70.4	-70.4
	4	77	4	1	4970.02	4959.16	1520	5028.11	-68.95	-1.4%	-68.95	-68.95	-68.95
	5	78	4	1	4970.25	5007.41	1151	5073.33	-65.92	-1.3%	-65.92	-65.92	-65.92
	6	79	4	1	5093.06	5024.33	1126	5078.41	-54.08	-1.1%	-54.08	-54.08	-54.08
	7	80	4	1	4936.19	5041.59	816	5128.46	-86.87	-1.7%	-86.87	-86.87	-86.87
	8	81	4	1	5072.87	5106.94	1335	5235.8	-128.86	-2.5%		-128.86	-128.86
	32	105	4	1	4867.77	4894.13	687	4922.5	-28.37	-0.6%	-28.37	-28.37	-28.37
	33	106	4	1	4864.78	4868.29	571	4909.3	-41.01	-0.8%	-41.01	-41.01	-41.01
Section	Modify				?	2.84	593	4922.23	-49.39	-1.0%	-49.39	-49.39	-49.39
Section 8 f	rom structure	e #74B to str	ucture #E21	6A		89.5	633	4843.75	-54.25	-1.1%	-54.25	-54.25	-54.25
-Туре	<i>(</i>					2.08	745	4860.05	2.03	0.0%	2.03	2.03	2.03
	\civil\pls\r	ead-only\pls	\pls_cadd\c	ables\acsr\r	ail acsr 954 «	45_7 61.2	1077	4871.71	89.49	1.8%	89.49	89.49	89.49
Voltage		(kV) 161	Condu	ctors per pha	ase	2 2.36	1498	4873.31	199.05	3.9%		199.05	199.05
Sagging			_			6.26	1162	4939.82	216.44	4.2%			216.44
o ogging			Condit	ion	Initial BS	0.98	684	4991.43	159.55	3.1%		159.55	159.55
📃 Overri	de calculate	d ruling span	Tempe	erature	(deg F) 60.0	) 5.32	747	5078.04	97.28	1.9%	97.28	97.28	97.28
Ruling Sp	an	(ft) 1223.9	1 Catena	ary	(ft) 578	5.1 <b>3.59</b>	657	4911.14	52.45	1.1%	52.45	52.45	52.45
	Automatic S	agging	Horiz	Tension	(Ibe) 621:	9.0	521	4884.42	55.42	1.1%	55.42	55.42	55.42
- Display-		-33	Honz.	rension	(	2.20	594	4900.73	232.53	4.5%			232.53
	Color					9.92	618	4941.22	198.7	3.9%		198.7	198.7
Show	selected we	ather case				1.57	1029	4996.46	145.11	2.8%		145.11	145.11
WC			L. Wind F		Det	0.71	1037	5069.7	101.01	2.0%	101.01	101.01	101.01
Condition	d (748-E216	A) 110.3deg -	V WINUT	IOIII	BOU	9.45	399	4942.17	-272.72	-5.8%			-272.72
Condition	Creep Fb	:	Y Phase										
CRI Note	s: TVA Sir	ngle Circuit	Ed	lit <u>S</u> tringing	OK C	ancel							
Displayed	Phase will n	ot take effec	t until overrir	le in Section	/Display-Ont	tions is			-1754.58		-739.25	287.62	264.23
disabled.									143		115	138	142
- SAPS Fir	nite Element	Sag-Tension	Options								0.80	0.97	0.99
📃 Clip In	sulators (loc	k unstressed	length, force	e finite eleme	ent sag-tensio	on)			-12.26979		-6.42826	2.084203	1.860775
Graph	Tension vs.	Elongation		Edit Leng	ths/Stiffness	es							

## Stringing condition 60deg Initial Assumed insulators plumb (to be corrected)



#### **Before Adjustments**

#### Wire Lengths and Attachment Stiffness

The data below applies only to finite element sag-tension (not ruling span). Unstressed lengths are at 0 de Stiffnesses below are for level 2 SAPS analysis and also for level 3 analysis of structures not modeled with For level 3 SAPS analysis with PLS-POLE or TOWER structures attachment stiffnesses will be determined Light blue columns used to define optional concentrated loads (marker balls, spacer-dampers...). Unstressed lengths are calculated prior to the addition of concentrated loads (concentrated loads assume

Sagging condition: Initial RS

I		Structure	Set	Phase	Structure	Structure	#1
I		Number	Number	Number	Attachment	Attachment	Load
I					Transverse	Longitudinal	Point
I					Stiffness	Stiffness	Span
					(lbs/ft)	(lbs/ft)	Fraction
	1	74B	10	1	NA	NA	
	2	75	5	1	Default	Default	
	3	76	3	1	Default	Default	
	4	77	3	1	Default	Default	
	5	78	5	1	Default	Default	
	6	79	5	1	Default	Default	
	7	80	5	1	Default	Default	
	8	81	5	1	Default	Default	
	9	82	5	1	Default	Default	
	10	83	5	1	Default	Default	
	11	84	5	1	Default	Default	
	12	85	5	1	Default	Default	
ſ	13	86	5	1	Default	Default	

### As captured temperature no adjustment



#### As captured temperature no adjustment



raphical Sag Options					?
inap Mode	C Fit to mouse coo	dinates			
1) Ruling Span 1) Ruling Span Horizontal tension is always the same for all spans in Sagging tension and condition will be changed. Disp	section. play condition will be changed.				
2) Finite Element Insulators Plumb at Sagging Conditi Horizontal tension constant throughout section at say Sagging tension will be changed. Display condition	ion. gging condition but may vary at o will be changed.	ther conditions.			
3) Finite Element Selected Spans Wire Length Adjus Adjust length of wire in selected spans without regard Wire lengths for selected spans will be changed. Dis	tment d for effects on other spans. splay condition will be changed.				
) 4) Finite Element All Spans Wire Length Adjustment Adjust wire length in all spans to fit selected point(s) ( Wire length for all spans in section will be changed.	without changing mid span wire e Display condition will be change	levation in other J.	spans.		
Tip: There can be a delay after each left click while upoints without a fit delay. When done selecting point	wire is fit to the selected point(s). ts use a left click to perform the f	Use middle click t.	s or the Enter	rkey to select	
) 5) Finite Element Manual Length Adjust Manually enter change in unstressed wire length for Unstressed wire length for selected spans is change	a span. d. Display condition will be char	ged.			
) 6) Finite Element Multiple Point Fit Calculate catenary constant and required wire & insu May change wire lengths, structure locations and dis	lator attachment points required play condition.	o fit through three	e points in ea	ch span.	
Adjust wire length in each span to fit calculated c	atenary and wire attachment poi	nts			
Adjust structure stations, height and offset adjustr	ments to match calculated insula	or attachment po	pints		
Follow up with a Finite Element All Spans Wire Le	ength Adjustment (option 4) after	adjustments abov	/e		
Least squares fit to all wire points within specified	distance of 3 point catenary cur	ve Maxidist	ance from 3 p	point (ft) 3.00	0
Generate report showing attachment point location	ons and tensions	Wire attach, fe	ature	1702 cond mid	FEG
🗹 Draw markers showing fit results (fit points, cateri	ary curve, attachment points)	Insulator attack	h faatura	1702 cond mid	
Create survey points at calculated mid span and (	wire/insulator attachment points	Mid spap point	fosturo	1702 Cond Inid	
		mia span point	reature	1702 cond mid	FEB
Feature code for structure points (may be used to hel	p refine attachment point calcula	tionj	99999 S	ubstation Data	1
Automatically select fit points in each span (for fit mo	de 4 and 6) Feature code	for wire fit	1702 co	nd mid FE6	•
OUse single point closest to current wire position	ı (old way)				
O Use centroid of all points within 1m of current v	vire position (tends to err on high	side for bundles)			
Ollise center of rectangle encompassing all point	ts within 1m of current wire positi	on faced for bund	tles hut sensit	tive to outliers)	
Ollse lowest of all points within 1m of ourrent wir	e position (good for bundles but	sensitive to outlie			
O Use contex of amplifiest circle enclosing all points	e position (good for bandles bat a within 1 m of ourront wire (good	tor bundlos but	roj movi bo concit	ius to outlists)	
	s within the or culterit wite (good		may be sensit	ive to outliers)	
Use bundle-aware centrola: centrold of each w     Enter either the bundle diameter :	(in) 13.000 or the bundle s	n im or current p bacing :	(in) 13.000	ensitive to outliefs)	
		IA D SH C	Deinte"		

#### All phases As captured temperature with adjustment



#### Center phase As captured temperature with adjustment



ection #8, phase 1, 161kV, 'rail acsr 954 45_7', from Str. #74B Set 9 'Mahead' to Str. #E216A Set 4 'MID Back', Section at cond (74B-E216A) 110.3deg 'Creep FE', S=150

#### As captured temperature with adjustment



ection): Section #20, phase 1, 0kV, '7_16 7 strand hs steel', from Str. #184 Set 8 'LGWDEahead' to Str. #198 Set 6 'LGWDEback', Section at ohgw (74B-E216A) 104.3deg 'Creep F

#### After Adjustments

#### Wire Lengths and Attachment Stiffness

The data below applies only to finite element sag-tension (not ruling span). Unstressed len Stiffnesses below are for level 2 SAPS analysis and also for level 3 analysis of structures n For level 3 SAPS analysis with PLS-POLE or TOWER structures attachment stiffnesses wi Light blue columns used to define optional concentrated loads (marker balls, spacer-damp Unstressed lengths are calculated prior to the addition of concentrated loads (concentrate

Sagging condition:

Initial RS

	Structure	Set	Phase	Ahead	Ahead	Stru
	Number	Number	Number	Span	Span	Attac
				Instressed	Instressed	Trans
				Length	Length	Stif
				(ft)	Change	(lbs
					(ft)	
1	74B	10	1	96.983	0.000	ŀ
2	75	5	1	1324.902	0.602	
З	76	3	1	1030.835	-0.496	
4	77	3	1	1216.563	0.486	
5	78	5	1	1373.415	0.090	
6	79	5	1	1171.375	-0.001	
7	80	5	1	1262.355	0.080	
8	81	5	1	1803.991	0.953	
9	82	5	1	1160.212	0.520	
10	83	5	1	1292.692	-0.220	
11	84	5	1	1182.843	0.552	
12	85	5	1	1360.806	-0.432	

Stringing condition 60deg Initial with adjustments (Assumption of plumb Insulator removed)



ection): Section #9, phase 1, 161kV, 'rail acsr 954 45_7', from Str. #74B Set 10 'Rahead' to Str. #E216A Set 5 'BOT Back', All sections at BARE 60 'Initial FE', S=151539.84

# Angle brackets 3'-5"



# Brackets do not swing with Level 2

SAPS Finite Element Sag-Tension	? 🔀
<ul> <li>SAPS Analysis Level</li> <li>Selection below will affect type of model used when do</li> <li>L2 Finite element analysis of single section (no integrated (sag-tension will take longer than for ruling span)</li> <li>L3 Finite element analysis of system of sections into (sag-tension computations will generally take a for Level 3 options)</li> </ul>	bing finite element sag-tension. raction between sections) but still reasonably responsive) erconnected by stiffness matrices ew seconds and use lots of RAM)
Limit level 3 modeling to PLS-POLE structure	s, TOWER structures as level 2
<ul> <li>L4 Finite element analysis of system of sections into (sag-tension computations could range from mining Level 4 options</li> <li>Limit level 4 modeling to PLS-POLE structure</li> <li>Limit level 4 modeling to guyed or otherwise a Strip joints/members that don't move significations</li> </ul>	erconnected by full structure models utes to hours depending on model) s, TOWER structures as level 3 asymmetrical structures antly from level 4 TOWER models
<ul> <li>Default Structure Attachment Stiffnesses for L2</li> <li>The following default attachment stiffness values are us</li> <li>These values may be overridden on a attachment by a</li> </ul>	sed in calculations requiring a SAPS analysis. ttachment basis in Section/Modify. Transverse Longitudinal
Dead ends	(bs/ft) Fixed
Non dead end with post insulator	(lbs/ft) Fixed V Fixed V
Non dead end with non post insulator	(lbs/ft) Fixed 🗸 Fixed 🗸
	<u>C</u> ancel

# Only Insulators Swing (not brackets)



# Use all adjustments

<ul> <li>6) Finite Element Multiple Point Fit Calculate catenary constant and required wire &amp; insulator attachment points required</li> </ul>	to fit through three p	pints in each sp	oan.	
May change wire lengths, structure locations and display condition.  Adjust wire length in each span to fit calculated catenary and wire attachment poir	nts			
Adjust structure stations, height and offset adjustments to match calculated insulat	tor attachment points	\$		
Follow up with a Finite Element All Spans Wire Length Adjustment (option 4) after a value of a point category current of a point category c	adjustments above ve May distand	re from 3 point	(m) 3.000	
Generate report showing attachment point locations and tensions	Wire attach. featur	e 1	732 Lohgw FE6	~
Draw markers showing fit results (fit points, catenary curve, attachment points) Create survey points at calculated mid span and wire/insulator attachment points	Insulator attach. fe	eature 1	732 Lohgw FE6	~
Feature code for structure points (may be used to help refine attachment point calculation) 99999 Substation [				~
Automatically select fit points in each span (for fit mode 4 and 6)	for wire fit	1701 Conduc	tor (OH)-Transmis	* 🗸
Use single point closest to current wire position (old way)				
OUse centroid of all points within 1m of current wire position (tends to err on high	side for bundles)			
Use center of rectangle encompassing all points within 1m of current wire position	on (good for bundles	but sensitive ti	o outliersj	
Use rowest or all points within 1m of current wire position (good for bundles but a	t for bundles but may	, he sensitive tr	outliers)	
Use bundle-aware centroid: centroid of each wire's centroids, using points within	n 1m of current posit	ion (less sensiti	ive to outliers)	
Enter either the bundle diameter : (in) 13.000 or the bundle sp	pacing: (in)	13.000	,	
Show Web technical note "Graphical Sag Options: Making the Wire System Match	n 'As-Built' Survey Po	bints"	OK Can	ncel
# Moved Structure based on one phase only

bundle conductor located tower to centroid









Using FE6 adjust str moved str of PI

### FE6 first three options not selected

### FE6 with first three options selected

Section Modify				
Section 8 from structure #74B to structure #E216A				
Vivil\pls\read-only\pls\pls_cadd\cables\acsr\rail acsr 954 45_7				
Voltage	(kV) 161	Conductors per pha	ise 2	
Sagging		Condition	Initial RS 💌	
🔲 Override o	calculated ruling span	Temperature	(deg F) 60.0	
Ruling Span	(ft) 1223.91	Catenary	(ft) 5785.1	
Automatic Sagging		Horiz. Tension	(lbs) 6219.0	
Display				
Color				
Show selected weather case				
WC cond (7	4B-E216A) 110.3dec 🗸	Wind from	Both 💌	
Condition	Creep FE 🛛 🔽	Phase	1 🐱	
CRI Notes:	TVA Single Circuit	Edit <u>S</u> tringing	OK Cancel	
Displayed Phase will not take effect until override in Section/Display-Options is disabled.				
SAPS Finite Element Sag-Tension Options				
Clip Insulators (lock unstressed length, force finite element sag-tension)				
Graph Tension vs. Elongation Edit Lengths/Stiffnesses				

Section Modify				
Section 8 from structure #74B to structure #E216A				
Lype \civil\pls\read-only\pls\pls_cadd\cables\acsr\rail acsr 954 45_7				
Voltage (kV) 161	Conductors per phase 2			
Sagging Override calculated ruling span Buling Span (ft) 1223.5	Condition Creep RS Temperature (deg F) 110.3 Catenary (ft) 4601 1			
Automatic Sagging Horiz. Tension (lbs) 4946.1				
✓ Show selected weather case         WC       cond (74B-E216A) 110.3dec          Condition       Creep FE	<ul> <li>✓ Wind from</li> <li>Phase</li> <li>1 ✓</li> </ul>			
CRI Notes:       TVA Single Circuit       Edit Stringing       OK       Cancel         Displayed Phase will not take effect until override in Section/Display-Options is disabled.         SAPS Finite Element Sag-Tension Options         ✓ Clip Insulators (lock unstressed length, force finite element sag-tension)         Graph Tension vs. Elongation				

# Also

Longitudinal Loads on the structure will be determined from modeled insulator swings at As captured and sagging conditions

## Str Loads FE3 wire adjustment As Capture





(Click on section): Section #8, phase 1, 161kV, 'rail acsr 954 45_7', from Str. #74B Set 9 'Mahead' to Str. #E216A Set 4 'MID Back', All sections at BARE 60 'Initial RS', S=151552.54







## **Structural Loads**

- Longitudinal loads will depend on Sagging Conditions FE3 (Initial 60) FE4 (AS Captured Final)
- NESC ICE (250D) loads will be influenced by As Capture Swing
- Additional Longitudinal Load created by Cut/Slide to provide clearances

## Conclusion

- Assumption of insulators are plumb is removed by FE3 adjustment with correct sags in each span
- Results are still based on how well derive the conductor Temperature from weather data
- Range Ambient 66.1deg to No Wind 90.7deg
- Using all the weather data including solar radiation gave 71.2deg
- Thermal Rating is impacted approximately an equal temperature from the input conductor temperature
- Cost of additional modifications