```
# REFERENCE FUNCTIONS
In [1]:
In [2]: import pandas as pd
         import numpy as np
         import Template_GeneralFunctions as GenFun
         import Template_CatenaryFlexibleFunctions as Flex
In [3]: # INPUT DATA
In [4]: ## CALCULATION AND DESIGN CONSTANTS
         ### Calculation variables
In [5]: xRound=1
         xStep=1
         xMultiplier=1
         yMultiplier=1
         xStaticMultiplier=0.2
         yStaticMultiplier=10
In [6]: ### Design variables (Base Units [ft, lbf])
In [7]: MaxHASpacing=30
         minCW P=0
         MinHALength=3/12
         HA Accuracy=1/50/12
         SteadyArmLength=3
In [8]: ## CONDUCTOR PARTICULARS AND LOADING CONDITIONS
In [9]: Conductors = pd.DataFrame(
             {'Type': ['Messenger Wire', 'Contact Wire', 'Hangers'],
             'Weight': [1.544,1.063,0.2],
             'Tension': [5000,3300,0]})
In [10]: ## LAYOUT DESIGN
In [11]: df=pd.read_csv('InputData.csv')
In [12]: ## DISCRETE SPAN LOADS AND DESIGN CONDITIONS
         ### Discrete span loads. + weight is in the downward direction
In [13]: STA_DiscreteLoad_CW = np.array([162298,162612,0])
         P_DiscreteLoad_CW = np.array([5,10,0])
         STA_DiscreteLoad_MW = np.copy(STA_DiscreteLoad_CW)
         P_DiscreteLoad_MW = np.array([0,0,0])
In [14]: #Steady arms with fixed elevations (applied load calculated by span geometry)
In [15]: ExpectedSupport_P = 5
         STA_FixedSupport_CW=np.array([0,0,0,0])
         FixedSupport_EL_Tolerance = 0.1/12
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In [16]: #Critical Clearance Stationing and Elevation
In [17]: ClearanceSTA = np.array([0,0])
ClearanceEL = np.array([0,0])

In [18]: #Stationing of Interest

In [19]: FocusStation=165250
    FocusNeg:350
    FocusPos=350

In [20]: # CALCULATIONS

In [21]: FullWireRun=GenFun.WireRun_df(df,xRound)
    FullWireRun['PreSag']=0
    FullWireRun
```

	PoleID	STA	Rail EL	MW Height	CW Height	PreSag	Deviation Angle	SpanLength
0	1	162297.0	0	24.00	20.000000	0	0	155.0
1	2	162452.0	0	23.50	19.250000	0	0	160.0
2	3	162612.0	0	23.50	18.500000	0	0	133.0
3	4	162745.0	0	22.50	18.500000	0	0	150.0
4	5	162895.0	0	22.50	18.500000	0	0	173.0
5	6	163068.0	0	22.50	18.500000	0	0	190.0
6	7	163258.0	0	22.50	18.500000	0	0	190.0
7	8	163448.0	0	22.50	18.500000	0	0	190.0
8	9	163638.0	0	22.50	18.500000	0	0	190.0
9	10	163828.0	0	22.25	18.250000	0	0	186.0
10	11	164014.0	0	21.75	17.750000	0	0	170.0
11	12	164184.0	0	21.25	17.250000	0	0	190.0
12	13	164374.0	0	20.75	16.750000	0	0	190.0
13	14	164564.0	0	20.25	16.250000	0	0	191.0
14	15	164755.0	0	19.75	15.750000	0	0	192.0
15	16	164947.0	0	19.25	15.250000	0	0	130.0
16	17	165077.0	0	18.00	15.000000	0	0	130.0
17	18	165207.0	0	17.25	14.750000	0	0	130.0
18	19	165337.0	0	16.50	14.500000	0	0	130.0
19	20	165467.0	0	16.50	14.500000	0	0	126.0
20	21	165593.0	0	16.50	14.500000	0	0	82.0
21	22	165675.0	0	15.75	14.500000	0	0	74.0
22	23	165749.0	0	15.75	14.500000	0	0	120.0
23	24	165869.0	0	16.50	14.500000	0	0	119.0
24	25	165988.0	0	16.50	14.500000	0	0	120.0
25	26	166108.0	0	16.50	14.500000	0	0	119.0
26	27	166227.0	0	15.75	14.500000	0	0	58.0
27	28	166285.0	0	15.50	14.500000	0	0	94.0
28	29	166379.0	0	17.00	14.500000	0	0	95.0
29	30	166474.0	0	17.50	14.500000	0	0	52.0
30	31	166526.0	0	17.50	14.583333	0	0	154.0
31	32	166680.0	0	19.00	14.833333	0	0	135.0
32	33	166815.0	0	20.00	15.000000	0	0	165.0
33	34	166980.0	0	20.00	15.750000	0	0	180.0

Out[21]:

```
PoleID
                        STA Rail EL MW Height CW Height PreSag Deviation Angle SpanLength
         34
                35 167160.0
                                 0
                                         21.00
                                                17.000000
                                                                                     NaN
         L_DesignBase=[xStep,xRound,xMultiplier,yMultiplier,SteadyArmLength]
In [22]:
         L SpanLoading=[P DiscreteLoad CW,STA DiscreteLoad CW,P DiscreteLoad MW,STA DiscreteLoad
         L DesignHA=[MaxHASpacing,minCW P,MinHALength,HA Accuracy]
         L_StaticCWLoading=[-25,162475]
In [23]: Nominal = Flex.CatenarySag_Flexible(FullWireRun, Conductors['Weight'],
                                              Conductors['Tension'], L SpanLoading, L DesignHA, L D
         # Nominal dictionary keys
         # Stationing, HA_STA, HA_EL
         # LoadedSag, SupportLoad CW, P SpanWeight
         # LoadedSag_MW, SupportLoad_MW, P_SpanWeight_MW
         subloop = 1
In [24]: Uplift, cloops, NewCWSupportReaction = Flex.CatenarySag_FlexibleHA_Iterative(FullWireF
                                                                                        Conductor
                                                                                        L DesignE
         # Uplift dictionary keys
         # Stationing, HA STA, HA EL
         # LoadedSag, SupportLoad_CW, P_SpanWeight
         # LoadedSag MW, SupportLoad MW, P SpanWeight MW
         Main Loops= 4 subLoop2= 0 subLoop1= 0
In [25]: FocusSPT = 2
         StartSPT = FocusSPT-1
         EndSPT = FocusSPT+1
         Elasticity = Flex.CatenaryElasticity FlexibleHA(FullWireRun, 0*Conductors['Weight'],
                                                          Conductors['Tension'], L DesignHA, L [
                                                          Nominal, StartSPT, EndSPT)
         # Elasticity dictionary keys
         # STAVal, DiffMIN, DiffMAX, CycleLoops
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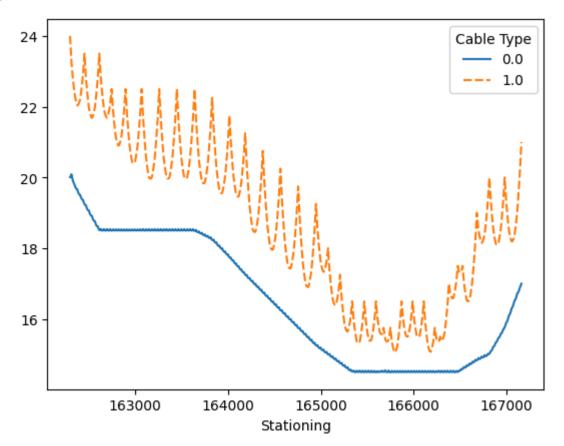
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Elasticity with uplift at STA= 162722.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162723.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162724.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162725.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162726.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162727.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162728.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162729.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162730.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162731.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162732.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162733.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162734.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162735.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162736.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162737.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162738.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162739.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162740.0 Main Loops= 3 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162741.0 Main Loops= 2 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162742.0 Main Loops= 2 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162743.0 Main Loops= 2 subLoop2= 0 subLoop1= 0 Elasticity with uplift at STA= 162744.0 Main Loops= 2 subLoop2= 0 subLoop1= 0

```
Out[28]: Cable Type
                             0.0
                                       1.0
           Stationing
            162297.0
                      20.009060
                                 24.000000
                                 23.948176
            162298.0
                       20.010994
            162299.0
                      20.014007
                                 23.896701
            162300.0
                      20.018100
                                 23.845575
            162301.0 20.022516 23.794797
```

In [29]: sns.lineplot(data=NominalSag)

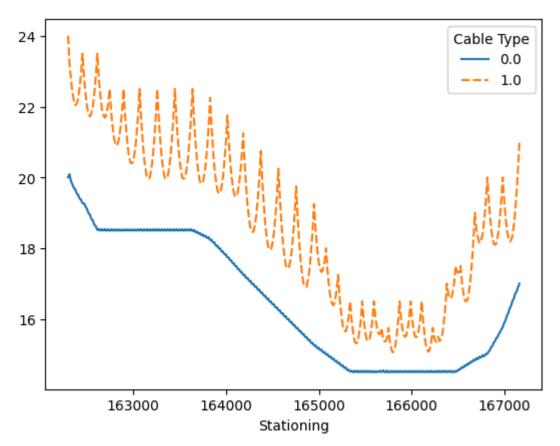
Out[29]: <Axes: xlabel='Stationing'>



```
Out[30]: Cable Type
                             0.0
                                       1.0
           Stationing
            162297.0
                      20.009060
                                 24.000000
                      20.011075
                                 23.948256
            162298.0
            162299.0
                      20.014171
                                 23.896860
            162300.0 20.018346
                                 23.845813
            162301.0 20.022843 23.795115
```

```
In [31]: sns.lineplot(data=UpliftSag)
```

Out[31]: <Axes: xlabel='Stationing'>



 Out[32]:
 Cable Type
 0.0
 1.0

 Stationing

 162297.0
 0.000000
 0.000000

 162298.0
 0.000980
 0.000952

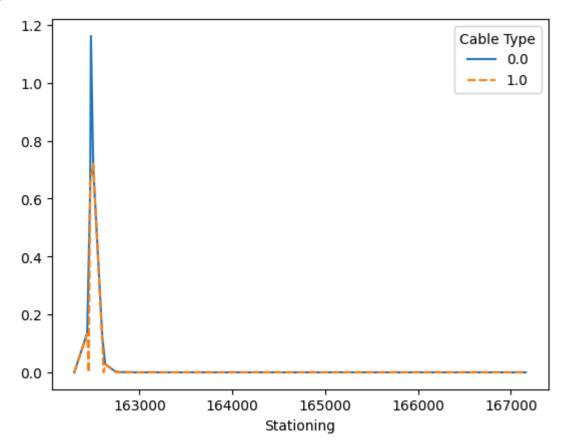
 162299.0
 0.001961
 0.001905

 162300.0
 0.002941
 0.002857

 162301.0
 0.003921
 0.003810

In [33]: sns.lineplot(data=DiffSag)

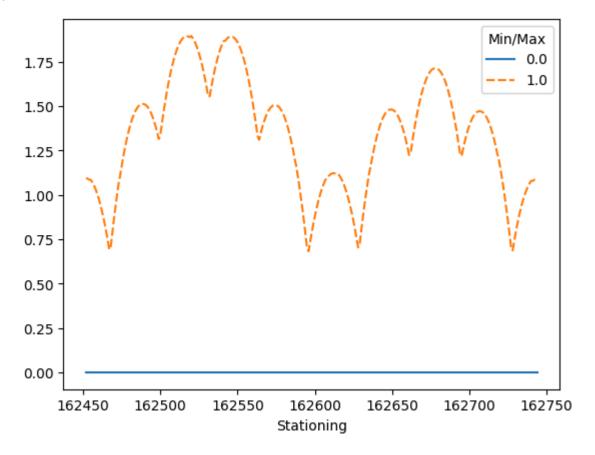
Out[33]: <Axes: xlabel='Stationing'>



```
Out[34]:
           Min/Max 0.0
                               1.0
           Stationing
            162452.0
                      0.0 1.094093
                         1.091717
            162453.0
                      0.0
            162454.0
                      0.0
                         1.085467
            162455.0
                      0.0
                         1.084777
            162456.0 0.0 1.071872
```

```
In [35]: sns.lineplot(data=ElasticityGraph)
```

Out[35]: <Axes: xlabel='Stationing'>



```
In [36]: # SAVE OUTPUT

In [37]: NominalSag.to_csv('OutputData.csv')

In [38]: FullWireRun['STA'].iloc[3]-FullWireRun['STA'].iloc[1]

Out[38]: 293.0

In [39]: Uplift.get('SupportLoad_CW')-Nominal.get('SupportLoad_CW')
```

```
4.90274488e-13, -1.20792265e-13,
          array([-2.69577627e-01, -4.83169060e-13,
Out[39]:
                  1.20792265e-13, -3.96834010e+00, -1.56199419e+01, -3.48251826e+00,
                  1.86454088e-02, -2.59641374e-04,
                                                     -8.36273803e-01, -7.81324877e-01,
                  5.40824544e-03, -7.04967462e-06,
                                                     -3.00637744e-02, -3.39390698e-02,
                  1.72825138e-04, -2.74382170e-06,
                                                      0.00000000e+00, -9.41854197e-04,
                 -1.00063376e-03,
                                    9.10257054e-06,
                                                      4.01456646e-13, -4.05009359e-13,
                  4.05009359e-13, -2.36000374e-05,
                                                     -2.06500318e-05,
                                                                        0.00000000e+00,
                  0.00000000e+00,
                                    0.00000000e+00,
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                                                                        0.00000000e+00,
                  0.00000000e+00,
                                    0.00000000e+00,
                                                      0.00000000e+001)
          len(Uplift.get('SupportLoad_CW'))
In [40]:
          159
Out[40]:
          len(Uplift.get('HA STA'))
In [41]:
Out[41]:
```