An Extensive Literature Survey of Unit Commitment Problem in Electrical Power System using Hybrid/ Non-Hybrid Solution Approaches

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***Abstract*— This survey paper helps in the area of scheduling inconvenience of various generating units in electrical power system. It shows several common surveys of developments plus research in area of unit commitment centered on published articles and journals. A detailed survey is done in the sphere of unit commitment for finding different hybrid and non-hybrid methods by means of which unit commitment problem can be solved effectively. It will be quite helpful to the scientists, investigators or researchers employed in the region of the unit commitment.**

Keywords*— *Unit Commitment, Particle Swarm Optimization Algorithm, Harmony Search Algorithm, Shuffled Frog Leaping Algorithm, Pattern Search Algorithm, Binary Fireworks Algorithm, Gravitational Search Algorithm

I. INTRODUCTION

In the high-tech era of the power system process, the most thought-provoking point of interest is to elect in each period that which of the electrical generating units must run so as to befit a varying demand for electricity & every unit has its peculiar traits. These kind of evaluations and activities falls underneath the Unit Commitment (UC). The production scheduling of electric power generated by generating units for a day-to-day to weekly time sphere in turn to achieve some goal is known as unit commitment problem. The solution found for the UC problem must satisfy the generator constraints (like ramp rate limits & minimum up / minimum down times) and the system constraints (like reserve capacity and transmission constraints and energy requirement).

Over a given time period the task to find a production level and an optimum schedule, for every generating unit which is bring up by Unit Commitment problem (UCP). It specifies in a scheduling sphere at every point in a time period for which the generating units should be put into use [3]. Because human activities depends a lot on electrical power system, throughout the hours of daylight overall load will usually be more on the system and late afternoon when prominent loads are industrial loads, turning on of lights, and slighter in the late twilight & early dawn while the majority of the population is sleeping. Furthermore, electric power is used in a weekly sequence, during weekdays the load is more than the weekend days. What's the reason that this is considered as a problem in the operation of electric power system? Is it possible to just simply commit enough units to satisfy the maximum system load necessity and leave them functioning? "Commit" a generating unit signifies "turning it on" i.e. to bring about the unit up to speed, harmonize it to the system load & attach it in such a manner that it can supply power to the system. The one of cost-effective problem is with obligating sufficient units and desert them in on situation. Handling too many generating units is rather costly. A huge sum of money can be spared by de-committing the units once they are not in demand [1].

In the electrical power industries from several years optimization methods are being utilized for resolving the unit commitment (UC) problem. A large amount of money is saved in fuel costs. Due to the restructuring of industry and advancement in the Optimization technology, there is a change in the role of unit commitment. Therefore the need of algorithm with better solution is increasing day by day. This paper purpose is to help the investigators, researchers and scientists to well known about some of the various hybrid and non-hybrid algorithms which are being used in the unit commitment problem. Algorithm development is necessary due to the unit commitment problem complexity, large size and high economic benefits obtained from improved solution [2]. Some of the Unit Commitment problem methodologies are discussed in the following section.

II. METHODOLOGIES

For solving, the Unit Commitment problem various methodologies have been developed in the past years. There are two types of methods for solving Unit Commitment problem, these are given as follows:

1. Non-Hybrid Methods
2. Hybrid Methods

The Non-Hybrid Methodologies which are used in the recent years by the researchers, scientists and inventors are discussed below:

1. Simulated Annealing Algorithm
2. Particle Swarm Optimization Algorithm

3. Fuzzy Logic Algorithm
4. Harmony Search Algorithm
5. Genetic Algorithm
6. Fast Heuristic Algorithm
7. Evolutionary Algorithm
8. Pattern Search Algorithm
9. Binary Fireworks Algorithm
10. Shuffled Frog Leaping Algorithm
11. Biogeography-Based Optimization
12. Artificial Bee Colony Algorithm
13. Invasive Weed Optimization
14. Gravitational Search Algorithm
15. Binary Gravitational Search Algorithm
16. Bat-Inspired Algorithm
17. Imperialistic Competition Algorithm

The HYBRID methodologies which are used in the recent years by the researchers, scientists & inventors are discussed below:

1. Particle Swarm-Based-Simulated Annealing Optimization Approach
2. Quantum-Inspired Binary PSO
3. Improved Priority List and Enhanced Particle Swarm Optimization
4. hybrid of Genetic Algorithm And Differential Evolution (hGADE)
5. Quadratic Programming & unit de-commitment (QPUD)
6. Particle Swarm Optimization And Grey Wolf Optimizer Algorithm (PSO-GWO)
7. Improved Firefly & Particle Swarm Optimization Hybrid Algorithm
8. Gbest Artificial Bee Colony Algorithm (GABC) & Teaching Learning Based Optimization (TLBO) Algorithm.

The various NON-HYBRID algorithms used in these methodologies are discussed below:

A. Simulated annealing algorithm

A feasible solution with higher cost is acknowledged with the temperature reliant probability, but in simulated annealing method other solutions are accredited deterministically. It can escort to the near optimization slowly. Though, acceptance probabilities are associated with both greater and lesser cost for all the solutions. The constraints are handled efficiently for additional units with system reliant probability distribution. However the hill-climbing search is fast it suffers from local optimization and only select better solution. The Absolute Stochastic Method merges the smart properties of genetic algorithm and hill-climbing search. Whereas, genetic algorithm is completely stochastic algorithm, it is a very sluggish process as it wants long generation [4]. The temperature, control parameter, is modified to the cost levels in Adaptive simulated annealing algorithm plan, on which during the annealing process algorithm works. In finding a good solution the time taken is shortened improving the convergence and satisfying all constraints of the algorithm. This method includes minimum up / down time constraints, demand and reserve constraints, unit power generation limits, and time reliant start-up costs. During the operation of the algorithm some information is gathered from which the parameters of Adaptive schedules are modified. For the Unit Commitment problem stable and acceptable solutions near-optimal are given by the adaptive Simulated Annealing [5].

Advantages:

- It has the capability to strive for near global optimal solutions.
- It is robust in nature.
- This algorithm has good execution time.
- This algorithm has a better convergence.
- Simulated annealing algorithm has a uniform probability distribution over global optima. [37]

Disadvantages:

- Due to the non-parallel algorithm arrangement simulated annealing takes longer calculation time than the genetic algorithm.
- The first and most significant problem is that SA uses only one search agent.
- For multi-objective optimization, Simulated Annealing algorithm has been hardly used.[37]

B. Particle swarm optimization algorithm

In year 1995, Kennedy and Eberhart first proposed Particle Swarm Optimization (PSO) technique. Initialization of PSO is done by particles known as population of possible solutions. Each particle flies with a definite velocity in the search area. During exploration, social and cognitive information is attained which influences the particle's flight. The evolutionary process is very easy and has few tunable parameters. It is effectively applied to solve combinatorial, multimodal, multi-objective and nonlinear problems. Many complex power system problems is provided with quality solutions by this algorithm [6]. Adaptive particle swarm optimization (APSO) is a new parameter free approach which solves the unit commitment problem (UCP). This algorithm overcomes major drawbacks of PSO such as problem reliant penalty functions, choice of optimal swarm size and parameter tuning. An adaptive penalty function approach solves the constrained optimization problem. The APSO is a parameter boundless method. On the basis of their performances, the flight of particles can be adjusted by the algorithm. Therefore no parameter tuning is needed. It is can easily find the most suitable swarm size. For attaining the optimal solution, Tribes move in the search space having diverse sized clusters of particles in it. In turn to locate a local minimum flying experiences are shared among all the particles in a group. Several promising areas are explored by the tribes concurrently and correlate among each other to choose on the global minimum. The algorithm is liberated of the problem to be solved, as it is self-adaptive [7]. Multi Particle Swarm Optimization (MPSO) is a novel strategy which solves the Unit Commitment (UC) problem by producing possible particles and renders the search space thin inside the possible solutions. The new strategy generates a few particle swarms, and in each particle swarm location optimum solutions are explored, after that a new particle swarm is devised of location optimum solutions, & in this new particle swarm the global optimal solution is explored. This new generating approach in PSO can efficiently break out from local minima and improves the global searching capability. This strategy applies multi particle swarm to the parallel arithmetic and enhanced

the convergence speed [8]. To solve UCP a novel intelligent binary PSO (IBPSO) method is developed. In this technique, mutation point (MP) is attained with an intellectual method. The unit scheduling problem of the UCP comes under discrete optimization problem using 0–1 decision variables which represents on and off status of units, in each time span of planning horizon it decides on and off status of the generating units. So the real-valued PSO has to be extended to manage discrete area of UC schedule. In the IBPSO technique an individual is a bit sequence which begins its tour from a arbitrary position in the search area & attempts to reach near to global best position and earlier best position of himself [9].

Advantages:

- The PSO is an intellectual technique which can be applied for engineering applications and scientific study.
- The PSO has no mutation calculation and overlapping.
- It has very fast search speed.
- The calculation in PSO is very simple as compared to the other emerging algorithms. [51]

Disadvantages:

- It requires parameter tuning and selection of optimal swarm size.
- It suffers from less exact regulation of its speed and the direction due to the partial optimism.
- This technique cannot solve the problems of non-coordinate system. [51]

C. *Fuzzy logic algorithm*

For solving multi constrained, highly non-linear optimization problems fuzzy logic based techniques are powerful tools in electrical power system. This technique is a mathematical scheme which holds within the concept of ambiguity when describing a theory or a meaning like presence of vagueness or “Fuzziness” in phrase like “more" or "less" as these terms are relative & vague. Thus Variables believed are called as “fuzzy” as contrasting to “crisp”. Uncertainty is similar to fuzziness. Ideas like these are applicable to the unit commitment problem. These techniques assures the creation of solution that does not breach unit or system constraints, only if generators accessible in the selection group to encounter the needed load requirement. But generally near optimal solutions are satisfactory in most practical cases, although the global optimality is desirable. It permits a qualitative depiction of the system’s features, response and behaviour of a system without the need for precise mathematical formulation. The qualitative analysis of results appears to be attractive using this method [10].

Advantages:

- It can solve multi constrained and highly non-linear optimization problems.
- It provides a powerful global search mechanism.
- In problem solving, it is helpful in decreasing the necessity for intricate mathematical models.
- It has the capability to control any kind of unit attributes data.

Disadvantages:

- It lacks an effective learning capability.

D. *Harmony search algorithm*

For solving the unit commitment problem an effective and innovative solution based Harmony Search (HS) Algorithm is created. This algorithm is simple to use as compared to the other Evolutionary techniques and within a reasonable time it reaches to optimal solution. This algorithm is inspired from a natural phenomenon i.e. while a musician explores for a superior state of harmony, which is a natural musical performance process. A number of optimization operators are included in HS algorithm, like harmony memory size known as the numeral of solution vectors in the harmony memory, pitch adjusting rate, harmony memory it stores the possible vectors and harmony memory considering rate. In the harmony memory a fresh vector is created by choosing the elements of dissimilar vectors arbitrarily. This algorithm can solve the non-linear and complex optimization problems efficiently [11].

Advantages:

- It reaches to the optimal solution within a reasonable time.
- This technique can resolve both large scale and small scale UC problems data efficiently.
- This algorithm is an effectual technique to resolve the non-linear, hard satisfactory and complex optimization problems.

Disadvantages:

- As the iteration solution approaches to the optimal solution, it suffers from slow local convergence speed especially.
- For finding an optimal solution the number of iterations rises.

E. *Genetic algorithm*

An adaptive search technique called Genetic algorithms (GA) motivated from natural evolution centred on the rules of natural choice & persistence of the fittest. The previous techniques do not offer satisfactory or somewhat information about the management of objectives and constraints. Without considering minimum up time (MUT) / minimum down time (MDT) constraints UC problem is unfinished. An improved technique called Improved Genetic Algorithm; it provides enhancement in price and value of solution for unit commitment problem [12]. A novel advanced Genetic Algorithm GA is developed which handles the constraints very well. The solution is not certified to be optimum owed to the heuristic character of the algorithm. The advanced GA can effectually search near global optimal or global solution to the unit commitment problem [13]. In this method of GA for the UC problem, for controlling the minimum up/down time constraints directly, scheduling variables are implied as integers. The GA reduces the emission cost and operating cost considering the constraints very well. GA involves various steps for solving unit UC problem, in order to get a high precision solution and good convergence, fitness function, parameter coding, genetic operation like mutation, convergence and crossover criterion are chosen centred on the traits of UC problem [14].

Advantages:

- Ease of implementation and Computational simplicity.
- Fast calculation speed.
- Powerful search ability to attain global optimum.

Disadvantages:

- The algorithm becomes really complex while integrating it with a software program.
- Requires huge effort and computational time.
- Premature convergence problem.

F. Fast heuristic algorithm

The Loss of Load Probability (LOLP) constraint is satisfied by the iteration amid the operating reliability estimation and the conventional spinning reserve requirement constrained Unit Commitment using a fast heuristic algorithm considering reliability constrained unit commitment. The algorithm can converge in very less time even for system with large number of units, while the result is attainable and suboptimal. This technique makes UC considering LOLP constraints equivalent among conventional deterministic UC methods in calculation swiftness and it will endorse the use of the probability UC methods. The method comprises two main parts: reliability evaluation and spinning reserve (SR) constrained UC. First, for each time interval the algorithm initializes the SR requirement as zero. After that, Lagrangian relaxation (LR) approach considering SR constraints solves the UC problem. Then, from UC results LOLP is calculated. Spinning reserve requirement (SRR) is updated when the LOLP gets larger than predetermined utmost LOLP limit. This whole process is repeated again or else the algorithm converges [15].

Advantages:

- The qualities of this method are the robustness & swiftness of the algorithm.
- It finds a solution close to the best one.

Disadvantages:

- A few of the problem's requirements are disregarded or even overpowers in turn to be simple and fast.

G. Evolutionary algorithm

In uncertain environment the multi objectivised unit commitment (UC) problem is resolved by means of multi-objective Evolutionary Algorithm (EA). Uncertainties due to load forecast error and unit outage has to be included in the result using the reliability index, Loss of Load Probability (LOLP) and Expected Unserved Energy (EUE). LOLP index conveys the possibility that the forecasted demand will not covered by generation system & EUE index conveys that during the scheduling sphere the generation system is not providing the expected quantity of energy. The reasons for the success of this algorithm are using population centred algorithm and by means of helper-objective contrary in environment with the prime goal to help sustain population variety & leads exploration away from the local optimum. Added benefit of using helper objective like in one sole run reliability provides a varied group of trade-off cost reliability results [16].

Advantages:

- This algorithm is robust with respect to noisy evaluation functions, non-linear constraints, multi-modalities and discontinuities.
- This algorithm is helpful for those problems, where numerous results are necessary.
- Parallel implementation is easier.

Disadvantages:

- Finding of an optimal solution cannot be assured in a limited quantity of time.
- By using the trial and error method the parameter tuning is done.
- The population methodology might be costly.

H. Pattern search algorithm

A Pattern Search (PS) algorithm is used for solving unit commitment to produce an optimal & robust solution. This algorithm is developed to set up relationship amid various factors subjected to the fulfilment of diverse constraints like power demand is equal to power generation and generation limits for developing robust solution. The PS optimization technique is a superior search based method specifically appropriate to resolve a variety of optimization problems which remain external to the extent of typical optimization techniques. The PS possesses an adaptable and stable operator to improve and attune the fine tune local and global search distinct to other heuristic algorithms, like Genetic Algorithm. The PS algorithm, keep on assessing a string of facts which cannot or can come close to the optimum solution. For a complex UC problem an effectual robust solution is necessary for overall optimization, where uncertainty exists because of number of constraints & by using PS such problem can be dealt easily. With the increase in the unit size intricate constraints are inflicted, by using conventional methods the problems are difficult to address. PS can easily resolve this difficulty as a consequence of logical representation of parameters [17].

Advantages:

- The concept of this algorithm is simple, computationally effectual and easy to implementation.
- It can be used for a large number of units.
- The proposed algorithm is efficient and faster [54].
- It can be operated on functions which are neither differentiable nor continuous [54].

Disadvantages:

- The PS is highly responsive to the early estimate and it seems to trust on that how near the known initial point is to global solution. It creates the technique feasibly more vulnerable to get stuck in the local minimum [54].

I. Binary fireworks algorithm

Binary fireworks algorithm (BFWA) solves the commitment and scheduling problem, for classifying search space it imitates explosion of fireworks in the sky and distance amid linked sparks to calculate global minimum by imitating specific action of fireworks explosion in the sky. Fireworks are generally of two types; good and bad fireworks depend on the explosion & related sparks. A good firework is defined as

the firework explosion with fine group and strongly connected sparks & vice versa. The FWA follows the base rule framed such that, the group of sparks emerged from firework explosion symbolizes the search space. Thus, the firework with strongly connected spark group reduces the search space & consequently leading to an optimal solution existence & a bad firework with lightly spaced sparks will result in big search space becoming an incompetent optimal solution [18].

Advantages:

- Fast convergence speed.
- Good optimization accuracy.
- Achieves near optimal solution.

Disadvantages:

- Sometimes when a bad firework occurs the optimal solution becomes inefficient.

J. Shuffled frog leaping algorithm

The novel evolutionary algorithm which is also called as Shuffled Frog Leaping Algorithm (SFLA) is used to find an answer to Unit commitment (UC) of the thermal units. The SFLA algorithm is integer Coded centred on the performance of the cluster of frogs exploring for the place having a large quantity of foodstuff availability. For controlling precisely the Minimum up time / down time constraints, scheduling variables are implied as integers. SFLA is a type of meta-heuristic optimization technique it unites the PSO algorithm social activities and GA algorithm memetic evolution. It is the blend of arbitrary & deterministic approaches. Deterministic method permits the process to make use of the search area effectively escorting its heuristic quest & the arbitrary method confirms sturdiness & elasticity of the search method. It is able of resolving continuous and discrete optimization problems and also able of resolving non-differentiable, multi modal and non-linear optimization problems [19].

The thermal plants Unit Commitment (UC) is an intricate constrained optimization problem with the introduction of ecological aspects have crafted the UC problem extra intricate. UC problem comprising of environmental constrained is resolved via the evolutionary method called SFLA. In which the frog is the potential solution, for generating an arbitrary population group of simulated frogs. The primary population is clustered into similarly dispersed subsections called memeplexes. Every frog in the memeplex embraces discrete plan & will attempt to increase into direction of the optimal location. Here frogs of the similar memeplex gets affected by the schemes of the other frogs of that memeplex. Aids towards the direction of the optimal frog with increase in position of poorest located frogs. The method of delivering data amid frogs is also famous as memetic evolution step or local search in a memeplex. Swapping of concepts among the memeplex is made next to a set amount of the memetic evolution stride. Simulated frogs are reorganized & mixed up for enhancing the memeplex attribute. Until a unit reaches an essential convergence, this technique of shuffling and memetic evolution is replicated [27].

Advantages:

- It has faster convergence speed.
- The algorithm is able of resolving continuous & discrete optimization problems [19].
- It is able of resolving non-differentiable, multi modal & non-linear optimization difficulties [19].

Disadvantages:

- Non-uniform initial population [42] [49].
- Slow convergent rate [42] [49].
- Limitations in local searching ability [42].
- Premature convergence [42].
- Easy trapping into local extremum [42].

K. Biogeography based optimization (BBO)

This Biogeography Based Optimization algorithm can be applied for solving the Unit Commitment problem in the electrical power system. A study on the topographical dispersal of biological creatures is called biogeography. BBO have qualities in general with additional biology centred optimization techniques, like Particle Swarm Optimization & Genetic Algorithms. The problems which PSO and GA can solve will also be solved easily by BBO. This technique can easily solve non convex & non smooth problem generally using two phases: 1) Mutation 2) Migration. The migration of species from one isle to another is depicted by BBO using mathematical models, how the species ascend & turn out to be non-existent. An isle in BBO is explained as any locale that secluded geographically from other locale. Well fit locale for the species represents the High Locale Suitability Index (HSI) although locale with low HSI said to not so well fit. Every locale comprises of characteristics which chooses the HSI for the locale. These characteristics are called Suitability Index Variable (SIV) considered as independent variable which plots the value of the HSI of the locale. A huge amount of the species has high (HSI) locale whereas lesser amount of the species has low (HSI) locale. In BBO, HSI of the locale may be raised by the migration process although due to mutation process the species in the locale will tend to go extinct if the HSI does not ascend and swapped by new species [26].

Advantages:

- Doesn’t take unnecessary computational time [44] [53].
- Good in exploiting the solutions [44] [53].
- Unlike the other optimization techniques solutions do not perish in the end of every generation [44] [53].

Disadvantages:

- Exploitation of the solutions by BBO is bad [53].
- During every generation no facility is given for choosing the finest members [53].
- While founding the qualities, a locale do not consider its resulting fitness, which may result in the generation of several infeasible results [53].

L. Gbest artificial bee colony algorithm

The Scheduling of units is an optimization task known as Unit Commitment (UC) for the generation corporations attaining utmost benefit with least operation price exclusive of any impulse of filling consumer's need owed to the deregulation of the power industries. Hence, Gbest Artificial Bee Colony (Gbest ABC) algorithm is operated for solving Profit Based Unit Commitment (PBUC). The Gbest ABC method emphases on a group of honeybees & their food search behaviour. There are generally categorised into three clusters of bees i.e. Onlookers, scouts and employed bees. In

the ABC algorithm bees hover to search food in the multi-dimensional search area. Reliant on previous experience, a number of bees hunt for food supply whereas other bees lacking experience search arbitrarily. The onlooker bees gets food statistics from the employed bees. The best food locations from those explored by the employed bees are selected by the onlookers & after that they further search food resource nearby the elected food resource. Having no possibility of progress in the food resource, the scout bees hover & locate fresh food resource arbitrarily lacking earlier experience [28].

Advantages:

- Flexibility, sturdiness & simplicity.[41]
- Unlike other search methods uses less control parameters. [41]
- Other optimization algorithms can be easily hybridized with it. [41]
- It has the capability of handling objective cost having stochastic character. [41]
- Using logical & basic mathematical operations it can be easily implemented. [41]

Disadvantages:

- In ABC, for local minima the convergence performance is slow. [41]
- Premature convergence to local minima due to poor exploitation. [40]

M. Invasive weed optimization (IWO)

IWO is a novel method to effectually resolve unit commitment (UC) and generation cost solution. The load demand is dispersed amid all the generating units using an existing technique IWO .This technique exploits the yield of UC attained by means of the Lagrangian Relaxation technique & it evaluates the essential generation through the plants leaving the OFF & considering the ON generator units, hence providing a more accurate & faster response. This technique comes under the meta-heuristic technique it imitates the inhabiting behaviour of weeds. The technique of cultivating of weed plants is used to banquet out above a space. Initially, in open periphery ground the arbitrarily spread out seeds are permitted to grow. Like the growth of plants, estimation of their fitness functions is done & arranged in the order of fitness declining. At the top, only the best fit plant is positioned. New seeds of the plants get implanted reliant upon the fitness values. The evaluation between fitness of seed & the parental weed is evaluated collectively. A normalized standard deviation assessment decides the location at a space where the plant new seeds are to be dispersed. In the record, weeds having smallest fitness is eliminated. In comparison to other evolutionary algorithms this method of congregating to the optimum result i.e. getting relatively accurate best fit parent-seed mixture [29].

Advantages:

- It has a faster and accurate response.
- This method could be stretched for any duration and no. of generating units for load scheduling.

Disadvantages:

- The convergence of results and the speed of execution is reduced due to reason that IWO technique obtains the outputs of UC from various other techniques.

N. Gravitational search algorithm (GSA)

For the wind-hydro-thermal synchronization problem, GSA is utilized for resolving & for dealing with the equality constraints pseudo code centred process is advised for increasing optimization process of the problem. Penalty function methods are not used in this module for dealing with the equality constraints other than. The major drawback of penalty function technique is reduction in the search area & if is a greatly constrained problem, it can employ good deal of time to search the possible solutions. This algorithm follows the law of gravity. Objects are deemed as agents in GSA & their masses helps in the evaluation of their functioning. Fitness function is clearly proportionate to the masses of the agents. The masses draw each other owing to gravitational push of attraction enacting on them through every iteration & all the agents experiences a global transfer toward the agents with heftier masses. An efficient agent has heavier mass. GSA is engaged to inspect the impact of various circumstances. This suggested method is pretty effectual for attaining result due to the influence of dissimilar groups [30].

Advantages:

- Ease of implementation.
- Convergence is fast.
- Has low computational cost.

Disadvantages:

- Its convergence speed slows down in the late search phase.
- Easily falls into local optima solution.

O. Binary gravitational search algorithm (BGSA)

The BGSA is novel technique which is employed to enhance the scheduling process of micro grid (MG) with dynamism, it comprises vigorous power dispatch and optimal unit commitment. Initially, according to the features of MG operation & its inner relationships amid diverse time phases. For attaining smallest environmental & working cost a mathematical optimization prototype is created, though convening the system operating requirements and load demand. In MG, GSA gets being crafted into binary algorithm in an order to convene the advanced constraints in vigorous optimum operation scheduling. The position of each particle is taken as 1 or 0 during the iteration process of BGSA optimization algorithm. Thus in of MG, BGSA enhances the operation scheduling, it comprises power dispatch and optimal unit commitment [31].

Advantages:

- It is a dependable & robust optimization algorithm for solving dynamic optimum operation scheduling problem.
- It takes a smaller amount of computational time for solving the scheduling problem.

Disadvantages:

- Depends upon randomise exploration process too much.

P. Bat-inspired algorithm (BA)

A novel evolutionary meta-heuristics algorithm enthused by a recognized behaviour of bats for locating prey known as Bat-Inspired Algorithm (BA). It is a self-adaptive method used for unravelling unit commitment (UC) problem which upsurges population variety and progresses the exploration ability of BA resulting in enhanced solutions & greater speed of convergence in resolving UC problem. Without using any penalty function it applies easier approaches to manage the spinning reserve & minimum on /off time constraint necessity in generation of all results precisely. This algorithm is centred on bats behaviour of echolocation. They has the ability of identifying the food & distinguishes varieties of the insects sited closer yet in entirely gloominess. This echolocation ability of bats is used to optimize anticipated function. BA applies all of the above stated techniques of bats in the manner of food scavenging to model an effective evolutionary algorithm. During every step of this algorithm, each bat act as a population associate, flying arbitrarily throughout creating a call with loudness & frequency in the search space to search food. Although adjusting the degree of pulse emission repeatedly. The easy structure of BA gives fast results using the period of operation in dissimilar cycles rather than binary variables expressing the status of units. Additionally, by coding spinning reserve requirement & minimum up time / down time, these constraints are controlled precisely without employing penalty functions resulting in extra realistic solutions [32]. This method provides accurate results for the electrical power generating system incorporating constraints of unit & network. BAT algorithm when associated with computational algorithms provides great characteristics of particularity which results in steady convergence & computational effectiveness. Hence, BAT algorithm is a capable method for resolving complex problems. BAT algorithm decreases the overall production cost of power generation & appropriate to resolve unit commitment problem [33].

Advantages:

- It finds better solutions at high convergence speed.
- Ease of implementation.
- Requires less execution efforts.
- This mechanism is highly stable.

Disadvantages:

- Due to local optima this algorithm confronts improper convergence.
- This algorithm has slow progress & also there is lack of variety in the population.

Q. Imperialistic competition algorithm

For resolving unit commitment (UC) problem a new approach known as Imperialistic Competition Algorithm (ICA). In the ICA, the empire comprises of initial population entities (countries) generally of two kinds: colonies & imperialists altogether. The Imperialistic rivalries amid empires congregate to a situation wherein only one empire will survive. Scheduling variables are implied as integers in ICA. For precise control of minimum up time / minimum downtime constraints can be. It begins with countries having an initial population. The imperialists have finest objective functions amid the other finest countries. Colonies are created from the remnants of the countries. Depending upon the imperialist's dominance the colonies are dispersed amid the imperialists. The cost function & effectiveness of an imperialist minimization problem is contrariwise comparative. Afterwards colonies drifts near to the appropriate imperialist & location of the imperialists will be revised if needed. After that the imperialistic rivalry amid the empires initiates and amidst this competition feeble empires are excluded. Imperialistic rivalry will progressively spearhead into an upsurge under the command of empires having an influence & a decline in command of the frailer empires. Lastly deformation of the frail empires starts, which are not capable of developing their location. The rivalries will affect the countries to congregate into a situation in which only one empire will survive amid all empires present in the world & all remnants countries becomes colonies of the empire [34].

Advantages:

- Good convergence rate.
- Better global optimal solution.

Disadvantages:

- If the parameters are not adjusted properly then the efficiency of the global optimal solution decreases and it also takes more computational time.

The various HYBRID algorithms used in these methodologies are discussed below:

R. Particle swarm based simulated annealing optimization approach

The Particle Swarm Based Simulated Annealing (PSOBSA) solves the two sub-problems concurrently and separately, economic dispatch problem for the production cost of the generating units & the unit scheduling problem which decides on-off condition of units. In this optimization method PSO is combined with SA. Indeed by merging PSO with the SA, the sturdy qualities of SA can be consumed in the PSO. It is the fundamental scheme of the PSOBSA. In this algorithm, initializing a cluster of arbitrary particles will starts the search process. The PSOBSA method offers a low-priced cost rather than those attained from other algorithms [20].

Advantages:

- It can easily escape from local minimums [38].
- It has better computational speed [38].
- It has faster convergence rate [38].

S. Quantum inspired binary PSO

The inspiration for Binary Particle Swarm Optimization (BPSO) technique is taken from the quantum computing, also known as Quantum Inspired BPSO (QBPSO), which solves unit commitment (UC) problem. For solving a combination of optimization problems in power systems BPSO based approaches has effectively been applied, but it has some limitations like when handling heavily constrained problems suffers from premature convergence. The QBPSO unites the typical BPSO with idea & rules of quantum computing like superposition of states and a quantum bit. QBPSO takes Q-bit entity for the probabilistic illustration, it changes the update process of velocity in PSO. For improving the exploration ability of the quantum computing it suggests a proficient rotation gate for renewing Q-bit entities [21].

Advantages:

- It does not suffers from premature convergence.
- It has improved search capability.
- It has shorter computation time.

T. Improved priority list and enhanced particle swarm optimization

The Improved Priority List & Enhanced Particle Swarm Optimization (IPL-EPSO) combines the Improved Priority List (IPL) method & the Enhanced Particle Swarm Optimization (EPSO), it divides Unit Commitment (UC) problem in two sub-optimal problems & finds solution for them individually. IPL is used for resolving unit scheduling problem, taking into consideration system reverse constraint, power balancing constraint, operation ramp rate constraint, minimum up / down time constraint and start-up / shut-down ramp rate constraint. The EPSO solves ramp rate constrained economic dispatch problem, for providing satisfying particular solutions for the ramp rate and power balancing constraint. This mutual aid completely represents benefit of the intelligent algorithm while referring the NP hard problem and human knowledge supervising effect, reduced computational complexity. Particles congregate to the global best solution effectively & a lot swiftly through numerous improvements of updating velocities and repairing strategies of particles. IPL—EPSO converges more rapidly and uses less time than others [22].

Advantages:

- Particles congregate to the global best solution effectively & a lot swiftly.
- It takes less computational time.
- It converges more rapidly.

U. Hybrid of genetic algorithm and differential evolution (hGADE)

The Genetic Algorithm (GA) And Differential Evolution (DE) in collaboration makes a hybrid, termed hGADE for solving power system important optimization problem called the unit commitment (UC) scheduling. This problem is combinatorial, highly constrained, nonlinear mixed integer and high dimensional optimization UC problem comprising together continuous power dispatch variables & binary UC variables. The GA can effectively handle binary variables, but for real parameter optimization the operation of DE is much more significant. In this algorithm, continuous power dispatch variables evolve using DE whereas the binary UC variables evolve using GA. For enhancing the search ability of the hybrid alternates of the UC problem certain heuristic initial population generation procedure & placement method centred on conservation of unrealistic solutions are included in the population [23].

Advantages:

- Good convergence speed.
- No premature convergence.
- Fast computational time.

V. Quadratic programming and unit de-commitment (QPUD)

QPUD is a modern method for power generation scheduling by means of Quadratic Programming & Unit De-Commitment. It gives the benefit of applying this technique concurrently for resolving economic load dispatch & unit commitment problems. To relate QP with the problem the unit state binary variables set free into the continuous variables. Initially unit commitment (UC) is formulated if the variable is higher than 0, then it is taken as 1 & other to 0. Afterwards in all time spheres for just one unit continuous variables are fixed & using QP a generation schedule is prepared in this state. The unit can be de-committed if continuous variable is equivalent to zero and rest of the variables are taken as 1. The value of the variables converges to 1 or 0 using this process & reducing the objective function of the problem i.e. aggregate of start-up & fuel cost. It allows the UC to fulfil every constraint comprising minimum up / down times, load power balancing, fuel utilization & operation reserve [24].

Advantages:

- It uses the relative cost saving feature in which if the relative cost saving is positive only the unit will be de-committed; overall cost reduces monotonically for every iteration sustaining probability with the result.

W. Particle swarm optimization and grey wolf optimizer algorithm (PSOGWO)

The Particle Swarm Optimization algorithm is a stochastic search technique centred on inhabitants; it provides a population centred search technique by selecting particles & moving them around in the search area for attaining the finest solution, therefore making it effective for global exploration. Recently, Canis-lupus developed a meta-heuristic search algorithm known as Grey Wolf Optimizer. Some qualities of Particle Swarm Optimization (PSO) are ease of implementation, easy concepts, computational efficiency & control parameters are relatively robust, even though it has several advantages, due to inhibited local / global searching capabilities whilst controlling greatly constrained problems, it easily get trapped in local minimum. Mirjalili proposes a powerful evolutionary algorithm called Grey Wolf Optimizer (GWO) it converges towards near optimal solution with a superior quality & also gives superior convergence attributes than the previous methods. The GWO provides fine stability among exploitation & exploration which avoids high local optima [25].

Advantages:

- Computational efficiency & control parameters are relatively robust.
- Converges towards superior quality near optimal result.
- High local optima avoidance.

X. Improved firefly & particle swarm optimization hybrid algorithm

For solving the unit commitment (UC) problem quickly & economically, together with both continuous and discrete parts proposes an Improved Firefly Algorithm (FA) & Particle Swarm Optimization (PSO) algorithm. Starting and shutdown state of the units were optimized using discrete binary real coded firefly algorithm. In repair strategy the inheritance from previous state and shutdown time & all constraints were considered for running time at later phase of time. Continuous PSO is used for solving unit's load dispatch problem after the course of electing starting/stopping states, considering

constraints of unit ramp, load power balancing, lower/upper limits & spinning reserve. The upper limits are dealt using Penalty function.

Xin-She Yang developed a stochastic optimization algorithm inspired from nature known as Firefly Algorithm (FA) lately, by mimicking the behaviour of firefly luminescence. But some fireflies glow biological significance is rejected considering the flashes attributes centred on their search area gazing for partners and for attaining the position in a sequence to develop fireflies move to the optimum position within the structure. The algorithm comprises of dual sections, to be specific Attractiveness & Brightness. Where brightness replicates the pros & cons of position of the fireflies & decides to advance in which direction, attractiveness decides space covered by the firefly, and by continuously updating between the brightness and attractiveness, we can achieve the target optimization.

In 1995, Kennedy and Eberhart put forward an evolutionary algorithm Particle Swarm Optimization algorithm, by studying the birds feeding behaviour this algorithm is developed. It has been successfully applied in neural network design, multi objective optimization, function optimization parameter estimation, constrained optimization, automatic control signal processing & other several areas. In the beginning, PSO arbitrarily prepares a cluster of the particles in search space & afterwards these particles travels with a definite consistency in search space finding the optimal solution through numerous iterations. By trailing the global extremum & individual extremum particles updates themselves at every iteration [35].

Advantages:

- Better convergence rate than individual algorithms used.
- A satisfactory solution can be attained effectually & precisely.
- Fast convergence speed.

Y. Gbest artificial bee colony algorithm (GABC) and teaching learning based optimization (TLBO) algorithm

A challenging optimization task is price based unit commitment resolved by using newly created Gbest Artificial Bee Colony Algorithm & Teaching Learning Based Optimization Algorithm. The food exploring pattern of the cluster of honeybees is centred in ABC algorithm. Generally there are three types of bees i.e. onlooker, scouts & employed bees. For tracking food in multi-dimensional search area the bees fly in it everywhere. A few of them look for food resource reliant on experience of previous search & a few locate food resource without any experience arbitrarily. The information is communicated to the onlooker bees by the employed bees about their food source. The good food resources are chosen by the onlookers amid those founded by the employed bees & further exploration starts for food resource closer to the chosen food resources. The scout bees fly away if there is no more food source available there and without any sort of experience finds out the fresh food resources arbitrarily.

The Teaching learning manners of the class teacher & learners-students of the class are being simulated in the TLBO. A learner can gain higher grades depending upon that teacher's teaching ability. The outcome of learners by means of better grades shows the qualities of a good teacher. This algorithm assumes population as a cluster of learners & the teacher is assumed to be the most excellent result amid the whole results. The method consists two dissimilar stages that are Learning Stage & Teaching Stage [36].

Advantages:

- Faster convergence rate.
- Higher calculation accuracy than individually.

III. CONCLUSION

This paper concludes that various algorithms hybrid & non-hybrid are used for solving the unit commitment problem (UCP). The hybrid algorithm which is the combination of more than one algorithm is much more effective than the non-hybrid algorithm i.e. an individual algorithm for solving the UCP. The non-hybrid algorithm suffers from the problems like slow convergence speed, premature convergence, large computational time & easy trapping in local optimum solution etc. These problems can be easily removed by the hybrid algorithm, because drawback of one algorithm is overcome by the other algorithm in combination with it gives the advantages like easy escape from local optimum, better computational speed, faster convergence rate, no premature convergence & higher calculation accuracy etc. The results obtained for the UCP by the non-hybrid algorithms are good but in comparison the results of the hybrid algorithms are much better and efficient.

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