Comparison of EPSO, PSO and EP Approaches in Transmission Loss Minimization in Power System Network

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Abstract. The paper presents a comparison of Computational Intelligence techniques are Evolutionary Programming Swarm Optimization (EPSO), Particle Swarm Optimization (PSO), Evolutionary Programming (EP) to optimal placement and sizing of Static Var Compensator. The technique has been implemented to minimize the transmission loss and improve the voltage profile of the system. Simulation performed on standard IEEE 118-Bus RTS and indicated that EPSO a feasible to achieve the objective function.

Introduction

One of the problems experienced in power system is the large amount of data set and system complexity. Even if an exact algorithm may be developed and applied to find an exact optimal solution of the problem, its resolution time or space complexity may not be acceptable in a simulation scenario. However, many problems can be solved using an approximate solution if the dimension and the complexity of the problem do not encourage the use of exact resolution techniques. Heuristic algorithms work with approximated solutions and the objective is to find the optimum among all possible solutions. This solution presented a compromise between quality and speed, being the solution admissible within a reasonable simulation time.

This paper presents a computational intelligence technique namely: Evolutionary Particle Swarm Optimization (EPSO), Particle Swarm Optimization (PSO), and Evolutionary Programming (EP) for optimal location of Static Var Compensator (SVC) installation in the power system network. The objectives function for this research to minimize the transmission loss and improve the voltage profile of the system. The simulation tests were conducted on IEEE 118 RTS for validation of the proposed techniques.

Transmission Loss Minimization

This section describes the problem formulation of single-objective function using EPSO, PSO and EP techniques under loading condition in Bus 20 of IEEE 118 Bus RTS. The objective function for this research is to minimize the transmission loss. The mathematical equation is given by:-

$$min \sum_{l=i}^{N_L} (P_{ab}^{l} + P_{ba}^{l}) \tag{1}$$

where $P_{ab}^{l} + P_{ba}^{l}$ is the transmission loss of line l, P_{ab}^{l} is the active power flow from bus a to bus b of line l, P_{ba}^{l} is the active power flow from bus b to bus a of line l, and N_L is the number of transmission line. The power flow P_{ab} through the transmission line l is a function of line impedance X_{ab}, the voltage magnitude V_a, V_b and the phase angle between the sending and receiving end voltage ($\delta_a - \delta_b$) [1].

$$P_{ab} = \frac{V_a V_b}{x_{ab}} (\delta_a - \delta_b) \tag{2}$$

where: V_a = the sending voltage, V_b = the receiving voltage, δ_a = the sending phase angle, δ_b = the receiving phase angle.

Evolutionary Particle Swarm Optimization

In this section, the fundamental of EPSO technique and the steps to relate with SVC installation will be discussed briefly. The new category of computational intelligence techniques has emerged to cope with the some conventional methods shortcomings [2]. These techniques have been successfully applied to a wide range of optimization problems. Also they are known for their capabilities of fast search of large solution spaces and ability to account for uncertainty in some parts of the power system networks [2,3].

EPSO proposed by Miranda [4] is one of the optimization methods based on swarm intelligence. EPSO is the modified PSO method that considers the diversity of solution candidates with some strategy [5, 6]. EPSO combines the PSO method with evolutionary strategy of the replication, mutation, and reproduction, evaluation and selection. In [7], the movement rule of EPSO is determined by three strategic parameters namely inertia, memory and cooperation. In other words, EPSO means a technique that takes in the information exchange of the search in PSO and concepts such as natural selection or the mutation in the evolutionary strategy. The step by step EPSO algorithm for the proposed optimal location and sizing of SVC is given below:

Step 1: Set the loading condition, Q_{load} at weak buses before SVC installation (base case value). Set the loss and voltage constraints, i.e $loss1 \leq loss\_0$ and $voltage1 \geq voltage\_0$. This is to ensure that all the generated initial populations satisfy all the equality and inequality constraints.

Step 2: Initialize the related parameters, such as the population sizing, the sizing of particle, the maximum number of iteration, and the power flow data i.e. linedata and busdata.

Step 3: Generate initial population. This population considers the variable that should be optimized (the location and the sizing of SVC). The random numbers, x as a control variables of SVC ($x_1, \ldots x_n$) where $x_1, \ldots x_{n/2}$ are the location of SVC and $x_{n/2+1}, \ldots x_n$ are the sizing of SVC.

Step 4: Calculate fitness I. Fitness is computed for each particle. Determine the $P_{best\ 1}$ and $G_{best\ 1}$ value and it is stored in ascending order for the purpose of minimization of loss. $P_{best\_1} = min(x_1, \ldots x_n)\_old$ and $Fitness\ 1 = Loss_{min\_1}$.

Step 5: Update the velocity and position of the particle according to Eq. 8 to Eq. 12. The velocity EPSO updates and modified the solutions as follows [8]:

$$v_i^k = w_{i0}^* \times v_i^{k-1} + w_{i1}^* \times (p_{best} - s_i^{k-1}) + w_{i2}^* \times (G_{best}^* - s_i^{k-1}) \tag{8}$$

where w_{ij}^* is weights updated by the evolutionary strategy. So far, Eq. 8 like in PSO, the movement rule keeps its terms of inertia, memory and cooperation. However, the weights undergo mutation as represented Eq. 9

$$w_{ij}^* = w_{ij} + \tau N(0,1) \tag{9}$$

where j is 0, 1, 2 , τ is the learning parameter, N(0,1) is a random variable with Gaussian distribution; 0 mean and variance 1, and the global best G_{best} is randomly distributed to give in Eq. 10 and Eq. 11:

$$G_{best}^* = G_{best} + w_{i3}^* N(0,1) \tag{10}$$

$$w_{i3}^* = w_{i3} + \tau' N(0,1) \tag{11}$$

where w_{i3} is the fourth strategic parameter (weight) associated with particle i. Besides that the new position can be modified using Eq. 12:

$$s_i^{k+1} = s_i^k + v_i^{k+1} \tag{12}$$

Step 6: Calculate *Fitness 2* and determine the P_{best_2} and $G_{\text{best\_2}}$. $P_{best\_2}=min(x_1,...x_n)\_2$ and *Fitness 2*=$Loss_{min\_2}$.

Step 7: Convergence criterion. The convergence criterion is determined by $Loss_{min\_2}<<Loss_{min\_1}$. Otherwise, repeat Steps 5 – 7 until stopping criterion, as such sufficiently excellent $Loss_{min}$ fitness or a maximum numbers of iteration is met.

Step 8: Calculate the cost of installation SVC using the Eq. 13 to Eq. 15. The cost of installation of SVC has been mathematically formulated and is given by Eq. 13:

$$IC= C\times A\times 1000\text{[US\$]} \tag{13}$$

From the Siemens AG Database, the cost function for SVC is given in Eq. 14, and Eq. 15 are given from [9]:

$$C_{SVC}=0.0003A^2-0.0305A+127.38 \text{ [US\$/kVar]} \tag{14}$$

$$A=|Q_2-Q_1| \tag{15}$$

Step 9: End.

Results and Discussion

The IEEE 118 Bus RTS has been used to demonstrate the application of the proposed formulation and evaluate the effectiveness of the EPSO, PSO and EP in the solving the SVC installation problem. Figure 1 illustrated the single-line diagram of IEEE 118-Bus RTS as a test system.

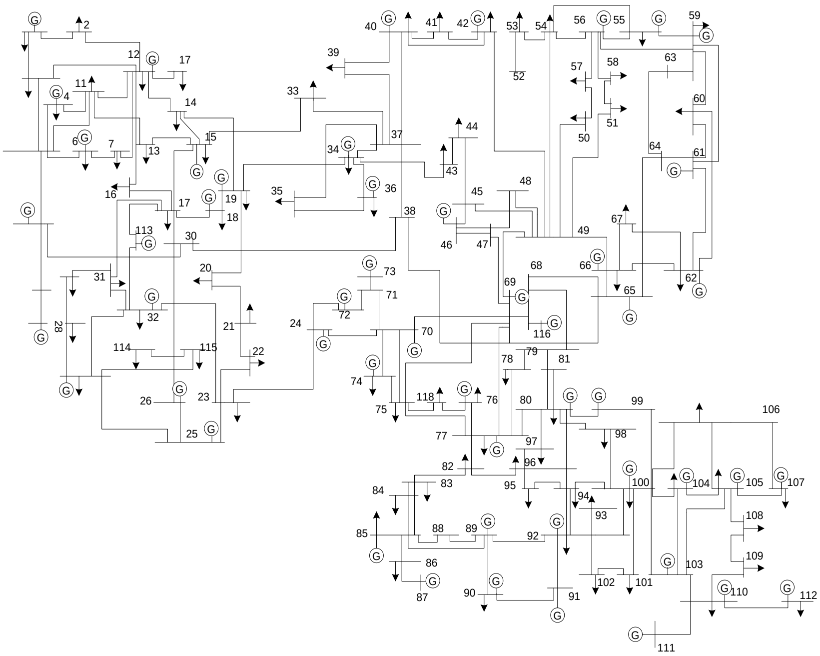

Figure 1: Single-line Diagram of IEEE 118 Bus RTS

The SVC installation in the transmission line to minimize the loss and improve the voltage of the system have been conducted at several load condition are subjected to Bus 20.

Case 1: Installation of SVC with Load Variation at Bus 20

Results for transmission loss minimization and voltage improvement when load increased to 100, and 150MVar at Bus 20 are tabulated in Table 1 and Table 2, respectively. Table 1 tabulates the results of transmission loss minimization when loading variation is subjected to Bus 20 using EPSO, PSO and EP techniques. In addition, Table 2 tabulates the results of cost of installation and voltage profile improvement when loading variation is subjected to Bus 20 using EPSO, PSO and EP techniques. For instance, when load increased to 100MVar, the transmission loss is minimized to 138.1MW (3.91% reduction) with ten unit SVC installed at the system using EPSO technique, while, the loss is minimized to 138.2051MW (3.84% reduction) and 138.2784MW (3.79% reduction) using PSO and EP techniques, respectively. Next, when load is increased to 150MVar to bus 20, the transmission loss is minimized to 137.7742MW (9.14% reduction) with three units SVC installed at the system using EPSO technique. With the same loading condition, the loss is minimized to 137.6525MW or (9.22% reduction) with three units of SVC is installed into the system using PSO technique. Although, with the same loading condition, the loss is minimized to 138.2983MW or (12.44% reduction) with three units of SVC is installed into the system using EP technique.

Table 1: Results of Transmission Loss when Loading Variation is subjected to Bus 20 using EPSO, PSO and EP Techniques

Loading Variation Q_{d20}(MVar)	Technique	Quantity	Loss (MW)		%Loss Red.
			without SVC	with SVC	
100	EPSO	3	143.7236	138.2579	3.80%
		5		138.5501	3.60%
		10		**138.1000**	**3.91%**
	PSO	3		138.2311	3.82%
		5		138.6208	3.55%
		10		138.2051	3.84%
	EP	3		138.9182	3.34%
		5		138.4412	3.68%
		10		138.2784	3.79%
150	EPSO	**3**	151.6378	**137.7742**	**9.14%**
		5		138.1184	8.92%
		10		137.8317	9.10%
	PSO	3		138.1652	8.88%
		5		138.0291	8.97%
		10		137.6525	9.22%
	EP	3		138.1635	8.89%
		5		138.3213	8.78%
		10		139.8825	7.75%

Furthermore, with the SVC installation in the system, the voltage profile increases more than 1.00p.u. using EPSO, PSO and EP techniques. For instance, when Q_{d20}=100MVar, the voltage is increased to 1.0029p.u., 0.9716p.u. and 0.959p.u. with three, five and ten units of SVC is installed into the system using EPSO. Next, when load is increased to 150MVar, the voltage is improved to 1.0047p.u., 0.9845p.u., and 0.993p.u. with three, five and eight units of SVC is installed into the system.

Conclusion

The proposed technique was implemented on IEEE 118-Bus RTS with buses 20 is subjected to loading variation condition respect. Next, results obtained from the EPSO technique were compared with PSO and EP. Experiment results demonstrated that the proposed EPSO technique is feasible for loss minimization scheme in other power system network. It was found that EPSO is superior with respect to PSO and EP techniques in most cases.

Table 2: Results of Cost of Installation and Voltage Profile Improvement when Loading Variation is subjected to Bus 20 using EPSO, PSO and EP Techniques

Loading Variation Q_{d20}(MVar)	Technique	Qty	Cost (US$)	Voltage (p.u) without SVC	with SVC	%Voltage Improve.
100	EPSO	3	4,134,700	0.8291	1.0029	20.96%
		5	3,513,900		0.9716	17.19%
		10	**3,544,900**		**0.959**	**15.67%**
	PSO	3	4,281,100		0.9728	17.33%
		5	3,944,500		1.0269	23.86%
		10	5,089,300		1.0112	21.96%
	EP	3	3,429,500		0.9501	14.59%
		5	3,508,000		0.9842	18.71%
		10	3,478,600		0.9697	16.96%
150	EPSO	**3**	**7,905,500**	0.7393	**1.0047**	**35.90%**
		5	7,734,400		0.9845	33.17%
		10	8,530,700		0.9930	34.32%
	PSO	3	7,892,600		1.0033	35.71%
		5	8,064,600		1.0026	35.61%
		10	8,618,100		1.0108	36.72%
	EP	3	7,893,700		1.0032	35.70%
		5	7,232,400		0.9547	29.14%
		10	8,585,300		1.0090	36.48%

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