Optimal placement of electric vehicle charging station with DG and DSTATCOM using Whale Optimization Algorithm

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Abstract

Due to their decreased greenhouse gas emissions, electric vehicles are anticipated to become the dominant means of transportation in the future. The large increase in electric load penetration in, on the other hand, causes a multitude of difficulties such as disturbance of generation demand equilibrium, increased network power loss, voltage profile deterioration, voltage margin deterioration. The more power losses and drops in voltages in distribution feeders are mainly due to the high ratio of reactance to resistance. These losses for sure effect the efficiency and stability of the system and moreover effect the financial system. Optimal integration of electric vehicle charging stations is required to overcome the aforementioned concerns. We can reduce the power loss by using compensating devices .DG and DSTATCOM are incorporated into electric vehicle charging station to mitigate the impact of electric vehicle charging demand .This effort links charging stations with DG and DSTATCOM, which encourages the use of electric vehicles. To do a detailed analysis of nodes suited for electric vehicle charging station and DGs, this work employs a suitable method for finding the optimal positioning of above mentioned devices globally.

For this, we use Whale Optimization Algorithm. Also assessed are the load-oriented reliability indices for this system.

Keywords:- Electric vehicles ,Green Technologies, DG,DSTATCOM, Whale Optimization Algorithm.

1.Introduction

Technology has its own way of emergence and it work hand in hand in the automobile industry. Every day there is a new technology and innovation comes as a result. Today, automobile inventors are more likely to produce ecofriendly vehicles keeping in mind the reduction of fossil fuels. Along with, the pollution due to the fossil fuel based vehicles is also one of the reasons behind this. As, the growing pollution has become a serious concern, electric vehicles are quite a relief. And, according to the research electric vehicles are better for the environment. Whereas the fuel vehicle emits harmful gases like carbon due to petrol or diesel.

And, these pollutants are responsible for so many health related problems. Lungs related problems are very common. Irritation of eyes, throat, nose and respiratory system, respiratory damage, convulsions and coma due to lead poisoning, the mercury from combustion of fossil fuel affects the nerves, brain and kidney are the common effects of pollution by fossil fuel based vehicles. Air quality in the world is decreasing day by day. All these things made us choose electric vehicle over fuel vehicles.

For all these health regarding issues, electric vehicles are more suitable option as they are nonpolluting and reliable in terms of linear performances. As, the growing pollution has become a serious issue, electric cars are quite a relief. It produces fewer greenhouse gases and air pollution than petrol. As, per research by the European Energy Agency, the carbon emissions of an electric car are around 17-30% lower than driving a petrol or diesel car.

But, the main issue with these electric vehicles is its charging. As, fuel vehicles need little time to be powered, but electric vehicles need long time to get charged. And, there is also unavailability of charging stations.

To, overcome this problem, we bring an idea of optimal placement of EV charging station with DG and DSTATCOM using whale optimization.

It is well known as an electric power system network consists of generation, transmission, utilities and distribution. We have command

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over all the three above parameters. But the fourth one is somehow critical. Distribution is the weakest one in the electric power system network. The more power losses and drops in voltages in high ratio of reactance to resistance (Ackermann et al 2001). Till date it is reported that 13% of the total generated power is lost in the distribution system. These losses for use effect the efficiency & stability of the system and moreover effect the financial system. Also, less amount of reactive power also effect the system. Therefore, there is a need to reduce this power loss.

We can reduce the power loss by using compensating devices. To achieve the objective of minimizing power losses, there are so many techniques like distribution network reconfiguration (DNR), capacitor placement and distributed generations (DG) (Kalambe & Agnihotri 2014). Out of these, the most preferred devices are DG and DSTATCOM (Distribution STATIC Compensator).

The installation of DGs comprises of less installation cost in comparison to a construction of new power plants, distribution and transmission lines. It improves power quality and is ecofriendly. (Ackermann et al 2001).

But, there is another problem regarding the positioning of these electronic devices. Ideal position of these electronic device enhances the load capability, reduce power loss, stability of the system compensation of reactive power and enhancement of power quality like voltage balancing, regulation and suppression of flicking system (Yuvaraj et al 2017). To overcome this positioning problem, we introduce whale optimization method.

2. Problem Formulation Load flow Analysis

There are so many methods for finding the optimal positioning of above mentioned devices globally. Some conventional methods are Newton-Raphson, Gauss- Seidel and fast decoupled load flow studies, But these are unfortunately didn’t give any favourable result. To overcome these limitations, evolutionary based algorithms have been evolved. Khushalani & Schulz (2006) found this as a hot topic for result and implemented backward / forward sweep (BFS) algorithm and proved that this method is most suitable for power flow studies in RDS. The main features of this method are higher efficiency with less consumption and reliability in finding optimal position.

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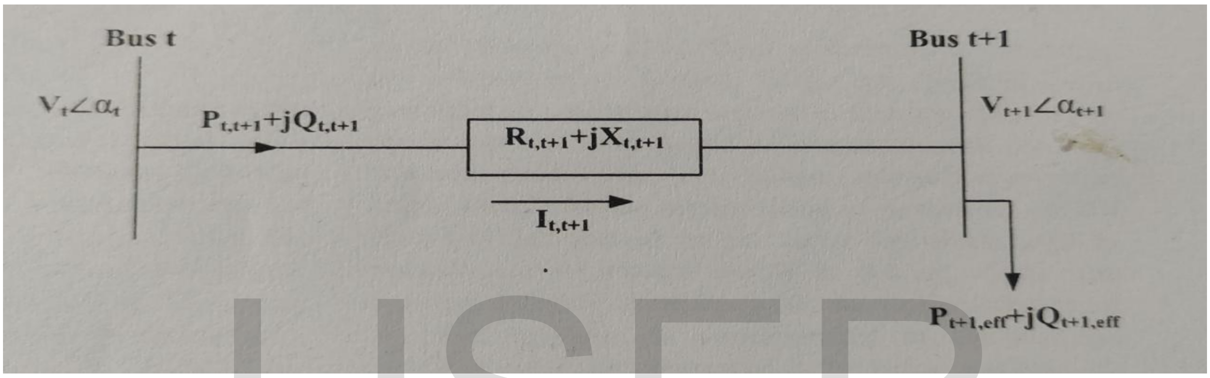
The integration of the DSTATCOM modeling in distribution power flow has been taken from Yuvaraj et al (2017) and (Iranian journal of Science & Technology).

Let us consider two buses interconnected to a branch in RDS as shown in fig.1. There are two buses namely k and k+1 are sending & receiving end buses respectively. $P_{k,k+1}$ and $Q_{k,k+1}$ are real and reactive power respectively transmitted among considered buses.

Fig.1



$P_{k,k+1} = P_{k+1;eff} + P_{loss(k,k+1)}$ (1)

$Q_{k,k+1} = Q_{k+1,eff} + Q_{loss(k,k+1)}$ (2)

Where,

$P_{k,k+1}$=Real power

$Q_{k,k+1}$=Reactive power

$P_{k+1,eff}$=Effective real power

$Q_{k+1,eff}$=Effective reactive power

P_{loss}=Effective real power loss

Q_{loss}=Effective reactive power loss

The total current between the two taken buses are as-----

$I_{k,k+1}=(P_{k,k+1} - jQ_{k,k+1})/(V_{k+1} \angle\alpha_{k+1})$ ------------(3)

Again,

$I_{k,k+1} = (V_k\angle\alpha_k - V_{k+1}\angle\alpha_{k+1})/(R_{k,k+1} + jX_{k,k+1})$ ----(4)

Where,

V_k= voltage at k

V_{k+1}=voltage at k+1

α_k=voltage angle at k

α_{k+1}=voltage angle at k+1

$R_{k,k+1}$=resistance

$X_{k,k+1}$=reactance

From equation (3) and (4) we have,

$V^2_k - V_k V_{k+1}\angle(\alpha_{k+1}-\alpha_k) = (P_{k,k+1} - Q_{k,k+1})(R_{k,k+1} + jX_{k,k+1})$ ----(5)

By equating real & imaginary parts in equation (5) -----

$V_k V_{k+1}\times\cos(\alpha_{k+1}-\alpha_k) = V^2_k - (P_{k,k+1}R_{k,k+1} + Q_{k,k+1}X_{k,k+1})$ ----(6)

$V_k V_{k+1}\times\sin(\alpha_{k+1}-\alpha_k) = Q_{k,k+1}R_{k,k+1} + P_{k,k+1}X_{k,k+1}$ -----(7)

By squaring and adding equation (6) and (7) ------

$V^2_{k+1} = V^2_k - 2(P_{k,k+1} + Q_{k,k+1}X_{k,k+1}) + (R^2_{k,k+1} + X^2_{k,k+1})$

$(P^2_{k,k+1} + Q^2_{k,k+1})/|V^2_k|$ ----(8)

Now , the active and reactive power loss can be calculated as--

$P_{loss(k,k+1)} = I^2_{k,k+1}\times R_{k,k+1}$ ------(9)

$P_{loss(k,k+1)} = (P^2_{k,k+1} + Q^2_{k,k+1})/|V_{k+1}|^2 \times R_{k,k+1}$ -------(10)

$Q_{loss(k,k+1)} = I^2_{k,k+1}\times X_{k,k+1}$ ------(11)

$Q_{loss(k,k+1)} = (P^2_{k,k+1} + Q^2_{k,k+1})/|V_{k+1}|^2 \times X_{k,k+1}$ ------(12)

Hence, total power loss of the distribution is given by-----

$P_{kL}=\sum^{Nb}P_{loss(k,k+1)}$ --------(13)

$Q_{kL}=\sum^{Nb}Q_{loss(k,k+1)}$

Where Nb is total no. of branches.

2.2 Power loss Reduction using DG/STATCOM Placement

The total losses reduced by optimal position of DG/DSTATCOM in the RDS can be calculated by the ratio of total power loss with or without DG/DSTATCOM position in the RDS and is given as---

$\Delta(P_{KL})^{DG/DST}=(P_{KL})^{DG/DST}/P_{KL}$ -------(15)

Hence, the total power loss can be reduced by minimizing $\Delta(P_{KL})^{DG/DST}$

2.3 Operational cost minimization

The total working expenses of the discussed system is from two segments. One from the substation and one from the expenses related with DG/DSTATCOM. Therefore, the total operating cost can be given by—

$TOC = (a_1 (P_{KL})^{DG/DST}) +(a_2P_{DG/DST})$ ----------(16)

Where a_1 & a_2 are the cost coefficients of power offered by substation and DG/DSTATCOM respectively. $P_{DG/DST}$ is the overall power drawn from installed DG/DSTATCOM.

Reduction in operating cost of DG/STATCOM can be given as -

$\Delta OC= TOC/a_2 (P_{DG/DST})^{max}$ -------(17)

Hence, the cost of the system can be reduced by controlling ΔOC.

2.4 Objective function

(a)Power Balance Constraints

The power balance constraints can be given as ----

$P_{k\ loss} + \sum P_{D(K)} = \sum P_{DG/DST(K)}$ --------(18)

Where $P_{D(k)}$ represents power demand and $P_{DG/DST(K)}$ represents power generation as bus $_K$ with the help of DG/DSTATCOM .

(b)Voltage magnitude constraints

The Voltage magnitude is another constraints which have to be maintained within its limits at every bus--------

$(V_k)^{min} \leq |V_k| \leq (V_k)^{max}$ ------------(21)

Where $(V_k)^{min}$ and $(V_k)^{max}$ are the minimum & maximum voltage limits respectively .

(c) Real AND Reactive power Compensation

Both the power either real or reactive should be within its acceptable limits .

$(P_{DG(K)})^{min} \leq P_{DG(K)} \leq (P_{DG(K)})^{max}$ k=1,2,3…..,nb ------(22)

$(Q_{DSTATCOM(K)}) \leq Q_{DSTATCOM(K)} \leq Q_{DSTATCOM(K)}$

K=1,2,3,…..,nb ------(23)

Optimal location

We have to pre-estimate the position of the Dg and STATCOM for the desired outcome. For this, LSF is being used .But ,the estimation of LSF is mainly relying upon the network topology , structure of configuration and load and so on.

To overcome these limitations Whale optimization Algorithm is used in this proposed paper.

4.Whale optimization Algorithm

Overview

Whale optimization Algorithm has been introduced by Mirjalili and Lewis in 2016. This algorithm is based on whale's hunting behaviour . At first , whales

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search for a prey .When it is found ,they swim around the prey and develop distinctive bubbles along a circle or 9-molded way. This way ,they trapped the prey and attack on it.

Based on this behaviour of humpback whales, we first search the needed location and encircle it .

This can be understand by the following equations----

$D = |C.X_{rand} - X|$ --------(24)

$X(k+1) = X_{rand} - A.D$ -------(25)

Where A & C are coefficient vectors.

$A = 2.a.r - a$ -------(26)

$C = 2.r$ ------(27)

Where the value of 'a' is linearly decreasing from 2 to 0 and 'r' is the random number between [0 ,1].

$D = |C.X^*(k) - X(k)|$ -------(28)

$X(k+1) = X^*(k) - A.D$ -------(29)

If A>1, searching prey is denoted by equation (24) and (25) and encircling prey is denoted by (28) and (29).Where k is the current iteration , X is the position vector and X*is the best value of the position vector.

4.2 Proposed Work Implementation

Whale Optimization Algorithm gives an idea for placing DG and DSTATCOM in the distribution system to reduce the power losses.This has following steps (Iranian Journal of Science and Technology,2019) as shown in the flowchart.

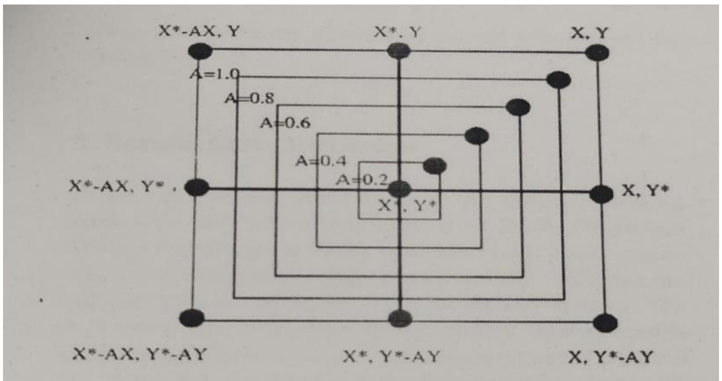

Fig. 2 Bubble net searching mechanism of WOA

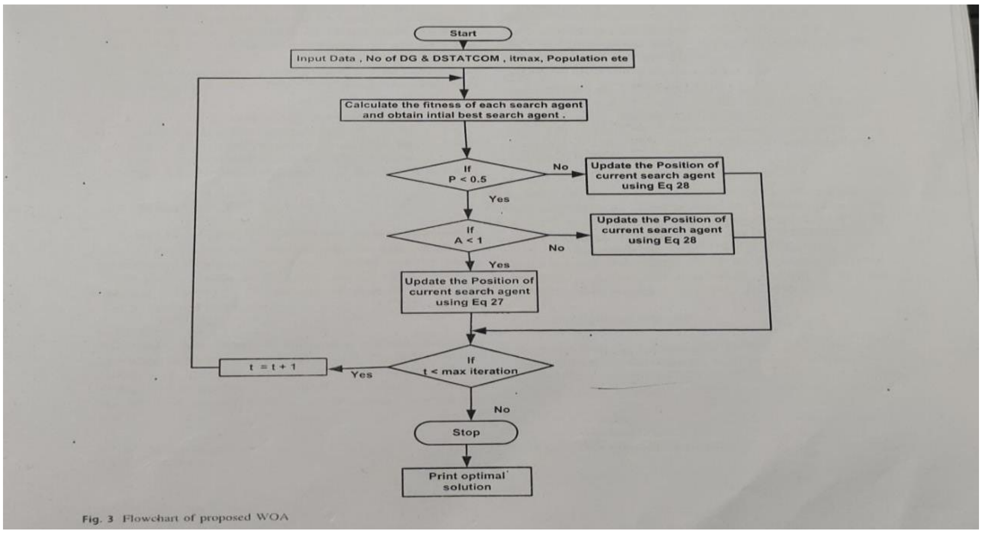

Fig. 3 Flowchart of proposed WOA

1. Initialize input data such as line data and load data.

2 .Calculate total power loss, operating cost and bus voltages using BFS method.

3. Initialize the number of search agents to be optimized. If the search agents go beyond the boundaries then bring back to within the boundary by inserting the limits.

4. Initialize the counter.

5. Calculate the fitness function for each search agent using Eq. (18) and obtain the initial best agent.

6. For each search agent update a, A, C, l and p, where l and p are random numbers.

7. If (p<0.5) go to step 8, otherwise go to step 10.

8. If |A|<1, then update the position of current search agent.

9. If |A| 1, then calculate new search agent and update its position.

10. Update the position of current search agent.

5.Result

In this paper, we consider the problems after replacement of fuel vehicles with electric vehicles on the basis of human health concern. Regarding this, we do so many practicals and come to the conclusion of using DG and DSTATCOM and its positioning should be done by Whale Optimization Algorithm. And, the utilization of the Whale Optimization Algorithm for the positioning of combined DG and DSTATCOM to minimize the system power losses, improve the voltage profile and power quality, correct power factor, balance load, avoid overload condition of feeders in distribution system and to increase overall efficiency of the system and one of the most important factor is to minimize the operational cost of the distribution system.

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