vqpoints

November 30, 2023

This notebook illustrates the conversion of system-oriented volt-var function parameters, e.g., slope (gain) and deadband, into the standard table of V1..V4, Q1..Q4 points as defined in IEEE 1547-2018.

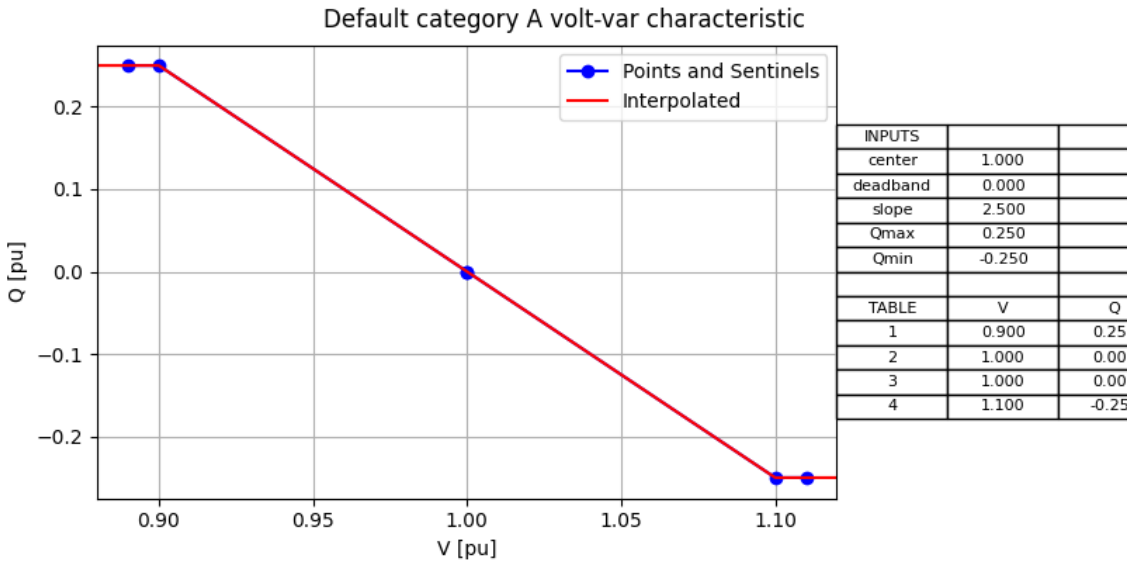
Run the following cell to define the plot and table functions using Matplotlib

[1]:
```
import sys
import os
import matplotlib.pyplot as plt
import numpy as np
import math

# convert center, deadband, slope, and q limits into a table of V and Q points.
# the function returns two arrays for the V and Q points
#    the arrays have sentinel elements below V1 and above V4, so they are 6␣
 ↪elements long (not 4)
#    the sentinel elements clarify that constant extrapolation is used outside␣
 ↪the range [V1..V4]
def set_characteristic (center=1.0, deadband=0.0, slope=22.0, qmax=0.44,␣
 ↪qmin=-0.44):
#    Vreg = center
  Q1 = qmax
  Q2 = 0.0
  Q3 = 0.0
  Q4 = qmin
  V2 = center - 0.5 * deadband
  V3 = center + 0.5 * deadband
  V1 = V2 - Q1 / slope
  V4 = V3 - Q4 / slope
  VL = V1 - 0.01 # min (V1, 0.95)
  VH = V4 + 0.01 # max (V4, 1.05)
  vtable = np.array ([VL, V1, V2, V3, V4, VH])
  qtable = np.array ([Q1, Q1, Q2, Q3, Q4, Q4])
  return vtable, qtable

# this function plots and tabulates a volt-var characteristic
def show_characteristic (label, center, deadband, slope, qmax, qmin):
  vtable, qtable = set_characteristic (center, deadband, slope, qmax, qmin)
```

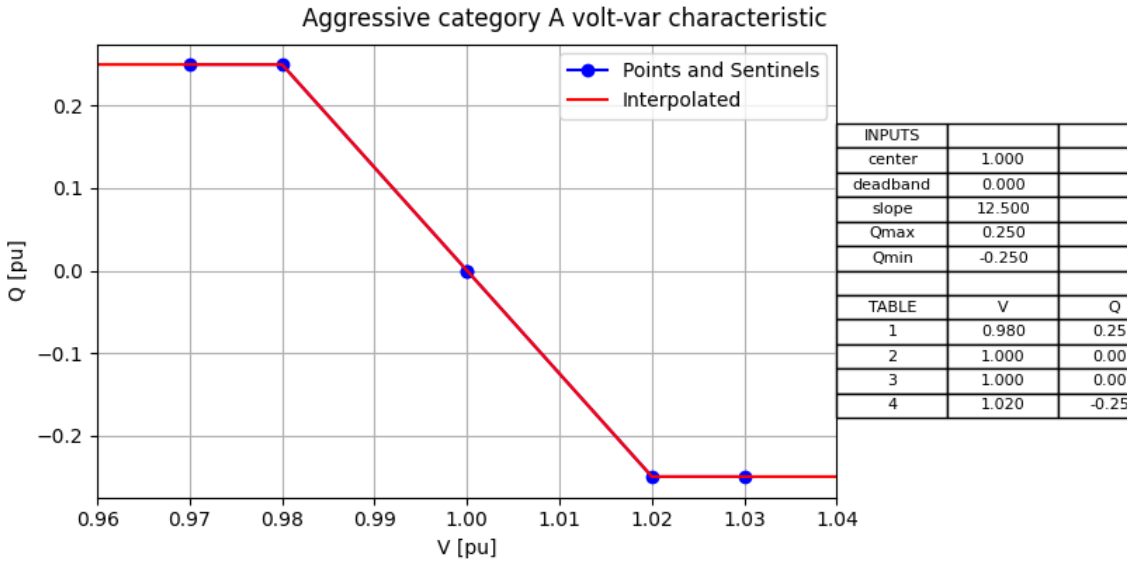
```
  # bounds for plotting the horizontal axis
  vmin = vtable[0]-0.01
  vmax = vtable[-1]+0.01

  # evaluate the characteristic over 500 equal voltage intervals
  v = np.linspace (vmin, vmax, 501)
  # interpolating Q using the numpy library function
  q = np.interp (v, vtable, qtable)

  # create the plot
  fig, ax = plt.subplots(1, 1, sharex = 'col', figsize=(8,4),␣
 ↪constrained_layout=True)
  fig.suptitle ('{:s} volt-var characteristic'.format (label))
  ax.plot (vtable, qtable, marker='o', color='blue', label='Points and␣
 ↪Sentinels')
  ax.plot (v, q, color='red', label='Interpolated')
  ax.grid ()
  ax.set_xlabel ('V [pu]')
  ax.set_ylabel ('Q [pu]')
  ax.set_xlim (vmin, vmax)
  ax.legend ()

  # create the data table with 3 columns
  cellText = []
  cellText.append (['INPUTS', '', ''])
  cellText.append (['center', '{:.3f}'.format (center), ''])
  cellText.append (['deadband', '{:.3f}'.format (deadband), ''])
  cellText.append (['slope', '{:.3f}'.format (slope), ''])
  cellText.append (['Qmax', '{:.3f}'.format (qmax), ''])
  cellText.append (['Qmin', '{:.3f}'.format (qmin), ''])
  cellText.append (['', '', ''])
  cellText.append (['TABLE', 'V', 'Q'])
  for i in range(4):
    cellText.append (['{:d}'.format(i+1), '{:.3f}'.format(vtable[i+1]), '{:.
 ↪3f}'.format(qtable[i+1])])
  cwidth = 0.15
  plt.table (cellText=cellText, cellLoc='center', colWidths=[cwidth, cwidth,␣
 ↪cwidth], loc='right')

  plt.show ()

# use the current directory as default location for the "save plot" buttons
plt.rcParams['savefig.directory'] = os.getcwd()
# invoke the Jupyter support for  Matplotlib graphics
%matplotlib widget
```

Run the following cell to show several volt-var characteristics of interest.

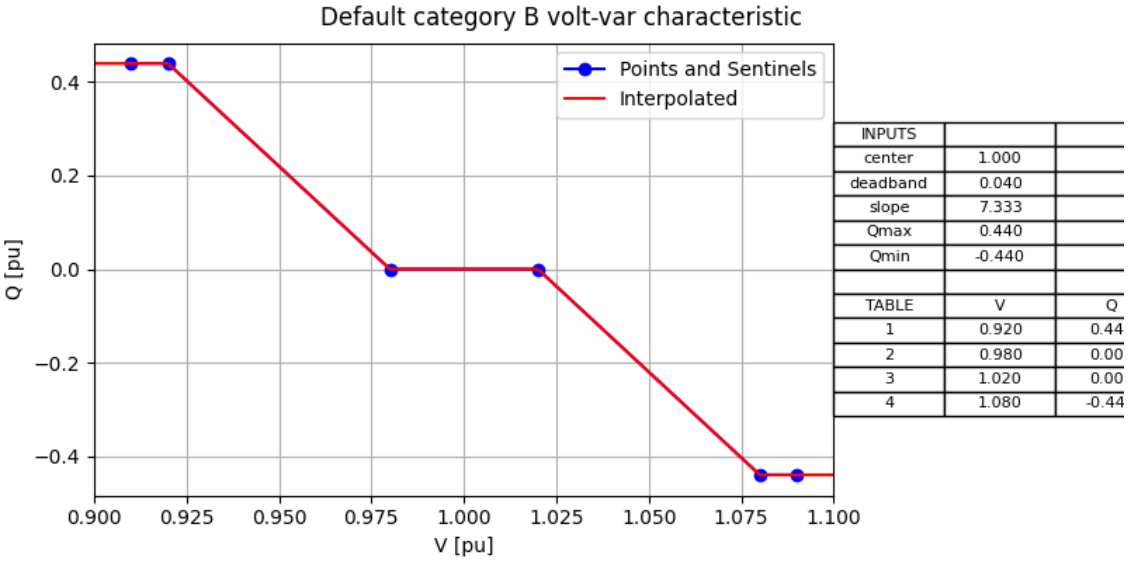
[2]:
```
show_characteristic ('Default category A',     center=1.0, deadband=0.0, ␣
 ↪slope=2.5,       qmax=0.25, qmin=-0.25)
show_characteristic ('Aggressive category A', center=1.0, deadband=0.0, ␣
 ↪slope=12.5,      qmax=0.25, qmin=-0.25)
show_characteristic ('Default category B',     center=1.0, deadband=0.04,␣
 ↪slope=22.0/3.0, qmax=0.44, qmin=-0.44)
show_characteristic ('Aggressive category B', center=1.0, deadband=0.0, ␣
 ↪slope=22.0,      qmax=0.44, qmin=-0.44)
show_characteristic ('Hawaii Rule 14H',        center=1.0, deadband=0.06,␣
 ↪slope=43.0/3.0, qmax=0.44, qmin=-0.44)
```



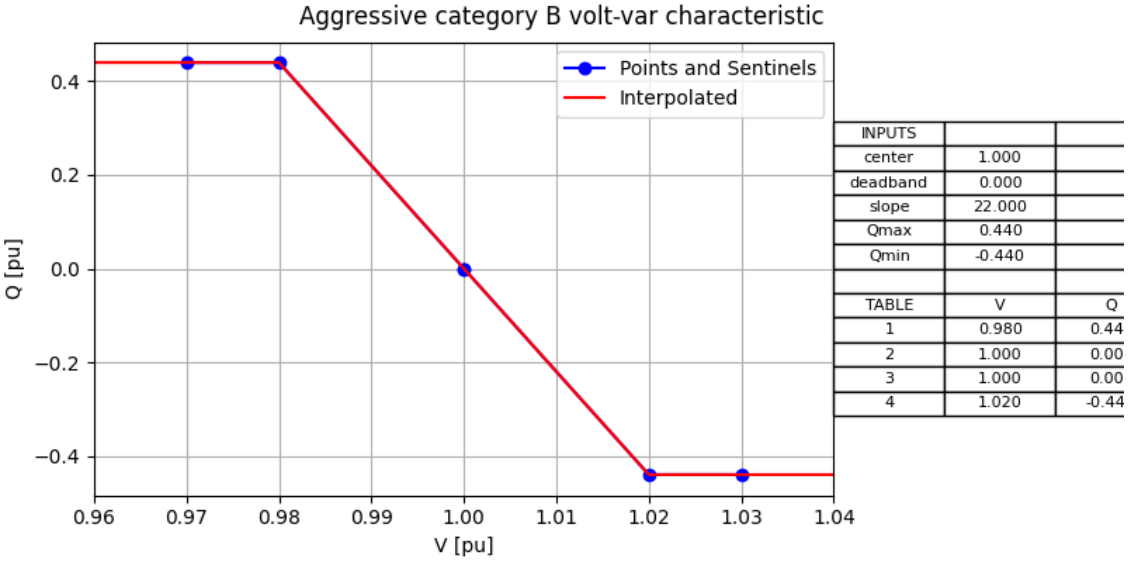
INPUTS		
center	1.000	
deadband	0.000	
slope	2.500	
Qmax	0.250	
Qmin	-0.250	
TABLE	V	Q
1	0.900	0.25
2	1.000	0.00
3	1.000	0.00
4	1.100	-0.25



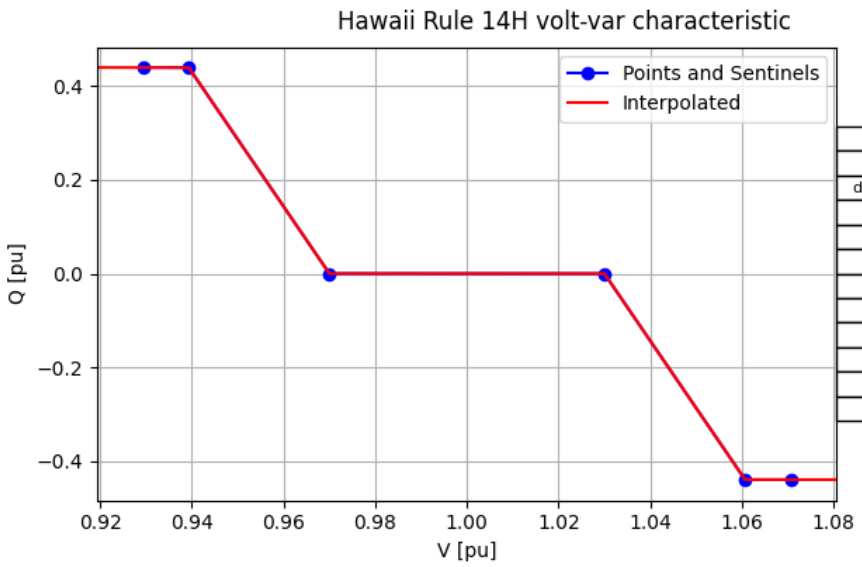
INPUTS		
center	1.000	
deadband	0.000	
slope	12.500	
Qmax	0.250	
Qmin	-0.250	
TABLE	V	Q
1	0.980	0.25
2	1.000	0.00
3	1.000	0.00
4	1.020	-0.25



INPUTS		
center	1.000	
deadband	0.040	
slope	7.333	
Qmax	0.440	
Qmin	-0.440	
TABLE	V	Q
1	0.920	0.44
2	0.980	0.00
3	1.020	0.00
4	1.080	-0.44



INPUTS		
center	1.000	
deadband	0.000	
slope	22.000	
Qmax	0.440	
Qmin	-0.440	
TABLE	V	Q
1	0.980	0.44
2	1.000	0.00
3	1.000	0.00
4	1.020	-0.44



INPUTS		
center	1.000	
deadband	0.060	
slope	14.333	
Qmax	0.440	
Qmin	-0.440	
TABLE	V	Q
1	0.939	0.44
2	0.970	0.00
3	1.030	0.00
4	1.061	-0.44

[ ]: