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Optimal Cost Analysisof Battery Swapping Station for EV Using PSO

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ABSTRACT: - Electric vehicles are the demand of the current scenario to fight with the increasing levels of pollution. Electric vehicles operate by getting power from the battery which needs to be charged after a particular duration. Battery swapping stations are used for providing the optimal power for charging these batteries. An algorithm known as Particle swarm optimization can be used to find the optimal cost of these battery swapping stations. The project presents an expository study about Particle Swarm Optimization and thus various factors related to it.

Keywords: - Battery Swapping Station, Battery Charging Station, Load flow Analysis, Particle Swarm Optimization

I. INTRODUCTION

Automobiles can also be called as "a necessary evil", has made living easy and convenient, they also make human life complicated and thus vulnerable to toxic emissions. Presently, fossil fuel products such as gasoline or diesel are the major source of power for vehicles. It is only a matter of time when the fossil fuel runs out. For every country, no matter developed or developing, the dependence on fossil fuels will have to be reduced to meet the demand of power in future. But, the consumption of Petroleum-based fuel is increasing rather it should decrease, the world current consumption of oil is about 100.63 million barrels per day whereas it was about 85.8 million barrels per day in the year 2008. Increasing demand of vehicles powered by fossil fuels has led to increasing of air pollution as the concentration of carcinogenic substances such as Sulphur Dioxide (SO2) and Nitrogen Dioxide (NO2) have increased by a considerable amount. Among the world's 30 most polluted cities, 21 are from India as reported in the year 2019. Indian Capital, Delhi was also among them.

The present scenario is based on using fossil fuel as the major fuel for running automobiles. Consumption of these fossil fuels in the current situation has two serious drawbacks:

- If used at the current rate of consumption, will be depleted in not more than 30 years. As fossil fuel are major fuels, for some people this drawback might be the reason for concern.
- Secondly, the major problem that arises today by the immense use of fossil fuel which makes the environment around us worst.

To mitigate all these problems, there is a demand for the inventions for some alternative to sustain the environment, which can be fulfilled by the advent of Electric Vehicles.

II. ADVANTAGE ASSOCIATED WITH ELECTRIC VEHICLES

By the use of Electric Vehicle, we can reduce the expenditure on crude oil and fossil-based fuel, also dependency on fossil fuel can be reduced up to a great extent thus they have certain advantages. These advantages are listed below:

- The Electricvehicle produces fewer greenhouse gases. Even when generated from a coal-based plant, an electric vehicle would reduce carbon dioxide compared to normal vehicles emission by as much 22 per cent.
- If electricity is produced from renewable sources such as PV Cell-based, wind energy-based, Tidal based, bio gas-based etc. than Electric Vehicle can prove as the cleanest source of transportation

By the use of Electric Vehicle, we can reduce the expenditure of crude oil and fossil-based fuel, up to a great extent.

III.COST ANALYSIS:

Cost is one of the most important parameters to initiate any kind of projects. If cost establishment is optimum than it will feasible for trader to invest on it. if cost of construction is too much high then it will createhesitantamongtraders.Ifanyhowthey start the project of establishment then directly or indirectly cost have to be bear by consumers.

There are many costs associated with construction of any kind of station (either charging station or swapping station). however, mainly three type of costs are considered. These are:

•**Annual average construction cost**:This cost will cover all the basic fundamental units which will require to establish any swapping station. All the inherent cost related with construction of station will covered in this cost.

•**Grid loss cost**:This cost associated with the overall cost require to generate the amount of power which is wasted during entire transaction that is from grid to substation.

•**Station electrification costs**:This cost describes the amount of money that has to be invest on swapping station to electrify it. This cost is mainly depending on the distance of swapping station from any nearest substation.

IV.PROJECT OBJECTIVE:

Whenworkingonplanningofswappingstation,thefollowingprinciplesshouldbefully considered:

- Battery swapping station dispersion with swapping demand dispersion as far as possible.
- Swapping station dispersion with traffic flow dispersion as far aspossible.
- The nearby substation should be taken into account while planning any swappingstation.
- Requirement should be fulfilled by the radius of particular swapping station as far aspossible.
- Future development aspects should be taken into consideration while planning any swappingstation.

There are many factors as well that affect the BSS layout. Some of them are listed below:

1. Number of electrical vehicles in aregion.
2. Types of EVusers
3. Electric Vehicle chargingways
4. Battery chargingcharacteristics
5. Chargingtime
6. Chargingenvironment

If all the above mention factors are fulfilled then a swapping station can be economical and safe from future point of view. Also, the above factors will decide the overall planning efficiency of any station. If these factors are not kept in mind than overall planning cost will higher and it will directly influence the users.

- Thus, in this project, we created a function on which system parameters depends and that function will be called as the objective function.
- In our case, we have considered function of clubbed cost as objective function.
- This Objective function will be used in PSO algorithm to find out the optimal cost of battery swapping station.

V.PROPOSED TOPOLOGY:

This illustrates the topology that is used in this project to find out the optimal cost for placement of Battery Swapping Station

- Particle swarm optimization is nature-inspired and one of the most popular known metaheuristic optimization algorithms which was developed by James Kennedy and Russell Eberhart in 1995.
- It is inspired by the behaviour of "bird flocking" or "fish schooling" and thus used for minimizing the function of a population-based approach.
- Each particle is treated as a point in an N-dimensional space which adjusts its "flying" according to its own flying experience as well as flying experience of other particles.
- Particle swarm optimization algorithms is done using the steps listed below:

1. Initialize each particle.
2. For each particle calculate fitness function (objective function)
3. The fitness value of each particle is represented by P_{best}. Thus, if the fitness value is better than the personnel best value in history set the current value as the new$Pbest$.
4. Choose the particle with the best fitness value of all particle as the global best which is represented by g_{best}.
5. For each particle Calculate the particle velocity (using equation (1)) and also update particle position (using equation (2))

- Thus,each particle tries to modify its position and velocity by using the following information

1. The current position or the initial position represented byX_{ki}
2. The current velocity is represented by V_{ki}.
3. Distance between the current position and personnel best ($Pbest$) represented as P_{ki}

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4. Distance between the current position and global best ($gbest$) represented as $P_{gi.}$

so, the equations for Updated Velocityis,
$V_{(k+1)\ i}= V_{ki}+ C_1*r_1* (P_{ki} - X) + C_2*r_2* (P_{gi}- Xk_i)$ ---(1)

And Updated Position is,
$X_{k+1\ i}= X_{ki}+ V_{k+1\ i}$----------------------------------(2)

here, $r_1 and r_2$ are two random number lies between 0 and 1

$C_1 and C_2$ are accelerating factor.

$C_1*r_1* (Pk_i - X)$ = implies personnel influence value.

$C2 *r2 * (Pgi - X)$ = implies social influence value and k is iteration number.

The figure below shows the flow diagram of Particle Swarm Optimization

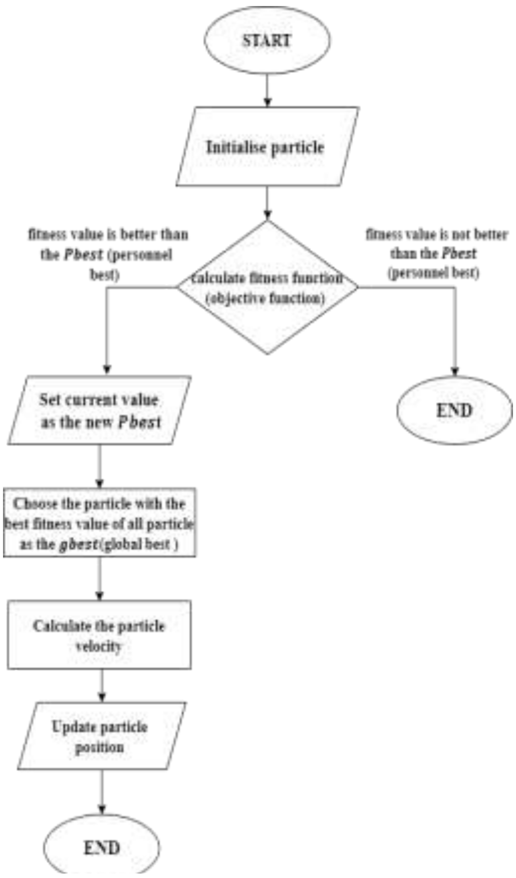

FIGURE 1: Flowchart of the PSO Algorithm.

VI.EXPERIMENTAL SETUP

All the algorithm is written in MATLAB R2018a (9.4.0.813654) software on a Laptop having AMD A10-8700P Radeon,10 computer core 4C+6G,1.80 GHZ processor and 8GB RAM.

1.ANNUAL AVERAGE CONSTRUCTION COST ($C1inRs$):

Some assumption that is taken into consideration to calculate the annual average construction cost are:
•Capacity of battery used in BSS is of 30 kwh.
•Rated capacity of a charging pile used in BSS is of 7 kw.
•Battery capital cost is 160 $/kwh i.e 12,800 Rs per kwh (assuming 1 $ = 80 Rs).
•Cost of a single port unit depends on level of charging. In our study, we are using level-1 charging from charger having rating 7 kw (200$/kw). Then, the overall cost of a single charging pile having rating 7 kw is 1,12,000 Rs.Annual construction cost can be given by the formula as mentioned below

$\mathbf{C_1}= \sum^{N}_{i=1}(r_O(1+r_O)^{m})\ (1+r_O)^{m-1}\{C_{initial}+ N_1 *x_i+ N_2 *y_i+ C_{land}*N_{bss}\}$------------—(1)

Where,
ro = rate of discount
$N1$ = unit price of battery,
$N2$ = unit price of charging pile
$Cinitial$ = station fixed cost (cost associate with basic equipment and facilities used to build a swapping station)
y_i = number of charging pile at $i'th$ station
C_{land} = cost of land
N_{bss} = number of battery swapping station
m = limit of year up to which BSS is operable

2.GRID LOSS COST (GLC_nor C_2inRs):

To find out the grid loss cost at first, we have to find the different parameters value. These parameters are discussed below:
Grid power loss (GPL): It is defined as the total power loss(TPL) when no swapping station is used.
$GPL = TPL\ [kw]\ \forall i\text{: } Si = 0$------------(2)
Where,
$Si = i^{th}$ swapping station
TPL= total power loss

Added power loss (APL_n): Added power loss $APLn$ due to connecting swapping station(i) to bus (n) is obtained by subtracting GPL from $TPLn$.
$APLn = TPLn - GPL\ [kw]$------------------(3)
Where,
$TPLn$ = Total power loss due to connection of only swapping station to bus-n.
GPL = total power loss of system when no swapping station is used.

Added Grid energy losses(AGL_n): The added grid energy loss due to swapping station(i) connected to bus(n) depends on the effective operating hours of the station.Effective operating hour can be calculated using given equation:

$H(n)$ = {$Cb(n)$/Sb(n)} ∗T[h r]-------(4)

Where,

Cb(n) = total number of EV swapped via bus (n)

Sb(n)= total number of charging pile connected to bus (n)

T = the average charging time of a battery in hour.

Thus, added grid energy losses is given by

$AGL_n = APL_n * H(n)$-------------(5)

Thus,grid loss cost can be calculated using the equation (2), (3) and (5) as

$C_2 = GLC_n = AGL_n * EP*TD$-----(6)

Where,

EP = electricity price in Rs/Kwh i.e.7 Rs/kwh

TD = total number of days in "m"years (if m = 20 $year$ then TD =7300)

3.STATION ELECTRIFICATION COST ($EC_i or C_3$):Station electrification cost depends upon the following given factors:

•Distance between BSS and point of connection with substation

•Types of conductor used for connection

•Area of conductor

To find the station electrification cost(ECi), first we have to find the application cost(ACi) of overhead line to electrify substation (i) which is given by the equation as:

AC_i = (8000 + 65.7∗ CS_i) --------(7)

Where,

ACi=application cost of overhead line to electrify substation i

CSi=cross-sectional area of overhead line ($mm2$).

Now, the station electrification cost can be expressed in term of application cost of overhead line and the distance between swapping station to nearest substation as below:

$EC_i = AC_i * d_i$ -------------------------(8)

$d_i = Min\ (d_{i,\ n})$ -----------------------(9)

Where,

di is distance of the BSS (i) to the closest substation in Km.

di,n is the distance between BSS (i) to the substation (n) in Km.

All the above three cost will be clubbed to form a single cost function and that cost function will be treated as objective function. This objective function will be used in PSO algorithm to find out optimal solution.

VII.RESULT:

CALCULATION OF ANNUAL AVERAGE CONSTRUCTION COST:

According to Indian context we are assuming the cost of land is 2,150 $Rs/m2$ for residential as well as commercial land. And we will use level-2 charging which require floor area of 693m^2 whose cost is around 14,89,950 Indian rupees. Some other parameters which were considered are below:

ro=3%

m=20

$Cinitial$ =50,2300Rs

$N1$=3,60,000Rs

$N2$=1,12,000Rs

$Cland$=2,150Rs/$m2$

$Nbss$=5

$Prated$=30kwh

After using above parameters value, the annual average construction cost as mentioned in equation (1) will become:

$C1$ = [**0. 0672156**∗ {**62, 36, 3, 750** + **3. 60. 000**(xi) +**1, 12, 000**(yi)}]

CALCULATION OF GRID LOSS COST (GLC_n):

Electricity price in this project is assumed to be 7 Rs for a unit consumption andm is taken for 20 years. So, the number pf days in the 20 year will be 7300.Hence, by assuming all the above parameters, Grid loss cost can be calculated. Simplified expression for grid loss cost is given below in equation:

$$C_2 = \frac{60841320.75}{x(1)} + \frac{1801800081.9}{x(2)} + \frac{15892419.38}{x(3)} + \frac{75262635}{x(4)} + \frac{65854805.63}{x(5)}$$

Now, these two will be clubbed to form a single equation. And that equation will be treated as objective function. Let new objective function is$C$whose value depends upon the cost function $C1$ &$C2$. That objective function will be used in PSO algorithm to determine optimal cost in terms of annual average construction cost and grid loss cost.

Bss location	Optimal no. of charging pile	Optimal no. of battery
S_{23}	20	20
S_{29}	15	15
S_{21}	12	12
S_{25}	16	16
S_{22}	15	15

Table: 1:Optimum value of charging piles and battery

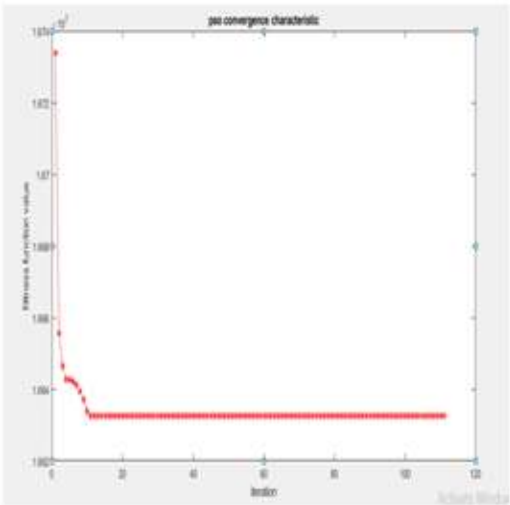

Figure 2: convergence curve for optimal annual average construction cost and grid loss cost

Thus, after applying PSOoptimization technique we are getting the overall cost including average annual and grid loss cost is about 16.734 crores for twenty years.

Calculation Of Station Electrification Cost (ECi):

To calculate the station electrification cost, we have to calculate distance between substation and battery swapping station.

We have considered Tripura Electricity Board, Agartala as a reference point. Now, from this point we will find five position for which BSS covers entire Area and as will provide optimal cost.

According to this project, the five places where BSS are installed are: -

- Between Agartala and Bodhjung Nagar
- Between Agartala and NEEPCO
- Between Agartala and Rokhia
- Between Agartala and Baramura
- Between Agartala and Dhalabir

Steps to calculate Station Electrification Cost are as follows :

- Assume the coordinates of each BSS installed between two cities.
- Calculate the distance of BSS from both end cities.
- Compare the distance & consider the distance which is minimum.
- Now, calculate application cost ($ACi = 8000 + 65.7 * CSi$) for overhead line assuming cross sectional area of conductor as 200 & 118.5 mm^2.
- Finally, calculate station electrification cost ($ECi = ACi * di$) where $di = \min(di, n)$.

After applying the steps given above, we finally got station electrification cost which is mentioned below: -

$ECi = 79025.45 * [\{(x1 - 2636.178811)^2 + (y1 + 2.495864)^2\}^{0.5} + \{(x2 - 2639.53628)^2 + (y2 + 2.643438759)^2\}^{0.5} + \{(x3 - 2612.386272)^2 + (y3 + 2.3237789)^2\}^{0.5} + \{(x4 - 2632.461535)^2 + (y4 + 3.038346256)^2\}^{0.5} + \{(x5 - 2660.187081)^2 + (y5 + 3.077399357)^2\}^{0.5}]$

Thus the Optimal cost required to electrify substation = $6.2 * 10^5\ Rs$

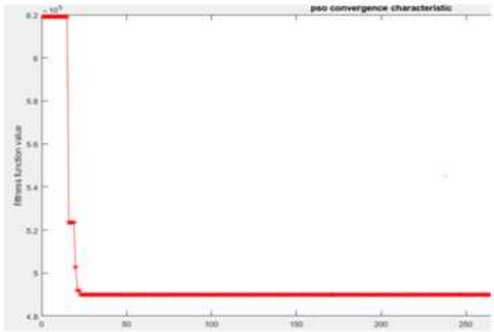

Figure 2: Convergence Curve for optimal station electrification cost

VII.CONCLUSION:

This presents the overall analysis of associated with Battery Swapping Station. In this project, a study is performed on the optimization of battery-swapping station locations analysis is done by taking samples of buses. And using PSO algorithm, an objective function (cost in thiscase) is optimized to get an optimal solution in terms of optimal cost.

IX. FUTURE SCOPE:

This project is mainly based on only one type of algorithm that is PSO (Particle Swarm Optimization), for finding the optimal location. A new algorithm such as grasshopper optimization (GO), whale optimization (WO) and grey wolf optimization (GWO) algorithm can also be used. These algorithms are also based on natural phenomenon and they have a greater capability of exploration and exploitation as compared to particle swarm optimization.

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