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Combined Economic Emission Dispatch for solar, wind Thermal power with Pumped Hydro Power Plant

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***Abstract* - In this paper the economic dispatch problem (EDP) has been actively studied in the electric power industry for optimal operation and planning of energy resources. This problem is usually formulated as an optimization problem. The ever increasing penetration of variable wind energy in power system it will affect the hourly dispatch of thermal power generation in electricity market. The variability of wind energy makes the wind energy non-dispatchable and difficult to control, could bring significant challenges to power system. A combined economic load dispatch integrated with a renewable energy source can be optimized using PSO optimization algorithm. The effects of wind power with the pumped storage plant and solar power on overall emission are investigated. These proposed techniques will reduce the production cost and emission of the generated power. The above work is shown in matlab/Simulink**

1. INTRODUCTION

Electrical power systems are designed and operated to meet the continuous variation of power demand. Economic dispatch have been used to plan over a given time horizon the most economical schedule of committing and dispatching generating units to meet forecasted demand levels and spinning reserve requirements while all generating unit constraints aresatisfied.

A 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

Combined Economic Emission Dispatch (CEED) is an optimization problem that allocates power to each committed generating unit so as to minimize the total operational cost and emission, subject to constraints like power balance, power limits of generators, ramp rate limits. The formulation takes into account ramping and reserve costs, carbon-di-oxide emissions from expected dispatches, and the transitions over time. Significant research has been conducted throughout the world for development of sustainable, renewable and efficient energy systems in order to meet the requirements of increased population and to reduce the extensive use of fossil fuels. Increasing energy prices, environmental concerns and rapid depletion of the known fuel reserves have significantly increased the scope of renewable energyresources.

It is important to realize that the objectives of operations planning are (a) economic operation (to minimize total cost); (b) secure and reliable operation (to observe operating constraints of all equipment and to supply all loads without interruptions). Specific implementations and procedures are driven by system structure and available technology. The recent advances in computer technology and analytical tools for power system operation analysis have greatly affected operations planning procedures. For example, in the past, the economic objective was accomplished in the planning stage. The operations planner would compute the economic dispatch for projected electric loads and provide a list of generation operating schedules versus electric load. Then, the power system operator will use this list in order to operate the system. However, in actual operation, the system loading conditions and available units may be quite different from those assumed at the planning stage. The introduction of energy management systems provided the ability to optimize system economic operation in real time. Economic scheduling functions have been integrated in the real time control of power systems. Security functions have been also integrated in the control

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I. EMISSIONDISPATCH

The pollutant emission dispatch problem can be described as the optimization of total amount of pollutant emission. The quantity of pollutant emission resulting from a fossil-fired thermal generating unit is based on the amount of power generated by every unit. The objective of emission dispatch is to minimize the total environmental degradation or the total pollution emission due to burning of fuels for production to meet the load demand. . The pollutant emission dispatch problem can be described as the optimization of total amount of pollutant emission given as below:

$$E=\sum_{i=1}^{N}(d_i P_i^2 + e_i P_i + f_i)$$

Where d_i, e_i and f_i are emission coefficients of the i^{th}generating unit.

II. COMBINED ECONOMIC EMISSIONDISPATCH (CEED)

The idea behind combined emission and economic dispatch is to compute the optimal generation for individual units of the power system by minimizing the fuel cost and emission levels simultaneously, subjected to the system constraints. Under the strict governmental regulations on environmental protection, the conventional operation at minimum fuel cost can no longer be the only basis for dispatching electric power. The economic dispatch deals with only minimizing the total fuel cost, On the other hand Emission dispatch deals with only minimizing the total emission of CO_2, SO_2, $NO_X$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).

III. DESCRIPTION

A **Distributed bisection algorithm** based on average consensus is proposed. This algorithm has the following features. Requires no prior knowledge of the systems, while in several global parameters need to be known in order to design an appropriate learning gain for the convergence purpose. Each node needs to know every other nodes parameter, which implies that the computation and communication package size will explode as the network size grows. The proposed system has the following advantages over the existing systems. In this algorithm no global information of the system is required. Each node only requires to know the local parameter. No master or leader node is required to know the total power demand needed. This algorithm only assumes that the communication network is a strongly connected directed graph, which minimizes the packet loss, device failure or symmetric bandwidth allocation to maximum extend. The various methods which are been implemented to present the

a) Graphtheory

b) Consensus like iterativealgorithm

c) Problemformation

d) Centralized solution forEDP

A distributed algorithm for gathering the aggregate power demand, then show distributed feasibility test of EDP, and finally give a distributed bisection algorithm for EDP.

IV. ECONOMICDISPATCH

The objective of the Economic dispatch is to minimize the total system cost by adjusting the power output of each of the generators connected to the grid. The total system cost is modelled as the sum of the cost function of each generator.

$$FT=\sum_{i=1}^{n} F_i(P_i)$$

$$F_i(P_i)=a_i+ b_iP_i+ c_iP_i^2$$

Where

FT	: total generatingcost;
Fi	: cost function of generatingunit;
ai,bi,ci	: cost coefficients of generatori
Pi	: power of generatori
n	: number ofgenerator

V.COMBINED ECONOMIC ANDEMISSION DISPATCH

The economic dispatch and emission dispatch are two various problems as discussed previously. Emission dispatch can be included in conventional economic load dispatch problems by merging an emission constraint with the economic load dispatch problem. The two objectives can be converted into a single objective function by introducing a price penaltyfactor

$$\text{Min } F_T = \sum_{i=1}^{N}((a_i P_i^2 + b_i P_i + c_i) + h_i (d_i P_i^2 + e_i P_i + f_i))$$

VI.WINDENERGY

Wind turbines convert mechanical energy produced by the wind to electrical energy. To use this electrical energy, voltage and frequency regulation are needed. The mechanical power produced by a wind turbine Airflows can be used to run wind turbines. Modern utility-scale wind

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have become the most common for commercial use; the power available from the wind is a function of the cube of the wind speed, so as wind speed increases, power output increases dramatically up to the maximum output for the particular turbine. Areas where winds are stronger and more constant, such as offshore and high altitude sites, are preferred locations for wind farms.

Winds are influenced by the ground surface at altitudes up to 100 meters Wind is slowed by the surface roughness and obstacles. When dealing with wind energy, we are concerned with surface winds. A wind turbine obtains its power input by converting the force of the wind into torque (turning force) acting on the rotor blades. The amount of energy which the wind transfers to the rotor depends on the density of the air, the rotor area, and the wind speed. The kinetic energy of a moving body is proportional to its mass (or weight). The kinetic energy in the wind thus depends on the density of theair

The economic dispatch of generation in a power system incorporating wind power plant involves the allocation of generation among the wind and thermal plants so as to minimize the total production cost while satisfying various constraints. The generation cost of wind power generation is ignored in the optimization process since renewable energy law regulate that all of them must be adopted.

Wind Power Formula

$$Power = kC_p 1/2\ \rho\ AV^3$$

Where,

P =Power output(KW)

C_p =Max Powercoefficient(0.25-0.45)P =Airdensity

A =Rotor sweptarea

V =Wind speed(m/s)

K =0.000133

VII.SOLARENERGY

Solar power formulae

Solar share

$$\sum_{j=1}^{m} Pgs_j Us_j$$

Solar cost

$$\sum_{j=1}^{m} PUcost_j\, Pgs_j\, Us_j$$

SCEED with solar power

SCEED with solar power

$$MinF_t = \sum_{T=1}^{N}\sum_{i=1}^{n}(a_iP_i^2 + b_iP_i + c_i + |e_i * \sin(f_i * (P_{imin}-P_i))| + h_i(\alpha_i\ P_i^2 + \beta_iP_i + \gamma_i + \varepsilon_i * \exp(\delta_i \sum_{j=1}^{m} PUCost_j \times Pgs_j \times Us_j + Ks(\sum_{j=1}^{m} Pgs_j - \sum_{j=1}^{m} Pgs_j \times Us_j)$$

Dynamic CEED with solar power

$$Min\ F_t = \sum_{T=1}^{N}\sum_{i=1}^{n}(a_i(P_i^t)^2 + P_i^t + c_i + |e_i * \sin(f_i * (P_{imin} - P_i^t))| + h_i((P_i^t)^2 + P_i^t + \gamma_i + \varepsilon_i * \exp(\delta_i * P_i^t))) + \sum_{j=1}^{m} PUCost_j \times Pgs_j\, x s_j^t + Ks(\sum_{j=1}^{m} Pgs_j^t - \sum_{j=1}^{m} Pgs_j^t x s_j^t)$$

VIII.CONSRAINTS

Equality constraints

The equality constraint is represented by the power balance 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 equals the total system load (*PD*) plus system losses (*PL*) .

$$P_D = \sum_{i=1}^{N} P_I - (P_D + P_L)$$

The exact value of the system losses can only be determined by means of a power flow solution. The most popular approach for finding an approximate value of the losses is by way of Kron's loss formula

$$P_L = B_{00} + \sum_{i=1}^{N} B_{i0}P_i + \sum_{i=1}^{N}\sum_{j=1}^{N} P_iB_{ij}P_j\ MW$$

Inequality constraints:

Generating units have lower and upper production limits of power output of the unit. These bounds can be defined as a pair of inequality constraints, as follows:

$$P_{gmin} \leq P_{gi} \leq P_{gmax}$$

The generation output should be within the minimum and maximum limits of the generation constraints.

IX.PARTICLE SWARMOPTIMIZATION

PSO is inspired from the swarming behaviour of animals and human social behaviour. PSO shares many similarities with evolutionary computation techniques such as GA.PSO is a robust stochastic optimization technique based on the movement and intelligence of swarms.PSO applies the concept of social interaction to problem solving. It was developed in 1995 by James Kennedy (social-psychologist) and Russell Eberhart (electrical engineer).

The problem is initialized with a population of feasible random solutions; however, PSO has no evolution operators such as crossover and mutation. In PSO, the feasible solutions called particles fly through the problem

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number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution. Christo Ananth et al.[5] discussed about E-plane and H-plane patterns which forms the basis of Microwave Engineering principles.

Each particle is treated as a point in aN-dimensional space which adjusts its "flying" according to its own flying experience as well as the flying experience of other particles. Each particle keeps track of its coordinates in the solution space which are associated with the best solution (fitness) that has achieved so far by that particle. This value is called personal best ,**pbest**.Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighborhood of that particle. This value is called **gbest.** The basic concept of PSO lies in accelerating each particle toward its pbest and the gbest locations, with a random weighted acceleration at each time step.

X. CONCEPT

The Concept of modification of a searching point by PSO is given by

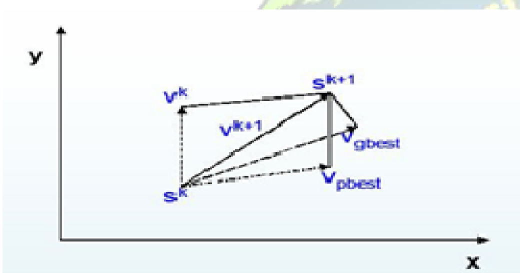

Fig 3.1 Concept of modification of a searching point by PSO

Where, S^k=current searching point

S^{k+1}

=modifiedsearchingpoinV

k

=currentvelocity

V^{k+1} =modifiedvelocityV_{pbest}

=velocity

basedonpbestV_{gbest}

=velocity based ongbest

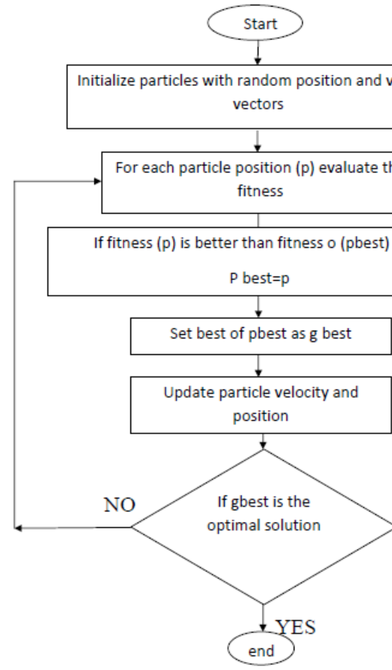

Fig 3.2 Flowchart for PSO

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XI.RESULTS

Hours	Power generation of units (MW)										Generation cost ($)	Emission cost(ton)	Startup cost($)	Total cost($)	Max capacity (MW)	Total demand (MW)	Loss (MW)	Reserve (MW)
	1	2	3	4	5	6	7	8	9	10								
1	455	266	0	0	0	0	0	0	0	0	16248.97	8351.96	0	16248.97	910	700	21.4	210
2	455	315	0	0	0	0	0	0	0	0	17103.44	9120.93	0	17103.44	910	750	20.9	160
3	455	283	130	0	0	0	0	0	0	0	18737.23	8932.9	550	19287.23	1040	850	18.3	290
4	455	388	130	0	0	0	0	0	0	0	20571.08	10874.62	0	20571.08	1040	950	23.8	90
5	455	306	130	130	0	0	0	0	0	0	21318.88	9630.36	560	21878.88	1170	1000	21.9	170
6	455	383	130	130	25	0	0	0	0	0	23159.28	11023.5	900	24059.28	1332	1100	23.9	232
7	455	435	130	130	25	0	0	0	0	0	24069.89	12223.38	0	24069.89	1332	1150	25.7	182
8	455	455	130	130	30	0	25	0	0	0	24520.35	12720.43	260	24780.35	1417	1200	25.2	217
9	455	455	130	130	121	20	25	0	0	0	26815.76	12783.62	170	26985.76	1497	1300	26.7	197
10	455	455	130	130	162	58	25	10	0	0	28536.64	12980.48	30	28566.64	1552	1400	25.7	152
11	455	455	130	130	162	80	25	28	10	0	29047.98	13004.03	30	29077.98	1607	1450	25.8	157
12	455	455	130	130	162	80	25	55	17	17	29047.98	13004.03	30	29077.98	1662	1500	26.2	162
13	455	455	130	130	162	0	25	55	13	0	27221.61	13088.93	0	27221.61	1527	1400	25.4	127
14	455	332	130	130	126	0	0	10	10	10	26471.14	12869.54	30	26501.14	1497	1300	26.7	197
15	455	281	130	130	58	0	0	0	0	0	25081.76	12698.43	0	25081.76	1332	1200	28.4	132
16	455	384	130	130	25	0	0	0	0	0	22267.93	10010.69	0	22267.93	1332	1050	22.8	282
17	455	455	130	130	25	0	0	0	0	0	21377.92	9159.87	0	21377.92	1332	1000	21.7	332
18	455	455	130	130	25	0	0	0	0	0	23177.04	11045.31	0	23177.04	1332	1100	24.9	232
19	455	455	130	130	30	0	25	0	0	0	24520.34	12720.44	260	24780.34	1417	1200	25.3	217
20	455	455	130	130	162	58	25	10	0	0	28536.65	12983.48	200	28736.65	1552	1400	25.7	152
21	455	455	130	130	111	20	25	0	0	0	26609.53	12741.94	0	26609.53	1497	1300	26.7	197
22	455	455	130	0	67	20	0	0	0	0	23530.93	12309.13	0	23530.93	1282	1100	27.7	182
23	455	423	0	0	25	20	0	0	0	0	19935.48	11207.05	0	19935.48	1152	900	23.7	252
24	455	367	0	0	0	0	0	0	0	0	18012.03	10099.78	0	18012.03	910	800	22.4	110

Table 1. Output for thermal unit

Hours	Power generation of units(MW)										Generation cost ($)	Emission cost (ton)	Startup cost($)	Wind (MW)	Wind Cost ($)	Wind Speed (m/s)	Total cost($)	Max capacity (MW)	Total demand (MW)	Loss (MW)	Reserve (MW)
	1	2	3	4	5	6	7	8	9	10											
1	455	266	0	0	0	0	0	0	0	0	16248.97	8351.96	0	11.3	169.6	7.784	16418.57	910	700	21.4	210
2	455	315	0	0	0	0	0	0	0	0	17103.44	9120.93	0	26.9	403.5	11.679	17506.94	910	750	20.9	160
3	455	283	130	0	0	0	0	0	0	0	18737.23	8932.9	550	21.9	328.5	9.73	19615.73	1040	850	18.3	290
4	455	388	130	0	0	0	0	0	0	0	20571.08	10874.62	0	41.3	619.5	16.541	21190.58	1040	950	23.8	90
5	455	306	130	130	0	0	0	0	0	0	21318.88	9630.36	560	41.3	619.5	17.514	22498.38	1170	1000	21.9	170
6	455	383	130	130	25	0	0	0	0	0	23159.28	11023.5	900	41.3	619.5	17.514	24678.78	1332	1100	23.9	232
7	455	435	130	130	25	0	0	0	0	0	24069.89	12223.38	0	41.3	619.5	16.541	24689.39	1332	1150	25.7	182
8	455	455	130	130	30	0	25	0	0	0	24520.35	12720.43	260	26.9	403.5	11.676	25183.85	1417	1200	25.2	217
9	455	455	130	130	121	20	25	0	0	0	26815.76	12783.62	170	37.5	562.5	13.622	27548.26	1497	1300	26.7	197
10	455	455	130	130	162	58	25	10	0	0	28536.64	12980.48	30	41.3	619.5	17.514	29186.14	1552	1400	25.7	152
11	455	455	130	130	162	80	25	28	10	0	29047.98	13004.03	30	39.4	591	14.595	29668.98	1607	1450	25.8	157
12	455	455	130	130	162	80	25	55	17	17	29047.98	13004.03	30	41.3	619.5	21.406	29697.48	1662	1500	26.2	162
13	455	455	130	130	162	0	25	55	13	0	27221.61	13088.93	0	41.3	619.5	16.541	27841.11	1527	1400	25.4	127
14	455	332	130	130	126	0	0	10	10	10	26471.14	12869.54	30	21.9	328.5	9.73	26829.64	1497	1300	26.7	197
15	455	281	130	130	58	0	0	0	0	0	25081.76	12698.43	0	4.4	66	6.84	25147.76	1332	1200	28.4	132
16	455	384	130	130	25	0	0	0	0	0	22267.93	10010.69	0	25.5	382.5	10.703	22650.43	1332	1050	22.8	282
17	455	455	130	130	25	0	0	0	0	0	21377.92	9159.87	0	13.1	196.5	8.757	21574.42	1332	1000	21.7	332
18	455	455	130	130	25	0	0	0	0	0	23177.04	11045.31	0	13.1	196.5	8.757	23373.54	1332	1100	24.9	232
19	455	455	130	130	30	0	25	0	0	0	24520.34	12720.44	260	21.9	328.5	10.703	25108.84	1417	1200	25.3	217
20	455	455	130	130	162	58	25	10	0	0	28536.65	12983.48	200	32.9	493.5	12.649	29230.15	1552	1400	25.7	152
21	455	455	130	130	111	20	25	0	0	0	26609.53	12741.94	0	26.9	403.5	11.676	27013.03	1497	1300	26.7	197
22	455	455	130	0	67	20	0	0	0	0	23530.93	12309.13	0	25.5	382.5	10.703	23913.43	1282	1100	27.7	182
23	455	423	0	0	25	20	0	0	0	0	19935.48	11207.05	0	32.5	487.5	12.649	20422.98	1152	900	23.7	252
24	455	367	0	0	0	0	0	0	0	0	18012.03	10099.78	0	32.5	487.5	12.649	18499.53	910	800	22.4	110

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Hours	Power generation of units(MW)										Generation cost ($)	Emission cost($/ton)	Start-up cost($)	Wind (MW)	Wind Cost ($)	Wind Speed (m/s)	Strategy	P_{PH}	Total cost($)	Max capacity (MW)	Total demand (MW)	Loss (MW)	Reserve (MW)
	1	2	3	4	5	6	7	8	9	10													
1	455	334	0	0	0	0	0	0	0	0	17430.7	9453.88	0	11.3	169.6	7.784	P	−114	17486.3	910	800	21.4	110
2	455	368	0	0	0	0	0	0	0	0	18031.83	10122.98	0	26.9	403.5	11.679	P	−114	18435.3	910	850	20.9	60
3	455	343	130	0	0	0	0	0	0	0	19786.37	9960.21	550	21.9	328.5	9.73	P	−114	20550.9	1040	950	18.3	90
4	455	324	130	0	0	0	0	0	0	0	19448.05	9604.55	0	41.3	619.5	16.541	S	0	20067.6	1040	950	23.8	90
5	455	244	130	130	0	0	0	0	0	0	20233.68	8714.68	560	41.3	619.5	17.514	S	0	21413.2	1170	1000	21.9	170
6	455	319	130	130	25	0	0	0	0	0	22036.44	9733.93	900	41.3	619.5	17.514	S	0	23555.9	1332	1100	23.9	232
7	455	369	130	130	25	0	0	0	0	0	22909.85	10723.92	0	41.3	619.5	16.541	S	0	23529.4	1332	1150	25.7	182
8	455	408	130	130	25	0	25	0	0	0	23598.96	11582.07	260	26.9	403.5	11.676	S	0	24262.5	1417	1200	25.2	217
9	455	378	130	130	25	20	25	0	0	0	23511.27	10844.15	170	37.5	562.5	13.622	G	104	24647.8	1497	1200	26.7	197
10	455	455	130	130	34	20	25	10	0	0	25043.19	12651.86	30	41.3	619.5	17.514	G	104	25796.7	1552	1300	25.7	252
11	455	455	130	130	76	20	25	10	10	0	25886.38	12649.73	30	39.4	591	14.595	G	104	26611.4	1607	1350	25.8	257
12	455	455	130	130	114	20	25	10	10	10	26666.18	12752.72	30	41.3	619.5	21.406	G	104	27419.7	1662	1400	26.2	262
13	455	455	130	130	44	0	25	10	10	0	24795.25	12702.89	0	41.3	619.5	16.541	G	104	25519.8	1527	1300	25.4	227
14	455	408	130	130	25	0	0	10	10	10	23599.2	11582.38	30	21.9	328.5	9.73	G	104	24061.7	1497	1200	26.7	297
15	455	455	130	130	26	0	0	0	0	0	24433.18	12728.75	0	4.4	66	6.84	S	0	2449.18	1332	1200	28.4	132
16	455	284	130	130	25	0	0	0	0	0	21438.78	9212.92	0	25.5	382.5	10.703	S	0	21821.3	1332	1050	22.8	282
17	455	247	130	130	25	0	0	0	0	0	20783.15	8681.1	0	13.1	196.5	8.757	S	0	20979.7	1332	1000	21.7	332
18	455	347	130	130	25	0	0	0	0	0	22527.5	10289.07	0	13.1	196.5	8.757	S	0	22724	1332	1100	24.9	232
19	455	413	130	130	25	0	25	0	0	0	23686.86	11698.38	260	21.9	328.5	10.703	S	0	24275.4	1417	1200	25.3	217
20	455	455	130	130	42	20	25	10	0	0	25210.74	12641.78	200	32.9	493.5	12.649	G	104	26008.2	1552	1300	25.7	252
21	455	388	130	130	25	20	25	0	0	0	23696.99	1071.75	0	26.9	403.5	11.676	G	104	24204.5	1497	1200	26.7	297

XII. CONCLUSION

The fuel cost for conventional energy sources are depleting in faster way due to the heavy consumption of energy. so, renewable energy has come into picture and its use is also growing in a faster way. Hence, economical generation of the renewable energy from its sources becomes primary concern. Also most of the renewable energy such as wind, pumped hydro storage and solar considered for our analysis are clean sources which reduces the emission of harmful gases like carbon monoxide, carbon dioxide to a larger value. Since the fuel for generation of renewable energy is freely occurring in nature, the cost for generation also reduces. This calls for more research and investment opportunities. Since the renewable energy is easy to harness, even the consumer can generate energy with very low cost and hence distributed generation has come into picture. This led to the conversion of conventional grid to a smart grid and led to decrease in losses of energy. Also, usage of these kinds of energy has led to a clean and green environment. The combine economic emission dispatch (CEED) of thermal system will reduce cost as well as emission. Economic dispatch of wind energy using PSO the fuel cost is reduced and emission is more. Therefore a combined economic emission dispatch (CEED) has been discussed and the solution is obtained by particle swarm optimization method(PSO)

XIII. REFERENCES

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