NOMENCLATURE, TAGGING and MARKINGS

$V \equiv |\underline{V}|$ - number, module of vector
$\underline{V}$ - complex voltage vector
$\mathbf{V}$ - matrix of vectors or numbers

Problem No. 1

Power Company (CP), i.e. Utility, provided data listed below for the connection point to the grid (i.e. Point of Common Coupling -> PCC). Base on these data, provide following calculations and/or information that will be used for new substation estimating, engineering and design.

System Configuration/ Scenario	Three Phase (I_A)	Single Phase ($3I_0$)	Thevenin's Equivalent Voltage Source
Both 138kV Lines In-Service	4953 MVA	3143 MVA	1.0367 p.u.
Ckt OHL1 Out-of-Service	2915 MVA	1746 MVA	1.0348 p.u.
Ckt OHL2 Out-of-Service	2333 MVA	1520 MVA	1.0362 p.u.

$S_{3PH\_AV\_L1L2} := 4953MVA$ $S_{3PH\_AV\_L1} := 2915MVA$ $S_{3PH\_AV\_L2} := 2333MVA$

$S_{LG\_AV\_L1L2} := 3143MVA$ $S_{LG\_AV\_L1} := 1746MVA$ $S_{LG\_AV\_L2} := 1520MVA$

$\underline{U}_{TH\_L1L2\_pu} := 1.0367 \cdot e^{-j \cdot 0deg} pu$ $\underline{U}_{TH\_L1\_pu} := 1.0348 \cdot e^{-j \cdot 0deg} pu$ $\underline{U}_{TH\_L2\_pu} := 1.0362 \cdot e^{-j \cdot 0deg} pu$

$U_n := \left|138 \cdot e^{-j \cdot 0deg}\right| kV = 138 \cdot kV$

Assumption about $\frac{X}{R}$ for each configurations are made based on references, Color Books and attached. As a result, $XR \equiv 9$

A. For each Utility configuration, calculate: three phase and single phase available short circuit currents in following forms:

$$\underline{I}_{Fault\_3PH\_L1L2} := \frac{S_{3PH\_AV\_L1L2}}{\sqrt{3} \cdot \underline{U}_{TH\_L1L2\_pu} \cdot U_n} \cdot (\cos(\operatorname{atan}(XR)) - i \cdot \sin(\operatorname{atan}(XR))) = (2.21 - 19.87j) \cdot kA$$

$$\left|\underline{I}_{Fault\_3PH\_L1L2}\right| = 19.99 \cdot kA$$

$$\underline{I}_{Fault\_3I0\_L1L2} := \frac{S_{LG\_AV\_L1L2}}{\sqrt{3} \cdot \underline{U}_{TH\_L1L2\_pu} \cdot U_n} \cdot (\cos(\operatorname{atan}(XR)) - i \cdot \sin(\operatorname{atan}(XR))) = (1.4 - 12.61j) \cdot kA$$

$$\left|\underline{I}_{Fault\_3I0\_L1L2}\right| = 12.68 \cdot kA$$

$$\underline{I}_{Fault\_3PH\_L1} := \frac{S_{3PH\_AV\_L1}}{\sqrt{3} \cdot \underline{U}_{TH\_L1\_pu} \cdot U_n} \cdot (\cos(\operatorname{atan}(XR)) - i \cdot \sin(\operatorname{atan}(XR))) = (1.3 - 11.71j) \cdot kA$$

$$\left|\underline{I}_{Fault\_3PH\_L1}\right| = 11.79 \cdot kA$$

$$\underline{I}_{Fault\_3I0\_L1} := \frac{S_{LG\_AV\_L1}}{\sqrt{3} \cdot \underline{U}_{TH\_L1\_pu} \cdot U_n} \cdot (\cos(\operatorname{atan}(XR)) - i \cdot \sin(\operatorname{atan}(XR))) = (0.78 - 7.02j) \cdot kA$$

$$\left|\underline{I}_{Fault\_3I0\_L1}\right| = 7.06 \cdot kA$$

$$\underline{I}_{Fault\_3PH\_L2} := \frac{S_{3PH\_AV\_L2}}{\sqrt{3} \cdot \underline{U}_{TH\_L2\_pu} \cdot U_n} \cdot (\cos(\operatorname{atan}(XR)) - i \cdot \sin(\operatorname{atan}(XR))) = (1.04 - 9.36j) \cdot kA$$

$$\left|\underline{I}_{Fault\_3PH\_L2}\right| = 9.42 \cdot kA$$

$$\underline{I}_{Fault\_3I0\_L2} := \frac{S_{LG\_AV\_L2}}{\sqrt{3} \cdot \underline{U}_{TH\_L2\_pu} \cdot U_n} \cdot (\cos(\operatorname{atan}(XR)) - i \cdot \sin(\operatorname{atan}(XR))) = (0.68 - 6.1j) \cdot kA$$

$$\left|\underline{I}_{Fault\_3I0\_L2}\right| = 6.14 \cdot kA$$

B. For per-unit calculations, assume that 100MVA base on 138kV is used. Calculate and/or provide following data: system ba voltage, base current and base impedance.

$$S_b := 100MVA$$

$$U_{b\_100MVA} := 138kV$$

$$I_{b\_100MVA} := \frac{S_b}{\sqrt{3} \cdot U_{b\_100MVA}} = 418.37\,A$$

$$Z_{b\_100MVA} := \frac{U_{b\_100MVA}^{2}}{S_b} = 190.44\,\Omega$$

or

$$Z_b := \frac{U_{b\_100MVA}}{\sqrt{3} \cdot I_{b\_100MVA}} = 190.44\,\Omega$$

C. For each Utility configuration, on the per-unit on a 100MVA base @ 138kV, calculate Positive, Negative and Zero sequence impedances at Thévenin's Equivalent system voltage at PCC. Calculated impedances to be presented in following forms:

From nonsymmetrical fault theory:

$$I_{F\_LG} = \frac{3U_F}{Z_1 + Z_2 + Z_0} \quad \text{or} \quad Z_0 = \frac{3 \cdot U_F}{I_{F\_LG}} - Z_2 - Z_1$$

For L1 and L2 lines in service:

From 3PH fault, we obtain

Z_1

$$\underline{Z}_{1\_L1L2} := \frac{\underline{U}_{TH\_L1L2\_pu}}{\left(\frac{\underline{I}_{Fault\_3PH\_L1L2}}{I_{b\_100MVA}}\right)} = (0.002396 + 0.021566i) \cdot pu \qquad z2r\theta\left(\underline{Z}_{1\_L1L2}\right) = \text{"(0.0217∡ 83.66°)"} \cdot pu$$

Assumption:

$$\underline{Z}_{2\_L1L2} := \underline{Z}_{1\_L1L2} = (0 + 0.02j) \cdot pu \qquad z2r\theta\left(\underline{Z}_{2\_L1L2}\right) = \text{"(0.0217∡ 83.66°)"} \cdot pu$$

$$\underline{Z}_{0\_L1L2} := \left[\frac{3 \cdot \underline{U}_{TH\_L1L2\_pu}}{\left(\frac{\underline{I}_{Fault\_3I0\_L1L2}}{I_{b\_100MVA}}\right)} - \underline{Z}_{1\_L1L2} - \underline{Z}_{2\_L1L2}\right] \qquad \underline{Z}_{0\_L1L2} = (0.01 + 0.06j) \cdot pu$$

$$z2r\theta\left(\underline{Z}_{0\_L1L2}\right) = \text{"(0.0592∡ 83.66°)"} \cdot pu$$

For L1 line in service only:

From 3PH fault, we obtain

Z_1

$$\underline{Z}_{1\_L1} := \frac{\underline{U}_{TH\_L1\_pu}}{\left(\frac{\underline{I}_{Fault\_3PH\_L1}}{I_{b\_100MVA}}\right)} = (0.004057 + 0.03651i) \cdot pu \qquad z2r\theta\left(\underline{Z}_{1\_L1}\right) = \text{"(0.0367∡ 83.66°)"} \cdot pu$$

Assumption:

$$\underline{Z}_{2\_L1} := \underline{Z}_{1\_L1} = (0 + 0.04j) \cdot pu \qquad z2r\theta\left(\underline{Z}_{2\_L1}\right) = \text{"(0.0367∡ 83.66°)"} \cdot pu$$

$$\underline{Z}_{0\_L1} := \left[\frac{3 \cdot \underline{U}_{TH\_L1\_pu}}{\left(\frac{\underline{I}_{Fault\_3I0\_L1}}{I_{b\_100MVA}}\right)} - \underline{Z}_{1\_L1} - \underline{Z}_{2\_L1}\right] \qquad \underline{Z}_{0\_L1} = (0.01 + 0.11j) \cdot pu$$

$$z2r\theta\left(\underline{Z}_{0\_L1}\right) = \text{"(0.1105∡ 83.66°)"} \cdot pu$$

For L2 line in service only:

From 3PH fault, we obtain

Z_1

$$\underline{Z}_{1\_L2} := \frac{\underline{U}_{TH\_L2\_pu}}{\left(\frac{\underline{I}_{Fault\_3PH\_L2}}{I_{b\_100MVA}}\right)} = (0.005082 + 0.045741i) \cdot pu \qquad z2r\theta\left(\underline{Z}_{1\_L2}\right) = \text{"(0.046∡ 83.66°)"} \cdot pu$$

Assumption:

$\underline{Z}_{2\_L2} := \underline{Z}_{1\_L2} = (0.01 + 0.05j) \cdot pu$

$z2r\theta(\underline{Z}_{2\_L2}) = \text{"(0.046∡ 83.66°)"} \cdot pu$

$$\underline{Z}_{0\_L2} := \left[\frac{3 \cdot \underline{U}_{TH\_L2\_pu}}{\left(\frac{\underline{I}_{Fault\_3I0\_L2}}{I_{b\_100MVA}} \right)} - \underline{Z}_{1\_L2} - \underline{Z}_{2\_L2} \right]$$

$\underline{Z}_{0\_L2} = (0.01 + 0.12j) \cdot pu$

$z2r\theta(\underline{Z}_{0\_L2}) = \text{"(0.1199∡ 83.66°)"} \cdot pu$

D. For each Utility configuration, calculate $\frac{X}{R}$ for each impedance calculated in C.

The $\frac{X}{R}$ ratio for all circuit was assigned and is identical for all impedances $\frac{X}{R} = 9$.

Problem No. 2

For transformer with data provided in attached TRANSFORMER_DATA.PDF, calculate following:

A. High Side (HS) and Low Side (LS) currents assuming transformer is loaded 100% and Power Factor (PF) is 1.00.

$S_{n\_OA\_55C} := 45MVA$ $\quad S_{n\_FA\_55C} := 60MVA$ $\quad S_{n\_2FA\_55C} := 75MVA$

$S_{n\_OA\_65C} := 50.4MVA$ $\quad S_{n\_FA\_65C} := 67.2MVA$ $\quad S_{n\_2FA\_65C} := 84MVA$

Connection = Yy0 $\quad \underline{U_{n\_HS}} := \left|138\cdot e^{-j\cdot 0deg}\right| kV$

$\underline{U_{n\_LS}} := \left|34.5\cdot e^{-j\cdot 0deg}\right| kV$ $\quad \underline{Z_{t\_HX}} := (1 + j\cdot 9.95)\%$

$\cos(\alpha) := 1$

$\alpha := acos(1) = 0\cdot deg$

$$\underline{I_{n\_HS\_OA\_55C}} := \frac{S_{n\_OA\_55C}\cdot e^{-j\cdot 0deg}}{\sqrt{3}\cdot \underline{U_{n\_HS}}} = 188.3\,A \qquad z2r\theta\left(\underline{I_{n\_HS\_OA\_55C}}\right) = \text{"(188.2664∡ 0°)"}\cdot A$$

$$\underline{I_{n\_HS\_FA\_55C}} := \frac{S_{n\_FA\_55C}\cdot e^{-j\cdot 0deg}}{\sqrt{3}\cdot \underline{U_{n\_HS}}} = 251.0\,A \qquad z2r\theta\left(\underline{I_{n\_HS\_FA\_55C}}\right) = \text{"(251.0219∡ 0°)"}\cdot A$$

$$\underline{I_{n\_HS\_2FA\_55C}} := \frac{S_{n\_2FA\_55C}\cdot e^{-j\cdot 0deg}}{\sqrt{3}\cdot \underline{U_{n\_HS}}} = 313.8\,A \qquad z2r\theta\left(\underline{I_{n\_HS\_2FA\_55C}}\right) = \text{"(313.7773∡ 0°)"}\cdot A$$

$$\underline{I_{n\_HS\_OA\_65C}} := \frac{S_{n\_OA\_65C}\cdot e^{-j\cdot 0deg}}{\sqrt{3}\cdot \underline{U_{n\_HS}}} = 210.9\,A \qquad z2r\theta\left(\underline{I_{n\_HS\_OA\_65C}}\right) = \text{"(210.8584∡ 0°)"}\cdot A$$

$$\underline{I_{n\_HS\_FA\_65C}} := \frac{S_{n\_FA\_65C}\cdot e^{-j\cdot 0deg}}{\sqrt{3}\cdot \underline{U_{n\_HS}}} = 281.1\,A \qquad z2r\theta\left(\underline{I_{n\_HS\_FA\_65C}}\right) = \text{"(281.1445∡ 0°)"}\cdot A$$

$$\underline{I_{n\_HS\_2FA\_65C}} := \frac{S_{n\_2FA\_65C}\cdot e^{-j\cdot 0deg}}{\sqrt{3}\cdot \underline{U_{n\_HS}}} = 351.4\,A \qquad z2r\theta\left(\underline{I_{n\_HS\_2FA\_65C}}\right) = \text{"(351.4306∡ 0°)"}\cdot A$$

$$\underline{I_{n\_LS\_OA\_55C}} := \frac{S_{n\_OA\_55C}\cdot e^{-j\cdot 0deg}}{\sqrt{3}\cdot \underline{U_{n\_LS}}} = 753.1\,A \qquad z2r\theta\left(\underline{I_{n\_LS\_OA\_55C}}\right) = \text{"(753.0656∡ 0°)"}\cdot A$$

$$\underline{I}_{n\_LS\_FA\_55C} := \frac{S_{n\_FA\_55C} \cdot e^{-j \cdot 0deg}}{\sqrt{3} \cdot \underline{U}_{n\_LS}} = 1004.1\,A$$

$$z2r\theta(\underline{I}_{n\_LS\_FA\_55C}) = \text{"(1004.0874∡ 0°)"} \cdot A$$

$$\underline{I}_{n\_LS\_2FA\_55C} := \frac{S_{n\_2FA\_55C} \cdot e^{-j \cdot 0deg}}{\sqrt{3} \cdot \underline{U}_{n\_LS}} = 1255.1\,A$$

$$z2r\theta(\underline{I}_{n\_LS\_2FA\_55C}) = \text{"(1255.1093∡ 0°)"} \cdot A$$

$$\underline{I}_{n\_LS\_OA\_65C} := \frac{S_{n\_OA\_65C} \cdot e^{-j \cdot 0deg}}{\sqrt{3} \cdot \underline{U}_{n\_LS}} = 843.4\,A$$

$$z2r\theta(\underline{I}_{n\_LS\_OA\_65C}) = \text{"(843.4334∡ 0°)"} \cdot A$$

$$\underline{I}_{n\_LS\_FA\_65C} := \frac{S_{n\_FA\_65C} \cdot e^{-j \cdot 0deg}}{\sqrt{3} \cdot \underline{U}_{n\_LS}} = 1124.6\,A$$

$$z2r\theta(\underline{I}_{n\_LS\_FA\_65C}) = \text{"(1124.5779∡ 0°)"} \cdot A$$

$$\underline{I}_{n\_LS\_2FA\_65C} := \frac{S_{n\_2FA\_65C} \cdot e^{-j \cdot 0deg}}{\sqrt{3} \cdot \underline{U}_{n\_LS}} = 1405.7\,A$$

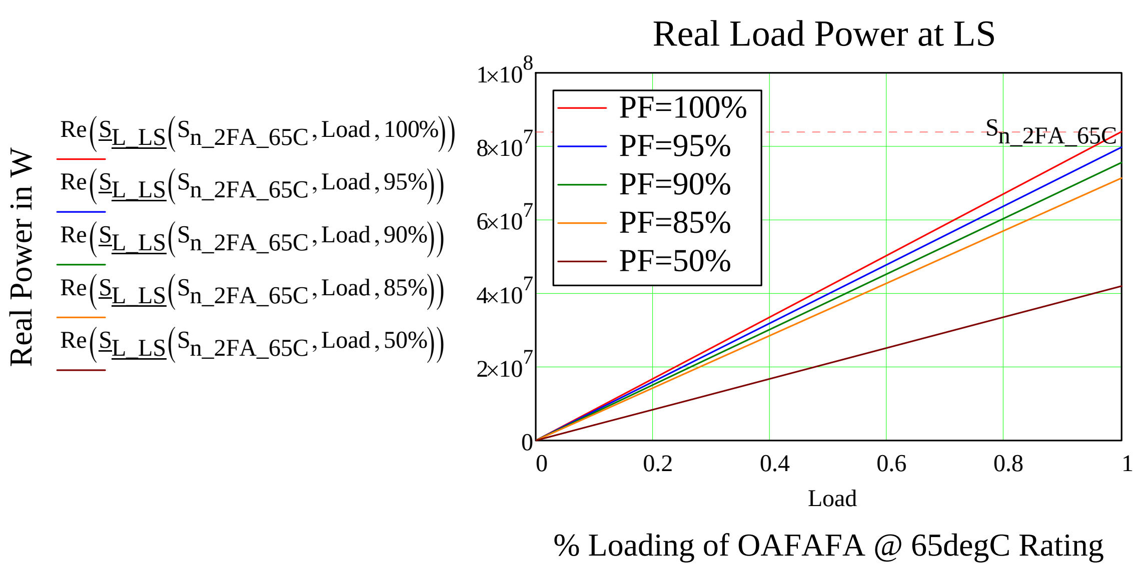
$$z2r\theta(\underline{I}_{n\_LS\_2FA\_65C}) = \text{"(1405.7224∡ 0°)"} \cdot A$$

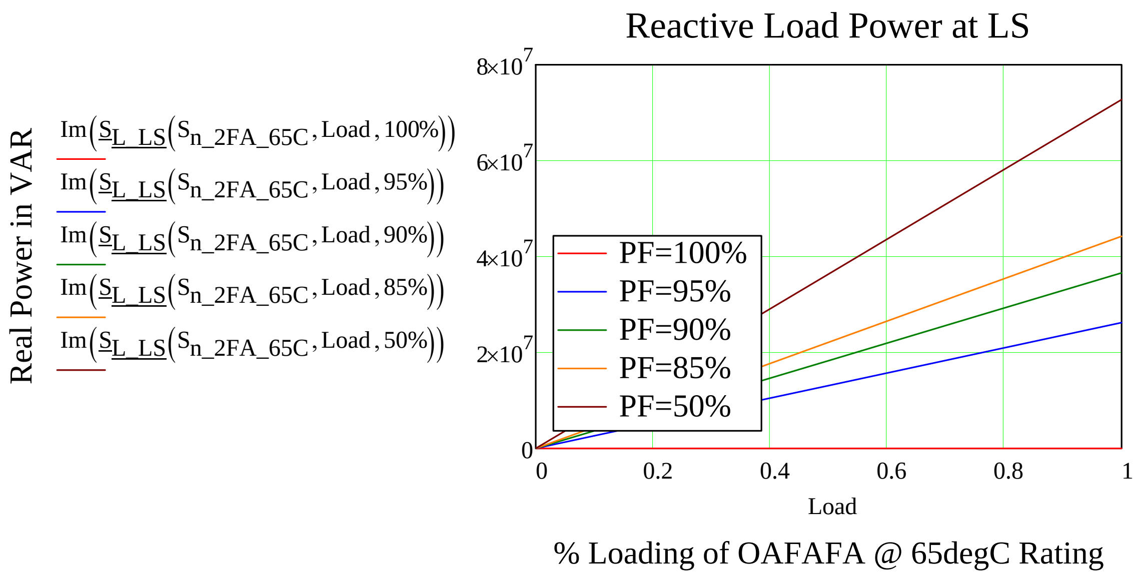
B. HS and LS apparent, real and reactive powers, currents for: 10%, 25%, 50%, 75%, 100% loads and following P.F.'s 1.00, 0.95, 0.90, 0.85, 0.50. Do not consider losses in the transformer (ideal transformer).

$$Load := (0\% \;\; 10\% \;\; 25\% \;\; 50\% \;\; 75\% \;\; 100\%)^T$$

$$PF_a := (100\% \;\; 95\% \;\; 90\% \;\; 85\% \;\; 50\%)^T$$

$$\underline{S}_{L\_LS}(S_{max}, Load, PF) := S_{max} \cdot Load \cdot e^{j \cdot acos(PF)}$$

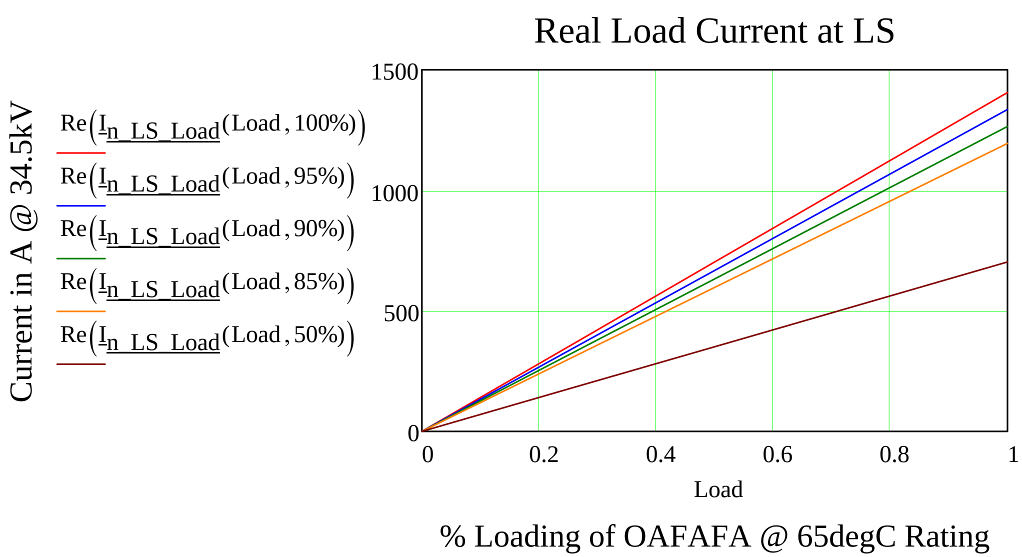


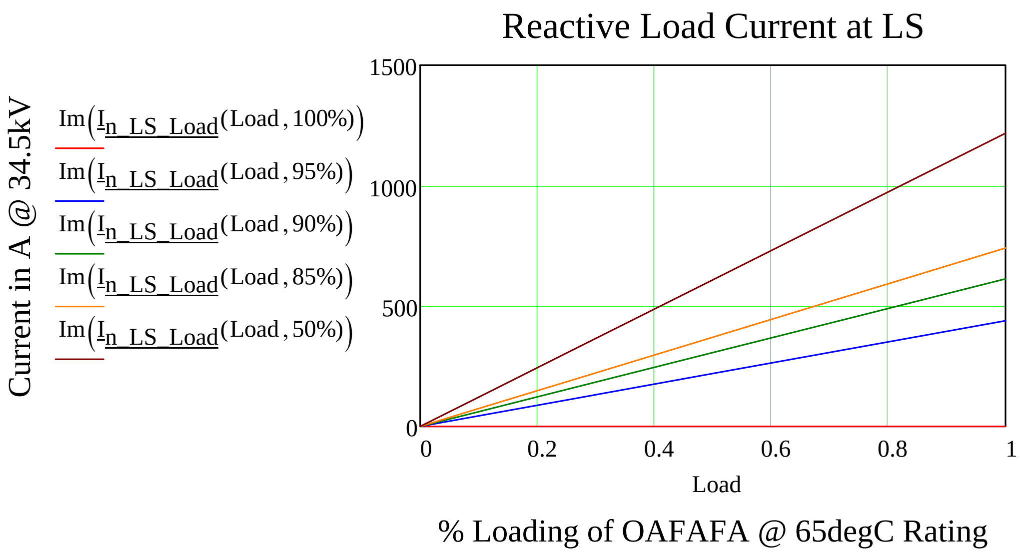


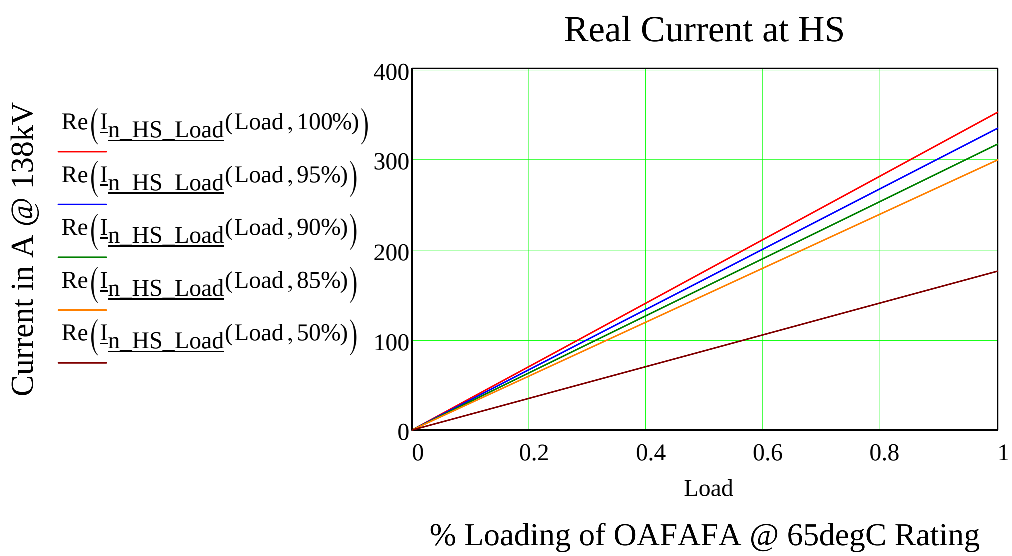
For loss less transformer, the LS and HS load power are equivalent and the LS and HS currents depend on LS and HS volta
and transformer connection.

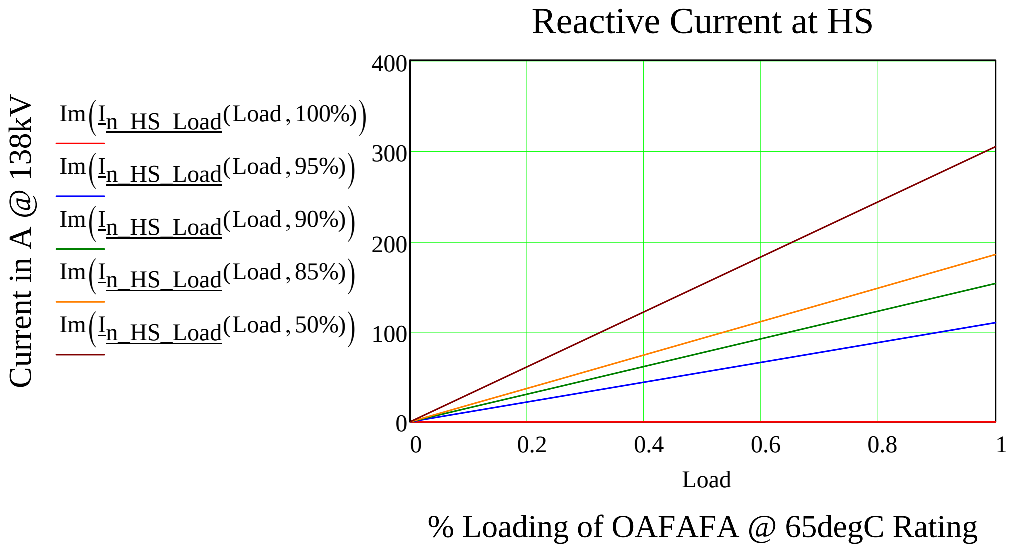
$$\underline{I}_{n\_LS\_Load}(Load, PF) := \frac{S_{n\_2FA\_65C} \cdot Load \cdot e^{j \cdot acos(PF)}}{\sqrt{3} \cdot \underline{U}_{n\_LS}}$$

$$\underline{I}_{n\_HS\_Load}(Load, PF) := \frac{S_{n\_2FA\_65C} \cdot Load \cdot e^{j \cdot acos(PF)}}{\sqrt{3} \cdot \underline{U}_{n\_HS}}$$

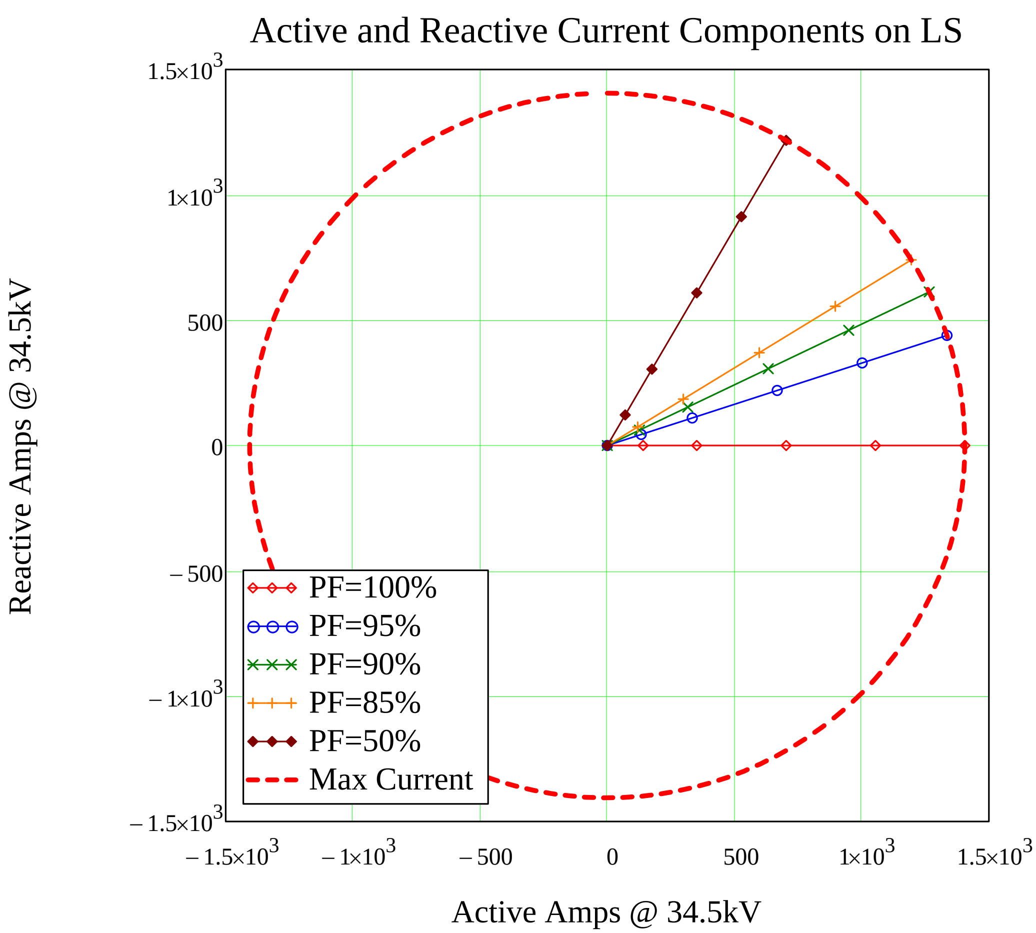



Reactive Load Current at LS
Current in A @ 34.5kV
Im(In_LS_Load(Load, 100%))
Im(In_LS_Load(Load, 95%))
Im(In_LS_Load(Load, 90%))
Im(In_LS_Load(Load, 85%))
Im(In_LS_Load(Load, 50%))
1500
1000
500
0
0
0.2
0.4
0.6
0.8
1
Load
% Loading of OAFAFA @ 65degC Rating

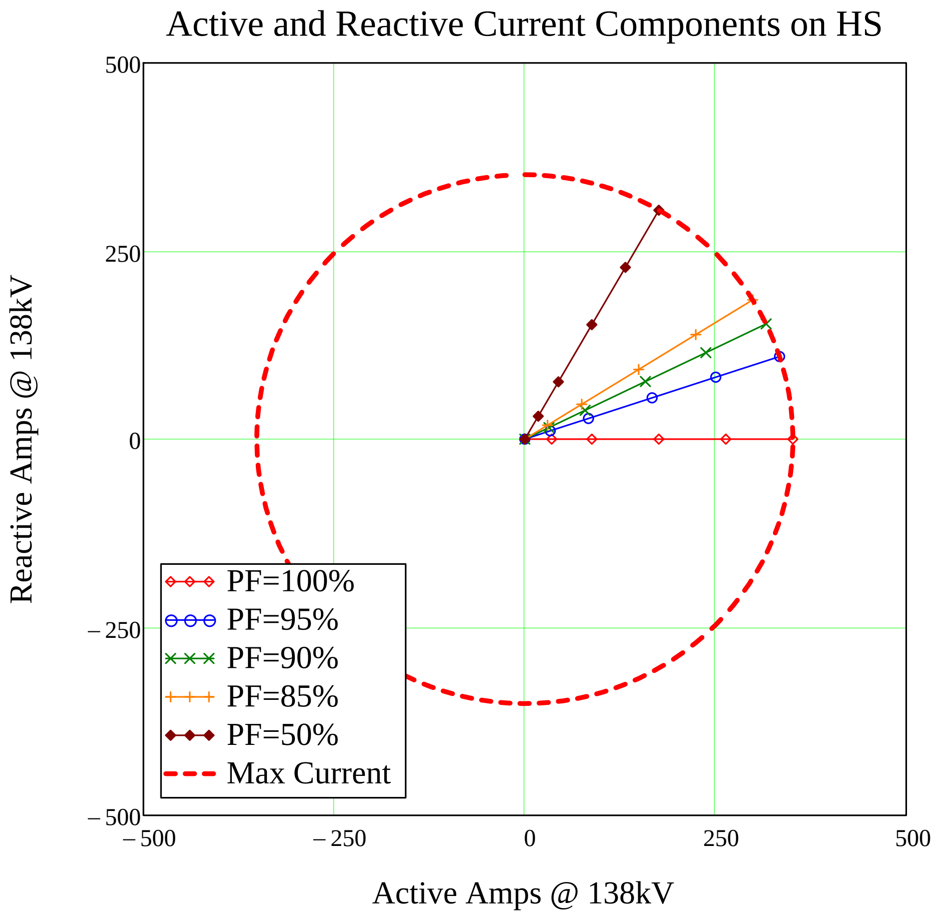

Real Current at HS
Current in A @ 138kV
Re(In_HS_Load(Load, 100%))
Re(In_HS_Load(Load, 95%))
Re(In_HS_Load(Load, 90%))
Re(In_HS_Load(Load, 85%))
Re(In_HS_Load(Load, 50%))
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
Load
% Loading of OAFAFA @ 65degC Rating



Reactive Current at HS
Current in A @ 138kV
Im(I_n_HS_Load(Load, 100%))
Im(I_n_HS_Load(Load, 95%))
Im(I_n_HS_Load(Load, 90%))
Im(I_n_HS_Load(Load, 85%))
Im(I_n_HS_Load(Load, 50%))
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
Load
% Loading of OAFAFA @ 65degC Rating



Active and Reactive Current Components on LS
Reactive Amps @ 34.5kV
1.5×10^3
1×10^3
500
0
− 500
− 1×10^3
− 1.5×10^3
PF=100%
PF=95%
PF=90%
PF=85%
PF=50%
Max Current
− 1.5×10^3
− 1×10^3
− 500
0
500
1×10^3
1.5×10^3
Active Amps @ 34.5kV


Active and Reactive Current Components on HS
500
250
0
− 250
− 500
− 500
− 250
0
250
500
Reactive Amps @ 138kV
Active Amps @ 138kV
PF=100%
PF=95%
PF=90%
PF=85%
PF=50%
Max Current

C. HS and LS apparent, real and reactive powers, currents and reactive power loss for: 10%, 25%, 50%, 75%, 100% loads and following P.F.'s 1.00, 0.95, 0.90, 0.85, 0.50. Consider losses in the transformer.

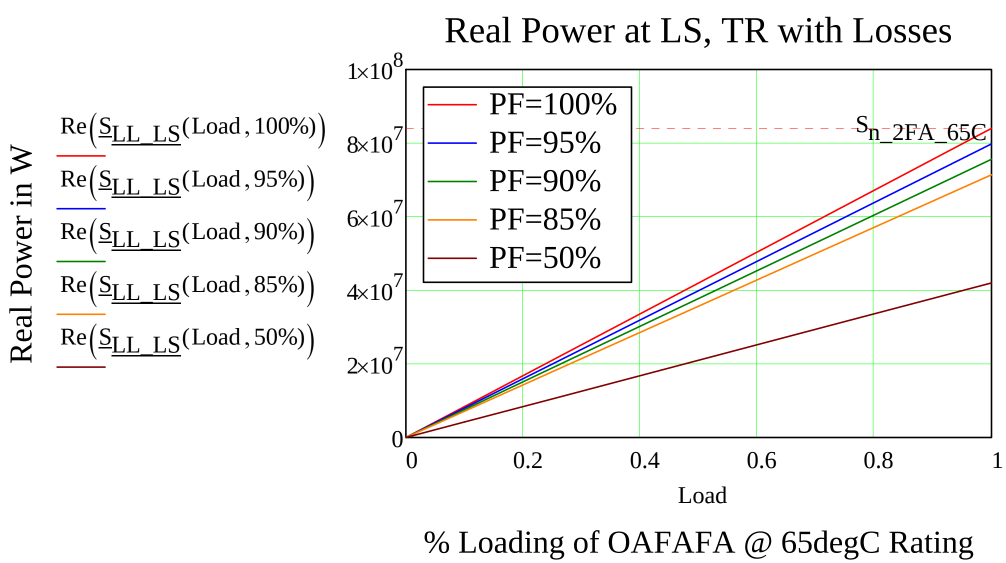
Losses in the transformer are approximated only by impedance of the transformer i.e. excitation loses are disregarded constant and minimal for overall power balance of the transformer during operation.

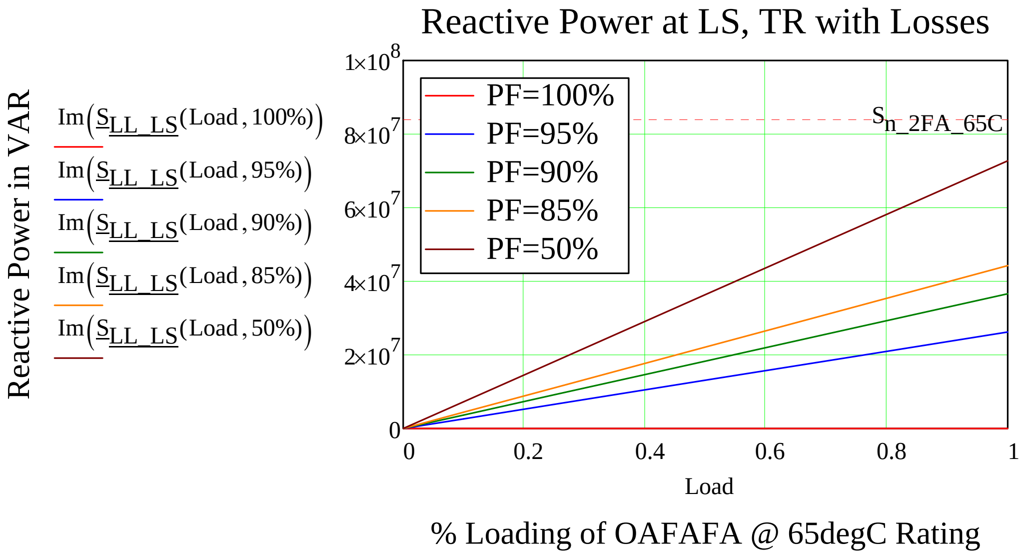
$$Load := (0\% \;\; 10\% \;\; 25\% \;\; 50\% \;\; 75\% \;\; 100\%)^T$$

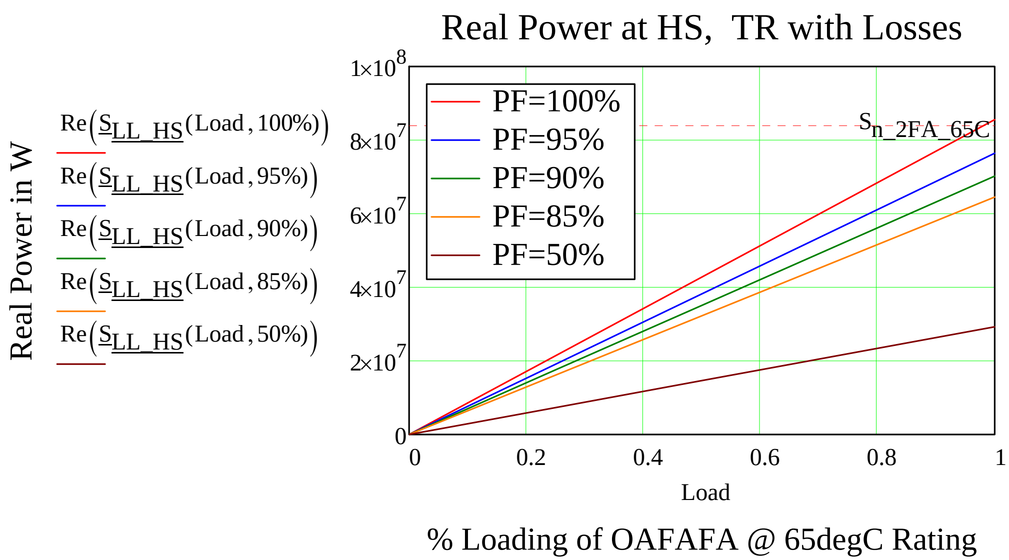
$$PF_a := (100\% \;\; 95\% \;\; 90\% \;\; 85\% \;\; 50\%)^T$$

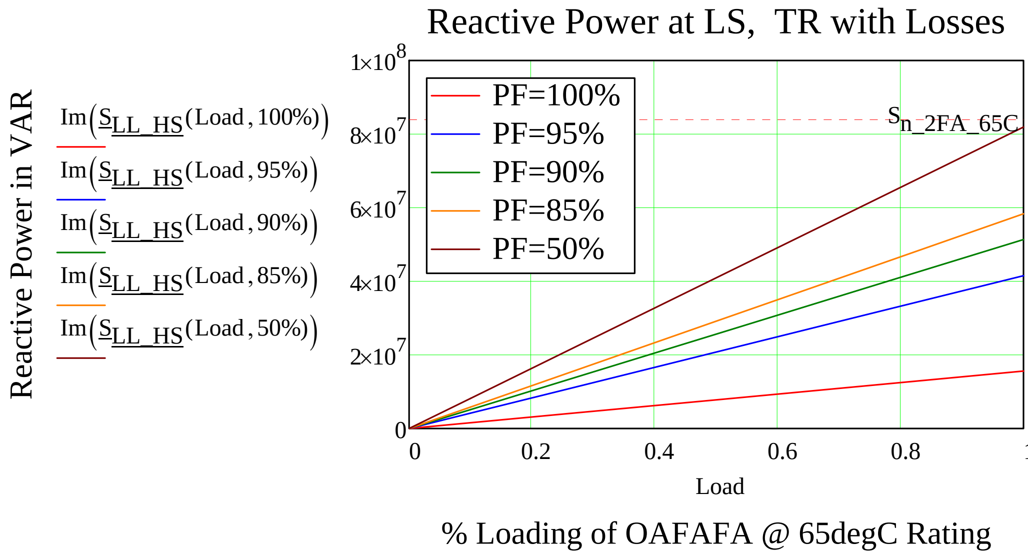
$$\underline{S}_{\underline{LL\_LS}}(Load, PF) := \left(S_{n\_2FA\_65C}\right)\cdot\left(Load\cdot e^{j\cdot acos(PF)}\right)$$

$$\underline{S}_{\underline{LL\_HS}}(Load, PF) := \left(S_{n\_2FA\_65C}\right)\cdot\left(Load\cdot e^{j\cdot acos(PF)}\right)\cdot\left[1 + \left(\frac{S_{n\_2FA\_65C}}{S_{n\_OA\_55C}}\right)\cdot \underline{Z}_{\underline{t\_HX}}\right]$$




Reactive Power at LS, TR with Losses
Reactive Power in VAR
Im(S_LL_LS(Load, 100%))
Im(S_LL_LS(Load, 95%))
Im(S_LL_LS(Load, 90%))
Im(S_LL_LS(Load, 85%))
Im(S_LL_LS(Load, 50%))
1×10^8
8×10^7
6×10^7
4×10^7
2×10^7
0
PF=100%
PF=95%
PF=90%
PF=85%
PF=50%
S_n_2FA_65C
0
0.2
0.4
0.6
0.8
1
Load
% Loading of OAFAFA @ 65degC Rating

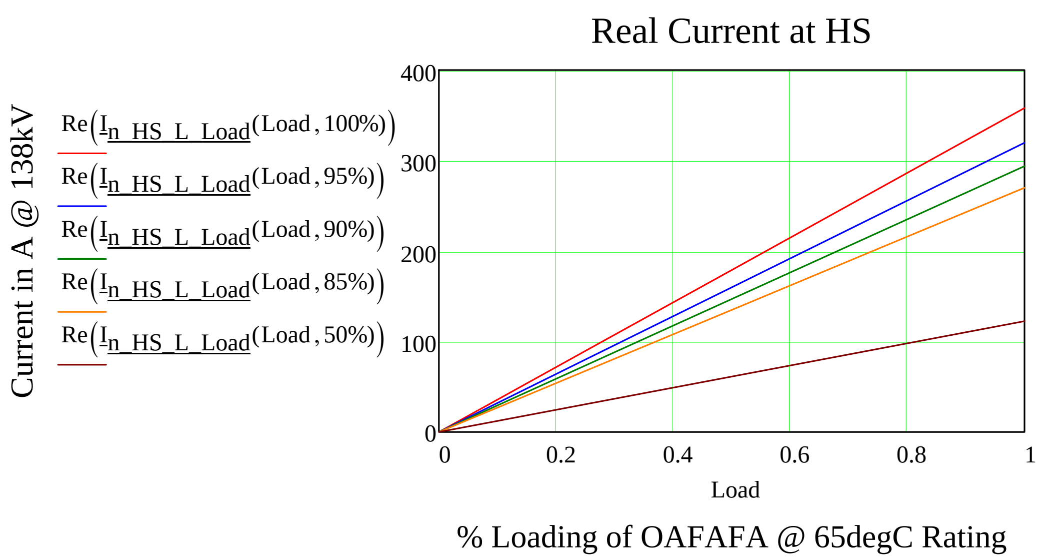

Real Power at HS, TR with Losses
Real Power in W
Re(S_LL_HS(Load, 100%))
Re(S_LL_HS(Load, 95%))
Re(S_LL_HS(Load, 90%))
Re(S_LL_HS(Load, 85%))
Re(S_LL_HS(Load, 50%))
1×10^8
8×10^7
6×10^7
4×10^7
2×10^7
0
PF=100%
PF=95%
PF=90%
PF=85%
PF=50%
S_n_2FA_65C
0
0.2
0.4
0.6
0.8
1
Load
% Loading of OAFAFA @ 65degC Rating

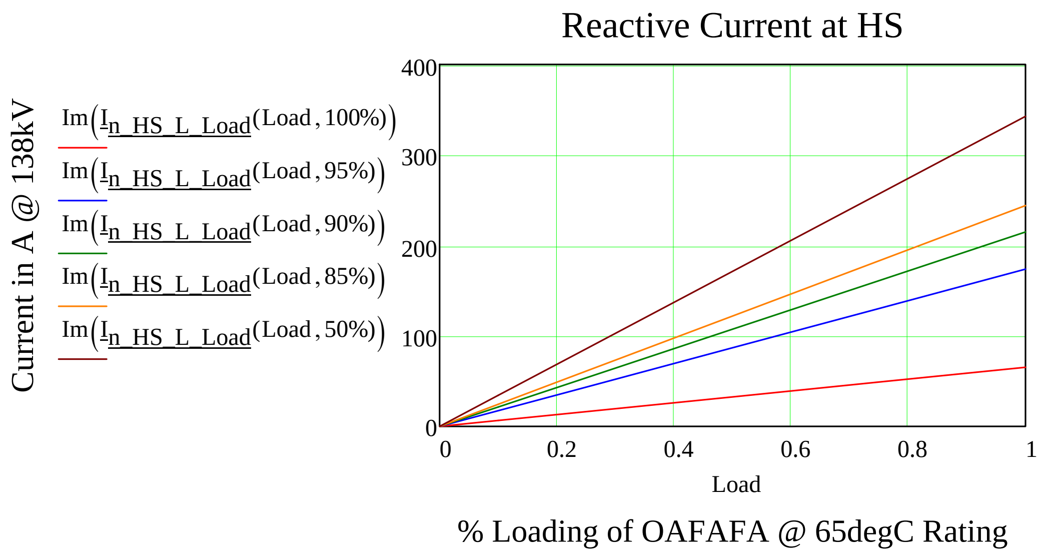


For LS side of TR currents for loss less and with losses transformer are identical to currents in task C. Currents for HS ai calculated below:.

$$\underline{I}_{n\_LS\_Load}(Load, PF) := \frac{S_{n\_2FA\_65C} \cdot Load \cdot e^{j \cdot acos(PF)}}{\sqrt{3} \cdot \underline{U}_{n\_LS}}$$

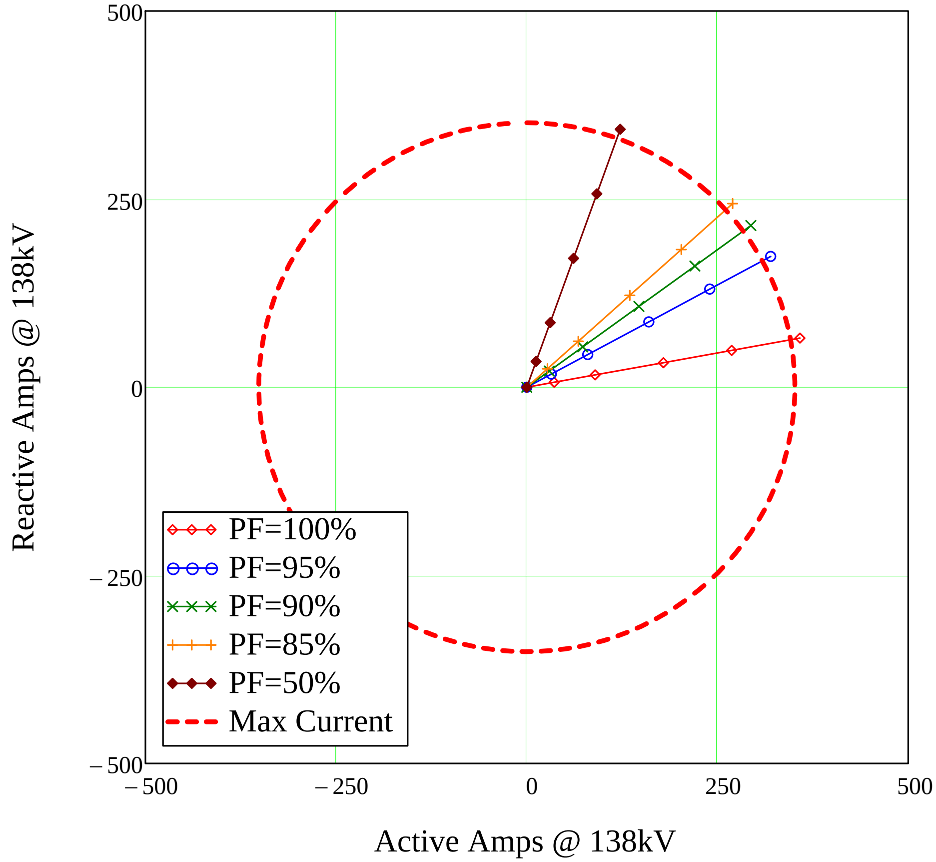
$$\underline{I}_{n\_HS\_L\_Load}(Load, PF) := \frac{S_{n\_2FA\_65C} \cdot Load \cdot e^{j \cdot acos(PF)} \cdot \left[1 + \left(\frac{S_{n\_2FA\_65C}}{S_{n\_OA\_55C}}\right) \cdot \underline{Z}_{t\_HX}\right]}{\sqrt{3} \cdot \underline{U}_{n\_HS}}$$





Reactive Current at HS
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
Load
Current in A @ 138kV
Im(I_n_HS_L_Load(Load, 100%))
Im(I_n_HS_L_Load(Load, 95%))
Im(I_n_HS_L_Load(Load, 90%))
Im(I_n_HS_L_Load(Load, 85%))
Im(I_n_HS_L_Load(Load, 50%))
% Loading of OAFAFA @ 65degC Rating

Active and Reactive Current Components on HS



For $Load = \begin{pmatrix} 0 \\ 0.1 \\ 0.25 \\ 0.5 \\ 0.75 \\ 1 \end{pmatrix}$ and $PF_a = \begin{pmatrix} 1 \\ 0.95 \\ 0.9 \\ 0.85 \\ 0.5 \end{pmatrix}$ loss at the transformer for each PF is:

$$S_{Loss}(Load, PF) := \underline{S_{LL\_HS}}(Load, PF) - \underline{S_{L\_LS}}(Load, PF)$$

$z2r\theta\left(S_{Loss}(10\%,100\%)\right) = "(\ 1568019.5999\measuredangle\ 84.26°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(25\%,100\%)\right) = "(\ 3920048.9997\measuredangle\ 84.26°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(50\%,100\%)\right) = "(\ 7840097.9994\measuredangle\ 84.26°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(75\%,100\%)\right) = "(\ 11760146.9991\measuredangle\ 84.26°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(100\%,100\%)\right) = "(\ 15680195.9988\measuredangle\ 84.26°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(10\%,95\%)\right) = "(\ 1568019.5999\measuredangle\ 66.07°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(25\%,95\%)\right) = "(\ 3920048.9997\measuredangle\ 66.07°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(50\%,95\%)\right) = "(\ 7840097.9994\measuredangle\ 66.07°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(75\%,95\%)\right) = "(\ 11760146.9991\measuredangle\ 66.07°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(100\%,95\%)\right) = "(\ 15680195.9988\measuredangle\ 66.07°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(10\%,90\%)\right) = "(\ 1568019.5999\measuredangle\ 58.42°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(25\%,90\%)\right) = "(\ 3920048.9997\measuredangle\ 58.42°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(50\%,90\%)\right) = "(\ 7840097.9994\measuredangle\ 58.42°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(75\%,90\%)\right) = "(\ 11760146.9991\measuredangle\ 58.42°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(100\%,90\%)\right) = "(\ 15680195.9988\measuredangle\ 58.42°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(10\%,85\%)\right) = "(\ 1568019.5999\measuredangle\ 52.47°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(25\%,85\%)\right) = "(\ 3920048.9997\measuredangle\ 52.47°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(50\%,85\%)\right) = "(\ 7840097.9994\measuredangle\ 52.47°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(75\%,85\%)\right) = "(\ 11760146.9991\measuredangle\ 52.47°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(100\%,85\%)\right) = "(\ 15680195.9988\measuredangle\ 52.47°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(10\%,50\%)\right) = "(\ 1568019.5999\measuredangle\ 24.26°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(25\%,50\%)\right) = "(\ 3920048.9997\measuredangle\ 24.26°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(50\%,50\%)\right) = "(\ 7840097.9994\measuredangle\ 24.26°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(75\%,50\%)\right) = "(\ 11760146.9991\measuredangle\ 24.26°\ )"\cdot VA$

$z2r\theta\left(S_{Loss}(100\%,50\%)\right) = "(\ 15680195.9988\measuredangle\ 24.26°\ )"\cdot VA$

Problem No. 3

For motor with data provided in attached MOTOR_DATA.PDF, calculate following:

A. Connecting cable current for motor operating at 100% (i.e. Full Load Amps (FLA) and motor operating at Service Factor (SF). Assume motor terminal voltage is nominal per provided data

$I_{FLA} := 506A$ $\qquad I_{100\%} := I_{FLA} = 506\,A$

$SF := 1.15$ $\qquad I_{SF\_A} := SF \cdot I_{FLA} = 581.9\,A$

B. Calculate operating condition and starting impedances. Estimate starting Power Factor (PF).

$U_{n\_motor} := 4kV$ $\qquad I_{LRC} := 3250A$

Nominal operating condition (100% load, 100% voltage, nominal PF, nominal RPM) impedance is

$Z_{op} := \frac{U_{n\_motor}}{\sqrt{3} \cdot I_{FLA}} = 4.56\,\Omega$, at the same time this is a machine "base" impedance. From motor data,

$n_n := 1780RPM$, $PF_n := 88\%$, $EFF_n := 96.8\%$, $P_n := 4000Hp \cdot 746 \frac{kW}{Hp} = 2984 \cdot MW$

As a result, $\underline{Z_{op}} := Z_{op} \cdot e^{-j \cdot acos\left(\frac{PF_n}{100}\right) deg} = (4.56 - 0.12j)\,\Omega$

From theory of Induction Machines, for nominal RPM, slip is $s_n := \frac{1800RPM - n_n}{1800RPM} = 0.0111$

Nominal torque of the motor is

$T_n := 9.55 \cdot \frac{P_n}{n_n} = 16009.66 \cdot kN \cdot m$ starting torque is $T_s := 0.85 \cdot T_n = 13608.21 \cdot kN \cdot m$, we can approximate that

starting real power for starting condition at 1 RPM is $P_s := \frac{T_s \cdot 1RPM}{9.55} = 1424.94 \cdot kW$, as a result starting

power factor $PF_s := \frac{P_s}{\sqrt{3} \cdot U_{n\_motor} \cdot I_{LRC}} = 0.0633$

For instant when motor is connected to the power supply and current starts flowing but motors is not rotating yet, the maximum RMS value of the current is called Lock- Rotor_Curent (LRC). If assuming that FLA current is a base current, then ratio of $I_{LRC} = 3250\,A$ to $I_{FLA} = 506\,A$ will represent inverse of the motor impedance at the starting time with $slip := 1$. This value is a total impedance of the motor as seen during tenderization from the motor terminals "inside" the motor.

$Z_{start\_pu} := \left(\frac{I_{LRC}}{I_{FLA}}\right)^{-1} = 0.1557 \cdot pu$ or at the "machine" bases

$Z_{start} := Z_{op} \cdot \left(\frac{I_{LRC}}{I_{FLA}}\right)^{-1} \cdot e^{-j \cdot acos(PF_s)} = (0.04 - 0.71j)\,\Omega$

Problem No. 4
Explain how often NEC code is updated/changed, who proposes/creates/requests changes and what is the process of submitting proposal for changes.

- NEC is updated / changed every 3 years. Latest edition is NEC-2008. Next revision is scheduled for 2011.
- Changes can be proposed by Public and/or any NEC users via "Form For Proposals For xxxx National Electrical Code." Form must be received before due date to be considered for review. The proposal needs to describe what article/paragraph you would like to change/revise/add/eliminate together with new version of the article/paragraph anc substantiation for the proposal.
- Twenty committees work and review proposed revisions. Each comity issues report on proposal (ROP) and "publish" i
- Comments from published cycle of ROP are considered for final revision of proposal in "published" in return on comments (ROC).
- NFPA members vote on ROC's inclusion/exclusion.
- NFPA committe votes on amendments and Standard Council issues new NEC.