SOLUTION FOR CEED USING HYBRID (FIREFLY-DE) ALGORITHM

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Abstract—

This project develops efficient algorithms by using firefly and differential evolution algorithm to minimize Economic Dispatch, NO_x Emission Dispatch and Combined Economic and Emission Dispatch problems in thermal power plant. The thermal power plants pollute air, soil and water. Due to this, the present energy production processes are not ecologically clean. The combination of fossil fuels gives rise to particulate materials and gaseous pollutants apart from discharge of heat to water courses. The three principal gaseous pollutants, namely carbon-dioxide, oxides of sulfur and nitrogen cause detrimental effects on human beings. This harmful ecological effects caused by the emission of particulate and gaseous pollutants can be reduced by adequate distribution of load between the plants of a power system. But, this leads to a noticeable increase in the operating cost of the plants. For successful operation of the system subject to ecological and environmental constraints, algorithms have been proposed for minimum cost, minimum NO_x emission and combined economic and emission dispatches. These are based upon quadratic type objective function and the solution gives the optimal dispatch directly. In the present work, a price penalty factor is introduced which blends the emission cost with normal fuel cost. This avoids the use of two classes of dispatching and the need to switch over between them.

Keywords—**Firefly Algorithm (FFA), Differential Evolution (DE).**

I. INTRODUCTION

The Resource scheduling problem is divided into two stages, the commitment stage and the constrained economic dispatch stages. The OPF constraints that are relevant to the active power such as transmission capacity constraints, different types of emission requirements (i.e. SO2 and NOx), emission caps for certain areas of the system and the total system emission as well as fuel constraints are considered in the formulation of the commitment stage to ensure the feasibility of the constrained economic dispatch stage. In the constrained economic dispatch, constraints corresponding to transmission capacity, load and reserve requirements as well as generating unit limits are incorporated. To obtain fast and efficient solutions, the constrained economic dispatch problem is decomposed into sub problems, each corresponding to constrained economic dispatch of committed units at a given period Economic power dispatch is a common problem pertaining to the allocation of the amount of power to be generated by different plants in the system on an optimum economy basis. Some of the states in India expertise severe power shortage for which optimization of fuel costs are not of current interest during peak load periods. But during lean load periods, economic dispatch reduced fuel cost and line losses. The existing energy production processes are not ecologically clean.

For instance thermal power plants pollute air, soil and water. The combustion of fossil fuels gives rise to particulate materials and gaseous pollutants apart from discharge of heat to water courses. The particulate materials do not cause a serious problem in air contamination but the three principal gaseous pollutants, namely, carbon-dioxide, oxides of nitrogen and optimization of cost of generation has been formulated based on classical ELD with emission and line flow constraints. The detailed problem is as follows.

For a given power system network, the optimization cost of generation is given by the following equation:

$$Min\ F(P_G) = C_t + h*E(P_G)\ \$/hour \qquad [1.1]$$

$F(P_G)$ = CEED cost in \$/hour
C_t = Total generation cost \$/hour
$E(P_G)$ = Total emission in ton/hour
h= price penalty factor in \$/ton

Bi – objective problem converted into single objective by using penalty factor (h) CEED used to find a generating pattern to minimize generating cost and emission. Generating cost and Emission are function of real power generation.The objective of the project work is to find the minimum generating cost, subjected to equality constraint of power balance equation and inequality constraint of control and depended variables

1.1 Economic And Emission Dispatch

The EED problem is a highly nonlinear and a multimodal optimization problem. Therefore, conventional optimization methods that make use of derivatives and gradients, in general, not able to locate or identify the global optimum. On the other hand, many mathematical assumptions such as analytic and differential objective functions have to be given to simplify the problem. Furthermore, this approach does not give any information regarding the trade-offs involved. Hybrid algorithm is used to minimize the both economic and emission dispatch problem and the hybrid algorithm such as differential evolution and firefly algorithm.

1.2 Firefly Algorithm

Thousands of fireflies lives together and communicate them with flashing light. They communication has two fundamental functions they are attract prey and attract mating partner**.** Firefly is unisex and attracted by another firefly in spite of sex Firefly moves towards brightest if no brighter one then firefly moves randomly in solution space Brightness of firefly is decreased with increased distance. Main reasons for reduction in attractiveness are absorption factors in nature are implemented by using absorption coefficient.

1.3 Differential Evolution

Differential Evolution was first proposed over1994-1996 by Storn and Price at Berkely . The ability of DE is to optimize nonlinear, non-continuous and non-differential real world problems. Compare to other population based Meta heuristic algorithms, DE emphasis on Mutation than Recombination or Crossover. It mutate vector with a help of randomly selected a pair of vector in the same population. DE works on population of vectors, where vector is a group of decision variables. Selection of decision variable is based on their impact on the problem to be optimized. These decision variables need to be encoded and set of initial values are chosen from the solution space. By mutation and recombination new vectors are created. The selection process selects the best vectors based on the selection criterion. DE is inherent minimization problem and suitable for cost minimization of OPF problem.

II. POWER PLANT EMISSIONS & DISPATCHING STRATEGY

2.1 Power Plant Emissions

The two primary power plant emissions from a dispatching perspective are sulfur dioxide (SO_2) and nitrogen oxides (NO_x). Figure 1 will aid in the following explanation. SO_2 is dependent on the amount of fuel burned. The sulfur enters the boiler as a part of the fuel. During the combustion process, some of the sulfur unites with oxygen from the fuel and the combustion air to form SO_2. The remaining sulfur becomes a part of the bottom ash in the boiler.

2.2 Emission Models

Emission models may be classified as either operation-related or startup related, which include startup, thermal cooling and banking. The most recent amendments to the Clean Air Act will require inclusion of startup related emissions. Emission dispatching techniques require operation-related emission output models that depend on unit's output. Two possible model types exits.

For SO2, the input-output may be defined as the amount of fuel consumed as a function of power output multiplied by a constant. This constant includes

(1) The percent of sulfur in the fuel,
(2) The high heating value of the fuel,
(3) The percent of fuel that becomes bottom ash as opposed to becoming SO_2 in the stack gas,
(4) The ratio of molecular weight of SO_2 to sulfur, and
(5) The efficiency of stack gas cleanup equipment present.

In equation form, this may be represented as

$$SO_{2EO} = (0.01 * SC_{FC}) * (F\,(p) * 10^6) / (HHV * 2000) \\ (64/14) * (0.01 * SGC_{SO2})\,(1.01 * EFF_{SO2}) \quad \ldots\ldots\ldots \quad [Eq.2.1]$$

where SO_{2EO} is actual SO_2 stack output in tons per hour, F (p) is fuel consumption in millions of Btu's per hour as a function of unit's net power output in megawatts, SC_{FC} is sulfur content of the fuel in percent, SGC_{SO2} is stack gas component of SO_2 in percent as opposed to the bottom ash content, EFF_{SO2} is stack gas clean up equipment SO_2 efficiency in percent and HHV is high heating value of the fuel in Btu's.

For fuel NOx, a similar input-output model may be defined and represented as

$$NOXF_{EO} = (0.01 * NC_{FC}) * (F\,(p) * 10^6) / (HHV * 2000) \\ (46/14) * (0.01 * SGC_{NOX}) \quad \ldots\ldots\ldots\ldots \; [Eq.2.2]$$

where $NOXF_{EO}$ is fuel NO_X production in tons per hour before any stack gas clean up equipment, NC_{FC} is nitrogen content of the fuel in percent, SGC_{NOX} is stack gas component of NO_X in percent as opposed to the bottom ash content.

2.3 Dispatching Strategies

Dispatching algorithms seek to minimize some objective function subject to a set of constraints. Ignoring emission considerations, the most common objective function to minimize is the total operating cost. The corresponding set of constraints includes:

(1) The total generation must equal the total system load plus any transmission losses, and

(2) Each individual generating unit must operate between minimum and maximum power output limits.

This type of optimization is commonly called economic dispatch and may be summarized mathematically as

Minimize: $\sum_{i=1}^{N}$ $(F_i\,(P_i)*FP_i$ [Eq.2.3]

Subject to:

$\sum_{i=1}^{N}$ $P_i=P_{load}+P_{losses}$ [Eq.2.4]

$P_{iMin}<=P_i<=P_{iMax}$ i=1, 2----, N [Eq.2.5]

Transmission losses may be represented in one of four ways:

(1) Being ignored or considered as included in the system load,

(2) Being represented by a single transmission loss polynomial that depends on the daily peak load and is used with constant penalty factors for each generating unit,

(3) Being represented by the transmission loss matrix equation that used with loss matrix penalty factors or reference bus penalty factors, and

(4) Being represented by a full power flow network representation.

III. FORMULATION OF DISPATCHING STRATEGIES

3.1 Problem Formulation

This section develops the formulation of objective function and constraints for economic dispatch, minimum NO_X emission dispatch and combined economic and emission dispatch methods [1].

3.1.1 Economic Dispatch

The fuel cost of a thermal plant can be regarded as an essential criterion for economic feasibility. The fuel cost curve is assumed to be approximated by a quadratic function of generator active power output as

$$C_t=\sum_{i=1}^{ng}\alpha_i+\beta_i P_{Gi}+\gamma_i P_{Gi}^2+\left|\zeta_i \sin\left[\lambda_i\left({P_{Gi}}^{\min}-P_{Gi}\right)\right]\right|$$

..... [Eq.3.1]

The economic dispatch problem is defined as to minimize

$$C_t=\sum_{i=1}^{ng}\alpha_i+\beta_i P_{Gi}+\gamma_i P_{Gi}^2+\left|\zeta_i \sin\left[\lambda_i\left({P_{Gi}}^{\min}-P_{Gi}\right)\right]\right| \qquad \text{…… [Eq.3.2]}$$

where

i=1,2,3………..n

3.1.2 Minimum No$_x$ Emission Dispatch

The economic dispatch is well recognized and will minimize total fuel cost while meeting total load plus transmission losses and generator limit constraints. Emission constraints may be violated. Minimum emission strategy can be implemented by direct substitution of an incremental emission curve for an incremental cost curve in a conventional economic dispatch algorithm.

The amount of NOx is given [1] [2] [3] as a function of generator output, that is, the sum of quadratic and exponential functions. This complex function is successfully approximated into a simple quadratic function of the form

$$E(P_G) = \sum_{i=1}^{ng} 10^{-2}(a_i + b_i P_{Gi} + c_i P_{Gi}^2) + d_i \exp(e_i P_{Gi}) \quad [Eq.3.3]$$

where N is the number of thermal units and E_i the NO_X emission of ith unit (ton/hr).

The minimum NOx emission dispatch problem is defined as to minimize

$$E(P_G) = \sum_{i=1}^{ng} 10^{-2}(a_i + b_i P_{Gi} + c_i P_{Gi}^2) + d_i \exp(e_i P_{Gi}) \quad [Eq.3.4]$$

Where E_i is the total NO_x emission (ton/hr), P_{Gi} the power output of the ith generator (MW); a_i,b_i,c_i, d_i, e_i the NO_xemission coefficients of ith unit and N the number of thermal units. This is subject to the generating unit constraint Eq.3.3 & load constraint Eq.3.4.

3.1.3 Combined Economic & Emission Dispatch

In minimizing total emission, local constraints may become intolerable, necessitating a shift away from minimum total emission to meet local constraints. So the problem of choosing the least cost generating schedule with environmental objectives still remains and so a combined economic and environmentally satisfied dispatch method is rather sensible than separate minimum emission as well as cost dispatches.

The NOx emissions of the thermal units are given by

$$E(P_G) = \sum_{i=1}^{ng} 10^{-2}(a_i + b_i P_{Gi} + c_i P_{Gi}^2) + d_i \exp(e_i P_{Gi}) \quad [Eq.3.5]$$

The emissions are converted into monetary units by inventing a price. That is, the emission costs are blended with the normal fuel costs with the use of the price factor defined as the price penalty factor h. This avoids the problem of dispatching and need to switchover between them. After the introduction of the price penalty factor, the total operating cost of the system is the cost of fuel plus the implied cost of NOx emission. So, the combined economic emission dispatch problem is defined as to minimize

$$Min\ F(P_G) = C_t + h*E(P_G)\ \$/hour \quad [Eq.3.6]$$

where h = price penalty factor ($/ton), which is the cost incurred to reduce 1 kg of NO_x emission output. This is subject to the generating unit constraint Eq.3.3 & load constraint Eq.3.4.

3.2 Operating Constraints

The active power generation of the generators is restricted to lie within the given minimum and maximum limits which are determined by the permissible extremes of operating conditions. Pi must fall within the minimum and maximum limits.

3.2.1 Lower Generation Limit

At optimum dispatch, if the optimum generation of the jth plant goes below its lower limit P_{jmin},then the jth plant is allowed to generate power equal to P_{jmin}.The remaining (n-1) plants are allowed to share the power P_D' in Eq.3.14 where

$$P_D' = P_D \ (P_{jmin} - P^2_{j\,min} B_{jj}) \qquad \text{……. [Eq.3.7]}$$

The values of σ_1, σ_2 and σ_3 are calculated for the remaining (n-1) plants excluding the jth plant to give a new value of λ.

3.3 Price Penalty Factor

A price penalty factor (h) is a price factor which blends the emission costs with the normal fuel costs. This avoids the use of two classes of dispatching and need to switch over between them. After the introduction of the price penalty factor, the total operating cost of the system is the cost of fuel plus the implied cost of NO_x emission.

This value is calculated as follow for a system operating with a load of PD MW

(1) The average cost of each generator is evaluated at its maximum output, that is,

$$\frac{F_i(Pg_{i2\,\max})}{Pg_{i\,\max}} = \frac{\alpha_i Pg_{i\,\max} + \beta_i Pg_{i\,\max} + \gamma_i}{Pg_{i\,\max}}, \$/Mwh \qquad \text{…. [Eq.3.8]}$$

(2) The average NOx emission of each generator is evaluated at its maximum output, that is,

$$\frac{E_i(Pg_{\max})}{Pg_{\max}} = \frac{a_i Pg_{2\,\max} + b_i Pg_{\max} + c_i}{Pg_{\max}}, ton/Mwh \qquad \text{.... [Eq.3.9]}$$

(3) By dividing the average cost of each generator by its average NOx emission, the price penalty factor is,

$$\frac{F_i(Pg_{i\,\max})/Pg_{i\,\max}}{E_i(Pg_{i\,\max})/Pg_{i\,\max}} = \frac{\alpha_i Pg_{i\max}^2 + \beta_i Pg_{i\max} + \gamma_i)}{a_i Pg_{i\,\max}^2 + b_i Pg_{i\,\max} + c_i)} = h_i, (\$/ton) \qquad \text{[Eq.3.10]}$$

(4) Obtained h_i is arranged in ascending order,

(5) The maximum capacity of each unit ($P_{gi\,\max}$) is added one at a time, starting from the smallest h_i unit, until $\sum P_{i\,\max} \geq P_D$.

(6) At this stage, h_i associated with the last unit in the process is the price penalty factor g (\$/ton) for the given load

IV. FIREFLY ALGORITHM

4.1 Basic Description

Firefly algorithm (FA) mimics firefly's intelligent technique to find optimal solution for engineering problems. For optimization flashing light is formulated based on objective function. Brightest firefly is the most optimal solution for the problem under consideration. A firefly is set of control variables of the problem considered. Brightness of the firefly is calculated by evaluating the objective function to be optimized. This algorithm used for maximization or minimization problem. FA has idealization as compared to natural firefly, they are

- Firefly is unisex and attracted by another firefly in spite of sex
- Firefly moves towards brightest if no brighter one then firefly moves randomly in solution space

- Brightness of firefly is affected by problem nature

,

Minimize $C_t = \sum_{i=1}^{NG} f_i(P_G)$ \$/hr (4.1)

Subject to: $g(|V|, \delta)=0$ (4.2)

$X_{min} \leq X \leq X_{max}$ (4.3)

Where,

C_t is total generating cost in \$/hr
$g(|V|, \delta)$ is power flow balance equation
X is a set of control variable
X_{min}, X_{max} are minimum and maximum value of control variable

4.2 Firefly Based Ceed

To optimize CEED problem the control variables, real power generation, generator bus voltages and transformer tap position are considered. The limits on these control variables form prime constraints in addition to power balance condition.

4.3 Encoding

Encoding is the process of converting set of control variables in CEED into firefly for optimization. Ability of FA is to operate on floating point and mixed integer makes ease of encoding. Final iteration of FA gives global bright firefly which is the optimal solution of CEED. For the evolution and better convergence fitness function is most important as follows.

4.3.1 Fitness Function

An appropriate fitness function (brightness) is vital for evolution and convergence of FA. It is an CEED objective functions and penalty functions if any. FA evaluates brightness for each firefly in the population. Objective function value for a firefly is called brightness of the firefly.

4.3.2 Attractiveness

. This attractiveness is decreases with increase in distance between fireflies. Main reasons for reduction in attractiveness are absorption factors in nature are implemented by using absorption coefficient. This function is monotonically decreasing function given below the equation 4.4.

$\beta = \beta_0 \exp(-\gamma r^2)$ (4.4)

where,

β is attractiveness of a firefly
β_0 is initial attractiveness
γ is absorption coefficient
r is distance between fireflies

4.4 Algorithm for Firefly Algorithm

Step 1: Firefly is a set of control variables in CEED
Step 2: Initialise fireflies in the population within solution space
Step 3: CEED objective function is used to find brightness of firefly
Step 4: Attractiveness of firefly with other fireflies is calculated
Step 5: Distance between fireflies is calculated
Step 6: firefly i is moved towards firefly j using equation 4.7
Step 7: Rank the fireflies and find the current global best

V. DIFFERIENTIAL EVOLUTION

5.1 Introduction

Differential Evolution was first proposed over1994-1996 by Storn and Price at Berkely . The ability of DE is to optimize nonlinear, non-continuous and non-differential real world problems.

5.2 Basic Description

DE has good convergence characteristic and use real value control variables hence no need of encoding and decoding. Set of control variables which decide problem solution forms a vector. Set of vector forms population, evolves iteration by iteration to converge into optimal solution.

Minimize $C_t = \sum_{i=1}^{NG} f_i(P_G)$ \$/hr (5.1)

Subject to: $g(|V|, \delta)=0$ (5.2)

$X_{min} \leq X \leq X_{max}$ (5.3)

Where,

C_t is total generating cost in \$/hr

$g(|V|, \delta)$ is power flow balance equation

X is a set of control variable

5.3 De Based Opf

To optimize OPF problem the control variables, real power generation, generator bus voltages and transformer tap position are considered.

5.3.1 Encoding

Encoding is the process of converting set of control variables in OPF into vector of DE optimization problem. Ability of DE is to operate on floating point and mixed integer makes ease of encoding. Final value of vector gives optimal values of control variables is the optimal solution of OPF. For the evolution and better convergence fitness function is most important as follows.

5.3.2 Fitness Function

An appropriate fitness function is vital for evolution and convergence of DE. It is an OPF objective functions and penalty functions

$$X^{k+1} = \begin{cases} X^{trail} & if \ f(trail) < f(target) \\ X^{target} & if \ f(target) \leq f(trail) \end{cases} \quad (5.4)$$

Selection process is repeated for every vector in the population to maintain population size same for all iterations.

5.4 Algorithm For Differential Evolution

The procedure for DE to solve OPF is given below

Step 1: Control variables of OPF is selected as particles of a vector
Step 2: Initialise vectors in the population within solution space
Step 3: OPF objective function is taken as fitness function of DE
Step 4: Target vector is selected and mutated to get mutated vector
Step 5: Crossover is done on mutated vector to get trail vector
Step 6: Selection process decides existence or replacement of target vector with trail vector
Step 7: Next iteration population is generated using selection process

VI. COMPARISON RESULTS

The method, CEED using hybrid algorithm like Firefly and Differential evolution and the test system consists of IEEE 30 Bus it consists of 6 generators, 4 Transformers and

6.1 COMPARISON OF CONVERGENCE CURVE

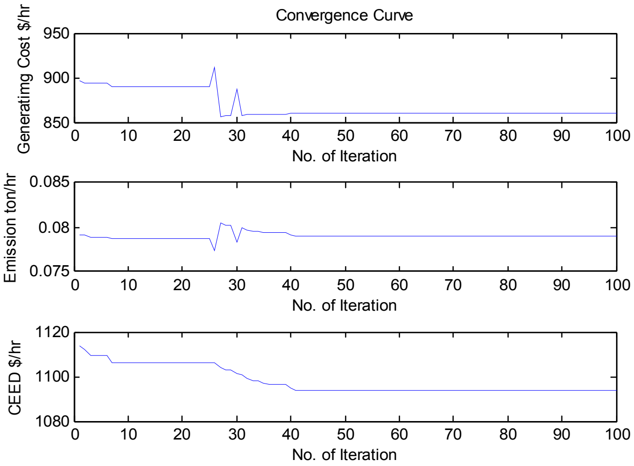

Fig.6.1 CEED graph for Firefly algorithm

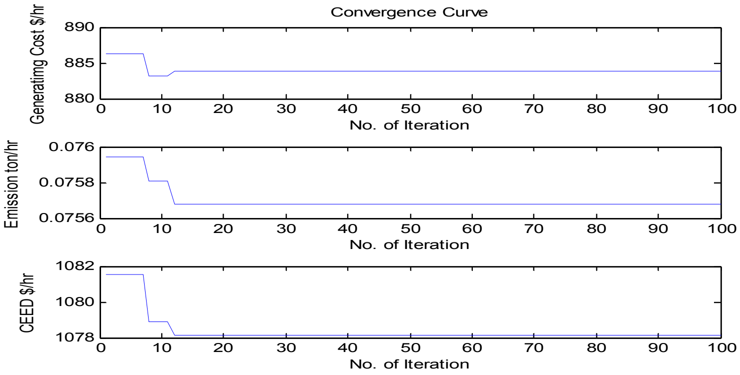

Fig.6.2 CEED graph for DE algorithm

6.2 Voltage Magnatitude For Firefly-De

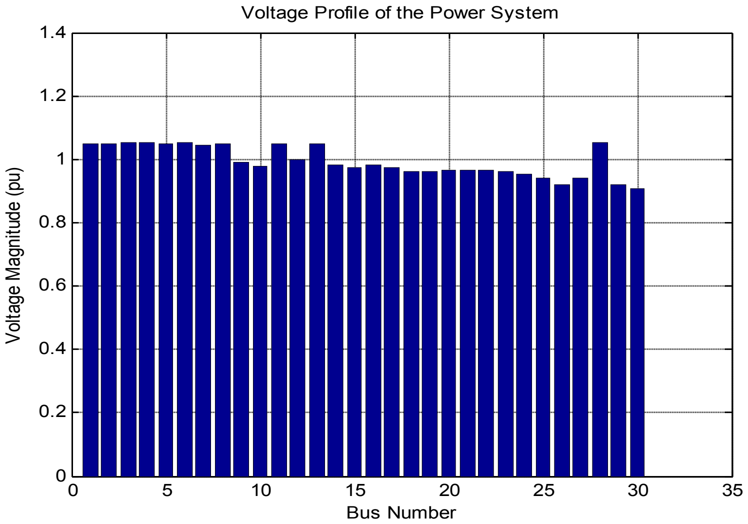

Fig.6.4 CEED Voltage magnitude

6.3 Comparison Tables

From the above table 6.3.1 shows the value of CEED for different algorithms

ALGORITHM	GENERATING COST $/Hr	EMISSION ton/Hr	CEED COST $/Hr
FIREFLY	859.869	0.07898	**1093.95**
DIFFERIENTIAL EVOLUTION	883.898	0.07567	**1078.15**
FIREFLY-DE	896.561	0.07179	**1051.83**

Table 6.3.1

VII. CONCLUSION

An algorithm has been developed for the determination of the global or near-global optimal solution for the Combined Economic and Emission Dispatch (CEED). The hybrid algorithm of Firefly and Differential Evolution has been tested for the IEEE 30 Bus system with six generating units and thirty bus in that one bus has slack bus. The result obtained from the CEED is compared with the Firefly and DE algorithm. The result obtained from the CEED which gives the better result of CEED cost which compared to the firefly and DE. The convergence curves are shown in the chapter 6 and the combined table and graph is analyze in the chapter 6 which shows the minimized value of the CEED in the FIREFLY-DE algorithm.

REFERENCES

[1] R. Yokoyama s.h. bae t. morita “multi objective optimal generation dispatch based on probability security criteria” IEEE transactions on power systems, vol. 3, no. 1, February 1988

[2] A.A. El-keib h. ma “Environmentally constrained economic dispatch using the lagrangian relaxation method”IEEE transactions on power systems, vol. 9, no. 4, November 1994

[3] James a. momoh “combined economic and emission dispatch using radial basis function”

[4] R. ran;ranathanj “emission constrained economic dispatch” IEEEtransactions on power systems, vol. 9, no. 4, november 1994

[5] M. A. Abido “environmental/economic power dispatch using multiobjective evolutionary algorithms” IEEE transactions on power systems, vol. 18, no. 4, november 2003

[6] Ahmed farag samir al-baiyat t.c.cheng “economic load dispatch multiobjective optimization procedures using linear programming techniques” IEEE transactions on power systems, vol. 10, no. 2, may 1995

[7]d.b. das c. patvardhan” new multi-objective stochastic search technique for economic load dispatch” iee proc.-gener. trunsm. distrih., vol. 14s, nu. 6, noveniher 1998 747

[8] M.A. abido a “novel multiobjective evolutionary algorithm for environmental/economic power dispatch” electric power systems research 65 (2003) 71_ 81

[9] M. A. ABIDO “multiobjective evolutionary algorithms for electric power dispatch problem” IEEE transactions on evolutionary computation, vol. 10, no. 3, june 2006

[10] N. A. Al-ali M. A. Abido “multi-objective differential evolution for optimal power flow” lisbon, portugal, march 18-20, 2009

]11] S. R. Spea & a. a. abou el ela M. A. Abido “multi-objective differential evolution algorithm for environmental-economic power dispatch problem 2010” IEEE international energy conference

[12] rainer storn differential evolution – a simple and efficientheuristic for global optimization over continuousspaces”*journal of global optimization* 11: 341–359, 1997.

[13] theofanis apostolopoulos and aristidis vlachos “application of the firefly algorithm for solving the

Economic emissions load dispatch problem international journal of combinatorics” volume 2011, article id 523806, 23 pages

[14] P. Venkatesh, r. gnanadass, and narayana prasad padhy “comparison and application of evolutionary programming techniques to combined economic emission dispatch with line flow constraints”IEEE transactions on power systems, vol. 18, no. 2, may 2003

[15] A. A. El-keib h. ma “economic dispatch in view of the clean air act of 1990” IEEE transactions on power systems, vol. 9, no. 2, may 1994