CALCULATION OF YBUS

Objectives

- Develop a generalized program for calculating bus admittance matrix of a power system- neglecting shunt elements and mutual coupling between elements.
- Modify the above program to include shunt elements
- Modify the program to include shunt elements and mutual coupling between lines.

Simulation Tool

- Scripting language like Octave, MATLAB, Python

Mathematical Model

- ❑ $Y_{BUS} = A^T Y A$

  - Bus admittance matrix : Y_{BUS} is an $n \times n$ matrix
  - Bus incidence matrix : A is an $e \times n$ matrix
  - Primitive admittance matrix : Y is an $e \times e$ matrix

  - n is the total no. of buses excluding reference bus
  - e is the total no. of elements including shunt and series elements

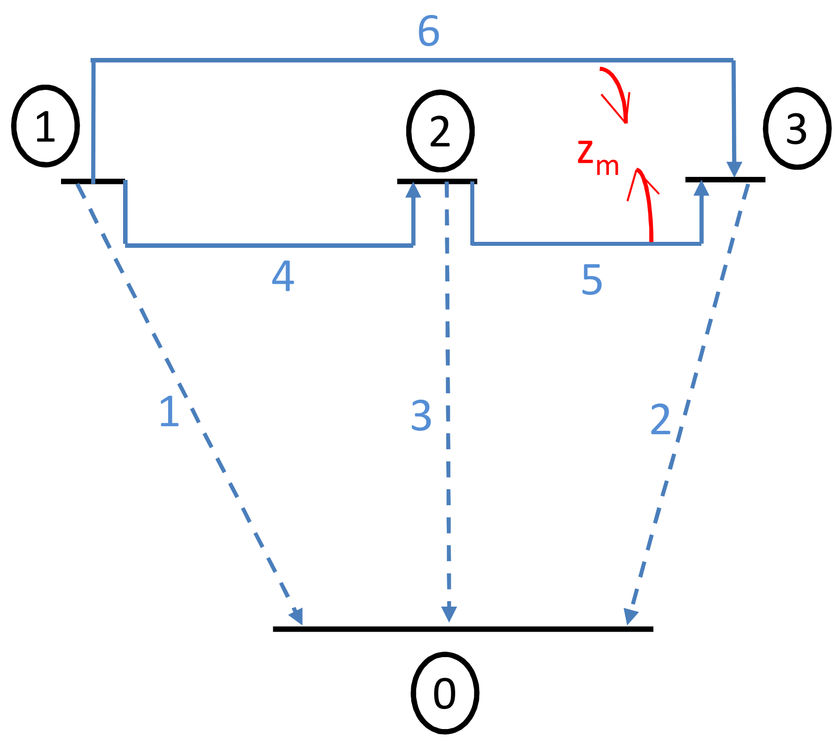
Input

- Line data
  - Column1: Element number
  - Column2: From bus
  - Column3: To bus
  - Column4: Primitive impedance in pu

  - Column5: Element to which the element is mutually coupled
    - 0 if no mutual coupling
  - Column6: Coupling impedance in pu

Example- Line Data

Element No.	From Bus	To Bus	z (pu)	Coupled Element	z_m (pu)
1	1	0	z_{11}	-	-
2	3	0	z_{22}	-	-
3	2	0	z_{33}	-	-
4	1	2	z_{44}	-	-
5	2	3	z_{55}	6	$Z_m=z_{56}$
6	1	3	z_{66}	5	$Z_m=z_{65}$



Case-I

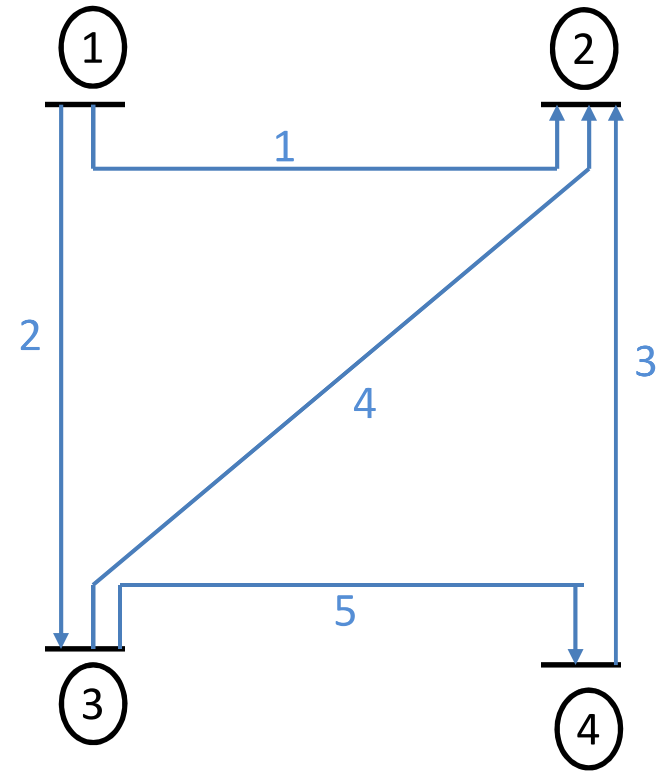
- Calculation of Y_{BUS} for a power system where shunt admittances and mutual coupling are neglected.

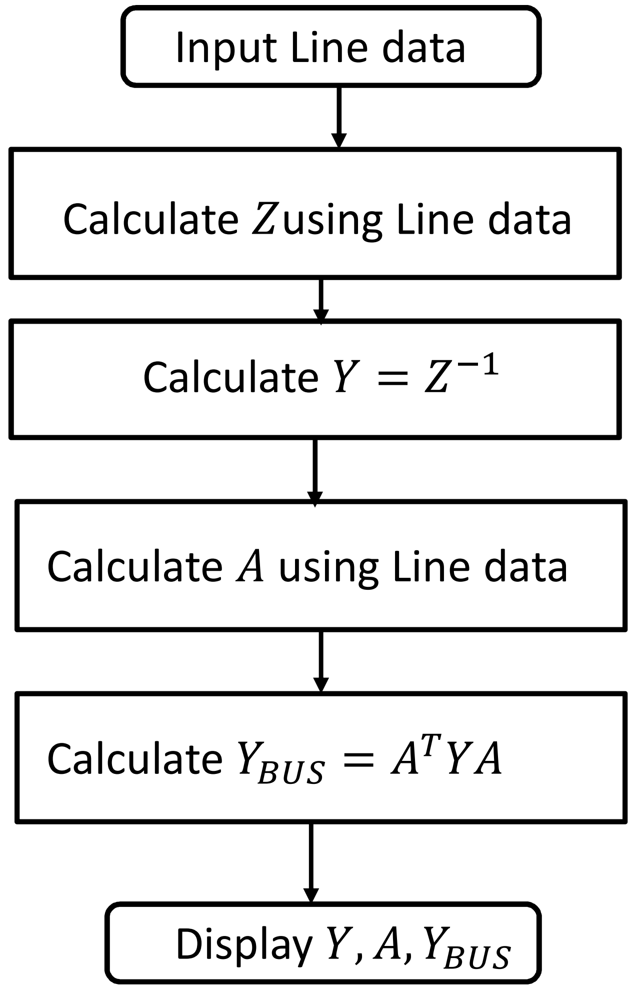
    - Elements connected to reference buses need not be considered
        - 0 will not appear in columns 2 and 3 of line data

    - Y will be diagonal matrix
        - Columns 5 and 6 of line data need not be considered

Input : Case-I

$$Line\_data = \begin{bmatrix} 1 & 1 & 2 & 0.50i & 0 & 0 \\ 2 & 1 & 3 & 0.45i & 0 & 0 \\ 3 & 4 & 2 & 0.40i & 0 & 0 \\ 4 & 3 & 2 & 0.30i & 0 & 0 \\ 5 & 3 & 4 & 0.35i & 0 & 0 \end{bmatrix}$$

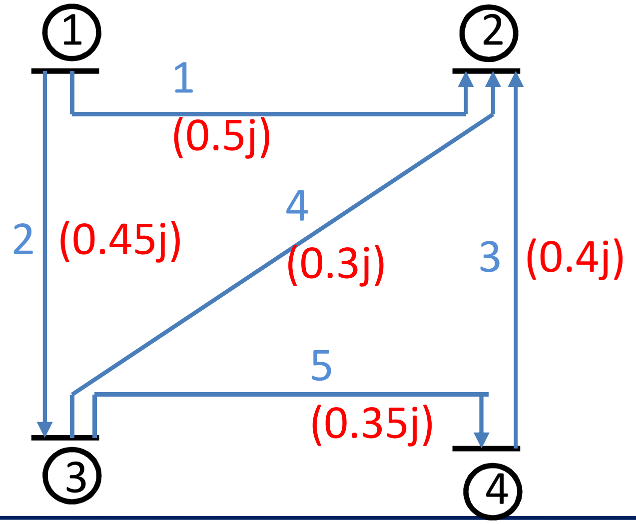



Input Line data
Calculate Z using Line data
Calculate $Y = Z^{-1}$
Calculate A using Line data
Calculate $Y_{BUS} = A^T Y A$
Display Y, A, Y_{BUS}

Primitive Admittance matrix

$Y = Z^{-1}$

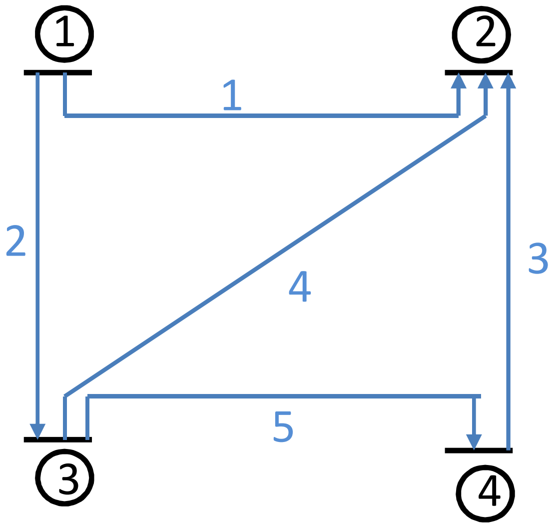
- Size $e \times e$
- Diagonal elements of Z are the self impedances z_{ii}
- Off-diagonal elements of Z represent the mutual impedances z_{ij}



$$Z = \begin{bmatrix} 0.5j & 0 & 0 & 0 & 0 \\ 0 & 0.45j & 0 & 0 & 0 \\ 0 & 0 & 0.40j & 0 & 0 \\ 0 & 0 & 0 & 0.30j & 0 \\ 0 & 0 & 0 & 0 & 0.35j \end{bmatrix}$$

Bus Incidence Matrix

$$a_{ij} = \begin{cases} 1, if\ i^{th} element\ is\ incident\ and\ oriented\ away\ from\ j^{th} bus \\ -1, if\ i^{th}\ element\ is\ incident\ and\ oriented\ towards\ j^{th}\ bus \\ 0, elsewhere \end{cases}$$



Bus → / Line ↓	1	2	3	4
1	1	-1	0	0
2	1	0	-1	0
3	0	-1	0	1
4	0	-1	1	0
5	0	0	1	-1

Outputs: Case-I

Y=

```
  0.0000 - 2.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 - 2.2222i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 - 2.5000i   0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 - 3.3333i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 - 2.8571i
```

A =

```
     1    -1     0     0
     1     0    -1     0
     0    -1     0     1
     0    -1     1     0
     0     0     1    -1
```

Ybus =

```
  0.0000 - 4.2222i   0.0000 + 2.0000i   0.0000 + 2.2222i   0.0000 + 0.0000i
  0.0000 + 2.0000i   0.0000 - 7.8333i   0.0000 + 3.3333i   0.0000 + 2.5000i
  0.0000 + 2.2222i   0.0000 + 3.3333i   0.0000 - 8.4127i   0.0000 + 2.8571i
  0.0000 + 0.0000i   0.0000 + 2.5000i   0.0000 + 2.8571i   0.0000 - 5.3571i
```

Case-II

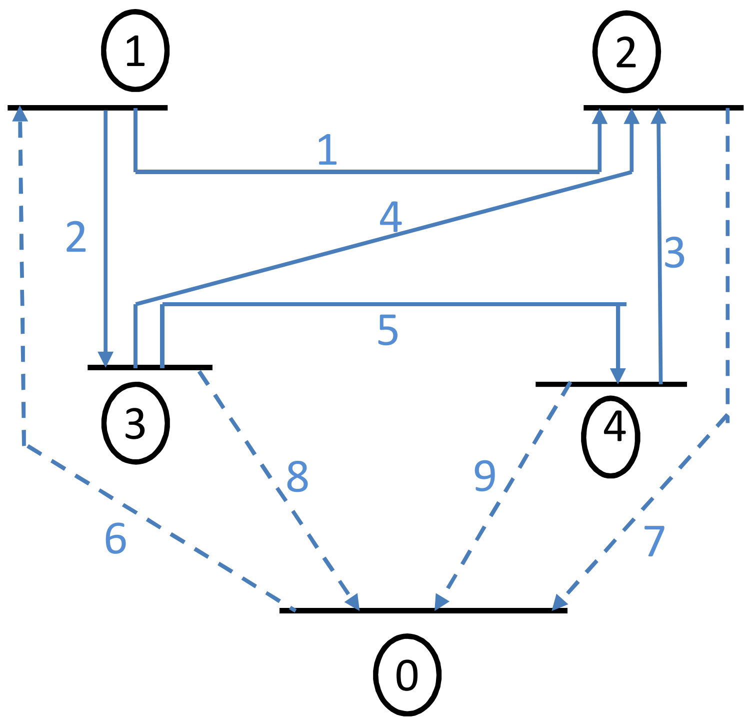
- Calculation of Y_{BUS} for a power system where shunt admittances are considered and mutual coupling is neglected.

  - Shunt elements should not be reflected in A

  - Y will be diagonal matrix
    - Columns 5 and 6 of line data need not be considered

Input : Case-II

$$Line\_data = \begin{bmatrix} 1 & 1 & 2 & 0.50i & 0 & 0 \\ 2 & 1 & 3 & 0.45i & 0 & 0 \\ 3 & 4 & 2 & 0.40i & 0 & 0 \\ 4 & 3 & 2 & 0.30i & 0 & 0 \\ 5 & 3 & 4 & 0.35i & 0 & 0 \\ 6 & 0 & 1 & -5i & 0 & 0 \\ 7 & 2 & 0 & -5i & 0 & 0 \\ 8 & 3 & 0 & -5i & 0 & 0 \\ 9 & 4 & 0 & -5i & 0 & 0 \end{bmatrix}$$



Outputs: Case-II

A =

1	-1	0	0
1	0	-1	0
0	-1	0	1
0	-1	1	0
0	0	1	-1
-1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

Ybus =

0.0000 - 4.0222i	0.0000 + 2.0000i	0.0000 + 2.2222i	0.0000 + 0.0000i
0.0000 + 2.0000i	0.0000 - 7.6333i	0.0000 + 3.3333i	0.0000 + 2.5000i
0.0000 + 2.2222i	0.0000 + 3.3333i	0.0000 - 8.2127i	0.0000 + 2.8571i
0.0000 + 0.0000i	0.0000 + 2.5000i	0.0000 + 2.8571i	0.0000 - 5.1571i

Case-III

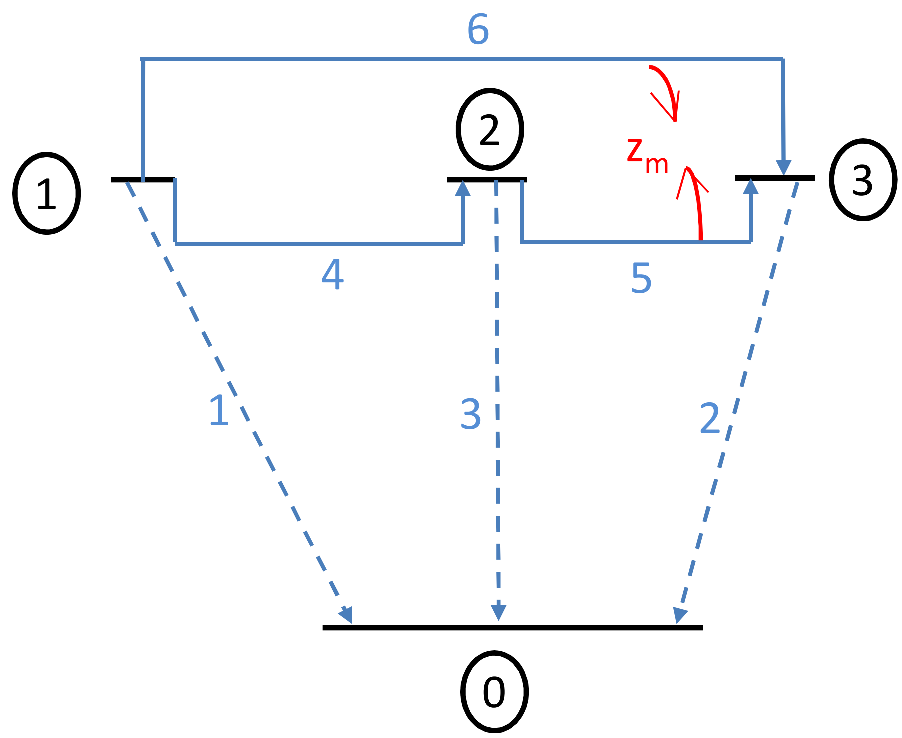
- Calculation of Y_{BUS} for a power system where shunt admittances and mutual coupling are considered.

  - Shunt elements should not be reflected in A

  - Y will not be diagonal matrix

Input : Case-III

$$Line\_data = \begin{bmatrix} 1 & 1 & 0 & -5i & 0 & 0 \\ 2 & 3 & 0 & -5i & 0 & 0 \\ 3 & 2 & 0 & -5i & 0 & 0 \\ 4 & 1 & 2 & 0.50i & 0 & 0 \\ 5 & 2 & 3 & 0.40i & 6 & 0.2i \\ 6 & 1 & 3 & 0.25i & 5 & 0.2i \end{bmatrix}$$



Outputs: Case-III

yprimitive =

```
   0.0000 + 0.2000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.2000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.2000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 - 2.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 - 4.1667i   0.0000 + 3.3333i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 3.3333i   0.0000 - 6.6667i
```

A =

```
     1     0     0
     0     0     1
     0     1     0
     1    -1     0
     0     1    -1
     1     0    -1
```

Ybus =

```
   0.0000 - 8.4667i   0.0000 + 5.3333i   0.0000 + 3.3333i
   0.0000 + 5.3333i   0.0000 - 5.9667i   0.0000 + 0.8333i
   0.0000 + 3.3333i   0.0000 + 0.8333i   0.0000 - 3.9667i
```