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AN OPTIMIZATION MODEL FOR REACTIVE POWER CONTROL OF SUPER HIGH VOLTAGE GRID SYSTEMS

This paper develops an optimization model to control the excessive (MVAR) generation by super high voltage gird systems for maintaining the nodal voltages within the required acceptable margin. The model enhances an approximate solution on the condition of balanced real power. The pseudo-inverse method of optimization is implemented as an optimal optimization is implemented as an optimal means of solving non-square systems of equations based on LaGrange's theory of optimization. It recommends the locations and ratings of the minimum required reactors from the preinstalled ones that to be in service for optimum nodal reactive power and voltage controls.

1. INTRODUCTION

Present power flow optimization methods can be classified into two categories, one is providing exact solutions, and the other, approximate solutions. Exact methods take into account both real and reactive flows in obtaining the solution. While approximate methods achieve simplified representations and possibly computational efficiencies by ignoring either the real or reactive equations. Approximate models are normally tailored for particular applications and do not have the generality inherent in the exact models.The reduced gradient method of Dommal and tinny, the Fletcher Powell method as developed by Sassoon for power flow applications, and carpenter's method based on satisfying the Kuhn-tucker conditions, are all extremely accurate and widely applicable. While some have been developed to become computationally very sufficient number of approximate models dealing exclusively with either the real or reactive power equations, have also been develop. Hanna, et A1 and kumis, et A1, used primarily the reactive equation to develop a method for real time control of voltage and reactive powers. The need to adjust voltage magnitudes and reactive powers at times so that the overall solution is operationally implement able, led to the considerations of reactive equations.

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2. MATHEMATICAL FORMULATION

Figure 1 is simulating a super high voltage grid system by representing the nodes into four categories from the point of view of their voltages [either they are within (m) or out (o) of the acceptable margin] and (VAR) absorption installations [either there are (r) or none (w)]. Considering the system in steady-state condition and the real power mismatch ΔP is zero, then the following linearzed equations describe the effect of (Q) on (V) for the four categories of the system:-

$$\frac{dQ_{mw}}{dV_{mw}}\Delta V_{mw}+\frac{dQ_{mr}}{dV_{mr}}\Delta V_{mr}+\frac{dQ_{mw}}{dV_{mw}}\Delta V_{ow}+\frac{dQ_{mw}}{dV_{or}}\Delta V_{or} \qquad (1.a)$$

$$\frac{dQ_{mr}}{dV_{mw}}\Delta V_{mw}+\frac{dQ_{mr}}{dV_{mr}}\Delta V_{mr}+\frac{dQ_{mr}}{dV_{ow}}\Delta V_{ow}+\frac{dQ_{mr}}{dV_{or}}\Delta V_{or}=\Delta Q_{mr} \qquad (1.b)$$

$$\frac{dQ_{ow}}{dV_{mw}}\Delta V_{mw}+\frac{dQ_{ow}}{dV_{mr}}\Delta V_{mr}+\frac{dQ_{ow}}{dV_{ow}}\Delta V_{ow}+\frac{dQ_{ow}}{dV_{or}}\Delta V_{ow}=0 \qquad (1.c)$$

$$\frac{dQ_{or}}{dV_{mw}}\Delta V_{mw}+\frac{dQ_{or}}{dV_{mr}}\Delta V_{mr}+\frac{dQ_{or}}{dV_{ow}}\Delta V_{ow}+\frac{dQ_{or}}{dV_{or}}\Delta V_{or}=\Delta V_{or} \qquad (1.d)$$

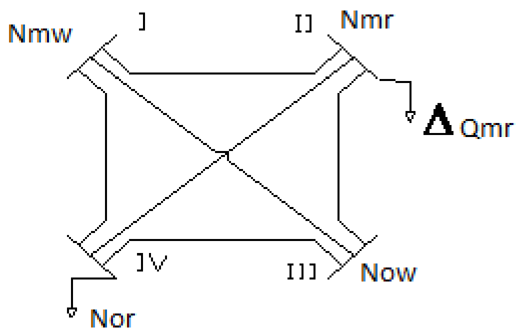

Fig.1. Schematic single line diagram of the optimization model

The system can be rewritten as below:-

$$\left[\begin{array}{cc|cc} dQ_{mw}/dV_{mw} & dQ_{mw}/dV_{mr} & 0 & 0 \\ dQ_{mr}/dV_{mw} & dQ_{mr}/dV_{mr} & -E & 0 \\ \hline dQ_{ow}/dV_{mw} & dQ_{ow}/dV_{mr} & 0 & 0 \\ dQ_{or}/dV_{mw} & dQ_{or}/dV_{mr} & 0 & -F \end{array}\right] \begin{bmatrix} \Delta V_{mw} \\ \Delta V_{mr} \\ \Delta Q_{mr} \\ \Delta Q_{or} \end{bmatrix} = \begin{bmatrix} b1 \\ b2 \\ b3 \\ b4 \end{bmatrix} \qquad (2)$$

where E and F are unit diagonal matrices reducing system using Newton-gauss technique, it will be:-

$$\begin{bmatrix} A...........0 \\ B........-F \end{bmatrix} \begin{bmatrix} \Delta Q_{mr} \\ \Delta Q_{or} \end{bmatrix} = \begin{bmatrix} C1 \\ C2 \end{bmatrix} \qquad (3)$$

$$\text{Or } \Delta Q_R = C \qquad (4)$$

where D= $\begin{bmatrix} A...........0 \\ B........-F \end{bmatrix}$, $\Delta Q_R = \begin{bmatrix} \Delta Q_{mr} \\ \Delta Q_{or} \end{bmatrix}$ and $C = \begin{bmatrix} C1 \\ C2 \end{bmatrix}$

The ranks of the main and sub matrices are:

MAIN MATRIX	
D	$N_o \times N_r$
ΔQ_R	$N_r \times 1$
C	$N_o \times 1$

where $N_r = N_{mr} + N_{or}$, $N_o = N_{or} + N_{ow}$

The objective function of this model is:

$$[\Delta Q_R]^T - [\Delta Q_R] = \min imum \qquad (5)$$

To approach ΔQ_R optimum, the following algorithms will be followed during the iterative computational process.

Algorithm I: - if $N_o = N_r$, than

$$\Delta Q_R = D^{-1} C \qquad (6)$$

SUB MATRICES			
A	$N_{ow} \times N_{mr}$	F	$N_{or} \times N_{or}$
B	$N_{or} \times N_{mr}$	$N_{or} \times C1$	$N_{ow} \times 1$
E	$N_{mr} \times N_{mr}$	$C2$	$N_{or} \times 1$
ΔQ_{or}	$N_{or} \times 1$	ΔQ_{mr}	$N_{mr} \times 1$

Algorithm II: - if $N_o \langle N_r$, than

$$\Delta Q_R = D_1^+ C \qquad (7)$$

where

$$D_1^+ = D^T (DD^T)^{-1} \qquad (8)$$

Algorithm III: - if $N_o \rangle N_r$,than

$$\Delta Q_R = D_2^+ C \tag{9}$$

where

$$D_2^+ = (D^T D)^{-1} D^T \tag{10}$$

D_1^+ And D_2^+ are the Pseudo-inverses of the derivations.

3. MODEL'S PERFORMANCE

This optimization model had tested successfully on the super high voltage grid system shown in Fig. (2) at minimum load condition. The recognize the significance of the optimization model, three modes for (MVAR) controls were implemented on the system at the same load condition as follows:-

1. Mode I :- in this mode, No (MVAR) absorption assistance was made to the system ($\Delta Q_R = 0$).
2. Mode II :- All (MVAR) absorption resource were linked to the system ($\Delta Q_R = Maximum$).
3. Mode III: - in this, the optimization model was tested on the system to achieve he optimum performance of the (MVAR) absorption resources by recommending the locations and ratings of the minimum required reactors from the preinstalled ones.

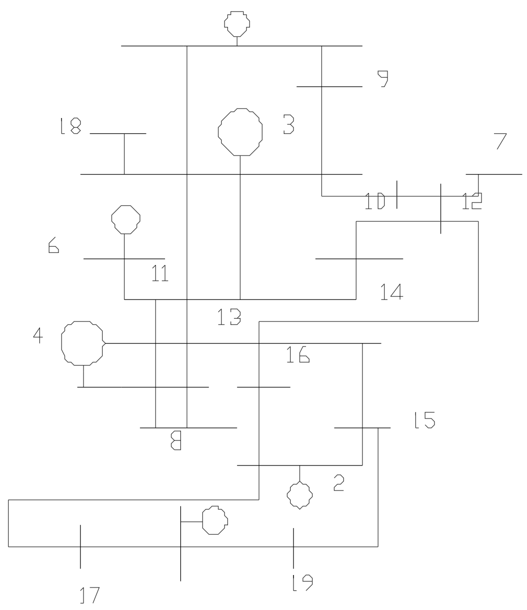

Fig. 2. Super hight voltage grid system

4. CONCLUSION

The proposed optimization model for the reactive and nodal voltage controls is based on linearzed load flow reactive power equations and Lagrange's theory of optimization. The Pseudo-inverse method of solving rectangular matrices is implemented via the algorithms of computing [ΔQ_R] when this matrix is not square. The model proved to be reliable in convergence, the solution is obtained in few iterations and it needs less memory requirements due to that he Jacobin matrix is formulated with 1/2 of the linearzed load flow equations (Reactive power equations only) in the first iteration of the solution and it is reduced when ignoring he healthy nodes iteratively. Three modes of (MVAR) control are implemented on the super high voltage grid system at its worst operating condition, to recognize the significance and the efficiency of the proposed optimization model concerning the nodal voltage and (MVAR) controls. It has given better nodal voltage regulation at 25% of saving of total reactors rating and has improved the performance of the generating stations from the point of view of reactive power generation/absorption, and then it improves the stability of the system.

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