

# Enhanced Evolutionary Algorithm Based Security-Constraint Unit Commitment with Reserve Requirements

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**ABSTRACT:** Nowadays, due to the rapid development in technology load unit in a power system has been drastically improved. Eventually the generation also need to improvise to balance the load demand increments. Hence it is necessary to optimize the generation unit with the load demand to provide reliable power supply to the customers. Unit Commitment problem provides the solution for the above generation and load demand balance in optimized way issue. Unit commitment is an important optimizing task in daily operational planning of power systems which can be mathematically formulated as a large scale on non- linear mixed -integer problem for which there is no exact solution technique. It is difficult to use the Mathematical optimization technique for handling the non- linear mixed -integer problem. The above problem can be resolved by using stochastic optimization techniques. The stochastic optimization can handle any complex nonlinear problem in an easy manner. Nowadays, the evolutionary based stochastic optimization has been utilized drastically in solving the complex power system problems. One among the evolutionary algorithm is Particle Swarm Optimization algorithms (PSO) that are indeed capable of obtaining higher quality solutions efficiently in solving Unit Commitment Problems. In this work, the PSO based unit commitment method to determine the better generation unitsschedule to balance the load demand with the minimized production cost by maintaining the systems security constraints such as transmission line power flow limits and Bus voltage limits.

**KEYWORDS:** Unit Commitment (UC), Particle Swarm Optimization (PSO), Security Constraint Unit Commitment (SCUC), Fuel Cost, Production Cost, Power Generation.

## I.INTRODUCTION

The total load of the power system is not constant but varies throughout the day and reaches a different peak value from the one day to another. It follows a particular hourly load cycle over a day. There will be different discrete load levels at each period as over a day. Due to the above reason, it is not advisable to run all available units all the time, and it is necessary to decide in advance which generators are to start-up, when to connect them to the network, the sequence in which the operating units should be shut down, and for how long. The computational procedure for making such decisions is called UNIT COMMITMENT (UC), and a unit when scheduled for connection to the system is said to be COMMITTED. The problem of UC is nothing but to determine the units that should operate for a particular load. To commit a generating unit is to 'turn it on', to bring it up speed, synchronize it to the system, and connect it, so that it can deliver power to the network. The plant commitment and unit ordering schedules extend the period of optimization from a few minutes to several hours. Weekly patterns can be developed from daily schedules. Likewise, monthly, seasonal, and annual schedules can be prepared by taking into consideration the repetitive nature of the load demand and seasonal variations. A great deal of money can be saved by turning off the units when they are not needed for the time. If the operation of the system is to be optimized, the UC schedules are required for economically committing units in plant to service with the time at which individual units should be taken out from or returned to services. Security Constrained Unit Commitment (UC) is an optimization problem that schedules generators (units) to be available (committed) to provide power to consumers in a reliable and economically efficient manner. UC plays a

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central role in day-ahead scheduling and rescheduling of power systems. Commercial models include a variety of physical generator constraints and a linear approximation of power flow.

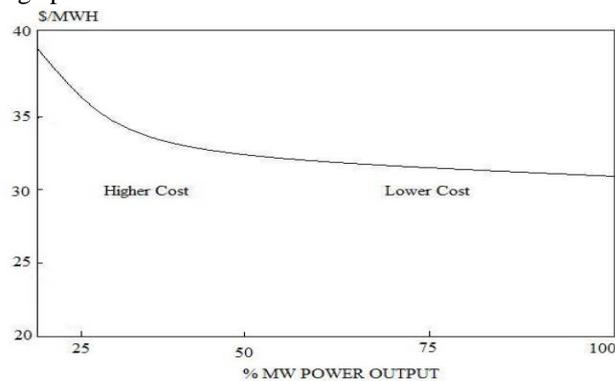
## II. RELATED WORK

Due to the nature of changing technology, unit commitment is also undergoing a change in its solution method. This is because there must be an efficient method to commit the generators to meet the load. Many methods have been introduced to solve unit commitment. Even if the methods have advantages, most of the methods suffer from local convergence and curse of dimensionality. So a new method known as PSO is introduced to solve unit commitment. One such area is the commitment of thermal units. Particle swarm optimization has roots in biological simulation and behaviour of birds and animals such as bird flocking, fish schooling, and swarming theory. It is also related to evolutionary computation, and has ties to both genetic algorithms and evolutionary programming. Particle swarm optimization as developed by the authors comprises a very simple concept, and paradigms can be implemented in a few lines of computer code. It requires only primitive mathematical operators, and is computationally inexpensive in terms of both memory requirements and speed.

## III. UNIT COMMITMENT

### UNIT COMMITMENT IN POWER SYSTEM

Many utilities have daily load patterns which exhibit extreme variation between peak and off peak hours because people use less electricity on Saturday than on weekdays, less on Sundays than on Saturdays, and at a lower rate between midnight and early morning than during the day. If sufficient generation to meet the peak is kept on line throughout the day, it is possible that some of the units will be operating near their minimum generating limit during the off peak period. When load increases the utility to decide in advance the sequence in which the generator units are to be brought in. Similarly when load decreases the operating advance in which the generator units are to be shutdown. The total operating cost involved on that day is minimum is called unit commitment problem. Start-up cost and operating cost of thermal units. Pumped storage plants do not cause direct fuel cost. Spinning reserve is down time for thermal units and pumped storage plants.



a. Average Operating Cost

### CONSTRAINTS IN UNIT COMMITMENT

Many constraints can be applied on the unit commitment problem. Each individual power system, power pool, reliability council, may impose different rules on the scheduling of units, depending on the generation.

#### Constraint I: Bus voltages

The systems Bus voltage must be maintained around its nominal value within a permissible voltage band, specified as  $[V_{\min} \ V_{\max}]$ . This can be mathematically described as:

$$V_{i \min} \leq V_i \leq V_{i \max}$$

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Where,

$V_{imin}$  is the minimum permissible voltage at  $i^{th}$  bus

$V_{imax}$  is the maximum permissible voltage at  $i^{th}$  bus

## Constraint II: Power balancing Constraints

The Power Balance constraints of each bus to be met is given as follows.

$$P_{Gi} - P_{Di} - V_i \sum_{j=1}^N V_j Y_{ij} \cos(\theta_{ij} - \delta_i + \delta_j) = 0$$

$$Q_{Gi} - Q_{Di} - V_i \sum_{j=1}^N V_j Y_{ij} \sin(\theta_{ij} - \delta_i + \delta_j) = 0$$

Where

$P_{Gi}$  is the Real Power supply by DG in p.u

$Q_{Gi}$  is the Reactive Power supply by DG in p.u

$P_{Di}$  is the Real Power Load Demand in p.u

$Q_{Di}$  is the Reactive Power Load Demand in p.u

$V_i$  is the Voltage Magnitude at the  $i^{th}$  bus in p.u.

$V_j$  is the Voltage Magnitude at the  $j^{th}$  bus in p.u.

$Y_{ij}$  is the Magnitude of the Admittance Matrix.

## III. Real Power Generation limits

The generation of the unit is under its minimum and maximum limit.

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max}$$

## IV. Minimum up Time

This constraint signifies the minimum time for which a committed unit should be turned on and removed from online.

$$T_{i,t}^{on} \geq MUT_i$$

## IV. Minimum Down Time

This constraint signifies the minimum time for which a de-committed unit should be turned on and brought on-line.

$$T_{i,t}^{off} \geq MDT_i$$

## PROBLEM FORMULATION OF UNIT COMMITMENT

The objective of the UC problem is to minimize the total operating costs subjected to a set of system and unit constraints over the scheduling horizon. It is assumed that the production cost, for unit 'I' at any given time interval is a quadratic function of the generator power output,  $p_i$ .

$$PC_i = a_i + b_i p_i + c_i p_i^2$$

Where,

$a_i, b_i, c_i$  are the unit cost coefficients. The generator start-up cost depends on the time the unit has been switched off prior the start-up cost at any given time is assumed to be an exponential cost curve.

$$SC_i = \sigma_i + \delta_i \left\{ 1 - e^{\left( \frac{-T_{off,i}}{\tau_i} \right)} \right\}$$

The hot start-up cost, the cold start-up cost and cooling time constant.

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$$OC_T = \sum_{t=1}^T \sum_{i=1}^N PC_{i,t} U_{i,t} + SC_{i,t} (1 - U_{i,t-1}) U_{i,t}$$

The overall objective is to minimize OCT subject to a number of system and constraints. All the generators are assumed to be connected to the same bus supplying the total system demand.

## UNIT COMMITMENT FORMULATION

- 1) Non-linear.
- 2) Mixed Integer Programming (MIP).
- 3) Large Scale.
- 4) Dynamic Programming (DP).
- 5) Genetic Algorithm (GA).
- 6) Lagrangian Relaxation (LR).
- 7) Benders Decomposition (BD).
- 8) Particle Swarm Optimization (PSO).

## IV. SECURITY CONSTRAINED UNIT COMMITMENT (SCUC)

Security Constrained Unit Commitment (SCUC) refers to the economic scheduling of generating units for serving the hourly load demand while satisfying temporal and operational limits of generation and transmission facilities in power systems. In a vertically integrated utility, regulatory departments apply SCUC is utilized by Independent System Operator (ISO) to clear real-time and day-ahead markets. The objective of SCUC is to minimize the social welfares based on energy and price bids submitted by market participants, generation suppliers, and load demanders. Unit Commitment (UC) remains to be one of the important daily functions for independent system operator (ISO) to clear the electric power market and for generation companies (GENCO) to analyse generation costs and determine bidding strategies. Since in the open-access market environment, the power grid is being driven to take more transaction, incorporating security related transmission constraints into the UC, called SCUC. It is the process of deciding the commitment status of generating units and dispatch levels of the units to meet all the power constraints such as generator output, power flow, power balance, spinning reserve, ramp rate and minimum up and minimum down time constraints. Total cost that includes variable operating costs, no load costs, start-up costs and shutdown costs. UC solution is considered based on uncertainly and a combination of benders decomposition to develop integrating of wind power and demand response. The UC is the one of the most important problems in power system operation. The objective function of vertically integrated utility system was minimizing the operation cost. It is an important sub-problem of production scheduling which relates to determination of the generating units to be in service (on/off) during each interval of the scheduling period, to meet system demand and reserve requirements at minimum/optimal cost for the scheduling period, subject to variety of equipment, system/operation.

## V. EVOLUTIONARY ALGORITHM (EAs)

EAs are population based, instead of using a single solution. EAs operate on a population of potential solutions applying the principle of survival of the fittest to produce better approximation is created by two process. First, selecting individuals according to their level of fitness in the problem domain. Second, breeding them together using operators borrowed from natural genetics. This process leads to the evolution of populations of individuals that are better suited to their environment than they were created from, just as in natural adaption. Evolutionary algorithms model natural processes such as selection, recombination, mutation, migration, locality and neighborhood the majority of the present implementations of EA come from any of these three basic types, which are strongly related through independently developed: Genetic Algorithm (GA), Evolutionary Programming (EP) and Evolutionary Strategies (ES).

## BASIC EVOLUTIONARY ALGORITHM

Select initial population  
Repeat  
    Evaluate population;

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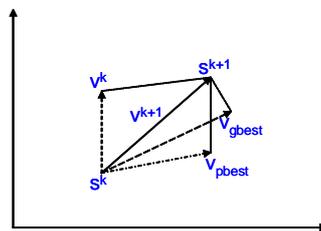
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Select mating pairs;  
Apply reproduction operators;  
Until stopping\_criteria satisfied;

## VI. PARTICLE SWARM OPTIMIZATION (PSO)

PSO is a robust stochastic optimization technique based on the movement and intelligence of swarms. PSO applies the concept of social interaction to problem solving. It uses the number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution. Each particle is treated as a point in N-dimensional space which adjusts its “flying” according to its own flying experience as well as the other particles. Each particle keeps track of its coordinates in the associated with the best solution (fitness) that has achieved so far by that particle. This value is called personal best, pbest. Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighborhood of that particle. This value is called gbest. This basic concept of PSO lies in accelerating each particle toward its pbest and the gbest locations, with a random weighted acceleration at each time step. A swarm consists of a set of particles, where each particle represents a potential solution. Particles are then flown through the hyperspace, where the position of each particle is changed according to its own experience and that of its neighbours. The global best, gbest, of PSO reflects the star neighbourhood structure. The social knowledge used to drive the movement of particles includes the position of the best particle from the entire swarm.



a. concept of modification of a searching point by PSO

## VII. PARTICLE SWARM OPTIMIZATION USING UNIT COMMITMENT METHOD

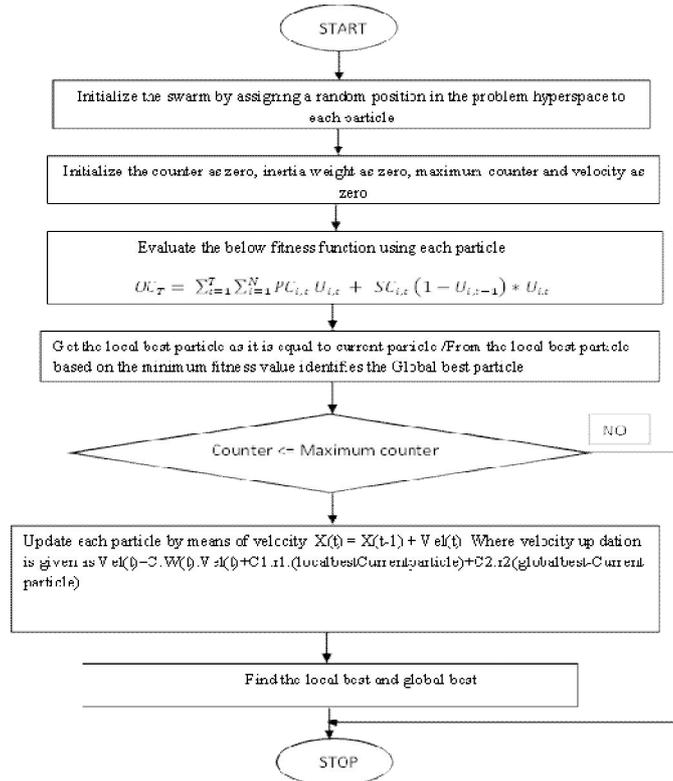
PSO is a population based searching algorithm. This approach simulates the simplified social system such as fish schooling and birds flocking. PSO is initialized by a population of potential solutions called particles. Each particle flies in the search space with a certain velocity. The particle’s flight is influenced by cognitive and social information attained during its exploration. It has very few tunable parameters and the evolutionary process is very simple. It is capable of providing quality solutions to many complex power system problems. One such problem is the unit commitment of thermal units in the power system. PSO is used to minimize the total operating cost by committing those optimal combinations of the units which satisfy the constraints and gives the minimum cost corresponding to that combination. Our main aim is to minimize the operating cost and start - up cost with respect to the equality and inequality constraints. In this problem, the up and down time of the units are taken into consideration. Here the generating units are behaving like dimension of the system. In PSO the position of both upper and lower limit of the position value of the generating units. A swarm consists of a set of particle represents a potential solutions. Where each particle represents a potential solution particles are flown through the hyperspace, where the position of each particle is changed according to its own experience and that of its neighbor. The application of PSO is generally speaking, PSO, like the other evolutionary computation algorithms, can be applied to solve most optimization problems and problems that can be converted to optimization problems. Among the applications areas with the most potential are system design, multi objective optimization, classification, pattern recognition, biological system modeling, scheduling (planning), signal processing, games, robotic applications, decision making, simulation and identification. It includes fuzzy controller design, job shop scheduling, real time robot path planning, image segmentation, EEG signal simulation, speaker verification, time frequency analysis, modeling of the spread of antibiotic resistance, burn diagnosing, gesture recognition and automatic target detection.

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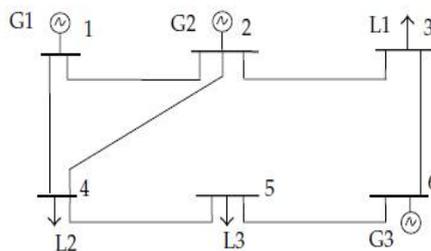
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## VII.FLOW CHART FOR PARTICLE SWARM OPTIMIZATION METHOD



a.. Flow Chart

## IX. CASE STUDY



a.Six Bus System

The six-bus system has three thermal units and seven transmission lines. The characteristics of generators, transmission lines, and the hourly load are listed. A comparative case is conducted between the generation schedules obtained from traditional SCUC formulation (denoted by TF) and the formulation presented in this paper (denoted by NF) to show the energy of generation schedule. Commitment states in TF and NF are listed in which 1/0 represents ON/OFF state of a unit, and hour 0 represents the initial ON/OFF state of the unit. It is seen that in order to minimize the total generation costs, the expensive unit. The unit 2 and unit 3, are not committed at certain hours, while the cheap unit 1 is always committed over the entire schedule horizon. Compare the power output of unit 1 in NF with that in TF. It is seen that the

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power output of unit 1 in NF with that in TF, and the areas under both trajectories are equal to hour. As observed from the labeled TF in order to satisfy the energy demand from hour, the power output of unit 1 ramps down as the maximum ramp rate from 215 MW to 185 MW and increases to 195 MW. However, the energy output if unit 1 ramps up in full speed. In comparison with TF, it is energy-realizable in the whole schedule horizon, and the ramping processes for implementing the desired energy output are also given as demonstrated. Furthermore, the piecewise-linear power output trajectory is closer to the practical operation of a generator since its power output does not change instantaneously.

## X.RESULT AND DISCUSSION

The Best on/off status of Gen1:

Ans = 1 1 1 1 1 1 1 1

The Best on/off status of Gen2:

Ans = 1 1 1 1 1 0 0 0

The Best on/off status of Gen3:

Ans = 0 0 0 0 0 1 1 1

The Best Real Generation value of Gen1 of each hr.:

Ans = 55.4531 61.6536 75.0736 99.7183 106.0419 131.4911 109.0444 105.9210

The Best Real Generation value of Gen2 of each hr.:

Ans = 115.8975 112.7877 145.8122 92.5468 124.3629 0 0 0

The Best Real Generation value of Gen3 of each hr.:

Ans = 0 0 0 0 0 105.0376 140.3088 154.4053

The Best Reactive Generation value of Gen1 of each hr.:

Ans = -4.3435 -4.5117 -7.2542 -22.6422 -11.0644 -23.8691 -14.3364 -10.3388

The Best Reactive Generation value of Gen2 of each hr.:

Ans = -30.4292 -26.8533 -24.2385 -15.0691 -11.1400 0 0 0

The Best Reactive Generation value of Gen3 of each hr.:

Ans = 0 0 0 0 0 30.8194 24.8739 22.7307

The Best Start-up cost of Gen1 for each hour:

Ans = 69.1445 0 0 0 0 0 0 0

The Best Start-up cost of Gen2 for each hour:

Ans = 144.4199 0 0 0 0 0 0 0

The Best Start-up cost of Gen3 for each hour:

Ans = 0 0 0 0 0.13 0.8979 0 0

The Best gen cost of each hour:

Ans = 1.0e+03 \*

Columns 1 through 12= 0.8766 1.5170 0 0.9528 1.4785 0 1.1192 1.8957 0 1.4297 1.2324  
0

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Columns 13 through 24= 1.5104 1.6225 0 1.8396 0 1.4596 1.5489 0 1.9058 1.5089 0  
2.0893

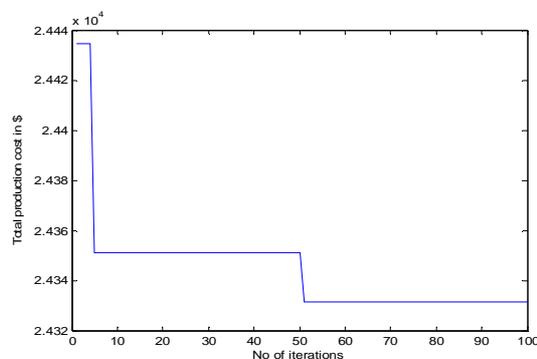
The Best total gen cost of each hour:

Ans =1.0e+03 \*2.3936 2.4313 3.0149 2.6621 3.1330 3.2993 3.4548 3.5982

The Best Fitness:

Ans =2.4332e+04

## FITNESS RESULT



a. fitness result

## XI. CONCLUSION

The security constraint unit commitment technique is used to reduce the limits violation and also reduces generation costs. It obtain load curves from the deregulated market at which some constraints such as Spinning reserve, thermal constraints are not violated. In a restructured power market, the independent system operator (ISO) executes the security-constrained unit commitment (SCUC) program to plan a secure and economical hourly generation schedule for the day-ahead market. Thereseerve requirements ensure that reserve is available to re-balance the system following a contingency but do not guarantee reliability in congested systems where reserve activation is limited by transmission constraints.

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