



OPTIMAL AND RELIABLE TRANSMISSION COST ALLOCATION USING LIGHTNING SEARCH ALGORITHM - PARTICLE SWARM OPTIMIZATION IN DISTRIBUTED ENERGY RESOURCES (DER) PLANNING

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Abstract

In the present world scenario, the Distributed Energy Resources (DERs) were getting importance because of their vital importance to plan out a well-defined scheme of Transmission Cost Allocation to the power system. This study focuses on the allocation of optimal and reliable costs for each generating unit for IEEE 30-bus system. This results in economic power generation in all the units of the distributed Energy Resources (DER). To obtain optimal and reliable cost, a cascaded algorithm combining Lightning Search Algorithm (LSA) and Particle Swarm Optimization (PSO) is employed. The LSA obtains the optimal generation unit whereas the PSO determines the optimal cost of generation. Analysis of the power flow was done using the method of Newton Raphson's method. Line Outage Distribution Factor, Transmission Reliability Margin, Generation cost and load cost are calculated before and after the line outage. The cost values obtained for the proposed approach of Transmission Cost Allocation are validated with the existing work of Transmission Cost Allocation. The proposed system results in optimal and reliable cost, with economic power generation when compared to the existing method.

Keywords: Transmission Cost Allocation, Lightning Search Algorithm, Particle Swarm Optimization, Distributed Energy Resources, Economic Power Generation

I. Introduction

Raising awareness of the need for reliable power generation, most conventional energy sources are faced with many environmental issues in a centralized power supply scheme. As a result of above, centralized electricity supply systems shift to the newly developed dispersed system technology, called distributed energy resources (DERs) [VII].

A proper price signal indication in the market environment could incentivise clients for utilizing the energy reasonably and to move towards investing for this sector. Therefore, designing a proper pricing mechanism is essentially important to sensibly distribute the transmission costs within the power system to the clients. A well-planned structure allotment plan could promote proficient utilization of transmission resources and defer the transmission extension [VIII], which upgrades the arranging of the power system's financial effectiveness. Most of the transmission costs are fixed as the transmission assets costs [XI], the real use of transmission resources by various clients ought to be reflected in the allocation scheme. Clients can decline electricity usage and transmission costs and increment long-duration earnings by deliberately arranging DERs by considering TCA on the other hand.

This work proposes LSA-PSO optimization algorithm for the optimal and reliable transmission cost allocation. The power analysis is carried out using Newton Raphson's method. Parameters such as Total generation cost, load cost, Transmission Reliability Margin (TRM), Line Outage Distribution Factor, etc. are calculated.

II. Literature Review

Galiana, F. D. et al. (2002) discussed "pool/bilateral mix and their influence in cost, power levels, prices, revenues under various curtailment strategies. Bilateral coordination contact curtailment in that work, an optimization problem of the mixed pool. A set of performance measures are then defined and tested" [VIII].

Padhy, N. P., & Kumari, L. (2004) analyzed "a commercial dispatch with independent energy producers. Both bilateral and multilateral transactions are discussed. The Injected Power is due to various transactions which can affect transmission loading and depend on transacted power, location and system conditions. Selecting an optimal location and feasible transactions are possible through this analysis" [XII].

Pipattanasomporn, M. et al. (2005) used various combinations of distributed generators with different facility outage costs along with or without an emission limitation. Estimation is made for break-even costs for micro turbines and different cost of facilities outage depending on the levels of a micro-turbine forced outage. The authors have dealt with the deployment of backup energy storage systems as DERs, based on the affect of shifting the reliability of the grid and the capital costs of Distributed Generation [VI].

Bando, S. et al. (2009) states that annual cost of a microgrid system can be minimized by taking into account the partial gas engine load efficiency. Annual operating scheduling was carried out with mixed integer non-linear programming for cost evaluation [V].

Monsef, H., & Jaefari, M. (2009) provided an allocation of transmission costs dependent on the use of the margin of reliability under the condition of contingency. A probability index is specified for this purpose. In this study the expense of unutilized facility capacity under non-contingency condition, i.e. the cost of the reliability margin, was proposed distributed to transmission users after an analysis of contingency [XIV].

El Ela, A. A. et al. (2010) has presented an effective and reliable evolutionary way for Optimal Power Flow problem for the system. Solution utilizes differential evolution algorithm for optimal settings of factors for the management of the OPF issue. The suggested solution is investigated and evaluated with the IEEE standard 30-bus test system with different objectives which affect the improvement of voltage profile, fuel cost, and improvement of voltage stability [I].

Sivasubramani, S., & Swarup, K. S. (2011) suggest a multi-objective harmony search (MOHS) algorithm for the Optimal power flow problem. This problem is defined as a non-linear, multi-objective optimization issue, where multi objectives and constraints have taken under consideration within the formulation. Fast elitist undominated sorting and crowding remove Techniques were utilized to discover and oversee the optimal front of the Pareto. Fuzzy based mechanics utilized for the selection to a satisfactory solution from the set of Pareto [IX].

Basu, M. (2011) proposed a multi objective differential evolution technique for economic environmental dispatch [V]. Basu, A. K. et al. (2011) using the Partial Swarm Optimization (PSO) technique, achieved the highest benefit-to-cost ratio of a microgrid owner. An optimal selection of size and separation of the micro-generator is made through the maximum benefit-to-cost ratio. [XV].

Duman, S. et al. (2012) proposed to estimate the optimum solution for the Optimal Power flow problem by the Gravitational Search Algorithm (suggested method is to evaluate the optima settings of the for the control variable of the Optimal power flow problem). Suggested method is used to determine the optimum settings of control variables for the Optimal power Flow problem. Suggested method is examined and evaluated with various objective functions [III].

Naderi, E. et al. (2012) presented a model for an effective planning for the distribution system by considering Distributed Generation (DG). In this model, OPF is implemented to minimize the capital cost for improving the network, maintenance costs, and the cost of load growth [II].

Soares, T. et al. (2015) suggested methodology for allocating costs for the distribution network to all consumers who use the network over each period [IV]. But only operating costs were allocated by neglecting the reserved capacities which are kept in aside for contingencies and planning.

Yang, Z. et al. (2015) proposed a structural distribution of transmission costs focused on the identification of capacity utilization. The transmission capacity (TC) is partitioned into four categories: capacity utilized in normal conditions (CN), capacity reserved for contingencies (CC), capacity reserved for future utilization (CF) and

invalid capacity (IC). And the cost of the and invalid capacity would not be distributed to organize clients [XI].

Wang, J. et al. (2017) presented “The structural TCA, an optimal planning approach with a proposed model for Distributed Energy Resources were formulated. Proposed TCA scheme considered the effects of DERs. If the Distributed Energy Resources quick-responding service is totally used to authenticate the emerging demand help for a large power system, the system’s maximum loads can be decreased, and the problem faced due to the faults or loads which will affect the transmission assets will be mitigated or declined to a negligible value [XVI].”

Wang, J. et al. (2018) proposed a three-level mode of expansion as concern to a TCA Transmission Networks and DER’S. A co-planning framework was developed to evaluate the impacts to TCA on centralized transmission networks and DERs. The relations between energy consumers with market operator were developed as an Electric Power and Energy Contract, which was implemented by process of diagonalization method [XVIII].

III. Proposed Methodology

In this analysis, the system considered for DER planning is the IEEE 30-bus system. Transmission cost allocation is carried out using the combined model of LSA and PSO. This chapter includes the single line diagram of the 30-bus system followed by power flow analysis, the process of LSA-PSO, bilateral contracts, the calculation of Transmission Reliability Margin (TRM) and Transmission Cost Allocation. The process chart of the research work is referred in Fig. 1.

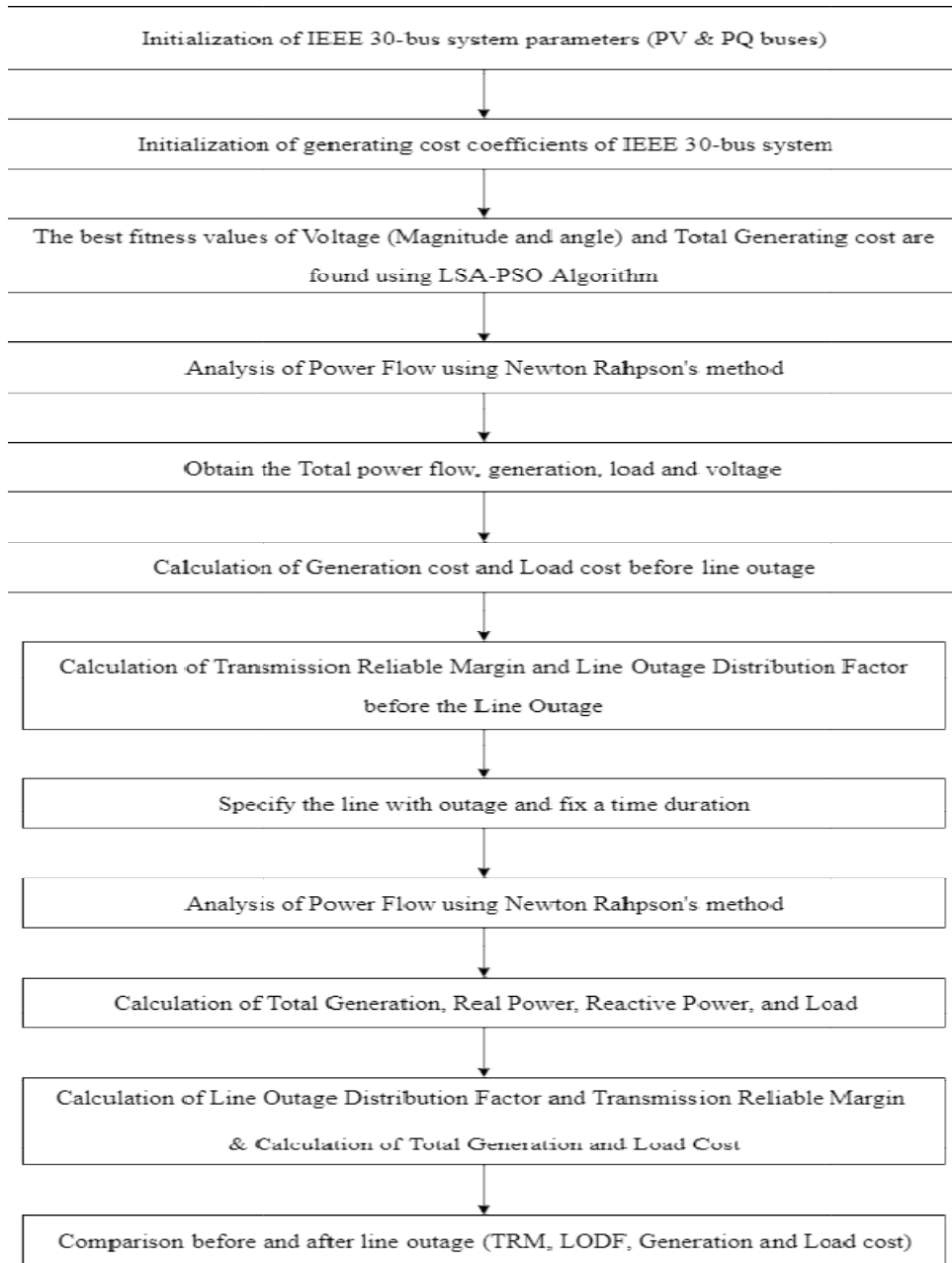


Fig. 1:The Proposed DER Planning Process

The LSA-PSO projecting worked is applied for the standard IEEE 30-bus system, which is refer in Fig. 2.

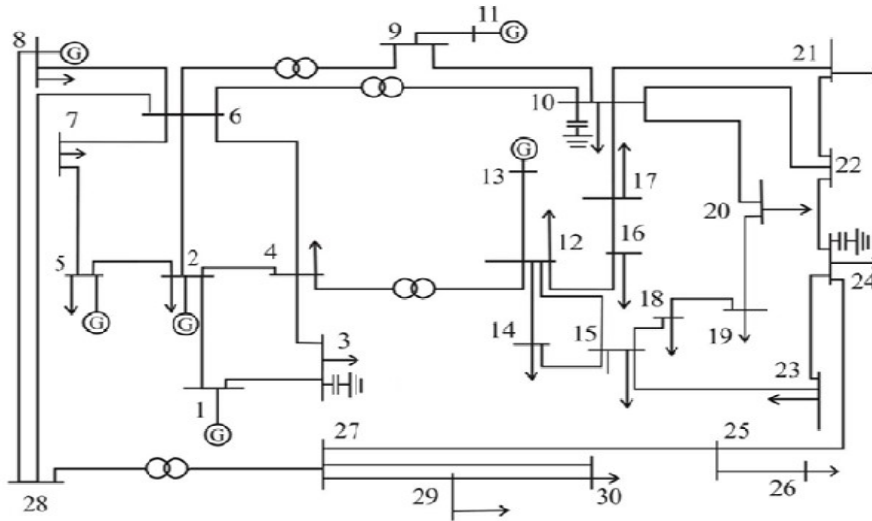


Fig. 2: Single Line Diagram of IEEE 30-Bus System

The suggested IEEE standard 30-bus system is having six generating sources i.e generated in buses numbers 1, 2, 5, 8, 11, 13. Connected to loads to the buses 2, 3, 4, 5, 7, 8, 10, 12, 14, 15, 16, 17, 18, 19, 20, 21, 23, 24, 26, 29, 30.

III.a. Transmission Cost Allocation using Lightning Search Algorithm – Particle Swarm Optimization (LSA)

Optimal transmission cost allocation in the proposed system is implemented using LSA-PSO algorithm. Initially, generating cost coefficients of each generating sources are given as inputs to the LSA. The LSA obtains the optimal generating unit by employing a lightning based optimization scheme. The optimal generating cost is obtained for the optimal generating unit using PSO algorithm. The following sub sections explain how the optimization algorithms work.

III.b. Lightning Search Algorithm (LSA)

Lightning is a natural phenomenon which is intriguing and noteworthy. The undeterministic nature of lightning discharges occurring near to the area and a convoluted feature begins from a thunder storm. The event in lightning research is among the normal focusing of lightning, the descending negative cloud-to-earth lightning flashes. Charging partition happens inside the cloud during a thunderstorm, for the most part with a +ve charge over and -ve charge in the down, This procedure makes an amazing electric field. Natural radioactivity or Cosmic radiation or produces free electrons that were normally bound to O₂ molecules to form -ve ions.

However a division or a sub part of the electron speed dissemination has sufficient energy under high electric fields to ionize the air, thus producing extra electrons at the side the initial ones. An electron avalanche at the point as any of the freely moving electrons is quickened with the field of electric in that area, at that time the probability of ionization was more than the probability of attachment. Ultimately this effect creates a negative streamer of the corona. Nevertheless, when the probability of

ionization is lower than the probability of attachment the streamers are frail and ended up electrically disconnected from their point of beginning. The implied streamer-to-pioneer alter happens when the limit channels are thermalized at huge densities of electron and temperatures.

The movement of the –ve or the step leaders as at cloud to the earth is not at all uninterrupted but it is progressing through definite and distinct steps. As concerned to the leader for movement, a layer of leaders in the particular area before the former leader channel, referred as the space leader, which will increase the preceding corona streamers. The space leader spreads and left aside until it blinds to the former leader channel that forms a large duration of time for the channel for the tip that has the same potential difference (V). During this phase a wave of current is produced.

As the wave of current comes to the new leader's tip, an eruption of crown streamers engenders out before the new tip. To create a new space leader from the current leader tip afterwards. Then, this method is repeated. The advancement could be a stochastic development prepared in this the chances of a step leader to expand a specific way was chosen with the state of the medium and the movement toward that path of the concerned electric field.

The greater -density –ve charges at the leader tip fortify a focused +ve charge to the ground as the progression heads approach the ground. At the point when the force of the electric field coming about because of the positive charges close to the ground turns out to be sufficiently enormous, positive upward streamers at the earth were retarded, along with the step leader which bridges the gap as it moves descending. This situation directs the point of lightning strike between the cloud with the most lightning current path. This stepped leader isn't the lightning strike; it fairly links with the ideal cause that will take after the strike.

The presence of quick particles which is referred as projectiles within the creation of step leader's tree structure of binary. A simultaneous arrangement of two leader tips at fork points, without the conventional step pioneer component which utilizes the streamers rule.

The LSA stepwise procedure is set out below.

Step 1: Propagation of step leader and projectile.

Step 2: projective properties. The following equation defines the properties of the projectile.

$$V_p = \left[1 - \left(\frac{1}{\sqrt{1 - \left(\frac{V_0}{c}\right)^2}} - \frac{l \alpha_i}{mc^2} \right)^{-2} \right]^{-1/2} \quad (1)$$

where V_p and V_0 represent the current and initial projectile velocity, c was the speed of light, α_i was the rate of ionization, m and l are the projectile mass and length of the path travelled. The projectile nuclei collision can be realized using the opposite number as shown in

$$\hat{p}_i = lb + ub - p_i \quad (2)$$

Where p_i and \hat{p}_i are the original and opposite projectiles, lb and ub are the boundary limits.

Step 3: Projectile modelling and step leader movement.

Step 4: Transition projectile

$$f(Z^T) = \begin{cases} \frac{1}{ub-lb} & \text{for } lb \leq Z^T \leq ub \\ 0 & \text{for } X \{ub \text{ or } Z^T\} lb \end{cases} \quad (3)$$

where Z^T is the random number which provides a solution,

Step 5: Space projectile

The probability density function(PDF) of the exponential distribution was represented as

$$f(Z^S) = \begin{cases} \frac{1}{\mu e^{-Z^S/\mu}} & \text{for } Z^S \geq 0 \\ 0 & \text{for } Z^S \leq 0 \end{cases} \quad (4)$$

where μ is the shaping parameter.

$$P_{new_i}^S = P_i^S \pm \exp r \text{ and } (\mu_i) \quad (5)$$

Step 6: Lead Projectile

The probability density function is represented as

$$f(Z^L) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(Z^L-\mu)^2/2\sigma^2} \quad (6)$$

where σ is the scale parameter.

$$P_{new}^L = P^L + \text{normr and } (\mu_L, \sigma_L) \quad (7)$$

III.c. Particle Swarm Optimization (PSO)

The technique of PSO is an adaptive process linked with the social-psychological metaphor; an individual population link up by returning stochastically to the old successful areas. Velocity and position in this technique should be continually updated. The particles are accelerated toward the last best position and to the best global position during each iteration.

The position of the particle is modified under each iteration with the recent velocity as it was counted as the distance from last best position, the distance at the best global position will be measured. Each particle's new velocity is evaluated to calculate the future position in the search space. For a number of iterations, this process will be repeated again, unless a minimum value of the error is reached.

During the optimization of PSO step, the velocity and position for the particle are shown in equations (8) and (9)

$$v_{ij} = w \cdot v_{ij} + c_1 \cdot r_1 (p_{ij} - x_{ij}) + c_2 \cdot r_2 (p_g - x_{ij}) \quad (8)$$

$$x_{ij} = x_{ij} + v_{ij} \tag{9}$$

where, c_1 and c_2 are constants from zero(0) to Four(4) and utilized as 2 in this work, w was the inertia, r_1, r_2 were random variables which were distributed randomly from zero(0) to one(1), p_g is refer to be as the best global position, x_{ij} was present position, p_{ij} the best present particle position along with v_{ij} were the particle velocity. j is an iteration number counter and i is the particle counter.

III.d. Bilateral Contracts

A bilateral contract is the exchanges between vendors and purchasers. The two conclusion parties are free to arrange their. When this exchanges are formulated, Independent System Operator (ISO) ought get informed about the business statistics data ,majorly the need for system security. Bilateral transaction matrix indicates the relation between vendors and purchasers involved in it.

Let the generation at a particular bus is i is P_{Gi} , it is concern to have a respective settlement for the stack at bus j P_{Lj} . The partition of contribution P_{Gi} to the load is P_{Lj} is referred as the division for the load required with the generator P_{Gi} with the overall generation of P_{Gi} [XV],

Let a framework with n buses and two-sided transactions can arises with any generator along with different loads located to any bus that is with the combination of generator with load are found either at the particular bus or at distinctive buses. The share of a particular generator to the system to particular load associated with the framework is referred as the utilization co-efficient matrix.

$$\begin{bmatrix} P_{L1} \\ P_{L2} \\ \vdots \\ P_{Ln} \end{bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \dots & \alpha_{1n} \\ \alpha_{21} & \alpha_{22} & \dots & \alpha_{2n} \\ \vdots & \vdots & \dots & \vdots \\ \alpha_{n1} & \alpha_{n2} & \dots & \alpha_{nn} \end{bmatrix} \begin{bmatrix} P_{G1} \\ P_{G2} \\ \vdots \\ P_{Gn} \end{bmatrix} \tag{12}$$

where, α co-efficient of use. The above matrix can be rearranged with respect to the injecting power. P_i is the active power injected to the i^{th} bus and it is given as

$$P^i = P_G^i - P_L^i \tag{13}$$

where P_L^i is the load on the i^{th} bus expressed as a whole for the usage values with distinctive generators as examined over in Eq. (12).

$$P_L^i = \sum_{l=1}^{Ngen} \alpha_{il} P_G^l \tag{14}$$

where α_{il} was the usage coefficient i.e., power fraction generated at l^{th} bus to the load with i^{th} bus and $\alpha_{il}=0$, for the state when no transaction takes place with the l^{th} generator.

with Eq. (13) , (14) in

$$P_{jk} = \sum_{i=1}^n \alpha_{jk}^i \cdot P^i \tag{15}$$

$$P_{jk} = \sum_{i=1}^n \alpha_{jk}^i \left[P_G^i - \sum_{l=1}^{Ngen} \alpha_{il} P_G^l \right] \tag{16}$$

By taking PG same for the both the terms, Eq. (15) and (16) is rewritten by taking the new term β_{il} , as

$$P_{jk} = \sum_{i=1}^n a_{jk}^i \sum_{l=1}^{Ngen} \beta_{il} P_G^l \tag{17}$$

Where l denotes generator buses.

The Eq. (17) equation is referred in matrix form as

$$\begin{bmatrix} P_1 \\ P_2 \\ \vdots \\ \vdots \\ P_{jk} \\ \vdots \\ \vdots \\ P_{nline-(nline) \times 1} \end{bmatrix} = \begin{bmatrix} a_1^1 & a_1^2 & a_1^3 & \dots & a_1^n \\ a_2^1 & a_2^2 & a_2^3 & \dots & a_2^n \\ \vdots & \vdots & \vdots & \dots & \vdots \\ \vdots & \vdots & \vdots & \dots & \vdots \\ \vdots & \vdots & \vdots & \dots & \vdots \\ a_{jk}^1 & a_{jk}^2 & a_{jk}^3 & \dots & a_{jk}^n \\ \vdots & \vdots & \vdots & \dots & \vdots \\ \vdots & \vdots & \vdots & \dots & \vdots \\ a_{line}^1 & a_{line}^2 & a_{line}^3 & \dots & a_{line}^n \end{bmatrix}_{(nline) \times n} \begin{bmatrix} \beta_{11} & \beta_{12} & \dots & \beta_{1Ngen} \\ \beta_{21} & \beta_{22} & \dots & \beta_{2Ngen} \\ \vdots & \vdots & \dots & \vdots \\ \vdots & \vdots & \dots & \vdots \\ \vdots & \vdots & \dots & \vdots \\ \vdots & \vdots & \dots & \vdots \\ \vdots & \vdots & \dots & \vdots \\ \beta_{n1} & \beta_{n2} & \dots & \beta_{nNgen} \end{bmatrix}_{n \times (Ngen)} \begin{bmatrix} P_G^1 \\ P_G^2 \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ P_G^{Ngen} \end{bmatrix}_{(Ngen) \times 1} \tag{18}$$

Where

$$\begin{aligned} \beta_{il} &= -\alpha_{il} \text{ for non-gen buses} \\ &= 1 - \alpha_{il} \text{ for gen buses } i = 1, 2, \dots, n. \end{aligned}$$

Eq. (8) is stated as

$$P_{jk} = \sum_{i=1}^n a_{jk}^i [\beta_{i1} P_G^1 + \beta_{i2} P_G^2 + \dots + \beta_{il} P_G^l] \tag{19}$$

The above equation denotes search generator share of power in line jk. The share of the lth generator to the real power flow via the line jk is

$$P_{jk}^l = \sum_{i=1}^n a_{jk}^i [\beta_{il} P_G^l] \tag{20}$$

As concern to the bilateral transaction, the negative contribution is mainly because of to the flow reverse to the heading of net flow, this process is known as counter flows. The above flows are amid in bilateral exchanges, and this cost has to paid by the network providers to perform bilateral transactions. To overcome this there is a need to compromise on using the line for negative contribution by attaining the zero counter flow method.

III.e. Modified Kirchoff Matrix

$K = [k_{ij}]$ is Kirchoff matrix $K(G)$ where K is

$$K = \begin{cases} d^{-(v_i)} & \text{for } i = j \\ -x_{ij} & \text{for } i \neq j \end{cases} \quad (21)$$

i.e., $d_{(v_i)}$ = Degree of i th vertex

$-x_{ij}$ = (i, j) the adjacency matrix entry

Newton Raphson load flow constructs a power flow matrix. This matrix provides an overview for the system's power flow in complete. This is formed between machine nodes for the given system. The proposed matrix is defined as

$$Pf_{ij} = \begin{cases} -P_{ij} & \text{for } i \neq j \text{ and } P_{ji} < 0 \\ P_{ij} & \text{for } i \neq j \text{ and } P_{ij} < 0 \\ P_{Ti} & \text{for } i = j \end{cases} \quad (22)$$

Where $p_{ij} (> 0)$ = real power for the branch $i-j$

By using eq. 12 and the above matrix is used to build as follows:

Denoting Modified Kirchhoff matrix as $K_m = (k_{ij})_{n \times n}$ of a Power Network, then the following expression for Modified Kirchhoff matrix elements is:

$$K_{ij}^m = \begin{cases} -P_{ij} & \text{for } i \neq j \text{ and } P_{ij} > 0 \\ P_{Ti} & \text{for } i = j \\ 0 & \text{otherwise} \end{cases} \quad (23)$$

Now Kirchhoff loss matrix is framed with the Modified Kirchhoff matrix above as:

$$Kl_{ij} = \begin{cases} P_{ij}^1 & \text{for } i \neq j \text{ and } P_{ij} > P_{ji} \text{ and } P_{ji} < 0 < P_{ij} \\ P_{ji}^1 & \text{for } i \neq j \text{ and } P_{ji} > P_{ij} \text{ and } P_{ij} < 0 < P_{ji} \\ 0 & \text{otherwise} \end{cases} \quad (24)$$

Where $P_{ij}^1 = P_{ij} + P_{ji}$, and $P_{ji}^1 = P_{ji} + P_{ij}$

III.f. Transmission Reliability Margin (TRM) Calculation

TRM is assumed as the usage of transmission allotted for the generator is 100 percent. The share of the generator located at the bus s to the line t is shown as

$$P_{i \rightarrow s-t} = t_{is} P_{st} a_g \quad (25)$$

The allowable value of the transmission reliability margin (TRM) to generator and load is by considering

Transmission Reliability Margin (TRM) = Maximum line capacity p.u. – usage of the line in p.u.

$$TRM_{ij} = 1 - Pf_{ij} \quad (26)$$

The Transmission Reliability Margin calculation has been considered for a particular line. Maximum capacity of all line is 1 p.u. In this equation line flows are changed in terms with the reliability margins of transmission in lines that come from TRM $_{ij}$ elements. Consequently, the TRM margin of line from the s to ballotted to the generator at bus i is provided by:

$$TRM_{i \rightarrow s \rightarrow b}^1 = t_{is} trm_{sb}^1 \quad (27)$$

Likewise, the TRM for the line s to b allotted to the load with bus j is referred as

$$TRM_{j \rightarrow s \rightarrow b}^1 = r_{js} trm_{sb}^1 \quad (28)$$

III.F. Allocation of the Transmission usage Cost

For the allocation of Transmission usage MW-Mile method is chosen, here the charges were evaluated with respect to the MW-Miles of the network utilized for the concerned client, by neglecting the power flow direction towards the concerned path. For each line optimal capacity is referred as

$$plinef_{k,m} = pline_k + LOIF_{k,m} \cdot pline_m \quad (29)$$

where $plinef_k$, m was the power flow towards the line k after an outage on line m , $pline_k$ is the power flow for the line under normal operation along with LOIF k,m is the effect of contingency occurrence line on normal line with concern to a normal line

$$F_{opt,k} = \max(|plinef_{k,1}|, |plinef_{k,2}|, \dots, |plinef_{k,K}|) \cdot \frac{F_{k,max}}{F_{k,max}^e} \quad (30)$$

where $F_{opt,k}$ is the optimal capacity for the transmission line k and $F_{k,max}$ is the short duration emergency rating of line.

$$TC_t = \sum_{k \in K} C_a * \frac{|F_{t,k}|}{F_{opt,k}} \quad (31)$$

where $a C$ was the line k th cost, $t k F$, was the flow of power in the line k due to the user t and $k max, F$ was the capacity of k th line

III.g. Line Outage Impact Factor (LOIF) and Normalized Line Outage Impact Factor (NLOIF) Calculation

The reliability margin allocation for each user, arises the value of Line outage impact factor which is evaluated as follows.

$$LOIF_{g,h}^{(ll)} = \begin{cases} \frac{P_{g,h}^{(ll)} - P_g^{(ll)}}{P_g^{(ll)}} & \text{for } P_{g,h}^{(ll)} > P_g^{(ll)} \\ 0 & \text{for } P_{g,h}^{(ll)} \leq P_g^{(ll)} \end{cases} \quad (32)$$

To determine the relative impacts of an outage for each line on a concerned line g normalization of LOIF is made:

$$NLOIF_{g,h}^{ll} = \frac{LOIF_{g,h}^{(ll)}}{\sum_{m=1, m \neq g}^e LOIF_{g,h}^{(ll)}} \quad (33)$$

Reliability contribution is calculated from the following eq.

$$P_{g,j}^{(ll)} = \sum_{m=1, m \neq g}^e LOIF_{g,h}^{(ll)} \times P_{j \rightarrow m}^{(ll)} \quad (34)$$

Where, $P_{g,j}(l)$ = Reliability contribution for the generator j on the reliability capacity for line g at load level ‘ l ’, and $P_{j \rightarrow m}(l)$ was the usage contribution for the generator j to the base-case flow towards the line m at load level l .

IV. Results and Discussion

The projected work is done through in the MATLAB 2018A system configuration i3 3rd generation, 4GbRam,. The simulation results for the proposed DER planning scheme using LSA-PSO are presented in this section. Simulation Results obtained from the proposed algorithm are then contrasted with the existing works to show that the proposed method of DER planning is superior. Fig. 3 shows the convergence curve attained for the proposed LSA-PSO algorithm.

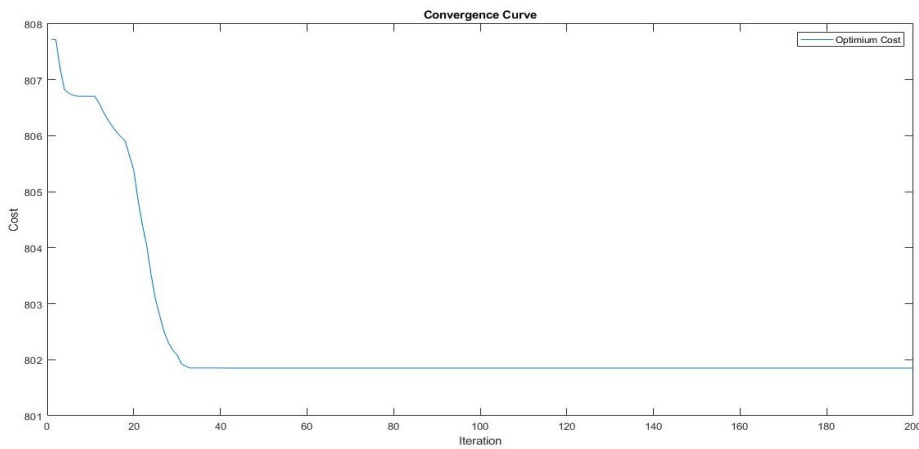


Fig. 3: Convergence Curve

It can be seen that the curve starts from the initial cost value and gradually decreases as the iteration increases. Around 35th iteration, the proposed LSA-PSO achieves convergence. For the validation of results, the optimal generation cost achieved before line outage and after line outage using the proposed methodology is compared with that of the existing methodology. The cost values obtained before line outage are tabulated in Table 1. And the cost values obtained after line outage are tabulated in Table 2.

Table 1: Comparison of Generation Costs before Line Outage

Generators at BUS	Cost(\$/h)		
	Existing	Proposed (Before line outage)	Proposed (After line outage)
1	142	0.0558	0.055296
2	67	15	15.80532
5	39	382	379.56
8	79	5.6	5.5684
11	35	14.74	14.6227

13	45	2.5859	2.564
Total	407	419	418

Table 2. Comparison of Generation Costs after Line Outage

Generators at BUS	Cost(\$/h)	
	Existing	Proposed
1	142	0.055296
2	67	15.80532
5	39	379.56
8	79	5.568499
11	35	14.62276
13	45	2.564051
Total	407	418

Before line outage, the total cost obtained for,Existing system is **4109** /- and The proposed method is**2126.503**And after line outage, the total cost obtained is **2108.516**For the validation of results, the reliability cost achieved before line outage and after line outage using the proposed methodology is compared with that of the existing methodology.

Reliability cost obtained for the existing system in sector allocations at each bus of the system is **\$2850**. And the sector average load at each load bus is **\$1749**. This has been calculated for a 20-bus system.Reliability cost obtained for the proposed system is \$2228 before line outage, and \$2126 after line outage.Whereas this is calculated for the IEEE 30-bus system.Furthermore, the comparison of generation cost and load cost for the existing system and the proposed system is given in Table 3.

Method	Load Cost (\$)	Generation Cost (\$)
Existing DER planning	4.2172	2.1264
Proposed DER planning	4.1652	2.2284

Thus the validations prove that the proposed method of DER planning produces not only the optimal cost of generation, but also improves the reliability.

V. Conclusion

In this work, the allocation of optimal and reliable transmission costs for each generating unit of the IEEE 30-bus system is done. The result is economic power generation in all the units of the DER is achieved. For obtaining optimal and reliable cost, a cascaded algorithm combining Lightning Search Algorithm (LSA) and Particle Swarm Optimization (PSO) is employed.

LSA-PSO algorithm determines the optimal cost of generation. Newton Raphson's method is used for analyzing the power flow in the system. Line Outage Distribution Factor, Transmission Reliability Margin, Generation cost and load cost are evaluated before and after the line outage. The cost values acquired for the proposed scheme of Transmission Cost Allocation are validated with that of the existing work.

The validation verifies that the proposed analysis results in optimal and reliable cost, with economic power generation when compared with the existing method. Like economic evaluation of power delivery systems comprising renewable and nonconventional energy resources, environmental analyses for different combinations of nonconventional as well as renewable energy resources can be made in the future.

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