분할기법을 이용한 최적 무효전력 운용 및 계획에 관한 연구

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A STUDY ON OPTIMAL REACTIVE POWER OPERATION AND PLANNING USING DECOMPOSITON ALGORITHM

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1. INTRODUCTION

As the structure of power system owing to the interconnection of power plants become larger, the tasks of controlling bus voltage and maintaining the stability of large scale system are needed.

Reactive power planning is to determine that the size and the site of anew invested reactive power facilities to achieve these purposes, also to obtain the optimal economic operation condition of system.

Thus reactive planning problem is composed of operation aspect and investment aspect.

In the former problem, the fuel costs are minimized and in the latter, the optimal sites and sizes of additional facilities are determined, while maintaining an acceptable system performance in terms of limits on generator real and reactive power output, outputs of shunt capacitor and reactor, transformer tap settings, bus voltage levels.

Therefore the fact that two different objectives have to be integrated and satisfied, makes reactive power planning problem complicated.

To handle the large scale problems of this nature, powerful mathematical methodology, New Decomposition Algorithm is applied.

Planning problem is divided into P-optimization problem and Q-optimization problem.

Even in the large scale system, the P-optimization problem is not difficult to solve.

But, Q-optimization problem has different aspect.

In this paper Q-optimization problem is also decomposed into master problem which determines the amounts of investment in reactive power compensation devices and sub-problems which determines the optimal economic operation condition of power system using anew developed Decomposition Algorithm.

2. MATHEMATICAL MODEL

2.1 Cost Function

The cost function is the sum of investment cost of additional reactive power facilities and each generator fuel cost which can be expressed as the quadratic function of generating power P_j for all generator j.

The cost function is presented as follows;

$$F(P\ ,U\ )=\sum_{k=1}^{\ell}\sum_{j=1}^{G}(A_j + B_j^k P_j + C_j^k P_j\ )+\sum_{i=1}^{N} C_i U_i$$

where, N : total number of buses

G : number of generation buses

C : unit cost of reactive power compensation devices (shunt capacitor and reactor)[/Mvar]

U_i : amounts of newly invested shunt capacitor or reactor on bus i

A_j, B_j, C_j : fuel cost coefficients of generator j

k : load levels, k=1,.....,l

2.2 Formulation of the problem

The reactive power planning problem can be formulated as follows:

Minimize $F(P_j, U_i)$

subjected to

$$P_{mn} \le P_{sg} \le P_{MX}$$
$$-U_L + Q_{mn} \le Q \le Q_{MX} + U_c$$
$$T_{mn} \le T \le T_{MX}$$
$$V_{mn} \le V \le V_{MX}$$
$$g(P_j, Q, T) = 0$$
$$0 \le U_c \le U_{cMX}$$
$$0 \le U_L \le U_{LMX}$$

where, P_{sg} : vector of real power of all generators including slack generator

Q : vector of reactive power of all buses

T : vector of off-nominal tap setting of LTC

V : vector of bus voltage magnitude

U_c, U_L : amounts of newly invested shunt capacitor and reactor, respectively

$g(\cdot)$: real and reactive power supply and demand balance equation

$(\cdot)_{MX}, (\cdot)_{mn}$: upper and lower limits, respectively

3. DECOMPOSITION METHODOLOGY

3.1 New Decomposition Algorithm

In the solving the programming problem of the following form:

Minimize $C_1^T X + C_2^T U$

subject to;

$$A X + B U \le b$$

where, A : [M by N] matrix

X : N vector

U : NN vector

B : [M by NN] matrix

b : M vector

C_1, C_2 : M vector and NN vector, respectively

Suppose that the feasiable initial point of variable of U, U_o , the original problem is converted as the following Sub-problem.

Minimize $C_1^T X$

subjected to: $A X \le b - B U_o$

Solving above problem of only X, the informations of active set of N in number,the value of dual lagrange multiplier: λ_x , optimal solution of X, are obtained.

Using the coefficients of variable X in active set, the sensitivity relation between ΔX and ΔU is acquired.

$$\Delta X = - A_a^{-T} B_a \Delta U$$

where, $(\cdot)a$: active set

$\Delta(\cdot)$: incrementals of $(\cdot)$

With this relation, the original problem is transformed following Master problem.

In this Master problem, the constraints are achieved in the non-active set.

Minimize $[- C_1^T A_a^{-1} B_a + C_2^T] \Delta U$

subjected to;

$$[- A_n A_a^{-1} B_a + B_n] \Delta U \le b_n - A_n X_p - B_n U_p$$

where, $(\cdot)_n$: non- active set

$(\cdot)_p$: previous value

Solving this Master problem, the information of active set of NN in number, the value of dual lagrange multiplier; λ_u, optimal value of ΔU, are obtained.

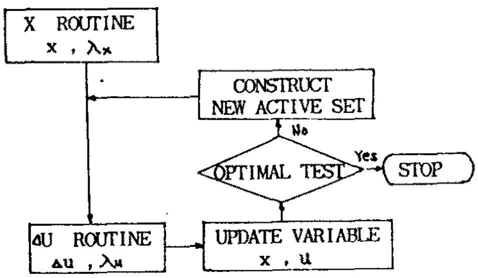
Taking λ_x, λ_u, into consideration, the lagrange multiplier equivalent to original problem are inducted as follows.

$$\lambda = \begin{bmatrix} \lambda_x - A_a^{-T} A_n^T \lambda_u \\ \lambda_u \end{bmatrix}$$

The values of variables are updated in terms of ΔX, ΔU, stopping criteria of this algorithm is non-negativity of lagrange multiplier of Λ.

In case of violation of criteria, the constraint relevant to negative multiplier leaves active set, the procedure is iterated.

3.2 FLOW CHART OF NEW ALGORITHM



3.3 Decomposition of planning problem

3.3.1 P-optimization

The quadratic fuel cost function is linearized.

$$\text{Minimize} \quad \beta_p^T \, \Delta^k P_{sg}$$

$$\text{subject to} \quad \Delta^k P_{sg\,mn} \le \Delta^k P_{sg} \le \Delta^k P_{sg\,MX}$$

$$g(\Delta^k P_{sg}) = 0$$

where, $\beta_p^T \triangleq [\, B_1 + 2C_1 P_1, \ldots, B_m + 2C_m P_m \,]$

m : total number of generator including slack generator

$\Delta(\cdot)$: incrementals of $(\cdot)$

3.3.2 Q-optimization

The Q-optimization problem is decomposed into the following two forms.

i) Sub-problems

$$\text{Minimize} \quad \beta_q^{T\,k} X$$

subjected to;

$$\begin{vmatrix} I & 0 \\ 0 & I \\ -I & 0 \\ 0 & -I \\ \multicolumn{2}{c}{J_D} \\ \multicolumn{2}{c}{-J_D} \end{vmatrix} \begin{vmatrix} {}^k X \end{vmatrix} \le \begin{vmatrix} \Delta^k Q_{MX} \\ \Delta^k T_{MX} \\ -\Delta^k Q_{mn} \\ -\Delta^k T_{mn} \\ \Delta^k V_{MX} \\ \Delta^k V_{mn} \end{vmatrix} - \begin{vmatrix} -I & 0 \\ 0 & 0 \\ 0 & -I \\ 0 & 0 \\ \multicolumn{2}{c}{0} \\ \multicolumn{2}{c}{0} \end{vmatrix} \begin{vmatrix} Y_0 \end{vmatrix}$$

where, $X : \begin{vmatrix} \Delta Q \\ \Delta T \end{vmatrix}$

Y : initial feasible value of $\begin{vmatrix} \Delta U_c \\ \Delta U_L \end{vmatrix}$

This sub-problem routine is computed l-times according to different load levels.

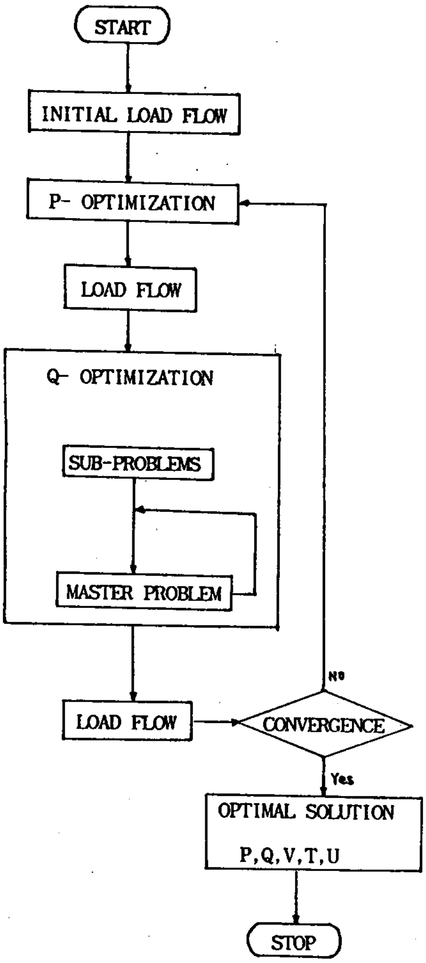
ii) Master problem

$$\text{Minimize} \quad C^T \Delta Y$$

subject to: $\Delta Y \in S$

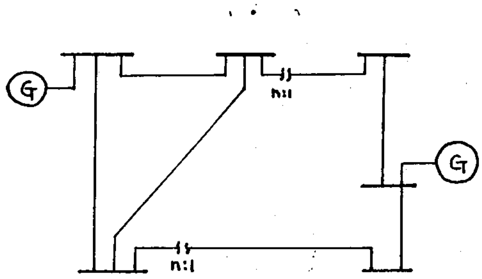
where, S : arbitrary subset composed of non-active set of original constraints

4. COMPUTER FLOW DIAGRAM



5.MODEL SYSTEM STUDY

To illustrate the feasibility of above new algorithm a small system with 2-generators, 6-buses,7-lines, has been considered.



6.CONCLUSION

- A method of finding the optimal site and size of newly invested shunt capacitor and reactor is presented in this paper.
- The optimal economic operation condition of power system which minimize fuel cost is conclued.
- Using decomposition algorithm, the efficient analysis of large scale system is within the limits of the possibility.

7. REFERENCE

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