Steady state calculations for a two area system with a TCSC

TCSC Data:

$f := 60$ $\qquad w := 2 \cdot \pi \cdot f$ $\qquad$ Systen frequence

$L := 0.01$ $\qquad C := 50 \cdot 10^{-6}$ $\qquad$ TCSC values

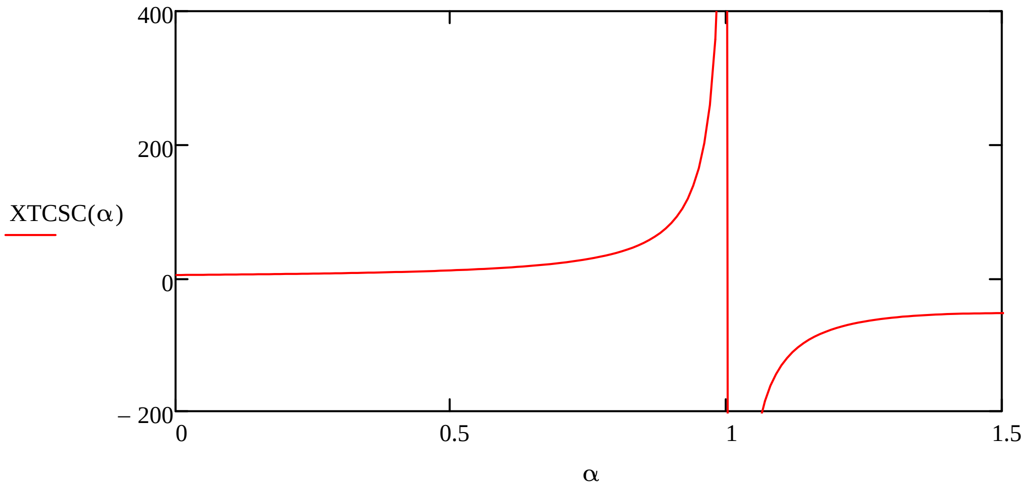
$XL1 := L \cdot w$ $\qquad XC := \frac{1}{C \cdot w}$ $\qquad XC = 53.052$

$\alpha := 0, 0.01 .. \frac{\pi}{2}$ $\qquad$ Firing angle (measured from a voltage paek (current zero in line)

$XL(\alpha) := XL1 \cdot \frac{\pi}{\pi - 2 \cdot \alpha - \sin(2 \cdot \alpha)}$ $\qquad$ Effective inductive reactance

$XTCSC(\alpha) := \frac{-XC \cdot XL(\alpha)}{XL(\alpha) - XC}$ $\qquad$ Effective reactance of the TCSC for a given firing angle

$XL(0) = 3.77$ $\qquad XL(0) = 3.77$ $\qquad XTCSC(0) = 4.058$



TWO AREA SYSTEM

Base MVA = 100 $MVA := 100$

System rated frequency = 60 Hz $f := 60$

High side rated voltage = 230 kV $kvh := 230$

Low side rated voltage = 33 kV $kvl := 33$

Transformer nominal ration = n $n := \frac{230}{33}$ $n = 6.97$

Define z $z := \left(\frac{kvl}{kvh}\right)^2$ $z = 0.021$

This factor is used to refer impedances from the HV to LV side.

Voltage phase angle of LV source equivalence = α

$\alpha 1 := 7 \cdot deg$

Transformer MVA = TMVA $TMVA := 100$

Transformer PU impedance = Xt $Xt := 0.1$

HV line PU impedance = Xl $Xl := 0.0528$

Impedance of HV source equivalence = Zsh Ohms $Zsh := 10$

Impedance of LV source equivalence = Zsl Ohms $Zsl := 1$

Total impedance between the sources (including equivalent source impedance but excluding the resistances) = Z230

$$Z230 := Zsh + Xl \cdot \frac{kvh^2}{MVA} + Xt \cdot \frac{kvh^2}{TMVA} + Zsl \cdot \frac{1}{z}$$

This is the equivalent value referred to the HV side.

$Z230 = 139.408$

Voltage behind the equivalent source impedance of the LV source = 35 kV

$k := \frac{35}{33}$ $k = 1.061$

The steady state power and reactive power flow:

$r := 1.5$

Define the firing angle in radians
(change this value to see the steady state quantities at different firing angles)

$d := r \cdot \frac{180}{\pi}$ $d = 85.944$ Convert to degrees

$degr := d$ $radi := degr \cdot \frac{\pi}{180}$ $radi = 1.5$

$degr = 85.944$ $radi = 1.5$ Angle in degrees and radians

$\beta(\alpha) := \frac{\alpha}{deg}$ Alpha in degrees

$Z230 = 139.408$ Reactance of the system without the TCSC

$XTCSC(radi) = -53.164$ Impedance of the TCSC

$XL(radi) = 2.506 \times 10^{4}$ Impedance of the switched reactor

$XTCSC(radi) := \frac{-XC \cdot XL(radi)}{XL(radi) - XC}$ **Reactance of the TCSC:**

$Zeq := Z230 + XTCSC(radi)$ Equivalent series reactance of the two area system

$Zeq = 86.244$

$\gamma(\alpha) := 90 + \beta(\alpha)$

Define an angle with voltage zero as the reference.
(PSCAD PLL measures the is defined this way)
γ corresponds to the angle defined in the PSCAD case

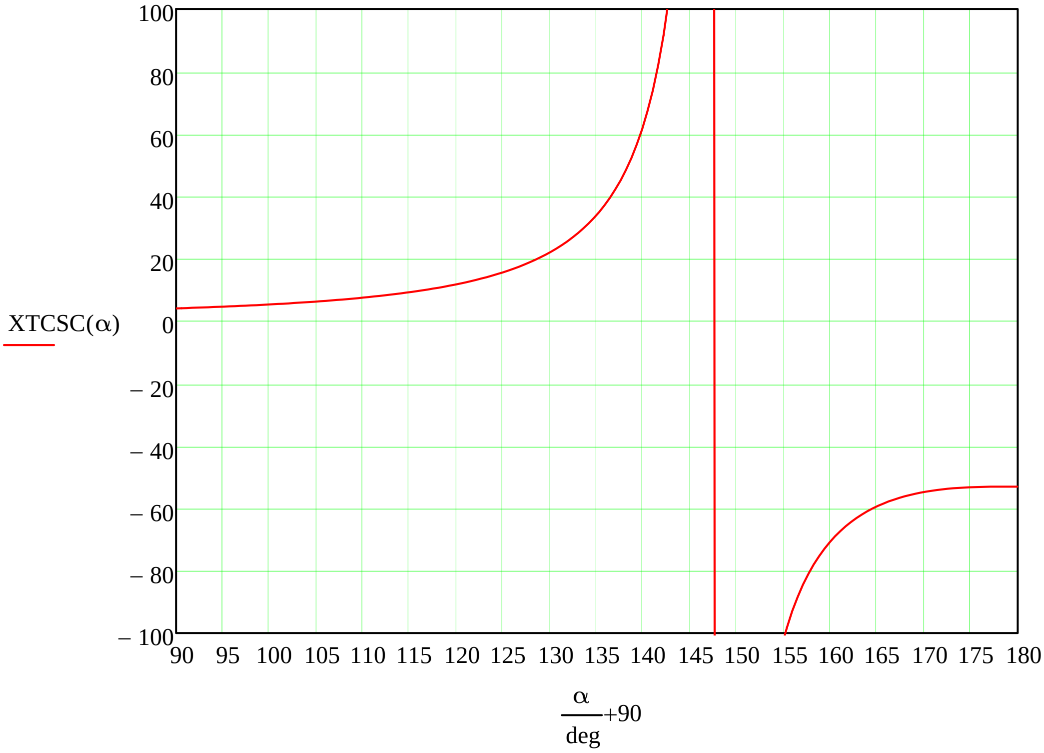
$\gamma(radi) = 175.944$

Steady state power flow:

$P := \frac{(kvh) \cdot (1.061 kvl \cdot n)}{Zeq} \cdot \sin(\alpha 1)$ $P = 79.312$

$Q := \frac{(1.061 \cdot kvl \cdot n)^{2}}{Zeq} - \frac{kvh \cdot 1.061 \cdot kvl \cdot n}{Zeq} \cdot \cos(\alpha 1)$ $Q = 44.549$

Approximate estimations as line capacitance is not included in evaluating Zeq. This has a
more significant effect on Q than P.



Line and transformer data:

Line Inductance = Lline

$$Zline := 0.0528 \cdot \frac{kvh^2}{MVA} \qquad Zline = 27.931 \qquad Lline := \frac{Zline}{2 \cdot \pi \cdot f} \qquad Lline = 0.074$$

Transformer (leakage) Inductance = Ltformer

$$Ztformer := 0.1 \cdot \frac{kvh^2}{MVA} \qquad Ztformer = 52.9 \qquad Ltformer := \frac{Ztformer}{2 \cdot \pi \cdot f} \qquad Ltformer = 0.14$$