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Optimization of Combined Economic and Emission Dispatch Problem using Artificial Intelligent Technique

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ABSTRACT

In this paper, a time varying acceleration coefficient particle swarm optimization (TVAC_PSO) algorithm has been proposed to address the combined economic and emission dispatch (CEED) problem in thermal power plants. Two different generating systems have been considered for the study - one consisting of three generators and the other comprising of the standard IEEE 30-bus six-generator systems. Performance of the proposed algorithm has been compared with the well-known particle swarm optimization (PSO) algorithm. Performance comparison has been carried out in the MATLAB environment. Results obtained clearly demonstrate the efficiency of the proposed TVAC_PSO algorithm over the PSO algorithm in terms of reduced fuel cost and NOx emissions and hence the total operating cost.

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INTRODUCTION

Since an engineer is always concerned with the cost of products and services, the efficient optimum economic operation and planning of electric power generation system have always occupied an important position in the electric power industry. With large interconnection of the electric networks, the energy crisis in the world and continuous rise in prices, it is very essential to reduce the running charges of the electric energy. A saving in the operation of the system of a small percent represents a significant reduction in operating cost as well as in the quantities of fuel consumed. The classic problem is the economic load dispatch (ELD) of generating systems to achieve minimum operating cost. This problem area has taken a subtle twist as the public has become increasingly concerned with environmental matters, so that economic dispatch (in this paper work economic load dispatch (ELD) and economic dispatch (ED) have been used interchangeably) now includes the dispatch of systems to minimize pollutants and conserve various forms of fuel, as well as achieve minimum cost.

In addition there is a need to expand the limited economic optimization problem to incorporate constraints on system operation to ensure the security of the system, thereby preventing the collapse of the system due to unforeseen conditions. However, closely associated with this economic dispatch problem is the problem of proper commitment of any array of units out of a total array of units to serve the expected load demands in an 'optimal' manner. For the purpose of optimum economic operation of this large scale system, modern system theory and optimization techniques are being applied with the expectation of considerable cost savings. These pollutants cause harmful effects on the human beings as well as on the environment. So, during the load allocation process, the cost economy should not be the only objective but the reduction of emissions should also be taken into account. A large number of fossil-fuelled power plants have been set up for fulfilling the ever increasing load demand which has resulted in the increased emission of pollutants such as sulphur oxides, nitrogen

oxides and carbon dioxide. With large interconnection of the electric networks, the energy crisis in the world and continuous rise in prices, it is very essential to reduce the running costs of electric energy. A saving in the operation of the power system brings about a significant reduction in the operating cost as well as in the quantity of fuel consumed.

The main aim of modern electric power utilities is to provide high-quality reliable power supply to the consumers at the lowest possible cost while operating to meet the limits and constraints imposed on the generating units and environmental considerations. These constraints formulates the economic load dispatch (ELD) problem for finding the optimal combination of the output power of all the online generating units that minimizes the total fuel cost, while satisfying an equality constraint and a set of inequality constraints. Traditional algorithms like lambda iteration, base point participation factor, gradient method, and Newton method can solve this ELD problems effectively if and only if the fuel-cost curves of the generating units are piece-wise linear and monotonically increasing. Practically the input to output characteristics of the generating units are highly non-linear, non-smooth and discrete in nature owing to prohibited operating zones, ramp rate limits and multi-fuel effects.

In power system, the economic load dispatch problem introduced when two or more generating units together produced the electrical power which exceeded the required generation. Engineers resolved this problem by implementing that how to divide the load among the committed generators. In reality, power plants are not situated near the load centres. Due to this, there is a change in fuel costs. If the generating system is in the normal operating condition, the generation would be more than power demand and losses. To cope up this, many methods of scheduling are employed. The modern power systems are the network of interconnections. In this interconnected system, the main task is to allocate the load demand among participating generators at minimum possible cost with satisfying all the system constraints. Thus, this is termed as economic load dispatch in power system. Many conventional methods applied to solve ELD problems through mathematical programming and optimization techniques. The main conventional methods are the lambda iteration method, base point and participation factor method, gradient method etc. From all these methods, the lambda iteration method uses frequently and this can be applied easily also. All these above mentioned methods can only feasible for linear cost approximation.

The practical power system has discontinuities and nonlinearities due to prohibited operating zones, ramp rate limits, valve-point loading, and multi fuel options. Due to these nonlinearities the practical ELD becomes a complicated and non-convex optimization problem which has complex characteristics as well as non-convex characteristics. This ELD have multiple minima and it is very difficult to find global minima. In this case, the traditional methods fail to optimize. Many heuristic approaches applied to the ELD problems such as dynamic programming, evolutionary programming, genetic algorithm, artificial intelligence, tabu search, particle swarm optimization. EP is a robust approach but in some cases it converges slowly near optimum. TS and SA are also robust approach to solve complex optimization problem.SA is time taking approach while TS is hard to explain the memory structure. DE is also a robust approach but its evaluating process is terminated at local optima. Thus DE cannot perform as per expectation. GA is a type of probalistic heuristic algorithm. GA is better than SA because of parallel search 3 technique in GA. GA uses as one of the main algorithms to solve the ELD problems because of its performance for global optimization.

Economic Load Dispatch

Economic dispatch is defined as the process of allocating generation levels to the generating units in the mix, so that the system load may be supplied entirely and most economically. To all intents and purposes, there has been concern that optimum economic dispatch was not the best environmentally. On the other hand, existing capacity is a source of most pollutant emissions, and technological change has opened up opportunities for producing electricity in a cleaner and cheaper manner. In the context to increasing public awareness of the environmental situation and the plea for clean air, many organizations came up with a new method so called minimum emission dispatching method to reduce air pollution. However, this leads to a noticeable increase in the operating cost. In view of modern stringent requirements imposed on electric utilities and sluggish growth in demand, the power industry planners are indicating stronger trends towards supplying electric power of higher quality by improving the system security and the impact on the environment in parallel with pursuit of economy.

Therefore, in order to obtain a more meaningful and practical optimal schedule of operation for power system, a study on economic load dispatch is conducted in multi-objective framework where operating cost and NOX emission objectives are undertaken simultaneously. Despite extensive research focusing on optimal power scheduling problems, much of the effort to date has involved the development of deterministic models applicable to steady- state conditions. Most of these attempts assume the system data to be deterministic. It means that all input information is known with complete certainty. Actually, there are several inaccuracies and uncertainties in the input information. The economy of operation of power systems is

significantly influenced to a certain degree by approximations in the operation planning procedures and by the inaccuracies and uncertainties in input system information. By way of this study, a theoretical basis and methodological grounding for the optimal dispatch problem in a unified multi-objective framework is established by giving quantitative representation of inaccuracies and uncertainties in input data for more realistic approach. The need for such a study comes from the fact that the very sophisticated procedure might show unexpected deviations on realistic small error in the input datum.

LITERATURE REVIEW

As power demand increases and fuel cost booms in the recent years, reduction in the operating costs of the power system becomes an important issue. One of the choices is to operate the generators more efficiently and economically. The objective of ELD problem is to control the committed generator's output such that the total fuel cost is minimized while satisfying the power demand and other constraints. Traditionally, fuel cost function of a generator is represented by a single quadratic function.

Economic load dispatch problem plays an important role in the operation of power systems. It is a method to determine the most efficient, low cost and reliable operation of a power system by dispatching the available electricity generation resources to supply the load on the system. The primary objective of the ELD is to minimize the total cost of generation while maintaining the operational costs of the available generation resources [31]. The economic load dispatch is very important optimized problem solution in power system operations for allocating generation among the committed units such that the system constraints imposed are satisfied and energy requirements in terms of Rupees per hour(Rs/hr) or Dollars per hour ($/hr) are minimized.

Yiğit Çağatay Kuyu, Nergis Erdem [1] The Vortex Search (VS) algorithm is a recently developed metaheuristic algorithm inspired by a vortex pattern which can be modeled as a number of the nested circles. This algorithm basically adjusts step sizes automatically according to changed values of the radius of circles to improve solutions. In this work, the VS algorithm is applied to solve the economic load dispatch (ELD) problem in the 20-unit test system by considering the system constraints and also the performance of this algorithm has been analyzed in terms of total generation costs and power losses. Simulation results have been compared to the different algorithms used before in the literature. The obtained results demonstrate that VS algorithm is capable of solving the ELD minimization problem efficiently and finding the output power of all the generation units properly.

Sushil Kumar, Harkamal Deep Singh [2] Economic Load Dispatch is basic research challenges and critical advancement work in the everyday operational arranging of age framework. It is here and now determination of the most ideal yield of various generators units, to meet the power framework stack, at the base conceivable cost, topic to operational requirements and transmissions. This research paper tries to show the numerical detailing of Economic load dispatch issue arrangement utilizing delicate registering method in electric era structure considering different physical and power induced system imperatives.

Mustafa Saka, Suleyman Sungur Tezcan, Ibrahim Eke [3] Economic load dispatch (ELD) is one of most fundamental issue for energy generation and distribution in power systems. For this purpose, different optimization techniques are developed and applied to ELD problem. In this paper, vortex search algorithm (VSA) is proposed and used for solving ELD problem. VSA method was developed from nature by observing the state of stirring liquids. Transmission losses, valve point loading effect, ramp rate limits and prohibited operating zone constraints are considered to solve ELD problem with VSA method. The feasibility and effectivity of this method is demonstrated for different cases. Obtained results are compared with different developed algorithms and these results clearly point out that proposed VSA method gives successfully outputs.

M. Saka, I. Eke, S. S. Tezcan, M. C. Taplamacioglu [4] in modern powers systems, one of the most considerable topics is economic load dispatch (ELD). ELD is non-linear problem and it became non-convex and non-smooth problem with some constraints such as valve point loading effect. ELD is very crucial for energy generation and distribution in power systems. For solving ELD problem, a lot of methods were developed and used at different power systems. Vortex search algorithm (VSA) is proposed and applied for solving ELD problem in this paper. VSA method was developed in the form of stirring liquids. Transmission line losses, valve point loading effect, ramp rate limits and prohibited zones constraints were used to make the results of ELD problem the closest to the truth. The results which are obtained from VSA compared with PSO, CPSO, WIPSO, MFO, GA and MRPSO techniques. It can be clearly seen that VSA gave minimum cost values with optimum generator powers so it is very effective and useful method and it gave the best solutions for ELD.

P. Bhui, N. Senroy [6] This paper proposes a new deterministic approach to solve economic dispatch problem with non-convex cost function. Earlier, several meta heuristic approaches were applied to solve this problem but these technique does

not guarantee the global solution, whereas the parameters of the methods need to be tuned before using and these parameters depend on the system operating condition. First, multiple minima are detected. Power in between two consecutive minima is taken as a step. Starting from minimum generation, power is increased in steps until demand is met. In case of last step, most efficient step is selected keeping the active power balance under consideration. Proposed method has been tested on 40 unit test system and compared with other methods.

N. Singh, Y. Kumar [13] Electric utility system is interconnected to achieve the benefits of minimum production cost, maximum reliability and better operating conditions. The economic scheduling is the on-line economic load dispatch, wherein it is required to distribute the load among the generating units which are actually paralleled with the system, in such a way as to minimize the total operating cost of generating units while satisfying system equality and inequality constraints. For any specified load condition, ELD determines the power output of each plant (and each generating unit within the plant) which will minimize the overall cost of fuel needed to serve the system load [1]. ELD is used in real-time energy management power system control by most programs to allocate the total generation among the available units. ELD focuses upon coordinating the production cost at all power plants operating on the system.

R.A. Jabr, A.H. Coonick, B.J. Cory [28] This paper presents a study of the simplified homogeneous and self-dual (SHSD) linear programming (LP) interior point algorithm applied to the security constrained economic dispatch (SCED) problem. Unlike other interior point SCED applications that consider only the N security problem, this paper considers both (N-1) and (N-2) network security conditions. An important feature of the optimizing interior point LP algorithm is that it can detect infeasibility of the SCED problem reliably. This feature is particularly important in SCED applications since line overloading following a contingency often results in an infeasible schedule. The proposed method is demonstrated on the IEEE 24 bus test system and a practical 175-bus network. A comparison is carried out with the predictor-corrector interior point algorithm for the SCED problem presented.

EVOLUTIONARY ALGORITHMS

As the history of the field suggests, there are many different variants of Evolutionary Algorithms. The common underlying idea behind all these techniques is the same: given a population of individuals the environmental pressure causes natural selection (survival of the fittest) and this causes a rise in the fitness of the population. Given a quality function to be maximized we can randomly create a set of candidate solutions, i.e., elements of the function's domain, and apply the quality function as an abstract fitness measure - the higher the better.

Based on this fitness, some of the better candidates are chosen to seed the next generation by applying recombination and/or mutation to them. Recombination is an operator applied to two or more selected candidates (the so-called parents) and results one or more new candidates (the children). Mutation is applied to one candidate and results in one new candidate. Executing recombination and mutation leads to a set of new candidates (the offspring) that compete - based on their fitness (and possibly age) – with the old ones for a place in the next generation. This process can be iterated until a candidate with sufficient quality (a solution) is found or a previously set computational limit is reached.

- In this process there are two fundamental forces that form the basis of evolutionary systems.
- Variation operators (recombination and mutation) create the necessary diversity and thereby facilitate novelty, while
- Selection acts as a force pushing quality.

The combined application of variation and selection generally leads to improving fitness values in consecutive populations. It is easy (although somewhat misleading) to see such a process as if the evolution is optimizing, or at least ”approximating", by approaching optimal values closer and closer over its course. Alternatively, evolution is often seen as a process of adaptation. From this perspective, the fitness is not seen as an objective function to be optimized, but as an expression of environmental requirements. Matching these requirements more closely implies an increased viability, reflected in a higher number of offspring. The evolutionary process makes the population adapt to the environment better and better.

Particle Swarm Optimization

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Kennedy and Dr. Eberhart [36] in 1995, inspired by social behavior of bird flocking or fish schooling. PSO shares many similarities with

evolutionary computation techniques such as Genetic Algorithms (GA). The system is initialized with a population of random solutions and searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles. The detailed information will be given in following sections. Compared to GA, the advantages of PSO are that PSO is easy to implement and there are few parameters to adjust. PSO has been successfully applied in many areas: function optimization, artificial neural network training, fuzzy system control, and other areas where GA can be applied.

Flowchart of PSO

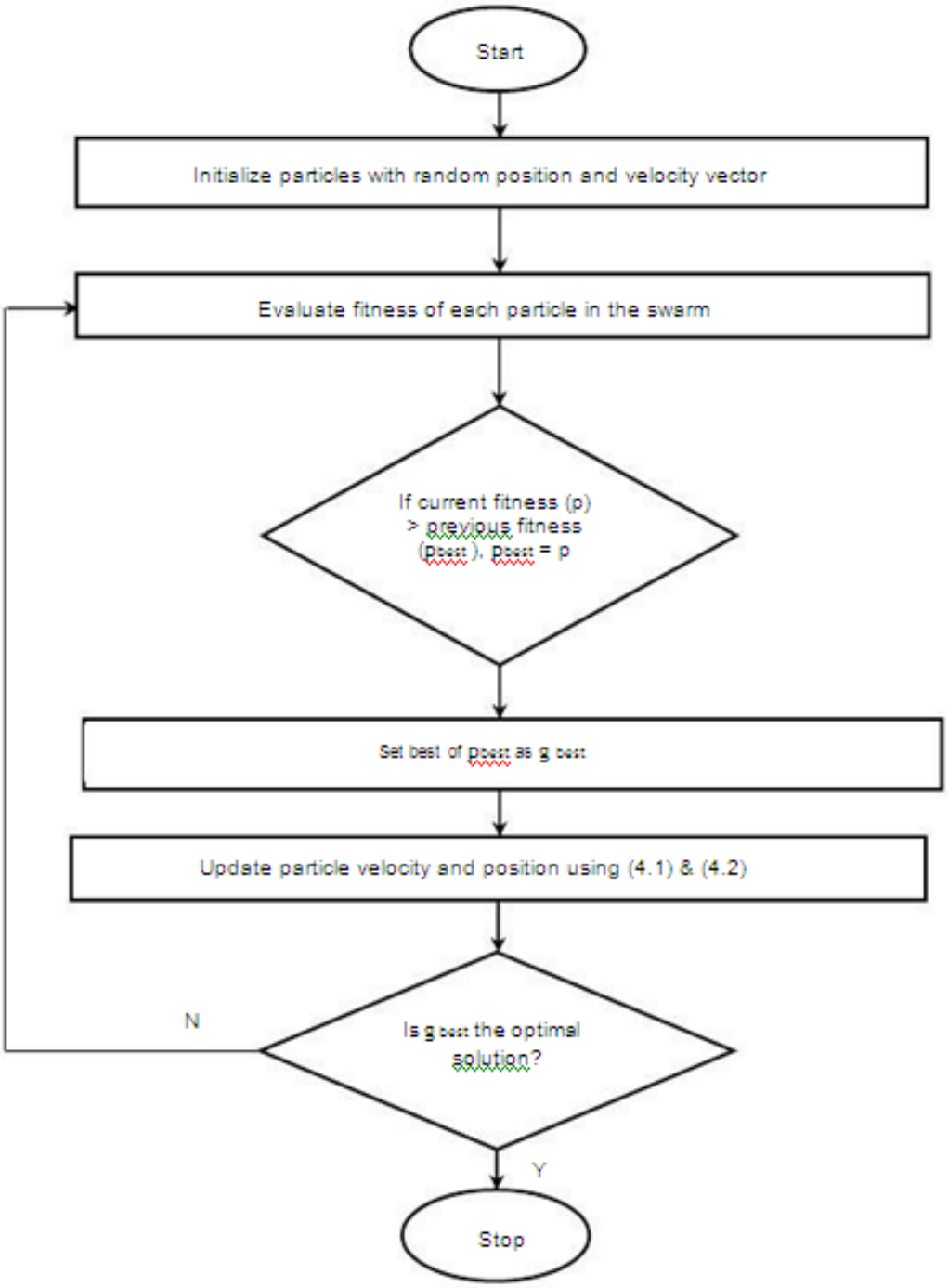

Figure 1: Flowchart of PSO

PSO with Time-Varying Acceleration Coefficients (TVAC_PSO)

Basic purpose of using the time varying acceleration coefficients [35] is to improve the global exploration in the early part of the process and to enhance the convergence of the particles in the later stages of the process. This is done by varying the acceleration coefficients $c1$ and $c2$ with time in such a manner that the cognitive component reduces and the social component increases as iterations increase. In short, it can be stated that a large cognitive component and a small social component at the beginning of the process help the particles to explore the search space in a better way while a smaller cognitive component and a larger social component at later stages of the process allow the particles to converge to the global optima.

ED Using TVAC_PSO

Particle Swarm optimization (PSO) is a population based search algorithm in which each particle is considered as a solution in the multi-dimensional optimization space. There are several types of PSO strategies proposed as discussed previously in this work. Here in this section TVAC_PSO is taken to solve the ED problem. The particles are generated keeping the constraints in mind for each generating unit.

TEST SYSTEMS AND RESULTS

In order to show the effectiveness of the proposed TVAC_PSO algorithm over the PSO algorithm, two different test systems have been taken into consideration. The first test system has been taken from [31] that consists of 3 generating units with a load demand of 850 MW whereas the second test system consists of IEEE standard 30 bus 6 generating units [30] with a load demand of 2.834 pu on a 100 MVA base.

Generator System

In this case, a 3-generator system has been considered [11]. Details of the system are In appendix-A. Performance comparison between the proposed algorithm and the PSO algorithm has been carried out for finding the optimal fuel cost, optimal NOx emission and finally a combined optimal cost i.e. combined economic and emission dispatch.

Table 1: Optimal fuel cost

Power Output (MW)	TVAC_PSO	PSO
P1	431.8391	441.3484
P2	301.5077	304.7564
P3	132.5373	119.8206
Optimal fuel cost ($/hr)	8343.3929	8344.5927
Corresponding NOx emission (kg/hr)	0.09899	0.09789
Losses (MW)	15.8841	15.9254

Results of optimization corresponding to optimal fuel cost, optimal NOx emission and combined optimal cost are tabulated in Tables 1, 2 and 3 respectively. From Table 1 it can be seen that the optimal fuel cost for the 3-generator system is 8343.3929 $/hr for TVAC_PSO whereas for PSO it is 8344.5927 $/hr.

Table 2: Optimal NOx emission

Power Output (MW)	TVAC_PSO	PSO
P1	555.7954	508.3236
P2	239.0158	251.0887
P3	70.1888	105.3453
Optimal NOx emission ($/hr)	0.09583	0.09592
Corresponding fuel cost (kg/hr)	8403.6681	8364.9792
Losses (MW)	15.0001	14.7576

Table 3: Combined optimal cost

Power Output (MW)	TVAC_PSO	PSO
P1	410.6348	535.3989
P2	319.5549	272.9036
P3	136.2880	57.3952
Optimal NOx emission (kg/hr)	0.10063	0.10072
Optimal fuel cost ($/hr)	8346.9696	8397.2053
Losses (MW)	16.4779	15.6977
Price penalty factor	147582.788	147582.788
Total Cost ($/hr)	23198.6321	23261.5244

From Table 2 it can be seen that the optimal NOx emission for the 3-generator system is 0.09583 Kg/hr for TVAC_PSO whereas for PSO it is 0.09592 Kg/hr. From Table 3 it can be seen that the combined optimal cost for the system is 23198.6321 $/hr for TVAC_PSO whereas for PSO it is 23261.5244 $/hr. Results obtained clearly demonstrate the efficacy of the proposed TVAC_PSO algorithm over the PSO algorithm. Convergence curves corresponding to optimal fuel cost, optimal NOx emission and combined optimal cost are shown in figures (1), (2) and (3) respectively.

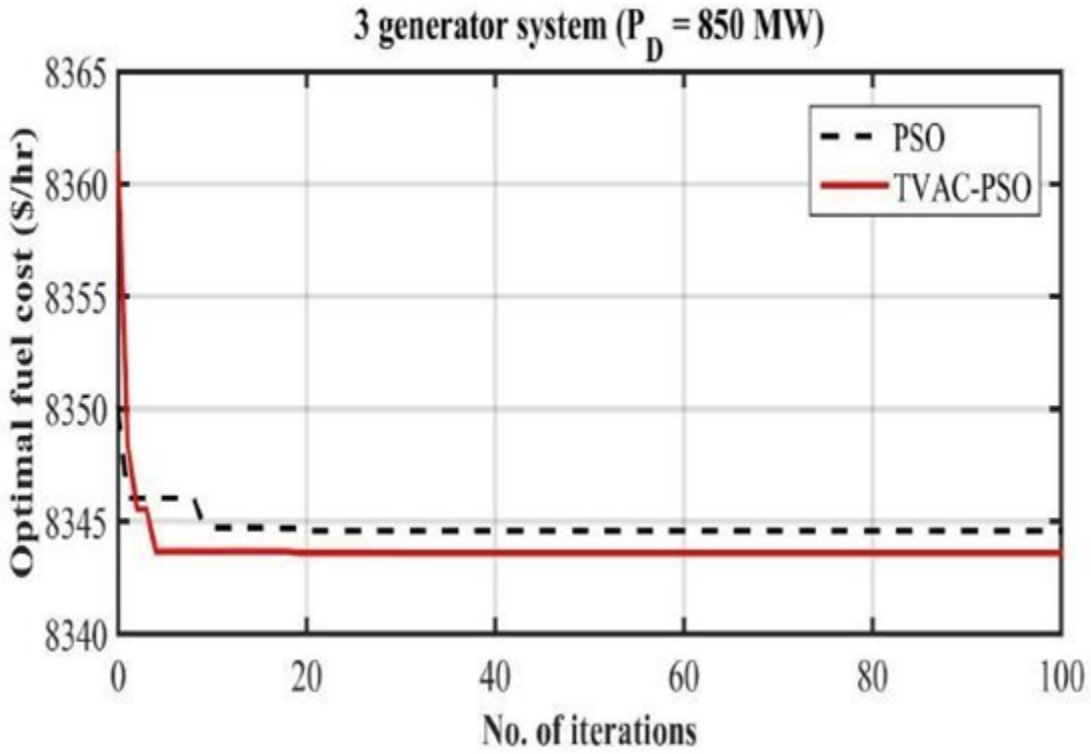

Figure 2: Convergence curves for optimal fuel cost for TVAC_PSO vs PSO

CONCLUSIONS

In this paper, combined economic and emission dispatch (CEED) problem has been presented. Two different generating systems have been considered for the study. One generating system consists of three generators while the other system consists of six generators. A novel TVAC_PSO algorithm has been proposed for analyzing the CEED problem. The analysis has been carried out in the MATLAB environment. Results of the TVAC_PSO algorithm have been compared with the PSO algorithm for both the 3-generator and 6- generator systems. Results obtained clearly demonstrate the efficacy of the proposed TVAC_PSO algorithm over the PSO algorithm in terms of reduced fuel cost, NOx emissions and overall operating cost.

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