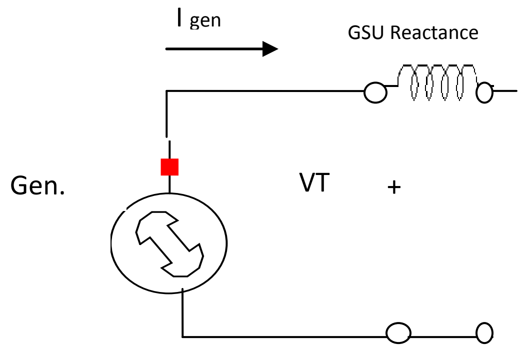
QUALIFIED VAR CALCULATION FOR SCHEDULE 2

Operations Support Services, ISO New England Inc.



1) Calculate the generator apparent power. The apparent power is calculated from the generator and the plant station service load real power and reactive power (gross values). Generally, the sign convention for the delivered VARs is positive and when VARs are being absorbed by the generator, the VARs are represented as negative.

   The calculation for lagging and leading apparent power is as follow:

   $S_{leading} = \sqrt{(Gen.\,gross\ Watts - Station\ Service\ Watts)^2 + (Gen.\,gross\ VARs - Station\ Serice\ VARs)}^{\,2}$

   $S_{lagging} = \sqrt{(Gen.\,gross\ Watts - Station\ Service\ Watts)^2 + (Gen.\,gross\ VARs - Station\ Service\ VARs)}^{\,2}$

   To demonstrate the formula above, consider the following example based on a leading test raw data set.

   Generator intended Gross MW Output =600 MW
   Generator intended Gross MVAR Output =-100 MVAR (Leading)
   Plant Station Service: 20 MW, 10 MVAR
   GSU impedance % = 1.92 @ GSU Tap 1.00 p.u
   V_T = 20.9 kV (Assume that S_{base} = 100 MVA); $1\text{x}10^6$ =Mega (M)

   $S_{gen\ leading}$ (Apparent Power)= $\sqrt{((600-20)E6)^2 + ((-100-10)E6)}^{\,2}$
   $S_{gen\ leading}$ (Apparent Power)= $\sqrt{((580)E6)^2 + ((-110)E6)}^{\,2}$
   $S_{gen\ leading}$(Apparent Power)= 590.339 MVA

2) Determine the power factor of the machine using Net Watt and VAR value

   P.f= P_{net} (Net real power)

$\sqrt{(Gen.\,gross\ Watts - Station\ Service\ Watts)^2 + (Gen.\,gross\ VARs - Station\ Serice\ VARs)}^{\,2}$

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$$= \frac{580\ \text{MW}}{590.339\ \text{MVA}} = .98248$$

p.f= .98248 rad in degrees $\Rightarrow$ $\cos^{-1}.98248 = 10.74\ \circ$

3) Determine the base current I_{base} (Please note that ($V_{base} = V_T$) and 1 kV= 1000 V)

$$I_{base} = \frac{S_{base}}{\sqrt[2]{3} * V_{base}}$$

$$I_{base} = \frac{100\text{MVA}}{\sqrt[2]{3} * 20.9\ \text{kV}} = 2.762\ \text{KA}$$

4) Determine the generator current (I_{gen}) and convert to p.u.

$$I_{gen*} = \frac{S_{gen}\ \text{(Apparent Power)}}{\sqrt[2]{3} * 20.9\ \text{kV}}$$

$$I_{gen*} = \frac{590.339\text{MVA}}{\sqrt[2]{3} * 20.9\ \text{kV}}\ \cos^{-1}.98248 = 10.74\ \circ = 16.307\ \text{KA}^{\ 10.74\ \text{degrees}}$$

*conjugate

$$I_{gen} = 16.307\ \text{KA}^{\ -10.74\ \text{degrees}}$$

$$I_{gen\ p.u} = \frac{I_{gen}}{I_{base}}$$

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$$I_{gen\ p.u} = \frac{16.307\ KA}{2.762\ KA} = 5.9034\ p.u$$

5) Determine the Q_{losses} in P.U where GSU X% = Generator Impedance data %

   X.p.u = X%/100

   Xp.u = 1.92/100 = .0192

   $Q_{losses\ p.u} = I_{gen}$ in p.u ^{2} * X.p.u

   $Q_{losses\ p.u} = (5.9034)^2 * (.0192) = .6691$ p.u

6) Calculate Actual GSU losses

   $Q_{actual} = Q_{losses\ p.u} * S_{base}$

   $Q_{actual} = .6691 * 100E6 = 66.912$ MVARs

7) Calculate the Leading Qualified VARs as follow:
   Leading Qualified VARs = Leading demonstrated MVAR value+ Station Service Load + GSU Losses

   Leading Qualified VARs= 100+10 + 66.912= 176.912.5 MVAR

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Consider The Following Example for Lagging VAR TEST

V_T = 13.8 kV Average S_{base} = 100 MVA
Gross MW = 90 Gross MVAR= 25 and GSU X% = 10.09
Plant Station Service Load : 8 MW, 3 MVAR

1) Calculate the generator apparent power. The apparent power is calculated from intended the Gen Gross MW and MVAR values.

$$S_{lagging} = \sqrt{(Gen.\,gross\ Watts - Station\ Service\ Watts)^2 + (Gen.\,gross\ VARs - Station\ Service\ VARs)^2}$$

$$S_{gen\ lagging}\ \text{(Apparent Power)} = \sqrt{((90-8)E6)^2 + ((25-3)E6)^2}$$

$S_{gen\ lagging}$ (Apparent Power)= 84.899 MVA

2) Determine the power factor of the machine at the Gross MW and MVAR value

$$P.f = \frac{P_{net}\ \text{(Net real power)}}{\sqrt{(Gen.\,gross\ Watts - Station\ Service\ Watts)^2 + (Gen.\,gross\ VARs - Station\ Serice\ VARs)^2}}$$

$$= \frac{82\ \text{MW}}{84.99\ \text{MVA}} = .96548$$

p.f= .96548 in degrees $\cos^{-1}.96548 = 15.02\ \circ$

3) Determine the base current I_{base} (Please note that ($V_{base} = V_T$) and 1 kV= 1000 V)

$$I_{base} = \frac{S_{base}}{\sqrt[2]{3} * V_{base}}$$

$$I_{base} = \frac{100\text{MVA}}{\sqrt[2]{3} * 13.8\ \text{kV}} = 4.183\ \text{KA}$$

4) Determine the generator current (I_{gen}) and convert to p.u.

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$$I_{gen^*} = \frac{S_{gen}\text{ (Apparent Power)}}{\sqrt[2]{3} * 13.8\text{ kV}}$$

$$I_{gen^*} = \frac{84.899\text{ MVA}}{\sqrt[2]{3} * 13.8\text{ kV}} \quad \cos^{-1}.96548 = 15.02\circ \quad = 3.551\text{ KA}^{\ 15.02\text{ degrees}}$$

$$I_{gen} = 3.551\text{ KA}^{\ -15.02\text{ degrees}}$$

$$I_{gen\ p.u} = \frac{I_{gen}}{I_{base}}$$

$$I_{gen\ p.u} = \ = \frac{3.551\text{ KA}}{4.183\text{ KA}} = .8490\text{ p.u}$$

5) Determine the Q_{losses} in P.U where GSU X% = Generator Impedance data %

X.p.u = X%/100

Xp.u = 10.09/100 = .1009

$Q_{losses\ p.u} = I_{gen}\text{ in p.u}^{2} * X.p.u$

$Q_{losses\ p.u} = (.8490)^{2} * (.1009) = .0727$ p.u

6) Calculate Actual GSU losses

$Q_{actual} = Q_{losses\ p.u} * S_{base}$

$Q_{actual} = .0727 * 100E6 = 7.272$ MVARs

7) Using the formula for lagging

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Lagging Qualified VARs= Lagging demonstrated MVAR value- Station Service Load - GSU Losses

Lagging Qualified VARs= 25- 3 – 7.272= 14.727 MVARs

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