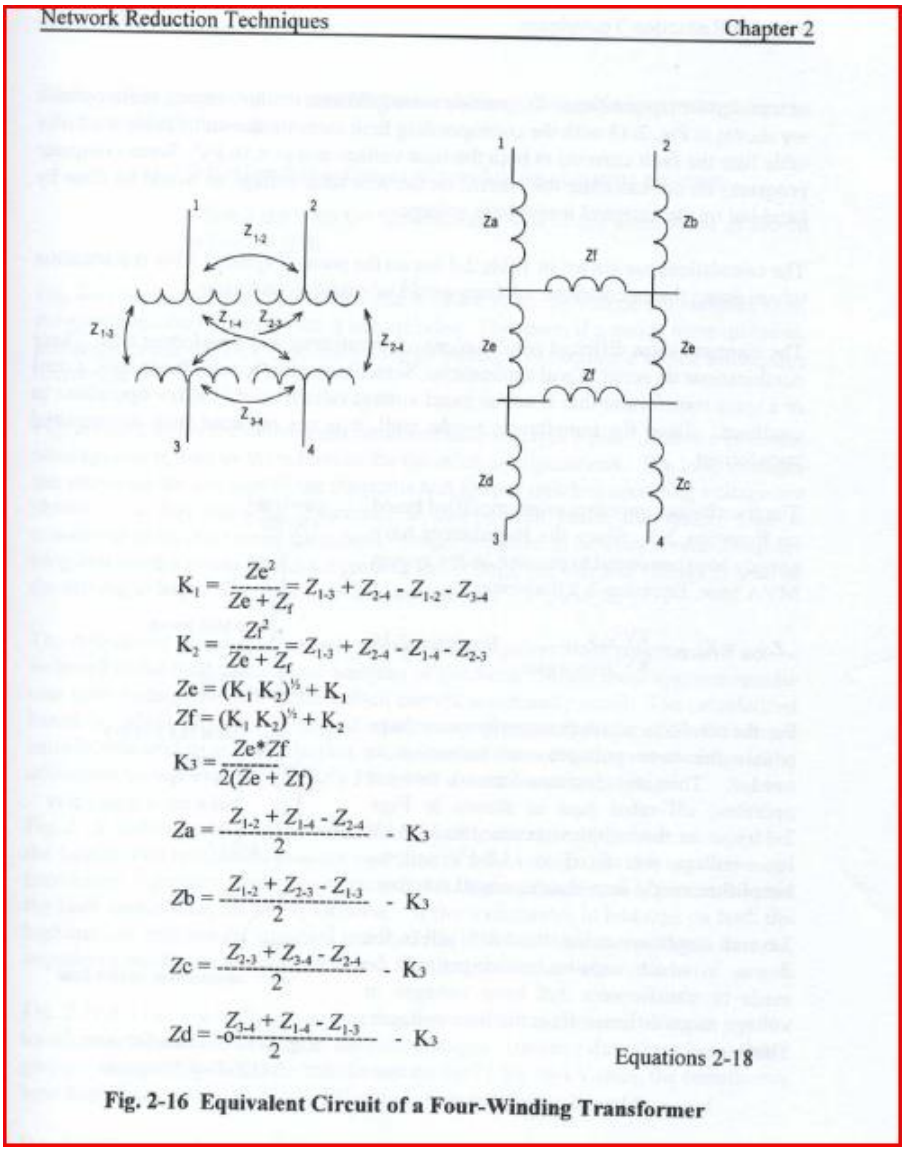
How do I model Four Winding Transformer in PTW?

Solution:
Using as reference "A Practical Guide to Short-Circuit Calculation" by Conrad St. Pierre, Page 37, users can model four-winding transformer as an 8 buses system.



Network Reduction Techniques — Chapter 2

$$K_1 = \frac{Ze^2}{Ze + Z_f} = Z_{1\text{-}3} + Z_{2\text{-}4} - Z_{1\text{-}2} - Z_{3\text{-}4}$$

$$K_2 = \frac{Zf^2}{Ze + Z_f} = Z_{1\text{-}3} + Z_{2\text{-}4} - Z_{1\text{-}4} - Z_{2\text{-}3}$$

$$Ze = (K_1 K_2)^{1/2} + K_1$$

$$Zf = (K_1 K_2)^{1/2} + K_2$$

$$K_3 = \frac{Ze * Zf}{2(Ze + Zf)}$$

$$Za = \frac{Z_{1\text{-}2} + Z_{1\text{-}4} - Z_{2\text{-}4}}{2} - K_3$$

$$Zb = \frac{Z_{1\text{-}2} + Z_{2\text{-}3} - Z_{1\text{-}3}}{2} - K_3$$

$$Zc = \frac{Z_{2\text{-}3} + Z_{3\text{-}4} - Z_{2\text{-}4}}{2} - K_3$$

$$Zd = \frac{Z_{3\text{-}4} + Z_{1\text{-}4} - Z_{1\text{-}3}}{2} - K_3$$

Equations 2-18

Fig. 2-16 Equivalent Circuit of a Four-Winding Transformer

Four winding Transformer model can be modeled as an 8-bus system.

Example 1
To make things simple, assume Z13=Z24=Z12=Z34=Z14=Z23=6.5%. This means that the transformer is closely coupled/made. So that K1=K2=Ze=Zf=0.

This model can be translated into:

```
K1= Z13+Z24-Z12-Z34;
K2= Z13+Z24-Z14-Z23;
Ze = sqrt(K1*K2) + K1;
Zf = sqrt(K1*K2) + K2;
if(abs(Ze+Zf) < 0.00001)
 K3 = 0.;
else
 K3=Ze*Zf/2./(Ze+Zf);
Za=(Z12+Z14-Z24)/2. -K3;
Zb=(Z12+Z23-Z13)/2. -K3;
Zc=(Z23+Z34-Z24)/2. -K3;
Zd=(Z34+Z14-Z13)/2. -K3;
```

Given:
Z13=Z24=Z12=Z34=6.5%

Results:
K1=K2=Ze=Zf=0.

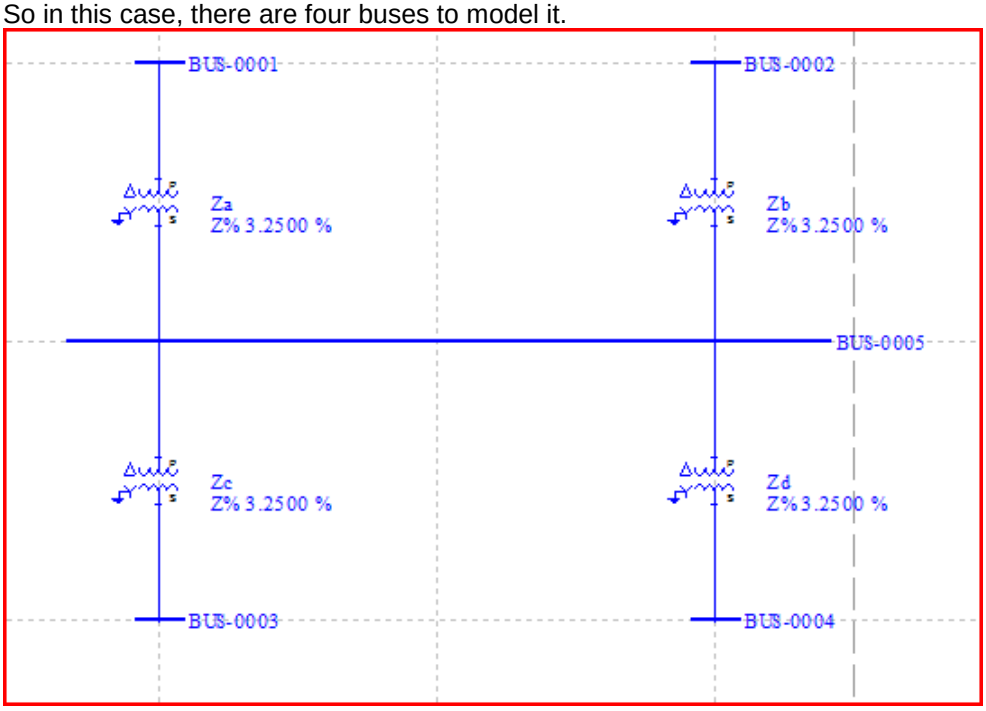
Za=Zb=Zc=Zd= 3.25%

Below are results of example1 using an Excel calculator:
Example 1:

Z12	Z13	Z14	Z23	Z24	Z34
6.5	6.5	6.5	6.5	6.5	6.5

K1= 0
K2= 0
Ze= 0
Zf= 0
K3= 0
Za= 3.25
Zb= 3.25
Zc= 3.25
Zd= 3.25

So in this case, there are four buses to model it.

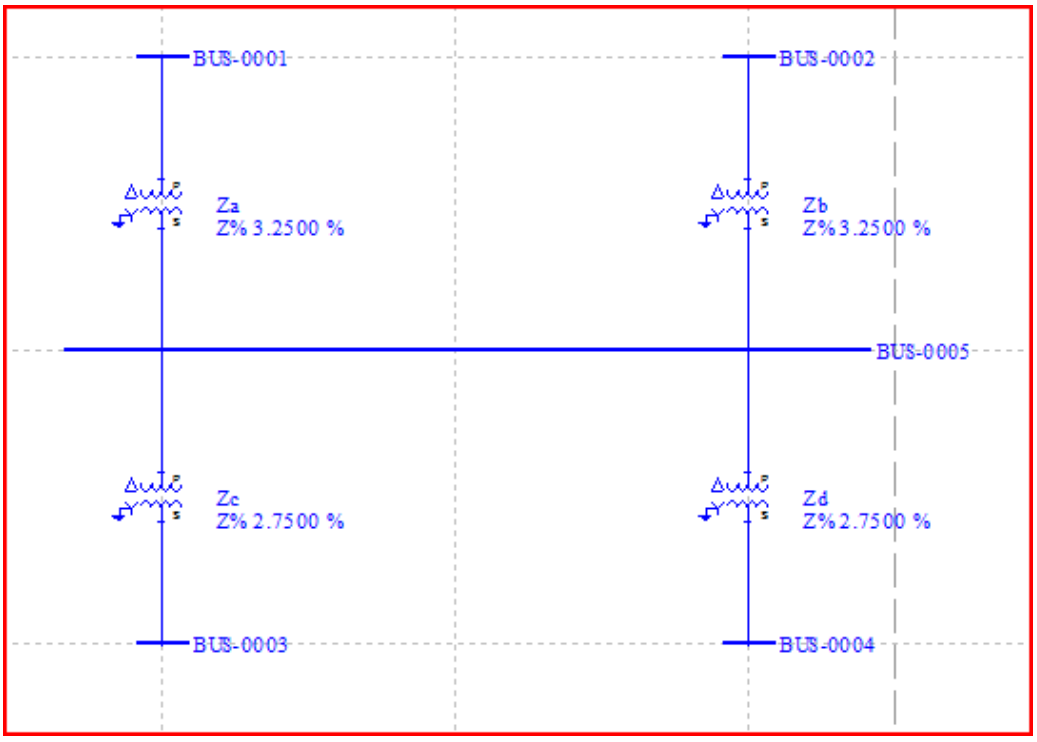


Example 2

Given: Z13=5.5%, Z24=5.5% Z12=6.5%, Z34=5.5%

Z12	Z13	Z14	Z23	Z24	Z34
6.5	5.5	5.5	5.5	5.5	5.5

K1=	-1
K2=	0
Ze=	0
Zf=	0
K3=	0
Za=	3.25
Zb=	3.25
Zc=	2.75
Zd=	2.75



If Z13, Z24, Z12, Z34 are not equal, “BUS-0005” could be expended into 4 buses. (Case 2 is a special case.) Ze and Zf can be calculated using equations given.