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Binary PSO approach for CEED problem in power system including solar energy

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Abstract**—***The harmful ecological effect by the emission of gaseous polluted from fossil fuel power plants can be reduced by proper load allocation among various generating units of the plant, but this load allocation may lead to increase operating cost of generating units and non-commensurable fuel cost. Various types of economic dispatch in power systems such as multi area economic dispatch with tie line limits, economic dispatch with multiple fuel options, combined economic and emission dispatch problem. This Combined Economic Dispatch and Emission Dispatch problem is a Multi objective problem. This Multi objective problem can be converted in to single objective problem by using penalty factor. This project presents Combined Economic Dispatch Models developed a system consists of multiple photovoltaic plants. Reliable and inexpensive electricity provision is one of the significant objective have been developed in order to address the challenge of continuous and sustainable electricity provision at optimized cost. Problem formulated was implemented on two test cases and results obtained from lambda-iteration, as conventional technique and proposed technique results are compared in terms of Cost, Emission, Convergence and No of iterations..*

Index Terms—*Economic Dispatch, Renewable energy, Solar PV generation, Penalty factor.*

I. INTRODUCTION

An important research has been show up around the world for expansion of continuous, renewable and efficient energy structure in order to meet the requirements of increased population and to reduce the expanded the use of fossil fuels. Expanding energy prices, environmental concerns and expeditious depletion of the known fuel reserves have significantly increased the extension of renewable energy resources. The power sector of Pakistan is designed as an interconnected system and heavily relies on typical sources of generation. This system needs adjustments and improvement in order to meet the twenty first century specifications. Pakistan's energy incorporate span of almost 67% thermal and 30% hydel resources. According to Pakistan's energy year book 2012 [1], total generated electrical energy in Pakistan during 2010–2011 was 95,365 GW hand part of different sources is: thermal power 64.3%; hydel29.9% and nuclear and imported 5.8%. In thermal power, oil include the largest part of 35.2% followed by natural gas 29.0% and coal0.1%. On the other hand, the country has a large hidden of solar energy which has been predicted to be everywhere of 2900 GW in [2]. In [3], the author explain the energy scheme of Pakistan and reviewed conventional and Renewable Energy (RE) resources of the county in detail. The author has been exhibited the supply, generation and using of available resources in significant manner. The paper is focused on RE advancement projects in the country, recent progress, planning and public sector goals in this field. On average, solar global insolation of 5–7 kW h/m2/day in almost95% areas of Pakistan with persistence factor of over 85% has been reported in [4,5]. Economic Dispatch (ED) is a significant and most constant step in power system operational planning [6]. ED is a development complication that set aside power to each committed generating unit so as to underestimate the total operational cost, subject to constraints. Different constraints build power balance, power limits of generators, prohibited operating zones, ramp rate limits etc. Several optimization capacities with equality and non-equality constraints have been used for ED and reported in literature [7]. In the past of ED dates back to 1920 [8]. Up till 1930 development methods used were the base load method and first-rate point loading. In early 30s, equal additional price tag method was take advantage to complete better conclusions [8]. In those days analog computers were used for computational achievement. First computer for transmission loss penalty factor was built up in 1954. By 1955 electronic prong commentator was developed. Digital computers were used for ED first time ever in 1954 and are being used till date [9]. The authors in [10] have approach the capacity of ED used during 1977–1988; optimal power flow, dynamic dispatch, ED in relation to Automatic Generation Control (AGC) and ED with non-conventional sources has been evaluated. Power system subsist of thermal generators has been broadly used to evaluate ED problem. Input–output (consultation productivity) cost curves of thermal generating units are mandatory for ED. The input–output price-tag curve of a thermal generating unit is achieved by multiplying cost per unit heat and its input–output (consultation productivity) heat rate curve[11]. In present days multi-valve steam turbines and multiple fuel turbines are regularly used in generating units. The ED with piecewise quadratic cost function (EDPQ) and ED with restricted operating zones (EDPO) are the two non-convex ED problems [12]. Valve point effects producing a ripple like no convex input–output heat rate curve. Complex constrained ED is forwarded by intelligent methods including Genetic Algorithm (GA), PSO [13,14], Neural Network (NN), Evolutionary Programming(EP), Tabu search etc. [15–17]. Kennedy and Eberhart introduced PSO in 1995 [18]. In this method, movement of particles is dependent on local and social components of velocity. Moreover, maximum value of velocity, Vmax, is also an important parameter. Its low value results in local exploitation while a higher value results in global international analysis. To obtain a better control over local exploitation and global research, an inertia factor x is introduced in[19]. ED with both cost and emission minimization becomes multiobjective optimization problem and is named as Combined Emission Economic

Dispatch (CEED). Using PSO, CEED has been solved by Selvakumar et al. [20]. Zhao et al. [21] solved bid based ED using Constriction Factor PSO (CFPSO) and inertia weight. In [22], a hybrid PSO, a combination of PSO and Sub sequent Quadratic Programming (SQP), is introduced in order to solve a non-convex constrained ED problem with valve point effects. In [23], CEED has been solved using a novel PSO scheme taking into account the generator limits and power balance constraints. An improved PSO has been proposed to solve ED problem of hydro-thermal co-ordination in[24]. Authors in [25]have expected scheduled an added to PSO(EPSO) for hydro-thermal scheduling problem which takes into account discrete constraints such as power balance, hydro and thermal generation limit, reservoir storage volume, initial and terminal storage limit, water balance equation and hydro discharge limit. In[26], PSO has been used to evaluate CEED problem with equality constraints handled by different manner and multi-objective optimization problem transformed into a single objective one. A lot of research on Economic Dispatch (ED) problem has been carried out during last five years. A few instances are as follows. In[8], a non-convex ED problem has been addressed by various hybrid development methods.

The problem has been addressed first by developing an extensible and flexible soft computational framework called ‘‘PED Frame’’, used as a platform for the computer application of different algorithms under scrutiny. This framework has been used to implement Genetic Algorithm (GA) based models and Hybrid models for ED. In [20], a PSO based technique with constriction factor (CFPSO) has been proposed for ED with valve point effects; CFPSO technique proved to be fast converging. In [20], a multi-objective CEED solution has been proposed by using Artificial Bee Colony (ABC) algorithm. For the solution of the problem, multi objective CEED has been converted into single objective CEED by using penalty factor. In [21], iteration PSO with time varying acceleration coefficients (IPSOTVAC) has been proposed for ED with valve-point effects; Iteration term in velocity equation and time varying acceleration coefficients improved the achievement (searching ability) of PSO technique. In [24], a novel optimization methodology has been proposed to solve a large scale non-convex ED problem. The proposed approach is based on a hybrid Shuffled Differential progression (SDE) algorithm that combined the benefits of shuffled frog leaping algorithm and differential evolution. The proposed algorithm integrated a new differential mutation operator in order to address the problem of ED.

In , Economic Environmental Dispatch (EED) has been carried out using one Photo Voltaic (PV) plant and one wind turbine. Authors used Strength Pareto Evolutionary Algorithm (SPEA) and tests have been conducted for an IEEE bus system with 30 nodes,8 machines and 41 lines. Dynamic Economic Emission Dispatch (DEED) model with security constraints has been used for ED in[32]. The authors have carried out their work on a system incorporating three thermal units, two solar PV plants and two wind turbines. Authors in [33] have presented altered good will search algorithm to solve Combined Economic and Emission Load Dispatch (CEELD) problem. Practical constraints of real-world power systems have been used and the experiments carried out on seven systems in order to check the effectiveness and behavior of the proposed algorithm. This paper presents a Combined Emission Economic Dispatch (CEED) using 13 PV plants and 6 thermal units. Two test cases of Static Combined Emission Economic Dispatch (SCEED) and Dynamic Combined Emission Economic Dispatch (DCEED) have been considered. SCEED is performed for full solar radiation level as well as for reduced emission level due to clouds effect whereas DCEED for full radiation only. PSO is used for optimization of the problem and simulation results have been computed in MATLAB. The proposed model contains various different solar plants unlike the work discussed in. Power demand data has been obtained from Islamabad Electric Supply Company (IESCO) [24].

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II PROBLEM FORMULATION

This area is enthusiastic for question formulation of CEED for a power system having thermal and solar PV generations.

As specified earlier, an ED problem can be formulated

(a) Mathematical formulation of SCEED with solar power:

CEED is a multi-objective optimization problem subsist of both economic and environmental dispatch. The CEED

problem can be formulated as:

The economic dispatch problem is a constrained optimization problem and it can be mathematically expressed as follows:

$$\textit{Minimize } F = \sum_{i=1}^{n} f_i\left(P_i\right)$$

(1)

where, F : total generation cost (Rs/hr)

n : number of generators

Pi : real power generation of ith generator (MW)

fi (Pi) : generation cost for Pi

Subject to a number of power systems network equality and inequality constraints. These constraints include:

a.System Active Power Balance

The total active power generation must balance the predicted demand plus losses, at each time interval over the scheduling horizon. Here losses in the system are neglected.

$$\sum_{i=1}^{n} P_i = P_D + P_{loss} \tag{2}$$

Where, PD : total system demand (MW)

Ploss : transmission loss of the system (MW)

b. Generation Limits:

The maximum active power generation of a source is limited by thermal consideration. Unless we take a generator unit off-line it is not desirable to reduce the real power output below a certain minimum value Pmin. For example, in fossil fuel plant minimum boiler temperature must be maintained to prevent liquidation [21]. These constraints reduce our permissible generator operating region to within two bounds.

$$P_{i,\min} \le P_i \le P_{i,\max} \tag{3}$$

Where, Pi,min : minimum power output limit of ith generator (MW)

Pi,max: maximum power output limit of ith generator (MW)

The generation cost function fi(Pi) is usually expressed as a quadratic polynomial:

$$fi(Pi) = a_iP_i^2 + b_iP_i + c_i \qquad (4)$$

Where, ai , bi and ci are fuel cost coefficients.

c. Network Losses :

Since the power stations are usually spread out geographically, the transmission network losses must be taken into account to achieve true economic dispatch. Network loss is a function of unit generation. To calculate network losses, two methods are in general use. One is the penalty factors method and the other is the B coefficients method. The latter is commonly used by the power utility industry. In the B coefficients method, network losses are expressed as a quadratic function:

$$P_{loss} = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j \qquad (5)$$

where, Bij are constants called B coefficients or loss coefficients. The B coefficients method can be used to find P_{loss}.

b.Emission Dispatch: There is urgency to protect environment from harmful emissions out of Thermal Generation Companies, thereby there is need for study of amount of harmful emissions into environment. So, Emission Dispatch has been formulated. Below figure shows that even the Current Technology will not protect Environment from Carbon emissions and there is need for most advanced technologies to Stabilize Atmospheric CO2.

The solution of economic dispatch problem will give the amount of power to be generated by various generating units of a power system for a minimum total fuel cost. But limitation on emission release is not considered by this problem. The emission of pollutants affects not only human beings, but it is harmful to other life forms. It also causes global warming. These effects may be interpreted as cost, as they degrade the environment in one or other form.

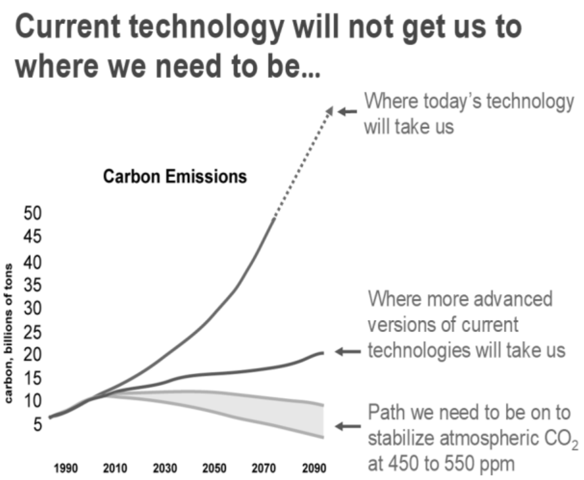

Fig 3.2 *Plot showing CO_2 emissions w.r.t technologies employed*

The objective of emission dispatch is to minimize the total environmental degradation or the total pollutant emission due to the burning of fuels for production of power to meet the load demand [22]. The emission function can be expressed as the sum of all types of emissions such as NOX, SO2, particulate materials and thermal radiation with suitable pricing for each pollutant emitted. In this project only NOX emission is taken into account, since it is more harmful than other pollutants. The NOX emission can be approximated as a quadratic function of the active power output from the generating units.

The emission dispatch problem can be defined as the following optimization problem,

$$Minimize\ E = \sum_{i=1}^{n} \alpha_i P_i^2 + \beta_i P_i + \gamma_i \qquad (6)$$

where

E : total emission release (Kg/hr)

αi, βi, γi : emission coefficients of the ith generating unit

subject to demand constraint and generating capacity limits .

c.Combined Economic and Emission Dispatch

The economic dispatch and emission dispatch are considerably different. The economic dispatch deals with only minimizing the total fuel cost (operating cost) of the system violating the emission constraint. On the other hand emission dispatch deals with only minimizing the total emission of NOX from the system violating the economic constraints. Therefore it is necessary to find out an operating point, that strikes a balance between cost and emission. This is achieved by combined economic and emission dispatch (CEED).

The multi-objective combined economic and emission dispatch problem is converted into single optimization problem by introducing price penalty factor h [12] as follows:

$$Minimize\ \Phi = F + h^* E \quad (Rs./hr) \qquad (7)$$

Subject to demand constraint (2.6b) and generating capacity limits (2.6c).

The price penalty factor h blends the emission with the normal fuel costs and Φ is the total operating cost of the system (i.e., the cost of fuel + the implied cost of emission).

Once the value of price penalty factor is determined, the problem reduces to a simple economic dispatch problem. By proper scheduling of generating units, comparative reduction is achieved in both total fuel cost and NOx emission.

III BINARY PSO APPROACH FOR CEED PROBLEM

Objective Function :

The economic dispatch problem is a constrained optimization problem and it can be mathematically expressed as follows:

Minimize
$$F_T=\sum_{i=1}^{n}F_i\left(P_i\right)$$
(8)

Where

F_T = Total cost of generation (Rs/hr)

n = Number of generators

P_i = Real power generation of ith generator

f_i = Fuel cost function of ith generator

Subject to a number of power systems network equality and inequality constraints.Each generator cost function establishes the relationship between the power injected to the system by the generator and the incurred costs to load the machine to that capacity. Typically, generators are modeled by smooth quadratic functions such as to simplify the optimization problem and facilitate the application of classical techniques

$$F_T=\sum_{i=1}^{n}F_i(P_i)=\sum_{i=1}^{n}a_i+b_iP_i+c_iP_i^2$$
(9)

Where, a_i , b_i and c_i are fuel cost coefficients

b Equality Constraint:

The power balance constraint is an equality constraint that reduces the power system to a basic principle of equilibrium between total system generation and total system loads. Equilibrium is only met when the total system generation ($\sum P_i$) equals to the total system load (P_D) plus the system losses(P_{Loss})

$$\sum_{i=1}^{n}P_i=P_D+P_L$$
(10)

Where, P_D : total system demand (MW)

P_{loss} : transmission loss of the system (MW)

c. Network Losses

Since the power stations are usually spread out geographically, the transmission network losses must be taken into account to achieve true economic dispatch. Network loss is a function of unit generation. To calculate network losses, two methods are in general use. One is the penalty factors method and the other is the B coefficients method. The latter is commonly used by the power utility industry. In the B coefficients method, network losses are expressed as a quadratic function:

$$P_L=\sum_{i=1}^{n}\sum_{i=1}^{n}P_iB_{ij}P_j+\sum_{i}P_iB_{i0}+B_{00}$$
(11)

Where, Bij are constants called B coefficients or loss coefficients.

d. Inequality Constraint

The maximum active power generation of a source is limited by thermal consideration. Unless we take a generator unit off-line it is not desirable to reduce the real power output below a certain minimum value Pmin. For example, in fossil fuel plant minimum boiler temperature must be maintained to prevent liquidation. These constraints reduce our permissible generator operating region to within two bounds.

$$P_{imin}\le P_i\le P_{imax}$$

where, $P_{i,min}$: minimum power output limit of ith generator (MW)

$P_{i,max}$:maximum power output limit of ith generator (MW)

The well known solution method to this problem using the coordination equation is

$$PF_i\frac{dF_i(P_i)}{dP_i}=\dots\dots\dots\dots=PF_n\frac{dF_n(P_n)}{dP_n}$$
(12)

Where $\frac{dF_i(P_i)}{dP_i}$ is the incremental cost denoted by 2ci

PFi is the penalty factor of unit i given by,

$$PF_i=\frac{1}{1-\partial P_L/\partial P_i}$$

and $\partial P_L/\partial P_i$ is the incremental loss of unit i.

From above equations power output of ith unit is given as

$$P_i=\frac{1-\frac{a_i}{\lambda}-\sum_{j=1}^{n}2B_{ij}P_j}{\frac{2b_i}{\lambda}+2B_{ii}}$$
(13)

For an efficient evolutionary method, the representation of chromosome strings of the problem parameter set is important. The proposed approach uses the equal system incremental cost (λcost) as individual (particles) of PSO[2]. Each individual within the population represents a candidate solution for solving the economic dispatch problem. The advantage of using system Lambda instead of generator units' output is that, it makes the problem independent of the number of the generator units and also number of iterations for convergence decreases drastically. This is particularly attractive in large-scale systems.

e. Evaluation Function

We must define the evaluation function (it is called fitness function in GA) for evaluating the fitness of each individual in the population. In order to emphasize the "best" chromosome and speed up convergence of the iteration procedure, the evaluation value is normalized into the range between 0 and 1. The evaluation function [3] adopted is

$$f = \frac{1}{1 + k\left(\frac{\sum_{i=1}^{n} P_i - P_D - P_{loss}}{P_D}\right)} \quad (13)$$

Where, k is a scaling constant (k = 50 in this study).

Algorithm :

1.Specify the lower and upper bound generation power of each unit, and calculate λ_{max} and λ_{min} .

2.Initialize randomly the individuals of the population according to the limit of each unit including individual dimensions, searching points, and Velocities. These initial individuals must be feasible candidate solutions that satisfy the practical Constraints.

3.Set iteration count=1.

4.Set population count=1.

5.To each individual in the population (i.e at each λ) compute power output of all generators using Eq.(10). Employ the B-coefficient loss formula Eq. (11) to calculate the transmission loss PL.

6.Calculate the evaluation value of each individual in the population using Eq.(13).

7. Compare each individual's evaluation value with its Pbest . If the evaluation value of each individual is better than the previous Pbest, the current value is set to be Pbest. Increment individual count by 1.

8. If count < population size goto step(4).

9.The best evaluation value among the Pbests is denoted as gbest.

10. Modify the member velocity V of each individual according to

vik+1 =k*(w* vik + c1*rand1*(pbesti - xi) + c2*rand2*(gbesti - xi))

xik+1= xi + vik+1

where

vik : velocity of particle i at iteration k
w : inertia weight factor
c1, c2 : learning factor
rand1, rand2 : random number between 0 and 1
xik : position of particle i at iteration k

If vik+1 >Vmax, then vik+1 = Vmax and if vik+1 <-Vmax, then vik+1 = -Vmax).

11.Modify the member position of each individual Pi according to

Pi(k+1)=Pi(k)+Vi(k+1)

Pi(k+1) must satisfy the constraints.

Increment iteration count by 1.If the number of iterations reaches the maximum,

then go to Step 13.Otherwise, go to Step 3

12. The individual that generates the latest gbest is the optimal generation power of Each unit with the minimum total generation cost.

13. At this power generation compute emission release. Run FDC load flow to determine system losses and stability index.

FLOW CHART:

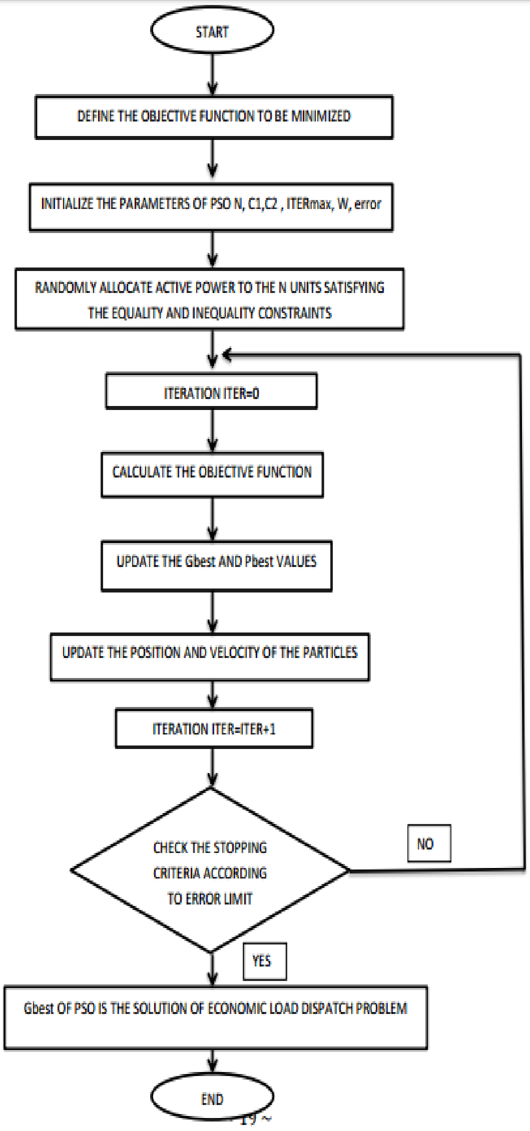

FIG.2 Flow Chart of Binary PSO Algorithm

IV RESULTS

This section shows the results for proposed Binary PSO based MIOP model. The above mentioned method was implemented in MATLAB R2013a. The proposed model has been implemented on two cases as follows.

Case I: In case I, the proposed model has been implemented on test system-I to investigate the problem of SCEED.

Case II: In case II, the proposed model has been implemented on test system-II to investigate the problem of DCEED.

Control settings used for PSO were: C1, C2 = 2; r1, r2 = random numbers between 0 and 1; Maximum number of iterations = 1500; swarm size = 10. Maximum and minimum values of velocity are 0.5 ⁄ Pmax and _0.5 ⁄ Pmin respectively. Best results were obtained by setting maximum and minimum values of x to 0.4 and 0.1 respectively, as evident from fitness value coefficients. The table presents the best values of objective function (Eq.(12)) obtained with various settings of x. Solar plants are considered to be operating for 6 h a day, from 10:00 to 16:00 h, as In Pakistan, these hours provide maximum radiation and are free of shadow effects in almost all the seasons. Following are the results and discussions for both cases.

Case I:

In this case, the simulations have been carried out for both full and reduced solar radiation; later is the case of cloudy weather. Simulation results of static CEED are depicted in Figs. 1–3 as well as in Tables 1–6. Graphs in Figs. 1–3 show simulation results in terms of the fitness value (FT) versus iterations. As evident from Figs. 1–3, the algorithm converges within 1000 iterations which Corresponds to a maximum of 3.56 s using 1.8 GHz core i5 processor. Generation of thermal units in MW is given in Tables 1–6 for the timings 10:00, 11:00. . . 15:00 respectively. Us1. Us13 correspond to status of solar plants which is either ON (represented by 1) or OFF (represented by 0). Power balance constraint violation is represented by demand-generation gap. Positive value of demand-generation gap means that generation is greater than demand while the negative value corresponds to generation not coping up with the demand. It can be seen from all tables that the proposed algorithm is well behaved. For instance, in Table 1 the thermal generation values for Units P1–P6 are well within 1.

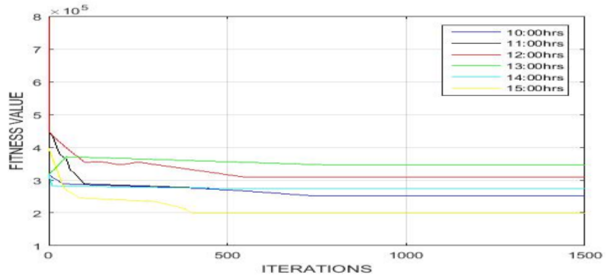

FIG 8.1: Simulation Results for Full Solar Radiation

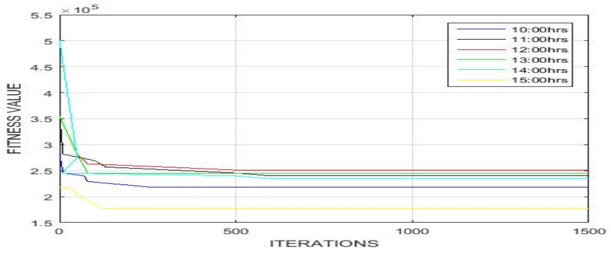

FIG 8.2: Simulation Results For 15% Reduced Solar Radiation.

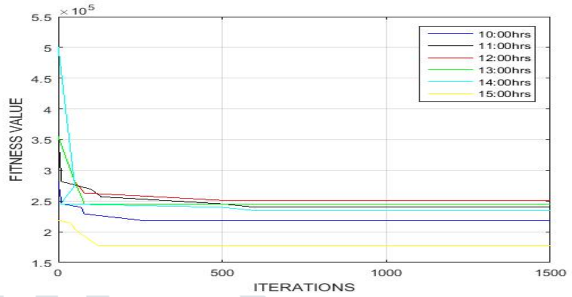

FIG 8.3: Simulation Results For 30% Reduced Solar Radiation.

TABLE 4.1: Results of CEED with solar power for 1244 MW demand at 10:00 h.

THERMAL GENERATION	P1(MW) P2(MW) P3(MW) P4(MW) P5(MW) P6(MW)	120.4479 92.2947 155.8062 76.4153 257.9089 302.2846
SOLAR GENERATION	Us1,Us2,…Us13 SOLAR POWER SHARE (MW)	0,1,0,1,1,1,1,0,1,1,0,1,1 238.825
COST	FUEL COST($/h) EMISSION COST($/h) SOLAR COST($/h) TOTAL COST($/h)	1.0e+04*5.2626 1.0e+04*4.2322 1.0e+04*6.2322 1.0e+04*1.5727
OTHERS	EMISSION(kg/h) Demand generation gap(MW)	1.0e+03*0.8808 -0.0173

TABLE 4.2: Results of CEED with solar power for 1088 MW demand at 11:00 h.

THERMAL GENERATION	P1(MW) P2(MW) P3(MW) P4(MW) P5(MW) P6(MW)	10.1062 10 99.1 168.682 235.8781 246.7809
SOLAR GENERATION	Us1,Us2,…Us13 SOLAR POWER SHARE (MW)	0,1,0,1,1,1,1,0,1,1,0,1,1 319.1076
COST	FUEL COST($/h) EMISSION COST($/h) SOLAR COST($/h) TOTAL COST($/h)	1.0e+04*4.6762 1.0e+04*3.8326 1.0e+04*8.2286 1.0e+03*0.6073
OTHERS	EMISSION(kg/h) Demand generation gap(MW)	1.0e+03*0.6073 0.0181

It can be noted from Tables 1–6 that the solar power share is well within the upper bound. The optimized cost values are consistent with the respective shares of thermal and solar power generation. The algorithm increases or decreases the solar share based on available solar radiation and temperature at any time as evident from Fig. 3.

The resulting solar share varies accordingly. Fig. 4 shows the solar share for various levels of solar radiation. The solar radiation often gets reduced due to clouds, depending on various parameters like thickness, height, amount, etc. of clouds. As we have taken into account the global solar radiation which is less affected by clouds as compared to beam radiation, therefore tests have been carried out for assumed reductions of 15% and 30% in solar radiation. It is evident from Fig. 4 that the solar share gets reduced for reduced solar radiation, in an expected manner.

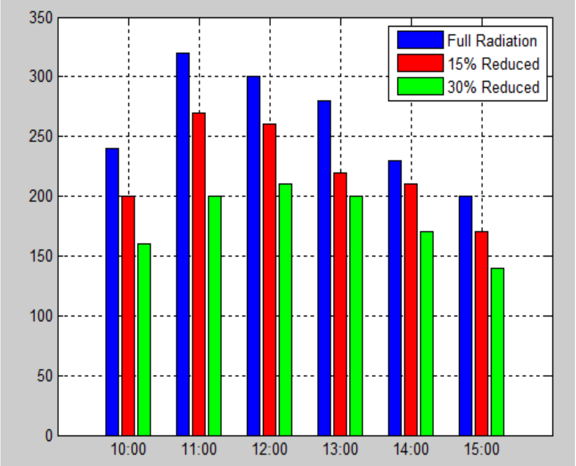

Fig.4. Solar shares at different solar radiation levels

The solar power contributes from hour 10 to hour 15 as in case of SCEED. The solar share varies in a manner similar to that of SCEED. The results at hour 12 can be compared with that of hour 14 due to comparable load demands of 1235MW and 1251MW respectively. The larger solar share of 335.063MW results in less fuel cost, emission cost and emissions while higher solar cost and total cost at hour 12 as compared to the respective quantities at hour 14, where solar share is 239.192 MW, for the same reasons discussed earlier in the case of SCEED. When solar generation is included to or removed from the system, the load ramp seen by the other plants gets increased. The greater the amount of solar share included or removed, the larger the load ramp seen by thermal which may cause failure of operation due to ramp rate limits of thermal units.

IV CONCLUSION

The paper presents a new dispatch model to solve CEED problem for a system containing conventional thermal and solar PV plants. Two case studies with six thermal units and thirteen solar plants, employing PSO as an optimization tool, have been investigated. SCEED problem has been investigated for full and reduced solar radiation and DCEED problem is solved for full radiation only with constraints of thermal generator limits, power balance and renewable energy limits. However, the ramp rate limits have been treated as an additional constraint in the case of DCEED. The largest solar shares of 319.1076MW (25.73% of 1240 MW) and 335.063MW (27.13% of 1235 MW) have been recorded at 12:00 h in case of SCEED and DCEED, respectively. It confirms that higher solar radiations contribute larger solar shares in both the cases. Larger solar share for a given load demand results in higher solar cost and total cost as well as lower fuel cost, emission cost and emissions.

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