Homework 4

Solution 1

1. Assume a three bus power system with buses 1, 2, and 3 with generators at each bus and bus 3 the system slack. Also assume there are three lossless lines with the line between 1 and 2 having a per unit impedance of j0.08, the line between 2 and 3 a per unit impedance of j0.1 and the line between 1 and 3 a per unit impedance of j0.15. Calculate the injection shift matrix.

$X_{12} = j0.08$ pu

$X_{23} = j0.1$ pu

$X_{13} = j0.15$ pu

$\tilde{B} = -\text{diag}(12.5,\ 10,\ 6.67)$

system incidence matrix =

	1	2	3
L1	1	-1	0
L2	0	1	-1
L3	1	0	-1

since bus is slack bus;

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

$$B' = A^T \tilde{B} A = \begin{bmatrix} 19.7 & -12.5 \\ -12.5 & 22.5 \end{bmatrix}$$

$$\Psi = \tilde{B} A [B']^{-1} = \begin{bmatrix} 0.4554 & -0.3031 \\ 0.4554 & 0.6969 \\ 0.5455 & 0.3031 \end{bmatrix}$$

2. Determine the TTC in both directions (to the nearest 5 MW) for a transfer from bus 1 to the system slack (bus 7). Consider all single line contingencies. For convenience the eleven single element contingencies have already been defined for you.

Solution 2:

Initial generation at bus 1 = 160MW

From bus 1 → 7

Case/Contingency	Line Violation (@100%) From Bus -> To Bus	Bus 1 generation	Transaction Change (UTC)
Base Case	1 → 2	280 MW	120 MW
Line 1 out	1 → 3	200 MW	40 MW
Line 2 out	1 → 2	200 MW	40 MW
Line 3 out	1 → 2	298 MW	138 MW
Line 4 out	1 → 2	296 MW	136 MW
Line 5 out	4 → 5	210 MW	50 MW
Line 6 out	2 → 5	216 MW	56 MW
Line 7 out	1 → 2	275 MW	115 MW
Line 8 out	1 → 2	275 MW	115 MW
Line 9 out	1 → 2	279 MW	119 MW
Line 10 out	1 → 2	283 MW	123 MW
Line 11 out	1 → 2	283 MW	123 MW

The UTC between bus 1 and system slack bus 7 is the minimum UTC. This equals 40 MW which occurs for single line contingencies for line 1 and line 2 outages.

From bus 7 → 1

Case/Contingency	Line Violation (@100%) From Bus -> To Bus	Bus 1 generation	Transaction Change (UTC)
Base Case	7 → 5	-122 MW	-182 MW
Line 1 out	2 → 3	-50 MW	-210 MW
Line 2 out	7 → 5	-123 MW	-183 MW
Line 3 out	7 → 5	-116 MW	-276 MW
Line 4 out	7 → 5	-116 MW	-276 MW
Line 5 out	5 → 4	-138 MW	-298 MW
Line 6 out	7 → 5	-40 MW	-200 MW
Line 7 out	2 → 3	-87 MW	-147 MW
Line 8 out	7 → 5	-152 MW	-312 MW
Line 9 out	6 → 2	-40 MW	-200 MW
Line 10 out	7 → 5	-90 MW	-250 MW
Line 11 out	7 → 5	-90 MW	-250 MW

The UTC between slack bus 7 and bus 1 is the minimum UTC. This equals 200 MW which occurs for single line contingencies for line 6 and line 9 outages.

3. Using a matrix package such as Matlab or the free scilab, calculate the injection shift factor (ISF) matrix.

```
clc;

%reading excel data into a table
filename = 'ECEN615_LineData.csv';
table = readtable(filename);

%converting table to a matrix
linedata = table{:,:};

L= size(linedata,1);%number of lines from excel = number of rows
N= linedata(7,2)+1;%number of buses from excel

A=zeros(L,N); %defining incidence matrix as L*N-1 (ignoring slack bus)

B = diag(linedata(:,4)); %Making the diagonal B~ matrix

Bp = zeros(N-1,N-1); %defining B' matrix as (N-1)*(N-1)
psi = zeros(L,N-1); %defining psi - the injection shift factor matrix as L*(N-1)

slackbus = 7; %storing slack bus given in the question, in a variable

%Calculating the incidence matrix with below convention
%from bus = +1
%to bus = -1
for i=1:1:L
    A(i,linedata(i,1))=1;
    A(i,linedata(i,2))=-1;
end

%removing slack bus from A and hence making it L*(N-1) matrix
A(:,slackbus)=[];
fprintf('Size of incidence matrix:\n');
display(size(A));

%calculating the Bprime matrix
Bp = transpose(A) * B * A;
fprintf('Size of Bprime matrix:\n');
display(size(Bp));

%calculating the injection shift factor matrix
psi = B * A * inv(Bp);
fprintf('Size of psi matrix:\n');
display(size(psi));


fprintf('ISF matrix:\n');
display(psi);
```

```
Warning: Column headers from the file were modified to make them valid MATLAB
identifiers before creating variable names for the table. The original column
headers are saved in the VariableDescriptions property.
Set 'VariableNamingRule' to 'preserve' to use the original column headers as
table variable names.
Size of incidence matrix:
    11     6

Size of Bprime matrix:
     6     6

Size of psi matrix:
    11     6
```

```
ISF matrix:

psi =

    0.8108   -0.0314    0.1799    0.1362    0.0105   -0.0210
    0.1892    0.0314   -0.1799   -0.1362   -0.0105    0.0210
   -0.0180    0.0524   -0.2998   -0.2270   -0.0175    0.0349
    0.0105    0.0664   -0.2130   -0.2875   -0.0221    0.0442
    0.3789    0.3999    0.2951    0.2672   -0.1333    0.2666
    0.4395    0.4499    0.3976    0.3836    0.1834   -0.3667
    0.1711    0.0838    0.5204   -0.3632   -0.0279    0.0559
    0.1816    0.1502    0.3073    0.3492   -0.0501    0.1001
   -0.5605   -0.5501   -0.6024   -0.6164   -0.8166   -0.3667
    0.2197    0.2250    0.1988    0.1918    0.0917    0.3166
    0.2197    0.2250    0.1988    0.1918    0.0917    0.3166
```

Published with MATLAB® R2021b