```
tic;
disableTaps = true;
epsilon = 0.01;
separatingImages = false;
```

Centralized Power Flow Solution

```
varNames = ["bus_i", "type", "Pd", "Qd", ...
    "Gs", "Bs"];

addpath functions\

busData = [
  1    3    50    30.99    0    0    1    1    0    230    1    1.1    0.9;
  2    1    170   105.35   0    0    1    1    0    230    1    1.1    0.9;
  3    1    200   123.94   0    0    1    1    0    230    1    1.1    0.9;
  4    2    80    49.58    0    0    1    1    0    230    1    1.1    0.9;
];
N = size(busData, 1);

busTable = array2table(busData(:, 1:6));
busTable.Properties.VariableNames = varNames;
busTable.Pd = busTable.Pd/100;
busTable.Qd = busTable.Qd/100
```

busTable = 4×6 table

	bus_i	type	Pd	Qd	Gs	Bs
1	1	3	0.5000	0.3099	0	0
2	2	1	1.7000	1.0535	0	0
3	3	1	2	1.2394	0	0
4	4	2	0.8000	0.4958	0	0

```
branchData = [
    1    2    0.01008    0.0504    0.1025    250    250    250    0    0    1    -360    360;
    1    3    0.00744    0.0372    0.0775    250    250    250    0    0    1    -360    360;
    2    4    0.00744    0.0372    0.0775    250    250    250    0    0    1    -360    360;
    3    4    0.01272    0.0636    0.1275    250    250    250    0    0    1    -360    360;
    ];
numBranch = size(branchData, 1);

branchTable = array2table(branchData(:, 1:5));
varNamesBranchData = ["fbus", "tbus", "R", "X", "B"];
branchTable.Properties.VariableNames = varNamesBranchData
```

branchTable = 4×5 table

	fbus	tbus	R	X	B
1	1	2	0.0101	0.0504	0.1025

	fbus	tbus	R	X	B
2	1	3	0.0074	0.0372	0.0775
3	2	4	0.0074	0.0372	0.0775
4	3	4	0.0127	0.0636	0.1275

```
[ybus, BMatrix, b, A] = ybusGenerator(busTable, branchTable, ...
    N, numBranch, disableTaps);
ybusTable = array2table(ybus, ...
    "RowNames", ["1", "2", "3", "4"], "VariableNames", ["1", "2", "3", "4"])
```

ybusTable = 4×4 table

	1	2	3	4
1 1	8.9852 -44.8360i	-3.8156 +19.0269i	-5.1696 +25.8091i	0.0000 + 0.0000i
2 2	-3.8156 +19.0269i	8.9852 -44.8360i	0.0000 + 0.0000i	-5.1696 +25.8091i
3 3	-5.1696 +25.8091i	0.0000 + 0.0000i	8.1933 -40.8638i	-3.0237 +15.0548i
4 4	0.0000 + 0.0000i	-5.1696 +25.8091i	-3.0237 +15.0548i	8.1933 -40.8638i

```
BMatrix = BMatrix([1 2 4], [1 2 4]);
BMatrixTable = array2table(BMatrix, ...
    "RowNames", ["1", "2", "4"], ...
    "VariableNames", ["1", "2", "4"])
```

BMatrixTable = 3×3 table

	1	2	4
1 1	46.7230	-19.8413	0
2 2	-19.8413	46.7230	-26.8817
3 4	0	-26.8817	42.6050

```
ATable = array2table(A, ...
    "RowNames", ["1-2", "1-3", "2-4", "3-4"], "VariableNames", ["1", "2", "3", "4"])
```

ATable = 4×4 table

	1	2	3	4
1 1-2	1	-1	0	0
2 1-3	1	0	-1	0
3 2-4	0	1	0	-1
4 3-4	0	0	1	-1

```
bTable = array2table(b, ...
    "RowNames", ["1-2", "1-3", "2-4", "3-4"], ...
    "VariableNames", ["1-2", "1-3", "2-4", "3-4"])
```

bTable = 4×4 table

	1-2	1-3	2-4	3-4
1 1-2	19.8413	0	0	0
2 1-3	0	26.8817	0	0
3 2-4	0	0	26.8817	0
4 3-4	0	0	0	15.7233

```
P = [-0.5, -1.70, -0.80]'; %P(i) = P_G(i) - P_L(i)
PTable = array2table(P,"RowNames", ["1", "2", "4"])
```

PTable = 3×1 table

	P
1 1	-0.5000
2 2	-1.7000
3 4	-0.8000

```
theta = BMatrix\P; %BMatrix elements are negative of ybus elements
thetaFull = [theta(1:2); 0; theta(end)];
thetaFullTable = array2table(thetaFull, ...
    "VariableNames", ["theta"], "RowNames", ["1", "2", "3", "4"])
```

thetaFullTable = 4×1 table

	theta
1 1	-0.0588
2 2	-0.1133
3 3	0
4 4	-0.0903

```
PL = b*A*thetaFull;
PLTable = array2table(PL, ...
    "RowNames", bTable.Properties.RowNames, ...
    "VariableNames", ["PL"])
```

PLTable = 4×1 table

	PL
1 1-2	1.0809
2 1-3	-1.5809
3 2-4	-0.6191
4 3-4	1.4191

```
if separatingImages
    imshow("images/heejin01.jpg", 'Border', 'tight', 'InitialMagnification', 15);
```

```
end
```

Upstream Branch with Virtual Loads aka Virtual Loads Area (VLA)

```
branchDataUpStream = [
    1    3    0.00744*(1-epsilon)    0.0372*(1-epsilon)    0.0775    250    250    250    0
    2    4    0.00744*(1-epsilon)    0.0372*(1-epsilon)    0.0775    250    250    250    0
    3    4    0.01272                0.0636                0.1275    250    250    250    0
    ];
numBranchUpStream = size(branchDataUpStream, 1);

branchTableUpStream = array2table(branchDataUpStream(:, 1:5));
varNamesBranchData = ["fbus", "tbus", "R", "X", "B"];
branchTableUpStream.Properties.VariableNames = varNamesBranchData
```

branchTableUpStream = 3×5 table

	fbus	tbus	R	X	B
1	1	3	0.0074	0.0368	0.0775
2	2	4	0.0074	0.0368	0.0775
3	3	4	0.0127	0.0636	0.1275

```
[ybusUpStream, BMatrixUpStream, bUpStream, AUpStream] = ...
    ybusGenerator(busTable, branchTableUpStream, ...
    N, numBranchUpStream, disableTaps);

ybusUpStreamTable = array2table(ybusUpStream, ...
    "RowNames", ["5", "6", "3", "4"], "VariableNames", ["5", "6", "3", "4"])
```

ybusUpStreamTable = 4×4 table

	5	6	3	4
1 5	5.2218 -26.0701i	0.0000 + 0.0000i	-5.2218 +26.0701i	0.0000 + 0.0000i
2 6	0.0000 + 0.0000i	5.2218 -26.0701i	0.0000 + 0.0000i	-5.2218 +26.0701i
3 3	-5.2218 +26.0701i	0.0000 + 0.0000i	8.2455 -41.1249i	-3.0237 +15.0548i
4 4	0.0000 + 0.0000i	-5.2218 +26.0701i	-3.0237 +15.0548i	8.2455 -41.1249i

```
BMatrixUpStream = BMatrixUpStream([1 2 4], [1 2 4]);
BMatrixUpStreamTable = array2table(BMatrixUpStream, ...
    "RowNames", ["5", "6", "4"], ...
    "VariableNames", ["5", "6", "4"])
```

BMatrixUpStreamTable = 3×3 table

	5	6	4
1 5	27.1533	0	0
2 6	0	27.1533	-27.1533
3 4	0	-27.1533	42.8765

```
AUpStreamTable = array2table(AUpStream, ...
    "RowNames", ["5-3", "6-4", "3-4"], "VariableNames", ["5", "6", "3", "4"])
```

AUpStreamTable = 3×4 table

	5	6	3	4
1 5-3	1	0	-1	0
2 6-4	0	1	0	-1
3 3-4	0	0	1	-1

```
bUpStreamTable = array2table(bUpStream, ...
    "RowNames", ["5-3", "6-4", "3-4"], ...
    "VariableNames", ["5-3", "6-4", "3-4"])
```

bUpStreamTable = 3×3 table

	5-3	6-4	3-4
1 5-3	27.1533	0	0
2 6-4	0	27.1533	0
3 3-4	0	0	15.7233

```
if separatingImages
    imshow("images/hyunjin01.jpg", 'Border', 'tight', 'InitialMagnification', 15);
end
```

Donwstream Branch with Virtual Generators aka Virtual Generator Area (VGA)

```
branchDataDownStream = [
    1    2    0.01008            0.05040          0.1025    250    250    250    0    0    1
    1    3    0.00744*epsilon    0.0372*epsilon   0.0775    250    250    250    0    0    1
    2    4    0.00744*epsilon    0.0372*epsilon   0.0775    250    250    250    0    0    1
    ];
numBranchDownStream = size(branchDataDownStream, 1);

branchTableDownStream = array2table(branchDataDownStream(:, 1:5));
varNamesBranchData = ["fbus", "tbus", "R", "X", "B"];
branchTableDownStream.Properties.VariableNames = varNamesBranchData
```

branchTableDownStream = 3×5 table

	fbus	tbus	R	X	B
1	1	2	0.0101	0.0504	0.1025
2	1	3	0.0001	0.0004	0.0775
3	2	4	0.0001	0.0004	0.0775

```
[ybusDownStream, BMatrixDownStream, bDownStream, ADownStream] = ...
    ybusGenerator(busTable, branchTableDownStream, ...
```

```
    N, numBranchDownStream, disableTaps);

ybusDownStreamTable = array2table(ybusDownStream, ...
    "RowNames", ["1", "2", "5'", "6'"], "VariableNames", ["1", "2", "5'", "6'"])
```

ybusDownStreamTable = 4×4 table

	1	2	5'	6'
1 1	5.2077e+02 - 2.6038e+03i	-3.8156 +19.0269i	-5.1696e+02 + 2.5847e+03i	0
2 2	-3.8156 +19.0269i	5.2077e+02 - 2.6038e+03i	0	-5.1696e+02 + 2.5847e+03i
3 5'	-5.1696e+02 + 2.5847e+03i	0	5.1696e+02 - 2.5847e+03i	0
4 6'	0	-5.1696e+02 + 2.5847e+03i	0	5.1696e+02 - 2.5847e+03i

```
BMatrixDownStream = BMatrixDownStream([1 2 4], [1 2 4]);
BMatrixDownStreamTable = array2table(BMatrixDownStream, ...
    "RowNames", ["1", "2", "6'"], ...
    "VariableNames", ["1", "2", "6'"])
```

BMatrixDownStreamTable = 3×3 table

	1	2	6'
1 1	2.7080e+03	-19.8413	0
2 2	-19.8413	2.7080e+03	-2.6882e+03
3 6'	0	-2.6882e+03	2.6882e+03

```

ADownStreamTable = array2table(ADownStream, ...
    "RowNames", ["1-2", "1-5'", "2-6'"], "VariableNames", ["1", "2", "5'", "6'"])
```

ADownStreamTable = 3×4 table

	1	2	5'	6'
1 1-2	1	-1	0	0
2 1-5'	1	0	-1	0
3 2-6'	0	1	0	-1

```
bDownStreamTable = array2table(bDownStream, ...
    "RowNames", ["1-2", "1-5'", "2-6'"], ...
    "VariableNames", ["1-2", "1-5'", "2-6'"])
```

bDownStreamTable = 3×3 table

	1-2	1-5'	2-6'
1 1-2	19.8413	0	0
2 1-5'	0	2.6882e+03	0
3 2-6'	0	0	2.6882e+03

```

if separatingImages
    imshow("images/haseul01.jpg", 'Border', 'tight', 'InitialMagnification', 15);
```

```
end
```

Solving for Distributed Power Flow

```
for iter = 1:3
    if separatingImages
        imshow("images/dahyun01.jpg", 'Border', 'tight', 'InitialMagnification', 7.50);
    end
    if iter == 1
        PUpStream = [0, 0, -0.80]'; %P(i) = P_G(i) - P_L(i)
        PUpStreamTable = array2table(PUpStream, "RowNames", ["5", "6", "4"])
        thetaUpStream = BMatrixUpStream\PUpStream; %BMatrix elements are negative of ybus eleme
        thetaFullUpStream = [thetaUpStream(1:2); 0; thetaUpStream(end)];
        thetaFullUpStreamTable = array2table(thetaFullUpStream, ...
            "VariableNames", ["theta"], "RowNames", ["5", "6", "3", "4"])
        theta5 = thetaFullUpStream(1);
        theta6 = thetaFullUpStream(2);
        PLUpStream = bUpStream*AUpStream*thetaFullUpStream;
        PLUpStreamTable = array2table(PLUpStream, ...
            "RowNames", bUpStreamTable.Properties.RowNames, ...
            "VariableNames", ["PL"])

        PDownStream = [-0.5, -1.70, 0.00]'; %P(i) = P_G(i) - P_L(i)
        PDownStreamTable = array2table(PDownStream, "RowNames", ["1", "2", "6'"])
        thetaDownStream = BMatrixDownStream\PDownStream; %BMatrix elements are negative of ybus
        thetaFullDownStreamRelative = [thetaDownStream(1:2); 0; thetaDownStream(end)];
        thetaFullDownStreamRelativeTable = array2table(thetaFullDownStreamRelative,...
            "RowNames", ["1", "2", "5'", "6'"], 'VariableNames', ["theta"])
        PLDownStream = bDownStream*ADownStream*thetaFullDownStreamRelative;
        PLDownStreamTable = array2table(PLDownStream, ...
            "RowNames", bDownStreamTable.Properties.RowNames, ...
            "VariableNames", ["PL"])
    else
        PUpStream(1) = PLDownStream(2);
        PUpStream(2) = PLDownStream(3);
        PUpStreamTable(:, :) = array2table(PUpStream)
        thetaUpStream = BMatrixUpStream\PUpStream;
        theta5 = thetaUpStream(1) %send to DS
        theta6 = thetaUpStream(2) %send to DS
        thetaFullUpStream = [thetaUpStream(1:2); 0; thetaUpStream(end)];
        thetaFullUpStreamTable(:, :) = array2table(thetaFullUpStream)
        PLUpStream = bUpStream*AUpStream*thetaFullUpStream;
        PLUpStreamTable(:, :) = array2table(PLUpStream)

        thetaFullDownStreamRelative = [thetaDownStream(1:2); 0; thetaDownStream(end)];
        thetaFullDownStreamRelativeTable = array2table(thetaFullDownStreamRelative,...
            "RowNames", ["1", "2", "5'", "6'"], 'VariableNames', ["theta"])
        thetaFullDownStream  = thetaFullDownStreamRelative +  [ones(4, 1)*theta5];
        thetaFullDownStream(end) = thetaFullDownStream(end) + theta6 - theta5;
        thetaFullDownStreamTable(:, :) = array2table(thetaFullDownStream)
```

```
        PLDownStream = bDownStream*ADownStream*thetaFullDownStream;
        PLDownStreamTable(:, :) = array2table(PLDownStream)
    end
end
```

PUpStreamTable = 3×1 table

	PUpStream
1 5	0
2 6	0
3 4	-0.8000

thetaFullUpStreamTable = 4×1 table

	theta
1 5	0
2 6	-0.0509
3 3	0
4 4	-0.0509

PLUpStreamTable = 3×1 table

	PL
1 5-3	0
2 6-4	0
3 3-4	0.8000

PDownStreamTable = 3×1 table

	PDownStream
1 1	-0.5000
2 2	-1.7000
3 6'	0

thetaFullDownStreamRelativeTable = 4×1 table

	theta
1 1	-0.0008
2 2	-0.0865
3 5'	0
4 6'	-0.0865

PLDownStreamTable = 3×1 table

	PL
1 1-2	1.7000
2 1-5'	-2.2000
3 2-6'	0

PUpStreamTable = 3×1 table

	PUpStream
1 5	-2.2000
2 6	0

	PUpStream
3 4	-0.8000

theta5 = -0.0810
theta6 = -0.0509
thetaFullUpStreamTable = 4×1 table

	theta
1 5	-0.0810
2 6	-0.0509
3 3	0
4 4	-0.0509

PLUpStreamTable = 3×1 table

	PL
1 5-3	-2.2000
2 6-4	0
3 3-4	0.8000

thetaFullDownStreamRelativeTable = 4×1 table

	theta
1 1	-0.0008
2 2	-0.0865
3 5'	0
4 6'	-0.0865

thetaFullDownStreamTable = 4×1 table

	theta
1 1	-0.0818
2 2	-0.1675
3 5'	-0.0810
4 6'	-0.1374

PLDownStreamTable = 3×1 table

	PL
1 1-2	1.7000
2 1-5'	-2.2000
3 2-6'	-81.0258

PUpStreamTable = 3×1 table

	PUpStream
1 5	-2.2000
2 6	-81.0258
3 4	-0.8000

theta5 = -0.0810
theta6 = -8.1881
thetaFullUpStreamTable = 4×1 table

	theta
1 5	-0.0810
2 6	-8.1881
3 3	0
4 4	-5.2041

PLUpStreamTable = 3×1 table

	PL
1 5-3	-2.2000
2 6-4	-81.0258
3 3-4	81.8258

thetaFullDownStreamRelativeTable = 4×1 table

	theta
1 1	-0.0008
2 2	-0.0865
3 5'	0
4 6'	-0.0865

thetaFullDownStreamTable = 4×1 table

	theta
1 1	-0.0818
2 2	-0.1675
3 5'	-0.0810
4 6'	-8.2746

PLDownStreamTable = 3×1 table

	PL
1 1-2	1.7000
2 1-5'	-2.2000
3 2-6'	2.1793e+04

```
toc;
```

```
Elapsed time is 2.855459 seconds.
```