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Minimization Operational Cost of R.D.S. using GA

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Abstract

Loss Minimization in power system has assumed greater significance, because substantial amount of generated power is being wasted as losses. Studies have shown that 70% of the total system losses are occurring in the distribution system, while transmission lines account for only 30% of the total losses. The pressure of improving the overall efficiency of power delivery has forced the power utilities to reduce the loss, especially at the distribution level. The reactive power compensation method is adopted for reduction of distribution system losses.

The distribution network is usually compensated by either series or shunt capacitors. Series capacitors increase the maximum power limit while shunt capacitors have several benefits.

Loss Snsitivity Factor

The aim of the present work is to find out the location and sizes of the shunt capacitor so as to maximize the net saving by minimizing the **energy loss cost** for a given period of time and considering cost of shunt capacitors. Therefore, the objective function consists of two main terms: **energy loss cost and capacitors cost**. Mathematical formulation of the terms used in objective function is given below:

Term 1: Energy loss Cost (ELS)

If I_i is the current of section-i in time duration T, then energy loss in section-i is given by:

$$ELi, = Ii * Ii * Ri * T \quad (3.1)$$

The Energy loss (EL) in time T of a feeder with n sections can be calculated as:

$$EL = \sum_{i=1}^{n} EL_i \quad (3.2)$$

The Energy loss cost (ELC) can be calculated by multiplying eq. (3.2) with the energy rate (C_e)

$$ELC = Ce \times EL \tag{3.3}$$

$EL_{i,}$ is energy loss (kW) in section–i in time duration T.

I_i is the current of the section-i

R_i is the resistance of section-i.

T is the time duration.

C_e is the energy rate.

ELC is the energy loss

Term 2: Capacitor Cost (CC)

Capacitor cost is divided into two terms: constant installation cost and variable cost which is proportional to the rating of capacitors. Therefore capacitor cost is expressed as:

$$CC = Cci + (Ccv \times Qck) \tag{3.4}$$

where,

C_{ci} is the constant installation cost of capacitor.

C_{cv} is the rate of capacitor per kVAr.

Q_{ck} is the rating of capacitor on bus-k in kVAr.

The cost function is obtained by combining eqs. (3.3) and (3.4). This cost function is considered as the objective function to be minimized in the present work. The cost function 'S' is therefore expressed as:

$$\text{Minimize} \quad S = C_e \times \sum_{i=1}^{n} EL_i + \sum_{k=1}^{ncap} C_{ci} + (C_{cv} \times Q_{ck})$$

where S is the cost function for minimization.

By minimizing the cost function, the net saving due to the reduction of energy losses for a given period of time including the cost of capacitors is given below: Net saving = BEL-CC (3.6)

where

BEL = ELC(without capacitor) -ELC(with capacitor)

BEL is benefit due to energy loss reduction.

ELC(without capacitor) is energy loss cost without capacitor.

ELC(with capacitor) is energy loss cost with capacitor.

CC is the total capacitors cost as expressed by eq. (3.4).

The loss sensitivity factor and the criterion to select the candidate buses for compensation are summarized in this section To identify the location for capacitor placement in distribution system Loss Sensitivity Factors have been used [39]. The loss sensitivity factor is able to predict which bus will have the biggest loss reduction when a capacitor is placed. Therefore, these sensitive buses can serve as candidate buses for the capacitor placement. The estimation of these candidate buses basically helps in reduction of the search space for the optimization problem. As only few buses can be candidate buses for compensation, the installation cost on capacitors can also be reduced.

Consider a distribution line with an impedance R + jX and a load of P_{eff} + jQ_{eff} connected between 'i' and 'j' buses as given below in Fig. 3.1.

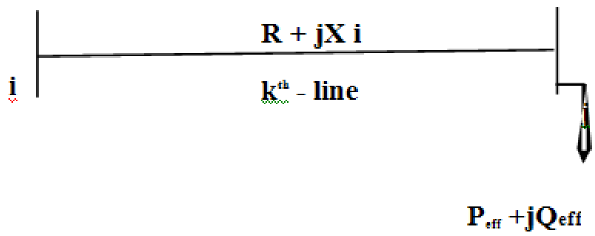

Figure 3.1: A distribution line Impedence and load.

Real power loss in the line of the above Fig. 3.1 is given by [Ik] * [R_k], which can also be expressed as

$$P_{lineloss}[j] = \frac{\left(P_{eff}^2\,[j] + Q_{eff}^2[j]\right) * R[k]}{(V[j])^2}$$

Similarly the reactive power loss in the k^{th} line is given by

$$Q_{lineloss}[j] = \frac{\left(P_{eff}^2\,[j] + Q_{eff}^2[j]\right) * X[k]}{(V[j])^2}$$

where

Peff [j] = Total effective active power supplied beyond the bus 'j'

Qeff [j] = Total effective reactive power supplied beyond the bus 'j'

Now, the Loss Sensitivity Factors can be calculated as:

$$\frac{\partial P_{lineloss}[j]}{\partial Q_{eff}[j]} = \frac{(2 * Q_{eff}[j]) * R[k]}{(V[j])^2} \quad (3.9)$$

$$\frac{\partial Q_{lineloss}[j]}{\partial Q_{eff}[j]} = \frac{(2 * Q_{eff}[j]) * X[k]}{(V[j])^2} \quad (3.10)$$

The Loss Sensitivity Factor as given in eq. (3.9) has been calculated from the base case Load flows. The values of loss sensitivity factors have been arranged in descending order and correspondingly the bus numbers are stored in bus position ‘bpos[i]’ vector. The descending order of (elements of ‘bpos [i]’ vector will decide the sequence in which the buses are to considered for compensation. At these buses of ‘bpos [i]’ vector, normalized voltage magnitudes are calculated by considering the base case voltage magnitudes given as below:

$$norm[i] = |V[i]|/0.95 \quad (3.11)$$

The ‘norm[i]’ decides whether the buses need reactive compensation or not. The buses whose norm[i] value is less than 1.01 can be selected as the candidate buses for capacitor placement. The following are the steps to be performed to find out the potential buses for capacitor placement:

Step 1: Calculate the Loss Sensitivity Factor at the buses of distribution system using Eq. (3.9).

Step 2: Arrange the value of Loss Sensitivity Factor in descending order.
Also store the respective buses into bus position vector bpos[i].

Step 3: Calculate the normalized voltage magnitude norm[i] of the buses of bpos[i] using Eq. (3.11).

Step 4: The buses whose norm[i] is less than 1.01 are selected as candidate buses for capacitor placement.

The algorithm has been developed in matlab environment, the effectiveness of the algorithm for the said system has been studied two cases. Test results for case i are as under.

GA Output (Case-1)

X(1)	X(2)	X(3)	Loses with Capacitor	Loses without capacitor
10	10	10	5510162	7871413
26	27	17	7317079	7871413
25	32	29	7633101	7871413
37	17	25	7547873	7871413
34	32	15	7724710	7871413
32	39	33	8222437	7871413
12	36	13	6587334	7871413
12	13	19	5977216	7871413
13	21	17	6294113	7871413
34	21	26	7624111	7871413
38	31	13	7799150	7871413
31	28	22	7634519	7871413
14	34	13	6693779	7871413
32	21	13	7248375	7871413
13	16	34	6515628	7871413
14	13	19	6067089	7871413
29	33	28	7855699	7871413
20	16	39	7015691	7871413
30	22	23	7402424	7871413
32	27	31	7850542	7871413
10	10	10	5510162	7871413
12	13	19	5977216	7871413
12	13	19	5977216	7871413
32	21	13	7248375	7871413
10	10	39	6141971	7871413
14	34	23	6924487	7871413
32	27	13	7471444	7871413
26	27	29	7588041	7871413
34	36	13	7793471	7871413
13	16	34	6515628	7871413
10	13	10	5611954	7871413
13	17	17	6144354	7871413
13	21	17	6294113	7871413
30	22	10	7102321	7871413
14	13	19	6066577	7871413
31	28	19	7557820	7871413
34	32	14	7701520	7871413
38	31	14	7822262	7871413

x(1), x(2), x(3) are the capcitances to be put across the candidate buses. In the GA function above their value is varied from 10 to 40 (u farad) and for each combination the program calculates the value of fitness function i.e loses with capacitor in place and compares it with loses without capacitor. Those values are selected for which the loses the minimum.The developed algorithm is effective in deciding the allocation of capacitor for different number of candidate buses and for different capacitor sizes

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