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Internal Assesment Test - I

Sub:	Power System Analysis II							Code:	15EE71
Date:	21/9/2018	Duration:	90 mins	Max Marks:	50	Sem:	7	Branch:	EEE
Answer Any FIVE FULL Questions									

		Marks	OBE CO	OBE RBT
1a	Derive an expression for obtaining the Ybus using singular transformation method	[5]	CO1	L2
1b	Explain in brief the various types of buses used in power system network and mention the significance of slack bus.	[5]	CO2	L2
2	The following is the system data for a load flow solutions. The line admittance are	[10]	CO2	L3

Bus code	Admittance
1-2	2-j6.0 p.u
1-3	1-j4.0 p.u
2-3	0.666-j2.664 p.u
2-4	1-j4.0 p.u
3-4	2-j8.0 p.u

The schedule of active and reactive powers

Bus code	P	Q	V	Remarks
1	-	-	1.06	Slack
2	0.5	0.2	1+j0.0	PQ
3	0.4	0.3	1+j0.0	PQ
4	0.3	0.1	1+j0.0	PQ

Determine the voltage at the end of first iteration using Gauss –seidal method. Take α =1.6.

		Marks	CO	RBT
3	Consider three passive elements whose data is given in table below. Form the primitive network impedance matrix & primitive network admittance matrix.	[10]	CO2	L2

Element number	**Self impedance** (z_{pq-pq})		**Mutual impedance** (z_{pq-rs})	
	Bus-code, (p-q)	**Impedance in p.u**	**Bus-code, (r-s)**	**Impedance in p.u**
1	1-2	J 0.452		
2	2-3	J 0.387	1-2	J 0.165
3	1-3	J 0.619	1-2	J 0.234

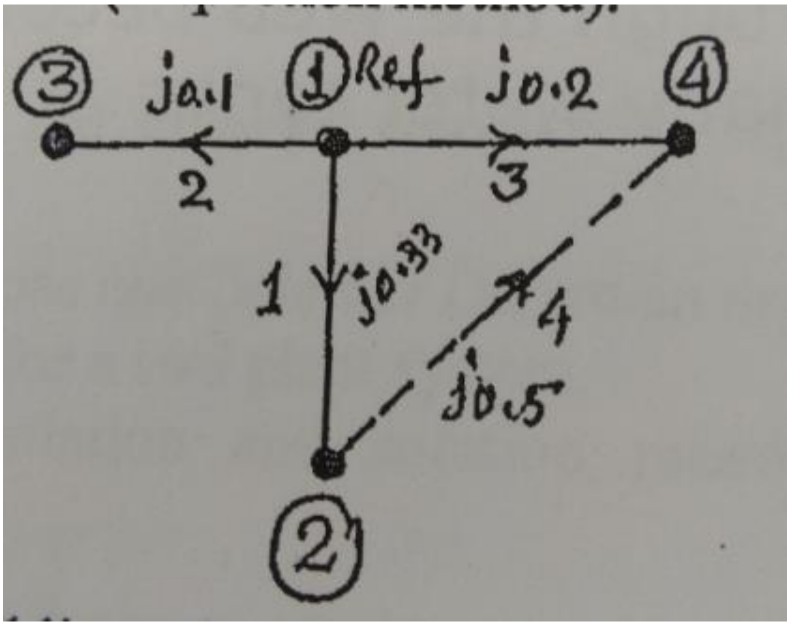
		Marks	CO	RBT
4a	Explain briefly the primitive network used in the formation of bus admittance matrix by singular transformation	[5]	CO1	L2

4b The bus incidence matrix A for a network of 8 elements and 5 nodes is as given below. Reconstruct the oriented graph. Hence obtain the one line diagram of the system indicating the generator positions. [5] CO1 L3

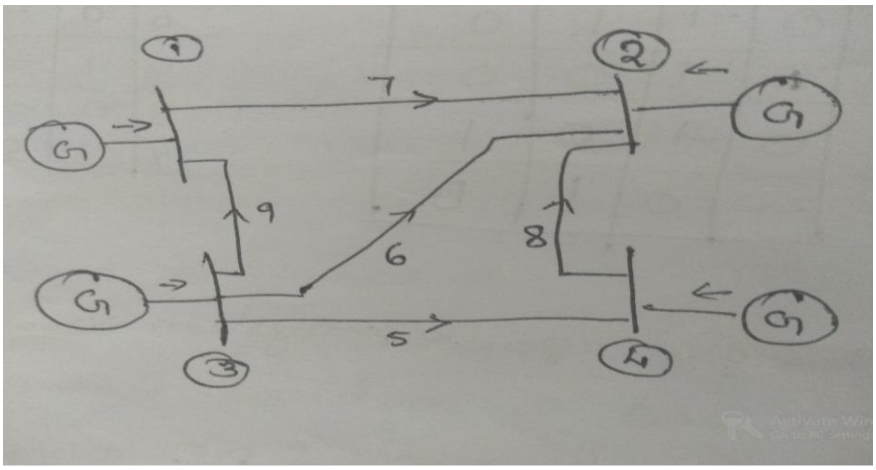
A=

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	1	0	0	0	-1	0	-1	0
2	0	1	0	0	1	-1	0	-1
3	0	0	1	-1	0	1	0	0
4	0	0	0	1	0	0	1	1

5 With the help of singular transformation method, determine the bus admittance matrix Y_{bus} for the power system whose oriented graph is shown in fig. Element no and self impedance of the elements in pu are marked on the diagram. Neglect mutual coupling .Verify the same using direct inspection method. [10] CO1 L2



6 Obtain the oriented graph for the system shown in fig. Select T(1,2,3,4) as the tree. Show that $\mathbf{B_l = A_l.K^t}$ [10] CO1 L3



Solutions

1a

performance equation relating the bus voltages to bus current injections in bus frame of reference in admittance form is given by

$$I_{BUS} = Y_{BUS} E_{BUS} \qquad (17)$$

Where E_{BUS} = vector of bus voltages measured with respect to reference bus

I_{BUS} = Vector of currents injected into the bus

Y_{BUS} = bus admittance matrix

The performance equation of the primitive network in admittance form is given by

$$i + j = [y]\, v$$

Pre-multiplying by A^t (transpose of A), we obtain

$$A^t i + A^t j = A^t [y]\, v \qquad (18)$$

However, as per equation (4),

$$A^t i = 0,$$

since it indicates a vector whose elements are the algebraic sum of element currents incident at a bus, which by Kirchhoff's law is zero. Similarly, $A^t j$ gives the algebraic sum of all source currents incident at each bus and this is nothing but the total current injected at the bus. Hence,

$$A^t j = I_{BUS} \qquad (19)$$

Thus from (18) we have, $I_{BUS} = A^t [y]\, v$ **(20)**

However, from (5), we have

$$v = A\, E_{BUS}$$

And hence substituting in (20) we get,

$$I_{BUS} = A^t [y]\, A\, E_{BUS} \qquad (21)$$

Comparing (21) with (17) we obtain,

$$Y_{BUS} = A^t [y]\, A \qquad (22)$$

The bus incidence matrix is rectangular and hence singular. Hence, (22) gives a singular transformation of the primitive admittance matrix [y]. The bus impedance matrix is given by ,

$$Z_{BUS} = Y_{BUS}^{-1} \qquad (23)$$

Note: This transformation can be derived using the concept of power invariance, however, since the transformations are based purely on KCL and KVL, the transformation will obviously be power invariant.

1b

Chapter 18

Load Flows

Introduction

Load flow solution is a solution of the network under steady state condition subject to certain inequality constraints under which the system operates. These constraints can be in the form of load nodal voltages, reactive power generation of the generators, the tap settings of a tap changing under load transformer etc.

The load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting power channels (transmission lines). Load flow solution is essential for designing a new power system and for planning extension of the existing one for increased load demand. These analyses require the calculation of numerous load flows under both normal and abnormal (outage of transmission lines, or outage of some generating source) operating conditions. Load flow solution also gives the initial conditions of the system when the transient behaviour of the system is to be studied.

Load flow solution for power network can be worked out both ways according as it is operating under (i) balanced, or (ii) unbalanced conditions. The following treatment will be for a system operating under balanced conditions only. For such a system a single phase representation is adequate. A load flow solution of the power system requires mainly the following steps:

(i) Formulation or the network equations.

(ii) Suitable mathematical technique for solution of the equations.

Since we are studying the system under steady state conditions the network equations will be in the form of simple algebraic equations. The load and hence generation are continually changing in a real power system. We will assume here that loads and hence generation are fixed at a particular value over a suitable period of time, e.g. half an hour or so.

18.1 Bus Classification

In a power system each bus or node is associated with four quantities, real and reactive powers, bus voltage magnitude and its phase angle. In a load flow solution two out of the four quantities are specified and the remaining two are required to be obtained through the solution of the equations. Depending upon which quantities have been specified, the buses are classified in the following three categories:

1. *Load bus:* At this bus the real and reactive components of power are specified. It is desired to find out the voltage magnitude and phase angle through the load flow solution. It is required to specify only P_D and Q_D at such a bus as at a load bus voltage can be allowed to vary within the permissible values e.g. 5%. Also phase angle of the voltage is not very important for the load.

2. *Generator bus or voltage controlled bus:* Here the voltage magnitude corresponding to the generation voltage and real power P_G corresponding to its ratings are specified. It is required to find out the reactive power generation Q_G and the phase angle of the bus voltage.

3. *Slack, swing or reference bus:* In a power system there are mainly two types of buses: load and generator buses. For these buses we have specified the real power P injections. Now $\sum_{i=1}^{n} P_i$ = real power loss P_L where P_i is the power injection at the buses, which is taken as positive for generator buses and is negative for load buses. The losses remain unknown until the load flow solution is complete. It is for this reason that generally one of the generator buses is made to take the additional real and reactive power to supply transmission losses. That is why this type of bus is also known as the slack or swing bus. At this bus, the voltage magnitude V and phase angle δ are specified whereas real and reactive powers P_G and Q_G are obtained through the load flow solution. The following table summarises the above discussion:

Bus type	*Quantities specified*	*Quantities to be obtained*
Load bus	P, Q	$\lvert V\rvert, \delta$
Generator bus	$P, \lvert V\rvert$	Q, δ
Slack bus	$\lvert V\rvert, \delta$	P, Q

The phase angle of the voltage at the slack bus is usually taken as the reference. In the following analysis the real and reactive components of voltage at a bus are taken as the independent variables for the load flow equations i.e.

$$V_i \angle \delta_i = e_i + jf_i$$

where e_i and f_i are the real and reactive components of voltage at the ith bus. There are various other formulations wherein either voltage or current or both are taken as the independent variables. The load flow equations can be formulated using either the loop or bus frame of reference. However, from the viewpoint of computer time and memory, the nodal admittance formulation, using the nodal voltages as the independent variables is the most economic.

...al Admittance Matrix

2

	1–j4.0
2–4	0.666–j2.664
3–4	1–j4.0
	2–j8.0

The schedule of active and reactive powers:

Bus code	P	Q	V	Remarks
1	–	–	1.06	Slack
2	0.5	0.2	1 + j0.0	PQ
3	0.4	0.3	1 + j0.0	PQ
4	0.3	0.1	1 + j0.0	PQ

Determine the voltages at the end of first iteration using Gauss-Seidel method. Take α = 1

Solution: The admittance matrix will be as given below:

$$Y_{pq} = \begin{bmatrix} 3 - j12.0 & -2 + j8.0 & -1 + j4.0 & 0.0 \\ -2 + j8.0 & 3.666 - j14.664 & -0.666 + j2.664 & -1 + j4.0 \\ -1 + j4.0 & -0.666 + j2.664 & 3.666 - j14.664 & -2 + j8.0 \\ 0.0 & -1 + j4.0 & -2 + j8.0 & 3 - j12.0 \end{bmatrix}$$

The powers for load buses are to be taken as negative and that for generator buses positive.

For the system given

$$V_2^1 = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_2^*} - Y_{21}V_1^0 - Y_{23}V_3^0 - Y_{24}V_4^0\right]$$

$$= \frac{1}{(3.666 - j14.664)}\left[\frac{-0.5 + j0.2}{1 - j0.0} - 1.06(-2 + j8) - 1.0\right.$$

$$\left.(-0.666 + j2.664) - (-1 + j4.0)1.0\right]$$

$$= (1.01187 - j0.02888)$$

$$V_{2\,acc}^1 = (1.0 + j0.0) + 1.6[1.01187 - j0.02888 - 1.0 - j0.0]$$

$$= 1.01899 - j0.046208$$ **Ans.**

$$V_3^1 = \frac{1}{Y_{33}}\left[\frac{P_3 - jQ_3}{V_3^*} - Y_{31}V_1 - Y_{32}V_2^1 - Y_{34}V_4^0\right]$$

$$= \frac{1}{(3.666 - j14.664)}\left[\frac{-0.4 + j0.3}{1 - j0.0} - (-1 + j4.0)1.06\right.$$

$$-(-0.666 + j2.664)(1.01899 - j0.046208) - (-2 +$$

$$= 0.994119 - j0.029248$$

$$V_{3\,acc}^1 = (1 + j0.0) + 1.6[0.994119 - j0.029248 - 1 - j0.0]$$

$$= 0.99059 - j0.0467968$$ **Ans.**

$$V_4^1 = \frac{1}{Y_{44}}\left[\frac{P_4 - jQ_4}{V_4^{0*}} - Y_{42}V_2^1 - Y_{43}V_3^1\right]$$

$$= \frac{1}{(3 - j12)}\left[\frac{-0.3 + j0.1}{1 - j0.0} - (-1 + j4.0)(1.01899 - j0.0462\right.$$

$$-(-2 + j8)(0.99059 - j$$

$$= 0.9716032 - j0.064684$$

$$V_{4\,acc}^1 = 1.0 + j0.0 + 1.6[0.9716032 - j0.064684 - 1 - j0.0]$$

$$= 0.954565 - j0.1034944$$ **Ans**

3

$$[Z] = \begin{pmatrix} j0.452 & j0.165 & j0.234 \\ j0.165 & j0.387 & 0 \\ j0.234 & 0 & j0.619 \end{pmatrix}$$

$$[Y] = \begin{bmatrix} -3.41j & 1.45j & 1.28j \\ 1.45j & -3.20j & -0.549j \\ +1.289 & -0.5497 & -2.10j \end{bmatrix}$$

4a

PRIMITIVE NETWORKS

So far, the matrices of the interconnected network have been defined. These matrices contain complete information about the network connectivity, the orientation of current, the loops and cutsets. However, these matrices contain no information on the nature of the elements which form the interconnected network. The complete behaviour of the network can be obtained from the knowledge of the behaviour of the individual elements which make the network, along with the incidence matrices. An element in an electrical network is completely characterized by the relationship between the current through the element and the voltage across it.

General representation of a network element: In general, a network element may contain active or passive components. Figure 2 represents the alternative impedance and admittance forms of representation of a general network component.

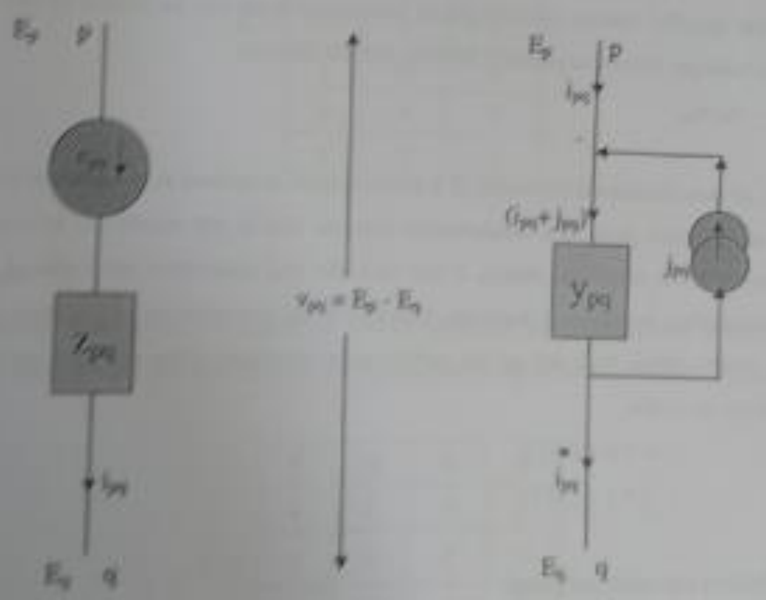


Fig.2 Representation of a primitive network element

(a) Impedance form (b) Admittance form

a

The network performance can be represented by using either the impedance or the admittance form of representation. With respect to the element, p-q, let,

v_{pq} = voltage across the element p-q.

e_{pq} = source voltage in series with the element p-q.

i_{pq}= current through the element p-q.

j_{pq}= source current in shunt with the element p-q.

z_{pq}= self impedance of the element p-q and

y_{pq}= self admittance of the element p-q.

Performance equation: Each element p-q has two variables, v_{pq} and i_{pq}. The performance of the given element p-q can be expressed by the performance equations as under:

$v_{pq} + e_{pq} = z_{pq} i_{pq}$ (in its impedance form)

$i_{pq} + j_{pq} = y_{pq} v_{pq}$ (in its admittance form) **(6)**

Thus the parallel source current jpq in admittance form can be related to the series source voltage, epq in impedance form as per the identity:

$j_{pq} = - y_{pq} e_{pq}$ (7)

A set of non-connected elements of a given system is defined as a *primitive Network and* an element in it is a fundamental element that is not connected to any other element. In the equations above, if the variables and parameters are replaced by the corresponding vectors and matrices, referring to the complete set of elements present in a given system, then, we get the performance equations of the primitive network in the form as under:

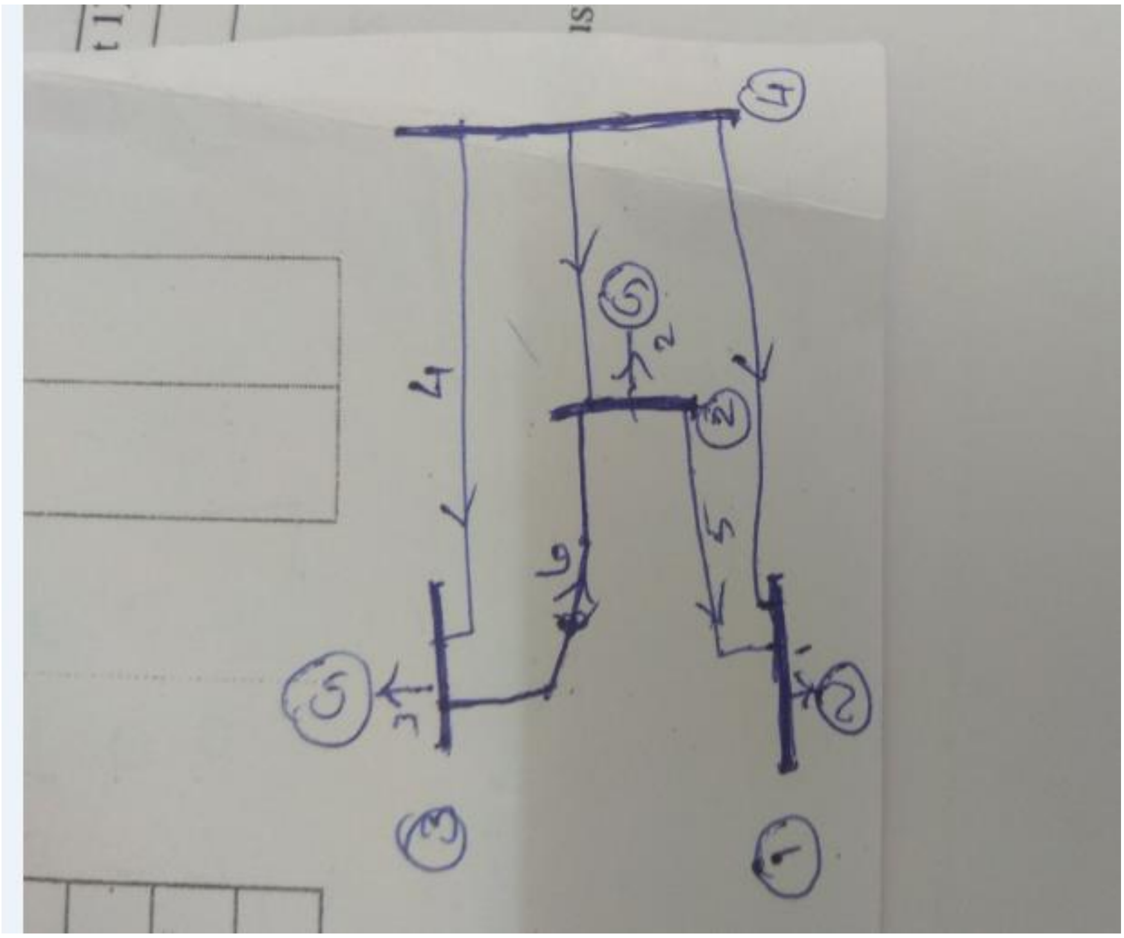
$$v + e = [z]\, i$$

$$i + j = [y]\, v \qquad (8)$$

Primitive network matrices:

A diagonal element in the matrices, [z] or [y] is the self impedance $z_{pq\text{-}pq}$ or self admittance, $y_{pq\text{-}pq}$. An off-diagonal element is the mutual impedance, $z_{pq\text{-}rs}$ or mutual admittance, $y_{pq\text{-}rs}$, the value present as a mutual coupling between the elements p-q and r-s. The primitive network admittance matrix, [y] can be obtained also by

4b



5

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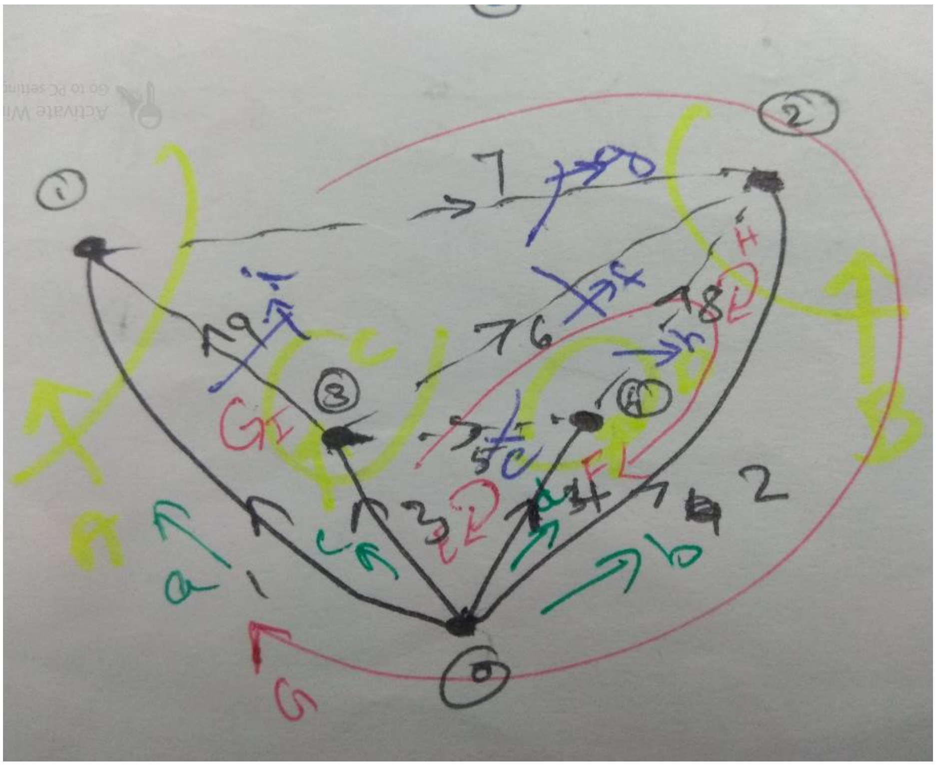
$$Y_{bus} = \begin{bmatrix} -j5.03 & 0 & j2 \\ 0 & -j10 & 0 \\ j2 & 0 & -j7 \end{bmatrix}$$

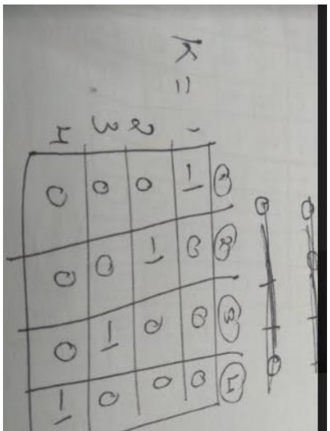
$$Y_{bus} = A^t \cdot y \cdot A.$$

$$y = \begin{bmatrix} -3.03 & 0 & 0 & 0 \\ 0 & -j0 & 0 & 0 \\ 0 & 0 & -j5 & 0 \\ 0 & 0 & 0 & -j2 \end{bmatrix}$$

$$A = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$$

6





$$A_b = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

$$A_b^{k^t} = \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix} \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \underline{\underline{U}}$$

$B =$

	A	B	C	D	
1	1	0	0	0	
2	0	1	0	0	
3	0	0	1	0	U_b
4	0	0	0	1	
5	0	0	-1	1	
6	0	1	-1	0	
7	-1	1	0	0	B_l.
8	0	1	0	-1	
9	1	0	-1	0	

$$B_l = A_l \cdot K^t = \begin{bmatrix} 0 & 0 & 1 & -1 \\ 0 & -1 & 1 & 0 \\ 1 & -1 & 0 & 0 \\ 0 & -1 & 0 & 1 \\ -1 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

$$\begin{bmatrix} 0 & 0 & -1 & 1 \\ 0 & 1 & -1 & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 1 & 0 & -1 \\ 1 & 0 & -1 & 0 \end{bmatrix}$$