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Formation of Exact Co-Ordination Equations With Proper Selection Of Design Variables For Active And Reactive Power Scheduling

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Abstract:

There are various methods for optimizing active and reactive powers scheduling for a Power System. The problem involves optimization of multi objective functions with many constraints based on reality. Deciding proper design variables is impartment for any mathematical techniques to reach the best solutions. The solutions arrived by all the recent soft computing techniques for the problems were mostly validated by comparison with the results of conventional optimization techniques. The derivation of the basic mathematical model (Co-ordination equations) for the optimization problem is revised with proper design variables and presented in this work for obtaining best results. In this method, the power contribution to every load of the power system by each generator in the system is considered as independent variable (design variable). The refined model results best solution when comparing with conventional model in which the total power supplied by a generator to the grid is considered as independent variable. An example is given. This fundamental concept indicates the same design variables must be used in all the existing power system optimization techniques for the best solution.

Key words: Active power, Reactive power, Coordination equations, Independent variables, Courant Lagrange multiplier Lagrange
function, design variables, Objective function, load demand, Conventional method, Generator contribution, sub optimum

I .INTRODUCTION

Any physical problem should be represented by an exact mathematical model for analysis. For forming such mathematical model one should properly decide the independent variables (design variables) based on the physical phenomenon. The same concept is also stated by Courant in his Lagrange multiplier method (Base method for all classical formulations) for optimization process [7]. He stated that for establishing the necessary conditions for obtaining the minimum value of the objective function, the first derivative of the Lagrange function with respect to each of the independent variables has to be set equal to zero. The Generator (source) power is divided in to two parts one for sharing the system load another is for system loss .Since sharing of network loss depends on sharing of load by the source, sharing of system load by each source is considered as design (independent) variable. Firefly Algorithm is applied for optimization.[1]. The work considered the effects on the loss and voltage profile of the system resulted from the optimization, where the Fast Voltage Stability Index (FVSI) value at the observed line, minimum voltage of the system and loss were monitored during the load increment. The total active and reactive powers are considered as design variables will not result best results. Coordinated active-reactive power optimization model has been developed for distribution system [2]. The development of the model also with entire active & reactive powers as design variables will not provide best results. A bi–objective DC–optimal power flow model using linear relaxation–based second order cone programming by selecting entire active & reactive power gives sub optimal solutions only [4]. A novel algorithm for optimal operation has been developed under consideration of the constraints in transmission networks of optimal solution [3] Solutions are sub optimal because of considering entire active & reactive powers as design variables. The work in [5] is the coordinated optimal dispatch in grid-connected micro-grids and in the [6], optimal placement of SVC is by Fuzzy and Firefly Algorithm. In both the techniques are based on entire active and reactive powers end with sub optimal solutions. This paper presents the concept of selecting the basic design variables in deriving exact coordination equations. The equations applied to a 220KV system for obtaining the best optimal solution in comparison with basic conventional method which indicates the need for selection of the same design variables in all other optimization methods related to power systems.

II Derivation

The proper independent variables for the objective function should be chosen based on the physical properties so as to establish the necessary condition for arriving the exact optimum.

The cost equation for i^{th} plant generator is given in the equation as

$$F_i = A_i \, PG_i^2 + B_i \, PG_i + C_i \qquad \text{------------------ (1)}$$

The total output active power of the generator PGi is injected into the system network. Local load is not considered. The generator power can be spitted as

$$PG_i = P_{ri} + P_{li} \qquad \text{--------------------------------- (2)}$$

Where

P_{li} = Contribution of i_{th} generator to the network active power loss

P_{ri} = Contribution of i^{th} generator to the System load demand

Substituting (2) in to (1) results

$$F_i = A_i(P_{ri} + P_{li})^2 + B_i(P_{ri} + P_{li}) + C_i \qquad \text{-------- (3)}$$

Current injected by a generator into the system network causes network (transmission) loss while contributing power to the total system load demand.Therefore the transmission loss contribution of a generator depends on the contribution of all the generators to the total system load demand

$$P_{li} = f(P_{r1}, P_{r2}, \ldots P_{rn}) \quad \text{---------------} (4)$$

It is desired to minimize the total cost

$$F_T = \sum_1^n F_i \quad \text{-----------------------------------} (5)$$

for a given total system active power demand of PD and to satisfy the power balance equation

$$\sum_1^n P_{ri} = PD \quad \text{-----------------------------------} (6)$$

By the application of the method of Lagrange multipliers, the minimum cost for a given active power demand is
obtained when

$$\frac{\partial \Phi}{\partial P_{ri}} = 0 \quad i=1 \text{ to } n \quad \text{---------------} (7)$$

Where Φ is the Lagrange function expressed as

$$\emptyset = F_T - LA_1 \left(\sum_1^n P_{ri} - PD\right) \quad \text{--------} (8)$$

From (7) and (8)

$$\frac{\partial F_T}{\partial P_{ri}} = LA_1 \quad i=1 \text{ to } n \quad \text{--------------} (9)$$

From (3), (5) and (9)

$$\frac{\partial F_T}{\partial P_{ri}} = [2A_i(P_{ri}+P_{li}) + B_i)] \left[1+ \frac{\partial P_{li}}{\partial P_{ri}}\right] + \sum_{\substack{j=1 \text{ to } n \\ \neq i}}^{n} [2A_j (P_{rj}+P_{lj})] \frac{\partial P_{lj}}{\partial P_{ri}} = LA_1 \quad \text{---} (10)$$

Equation (10) is the exact Co-ordination Equations

Reactive Power optimization:

Usually the reactive power optimization is performed for minimizing the total active power transmission loss. Therefore in the classical approach, the Lagrange function is the total active power transmission loss expressed in terms of reactive power injected by the generator into the system network. The Lagrange function

$$\emptyset = P_L - LA_2 \left[\left(\sum_1^n QG_i - QD - Q_L\right)\right] \quad \text{--------} (11)$$

Partially differentiating (11) w.r.t. QG_i and equating to zero results

$$\frac{\partial P_L}{\partial QG_i} = LA_2 \left(1 - \frac{\partial Q_L}{\partial QG_i}\right) \quad i=1 \text{ to } n$$

$$\frac{\dfrac{\partial P_L}{\partial QG_i}}{\left(1 - \dfrac{\partial Q_L}{\partial QG_i}\right)} = LA_2 \quad i=1 \text{ to } n \quad \text{- ----------} (12)$$

If the above condition is implemented, the exact minimization of active power loss is not at all possible since QG_i is not an Independent variable (Design variable).. Hence as stated in the exact approach, the reactive power contribution to the total system reactive power demand by generators are considered as independent variables.

Then Lagrange function

$$\emptyset = P_L - LA_2\,[(\sum_1^n Q_{ri} - QD)] \qquad \text{-------------- (13)}$$

Where Q_{ri} is the i^{th} generator contribution to system reactive power demand.

The condition for minimum active power loss.

$$\frac{\partial \Phi}{\partial Q_{ri}} = 0 \qquad i=1 \text{ to } n$$

$$\frac{\partial P_L}{\partial Q_{ri}} = LA_2 \qquad i=1 \text{ to } n \qquad \text{--------------- (14)}$$

Minimization of active power loss with respect to the reactive power contribution to system reactive power demand by all the generators (14) is the same as minimizing the total reactive power loss or the total reactive power generation with respect to the independent parameters (reactive power contribution of generators to the system reactive power demand) Consider the objective function is to minimize the total reactive power generation

$$Q_{TG} = \sum_i^n Q_{ri} + \sum_i^n Q_{li} \qquad \text{----------------- (15)}$$

Where Qri is the load component of i^{th}generator

Q_{li} is the loss component of i^{th}generator

Subject to the reality constraint $\sum_i^n Q_{ri} - QD = 0$ -------------------------- (16)

Lagrange function $\emptyset = Q_{TG} - LA_3\,(\sum_1^n Q_{ri} - QD\,)$ -------------------- (17)

For minimum Q_{TG}

$$\frac{\partial \Phi}{\partial Q_{ri}} = 0$$

$$\frac{\partial Q_{TG}}{\partial Q_{ri}} = LA_3 \qquad i=1 \text{ to } n \qquad \text{-------------- (18)}$$

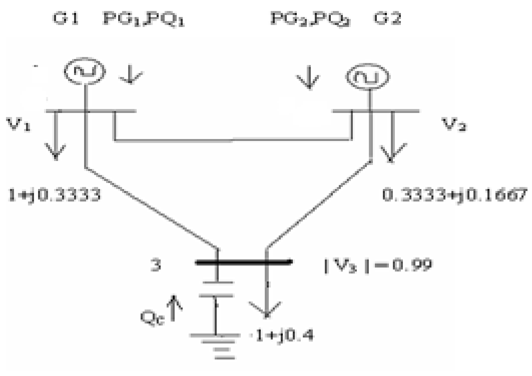
From equation (15) and (18)

$$\frac{\partial \emptyset}{\partial Q_{ri}}\left(\sum_1^n Q_{ri} + \sum_i^n Q_{li}\right) = LA_3 \qquad \text{----------- (19)}$$

$$1 + \frac{\partial Q_{li}}{\partial Q_{ri}} + \sum_{\substack{j=1 \\ \neq i}}^{n} \frac{\partial Q_{lj}}{\partial Q_{ri}} = LA_3 \quad i= 1 \text{ to } n \qquad \text{--------- (20)}$$

III Example

220KV System



Base MVA =150

All the three transmission lines are identical with line reactance of 150 ohms and resistance of 35 ohms. The half line charging reactance is 2000 ohm.

The Cost Characteristics are

$F_1 = 0.15\ PG_1{}^2 + 20\ PG_1$ Rs./ hr

$F_2 = 0.05\ PG_2{}^2 + 30\ PG_2$ Rs./ hr.

Where PG_1 and PG_2 are in MW

Table 1 Results

Slack Bus No.	CLASSICAL		PROPOSED			
	VOLTAGE P.U	GENERATION P.U	VOLTAGE P.U	GENERATION P.U	CONTRIBUTION P.U	
					TOTAL DEMAND	LOSS
V_1	1+j0	1.1556+j0.0575	1+j0	1.1409+j0.0723	0.1217-j0.1067	0.0192-j0.2988
V_2	0.9886+j0.1249	1.2510+j0.24	1.0492+j0.1110	1.2607+j0.0311	0.8768-j0.1067	0.0490-j0.0909
V_3	0.9713+j0.1971		0.9725+j0.1851		0.9985 j0.2134	0.9682 j0.3897
	LINE LOSS = 0.0732 P.U				LINE LOSS = 0.0682 P.U	

Table2 Comparison of Results of the Example

Slack Bus No.	CLASSICAL METHOD				PROPOSED METHOD			
	Total cost FT Rs../ hr	Active power loss in MW	Reactive power loss in MVAR	Required MVARS at Bus 3	Total cost FT Rs./ hr	Active power loss in MW	Reactive power loss in MVAR	Required MVARS at Bus 3
1	17123.94	10.9815	45.6165	64.095	17064.66 (10.35%)	10.2356 (7.29%)	42.3638 (7.68%)	43.1511 (48.53%)

In the Table 2, the proposed method shows less cost, less loss in active & reactive powers and less injected MVAR at bus 3 for maintaining the voltage magnitude when comparing with classical method. Percentage reduction is given for each case in the table.

IV Conclusion

The basic work proves in this paper about the importance of deciding the design variables for the exact solutions to power system optimization problems. The optimization can be any mathematical or computing techniques. The generator powers are divided in to two parts, one to contribution to the system load another one to system network loss. Contribution to system load is considered as design (independent) variable since loss depends on how the generator contributes to the system load. The fundamental optimization with the proposed design variable in the basic coordination equations is presented. The derived equations are applied to an example of 220KV power system and the results are compared with conventional method. The table 2 shows the cost, loss and compensating reactive power are reduced in proposed basic method, which indicates the selection of contribution of generator (source) to system load as design variable in any power system optimization techniques for the best solutions.

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