DC Power Flow

Poměrné hodnoty. Předpoklady:

$$u_i \approx u_j \approx 1 \qquad \sin\delta_{ij} \approx \delta_{ij} \qquad b_{ij} = -\frac{1}{x_{ij}}$$

$$P_{ij} = \frac{U_i U_j}{X_{ij}} \sin\delta_{ij}$$

$$p_{ij} \cdot S_v = \frac{u_i \cdot U_v \cdot u_j \cdot U_v}{x_{ij} \cdot Z_v} \sin\delta_{ij}$$

$$p_{ij} = \frac{u_i \cdot u_j}{x_{ij}} \sin\delta_{ij} \Rightarrow p_{ij} = \frac{\delta_{ij}}{x_{ij}} = \frac{\delta_i - \delta_j}{x_{ij}}$$

Maticově

$$p_i = \sum_{\substack{j=1 \\ j\neq i}}^{n} \frac{\delta_i - \delta_j}{x_{ij}} = \delta_i \sum_{\substack{j=1 \\ j\neq i}}^{n} \frac{1}{x_{ij}} - \sum_{\substack{j=1 \\ j\neq i}}^{n} \frac{\delta_j}{x_{ij}}$$

$$p_i = \delta_i b'_{(i,i)} + \sum_{\substack{j=1 \\ j\neq i}}^{n} \delta_j b'_{(i,j)}$$

$$(p) = (b')(\delta)$$

Jen podélné reaktance → **b´** singulární. 1 uzel jako referenční s $\delta = 0$ → matice **b´´** o řád menší.

(DC model nepočítá ztráty, tedy netřeba slack, ale reference úhlu ano.)

$$(\delta) = (b'')^{-1}(p)$$

$$(u) = (g)^{-1}(i)$$

Ustálený chod sítě

In[1]:=
$$y12 = \frac{1}{0.002 + 0.04\,I}$$
$$y13 = \frac{1}{0.001 + 0.03\,I}$$
$$y23 = \frac{1}{0.00125 + 0.025\,I}$$

Out[1]= 1.24688 − 24.9377 i

Out[2]= 1.10988 − 33.2963 i

Out[3]= 1.99501 − 39.9002 i

In[4]:=
$$Sc = 100;$$
$$s2 = -\frac{250 + 110\,I}{Sc}$$
$$s3 = -\frac{140 + 40\,I}{Sc}$$

Out[5]= $-\frac{5}{2} - \frac{11\,i}{10}$

Out[6]= $-\frac{7}{5} - \frac{2\,i}{5}$

In[7]:=
$$u1 = 1.05;$$
$$u20 = 1;\ u30 = 1;$$

DC power flow

In[9]:=
$$b12 = 1 / \mathrm{Im}[1 / y12]\ (*\ \tfrac{1}{0.04}\ *)$$
$$b13 = 1 / \mathrm{Im}[1 / y13]\ (*\ \tfrac{1}{0.03}\ *)$$
$$b23 = 1 \Big/ \mathrm{Im}[1 / y23]\ (*\ \tfrac{1}{0.025}\ *)$$

Out[9]= 25.

Out[10]= 33.3333

Out[11]= 40.

In[12]:=
```
bmat = {{b12 + b13, -b12, -b13}, {-b12, b12 + b23, -b23}, {-b13, -b23, b13 + b23}};
MatrixForm[bmat]
```

Out[13]//MatrixForm=

$$\begin{pmatrix} 58.3333 & -25. & -33.3333 \\ -25. & 65. & -40. \\ -33.3333 & -40. & 73.3333 \end{pmatrix}$$

In[14]:=
```
bmat2 = bmat[[2 ;; 3, 2 ;; 3]]
```

Out[14]= {{65., −40.}, {−40., 73.3333}}

In[15]:= `p = Re[{s2, s3}]`

Out[15]= $\left\{-\frac{5}{2}, -\frac{7}{5}\right\}$

In[16]:= `Inverse[bmat2]`

Out[16]= {{0.0231579, 0.0126316}, {0.0126316, 0.0205263}}

In[17]:=
```
delta = Insert[Inverse[bmat2].p, 0, 1]
% * 180 / Pi
```

Out[17]= {0, −0.0755789, −0.0603158}

Out[18]= {0, −4.33035, −3.45584}

In[19]:=
```
p12 = (delta[[1]] - delta[[2]]) * b12
p13 = (delta[[1]] - delta[[3]]) * b13
p23 = (delta[[2]] - delta[[3]]) * b23
```

Out[19]= 1.88947

Out[20]= 2.01053

Out[21]= −0.610526

In[22]:=
```
p12 + p13
p23 - p12
-p13 - p23
```

Out[22]= 3.9

Out[23]= −2.5

Out[24]= −1.4

Gauss-Seidel

In[25]:=
$$a = \frac{\frac{\text{Conjugate[s2]}}{\text{Conjugate[u20]}} + y12 * u1 + y23 * u30}{y12 + y23}$$
$$\frac{\frac{\text{Conjugate[s3]}}{\text{Conjugate[u30]}} + y13 * u1 + y23 * a}{y13 + y23}$$

Out[25]= 1.00038 − 0.0376154 i

Out[26]= 1.01684 − 0.0395766 i

In[27]:=
```
gs1[{i_, u2_, u3_, d2_, d3_}] := {i + 1, a = (Conjugate[s2]/Conjugate[u2] + y12 * u1 + y23 * u3)/(y12 + y23),
  b = (Conjugate[s3]/Conjugate[u3] + y13 * u1 + y23 * a)/(y13 + y23), a - u2, b - u3}
NestList[gs1, {0, u20, u30, 0, 0}, 10] // N // MatrixForm
u2 = %[[Length[%], 2]]
u3 = %%[[Length[%%], 3]]
```

Out[28]//MatrixForm=

0.	1.	1.	0.	
1.	1.00038 − 0.0376154 i	1.01684 − 0.0395766 i	0.000384615 − 0.0376154 i	
2.	1.00937 − 0.0611953 i	1.02122 − 0.0518176 i	0.00898252 − 0.02358 i	
3.	1.01144 − 0.0678898 i	1.0222 − 0.0552894 i	0.00207019 − 0.00669442 i	0
4.	1.01186 − 0.0698024 i	1.02238 − 0.0562865 i	0.000419723 − 0.00191261 i	0.
5.	1.01192 − 0.0703576 i	1.0224 − 0.0565779 i	0.0000585796 − 0.000555224 i	0.
6.	1.01191 − 0.0705221 i	1.02239 − 0.056665 i	-5.9596×10^{-6} − 0.000164514 i	−7.4
7.	1.0119 − 0.0705721 i	1.02239 − 0.0566918 i	−0.000010258 − 0.0000499864 i	−6.5
8.	1.01189 − 0.0705877 i	1.02238 − 0.0567002 i	-6.19534×10^{-6} − 0.0000156386 i	−3.8
9.	1.01189 − 0.0705928 i	1.02238 − 0.056703 i	-3.02663×10^{-6} − 5.05211×10^{-6} i	−1.8
10.	1.01189 − 0.0705945 i	1.02238 − 0.0567039 i	-1.35144×10^{-6} − 1.68686×10^{-6} i	−7.9

Out[29]= 1.01189 − 0.0705945 i

Out[30]= 1.02238 − 0.0567039 i

In[31]:=
```
{Abs[u2], Arg[u2] * 180 / Pi}
{Abs[u3], Arg[u3] * 180 / Pi}
```

Out[31]= {1.01435, −3.99078}

Out[32]= {1.02395, −3.17452}

In[33]:=
```
s1v = u1 * Conjugate[y12 (u1 - u2) + y13 * (u1 - u3)]
s2v = u2 * Conjugate[y12 (u2 - u1) + y23 * (u2 - u3)]
s3v = u3 * Conjugate[y13 (u3 - u1) + y23 * (u3 - u2)]
```

Out[33]= 3.913 + 1.80501 i

Out[34]= −2.49996 − 1.09997 i

Out[35]= −1.4 − 0.399998 i

In[36]:=
```
i12 = y12 * (u1 - u2)
s12 = u1 * Conjugate[i12] * Sc
s21 = u2 * Conjugate[-i12] * Sc
```

Out[36]= 1.80798 − 0.86238 i

Out[37]= 189.838 + 90.5499 i

Out[38]= −189.035 − 74.4999 i

In[39]:=
```
ds12 = s12 + s21
```

Out[39]= 0.802499 + 16.05 i

In[40]:=
```
i13 = y13 * (u1 - u3)
s13 = u1 * Conjugate[i13] * Sc
s31 = u3 * Conjugate[-i13] * Sc
```

Out[40]= 1.91869 − 0.856681 i

Out[41]= 201.462 + 89.9515 i

Out[42]= −201.021 − 76.7057 i

In[43]:=
```
ds13 = s13 + s31
```

Out[43]= 0.441526 + 13.2458 i

In[44]:=
```
i23 = y23 * (u2 - u3)
s23 = u2 * Conjugate[i23] * Sc
s32 = u3 * Conjugate[-i23] * Sc
```

Out[44]= −0.575167 + 0.390924 i

Out[45]= −60.9603 − 35.4968 i

Out[46]= 61.0207 + 36.7059 i

In[47]:=
```
ds23 = s23 + s32
```

Out[47]= 0.0604549 + 1.2091 i

In[48]:=
```
ds12 + ds13 + ds23
(s1v + s2v + s3v) * Sc
```

Out[48]= 1.30448 + 30.5049 i

Out[49]= 1.30448 + 30.5049 i