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EADPSODV Technique for Solving UC Problem

M Ramu, Pramod Kumar Irlapati, S.V.Bharath Kumar Reddy

Abstract: *Unit Commitment problem (UC) is a large family of mathematical optimization problems usually either match the energy demand at minimum cost or maximize revenues from energy production. This paper proposes a new approach for solving Unit Commitment problem using the EADPSODV technique. In PSODV, the appropriate mutation factor is selected by applying Ant Colony search procedure in which internally a Genetic Algorithm (GA) is employed in order to develop the necessary Ant Colony parameters. In EADPSODV method the advantageous part is that, for determining the most feasible configuration of the control variables in the Unit Commitment. An initial observation and verification of the suggested process is carried on a 10-unit system which is extended to 40-unit system over a stipulated time horizon (24hr). The outcomes attained from the proposed EADPSODV approach indicate that EADPSODV provides effective and robust solution of Unit Commitment.*

Keywords: *Unit commitment, Economic Dispatch, ADPSODV.*

I. INTRODUCTION

Unit commitment (UC) is an optimization problem used to determine the operation schedule of the generating units at every hour interval with varying loads under different constraints and environments. The calculations involving the scheduling of the on/off timings of a set of generation units present in a power system under specified system constraints (namely- minimum up- and down-time constraints, generation constraints and reserve constraints) and to find out the total cost for this particular generation is called a Unit Commitment Problem (UCP) [1-3].The popular techniques available to solve the UCP are branch and bound [4], dynamic programming [5], Lagrangian programming [6], genetic algorithm [7], differential evolution [8], hybrid methods [9-10]. Recently an innovative Heuristic search algorithm based on Newton's gravitational rule is gravitational search algorithm (GSA) was suggested. In specific, gravitational law and law of motion are used in the search process [11-12]. In this paper, a new technique called EADPSODV is proposed. To solve the UCP, LR method is used. EADPSODV will be using the ant colony search system to realize the appropriate mutation operator for a faster pursuit in attaining a global solution. Here, the mutation operation of DE is combined with velocity part of PSO [13-16].

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* Correspondence Author
M Ramu, Electrical and Electronics Engineering, GITAM University, Visakhapatnam, India.
Pramod Kumar Electrical and Electronics Engineering, GITAM University, Visakhapatnam, India.
S.V.Bharath Kumar Reddy, Electronics and Instrumentation Engineering, GITAM University, Visakhapatnam, India.

II. MATHEMATICAL FORMULATION OF UNIT

This objective function is written as:

$$F(P_i^t, U_{i,t}) = \sum_{t=1}^{T}\sum_{i=1}^{N}[F_i(P_i^t) + ST_{i,t}(1-U_{i,t-1})]U_{i,t} \qquad (1)$$

Subject to the following constraints

A. Power balance constraint

$$\sum_{i=1}^{N} P_i^t U_{i,t} = P_D^t \qquad (2)$$

B. Spinning reserve constraint

$$\sum_{i=1}^{N} P_{i,\max} U_{i,t} \geq P_D^t + R^t \qquad (3)$$

C. Generator limit constraints

$$P_{i,\min} U_{i,t} \leq P_i^t \leq P_{i,\max} U_{i,t},\ i = 1,....,N \qquad (4)$$

D. Minimum up and down time constraints

$$U_{i,t} = \begin{cases} 1, & if\ T_{i,on} < T_{i,up}, \\ 0, & if\ T_{i,off} < T_{i,down}, \\ 0\ or\ 1, & otherwise \end{cases} \qquad (5)$$

E. Startup cost

$$ST_{i,t} = \begin{cases} HSC_i & if\ T_{i,down} \leq T_{i,off} \leq T_{i,cold} + T_{i,down}, \\ CSC_i & if\ T_{i,off} > T_{i,cold} + T_{i,down} \end{cases} \qquad (6)$$

III. LAGRANGIAN RELAXATION

LR method is employed to mitigate the coupling constraints present in UCP, which is truly comprehended through dual optimization method [6].

$$L(S,V,\lambda,\mu) = F(S_i^t, V_{i,t}) + \sum_{t=1}^{T}\lambda^t (S_D{}^t - \sum_{i=1}^{N} S_i{}^t V_{i,t})$$
$$+ \sum_{t=1}^{T}\mu^t (S_D{}^t + R^t - \sum_{i=1}^{N} S_{i,\max} v_{i,t}) \qquad (7)$$

In reference to nonnegative λ^t and μ^t, However, curtailing them in regard to additional control variables in problem, i.e.

$$q^*(\lambda,\mu) = Max_{\lambda^t,\mu^t}\, q\ (\lambda,\mu) \tag{8}$$

$$q\ (\lambda,\mu) = Min\ S_i^t, U_{i,t}\ L\ (S,S,\lambda,\mu) \tag{9}$$

For the thermal generators considered here, Equations (2) & (3) show the requisite coupling constraints.
Lagrangian function is rewritten as

$$L = \sum_{i=1}^{N}\sum_{t=1}^{T}\{[F(S_i^{\ t}) + ST_{i,t}(1-V_{i,t-1})]V_{i,t} - \lambda^t S_i^{\ t} V_{i,t}$$

$$-\mu^t S_{i,\max} V_{i,t}\} + \sum_{t=1}^{T}(\lambda^t S_D^{\ t} + \mu^t (S_D^{\ t} + R^t)) \tag{10}$$

$$\sum_{t=1}^{T}\{[F(S_i^{\ t}) + ST_{i,t}(1-V_{i,t-1})]V_{i,t}$$

$$-\lambda^t S_i^{\ t} V_{i,t} - \mu^t S_{i,\max} V_{i,t}\}$$

The qualification of coupling constraints is carried out later in the thermal units. The finest value for LR function is obtained for each individual unit within the specified duration-i.e.,

$$Min S_i^{\ t}, V_{i,t} L(S,V,\lambda,\mu) =$$

$$\sum_{t=1}^{N}\min\sum_{t=1}^{T}\{[F(S_i^{\ t}) + ST_{i,t}(1-V_{i,t-1})]V_{i,t}\} - \lambda^t S_i^{\ t} V_{i,t} - \mu^t S_{i,\max} V_{i,t} \tag{11}$$

Subjected to $V_{i,t} S_{i,\min} \le S_i^t \le V_{i,t} S_{i,\min}$

For t=1..., T and the constraints in equation (6)

On/Off commitment guidelines:

Dynamic programming is an optimization approach that transforms a complex problem into a sequence of simpler problems; The dual condition is attained by applying Dynamic for individual units as portrayed in fig.1,which displays the only two probable conditions for unit i (i.e. $U_{i,t} = 0\, or\, 1$). There is no necessity for mitigation of the function at $U_{i,t} = 0$ state, so it is put on hold.

At $U_{i,t} = 1$,

The mitigated of function is set to $\left[F_i\left(P_i^t\right) - \lambda^t P_i^t\right]$. Subsequently, the mitigated function, in regard to P_i^t and the term $\mu^t P_{i,\max}$ are removed.

Min $\left[F_i\left(P_i^t\right) - \lambda^t P_i^t\right]$ is mitigated to calculate dual power with the help of optimality condition

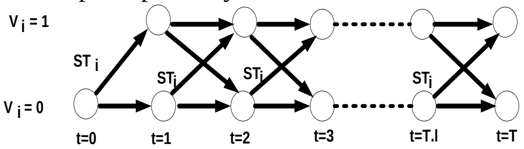

Fig. 1: Two-State Dynamic Programming

$$\frac{d}{dP_i^t}\left[F_i\left(P_i^t\right) - \lambda^t P_i^t\right] = 0 \tag{12}$$

The solution to this equation is

$$\frac{dF_i\left(S_i^{t,dual}\right)}{dS_i^t} = \lambda^t \tag{13}$$

The dual power is obtained

$$S_i^{t,dual} = \frac{\lambda^t - b_i}{2C_i} \tag{14}$$

The following cases are used to validate the limits of $P_i^{t,opt}$:

If $S_i^{t,dual} < S, then\ S_i^t = S_{i\min}$

If $S_{i\min} \le S_i^{t,dual} \le S_{i\max}$

$Then\ S_i^t \le S_i^{t,dual} \le S_{i\min}$

If $S_i^{t,dual} > P_{i\max}$ Then $S_i^t = S_{iMax}$

Optimal schedule of the generating units is chosen by Dynamic programming over the specified period of time. Evidently, a standard assessment of the start-up cost and accumulated charges is to be carried out in order to hand-pick the lowermost price for generation.

The dual power calculated will be substituted in the new On/Off decision criterion.

$$\left[F_i\left(S_i^t\right) + ST_{i,t}\left(1 - V_{i,t-1}\right)\right] - \lambda^t S_i^t - \mu^t S_i^t - \mu^t S_{i,\max}^t \tag{15}$$

To mitigate the above term in equation (15) at every individual hour,

If $\left\{\left[F_i\left(S_i^t\right) + ST_{i,t}\left(1 - V_{i,t-1}\right)\right] - \lambda^t S_i^t - \mu^t S_i^t - \mu^t S_{i,\max}^t\right\} \le 0$, if $U_{i,t} = 1$(i.e. minimum downtime condition) is not violated then that corresponding unit is put into commission.

IV. EADPSODV ALGORITHM

In EADPSODV, ant colony search is employed to determine the appropriate mutation factor because this inclusion acts as a catalyst in speeding up the search for attaining a global solution [14]. The velocity part of PSO in this algorithm is combined with the mutation process of DE [15]. Whereas the genetic algorithm is utilized to find the feasible values of ant colony parameters such as pheromone trail t, visibility v, evaporation factor e_f, scaling factor for the adjustment of the trace s_f [13]. The EADPSODV is discussed below as:

Step 1: *Initialization*

In this step, initialization of the population and the required control variables is carried out. Then a random initialization of ant colony parameters in terms of binary strings is done. GA is employed to bring the random value into proper feasible limits.

Step 2: Execution of the power flow and fitness value estimation for every single individual.

Step 3: *Evolving ant direction search*

The parameters t, v, e_f and s_f are normally fixed in a generic ant colony direction search. Since, the mutation operator is set based on these parameters only here a genetic algorithm is employed in order to evolve these parameters to a better optimal value. The fluctuant pheromone quantity is written as:

$$\Delta\gamma_i = \begin{cases} s_f / N, \\ 0 \end{cases} \quad (16)$$

$$N = \left| o_n / \left(o_{pr} - o_n\right) \right| \quad (17)$$

The updating of pheromone is carried out by:

$$\gamma_i^{new} = \left(1 - e_f\right)\gamma_i^{old} + e_f \Delta\gamma_i \quad (18)$$

Pi is the probability of selecting a mutation operator. Because a mutation operator is properly chosen only if next generation has better fitness that the present generation ρ_i is written as:

$$\rho_i = \left(\sum_{j=1}^{n} \left(\left(Z_{ij}^{k+1} - Z_{bj}^{k} \right) / Z_{ij}^{k+1} \right)^2 \right)^{0.5} \quad (19)$$

Where unit count is n, Z_{ij}^{k+1} and Z_{bj}^{k} are the corresponding j^{th} gene of the i-th and best individual values of $(k+1)^{th}$ and the G^{th} generations respectively.
Therefore, the possible probability function for choosing a mutation operator is:

$$P_i(x) = \frac{\gamma_i^t(x)\rho_i^v}{\sum_{i=1}^{A_p}\gamma_i^t(x)\rho_i^v} \quad (20)$$

Here t and v are parameters assigned to adjust the effect of γ_i and ρ_i respectively.

***Step 4:** Mutation operation*

Usually any probability operation ranges from 0.0 to 1.0. So for the mutation operator selection the probabilities obtained from step 2 are compared with each other and the better value among them is passed to select the required appropriate value. For illustration purpose, following mutation operators are engaged [16]:

$$\theta_d = M_c\left(Z_{s1}^k - Z_{s2}^k\right) \quad (21)$$

$$\theta_d = M_c\left(Z_{s1}^k - Z_{s2}^k\right) - M_c\left(Z_{s3}^k - Z_{s4}^k\right) \quad (22)$$

$$\theta_d = M_c\left(Z_{best}^k - Z_i^k\right) \quad (23)$$

$$\theta_d = M_c\left(Z_{best}^k - Z_{s1}^k\right) - M_c\left(Z_{s2}^k - Z_{s3}^k\right) \quad (24)$$

$$\theta_d = \left(Z_{s1}^k + Z_{s2}^k + Z_{s3}^k\right)/3 + \left(n_2 - n_1\right)\left(Z_{s1}^k - Z_{s2}^k\right) + \left(n_3 - n_2\right)\left(Z_{s2}^k - Z_{s3}^k\right) + \left(n_1 - n_3\right)\left(Z_{s3}^k - Z_{s1}^k\right) \quad (25)$$

Where

M_c Is the mutation constant, and $s1 \neq s2 \neq s3 \neq s4 \neq s5 \neq i$ are extracted from N_p population in a random manner.

Here, the trigonometric mutation operator [17] is shown through Eq. (25), and n_i, i= 1, 2, 3 are attained through:

$$n_1 = \frac{\left|f\left(Z_{s1}^k\right)\right|}{n'}, n_2 = \frac{\left|f\left(Z_{s2}^k\right)\right|}{n'} \; and \; n_3 = \frac{\left|f\left(Z_{s3}^k\right)\right|}{n'}$$

With $n' = \left|f\left(Z_{s1}^k\right)\right| + \left|f\left(Z_{s2}^k\right)\right| + \left|f\left(Z_{s3}^k\right)\right|$, where the function that has to be optimized is $\left|f\left(Z\right)\right|$.

***Step 5:** Crossover operation*

This process is carried out for diversification of next generation individuals. Here, the perturbed velocity is added to Z_i^k for generating Z_i^{k+1} i.e. the individuals for future generations.

$$v_{ij}^{k+1} = \begin{cases} w_f v_{ij}^k + \gamma_d + \beta\,\sigma\left(P_{gj} - Z_{ij}^k\right), & if \; rand\,(0,1) < CR \\ v_{ij}^k & otherwise \end{cases} \quad (26)$$

Where $i = 1, \ldots A_p$; $j = 1, \ldots n$; $n =$ is the parameter count, acceleration factor .is β, weighting factor is denoted as w_f, σ is a random number (0, 1), and σ is selected from (20)-(24) by ant direction search. w_f Is written as

$$w_f = 1 - \left(gen / gen\max\right) \quad (27)$$

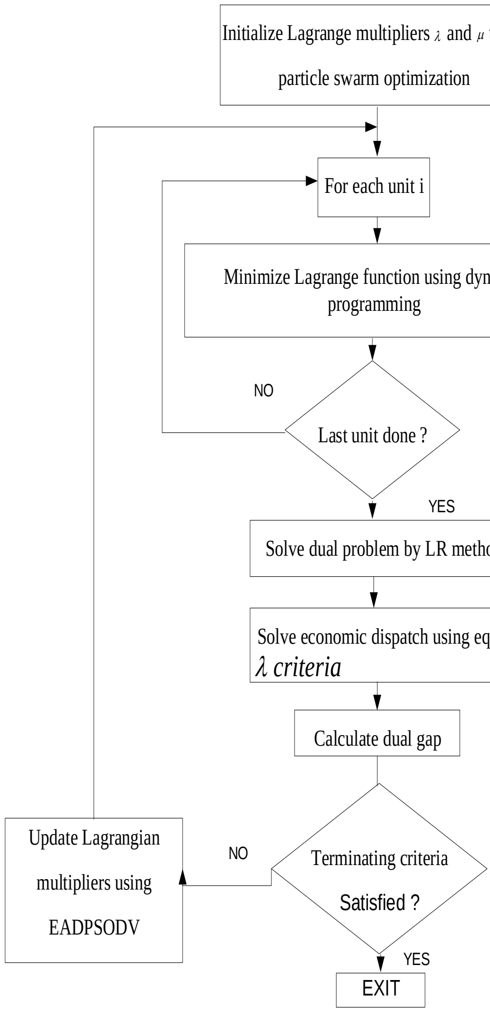

Fig. 3. Illustrates the Step by Step Process Involving in Applying EADPSODV Algorithm

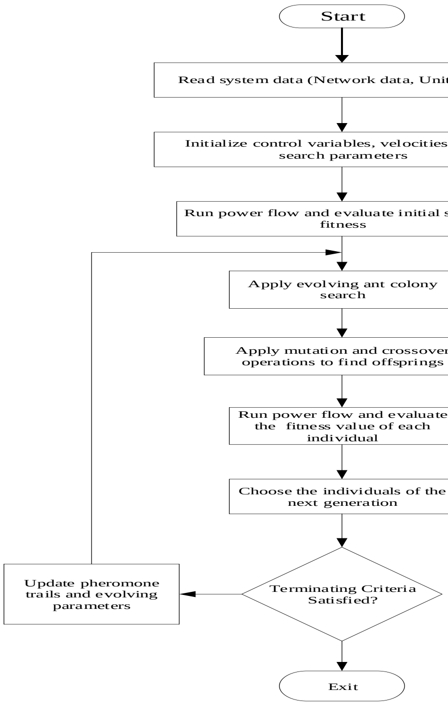

Fig. 2. Flow Chart of the Proposed EADPSODV Algorithm

V. EADPSODV ALGORITHM APPLIED TO UNIT COMMITMENT PROBLEM

The suggested method favor in managing the constraints flawlessly, which consists of a collection of real power output decision variables for each unit through-out the scheduling periods in UC problem.

Table 2: Unit commitment schedule of EADPSODV 40-unit system

40-UNIT SYSTEM
1111111100000000000000000000000000000000
1111111100000000000000000000000000000000
1111111100000000100000000000000000000000
1111111100000001111000000000000000000000
1111111100000011111100000000000000000000
1111111100011111111100000000000000000000
1111111100111111111100000000000000000000
1111111111111111111100000000000000000000
1111111111111111111111111000000000000000
1111111111111111111111111111111100000000
1111111111111111111111111111111111110000
1111111111111111111111111111111111111111
1111111111111111111111111111111100000000
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1111111111111111111100000000000000000000
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1111111111111111111100000000000000000000
1111111111111111111100000000000000000000
1111111111111111111100000000000000000000
1111111111111111111111111000111111111000
1111111111111111111111111000000000000000
1111111100001111110011111000000000000000
1111111100000000110000000000000000000000
1111111100000000000000000000000000000000

Table 1: Comparison of various methods

VI. CONCLUSION

In this paper, EADPSODV technique is proposed for solving

NO OF GENERATORS	10	20	40
LR[6]	565,825	1,130,660	2,258,503
GA[6]	565,825	1,126,243	2,251,911
EP[6]	564,551	1,125,494	2,249,093
ALR[6]	565,508	1,126,720	2,249,790
EADPSODV	**5,63,966**	**1,124,124**	**2,248,358**

unit commitment problem under specified system constraints. The results for pre-existing methods are used to validate the true efficacy of the suggested technique. This algorithm is used to simplify unit commitment problems successfully. Further work will spotlight on combination of hydro units also in the UC problem. This approach can also be featured in smart grid environments.

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AUTHORS PROFILE

M.Ramu received the B.Tech degree in Electrical and Electronics Engineering from JNT University, Hyderabad, India in 2006, M.Tech degree from GITAM University, Visakhapatnam, India in 2010. He is currently working as Assistant Professor, Dept. of EEE, GITAM University, Visakhapatnam, AP, India. His Research interests include power system operation and control, Non-conventional energy sources, power system optimization, soft computing applications.Pramod Kumar Irlapati presently pursing his M.Tech in GITAM University, Visakhapatnam. His Research interests include power systems, Non-conventional energy sources, power system optimization, heauistic applications.

S.V.Bharath Kumar Reddy received the B.Tech degree in Electronics Control Engineering from JNT University, Hyderabad, India in 2007, M.Tech degree from SRM University, Chennai, India in 2009. He is currently working as Assistant Professor, Dept. of EIE, GITAM University, Visakhapatnam, AP, India. His Research interests include power systems, Radar Signal Processing, soft computing applications.