Category: Modeling Subcategory: Transformer Subcategory: 4-winding

## 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


$$
\begin{aligned}
& K_{1}=\frac{Z^{2}}{Z \mathrm{e}+Z_{f}}=Z_{1 \cdot 3}+Z_{2-4}-Z_{1-2}-Z_{3-4} \\
& \mathrm{~K}_{2}=\frac{\mathrm{Zf}^{2}}{Z \mathrm{ee}+Z_{f}}=Z_{1-3}+Z_{2-4}-Z_{1-4}-Z_{2-3} \\
& \mathrm{Ze}=\left(\mathrm{K}_{1} \mathrm{~K}_{2}\right)^{1 / 2}+\mathrm{K}_{1} \\
& Z \mathrm{f}=\left(\mathrm{K}_{1} \mathrm{~K}_{2}\right)^{1 / 2}+\mathrm{K}_{2} \\
& K_{3}=\frac{Z e^{*} Z f}{2(Z e+Z f)} \\
& Z \mathrm{a}=\frac{Z_{1-2}+Z_{14}-Z_{24}}{2}-K_{3} \\
& Z \mathrm{~b}=\frac{Z_{1-2}+Z_{2,3}-Z_{1-3}}{2}-K_{3} \\
& Z \mathrm{Cc}=\frac{Z_{2-3}+Z_{3.4}-Z_{2-4}}{2}-K_{3} \\
& Z \mathrm{~d}=\frac{Z_{2-4}+Z_{1-4}-Z_{1-3}}{2}-\mathrm{K}_{3}
\end{aligned}
$$

Equations 2-18
Fig. 2-16 Equivalent Circuit of a Four-Winding Transformer

|  | Originated by: Mr.Li/Lowell | Date: 03/24/09 |
| :---: | :--- | :--- |
| Checked by: Mr.Li/Lowell | Date: 03/24/09 |  |
| Technical Support Group |  |  |
|  | Revised by: | Date: 03/24/09 |
|  | Applicable to: All Version | Doc Rev No: 0 |
| P.O. Box 3376, Manhattan Beach, CA 90266 - Tel: 310.698.4700, Fax: 310.698.4708 - www.skm.com |  |  |
| 1-4 © $\mathbf{4}$ | © 2005 SKM Systems Analysis, Inc. All rights reserved |  |

FAQ

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

## Example 1

To make things simple, assume $Z 13=Z 24=Z 12=Z 34=Z 14=Z 23=6.5 \%$. This means that the transformer is closely coupled/made. So that $\mathrm{K} 1=\mathrm{K} 2=\mathrm{Ze}=\mathrm{Zf}=0$.

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:
$\mathrm{K} 1=\mathrm{K} 2=\mathrm{Ze}=\mathrm{Zf}=0$.
$Z a=Z b=Z c=Z d=3.25 \%$

|  | Originated by: Mr.Li/Lowell | Date: 03/24/09 |
| :---: | :--- | :--- |
| Checked by: Mr.Li/Lowell | Date: 03/24/09 |  |
| Technical Support Group | Revised by: | Date: 03/24/09 |
|  | Applicable to: All Version | Doc Rev No: 0 |
| $2-4$ | P.O. Box 3376, Manhattan Beach, CA 90266 - Tel: 310.698.4700, Fax: 310.698.4708-www.skm.com |  |
| © 2005 SKM Systems Analysis, Inc. All rights reserved |  |  |

FAQ

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 |

$\mathrm{K} 1=\quad 0$
$\mathrm{K} 2=\quad 0$
$\mathrm{Ze}=\quad 0$
$\mathrm{Zf}=\quad 0$
K3= 0
$\mathrm{Za}=\quad 3.25$
$\mathrm{Zb}=\quad 3.25$
Zc= 3.25
Zd= 3.25
So in this case, there are four buses to model it.


|  | Originated by: Mr.Li/Lowell | Date: 03/24/09 |
| :---: | :--- | :--- |
| Checked by: Mr.Li/Lowell | Date: 03/24/09 <br> Revised by: | Date: 03/24/09 <br> Applicable to: All Version |
| Doc Rev No: 0 |  |  |

FAQ

## Example 2

Given: $Z 13=5.5 \%, Z 24=5.5 \% \quad Z 12=6.5 \%, Z 34=5.5 \%$

| Z12 | Z13 | Z14 | Z23 | Z24 | Z34 |
| :--- | :--- | :--- | :--- | :--- | :--- |
| 6.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 |

$\mathrm{K} 1=\quad-1$
$\mathrm{K} 2=\quad 0$
$\mathrm{Ze}=0$
$\mathrm{Zf}=\quad 0$
K3= 0
$\mathrm{Za}=\quad 3.25$
$\mathrm{Zb}=\quad 3.25$
$\mathrm{Zc}=\quad 2.75$
$Z \mathrm{~d}=\quad 2.75$


If $Z 13, Z 24, Z 12, Z 34$ 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.

|  | Originated by: Mr.Li/Lowell | Date: 03/24/09 |
| :---: | :--- | :--- |
| Checked by: Mr.Li/Lowell | Date: 03/24/09 |  |
| Technical Support Group |  |  |
|  | Revised by: | Date: 03/24/09 |
|  | Applicable to: All Version | Doc Rev No: 0 |
| $4-4$ | P.O. Box 3376, Manhattan Beach, CA 90266- Tel: 310.698.4700, Fax: 310.698.4708 - www.skm.com |  |
| © 2005 SKM Systems Analysis, Inc. All rights reserved |  |  |

