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Determination of MW-generation Participation factors for Voltage Stability Enhancement Employing Jaya Algorithm

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ABSTRACT: This paper describes a methodology for improving voltage stability margin by rescheduling real power output of generating plants with incorporation of an efficient Jaya optimization algorithm. Normally this type of situation arises when system operates near collapse point and improvement is not possible using reactive power control variables due to their loss of controllability and/ or limiting values. Optimum generation participation factors have been obtained for maximizing distance to voltage collapse by employing Jaya algorithm. Result has been obtained for a standard 57 bus IEEE test system.

Keywords: voltage stability margin, real power rescheduling, jaya algorithm,

I. INTRODUCTION

Modern interconnected power systems are operating close to their voltage collapse points due to increasing load and limitation of transmission network and sources. Under stressed operating condition coupling between real power and voltage increases and may be significant.

Thus impact of MW- generation rescheduling is an important consideration for improving voltage stability margin. Kirschen and Meeteron [1] employed MW-generation rescheduling for alleviating voltage limit violations. Further it was observed that voltage magnitude alone is not a good indicator for voltage stability considerations. Adequate voltage stability margin may not be available even adequate voltage profile is observed in power system. Hence Johansson *et al* [2] presented an algorithm for improving voltage stability by shifting MW- generation using classical optimization technique. Vishakha *et al* [3] used L-index and presented an algorithm for voltage stability improvement. Active power generation direction was obtained by Wang and Lasseter [4] for improving voltage stability limit using gradient search algorithm. Singh *et al* [5] presented and discussed MW-generation rescheduling at selected buses from voltage stability consideration viewpoint. Arya and Purey [6] employed modified bare bones particle swarm optimization technique for obtaining optimum real power generation participation factors to improve load ability margin of a power system.

In view of above this paper describes an algorithm for optimum real power rescheduling for voltage security improvement employing Jaya optimization algorithm. Section-II presents problem formulation. Section-III gives solution methodology and section-IV depicts results on a tests system. Section-V gives conclusions.

II. PROBLEM FORMULATION

The objective is to maximize load ability limits with respect to MW-generation search direction [6]. Performance index [PI] is written as follows:

$$PI = (P_d^{\lim it} - P_d^0) \qquad \ldots(1)$$

$P_d^{\lim it}$ maximum load ability

P_d^0 current loading points

Then PI indicates voltage stability margin. The above performance index is maximized subject to operating constraints given as follows.

(i) Load flow equations

The repeated load flow equations are written as follow

$$\underline{F}\left(\underline{V}, \underline{\delta}, \underline{\alpha}, \underline{\eta}\right)=0 \qquad \ldots(2)$$

In above V, δ, represent voltage magnitude and phase angle vector, respectively. $\underline{\alpha}$ vector of **MW**- generation participation factors, $\underline{\eta}$ bus load participation factors

(ii) Constraints on MW- generation participation factors *i.e*

$$\sum_k \alpha_k = 1 \quad \ldots(3)$$

This constraints accounts that's in repeated power flow k^{th} generation participates an increase in generation proportional to α_k for a total load real load $P_{d.}$

(iii) Further each participation factor α_k should satisfy

$$0 \le \alpha_k \le 1 \quad \ldots(4)$$

In power flow load at each bus have same participation factor which can be written as

$$P_{d-k} = \eta_k P_d \quad \ldots(5)$$

P_{d-k} real load at bus k

$P_{d.}$ total real power load

Reactive power at k^{th} bus is written as

$$Q_{d-k} = (\tan\phi_k) P_{d-k} \quad \ldots(6)$$

ϕ_k is power factor angle at k^{th} bus

Performance index (1) as optimized subject to constraints (i) ... (iii). The control or decision variables are generation participation factors α_k, $k = 1$…….NG

An efficient optimization technique *i.e* Jaya has been employed to obtain the optimal solution and implemented in following steps.

III. SOLUTION OF THE PROBLEM USING JAYA ALGORITHM

Jaya optimization technique [7] is a simple and efficient algorithm to solve constrained optimization problem. The implementation of the algorithm to solve presents problem is explains in following steps:

Step 1: System data and parameters.

Step 2: Obtain base case load flow solution.

Step 3: Generate initial population of size 'm'

$$\underline{\alpha}_i^{(0)} = \left[\alpha_{1i}^{(0)}, \alpha_{2i}^{(0)} \ldots\ldots\ldots \alpha_{NG,i}^{(0)}\right] \quad \ldots(7)$$

i = 1, ...m.

each α_{ki} is generated using random sampling such that

$$0 \le \alpha_{ki}^{(0)} \le 1 \quad \ldots(8)$$

i= 1,……….m

$$\sum \alpha_{k,i}^{(0)} = 1 \quad \ldots(9)$$

k=1,………..NG

Step 4: Obtain performance index (1) using repeated load flow solutions

Step 5: Determine best and worst candidate i.e $\underline{\alpha}_{best}^{(0)}$ and $\underline{\alpha}_{worst}^{(0)}$ based on the performance indices as obtained in step - 4.

Step 6: Set iteration counts $k = 1$.

Step 7: Update population using $\underline{\alpha}_{best}^{(k-1)}$ and $\underline{\alpha}_{worst}^{(k-1)}$ as follows –

$$\underline{\alpha}_i^{(k)} = \underline{\alpha}_i^{(k-1)} + \underline{r_1}\left(\underline{\alpha}_{best}^{(k-1)} - \left|\underline{\alpha}_i^{k-1}\right|\right) - \underline{r_2}\left(\underline{\alpha}_{,worst}^{(k-1)} - \left|\underline{\alpha}_i^{k-1}\right|\right) \quad \ldots(10)$$

$\underline{r_1}$ and $\underline{r_2}$ are random digit vectors between [0, 1]

$\left|\underline{\alpha}_i^{(k-1)}\right|$ represents simply $\underline{\alpha}_i^{(k-1)}$ taking each element to be positive.

Step 8: If any component of modified solution vector crosses the limit then set it to limiting limit value so as to satisfy the constraint (4).

Step 9: Each modified solution vector is modified to satisfying constraint (3) using following solution–

$$\underline{\alpha}_i^{(k)} = \frac{\underline{\alpha}_i^{(k)}}{\sum_{k=1} \alpha_{ki}} \quad (11) \quad \text{for i =1,……m}$$

Step 10: Select $\underline{\alpha}_i^{(k)}$ in new population If $\underline{\alpha}_i^{(k)}$ is better than $\underline{\alpha}_i^{(k-1)}$ in terms of objective function otherwise the updated particle is rejected and previous solution vector is retain in new population.

Step 11: Run repeated power flow for each member of updated solution and obtain PI's as given by equation (1)

Step 12: Increase iteration count $k = k + 1$ and repeat from step - 7 if $k \le k_{\max}$, otherwise stop, $k_{\max}$ is maximum iteration specified.

IV. RESULT AND DISCUSSIONS

The computational algorithm developed in previous section has been implemented on a standard IEEE 57 bus test system [8]. The 57 bus test system contains seven generating buses and remaining load buses. For jaya algorithm maximum iteration, $k_{\max} = 500$.

Population size was 10, optimum MW- generation participation factor were obtained in only 25 iteration and there after no improvements was observed in performance index (1).

The convergence characteristic with number of generation is shown Fig. 1. CPU time on Intel core2duo processor, 2.9 GHz required is 8.5 second including repeated power flow solution. Optimum generation participation factors were obtained and shown Table 1. The same table also shows load ability limit (P_d^{limit}) as 23.15pu, same limit was 20.35 pu with base case generation participation factors. Hence an increase of 2.8 pu is observed.

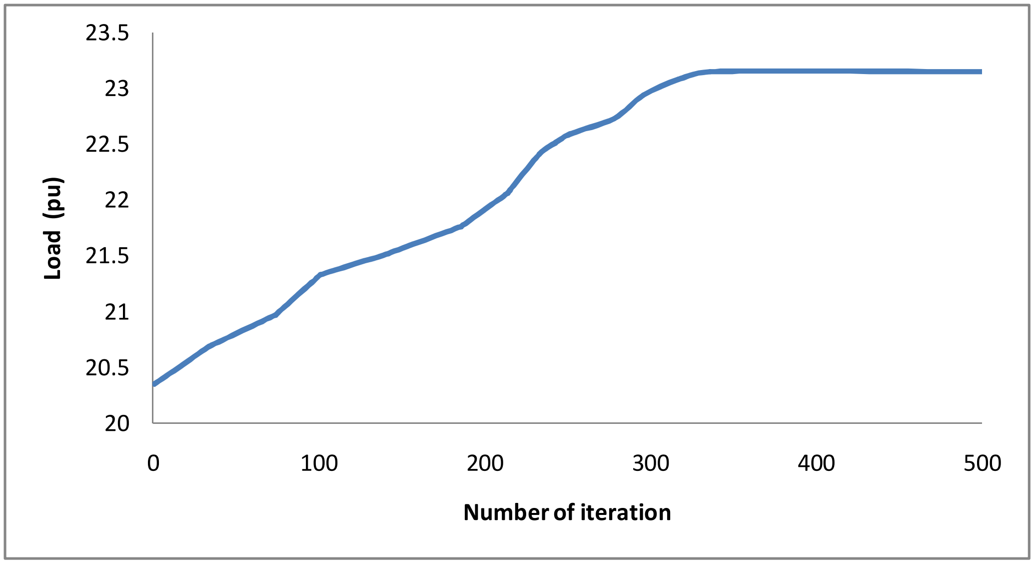

Fig. 1. Plot of convergence of (P_d^{limit}) with respect to number of iterations.

Table 1: Optimized MW-generation participation factors for seven generations and CPU time for 57 bus standard system.

α_1	α_2	α_3	α_4	α_5	α_6	α_7	P_d^{limit}	CPU time, sec
0.2215	0.0657	0.0778	0.0859	0.2450	0.1820	0.1221	23.15	8.5

V. CONCLUSIONS

It has been observed that relationship between MW – generation shifting and load ability is strong as the system is stressed towards collapsed point. Hence one of a very simple optimization technique *i.e.* Jaya has been employed to obtain optimal generation participation factors for 57 bus standard system.

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