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Utilising Ant Colony Search Algorithms to Assess the Economic Load Dispatch Issue in Power Generation Facilities

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Research Article

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Abstract: Around the globe, power companies are obligated to make sure that customers' requests for electrical energy are fulfilled in compliance with national laws. In order to meet the nation's load needs, they must also make sure that electricity is produced at the lowest possible cost. Therefore, in order to ensure the system operates economically, the entire load demand must be roughly divided among the producing units with the goal of minimizing the system's overall generation cost. The process of determining the amount of electricity to be produced by the dedicated generating units of a power system in order to reduce the system's overall production cost while simultaneously meeting the load demand, equality, and inequality requirements is known as economic load dispatch. The Ant Colony Search Algorithm (ACSA) method is used in this work to tackle the economic load dispatch issue. A meta-heuristic method for resolving challenging combinatorial optimization issues is called ACSA. This research used the Egbin Thermal Power Station in Nigeria as a case study with six generating units to evaluate the suggested method, which was implemented in MATLAB code. The Lambda technique and the ACSA outcome were compared. The results showed that the suggested algorithm is effective in finding the best solution to the issues of power loss and operational costs.

Keywords: Economic Load Dispatch, Ant Colony Search Algorithms, Operating Cost, Power plants, Optimization

1. INTRODUCTION

An significant problem in the electrical power sector has always been the efficient and cost-effective operation and administration of electrical power producing systems. The ideal mix of power producing units' production levels is required due to the expanding scale of power grids, the enormous load demand, and the ongoing increase in the cost of fossil fuels. The goal of Economic Load Dispatch (ELD) is to fulfill the different loads and losses in the power transmission system while minimizing the overall cost of power production (including fuel consumption and operating costs) of power plants. The goal is to minimize generation costs and meet operational limitations while distributing the total load demand and total loss across the producing units. The generating facilities must predict and plan the best possible energy dispatch in order to comply with the Economic Load Dispatch. Energy scheduling takes into account a number of factors, including the number of generating units that are currently in operation, the distance between load centers and the generating unit, the operating limits of each generating unit, including the ramp rate, the maximum and minimum generation level, and the maximum amount of time that the generating unit can run. In 1954, the Economic Load Dispatch was first studied using a digital computer, and it is still in use today [1].

Many approaches have been used to solve Economic Load Dispatch during the last few decades. These approaches include hybrid optimization techniques, artificial intelligence, and mathematical programming (based on classical calculus). Economic load dispatch is a non-convex problem that is more challenging to solve due to practical generation issues including multi-fuel, valve point impact, and forbidden zone. Conventional approaches continue to struggle with the non-convex optimization issue [2]. Therefore, new methods for addressing non-convex issues must be developed, particularly for large-scale systems. Because contemporary heuristic optimization approaches may discover a nearly global optimum solution, they have recently been used to tackle Economic Load Dispatch. Foraging behavior is used to move from an old population of people to a fresh population in order to find a global optimum for an optimization issue. Unlike traditional optimum algorithms, Ant Colony Search Algorithms look for many solutions at once. These days, a lot of optimization apps employ this [3].

2. Economic Load Dispatch

Finding the actual and reactive power scheduling is the primary objective of the Economic Load Dispatch for linked systems in order to lower the cost function of various producing units in the power system. Therefore, in order for the system to operate economically, the entire load demand must be distributed across all generating units in an efficient manner with the goal of minimizing the overall generation cost [1]. The process of scheduling the best possible mix of generation from all generating units in a power system to reduce the system's overall generation cost while meeting load demand, system equality, and inequality criteria is known as economic load dispatch, or ELD. The goal of economic load dispatch is to reduce current generator running costs as much as possible. The power limit restrictions of the producing units and the power balance constraint, which states that the total produced power must match the load demands plus the transmission losses on the electrical network, are the fundamental operating constraints. The distribution of the load (MW) among the different generating station units and among the various producing stations in a manner that minimizes the total cost of generation for the given load demand is the issue of economic operation of a power system, often known as optimum power flow (OPF). Reducing the power production cost function while satisfying a certain set of equality and inequality constraints is the goal of this optimization problem. Power flow analysis may be used to determine line flows, losses, and active and reactive power output for a given load demand. Additionally, the research provides various control parameters, including voltage phase differences and voltage magnitude. One way to conceptualize the economic scheduling issue is as the result of many power flow studies, one of which is deemed more suitable in terms of generating costs. Unless all of the system's restrictions are met, the solution to this issue cannot be optimum. Unit commitment (UC) and economic dispatch (ED) are the two subproblems that make up the issue of the power system's economic functioning. Economic dispatch (ED) is an online issue, while unit commitment (UC) is an offline one. Decisions on commitments are made weeks or months in advance. When a power utility decides to commit a generating unit to create energy, it indicates that it is prepared to pay fixed starting costs in order to have that generating plant ready and accessible to provide electricity in real time. Large combustion turbines and nuclear power plants are examples of generators that cannot operate at their best if their output is calculated using a single-period analysis (a "period" in the electric power industry typically refers to a length of time of about an hour). Rather, their operation has to be planned over a longer period of time—days or even weeks. Before starting a generator with a lengthy minimum run duration, a power company would need a demand prediction many weeks in advance. They would have to determine the least expensive combination of generating plants to satisfy the demand by looking at the demand estimate for those weeks. The unit-commitment decision is the name given to this choice. On the other hand, "economic dispatch" or "optimal power flow" refers to the process of allocating generating plants to satisfy consumer needs within a predetermined control footprint.

Transmission losses and high operational costs (fuel cost) are two common issues that affect economic load dispatch. The generating facilities must predict and plan the best possible energy dispatch in order to comply with the Economic Load Dispatch. Therefore, the idea is to choose the producing units as economically as possible to reduce the overall cost of meeting the system's dynamic needs [4].

2.1. Formulation of ELD Problem

The ELD problem is an optimization problem that determines the power output of each online generator that will result in a least cost system operating state.

Minimize $f(x)$ (2.1)

Subject to $g(x)$ (2.2)

$$⍰(x) \leq 0 \quad (2.3)$$

where f(x) = objective function, g(x) and h(x) are set of equality and inequality constraints respectively.

The objective of the Economic Load Dispatch is to minimize the total operating cost of a power system by adjusting the power output of each of the generators connected to the grid, while satisfying the total load demand plus transmission losses within generator limits.

The generator cost curves are modeled with smooth quadratic function given by equation (2.4) subject to the equality and inequality constraints in equations (2.5) and (2.7) respectively[2].

Minimize the cost function,

$$F_i P_i = \sum_{i=1}^{n_g} (\gamma_i P_i^2 + \beta_i P_i + \alpha_i) \quad (2.4)$$

Subject to power balance equation (equality constraint)

$$\sum_{i=1}^{n_g} P_i = P_D + P_L \quad (2.5)$$

The system losses can be determined by means of a power flow equation solution which is expressed in krons loss formula in equation (2.6).

$$P_L = \sum_{i=1}^{n_g} \sum_{j=1}^{n_g} P_i B_{ij} P_j + \sum_{i=1}^{n_g} B_{0i} P_i + B_{00} \quad (2.6)$$

And the inequality constraints,

$$P_{i(\min)} \leq P_i \leq P_{i(\max)} \quad (2.7)$$

Where $F_i P_i$ is the total generation cost, $\alpha_i, \beta_i, \gamma_i$ are cost coefficients ,P_D is the load demand,P_i is real power generation,P_L is power transmission loss ,n_g is number of dispatchable generating plants, $P_{i(\min)}$ and $P_{i(\max)}$ are the minimum and maximum power generation limits respectively.also B_{ij}, P_j, B_{0i} *and* B_{00} are B-coefficient[5].

2.2. Operating Cost of a Thermal Plant

The most efficient generator in the system does not guarantee minimum cost as it may be located in an area where fuel cost is high and also if power plant is located far from the load centre, transmission losses may be considerably higher and hence the power plant may become uneconomical. The operating cost of a Thermal Plant plays an important role in the economic scheduling of different generating plants such that the total operating cost is minimal.

The input to the thermal power plant is generally measured in Btu/h or Kcal/h and the output is measured in MW.

The input-output curve of a thermal unit is known as heat-rate curve. It is a graph drawn between fuel input in Btu/hr or kcal/hr and power output in MW on the x- and y-axis respectively. A typical heat-rate curve for a thermal unit takes the form as shown in Figure 2.1. Converting the ordinate of heat-rate curve from Btu/h to N/h results in the fuel-cost curve as shown in Figure 2.2.

In all practical cases, the fuel cost of generator *i* can be represented as a quadratic function of real power generation.

$$C_i = \alpha_i + \beta_i P_i + \lambda_i P_i^2 \quad (2.8)$$

Incremental Fuel-cost curve is obtained by plotting the derivative of the fuel-cost curve versus the real power as shown in Figure 2.3. It is a measure of how costly it will be to produce the next increment of power. It is drawn by taking the incremental fuel cost in ₦/MWh as an input on the y-axis and real power in MW as output on the x-axis.

$$\frac{dC_i}{dP_i} = 2\gamma_i P_i + \beta_i \quad (2.9)$$

The total operating cost includes the fuel cost, and the cost of labour, supplies and maintenance. These costs are assumed to be a fixed percentage of the fuel cost and are generally included in the incremental fuel-cost curve[6].

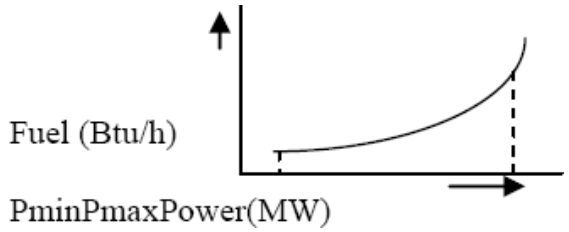


Figure2.1. *Heat curve of a Thermal Unit.*

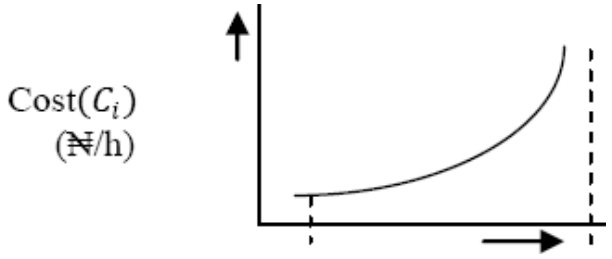


Figure2.2. *Fuel-cost curve characteristic of a Thermal Unit*

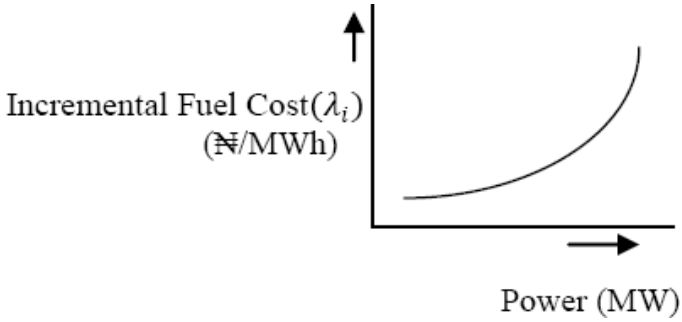


Figure2.3. Incremental Fuel-Cost Curve of a Thermal Unit

3. ANT COLONY SEARCH ALGORITHM

Inspired by ants' natural ability to discover the shortest route from a food source to their nest, the Ant Colony Search Algorithm (ACSA) is a population-based method for addressing combinatorial optimization problems. ACSA is the outcome of research on computational intelligence methods for combinatorial optimization that was first carried out by Dr. Marco Dorigo in association with Vittorio Maniezzo and Alberto Colorni. The basic methodology behind ACSA is an iterative process where a population of simple agents repeatedly builds potential solutions. This process is probabilistically guided by heuristic information about the given problem instance as well as by a shared memory that contains experience that the ants have gathered in prior iterations. A wide variety of challenging combinatorial problems have been solved using ACSA. Among them is the well-known Traveling Salesman Problem (TSP), in which a person must determine the quickest path to reach a certain number of locations [7].

3.1. Ant Colony Behaviour

Many ants have a very basic visual system. Certain creatures have total blindness. Ants often employ chemical cues to communicate with their surroundings [13]. Ants create pheromones, which they deposit on trials while searching for food. The following ants can locate food by detecting the pheromone. The double bridge experiment, which illustrates ant behavior, serves as an inspiration for ant colony algorithms. Two pathways of varying lengths link the ant nest to the food source. Ants first travel randomly, selecting a shorter or longer route with equal chance. Ants released pheromone when

they were moving. Ants were more likely to choose the route with the greatest concentration of pheromones. Ants that take the short route will return first with food. As a result, trails on shorter paths expand faster. Researchers from all around the globe have carried out a number of studies and surveys to provide better methods for stress management. The following are a few possible causes of work-related stress: interpersonal factors, work and role demands, and organizational structure [8].

4. Research Methodology

A MATLAB code was created to use the Ant Colony Search Algorithm Technique to tackle the Economic Load Dispatch issue. Cost coefficient data gathered from Egbin Thermal Power plants was used to run this MATLAB function on a Windows 7 computer. In order to ascertain their matching minimum generation fuel cost, this was done under variable load.

4.1. Ant Colony Search Algorithm For Economic Dispatch

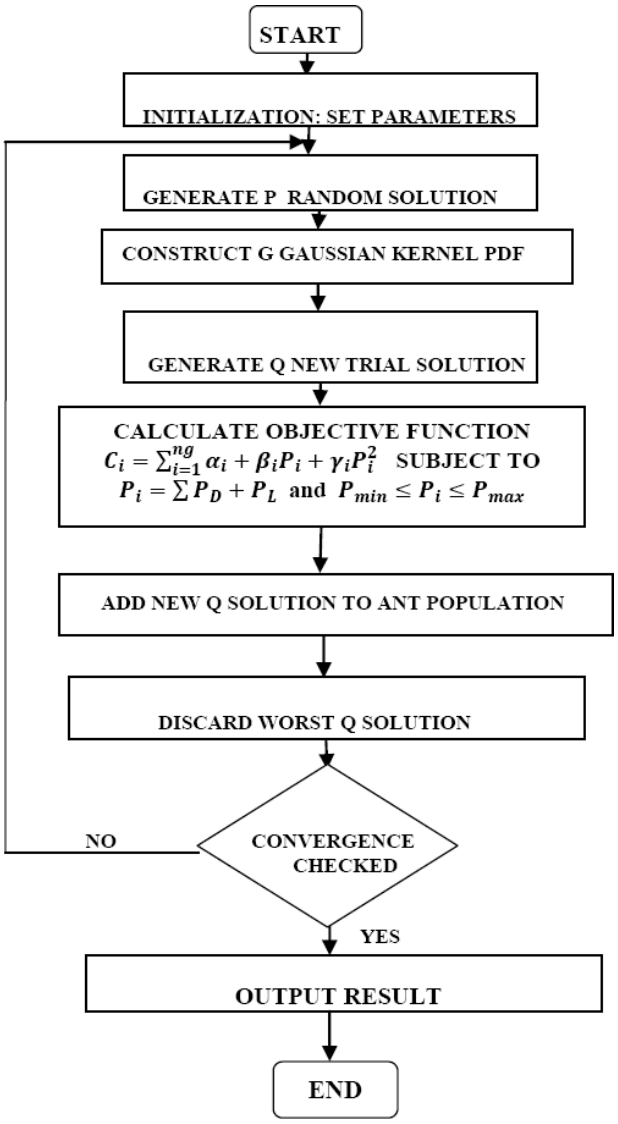


Figure4.1. *Flow Chart for Ant Colony Search Algorithm for Economic Dispatch*

4.2. ACSA Algorithm Procedures

Step 1: Initialization

In the beginning, the ACSA parameters have to be specified during initialization process. During initialization, the following parameters need to be initialized.

MaxIt = Maximum Number of Iterations.

nAnt = Number of Ants(Archives Population Size).

nSample = Number of New Ants(Sample Size).

q = Intensification Factor (Selection Pressure).

zeta(ζ) = Deviation-Distance Ratio

Step 2: Generate (P) Random Solution

The first node will be selected by generating random number based on the uniform distribution, ranging from 1 to *n*. An ant constructs a solution for the decision variable

$x_i = 1, \ldots\ldots n$by performing n construction steps.

Step 3: Construct G Gaussian Kernel PDF

At each construction step, ant k *applies* a state transition rule in order to decide which node to be visited next. The ant *k,* which is currently positioned at current node (*r*) will move to the next node (*s*) by applying the state transition rule. At the i^{th} construction step, the ant k chooses a value for the decision variable $x_i$by sampling the Gaussian kernel PDF G^i as described in equation 4.1

$$G^i_{(x)} = \sum_{i=1}^{k} w_i g_i(x) \quad (4.1)$$

Step 4: Generate Q new trial solution by sampling the G Gaussian Kernel Pdf

G^ican be defined by solving for the values of the vectors $\mu, \sigma and \omega$. The sampling process begins by first, choosing one of the Gaussian functions of the Gaussian kernel PDF. The probability ρ_l of choosing the l^{th} Gaussian function is

$$\rho_{\substack{l \\ r=1}} = \frac{\omega_l}{\Sigma^k \quad \omega_r} \quad (4.2)$$

The process of sampling the chosen Gaussian function is the same as using a random number generator that is able to generate random numbers according to a normal distribution parameterized by the l^{th} elements of the mean vector μ_i and standard deviation vector$\sigma^i l$. The whole process is performed for each dimension $i = 1, \ldots\ldots\ldots\ldots n$

Step 5: Add new solution to population

The Pheromone Update process is carried out by updating the ACSA representation of pheromone data, the solution archive Q. The solution archive is updated with the collection of freshly produced solutions.

Step 6: Discard worst Q Solution

The bad ones are eliminated. This guarantees that the ants are guided in their search by the best options.

Step 7: End Condition

When a maximum number of iterations (MaxIt) have been completed, the algorithm ends the iteration. If a better route is found throughout the process, it will be saved for later use. The optimum scheduling solution is engaged by the best route chosen among all iterations; when the termination condition is satisfied, the best solution discovered is updated and returned [9][10].

5. Simulations and Results

MATLAB R2008b software was used to model and construct the ACSA algorithm. Every software has been run on a Windows 7 computer with an Intel (R) 2.60GHz CPU and 2GB RAM. An Egbin Thermal Power Station case study was used to evaluate the algorithm's efficacy and efficiency. ACSA's impact on Economic Load Dispatch was examined and assessed. The Lambda (Classical Approach) approach was used to assess the system in comparison to ACSA.

Initial parameters to the proposed ACSA is presented as follows[11];

MaxIt = 200; Maximum Number of Iterations

nAnt = 10; Number of Ants(Archives Population Size)

nSample = 40; Number of New Ants(Sample Size)

q = 0.4; Intensification Factor (Selection Pressure)

zeta = 0.88; Deviation-Distance Ratio

5.1. Case Study: Egbin Thermal Power Station

There are six 220MW producing units in this case study. Reducing overall operating costs while maintaining system restrictions within permissible bounds is the goal. At first, it was anticipated that power loss could be minimized while lowering operational costs. Six generating units with quadratic functions make up this test scenario. as given in Table 5.1

Table5.1. *Cost coefficients for the six generators at Egbin Power Station*

Gen units	(α) alpha(N/hr)	(β) beta(N/MWhr)	(γ) gamma(N/MW^{2}hr)
1	2131.1667	13.1	0.186
2	2131.1667	13.1	0.186
3	2131.1667	13.1	0.186
4	2131.1667	13.1	0.186
5	2131.1667	13.1	0.186
6	2131.1667	13.1	0.186

Source: [12]

Table5.2. *Generating limits for 6 generators at Egbin Power Station*

Generating Units	Minimum(MW)	Maximum(MW)
1	55	220

2	55	220
3	55	220
4	55	220
5	55	220
6	55	220

Source:[12]

Table5.3. *Power Losses (B- coefficient) of Nigerian Power System*

B-coefficient data
0.0009919 0.0001556 -0.0001651 -0.0001736 -0.0001631 0.0001481 0.0001417 0.0001209 -0.0001278 -0.0001344 -0.0001263 0.0001155 -0.0001324 -0.0001169 0.0001256 0.0001321 0.0001238 -0.0001102 -0.0001408 -0.0001238 -0.0001328 0.0001396 0.0001309 -0.0001169 -0.0001332 -0.0001170 0.0001254 0.0001319 0.0001237 -0.0001105 0.0001481 -0.0001235 -0.0001290 -0.0001356 -0.0001276 0.0001190

Source: [12]

Table5.4. *Results obtained from Egbin Power Station (Comparison between Lambda Method and ACSA).*

Power Demand =500MW, Lambda = 43.38

Outputs	**Lambda Method**	**ACSA**
G1	71.116	70.401
G2	84.635	86.358
G3	83.273	87.101
G4	88.531	86.772
G5	83.304	83.535
G6	89.462	85.957
Total Generated(MW)	500.320	500.124
Total Losses(MW)	0.320	0.124
Total Generation Cost (₦/hr)	27141.209	27131.389

Table5.5. *Results obtained from Egbin Power Station (Comparison between Lambda Method and ACSA).*

Power Demand =600MW, Lambda = 49.64

Outputs	**Lambda Method**	**ACSA**
G1	83.605	84.810
G2	101.721	102.410
G3	99.768	101.220
G4	106.953	104.442
G5	99.810	101.784
G6	108.345	105.372
Total Generated Power(MW)	600.201	600.040
Total Loss(MW)	0.201	0.040
Total Generation Cost(₦ /hr)	31889.629	31862.792

Table5.6. *Results obtained from Egbin Power Station (Comparison between Lambda Method and ACSA).*
Power Demand =700MW, Lambda = 57.00

Outputs	**Lambda Method**	**ACSA**
G1	95.629	95.722
G2	118.895	124.212
G3	116.221	120.247
G4	125.627	120.903
G5	116.280	116.445
G6	127.593	122.477
Total Generated Power(MW)	700.246	700.006
Total Loss(MW)	0.246	0.006
Total Generation Cost(₦/hr)	37281.328	37251.525

5.2. Discussion of Results

Results from Tables 5.4, 5.5, 5.6, 5.7, 5.8 and 5.9 for the case study, shows that ACSA has effectively minimized the cost of generation as compared to the Lambda method. Hence the ACSA has offered better results when compared with the Lambda method. The total generation costs and transmission losses obtained via ACSA are also lower when compared with the values obtained using the Lambda method (Classical Approach).Also Figures 5.1,5.2,5.3 and 5.4 shows the convergence nature of ACSA..

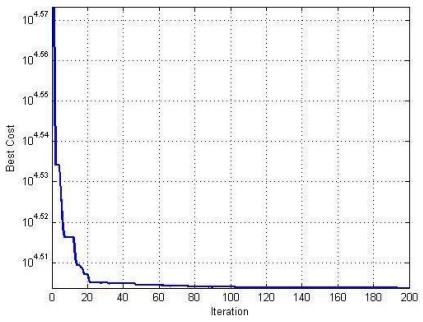


Figure5.1. *Cost curve of ACSA using Power demand of 500MW*

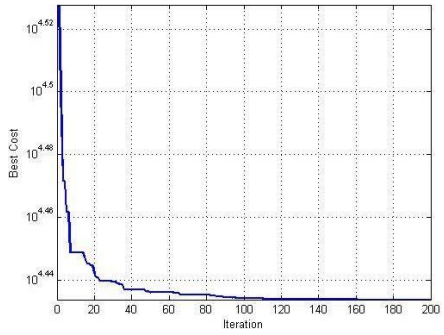


Figure5.2. *Cost curve of ACSA using Power demand of 600MW*

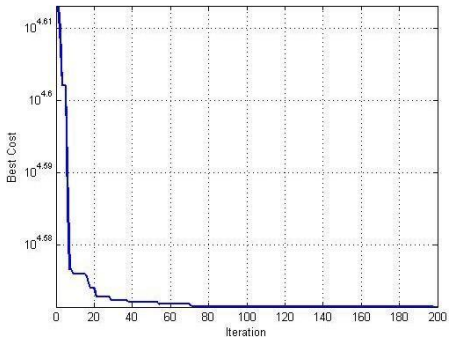


Figure5.3.*Cost curve of ACSA using Power demand of 700MW*

6. CONCLUSION

In this study, the proposed ACSA approach has been effectively applied to the power system's economic load dispatch problem. The effective use of the suggested ACSA on the Egbin thermal station while taking transmission losses into account turned out to be the necessary technique for resolving the actual power generating problem's economic load dispatch. It has been noted that under fluctuating load demand, the ACSA approach may optimize any given ELD issue. The analysis of the suggested ACSA technique, which was applied in a MATLAB environment using the Egbin Thermal Power Station as a case study while taking transmission losses into account, demonstrates that ACSA is extremely accurate, efficient, and capable of minimizing generator fuel costs while meeting all constraints. As a result, ELD issues in actual power systems may be effectively resolved using the ACSA approach.

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