Artificial Bee Colony and Cuckoo Search Algorithm for Cost Estimation with Wind Power Energy

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***Abstract* - Economic and efficient power system operation provides optimal scheduling for generators to reduce fuel cost of the generating units, in which emission is a predominant concern. This investigation deals with the hybrid approach by integrating Artificial Bee Colony (ABC) and Cuckoo Search procedures to resolve vastly constrained non-linear multi–objective crisis along with the Economic Dispatch conflicts to spotlight emission and economic objective. The mathematical ED computation for multi objective crisis is originated and changed to single objective with valve point and penalty factor methodology. Hybrid CS-ABC algorithm performance is authenticated with IEEE 30 buses which comprises of six generator systems with 10 generating unit systems. MATLAB simulation environment is utilized in this investigation for the computation of cost. The obtained results and computational time of anticipated method is contrast with ABC and CS procedure. Numerical outcomes show that the proposed hybrid algorithm has the ability to offer improved solution with reduced computational time.**

Keywords - Emission Dispatch, Economic Dispatch, Multi objective Optimization, Economic Dispatch.

I. INTRODUCTION

The unit commitment (UC) crisis dealt with optimum time of generating unit that must be operated on hourly basis to effectively sort out the load requirements. Using this

Optimization, it is probable to supply power with least losses and with reduced fuel consumption, to maximize the profit. To accomplish least total production cost, a scheduled generation needs to assure some operating constraints. The specified constraint reduces the freedom to select shutting-down and starting-up of generating units. The constraints must be satisfied with minimum down time, minimum up time, individual generating unit's restriction, limited ramp rate, power balance constraint, capacity limits, generation limit for first and last hour, spinning reserve constraint [1]-[2], group constraint, etc.

The higher dimensionality and combinatorial feature of UC problems, helps to develop an effectual mathematical optimization method, which is competent to resolve the entire crisis in the real time systems. The various investigations performed in literatures shows tremendous changes in simplification and approximation of the UC problem. In order to solve the constraints such as deterministic and stochastic loads [3]-[4], a detailed description of the recently developed optimization techniques has been proposed to sort out the UC problems.

The reminder of the work is composed of Section II related works, section III UC problem modeling, section IV illustrates the comparison of the proposed CS-ABC with the existing FA-GA, section V deals with the simulation results followed by conclusion at section VI.

II. RELATED WORKS

Amin Safari et al, demonstrates searching behavior using artificial bee colony algorithm. The wind power integration with generation and the impact of ELD are explored. The artificial bee colonies feasibility application for resolving economic load dispatch along with non-smooth and smooth cost function in accordance with systems diverse constraints have been evaluated profitably. The problem formulation with wind energy to estimate the economic advantages of wind power plant with power networks [5] has been explained. A numerical outcome obtained using four cases provides, that the anticipated procedure is competent for acquiring global solutions effortlessly, proficient and with steady dynamic convergence characteristics.

Xian Liu et al, presented a system's load dispatch model comprising both WPG and thermal generator units. In this work, constrained set values are included in the probabilistic stochastic wind power. The probabilistic infeasibility caused due to the average RVs is avoided. A threshold parameter is introduced the tolerance characteristics and shows that the complete load demand is not satisfied. Smaller consideration leads to the insufficient wind power risk mitigation, when raising the thermal power demand [6]. Wind power penetration and numerical analysis of computer program leads to analytical investigation. While there is an increase in wind speed, the optimal cost decreases in vice versa.

R. Soundarapandian, proposed an approach for unit commitment problem with wind power and pumped storage units. The proposed method is schedule for AUC of thermal generating units by considering the wind power uncertainty and PS units. The AUC schedule

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attained considers the wind uncertainty of ARMA model and PS units [7] that significantly reduce the systems total cost. The proposed method is effective, more reliable and feasible for complex problems. It was tested under IEEE 118 standard bench mark system with 4 pumped storage units and 54 thermal generator units wind plant. The numerical outcome was compared with Genetic Algorithm (GA). The comparison shows that the anticipated method minimizes the total cost effectively.

Sundaram Arunachalam, describes hybrid SA an ABC algorithm for resolving the emission and economic dispatch crisis in relation with the value point effect. The result obtained from the anticipated work has been compared with the Hybrid ABCPSCO, ABC and SA methods as in [8]. The anticipated algorithm has the ability to acquire optimal scheduling with proper computational time.

K. Chandrasekaran, anticipates fuzzified BRABC that eliminates the complete global preference information of decision maker in a multi-objective crisis and provides single optimal solution. An objective function for reducing the system reliability [9] is incorporated with MOUCP. The difficulty of fixing reliability limits is eliminated here. With the use of BRABC (heuristic approaches) and fuzzy set theory, the solution for obtaining a feasible population set has been obtained. To amplify the flipping status probability of binary variable and to enhance the binary ABC performance, a 'tanh' function is utilized. The likelihood and recital of anticipated methodology is given using benchmark test to solve objective functions of multi-objective optimization problem. The results are compared with other methods to show the superiority of anticipated methodology and its probability for resolving non-smooth multi-objective crisis [10] in the power system.

III. UC PROBLEM MODELLING

The significant method to eliminate the Unit Commitment problem has been elaborated in this section. The principle objective of this investigation is to examine the outcome of the stochastic approaches that faces UC problems devoid of the constraints associated with power flow [11]-[12]. In addition, here there is no inclusion of electric network is discussed.

$\mu_{i,}$ → Unit Commitment problems decision variables, that offers unit commitment status of unit 'k' at interval 'i';

$P_{i,}$ → 'k' unit real power generation at interval 'i'.

$\mu_{i,}$ → binary variable with value "1" during on status, and "0" at off status.

The equation (1) shows the unit objective functions:

$$\text{Min} \sum_{i=1}^{T} \sum_{k=1}^{M} \mu_{i,} k * (,k) + \mu i,k * (1 - \mu i{-}1,k)\ M\ k{=}1 * c_k{}^{star} \quad (1)$$

The objective function is the total operation costs minimization that the sum result of (i,k) and the unit's start costs, $c_k\ start$.

($,k$) i→operation cost due to generation of level unit 'k' at the interval 'i', defined by economic dispatch.

The constraints considered are given as:

$$\sum_{k=1}^{M} \mu_{i,} * P_{i,} = P_i{}^{load} - P_i{}^{wind}\ \forall \text{I} \quad (2)$$

The initial constraint represents the system power balance. The impact of generation level of committed units is equal to the level needed for load subtracting [13] the wind power generation:

$$\sum_{k=1}^{M} \mu_{i,} * P_k{}^{Min} \le P_i{}^{load} - P_i{}^{wind}\ \forall \text{I} \quad (3)$$

Equation (2) and (3) depicts the technical limits of the units' and load/reverse expected limits. Therefore, the maximum generation limits of the combined committed units should be equal to reverse or load while combined at the expected level [14]. When subtracting with the with the wind power generation (3), the sum of entire generation limits should be inferior to the expected load value, for operation period (4):

$$\mu_{i,} * P_k{}^{Min} \le P_{i,} \le \mu_{i,} * P_k{}^{Max}\ \forall\ ,\forall_k \quad (4)$$

The above mentioned equation depicts the system units' real power generation limits:

$$P_{i,} - P_{i-1,} \le R_k{}^{up} * \Delta t\ \forall_k \quad (5)$$

$$P_{i-1,} - P_{i,} \le R_k{}^{dn} * \Delta t\ \forall_k \quad (6)$$

Equation (5) and (6) signifies the ramping up and down constraints.

The ramp up Rk_{up} and down R limits the variation occurred in units' output level. Δt shows the 1 hour value.

Equation (8) and (9) are considered for executing the committed units' minimum up/down time constraints.

A. Conventional Fuel based Environment

Three costs have to be minimized in Eq. (1).
P(i, t) → 'i' unit generation at time t,
C(P(i, t)) → 'i' fuel cost at time 't'.
The second part is start-up cost and third part is shutdown cost,
Min:

$$\sum_{i=1}^{N_0} \left[C_i\big(p(i,t)\big) \right) I(i,t) + SU(i,t) + SD(i,t)] \quad (7)$$

B. Fuel based Constraint for UC

By using the resources properly, efficient power generation must be utilized properly [15]-[16]. The major economic cost dealt with the fuel cost. The fuel requirements will be reduced, by managing the generating units at off-peak load conditions:

$$F_{Min(i)} < \sum_{i=1}^{N_0} \left[C_i\big(p(i,t)\big)\right] I(i,t) + SU(i,t) < F_{Min(i)} \quad (8)$$

where $F_{min(i)}$ → 'i' unit minimum fuel consumption
and $F_{max(i)}$ → 'i' unit maximum fuel consumption
C_f → fuel consumption function; and
S_f → 'i' unit start-up fuel at time't'.

C. Economic Power Dispatch Problem

By combining the minimized fuel cost with the output of power generation unit, the economic power dispatch crisis can be sorted out [17]-[18]. The 'f' objective function, is formulated as follows:

$$min\ f = \sum_{i=1}^{n} Fi(Pi) \quad (9)$$

where F_i → total fuel cost for the i^{th} generator (in \$/h)
and Pi → power of generator 'I' (in MW).

Each generator unit has inequality constraint with each unit lies between maximum and minimum limits. The generator unit 'i' fuel cost without valve point effect is given in polynomial function:

$$F_i(P_i) = a_i P^2_i + b_i p_i + C_i \quad (10)$$

where a_i , b_i and c_i → generators cost coefficients 'i'.

There are about six dimensional optimization crisis and 30 generators are utilized in this work. The testing function and the description associated with the UC problem are also attained.

IV. PROPOSED SYSTEM

Determining the schedule for generating unit, subjective to operating constraints and power systems are known as UC. Numerous optimization methodologies have been anticipated to sort out the thermal UC problem and to resolve them. The obtainable solutions are categorized into conventional techniques, non-conventional techniques, and finally hybrid algorithm.

A. Hybrid Firefly and Genetic Algorithm for Cost Estimation

A hybrid model is developed by integrating the FA and GA algorithms which comprises of 15 Effort Multipliers (EMs). EM shows significant role in terms of cost estimation. EM factors possess linear relation with the cost and their values which is very effectual for successive investigation. In the hybrid replica, evaluation and analysis are performed using software criteria required for operational methods [19]-[20]. In the hybrid model, software complexity are evaluated which is the key factor for enhancing the performance effectively. Figure 1 shows the working functionality of the hybrid model.

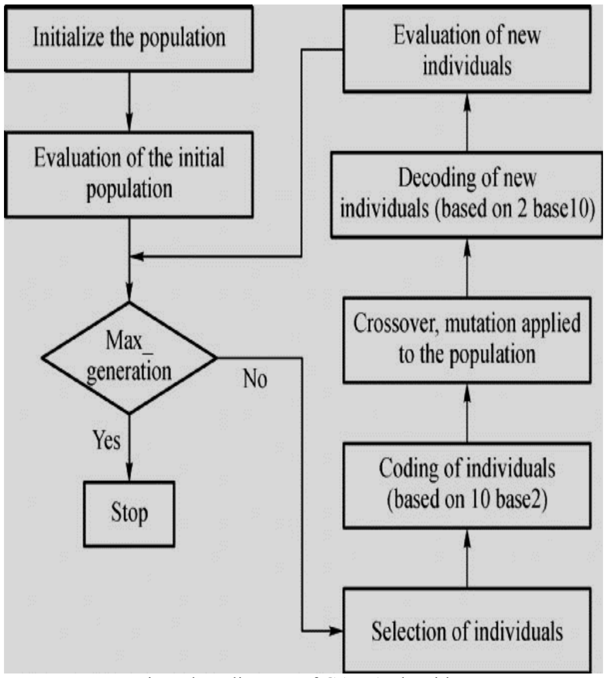

Fig : Flow diagram of GA-FA algorithm

In this hybrid replica, FA along with GA produces primary population strategy in terms of genes population adaptively. The FA convergence speeds is superior for providing convergence solutions based on absolute optimum, which shows negative effect in resolving algorithm [21].

GA compared with FA and the least possibility congregate with local optimum, alternatively there is a lack of chromosome structure, convergence, and collapse in attaining solution for an unsuitable solution which is not viable. The hybrid model adapts to continuous changes by itself and injects the best solutions obtained by FA to produce primary population for GA, and GA attempts to accomplish best outcome for cost factors through elitism and compute its fitness function [22]-[23] and offers the solution with least error as a final solution.

The hybrid model, Quasi code is:

1-GA functionality
Set size of population as N
Repeat
For i=1 to N do
Compute fitness for each N individuals
Place them based on fitness values assortment
If X >X_{besti} so
X_{besti}= X
End if
100% crossover
For N finest individuals, pertain two-parent crossover to urevisepdate
The N finest individuals.
End for
For GA-Mutation pertain PSO technique
End for
2- FA functionality
Use FA operator (compute/update light intensity)
For update t N individuals with worst fitness
Revise particles based on intensity/position
Repeat until termination criterion is attained
Algorithm 3: Pseudo-code of GA-FA

B. Hybrid Cuckoo Search and Artificial Bee Colony Algorithm for Cost Estimation

Here, the integration of Artificial Bee Colony Optimization and Cuckoo Search hybrid concept is applied for cost estimation. The main objective of this anticipated method is to circumvent the cuckoo birds' searching policy to isolate the host nest by performing ABC algorithms' global search policy.

Cuckoo search and Artificial bee colony algorithm comes under heuristics swarm intelligence. ABC algorithm projects relatively greater convergence rate, but falls in local optimum easily. Cuckoo search procedure possesses dynamic features of an intelligent procedure as well have a rapid global convergence which is not seen in particle swarm optimization and genetic algorithm. In addition, it easily escaped from local optimum. Owing to lack of information sharing approach of the individual population, the recital of the procedure based on convergence speed is restricted. This work dealt with the artificial bee colony's population updation based on improvement strategy.

It is noted that Levy flight strategy of CS algorithm possesses the global search operator characteristics but escapes from local optimum outcome. To some extent, artificial bee colony algorithm's effectual information sharing technique blemishes the Cuckoo search procedure. This work integrates the searching strategy to update the location of food source in addition to the enhancement of global search ability with artificial bee colony algorithm. With the advantages provided by the Levy flight, random walk characteristics prevents colony effectively prevents increase search space and local attractors.

$$d(p,q) = d(q,p) \quad (11)$$

$$\sqrt{(q_1 - p_1)2 + (q_2 - p_2)2} + \ldots + (q_n - p_n)2 \quad (12)$$

The process of executing the hybrid ABC-CS algorithm steps have been listed below:

1. The initial factors such as maximum amount of iterations, colony's utmost evolution generation, colony's group data and number of colonies N has to be set primarily.
2. The bee colonies food source, X (N) is randomly initialized, and individual fitness values are calculated in the population.
3. Repeat till the loop condition is fulfilled or skip to 9;
4. To generate a novel location, the employer foragers performs a global searching strategy based on equation (9); and picks up the better candidates for next generation solution with respect to the merit-based selection process.
5. Based on selection strategy, reserve or eliminate the colony; The probability of selected colony is performed based on the formula (3) and (4);
6. The locations of new food sources are selected by onlookers with accordance to $i_{p,}$ the food source location is updated using formula (9) and chooses the next generations good candidates based on greedy principle.
7. To generate novel solutions, scouts are re-initialized.
8. The colonies optimum solutions are computed and recorded then return to step (3);
9. End.

$$p_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n} \quad (13)$$

Where f_i → objective function of the problem. Compute probability value P_i using equation 9 underneath.

The following are the consecutive stages involved in the anticipated CS-ABC algorithm:

1. Emission cost, data point value and cost data of generating unit are specified using the system load.
2. The generating units' minimum and maximum operating limits are specified.
3. From the algorithm as in section 2.2, penalty factor to assimilate the multi objective crisis to a specific objective crisis is given.
4. With ABC algorithm, the penalty factor of lossless dispatch has been executed for formulating the equation (10) to (12) with 0.
5. AC power flow analysis has been carried out to acquire the B-loss coefficients [14]. For computing the real power loss in the forth coming iteration, these coefficients are cast off.

6. The control parameters with respect to ABC algorithms are initialized. The equation (10) and (12) has been solved using ABC algorithm on MATLAB environment.
7. Till achieving the max. no. of iterations ABC has been iterated.
8. Steps 7 to 10 have been compiled multiple times to attain the optimal control parameters. Thus, one control parameter remains ideal and all the others are varied. This steps shows repetition until an optimal solution is obtained.
9. With the finest control factors, ABC is executed and optimal outcome is acquired. New co-efficient are obtained using the AC load flow solution and it is considered for next iterations.
10. The starting point is obtained using ABC optimal solution (Initial guess vector) and the CS control parameters have been set.

Finally, the CS algorithm initiates search process, until it reaches the stopping criterion.

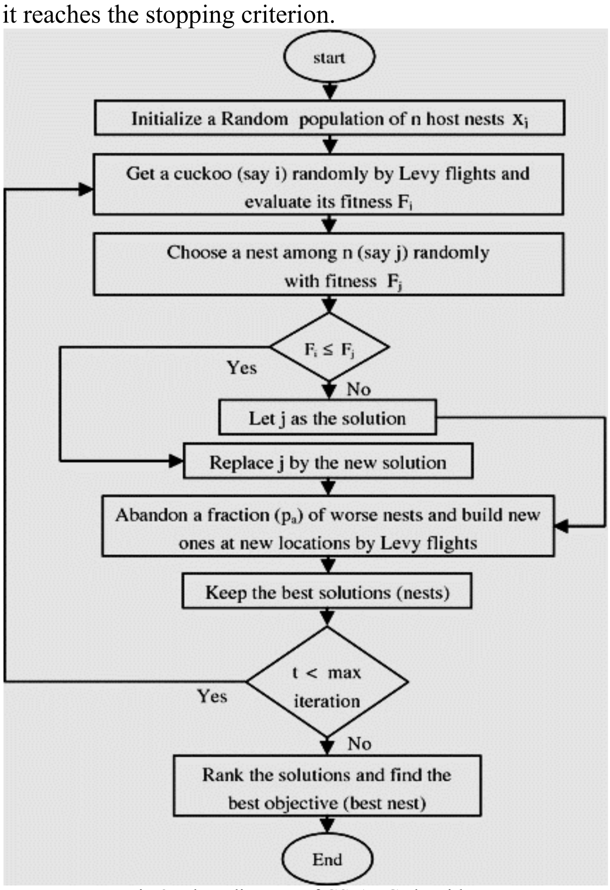

Fig 2: Flow diagram of CS-ABC algorithm

The total fuel cost and the emission cost of the thermal generating units are calculated from the obtained optimal solution.

C. Comparison of FF-GA with CS-ABC

The global minimum function of each benchmark functions are solved roughly about 20 times [20] using the algorithm with diverse initial population. For statistical analysis, the minimum and the run time function of best solution and global minimum value has been noted while performing the functions. The global minimum mean value (MeanOpt), MeanOpt' standard deviation (STD), and at last best solution (BestOpt) have been calculated with examination of traced global minimum throughout values [25]. The BestOpt values and MeanOpt, STD, are illustrated in tables II, III and IV respectively. The minimum-MeanOpt value comparison has been depicted in table V. The minimum-MeanOpt value represents minimum MeanOpt values for specific benchmark functionalities when the computation is performed using ABC and CS algorithm. The outcome of the table V represents the enhanced performance of the CS-ABC algorithms in contrast to the prevailing ABC and PSO algorithms.

TABLE I. COST ESTIMATION BASED ON CS-ABC OPTIMIZATION

WG1(MW)	120
WG2(MW)	200
Total Load Power (MW)	102
Total cost ($)	416000000

TABLE II. ESTIMATION OF WIND PROBABILITY

KM/Hr	M/Sec	Wind Probility
7.7	2.13	0.9425
8.9	2.47	0.9207
8.2	2.27	0.9207
10.0	2.78	1
13.1	3.64	0.9502
18.5	5.14	0.8884
18.1	5.03	0.8884
16.2	4.5	0.8976

V. SIMULATION AND RESULTS

A. IEEE 30 Bus System- Case study

To authenticate the anticipated technique, IEEE 30 bus test system is used. It comprises of 41 transmission lines and six generating units. Value of the point effect is not measured. 500 MW is load demand of the test system. The complete load demand of the test system is provided as 283.4MW. The real power demand is increased to 500 MW as an outcome of total demand.

Appendix table A1 depicts the fuel cost coefficients of each generator with its limiting capacity [28], [32]-[34]. The schedules of the lossless load flow and the co-

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efficient matrix to analyze the analysis of the load flow is provided in the A2 appendix table. The penalty factor to integrate multi objective crisis to specific objective crisis has been computed and provided in this section [29]-[38].

The optimal fuel cost outcome is acquired using CS-ABC algorithm and compared in the below given table III.

TABLE III: REPRESENTATION OF OPTIMAL COST ESTIMATION

OPTIMIZATION ALGORITHM	COST ESTIMATION
GA-ANN	523214.3
BAT-ANN	516347.9
Firefly-ANN	508168.5
CS-ABC	416000000

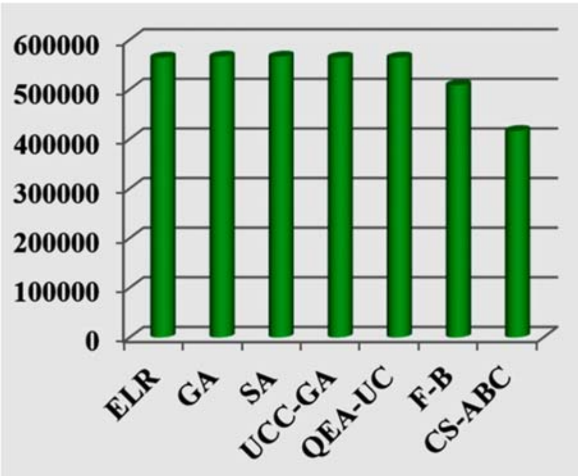

Fig 3: Cost estimation comparison with the existing algorithms

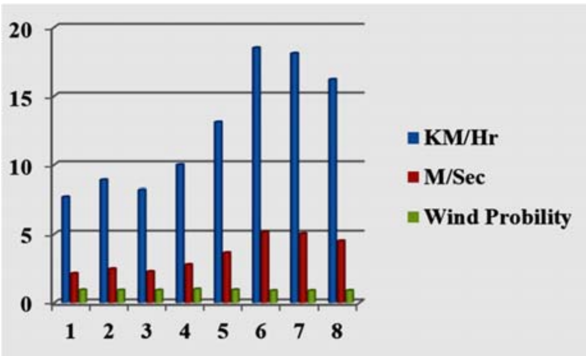

Fig 4: Graphical representation of wind probability estimation.

VI. CONCLUSION

Economic Load Dispatch and Unit Commitment (UC) are very important study as a large amount of money is optimized and saved in electric utilities which improve system reliability. This paper introduces comparison of GA-FA and CS-ABC to solve UC and then GA-FA and CS-ABC algorithm algorithms are functional to resolve the ELD crisis at 24 hours with different load demands. The optimal solution of total fuel cost and algorithmic efficiency is proved in contrast to the cost of PSO outcomes. Results obtained for different daily hour's to the test system show the robustness, consistency, quality and efficiency of the algorithm as it generates optimal solution through repetitive runs. This work investigates the UC problem completely and the techniques to eradicate the crisis with the assistance of the proposed work. The solution provides the newly evolved solutions of the hybrid model. The proposed hybrid model is the assortment of both non-classical and classical techniques. Thus, the real time UC problems are handled effectively using this technique.

This effort, also analyses about the hybrid technique which was proposed for solving the UCP in the system. The hybrid technique is the combination of enhanced Genetic algorithm and Firefly algorithm. Here, GA was used for training and enhancing their performance. Firefly algorithm was utilized to diminish the operating cost of unit system totally. Here, ten unit schemes was considered, which contains the wind power probability, system and generating unit constraints. The proposed method was implemented in Matlab/Simulink platform. Using the proposed algorithm, the optimized the cost function of UCP are determined. The proposed methods' performance is compared and evaluated with the prevailing approaches.

The anticipated technique is usually competent to produce the output effectively, in which the large scale constraints of the scheduling generators are provided to sort out the large scale optimization crisis. The anticipated method shows an efficient trade off based on cost when compared to the prevailing techniques, when validating the cost efficiency in ten-unit test system. The validated outcomes are extremely effectual in contrast to the available methodologies in the state of the art.

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APPENDIX – IEEE 30 bus system

Table A.1 represents the IEEE 30 bus test system. The shunt capacitor data, load, emission coefficients and generator cost, transmission lines respectively. With respect to non-smooth fuel cost functions based on ramp rate coefficients shows slight modification based on the IEEE 30 co-efficient cost. The available data is 100 MVA base. For complete analysis of the system with respect to Q_i^{Min}, Q_i^{Min} , - P_i^{Min} and P_i^{Max} and the value corresponding to the system analysis are -45 degree, 45 degree, 0.9 p.u, and 1 .I p.u respectively.

TABLE A1. GENERATOR COST ESTIMATION

Gen no.	P_i^{Min}	P_i^{Max}	Q_i^{Min}	Q_i^{Min}
1	50	200	-	-
2	20	80	-20	100
3	15	50	-15	80
4	10	35	-15	60
5	10	30	-10	50
6	12	40	-15	60

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