IMPLEMENTATION OF ON-LOAD TAP CHANGER IN POWER SYSTEM

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Abstract:

This paper studies the effects of on-load tap changer in power systems. Implementation of tap changer in power systems is very essential to maintain voltage profile. In general, tap changer transformer is applied at load buses which are prone to voltage stability. To implement these transformers, the power flow Jacobian matrix elements should be changed suitably. This paper main consideration is the changing of Jacobian matrix elements in Newton Raphson power flow analysis.

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Introduction: On load tap changers are one of the fundamental devices in power systems [1]. Their main purpose is to maintain the voltage within permissible limits at the buses. These are usually connected at vulnerable buses. The tapings are provided at high voltage side and these are in general used for control of distribution system voltage [2-3]. The automatic tapings are controlled from power electronic control circuitry. The power electronics devices offer very smooth control. If the load at the distribution system bus increases then voltage will decrease [4-5]. This decrement in voltage can affect and cause serious consequences to the main transmission grid. Therefor the tap changer characteristic and system characteristic are to be chosen very meticulously such that there should be an intersection point exist [6-7]. The change in tap position in high voltage side reflects the secondary distribution system voltage and at the same time the power system characteristic should have an intersection point with load characteristic and also the load tap change characteristic [8]. If this condition exists then the high voltage side change in tap position causes improvement in distribution side voltage [9].

Power flow Solution for OLTC:

The load flow model for on-load tap changer is based on two winding transformer model with several taps at high voltage side. The sending and receiving end bus current expressions are given as [2]

$$\begin{bmatrix} I_k \\ I_m \end{bmatrix} = \frac{1}{T_k^2 Y_k + U_m^2 Y_m + Y_0} \begin{bmatrix} U_m^2 Y_k Y_m + Y_k Y_0 & -T_k U_m Y_k Y_m \\ -T_k U_m Y_k Y_m & T_k^2 Y_k Y_m + Y_m Y_0 \end{bmatrix} \begin{bmatrix} V_k \\ V_m \end{bmatrix} \quad \ldots..(1)$$

$$\begin{bmatrix} I_k \\ I_m \end{bmatrix} = \begin{bmatrix} Y_k & -T_k Y_k \\ -T_k Y_k & T_k^2 Y_k \end{bmatrix} \begin{bmatrix} V_k \\ V_m \end{bmatrix} = \begin{bmatrix} Y_{kk} & T_k Y_{km} \\ -T_k Y_{mk} & T_k^2 Y_{mm} \end{bmatrix} \begin{bmatrix} V_k \\ V_m \end{bmatrix} \quad \ldots\ldots(2)$$

Where, T_k is allowed to vary within (T_{kmin}<T_k<T_{kmax}):

$P_k = V_k^2 G_{kk} + T_k V_k V_m [G_{km} \cos(\theta_k - \theta_m) + B_{km} \sin(\theta_k - \theta_m)]$, ... (3)

$Q_k = -V_k^2 B_{kk} + T_k V_k V_m [G_{km} \sin(\theta_k - \theta_m) - B_{km} \cos(\theta_k - \theta_m)]$, ... (4)

$P_m = T_k^2 V_m^2 G_{mm} + T_k V_k V_m [G_{km} \cos(\theta_m - \theta_k) + B_{km} \sin(\theta_m - \theta_k)]$, ... (5)

$Q_m = -T_k^2 V_m^2 B_{mm} + T_k V_k V_m [G_{km} \sin(\theta_m - \theta_k) - B_{km} \cos(\theta_m - \theta_k)]$, ... (6)

Where,
$Y_{kk} = Y_{mm} = G_{kk} + JB_{kk} = Y_k,\}$ .... (7)

$$Y_{km} = Y_{mk} = G_{km} + JB_{km} = -Y_k.$$

$$\begin{bmatrix} \Delta P_k \\ \Delta P_m \\ \Delta Q_k \end{bmatrix} = \begin{bmatrix} \frac{\partial P_k}{\partial \theta_k} & \frac{\partial P_k}{\partial \theta_m} & \frac{\partial P_k}{\partial T_k} T_k \frac{\partial P_k}{\partial V_m} V_m \\ \frac{\partial P_m}{\partial \theta_k} & \frac{\partial P_m}{\partial \theta_m} & \frac{\partial P_m}{\partial T_k} T_k \frac{\partial P_m}{\partial V_m} V_m \\ \frac{\partial Q_k}{\partial \theta_k} & \frac{\partial Q_k}{\partial \theta_m} & \frac{\partial Q_k}{\partial T_k} T_k \frac{\partial Q_k}{\partial V_m} V_m \end{bmatrix} \begin{bmatrix} \Delta \theta_k \\ \Delta \theta_m \\ \frac{\Delta T_k}{T_k} \end{bmatrix}$$

$[\Delta Q_m] = \begin{bmatrix} \frac{\partial Q_m}{\partial \theta_k} & \frac{\partial Q_m \partial Q_m}{\partial \theta_m \, \partial T_k} T_k & \frac{\partial Q_m}{\partial V_m} V_m \end{bmatrix} \begin{bmatrix} \frac{\Delta V_m}{V_m} \end{bmatrix} \}$.......... (8)

$\frac{\partial P_k}{\partial \theta_k} = -\frac{\partial P_k}{\partial \theta_m} = -Q_k - V_k^2 B_{kk}$, ... (9)

$\frac{\partial P_k}{\partial T_k} T_k = \frac{\partial P_k}{\partial V_m} V_m = P_k - V_k^2 G_{kk}$, ... (10)

$\frac{\partial Q_k}{\partial \theta_k} = -\frac{\partial Q_k}{\partial \theta_m} = P_k - V_k^2 G_{kk}$, ... (11)

$\frac{\partial Q_k}{\partial T_k} T_k = \frac{\partial Q_k}{\partial V_m} V_m = Q_k + V_k^2 B_{kk}$, ... (12)

$\frac{\partial P_m}{\partial \theta_m} = -\frac{\partial P_m}{\partial \theta_k} = -Q_m - T_k^2 V_m^2 B_{mm}$, ... (13)

$\frac{\partial P_m}{\partial V_m} V_m = \frac{\partial P_m}{\partial T_k} T_k = P_m + T_k^2 V_m^2 G_{mm}$, ... (14)

$\frac{\partial Q_m}{\partial \theta_m} = -\frac{\partial Q_m}{\partial \theta_k} = P_m - T_k^2 V_m^2 G_{mm}$, ... (15)

$\frac{\partial Q_m}{\partial V_m} V_m = \frac{\partial Q_m}{\partial T_k} T_k = Q_m - T_k^2 V_m^2 B_{mm}$. .... (16)

At the end of each iteration, i, the tap controller is updated using the following relation:

$$T_k^{(i)} = T_k^{(i-1)} + \left(\frac{\Delta T_k}{T_k}\right)^{(i)} T_k^{(i-1)} \qquad \ldots\ldots\ldots\ldots (17)$$

Results and discussions:

Simulation results are done in IEEE 14 bus test system and found that the OLTC is very effective in maintaining the voltage profile at weak buses.

CONCLUSION:

This paper shows the implementation of on load tap changer in power systems.

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