

# A Practical Approach For Solving Unit Commitment Problem

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## Abstract

*In this paper unit commitment problem is solved by using a new evolutionary algorithm known as imperialistic algorithm. In ICA the initial populations individuals (countries) are the countries are in two types: imperialistic and colonies that all together form some empires. Imperialistic competitions among these empires converge to state in their exist only one empire. In the proposed ICA for the unit commitment problem, the scheduling variables are coded as integers; therefore the some constraints are handled are handled directly as minimum up and down type constraints.*

## NOMENCLATURE

$N_{gen}$  = Number of units  
 $H$  = Scheduling horizon(in hours)  
 $P_D(t)$  = load demand at  $t^{th}$  hour.  
 $P_R(t)$  = system reserve at  $t^{th}$  hour.  
 $C$  = No. of operating cycle for each unit  
 $T_I^C$  = Duration of operating cycle  $c$  for unit  $i$   
 $P_i(t)$  = output power of unit  $i$   
 $P_{max,i}$  = Maximum output power of unit  $i$   
 $P_{min,i}$  = Minimum output power of unit  $i$   
 $P_{i,max}(t)$  = Maximum output power of unit  $i$  at hour  $t$   
 $P_{i,min}(t)$  = Minimum output power of unit  $i$  at hour  $t$   
 $MUT_i$  = Maximum up-time limit of unit  $i$   
 $MDTi$  = Minimum down time limit of unit  $i$   
 $RU_i$  = Ramp up rate of unit  $i$   
 $RD_i$  = Ramp down rate of unit  $i$   
 $SUC_i$  = start up cost of unit 'i'  
 $HSC_i$  = Hot start cost of unit  $i$   
 $CSC_i$  = cold start cost of unit  $i$   
 $CSH_i$  = cold start hour of unit  $i$   
 $FC_i$  = Fuel cost of unit  $i$   
 $TFC$  = total fuel cost  
 $IS_i$  = Initial state of  $i$

## 1. Introduction

The Unit commitment can be defined as the Scheduling of power production from generation units over a daily to weekly time horizon while respecting various generator constraints (such as ramp rate limits and mini" up or down times) and system constraints (reserve and energy requirements, and transmission constraints). The objective function includes costs associated with energy production and start-up and shut-down decisions, along with possible profits. The resulting problem is a large scale nonlinear optimization problem for which there is no exact solution technique.

The electric power industry has been using efficient methods for many years to solve the unit commitment problem to optimize the overall cost. However, as the power industry undergoes radical restructuring, the role of unit commitment models is changing. Due of the problem's sue and complexity, and because of the large economic benefits that could result from its improved solution, considerable attention has been devoted to development of better optimization algorithms. Some of the promising techniques include heuristics-based methods using Priority Lists (PL), dynamic programming, branch-and-bound mixed integer programming, Linear and network programming approaches, and Benders decomposition methods, among others. Lagrangian relaxation has been most successful and widely used approach for quick development of good, if not optimal, generator schedules. Modern power systems are usually large scale systems, and as the number of solutions to the UC problem grows exponentially with the number of units, the computation time would be excessive.

In this paper imperialistic competition algorithm is used to solve unit commitment problem through which better results are obtained. this method is inspired the imperialistic competition .here all the countries are divided among imperialists and colonies .these colonies are divided among imperialists. these imperialists and colonies are together form a empires. Then the imperialists competition among the empires begins

.this hope fully causes the colonies to converse global optimization of objective function .Atashpaz-Gargari and Lucas first introduced Imperialistic competition algorithm(ICA) in 2007.This method is inspired by imperialistic competitions. Here all the countries are divided into imperialistic and colonies. The colonies are divided among imperialists. The imperialists and colonies all together form some empires. Then the imperialistic competition among the empires begins. this hope fully causes the colonies to converge to global optimum of objective function. At the end of imperialistic competition, only one empire remains .the colonies of this empire are in the same position as the imperialist of this empire and have the same cost. Here anew initialization is based on priority list is proposed. The minimum up time/down time constraints and there is no need of using a penalty function for these constraints.

### 1.1 UC PROBLEM FORMULATION

The objective of the UC problem is to minimize total operating cost of the generating units during the scheduling horizon, while both unit and system constraints must be satisfied. Total operating cost consists of fuel, start-up, and shut-down costs of the generating units. The output powers of the units in each hour are determined by economic dispatch. In general, the fuel cost can be calculated using the fuel cost functions of the units.

$$FC_i(P_i)=a_i+b_iP_i+c_iP_i^2 \quad i=1,2,3,\dots\dots (1)$$

Where  $a_i, b_i, c_i$  are fuel cost coefficients generator  $i$   
Then the total fuel costs for an  $H$ -hour load horizon will be found. Start-up Costs are expressed as an exponential or linear function of the time.

$$TFC = \sum_{t=1}^H \sum_{i=1}^{N_{gen}} FC_i(P_i).u_i(t) \quad (2)$$

The UC problem has several constrains that must be satisfied:

1. Generating units initial operating status
2. Maximum and minimum power limits
 
$$P_{\min,i} < P_i(t) < P_{\max} \quad (3)$$
3. Ramp up/down rates
4. Power balance of the system

$$\sum_{i=1}^{N_{gen}} u_i(t)P_i(t) = P_D(t), t = 1,2,3,\dots\dots H \quad (4)$$

5. Spinning reserve of the system

$$\sum_{i=1}^{N_{gen}} u_i(t)P_{i,\max}(t) = P_D(t) + P_R(t) \quad (5)$$

6. Minimum up/down times

$$\begin{aligned} T_i^c &\geq \text{MUT}_i && \text{if } T_i^c \geq 0 \\ T_i^c &\leq \text{MUT}_i && \text{if } T_i^c \leq 0 \end{aligned} \quad (6)$$

Where  $T_i^c$  is a sign integer which represents the continuous ON/OFF status duration of the  $c_{th}$  cycle of the  $i_{th}$  unit .The sum of the absolute values of  $T_i^c$  for all units must be equal to the scheduling horizon:

$$\sum_{c=1}^C |T_i^c| = H \quad (7)$$

## 2. IMPERIALISTIC COMPETITION ALGORITHM

Atashpaz Gargari and Lucas introduced the imperialistic competition algorithm which is inspired by imperialistic competitions. They applied this method to some of benchmark cost functions. Similar to other evolutionary algorithms, the ICA starts with an initial population that is called countries. Some of the best countries that have the best objective functions are selected to be imperialists. The rest of the countries form the colonies of these imperialists. The colonies are divided among the imperialists based on the imperialists' power. The power of an imperialist in a minimization problem is inversely proportional to its cost function. Then the colonies move toward their relevant imperialist and the position of the imperialists will be updated if necessary. In the next stage, the imperialistic competition among the empires begins, and through this competition, the weak empires are eliminated. The imperialistic competition will gradually lead to an increase in the power of powerful empires and a decrease in the power of weaker ones. Finally the weak empires that are not able to improve their position will be collapsed. These competitions among the empires will cause all the countries to converge to a state in which there exists only one empire in the word and all the other countries are colonies of this empire.

In this competition each empire that cannot increase its power will be eliminated from competition. In the other hand weak empires will lose their power gradually and ultimately they will collapse. These processes ultimately cause that in the long time we have a world with one empire and all other countries will be colonies of this empire. In this new ideal world,

each colony has the same position and power as the imperialist. One of the important problem in each is that determine an appropriate format to represent a solution. For example in GA this format called “chromosome” and is an array of variables value as a solution. In ICA the term “country” is used for this array.

The proposed algorithm starts with an initial population (countries in the world). Some of the best countries in the population are selected to be the imperialists and the rest form the colonies of these imperialists. All the colonies of initial population are divided among the mentioned imperialists based on their power. The power of an empire which is the counterpart of the fitness value in GA, is inversely proportional to its cost. After dividing all colonies among imperialists, these colonies start moving toward their relevant imperialist country. The way by which they move is described. The total power of an empire depends on both the power of the imperialist country and the power of its colonies. We will model this fact by defining the total power of an empire by the power of imperialist country plus a percentage of mean power of its colonies. Then the imperialistic competition begins among all the empires. Any empire that is not able to succeed in this competition and can't increase its power (or at least prevent decreasing its power) will be eliminated from the competition.

The imperialistic competition will gradually result in an increase in the power of powerful empires and a decrease in the power of weaker ones. Weak empires will lose their power and ultimately they will collapse. The movement of colonies toward their relevant imperialists along with competition among empires and also the collapse mechanism will hopefully cause all the countries to converge to a state in which there exist just one empire in the world and all the other countries are colonies of that empire. In this ideal new world colonies, have the same position and power as the imperialist. A new evolutionary algorithm known as ICA for solving the UC problem is proposed. A new strategy for creating initial population is introduced. Also in the UC problem, minimum up/down time constraints is considered while producing the feasible solution and therefore no penalty function is used for these constraints. The efficiency of the proposed method is proved by considering one-day scheduling period with number of units from ten up to 100. The results obtained by the proposed ICA are compared with the results of some previous methods. The numerical results show that ICA can find high-quality solutions.

## 2.1 STEPS TO SOLVE IMPERIALISTIC ALGORITHM

- a. Initial population is created i.e countries
- b. Calculate Cost function for all countries
- c. Selection of imperialists.
- d. Selection of colonies.
- e. Movement of the colonies towards their Imperialists
- f. Updating positions of imperialists.
- g. Calculating the total power of an empire
- h. Imperialistic competition

### 1 .GENERATING INITIAL EMPIRES

The goal of optimization is to find an optimal solution in terms of the variables of the problem. We form an array of variable values to be optimized. In GA terminology, this array is called “chromosome”, but here the term “country” is used for this array. In an Nvar – dimensional optimization problem, a country is a 1 Nvar × array.

$$\text{Country}_i = (x_i^1, x_i^2, \dots, x_i^n) \quad (8)$$

### 2. INITIAL NO. OF COUNTRIES OF AN EMPIRE

The initial no. of colonies of an empire is directly proportional to its power. to do this ,the normalized costs of the empires are defined

$$IC_n = ic_n - \max(ic_i) \quad (9)$$

Normalized power of each imperialists is given by

$$IP_n = \frac{IC_n}{\sum_{i=1}^{N_{imp}} IC_n} \quad (10)$$

Then the initial no. of empires is

$$NC_n = \text{round}(IP_n \cdot N_{col}) \quad (11)$$

### 3. MOVING THE COLONIES TOWARDS IMPERIALISTS

Positions of the colonies of of the  $n_{th}$  empire are updated as follows

$$\text{new col}_n^i = \text{col}_n^i + \text{rand} \times B \cdot (I_n - \text{col}_n^i) \quad (12)$$

Where

$col_n^i$  - position of  $i_{th}$  colony of the  $n_{th}$  imperialist

rand - random no. between (0,1)

B - weight factor

$I_n$  - position of  $n_{th}$  imperialist

$$ps_n = \frac{NTP_n}{\sum_{i=1}^{N_{imp}} NTP_i} \quad (15)$$

#### 4. UPDATING POSITIONS OF THE IMPERIALISTS

During the previous stage, a colony may reach to a position with lower cost than that of the imperialist. In such a case, the positions of the imperialist and that colony must be exchanged. Then the rest of the colonies of this empire move towards the new position of the imperialist.

#### 5. CALCULATING TOTAL POWER OF AN EMPIRE

The total power of an empire depends on both the power of the imperialist and the power of its colonies. But it is mainly affected by the power of the imperialist. The total power is given by-

$$TP_n = \text{cost}(\text{imperialist}) + \xi \times \text{mean}(\text{cost}(\text{colonies of empire})) \quad (13)$$

where  $TP_n$  - Total power of  $n_{th}$  empire  
 $\xi$  - positive no. less than 1

#### 6. IMPERIALISTIC COMPETITION

In this stage, the imperialistic competition begins and all the empires try to take possession of the colonies of other empires. This competition is modeled by picking some of the weakest colonies (usually one) of the weakest empires and making a Competition among all empires to possess these colonies. Each of the empires will have a likelihood of taking possession of these colonies based on their total powers; therefore, the more powerful empires have greater chance to possess the mentioned colonies. To do this, the possession probability of each empire must be found.

$$NTP_n = TP_n - \max(TP_i) \quad (14)$$

Where  $NTP_n$  - normalized power of  $n_{th}$  empire

The possession probability of each empire is given by

#### 7. ELIMINATING THE POWERLESS EMPIRES

The powerless empires will collapse in the imperialistic competition. Different criteria can be defined for collapse mechanism. In this paper, an empire is assumed collapsed when it loses all of its colonies.

#### 8. CONVERGENCE

After some imperialistic competitions, all the empires except the most powerful one will collapse and all of the countries under their possession become colonies of this empire. All the colonies have the same positions and the same costs and there is no difference between the colonies and their imperialist. In such a case, the algorithm stops.

### 3. IMPLEMENTATION OF ICA FOR UC PROBLEM

#### 1. Country Position Definition

The position of a country in inter-coded ICA for UC problem consists of sequence of ON/OFF cycle durations of the units during the time horizon of the problem. A positive integer represents duration of continuous ON status while negative integer represents duration of continuous off cycle of unit.

It all is done by analyzing a load operating cycle operating between base loads, medium load and peak load.

#### 2. Creating Initial Population

Here we used new technique for the initialization. In these technique units are divided into three classes. The units are divided in base- load, medium-load, and peak-

load on the basis of similar characteristics, such as up/down time requirements, output power capacity and start up costs. Since the base load units are always in ON state, and peak load units are turned on in load peaks based costs, the optimal state of medium-load units must be found. To do this some priority lists are created. The base load units are of highest priority based on their fuel costs. The peak load units are in the lowest priority based on fuel costs. A random permutation of the medium load units is created and placed between the base load and peak load units. The population is created using these priority lists. It should be noted that if only one priority list is used for the whole scheduling period, the search space will be restricted and the results are not appropriate, especially in large systems. To overcome this drawback, different priority lists are created and used for the sequence of turning on or off the units.

3. Cost function

The cost function used ICA is equal to the sum of total production costs (fuel costs and start up/shut down cost) over the scheduling horizon and penalty function that penalizes the violation of system constraints. Here fuel cost is calculated by using equation (1), shut down cost is not considered in this paper. But the start up cost is given by

$$SUC_T = U(T_i^c) \cdot SUC_i \cdot (-T_i^{c-1}) \tag{16}$$

Then the total production cost is –

$$TC = (FC_i(P_i) \cdot U_i(t)) + SUC_T \tag{17}$$

Here the penalty function used in paper has two terms-

$$\Pi_{res} = w \sum_{t=1}^H \frac{1}{P_D(t)} \Re \left( (P_D(t) + P_R(t)) - \sum_{i=1}^{N_{gen}} u_i(i) \cdot \tilde{P}_{i,max}(t) \right)$$

$$\Pi_{ex} = w \sum_{t=1}^H \frac{1}{P_D(t)} \Re \left( \sum_{i=1}^{N_{gen}} u_i(i) \cdot \tilde{P}_{i,min}(t) - P_D(t) \right)$$

Where R(.) is unit ramp function and w is a multiple of the maximum operating cost of system over the scheduling period. Finally the ICA cost function is the formed follows:

$$CF = TC + \Pi_{res} + \Pi_{ex} \tag{18}$$

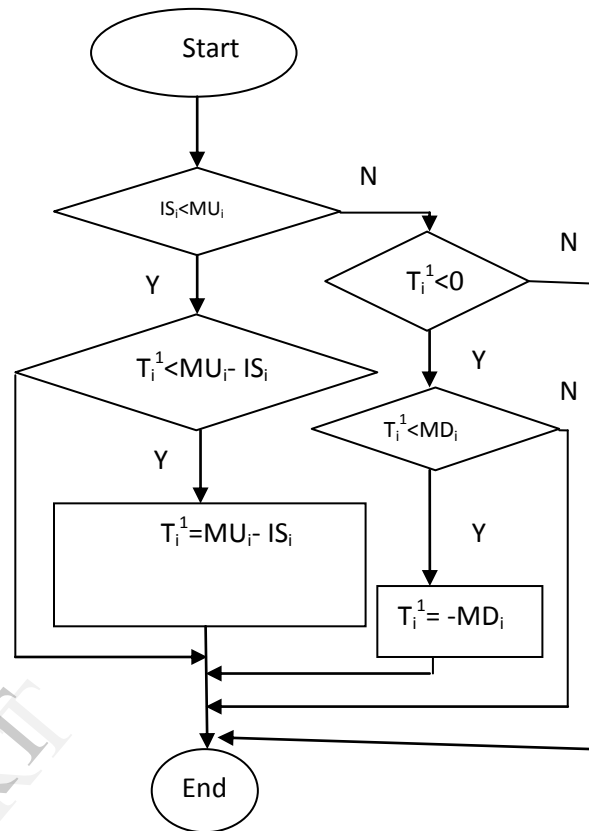


Fig.1 Flowchart of modifying the first cycle of a unit

D. Constraint Handling

After creating initial population (i.e countries), the initial empires are created. Now the movement of colonies towards their relevant imperialists begins. As said, the position of the colonies is updated using equations. In order to handle the constraints of the problem, it is necessary to modify the cycles of unit.

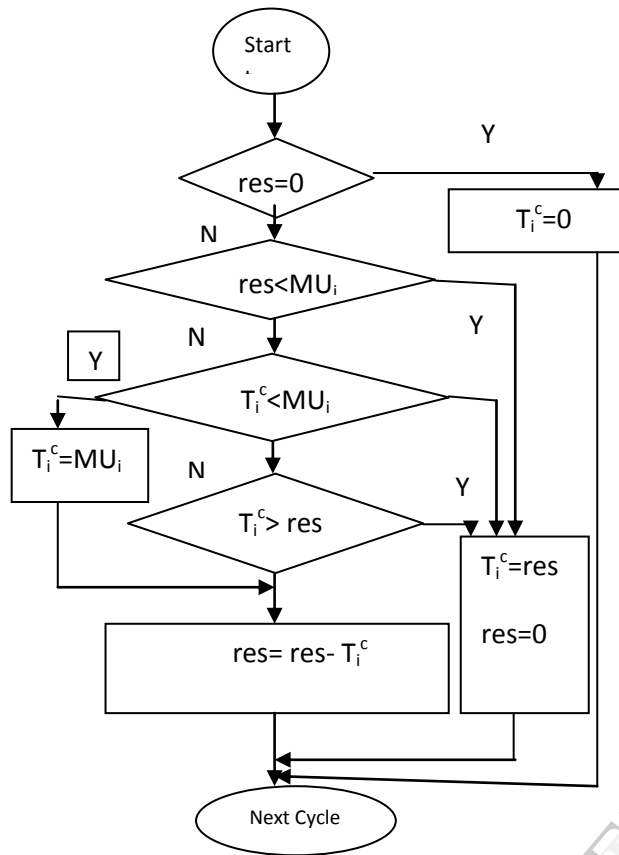


Fig 2 . Flowchart of modifying the cycles of a unit

**4. Test Results**

Here optimal parameters of ICA for the ten unit system which are obtained through several runs are obtained through several runs are  $N_{imp}=10, N_{col}=200, \xi=0.2$  and  $\beta=1.75$ . For systems with more units, the same parameters are used, except  $N_{col}$  and  $N_{imp}$  that may be increased.

Table 1. Operating cost for different countries

NUMBERS OF COUNTRIES	MEAN OPERATION COST
50	232523.3
100	282204.9
150	282204

Table 2. Cost coefficients of ten units

UNITS	$A_i$	$B_i$	$C_i$
1	1000	16.19	.00048
2	970	17.26	.00031
3	700	16.60	.002
4	680	16.50	.00211
5	450	19.70	.00398
6	370	22.26	.00712
7	480	27.74	.00079
8	660	25.92	.00413
9	665	27.27	.00222
10	670	27.79	.00173

Table 3. Load demand for 24 hours

HOURS	LOADS(MW)	HOURS	LOADS(MW)
1	700	13	1400
2	750	14	1300
3	850	15	1200
4	950	16	1050
5	1000	17	1000
6	1100	18	1100
7	1150	19	1200
8	1200	20	1400
9	1300	21	1300
10	1400	22	1100
11	1450	23	900
12	1500	24	800



Table 4.Data for Ten unit System

UNIT	Pmax	Pmin	C <sub>COST</sub>	H <sub>COST</sub>	M <sub>Ui</sub>	M <sub>Di</sub>	IS <sub>i</sub>
1	455	150	9000	4500	8	8	8
2	455	150	10000	5000	8	8	8
3	130	130	1100	550	5	5	-5
4	130	130	1120	560	5	5	-5
5	162	162	1800	900	6	6	-6
6	80	20	340	170	3	3	-3
7	85	25	520	260	3	3	-3
8	55	10	60	30	8	8	8
9	55	10	60	30	8	8	8
10	55	10	60	30	5	5	-5

## 10. References

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