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Solution to Unit Commitment Scheduling Problem-A Proposed Approach

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ABSTRACT

Unit Commitment Scheduling problem is one of the biggest concerns for power companies. It involves how many units need to be put in working state, how many units need to be put in inactive state and how much power one unit need to generate to satisfy load demand. Unit Commitment popularly known as UC problem need to be overcome by minimizing fuel cost, startup cost and shutdown cost which come from the generating units. From economy point of view, it has been matter of concern for most of the companies and need to be solved.

Keywords: Unit Commitment (UC), Differential Evolution (DE), Evolutionary Algorithm (EA)

1. Introduction

A power system has quite a lot of power plants. Each power plant has a number of generating units. At any point of time, the entire load on the system is met by the generating units in different power plants [1]. Daily load patterns show signs of acute deviation amid the rush and off rush hours for the reason that community utilize a smaller amount of electrical energy on Saturday than on weekdays, and at a lower rate between midnight and early morning than during the day. If adequate generation to fulfill the rush is kept online all through the day, it is promising that few of the units will be working near their least generating threshold during the off rush period. In most of the unified power systems, the power prerequisite primarily fulfills by thermal power generation. Quite a lot of working approaches are achievable to fulfill the requisite power requirement. It is recommended to use a most favorable operating approach based on financial measure. That is to say significant, the decisive factor in power system functioning is to meet the power demand at Least fuel cost. Furthermore, sequentially to provide first-rate electrical energy to consumers in a protected and cost-effective method, unit commitment (UC) is measured to be one of best existing alternative. It thus comprehends that the most favorable UC of thermal systems, dependent on device and operating restrictions stem in a cutback for electric utilities. So the general purpose of the UC problem is to reduce system entirety, operating cost while fulfilling all of the restrictions.

1.1. Introduction to Unit Commitment

Unit commitment (UC) is an optimization dilemma used to decide the functioning agenda of the generating units at every hour period with changeable loads under dissimilar restriction. Numerous techniques have been made-up in the last five decades for optimization of the UC dilemma; in spite of everything investigators are functioning in this field to unearth new fusion algorithms to construct the problem further convincing. The significance of UC is mounting with the persistently changeable demands. Therefore, there is a burning need in the power zone to keep trace of the most up-to-date methodologies to extra optimize the operational measures of the generating units. The character of the UC problem restrains the efforts to build up any

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demanding numerical optimization method competent of resolving the crisis for any system. Nonetheless, in the text, a lot of methods using some form of estimation and generality have been planned.

The UC problem is applying for deterministic and stochastic loads. The deterministic method gives the unique and concrete solutions. However, in the case of stochastic, results may not be exact. The different types of objective functions [28] are as follow that are applicable to different environments:

1.1.1. Conventional fuel based environment

In this environment, there are three costs to decrease: fuel cost, start up cost and shutdown cost

$$\min \sum_{t=1}^{Nt} \sum_{i=1}^{Nt} \left[Ci\left(P\left(i,t\right)\right) I\left(i,t\right) + SU\left(i,t\right) + SD\left(i,t\right) \right]$$

Where *Ci(P(i,t))* is fuel cost at unit i at time t, *SU* and *SD* are startup and shutdown respectively.

1.1.2. Stochastic environment

In this environment randomness is added. In today's world uncertainty occurs due to the integration of renewable sources of energy in power systems like solar energy, wind energy.

1.1.3. Profit based environment

The main goal of profit based environment is to increase the earnings of Generation Company.

Furthermore accomplishing smallest possible overall fabrication expense, a generation agenda need to fulfill a number of working constraints. There are several constraints involved in UC which are: Time based constraint, Emission based constraint, Fuel based constraint, Transmission based constraint, spinning reserve and Ramp based constraint. These constraints lessen liberty in the option of initializing and shutting-down of generating units.

1.2. Techniques for solving UC problem

Several researchers have applied various optimization techniques to find solutions to UC problem in the past. The available solutions are categorized into three categories:

(i) Conventional Techniques

(ii) Non Conventional Techniques

(iii) Hybrid Techniques

In spite of the availability of new solutions, UC solution techniques still use approximations of the problem. The approximation may result in inaccurate solutions, which are undesirable. Dynamic Programming is one of the oldest techniques to decipher the UC problem, but it's not capable of handling the complexity of the problem. Evolutionary algorithms are well known for handling the complex problems in an effective way. Fuzzy techniques on the other hand, are capable for handling the problem in situations where its parameters lack definiteness.

1.3. Evolutionary Algorithms

From the last few years the global optimization has received lot of attention from authors worldwide. The reason may be that optimization can play a role in every area, from engineering to finance, simply everywhere. Inspired by Darwin's theory of evolution, evolutionary algorithms can also be used to solve problems that humans don't really know how to solve [10].

1.4. Differential Evolution

Differential Evolution is one of the widespread algorithms for optimization available for researchers. Differential Evolution (DE) worked through identical steps as used by Evolutionary algorithms. DE was developed by Storn and Price in year 1995. Since its onset, it has brought interest of research fraternity worldwide as DE providing solutions to problems in different domains like big data, image processing and other fields [2]. The reason why DE is popular among evolutionary algorithm is the fact that DE is in complex to put into effect in comparison to other evolutionary algorithms. DE also showed better performance in terms of accuracy and convergence. It requires very few lines to code in C language or any other programming language [10]. DE used to provide optimal solution (global maxima) as it never got trapped in local maxima. As compared to other algorithms, space complexity is quite low in DE.

1.5. Genetic Algorithm

Genetic Algorithm is a method that mimics the procedure of natural selection. It frequently transforms a population of individual solutions. Every time fitness of individuals in the population is assessed; the fitness is generally the value of the objective function [10]. The fittest individuals are selected arbitrary from the present population to be parents and utilize them to produce offspring for the next generation. Over consecutive generations, the population "evolves" in the direction of an optimal solution. The algorithm concludes when satisfactory fitness level has reached. The genetic algorithm uses the following rules to generate the next generation from the existing population:

(i) Selection rules choose the individuals from current population and use them to produce the children for the next generation.

(ii) Crossover brings together two parents to form children for the next generation. One of the commonly used methods is to choose one crossover point which one can think of a threshold and binary sequence before this threshold, replicate from a first parent and then binary sequence after a crossover point replicate from the second parent.

Parent 1	1110|101011011
Parent 2	1000|100010101
Offspring 1	1110|100010101
Offspring 1	1000|101011011

Figure 1: Crossover Process

(iii) Mutation rules employ arbitrary modifications to parents to produce offspring. Using binary encoding we can exchange arbitrarily chosen bits from 1 to 0 or from 0 to 1.

Offspring 1	1010010101010
Offspring 2	1111010101010
Modified Offspring 1	1110010101010
Modified Offspring 2	1001010101010

Figure 2: Mutation Process

2. LITERATURE SURVEY ON DE

Storn and Price (1997) proposed Differential Evolution (DE). [2] The authors defined rules for Initialization, Mutation, Recombination and Selection [10].

Initialization: Describe higher and inferior bounds for each one parameter. Then randomly choose the initial parameter values.

Mutation: Mutation helps in expanding the search space. For a given parameter vector arbitrarily decide on three vectors, add the weighted dissimilarity of two of the vectors to the third.

$$u = r_1 + F(r_2 - r_3) \quad (1)$$

where u is mutant point, F is mutation factor and r1, r2, and r3 are three jointly discrete points arbitrarily taken from the population.

Janez Brest *et al* (2006) proposed the unique method for controlling the parameter settings of classical DE [3]. DE is widely used optimization algorithm and shown remarkable convergence properties. It has a handful of parameters which are kept permanently during the evolutionary process. Nevertheless, it is not a simple job to set the control parameters in DE properly. So authors devised a new algorithm called Self Adaptive Differential Evolution, which showed great performance on benchmark problems. The investigation results have shown that SADE outperforms DE when quality of solutions taken into consideration.

Montes and Carlos (2006) presented comparison of differential evolution variants to solve global optimization problems . In their paper, they have identified the variant with the best performance, regardless of the features of the problem to be solved. Statistical tests were performed in order to obtain more confidence on validity of results. Authors have proposed that best/1/bin is a top Differential Evolution variant for solving unimodal problems and for solving multimodal problems rand/2/dir can be used.

Ali W. Mohamed et al. (2011) proposed novel DE algorithm to work out unconstrained problems of optimization [4]. Authors have proposed a new mutation rule based on weighted difference vector among the fittest and the worst individuals of a specific generation [10].

To promote the exploration power of DE, Yong Wang et al. (2012) suggested a basic structure for using an Orthogonal Crossover in DE alternatives [5].

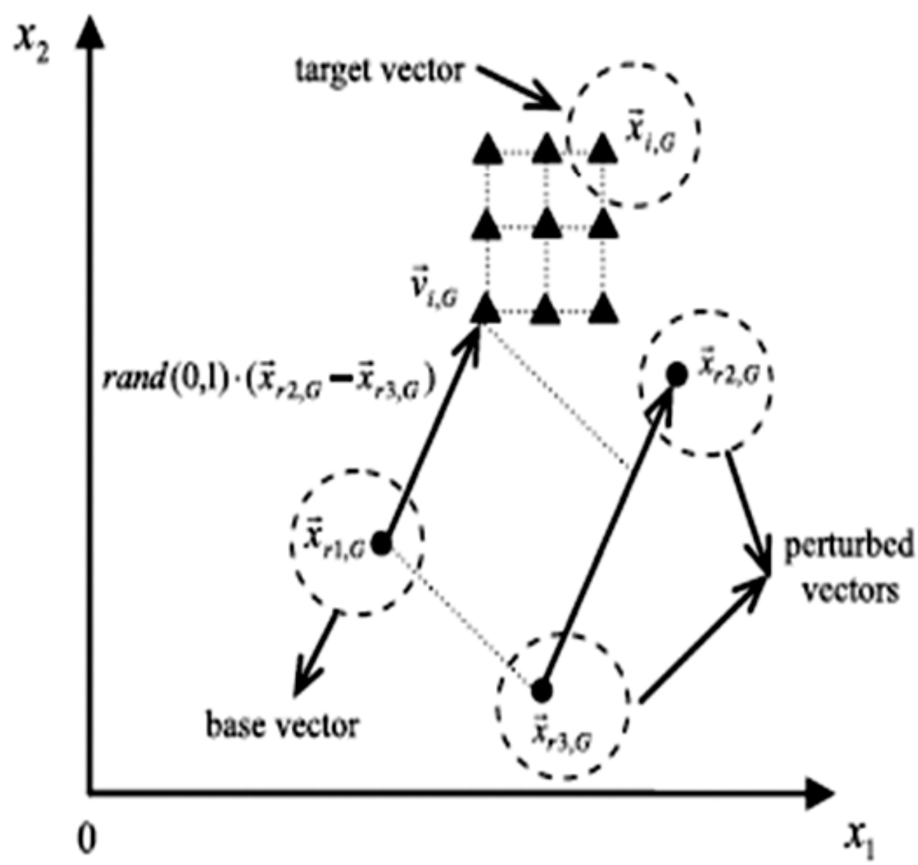

Figure 1: Demonstration of OXDE [5]

Dilip Datta et al (2012) put forward technique as answer to unit commitment problem. They named it as binary-real-coded Differential Evolution. Unit Commitment scheduling problem is one of the biggest concerns for power companies. It involves how many units need to be put in working state, how many units need to be put in inactive state and how much power one unit need to generate to satisfy load demand. Unit Commitment popularly known as UC problem need to be overcome by minimizing fuel cost, startup cost and shutdown cost which come from the generating units..

Anupam Trivedi et al. (2015) presented the unique approach for solving power system optimization problem popularly known as unit commitment scheduling problem [1]. Authors have named algorithm as hGADE (Hybridizing Genetic Algorithm and Differential Evolution). Unit Commitment scheduling problem is one of the biggest concerns for power companies. It involves how many units need to be put in working state, how many units need to be put in inactive state and how much power one unit need to generate to satisfy load demand. Unit Commitment popularly known as UC problem need to be overcome by minimizing fuel cost, startup cost and shutdown cost which come from the generating units. The constraints involved in UC are Spinning Reserve, Least up Time, and Least down Time, Startup Cost, Hydro Constraints, Generator 'Must Run' Constraints, Ramp Rate and Fuel Constraints. The presented hGADE algorithm is cross disciplinary and can be easily used to solve optimization problems.

Huifeng Zhang et al. (2015) presented a enhanced multi-objective DE algorithm popularly known as MOHDE-SAT to resolve dynamic economic emission dispatch problem (DEED). Economic Dispatch play important part in working of power system, it allows economic dispatch to be treated and ultimate goal is to run power systems at minimal fuel cost and optimizing the pollutant discharge simultaneously [6]. Furthermore pollutant emission will add to the fuel cost, DEED can be taken as a multi-objective problem. Considerable techniques have been proposed to solve this problem [10].

Yiqiao Cai and Jiahai Wang (2015) projected a novel linkage utilization technique, popularly known as hybrid linkage crossover (HLX) [10]. HLX automatically withdraw the linkage statistics about a particular dilemma and then utilize the linkage statistics to lead the way to crossover process [7]. By assimilating HLX into DE named HLXDE was projected.

Rammohan Mallipeddi and Minho Lee (2015) proposed an evolving surrogate model-based DE (ESMDE) method [8]. Josef Tvrdíka and Ivan (2015) proposed a novel technique combining DE and k-means [9]. Clustering is a method used for categorizing group of objects into similar groups based on object resemblance [10]. There are two main techniques how to determine the clustering problem, hierarchical and non-hierarchical. Originators have applied their algorithm on non-hierarchical clustering and analyze the same on eight well-known real-world data sets. The problem of optimal non-hierarchical clustering is well taken care of.

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Table 1
Literature survey on UC

Authors	*Type of Problem*	*Constraints used in the problem*	*Objective Function*	*Software Used*	*Algorithm Used*
Sum-im T, Ongsakul W. (2003) [11]	Deterministic	Ramp rate limits, Least up down time, Spinning reserve, Load demand	Minimize fuel cost	MATLAB	Ant System
Kazarlis S, Bakirtzis A, Petridis V. (1996) [11]	Deterministic	Load demand, Least up down timeRamp rate limits Spinning reserve	Minimize fuel cost	C++	GA
Zhang X H, Zhao J Q, Chen X Y. (2009) [11]	Deterministic	Power Balance, Least up down time, Spinning reserve, Generation Limits	Minimize fuel cost	VC++	GA
Kumar S S, Palanisamy V. (2006) [11]	Deterministic	Power Balance, Least up down time, Startup Cost, Generation Limits	Minimize fuel cost	MATLAB	Dynamic Programming, Hopfield Networks
Chang W P, Luo X J (2008) [11]	Deterministic	Ramp rate limits, Least up down time, Power Balance, Generation Limits	Minimize fuel cost	MATLAB	GA

(*contd...*)

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Authors	*Type of Problem*	*Constraints used in the problem*	*Objective Function*	*Software Used*	*Algorithm Used*
Alshareef A. (2011) [11]	Deterministic	Generation Limits, Least up down time, Power Balance, Ramp rate limits	Minimize fuel cost	VC++	PSO
Kumar C, Alwarsamy T (2011) [11]	Deterministic	Generation Limits, Least up down time, Power Balance, Ramp rate limits	Minimize fuel cost	MATLAB	PSO
Nascimento F R, Silva I C, Oliveira E J, Dias B H, Marcato A L M. (2011) [11]	Deterministic	Power Balance, Least up down time, Generation Limits,Ramp rate limits	Minimize fuel cost	MATLAB	Ant System

3. OBJECTIVES OF STUDY

Unit Commitment, commonly known as UC is important power system optimization problem. General purpose of the UC problem is to reduce system total operating cost while fulfilling all of the constraints. Anupam Trivedi et al. (2015) presented the unique approach for solving power system optimization problem popularly known as unit commitment scheduling problem [1]. Authors have named algorithm as hGADE (Hybridizing Genetic Algorithm and Differential Evolution). The objective of the study is to address the issues that were neglected by authors as they have given it as their future work which make base for further research.

The main objectives of this study would be:

(a) To investigate the usefulness of hGADE algorithm on the ramp rate constrained unit commitment problem. As the ramp up/down constraint was neglected by authors.

(b) To employ best/1/bin variant of Differential Evolution instead of DE/rand/1 for mutation process. As findings showed that best/1/bin is a top Differential Evolution variant for solving unimodal problems and for solving multimodal problems rand/2/dir can be used.

(c) To use Self Adaptive Differential Evolution algorithm instead of Differential Evolution algorithm for acting on the continuous component of chromosomes [3].

(d) To use hGADE algorithm for solving Economic Dispatch problem (multi objective optimization problem)

(e) Comparison of extended hGADE algorithm with existing hGADE algorithm.

4. PROPOSED METHODOLOGY

By comparing and analyzing various approaches for unit commitment problem, a scheme based on evolutionary algorithm would be utilized for solving the above said problem [1]. The hGADE algorithm belongs to category stochastic algorithms for determining the both best combination of on/off status of thermal units.

The hGADE algorithm starts with the initialization of the population. After initializing the population, the fitness of an individual is assessed [1]. The fitness is usually the value of the objective function. The

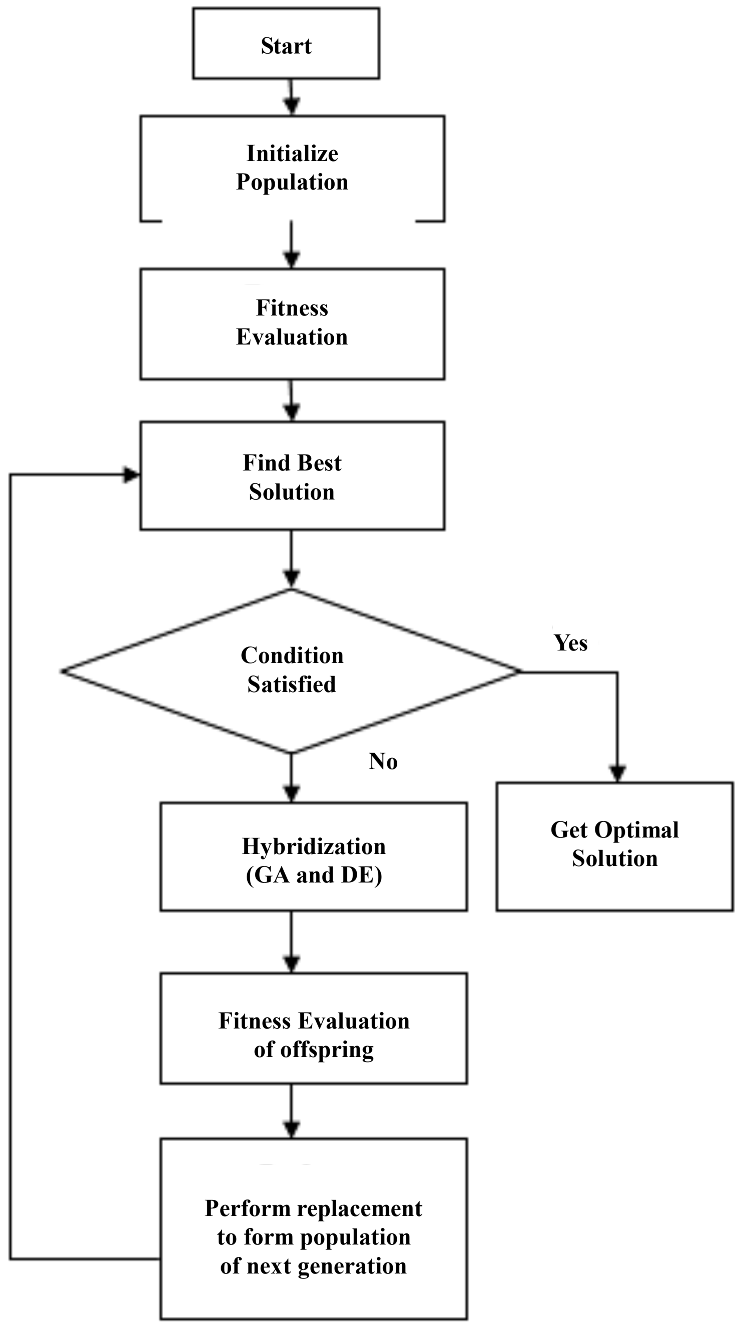

Figure 4: Working of Hybrid GADE Algorithm [1]

objective function system activity cost is determined for each chromosome using its Res.PM which is retrieved by applying the cross product between the corresponding elements of the Unit Commitment Matrix and Resultant Power Matrix. The variation operation is the place where the GA and SADE hybridized. Here binary unit commitment variables are evolved using Genetic Algorithms operators and power dispatch variables are evolved using Differential Evolution.

SADE operators work on resultant power matrix.DE best/1/bin variant to be used for mutation operation. For crossover operation, binomial crossover is preferred over exponential crossover. Then at last comes, the replacement operation. If the feasible solutions are fewer than the population size, then preserve all the solutions in next population. However, in the scenario if the workable solutions more than the population size, then the solution with best objective function value will enter the next population. In order to perform the research work, MATLAB could be utilized.

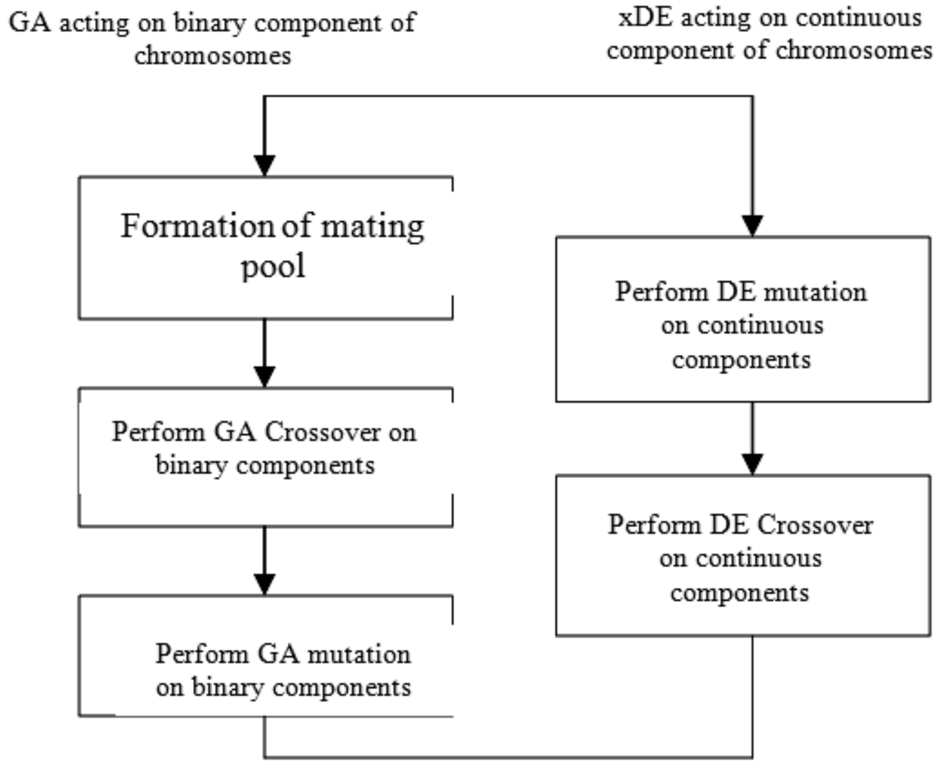

Figure 5: Working of Hybrid GADE Algorithm [1]

5. CONCLUSION

Numerous algorithms have been formulated in the past five decades for optimization of the UC problem, but in spite of everything investigators are operating in this field to discover novel hybrid algorithms to make the problem more practical. The significance of UC is growing with the continually varying demands. The proposed work will help in solving the unit commitment problem.

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