Exercise Set 8 - Voltage Stability

on

Power System Analysis

Part II: Power System Dynamics and Stability

EEH - Power Systems Laboratory
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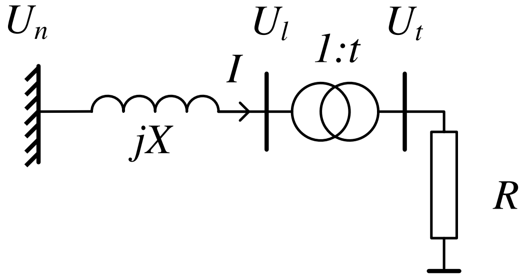
1. Consider the system in the figure below. The tap-ratio of the transformer, τ, can be varied by a tap-changer, so that the voltage U_t can be controlled. For simplicity it is assumed that τ can be changed continuously. (This is for many applications a good approximation.)



   (a) Derive an expression for $\frac{\partial U_t}{\partial \tau}$ as a function of U_l, τ, R and X. Hint: Make use of equation 13.3 in the lecture notes.

   (b) Derive a correlation in the form of a relationship between R, X and τ for voltage control regularity, i.e. $\frac{\partial U_t}{\partial \tau} > 0$.

2. Equation (13.3) in the compendium can be rewritten as

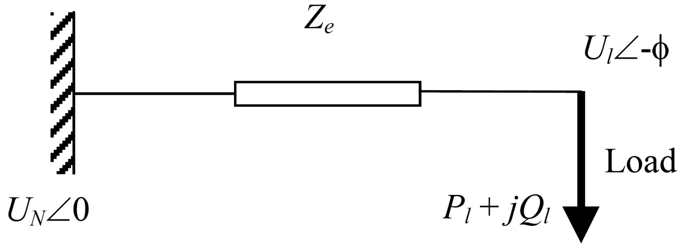
$$P_l^2 + Q_l^2 + 2\frac{U_l^2}{X_e}Q_l + \left(\frac{U_l^2}{X_e}\right)^2 = \frac{U_l^2}{X_e} \cdot \frac{U_N^2}{X_e}$$

   Solving the equation for $\frac{U_l^2}{X_e}$ gives:

$$\frac{U_l^2}{X_e} = \left(\frac{U_N^2}{2X_e} - Q_l\right) \pm \sqrt{\left(\frac{U_N^2}{2X_e} + Q_l\right)^2 - (P_l^2 + Q_l^2)} \ (*)$$

   + is for the "upper" solution of the nose curve (see below)
   - is for the "lower" solution

   Consider now the system in the figure below.



(a) Show that for solutions on the upper part of the nose curve that an injection of reactive power results in an increase of the load voltage if the load power and the voltage of the infinite bus are constant. Show also that for solutions on the lower part of the curve a reactive power injection results in a load voltage decrease, with the same assumptions.
Hint: Use again equation 13.3 and also equation (*).

(b) Show that for solutions on the upper part of the nose curve that an increase of the voltage U_N results in an increase of the load voltage, while for solutions on the lower part of the curve it results in a load voltage decrease. (Load power assumed constant as in (a)!)