OPTIMAL SIZE AND PLACEMENT OF DVR's IN DISTRIBUTION SYSTEM USING SIMULATED ANNEALING (SA)

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ABSTRACT

For the optimal size and placement of the dynamic voltage restorer (DVR) in a distribution network, in this paper the Simulated Annealing (SA) method is proposed. The multi-objective problem is converted to a single function using the goal attainment method. The obtained results show the voltage sag improvement on sensitive load nodes and other nodes in distribution system with minimum cost.

INTRODUCTION

Custom power devices using power electronic controllers can enhance the quality and reliability of power that is delivered to customers, so a customer receives a prespecified quality of power. There are many custom power devices which are connected in shunt or in series or a combination of both [1-3]. The compensating devices compensate a load, i.e. correct its power supply, unbalance etc. or improve the quality of the supplied voltage. A dynamic voltage restorer is one of the custom power devices which is used to protect sensitive loads from sag/swell or disturbances in the supply voltage. The DVR consists of a voltage source inverter (VSI), a switching control scheme, a DC energy storage device and a coupling transformer is connected in series with the ac system as illustrated in Fig.1.

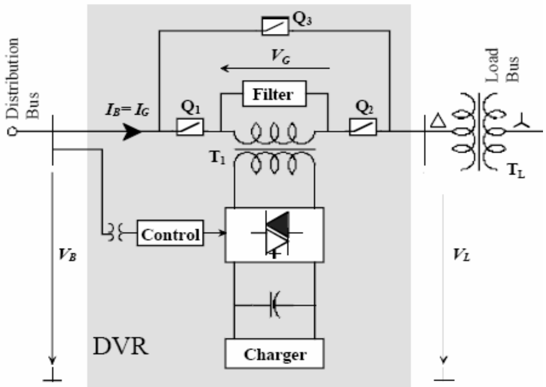

Fig.1 Structure of DVR

The DVR injects a set of three phase ac voltage in series and synchronized with the distribution feeder voltages of the ac system. The amplitude and phase angle of the injected voltages are variable thereby allowing control of the active and reactive power exchange between DVR and the ac system. The DVR control system compares the input voltage with a reference voltage and injects voltage so that the output voltage remains within specified value. According to Fig.2, the DVR boosts the supply voltage Vs to Vref by controlling the amplitude and phase of the Vinj using PWM thecnique. Small voltage disturbances are restored by exchange of reactive power while for larger disturbances the injection of the active power is required which is provided by energy storage element of DVR.

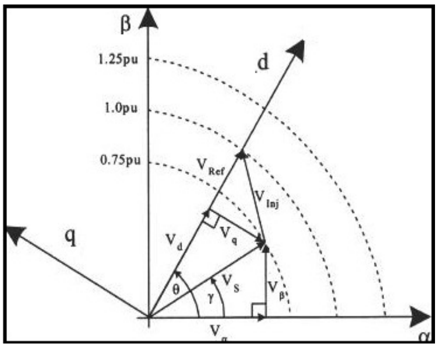

Fig.2 Phasor diagram

FORMULATION OF PROBLEM

To protect a large sensitive load from voltage disturbances a DVR with appropriate rating can be installed at load bus. However in an industrial state in which various sensitive loads are available, it is not economically acceptable to install a DVR for each load. In such cases the DVR planning should be performed in a way in which the number of DVR's and their ratings are optimized. In this optimization problem the following objective function to be considered [4]:

Maximizing the cost expenditure of DVR

In thecnical point of view this cost is proportional to the rating of DVR which is about 200-300$/kVA, so the first objective function is:

$$C_i = \sqrt{3}.V_{DVR}.I_{load} \qquad (1)$$

$$UFC = \sum_{i=1}^{NDVR} ci \qquad (2)$$

where Ci: is the rating of the DVR
Ndvr: is the No. of DVR

Maximizing the sensitive load voltage

According to the standard for sensitive loads the voltage limits should be within 80-90%. Therefore the second objective function to be maximized is:

UFC= Min (Vi) $i \in$ Ns (3)

where Vi: is the voltage of sensitive load.
Ns: is the No. of sensitive load.

Maximizing the overall system voltages

Since about 13% of residential loads, 35% of commercial loads, 75% of industrial loads are sensitive, according to the policy of the distribution company and the request of customers it is possible to improve the voltages on the other nodes , so the third objective function is to maximize the voltages on nodes without sensitive loads [5]:

$$UFNS = \sum_{i=1}^{Nns} vi \qquad (4)$$

where Nns: is the No. of nodes without sensitive loads.
To improve the quality of problem the above function are considered as in Fig.3 [3].

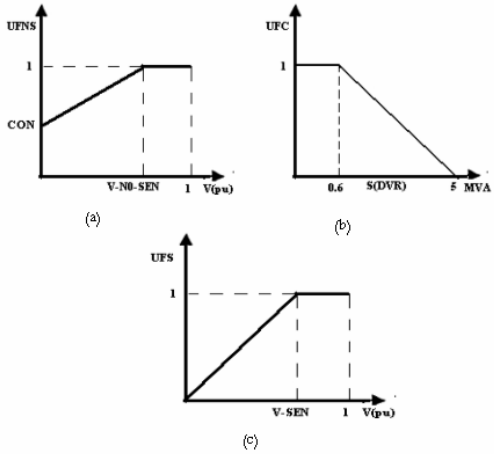

Fig.3 Relation between cost function and parameters

To obtain a single objective function from this multi-objective function a Goal Attainment Method has been used in this paper [6], so the objective is:

$$MIN \ (\alpha)$$

$$\alpha = MAX \ \left(\frac{b_i - f_i(x)}{w_i}\right) \quad i = 1,2,3 \quad (5)$$

where fi(x): is the objective function
bi: is the expected final value
wi: is the weight of objective function

STUDIED SYSTEM AND SIMULATION RESULTS

The concepts of the SA method are based on a strong analogy between the physical annealing process of solid and the problem of solving optimization problems [7].In this paper , the SA is used to optimized the above objective function. The developed algorithm has been applied to a 34 bus system shown in Fig.4. The network data appeared in Appendix. Details of the feeder and the load characteristics are given in Ref.[3].

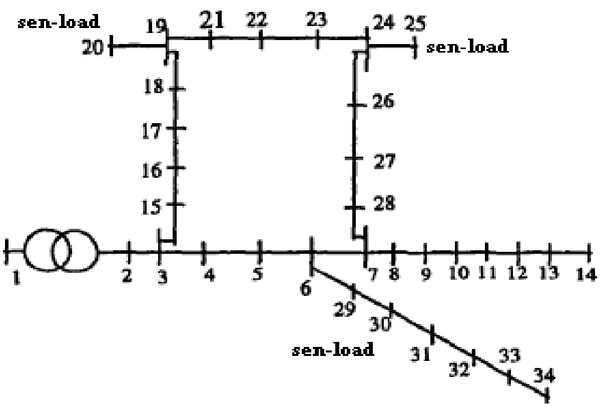

Fig. 4 Studied distribution system

In this system the sensitive loads are located at bus number 20, 25, and 30. Although a similar study has already performed in [3] but in the present work apart from different method used, the effects of external faults are considered and the location of DVR's are not candidate in advance, so the optimal locations of DVR are obtained by algorithm. In this paper 4 cases are studied: in case 1 the objective functions(2) and (3) with voltages at sensitive loads, Vsen=0.9 are considered. In case 2 all objective functions with Vsen= 0.8 and con=0.6 are considered. Case 3 is same as case 2 but Vsen=0.9. Case 4 is same as case3 but con=0.4. A three phase fault is applied on bus 12, the optimization results consists of location of DVR (between specified buses), rating of DVR , value and phase angle of the injected voltages. The results are shown in Table1. If the obtained results are compared with the results of [3] up to 19% reduction in the capacity of DVR's is justified. A three phase fault is also applied external to the system and the obtained results are shown in Table2.

Table1: DVR size and placement for internal fault

Location (DVR)		Injected voltage (pu)	Angle (rad)	Capacity (MVA)
			case1	
19	20	0.2131	2.905	0.5022
24	25	0.310	2.654	0.666
29	30	0.3362	2.450	0.4945
			case2	
27	28	0.295	2.870	0.390
29	30	0.350	2.350	0.5077
			case3	
19	20	0.2132	2.013	0.5181
24	25	0.1721	2.150	0.3642
27	28	0.3100	2.980	0.5255
29	30	0.4400	1.760	0.6435
			case4	
19	20	0.1195	2.375	0.2777
24	25	0.1000	2.604	0.2034
28	7	0.3058	2.863	0.4194
29	30	0.4500	1.901	0.6662

Table2: DVR size and placement for external fault (fault at the beginning of feeder)

Location (DVR)		Injected Voltage	Angle (rad)	Capacity (MVA)
Vsen=0.9				
1	2	0.2	2.269	1.896
Vsen=0.8				
1	2	0.12	2.31	1.02
			Case 1	
19	20	0.29	2.75	0.6612
24	25	0.30	2.96	0.6176
6	29	0.29	2.69	0.4769
			Case2	
7	8	0.3743	2.846	0.372
16	17	0.1853	2.90	0.4498
27	28	0.221	2.91	0.6079
29	30	0.34	2.775	0.4850
			Case 3	
7	8	0.35	2.8	0.3386
19	20	0.308	2.6	0.6984
24	25	0.30	2.8	0.6075
6	29	0.322	2.72	0.5388

CONCLUSION

In this paper an optimization problem i.e. the optimal size and location of one of CPD devices named DVR for the improvement of voltage at sensitive loads is studied using SA algorithm. The algorithm is developed in Matlab environment and has been applied to a 34 bus distribution system.

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APENDIX

BUS	BUS	R-Ω	X-Ω	BUS	P-KW	Q-KVAR
1	2	0.117	0.169	1	0	0
2	3	0.10725	0.044	2	260	142.5
3	4	0.1644	0.0456	3	0	0
4	5	0.1495	0.0415	4	260	142.5
5	6	0.1495	0.0415	5	260	142.5
6	7	0.3144	0.054	6	0	0
7	8	0.2096	0.036	7	0	0
8	9	0.3144	0.054	8	260	142.5
9	10	0.2096	0.036	9	260	142.5
10	11	0.1572	0.027	10	76	34.5
11	12	0.2096	0.036	11	76	34.5
12	13	0.1572	0.027	12	76	34.5
13	14	0.1048	0.018	13	76	34.5
3	15	0.1572	0.027	14	76	34.5
15	16	0.2096	0.036	15	90	45
16	17	0.1048	0.018	16	90	45
17	18	0.0524	0.009	17	90	45
18	19	0.262	0.045	18	53.5	7.5
19	20	0.131	0.0225	19	260	142.5
19	21	0.3144	0.054	20	2487	250
21	22	0.2096	0.036	21	260	142.5
22	23	0.131	0.0225	22	260	142.5
23	24	0.1048	0.018	23	260	142.5
24	25	0.1048	0.018	24	137	85
24	26	0.3144	0.054	25	2024	980.7
26	27	0.1572	0.027	26	95	48
27	28	0.1572	0.027	27	95	48
28	7	0.1572	0.027	28	95	48
6	29	0.1794	0.0498	29	260	142.5
29	30	0.1644	0.0456	30	260	142.5
30	31	0.2079	0.0473	31	260	142.5
31	32	0.2079	0.0473	32	260	142.5
32	33	0.189	0.043	33	260	142.5
33	34	0.189	0.043	34	260	142.5