# Review on Convex Optimization Solutions of combined heat and Power Economic Load Dispatch

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***Abstract -*** Economic load dispatch (ELD) in the operation of electric power framework is a basic undertaking, since it is required to decide the ideal yield of power creating offices, providing the ability to take care of load demand at least cost while fulfilling transmission and operational limitations. A few strategies were connected to take care of the monetary load dispatch issue, both ordinary and keen techniques. As of late, scientists are giving careful consideration to insightful systems, for example, Swarm-based calculations and their improvement keeping in mind the end goal to be utilized to effectively take care of entangled genuine enhancement issues. This paper introduces a study on the novel alterations connected to swarmbased calculations utilized as a part of taking care of ELD issues and its variations. Swarm streamlining calculations utilized as a part of this paper are: Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Bacterial Foraging Optimization Algorithm (BFOA), Shuffled Frog Leaping Algorithm (SFLA), Artificial Bee Colony (ABC), Firefly Algorithm (FA), Cuckoo Search Algorithm (CSA), Bat Algorithm (BA) and Gray Wolf Optimization (GWO). The financial load dispatch (ELD) is an intricate streamlining issue due to non-straight, non-curved sort fuel cost attributes of the petroleum product worked warm generators. Albeit numerous customary streamlining approaches have been produced to take care of such issue, over the previous decade, the bio-roused improvement (BIO) strategies have indicated promising execution on such compelled ELD issues. This paper endeavors to give an exhaustive audit of use of BIO calculations to take care of most complex down to earth ELD issues.

***Keyword -*** *ABC, PSO, FPA, OPTIMIZATION*

## I. INTRODUCTION

*Combined Heat and Power*

Combination of Heat and Power units is also termed as Cogeneration. It is more effective and beneficial form of power generation. This combined result provides high fuel efficiency and lowers the transmission losses. Combined Heat and Power has the tendency to convert single fuel into both electricity and heat in single process. There is a financial, operational and environmental benefit of CHP which stands for Combined Heat and Power. CHP plays an important role in utility industry. It is used to provide heat as well as electrical power to customer. CHP is thermally more efficient with the use of fuel than electricity generation. In individual production of electricity energy has been rejected as waste heat but in CHP this waste heat had been used for some good purposes. They use this wasted energy for heating which is termed as combined heat and power district heating (CHPDH). Efficiency of normal power generation lies between 50% to 60 % and the efficiency increases up to 90% by introducing CHP. CHP helps to reduce the emission of pollutant gaseous like $SO_2$, CO etc. about 13 to 18 %. To integrate the CHP system or to increase its economy, economic dispatch is applied to CHP. Economic dispatch (ED) is the most important optimization problems in power system operation. Minimizing the total generation cost is the main objective of the economic dispatch.

Various problems in Economic Dispatch:

- Economic dispatch with valve point (EDVP)
- Multi-area economic load dispatch (MAED)
- Companied economic-environmental dispatch. (CEED)
- Cubic cost function economic dispatch. (QCFED)

These are some problems occurred in ED. There are some algorithms used to resolve these problems:

- Real-coded Genetic Algorithms (RCGA)
- Particle Swarm Optimization (PSO)
- Differential Evolution (DE)
- Covariance Matrix Adapted Evolution Strategy (CMAES)

There are various researcher who proposed methods to solve the problem of economic dispatch. F. J. Rojier proposes a method which is based on the objective function of the problem. Two-level strategy is used in this method which is lower and upper level. To solve individual units for given power and heat lambda's is solved by lower level and upper level is used to update the lambda's by using sensitivity coefficients. This process will repeat until the problem has been solved. Tao Guo also gave a method which used to divide ELD problems into two part 1) heat dispatch 2) power dispatch. Two-layer algorithm is used to solve the problems.

Outer layer solve the power dispatch iteratively by using Lagrangain relaxation technique. The inner layer solved the heat dispatch with unit heat capacities passed by outer layer. Binding constraints of the heat dispatch are fed back to outer layer to move the CHP economic dispatch towards a global optimal solution. To solve CHPED problem Subharaj introduced a real-ended genetic algorithm (SARGA). There are various other authors who give the algorithms to solve the problem of ED.

Types of CHP plant:

- Gas Turbine CHP plant: In this plant, is used, waste heat in the fuel gas. The fuel used is natural gas.
- Gas engine CHP plants: This plant used a reciprocating gas engine which is better than gas turbine up to 5 MW. Fuel used is natural gas. These type of plants are made as fully packed unit which are easily installed according to needed place like plant room or external plant compound with simple connection.
- Bio fuel engine CHP plants: This plant used an adaptive reciprocating gas engine or diesel engine, which depends on the biofuel used. It is similar in design to a gas engine CHP plant. Bio-fuel gives reduction in the hydrocarbon fuel consumption and reduces in carbon emission too.
- Wood gasified CHP plant: In this plant a wood pellet or wood chip bio-fuel is gasified with zero oxygen in high temperature. The resulting gas is used to power the engines. This plant generally has small size.
- Combined cycle power plant
- Steam turbine CHP plant: In this plant heating system is used as a steam condenser for steam turbine.
- Microchip CHP: It is also called as distributed energy resources (DER). The installation is less than 5KW in a house or small business. In this plant energy is converted to electricity in addition to heat. This electricity will be used within home or business, sold back into the electric power grid if permitted by grid management.

## II. LITERATURE SURVEY

**Guo et al.[1]:**This paper introduces a algorithm for CHPED. This method splits the problem into two sub-problem 1) heat dispatch 2) power dispatch. These splitted problems are connected through heat-power feasible region constraints of cogeneration units. In Lagrangain function the connection can be interpreted by the unit heat power and this interpretation develops a two-layer algorithm, where Lagrangain relaxation technique in used by outer layer to solve the power dispatch by iteratively and the inner layer solve the heat dispatch with the unit heat capacity passed by the outer layer. This process is done by iteration of each patch. Then these binding constraints of the heat dispatch are taken back to the outer layer to move the CHP.

**Yang, et al. [2]:**General economic dispatch (ED) is introduced in this paper for generating units with non -smooth fuel cost function. Here on the basis of evolutionary programing (EP) technique, new algorithm is able to find the global or near global optimal dispatch solution where Lagrangain based method ceases to be applicable. This algorithm is verified in Taiwan power system (Tai power system). The results show that this method gives accurate solution in less time for any type of fuel cost function. This evolutionary programming on the bases of economic dispatch provides accurate solution in this result.

**Sudhakaran, et al. [3]:**In this paper CHPED problem has been solved by integrated genetic algorithm. In this method techniques are developed in such a manner that GA act as a base level search and directs the search towards optimal region and local searches which is combined with tabu search is next employed to fine tune to obtain maximum solution. This proposed technique is applied to reduce time for computation and also improve rate of accuracy. It is a fast, effective and is also applicable for all type of non-linear and discontinuous objective function. A test system with four units is considered to prove the validity and effectiveness of the proposed method. The first unit is conventional power unit; the second and third unit is cogeneration units and fourth is a heat unit. There is a comparison between the results of this technique and other technique it is shown that Proposed method is valid and a time application.

**Venkatesh, et al. [4]:** In this paper to obtain ELD solution for three, six, 13-unit system evolutionary computation (EC) like genetic algorithm (GA), micro genetic algorithm (MGA) and evolutionary programming (EP) are used. After having investigation on three algorithms it has been considered that evolutionary programming is better as compare to other two for solving ELD problems. EP-based CEED problem is tested on IEEE 14-.30-, and 118-bus system with or without line flow constraints. Here in EP algorithm a scaling factor is included to improve the performance of 13 units and IEEE system. The obtained result is quite encouraging and useful in economic emission environment.

**Chapa et al. [5]:** For solving economic dispatch problem in CHP system this paper introduced an algorithm. The basis of sequential quadratic programming (SQP) algorithm is taken to solve the non-linear problems and an idea of Lagrangain technique is used before optimal schedule of CHP. In this method it will temporary erase them from the problems instead of consider linear inequality constraints. By erasing the constraints it becomes easy to solve the problem by given algorithm. The problems are solved partially and check the region of the solution by using sequential quadratic programming. By using this method we check the region

weather it is inside the trust-region or not. The problem is trivial if the problem is in the trust region and if it is not in trust region then we use the right inequality line considering equality and solving the whole problem. There is an improvement in the global solution by proposing this algorithm

**Chiang, et al. [6]:**To solve power economic dispatch (PED) problems of unit an improved genetic algorithm with multiplier updating (IGA/spl. I bar/MU) is proposed in this paper. In this method integration is done for the improved genetic algorithm (IGA) and multiplier updating (MU). IGA is with an improved evolutionary direction operator and a migration operation can efficiently search and actively explore solution. MU handles the equality and inequality constraints of the PED problems .Both valve point loading and change fuel is addressed with PED related studies. One- one example to PED, MU and both valve point and multiple fuels has been considered to check or represent the advantage of proposed algorithm. There is also a comparison with previous methods and it concluded that this algorithm is effective for large – scale system of actual PED operations.

**Hernandaze et al. [7]:**This paper considered a micro grid which consists of two reciprocating gas engines 1) combined heat and power plant 2) photovoltaic array and a wind generator. The main aim of this method is to reduce the rate of fuel consumption and to fulfill the local energy demand both electrical as well as thermal and to provide certain minimum reserve power. For the production of excess of demand a penalty is applied. Communication infrastructure between power sources is indicated by the solutions of optimization problem.

**Wang et al. [8]:** Firstly for CHP a stochastic model is formulated in this paper. Then after an improved particle swarm optimization (PSO) method is developed which helps to deal with the economic CHP dispatch by simultaneously considering multiple conflicting objectives. Stochastic and deterministic models on power dispatch is investigated and analyzed on the basis of proposed optimization.

**Ummels et al. [9]:** New technique which fully assesses the impact of large-scale wind power on system operation is proposed in this paper. This method will also assess the impact of operation in cost, reliability and environmental perspective. Time series of observed and predicted 15 averages speed at foreseen onshore and offshore-wind farm location has been used in this method. For frequents revisions of conventional generation unit schedule a UC-ED unit commitment and economic dispatch is used by using information on current wind energy output and forecast for next 36 hour. This method included short-term planning activity for a system and a simple way to find actual operations with large wind power penetration. In this method results are given for future scenario of the Dutch power system. It shows that problems like insufficient regulate and reverse power can be assed in conjunction with conventional generation system. The problems are associated with the variability and limited predictability of wind power.

**Sinha et al. [10]:** There is an investigation in this paper .In this paper performance of Genetic Algorithm (GA) is investigated for solving combined heat and power dispatch (CHPD) in a power system. Different combination of crossover and mutation function of GA are explored and tested with different algorithm according to suitability for CHPD problems. After simulation results shows that floating point Gas is better than binary GA in performance to solve non-convex CHPD problems. The performances of FGPA with heuristic and crossover and multi-non uniform mutation is the best while talking about efficiency in achieving better quality solutions.

**GU, et al.[11]:**This paper gives an study on the problem of economic operation of cogeneration system which includes wind energy , PV, heat recovery boiler and battery. A non-linear optimal model is built to deal with the economic operation of available power resources by predicting the next 24-hours wind energy and PV power; power and heat demand and formulate the 24 hour work schedule. This paper focus on the effect of battery and peak- valley electricity price on system operation cost. Here four different cases are compared with a test CHP. The result of test indicates the peak –value electricity price would increase the system operating costs. By using battery and peak load shifting can effectively reduce operating cost.

**Augustine et al. [12]:**An easy and simple method is introduced in this paper to analyze the dispatch rate of power. In this paper an isolated micro grid with solar and wind is considered. Here generation cost function is modeled by inclusion of investment cost and maintenance cost of resources. By using reduced gradient method we solve the ED problems. In this paper we studied the effect of total cost with inclusion of wind energy into a micro grid and we find the most beneficial solution. Solution determined by considering different practices scenarios. This paper gives a brief relation between cost function, investment function, lifetime and the fluctuant energy forecasting of wind and solar resources. Advantages of renewable energy credits for solar panel are discussed in this paper.

**Basu et al. [13]:** this paper has a focus on the question which is incorporate originality in ideas to evaluate that how different optimal output sets of DER-mix, operating within their respective capacity limits, will share electrical tracking

demand, economically among micro-turbines and diesel generators of various size, satisfying heat demand. There is a compromising between fuel cost and emission in a 4 –DER 14_bus radial micro grid on the basis of multi objective optimization on the basis of multi-objective optimization. By using different evolution (DE) technique optimization is done under real power demand equality constraints, heat balance inequality constraint and DER capacity limits constraints. DE result is compared with PSO

**Adhvaryyu, et al. [14]:**For solving CHPED a new technique is introduced in this paper i.e. bio-inspired new krill herd (KH). This method is based on the herding individual behavior of krill. It is very efficient for finding the global optima in shortest time as possible. The distance of each krill individual from food and the highest density of herd are termed as objective function. Position of krill is depending upon 1) motion generated by surrounding krill 2) foraging motion 3) Diffusion motion. This method is described on test system and its result has been compared with the obtained result from PSO, EP and DE. Solution obtain from KH method is better than the other methods. This conclusion is given by the result.

**Li, Z., and Wu, et al. [15]:**In this paper CHPD is formulated to co-ordinate the operation of electric power system and district heating system (DHS). The temperature dynamics of the DHN for exploiting energy storage for managing the variability of wind energy is considered from CHPD model which is solved by iterative method. To find the potential benefits of the proposed method in terms of operation economics, wind power utilization and potential benefits for real system we discuss the determined results.

## IV. LITERATURE REVIEW FINDING.

| Authors Name | Year | Technology Used | Description |
|---|---|---|---|
| **Guo et al. [1]** | 1996 | Lagrangain method is used | In this method the problem splitted into two sub-problem 1) heat dispatch 2) power dispatch. These splitted problems are connected through heat-power feasible region constraints of cogeneration units. |
| **Yang,et al. [2]** | 1996 | Evolutionary program technique is used. | On the basis of EP new algorithm is able to find the global or near global optimal dispatch solution where Lagrangain based method cease to be applicable. This algorithm is verified in Taiwan power system (Tai power system) |
| **Sudhakaran, et al. [3]:** | 2003 | Integrated genetic algorithm. | This proposed technique is applied to reduce time for computation and also improve rate of accuracy. It is a fast, effective and is also applicable for all type of non-linear and discontinuous objective function |
| **Venkatesh, et al. [4]:** | 2003 | EC.GA and EP is used | EP-based CEED problem is tested on IEEE 14-.30-, and 118-bus system with or without line flow constraints. Here in EP algorithm a scaling factor is included to improve the performance of 13 units and IEEE system. |
| **Chapa et al. [5]:** | 2004 | Sequential quadratic programming | The problems are solved partially and check the region of the solution by using sequential quadratic programming. By using this method we check the region weather it is inside the trust-region or no |
| **Chiang, et al. [6]:** | 2005 | Multiplier updating (IGA/spl.I bar/MU) | In this method integration is done for the improved genetic algorithm (IGA) and multiplier updating (MU). IGA is with an improved evolutionary direction operator and a migration operation can efficiently search and actively explore solution. MU handles the equality and inequality constraints of the PED problem |
| **Hernandaze et al. [7]:** | 2005 | Micro grid | The main aim of this method is to reduce the rate of fuel consumption and to fulfill the local energy demand both electrical as well as thermal and to provide certain minimum reserve power |
| **Wang et al. [8]:** | 2006 | Stochastic model is formulated. | Development of PSO and which further help to deal with economy of CHP. |
| **Ummels et al. [9]:** | 2007 | Updated techniques are used. | Assessment of the impact of large-scale wind power on system operation |
| **Sinha et al. [10]:** | 2008 | Genetic algorithm | Solution of CHPD is done in power system and investigation of the performance of GA. |

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| **Gu, et al.[11]:** | 2010 | | Study in the effect of battery and peak valley electricity price on system operation cost. |
| **Augustine et al. [12]:** | 2012 | Isolated micro grid and reduced gradient method is used | Solving ED problems and also studying the effect total cost with inclusion of wind energy. |
| **Basu et al. [13]:** | 2012 | Different evaluation technique is used | This is a study on the optimal output sets of DER-mix . |
| **Adhvaryyu, et al. [14** | 2014 | Bio-inspired krill herd technique is used. | Solving CHPED by krill herd. Evaluate the position of krill. |
| **Li, and Wu, et al. [15]:** | 2016 | Iterative method and CHPD | CHPD is formulated to co-ordinate the operation of electric power system and district heating system (DHS). |

## V. CONCLUSIONS

Economic load dispatch (ELD) issue plays an essential part in the operation of energy framework. This paper presents essential variations and contemplations of the ELD issue. To begin with, the definition for the ELD issue was laid out. The fundamental goal of ELD is to decide ideal power age and limiting the fuel cost. At that point a survey of the swarm streamlining calculations was introduced. Despite the fact that these calculations have effectively tackled the ELD issue, yet further changes to the calculations were required. In this manner, updates and adjustments were acquainted with these calculations. This paper assessed the work detailed in writing in the field of utilizing swarm enhancement calculations and their current updates to illuminate financial dispatch issues.

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