Optimization Hydro-Thermal-Wind-PV Solar Using MOPSO Algorithm Applied to Economic/ Environmental Dispatch

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ABSTRACT

The purpose in this present work exposure the application of MOPSO multiple- objective particle swarm optimization algorithm to solver dynamic economic emission dispatch problems with ramp rate. The proposed MOPSO algorithm is applied in economic emission dispatch to fin the best solutions of hydro plant, thermal units, wind and PV solar generation scheduling powers and then calculate the cost, emission functions for SO_x and NO_x gas pollution, and combined the three function. The dynamic economic emission distribution (DEED) is an important subject in electrical power systems network. This consists of a valve point effect(VPE), transmission powers losses, a load, an equilibration power system and generator constraints. The proposed algorithm was exanimate on ten unit test power systems. All simulations results are thorough on the MATLAB-Simulinc space.

KEY WORDS: ECONOMIC EMISSION DISPATCH PROBLEM; RAMP RATE; SOLAR POWER; ENERGY STORAGE; WIND POWER; HYDRO PLANT; MOPSO; POWER SYSTEMS; TRANSMISSION LOSSES; VALVE POINT EFFECT.

INTRODUCTION

The role of best optimal dispatch production scheduling of a thermal-renewable power system of generation pointing modest economic and minimization of emission as a benefits is necessary actually in order to swelling the demanded power generation, escalating the total fuel price and high pollution rate. Optimization scheduling of power plant production is of large importance to electric interest systems. With the low misfit cost of power hydroelectric, the problem of minimizing the transition cost of a hydrothermal system basically reduces to that of minimize the fuel cost for thermal plants user the divers constraints on the hydraulic and power system grid.

A coal-fired power plant releases tons of ash, tons of toxic heavy metals, arsenic, mercury, cadmium, uranium, tons of thorium, soot and fine particles that escape to the atmosphere each year. Tons of CO₂ and tons of nitrogen oxide (NO_x). Thus, everyone is currently oriented towards the use of renewable energies by the integration of these different forms in electrical networks. Electricity production is responsible for 35% of CO₂ emissions linked to human activity worldwide. Fortunately, renewable energies, or green energies, have experienced a real boom since the 2000s. These new energy production sectors should in future represent a greater share of use because of the environmental impact of renewable energy.

The Clean Air Act 1990 aims to reduce greenhouse gases and acid rain. It requires that fossil fuel power plants must decrease its (NO_x) emission level and (SO₂) quantity. Though these approach previous have obtain simultaneously emission and total fuel cost, the scheduling problem is ultimately optimization problem of single objective both inevitable flaws. The results of optimization are critical to the balances which are difficult to be resolved. The Pareto best group cannot be acquired in one test by using different metering. To overcome the disadvantages mentioned above, many

Biosc Biotech Res Comm P-ISSN: 0974-6455 E-ISSN: 2321-4007

Identifiers and Pagination

Year: 2021 Vol: 14 No (5) Special Issue

Pages: 118-125

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DOI: <http://dx.doi.org/10.21786/bbrc/14.5/23>

Article Information

Received: 18th Jan 2021

Accepted after revision: 29th Mar 2021

authors have developed strength pareto evolutionary algorithm-2 (SPEA 2) and non-dominated sorting genetic algorithm-II.

Formulation of Problem: NOx emission, SOx emission and cost of generation represent the optimized objective functions simultaneously for EED problem of wind-solar-hydro-thermal plants system. while respecting the constraints of the system. The objectives functions and constraints problem given into account in the problem of formulation.

2.1.Objectives

2.1.1. Cost function: Economic dispatch, or modest economic dispatch is to research the generation power that given the minimum of total fuel cost respecting constraints necessary of the system. In comparison of the hydroelectric power station cost, the operating cost of a wind- solar -hydro-thermal system is reduced specially to that of the cost of total fuel cost for thermal power plants with the cost of the PV solar power system and wind power generation units and the PV solar power system. The following expression of total fuel cost is.

$$F_u = \sum_{t=1}^T \left\{ \sum_{g=1}^{N_g} [f_{g,t}(P_{g,t})] + \sum_{k=1}^{N_w} K_{w,k} * P_{w,k,t} + \sum_{m=1}^{N_{PV}} K_{PV,m} * P_{PV,m,t} \right\} \quad (1)$$

Equation (2) give The expression of the total fuel cost for thermal plant, taking into count the valve-point effect (VPE).

$$f_{g,t}(P_{g,t}) = a_g + b_g P_{g,t} + c_g P_{g,t}^2 + \left| d_g \times \sin \left[e_g \times \left(P_g^{\min} - P_{g,t} \right) \right] \right| \quad (2)$$

2.1.2. NOx emission function: In reference, the NOx emissions is given by the following equation:

$$E_{NO_X} = \sum_{t=1}^T \sum_{g=1}^{N_g} \left[\alpha_{ng} + \beta_{ng} P_{g,t} + \gamma_{ng} P_{g,t}^2 \right] \quad (3)$$

2.1.3.Sox emission function: The equation (4) that represent the expression of SOx emission is given by:

$$E_{SO_X} = \sum_{t=1}^T \sum_{g=1}^{N_g} \left[\alpha_{sg} + \beta_{sg} P_{g,t} + \gamma_{sg} P_{g,t}^2 \right] \quad (4)$$

2.2. Constraints of the problem: Depending on the size of the electrical network, in other words its complexity, the study of the switching of units can be conditioned by several constraints. In fact, in this context two constraints to be respected the spinning reserve constraints and demanded power of load.

- **Generating unit ramp-rate limits**

Violation of unit ramp rates will shorten the life for power production facilities. Thus, the ramp rate limits must be schown when the power demanded for variation of electric charge changes.

$$\left. \begin{aligned} P_{g,t} - P_{g,t-1} &\leq UR_g \\ P_{g,t-1} - P_{g,t} &\leq DR_g \end{aligned} \right\} \text{For } g \in N_g \text{ et } t = 2, 3, \dots, T \quad (5)$$

If unit ramp speed limits are considered into account, actual generated power limits (5) can be obtain the variation as equation (6):

$$\max \left(P_g^{\min}, P_{g,t-1} - DR_g \right) \leq P_{g,t} \leq \min \left(P_g^{\max}, P_{g,t-1} + UR_g \right) \quad (6)$$

- **Real power balance equation:**

$$\sum_{t=1}^{T=24} \left[\sum_{g=1}^{N_g} P_{g,t} + \sum_{j=1}^{N_h} P_{h,j,t} + \sum_{m=1}^{N_{PV}} P_{PV,m,t} + \sum_{k=1}^{N_w} P_{w,k,t} + P_{bat,t} \right] = P_{Dt} + P_{Lt} \quad (7)$$

Or the total power losses of the transmission line PLt can be calculated by using B-coefficient stated as equation number (8).

$$P_{Lt} = \sum_{t=1}^T \sum_{g=1}^{N_g} P_{g,t} B_{gj} P_{j,t} ; t = 1, 2, \dots, T \quad (8)$$

The hydroelectric generation is a function of reservoir and discharge water rate given by the following expression:

$$P_{h,j,t} = C_{1,j} V_{h,j,t}^2 + C_{2,j} Q_{h,j,t}^2 + C_{3,j} V_{h,j,t} + C_{4,j} Q_{h,j,t} + C_{5,j} V_{h,j,t} Q_{h,j,t} + C_{6,j} \quad (9)$$

For $j \in N_{h,t}$ et $t = 1, 2, \dots, T$

For the output of power for the kth generated power of wind unit for given speed and time t has the following expression:

$$P_{win} = \begin{cases} 0, & \text{for } v_{win,t} \leq v_{in} \text{ and } v_{win,t} > v_0 \\ pr \left(\frac{v_{win,t} - v_{in}}{v_r - v_{in}} \right), & \text{for } v_{in} \leq v_{win,t} \leq v_r \\ pr, & \text{for } v_r \leq v_{win,t} \leq v_0 \end{cases} \quad (10)$$

The output power [12] from PV cell has the following equation.

$$P_{PV,m,t}(G) = \begin{cases} P_S \left(\frac{G^2}{G_{std} \cdot R_c} \right) & \text{for } 0 < G < R_c \\ P_S \left(\frac{G}{G_{std}} \right) & \text{for } G > R_c \end{cases} \quad (11)$$

- **Real power generation limit**

$$\begin{aligned}
P_g^{\min} &\leq P_{g,t} \leq P_g^{\max}; \text{ For } g \in N_g, t \in T \\
P_{h,j}^{\min} &\leq P_{h,j,t} \leq P_{h,t}^{\max}; \text{ For } j \in N_h, t \in T \\
P_{w,k}^{\min} &\leq P_{w,k,t} \leq P_{w,k}^{\max}; \text{ For } j \in N_w, t \in T
\end{aligned} \quad (12)$$

- **Constraints of Hydraulic system:** All constraints of the hydraulic equipment include equations of the water balance for each hydroelectric unit in addition to the limits on the storage and rejection targets of the reservoirs :

- Physical limitations on reservoir storage volumes and discharge rates,

$$V_{h,j}^{\min} \leq V_{h,j,t} \leq V_{h,j}^{\max}; j \in N_h, t \in T \quad (13)$$

$$Q_{h,j}^{\min} \leq Q_{h,j,t} \leq Q_{h,j}^{\max}; j \in N_h, t \in T \quad (14)$$

-hydro reservoir system has the following equation of continuity:

$$\begin{aligned}
V_{h,j,t+1} &= V_{h,j,t} + I_{h,j,t} - Q_{h,j,t} - S_{h,j,t} \\
&+ \sum_{l=1}^{R_{uj}} \left(Q_{hl}(t - \tau_{lj}) + S_{hl}(t - \tau_{lj}) \right); j \in N_h, t \in T
\end{aligned} \quad (15)$$

- Energy storage system ESS

Equation (16) represent The maximum discharge and charge and battery capacity :

$$-P_b^{\max} \leq P_{bt} \leq P_b^{\min} \quad (16)$$

Pbt : positive in discharging P^d .

Pbt: negative in charging P^c .

* If the ESS is charging ($P_b(t) < 0$)

* If the ESS is discharging ($P_b(t) > 0$)

* If the ESS is idle ($P_b(t) = 0$)

Multi-Objective Function: The formulation of optimization in this case of multi-objective function CDEED dispatch is given by equation (17).

$$Min F(P_{gi,t}) = \left[F_u(P_{g,t}), E_{NO_X}(P_{g,t}), E_{SO_X}(P_{g,t}) \right] \quad (17)$$

Determine the optimal dispatch of active energy production which give the minimization of two contradictory objectives functions of total fuel cost and

emissions quantity while respecting several equality and inequality constraints. The CDEED is considered as an optimization of a single objective function using the weighting method as:

$$Min F = w F_u + (1-w)(pf_{NO_X} E_{NO_X} + pf_{SO_X} E_{SO_X}) \quad (18)$$

Where pf is the price penalty factor is as flows:

$$pf_{i_{NO_X}}(P_{ig}^{\max}) = \frac{F_{u,g,t}(P_{ig}^{\max})}{E_{NO_X}(P_{ig}^{\max})} \$ / ton \quad (19)$$

$$pf_{i_{SO_X}}(P_{ig}^{\max}) = \frac{F_{u,g,t}(P_{ig}^{\max})}{E_{SO_X}(P_{ig}^{\max})} \$ / ton \quad (20)$$

Where $0 \leq w \leq 1$ is the weighting factor.

If $w = 1$, minimizing only the cost.

If $w = 0$, minimizing only the emission.

If $w = 0.5$ minimizing simultaneously the economic and emission.

Mopso Approach

4.1. Overview: Several scientific researches use a lot of times Particle swarm optimization and consider them as very efficient and robust methods which can be applied or used for nonlinear optimization problems and more particularly for electrical systems. In fact, these algorithms ignore several conditions such as differentiability and continuity, whether for the objective functions to be optimized or these constraints to be respected. This algorithm is introduced by Eberhart and Kennedy as an optimization tool for non-linear optimization problems.

4.2. MOPSO Algorithm: It is at random, the initialization of all the particles in the research space for the MOPSO approach. A position and velocity are assigned For each particle in the decision research space. The proposed MOPSO approach is well detailed with these different steps in the reference.

4.3. Front pareto and best compromise solution: Decision maker (DM) can assume vague or imprecise objectives for each objective function. Fuzzy sets are defined by equations called functions of membership. The DM is able to give the best evaluation for the function of membership, μ_{Fk} subjectively and is defined as strictly monotonically with decrease and continuity function has the following expression:

$$\mu_{F_k}(i) = \begin{cases} 0 & , \text{otherwise} \\ \frac{F_k^{Max} - F_k(i)}{F_k^{Max} - F_k^{min}}, & F_k^{Max} \leq F_k(i) \leq F_k^{min} \end{cases} \quad (21)$$

The procedure is as follows:

$$F2 = \min E_{mit} (P_{gi,t}) \leq \varepsilon \quad (22)$$

The ε value will be varied from F2Max to F2min and then F1 (cost function) is minimized. The final solution using (DM) can then be found as:

$$\begin{matrix} \text{Max} \\ 1:n \end{matrix} \left(\begin{matrix} \text{min}(\mu_{F_k}) \\ 1:n \end{matrix} \right) \quad (23)$$

Where nS number of total solution and nF number of objective functions.

Analysis and Discussion of Results: In this paper, four cases are considered to demonstrate the performance of the proposed method such as:

Case 1: Economic dispatch.

Case 2: NOx emission dispatch.

Case 3: SOx emission dispatch.

Case 4: Combined economic emission dispatch.

Figure 1: Evolution convergence case 1 (a), case 2 (b), case 3 (c) and case 4 (d)

All results of simulations are obtained in MATLAB-simulink R2013a using i3-2310M CPU @ 2.10 GHz. This proposed method is applied with size of population as 200. 600 is the number maximum of iteration. The system power data for all cases are given from. Four reservoir hydroelectric power plants are considered in this system, three thermal plants, equivalent power of

wind generation unit, an equivalent PV solar power plant and an equivalent battery energy storage. A 24 intervals by day is the planning period. The valve point effect loading (VPEL) is considered into count. Hydrothermal parameters are more detailed in reference.

Figure 2: Pareto front and best solution case 1 (a), case 2 (b), case 3 (c) and case 4 (d)

Figure 3: Hydro plant discharges (104m3) case 1 (a), case 2 (b), case 3 (c) and case 4 (d)

Sox and NOx coefficients are given in. The rating of wind power generator is $p_r = 150\text{MW}$. The cut-in, cut-out and rated wind speeds are $v_{in}=4\text{m/s}$, $v_o=25\text{m/s}$ and $v_r=15\text{m/s}$ respectively. The direct cost coefficient K_{win} for the wind power generator is taken 3.25. The rating of solar PV generator is $PS=150\text{MW}$. The direct cost coefficient K_{pv} for the solar PV generator is taken 3.5.

The solar radiation in the standard environment Gstd and a certain radiation point Rc are taken as 1000 W/m² and 150 W/m². The forecasted wind velocity and solar radiation are taken from.

Figure 4: Hydro reservoir storage volumes (104m³) from case 1 (a), case 2 (b), case 3 (c) and case 4 (d)

Figure 5: The ramp up/ramp down values of case 1 (a), case 2 (b), case 3 (c) and case 4 (d)

Table 1. Best scheduling and dispatching of generation (MW) for case 1 of test system

H	PD	Thermal unit power generation								Hydro power generation				PV Solar	Wind	Pbat
		g1	g2	g3	g4	g5	g6	g7	g8	h1	h2	h3	h4			
t1	1750	455	450	130	20	50.3259	40	45	35	113.5000	111.2000	65.2784	327.8500	0.0000	0.0000	-93.1543
t2	1780	455	450	130	20	50.3259	40	45	35	66.7348	50.1640	55.2735	327.8500	0.0000	0.0000	54.6518
t3	1700	455	450	130	20	50.3259	40	45	35	69.2867	51.8500	48.7598	326.7162	0.0000	0.0000	-21.9386
t4	1650	455	450	130	20	50.3259	40	45	35	70.9992	53.4640	41.4710	327.8500	0.0000	0.0000	-69.1100
t5	1670	455	450	130	20	77.3516	40	45	35	71.9591	54.5000	38.2778	323.3603	0.0000	0.0000	-70.4489
t6	1800	455	450	130	20	127.3516	40	45	35	73.2429	55.0060	65.2563	304.1431	0.0000	0.0000	62.3855
t7	1950	455	450	130	20	177.3516	40	45	35	74.8164	55.0060	65.2694	327.8500	0.0000	12.3210	65.5504
t8	2010	455	450	130	20	227.3516	40	45	35	76.6334	55.5040	65.1445	298.1661	0.0000	46.6500	120.0000
t9	2090	455	450	130	20	237.1027	40	45	35	78.6879	59.8756	64.8314	298.2524	0.0000	56.2500	85.0073
t10	2080	455	450	130	20	235.5400	40	45	35	80.9089	65.1696	64.3405	298.5837	0.0000	75.4500	81.1576
t11	2100	455	450	130	20	235.5400	40	45	35	83.2384	69.6539	63.6748	299.1853	0.0000	92.5500	116.4466
t12	2150	455	450	130	20	235.5400	40	45	35	84.3106	72.8037	62.9514	300.0476	0.0000	102.9000	69.4525
t13	2110	455	450	130	20	235.5400	40	45	35	85.6290	75.4116	62.3578	301.1590	0.0000	105.4500	-77.7620
t14	2030	455	450	130	20	232.9904	40	45	35	87.1239	78.1588	61.6156	302.4732	60.0000	110.4000	-99.4109
t15	2010	455	450	130	20	232.9904	40	45	35	87.9190	80.3587	60.8740	303.9142	80.4546	87.9000	-29.8977
t16	2060	455	450	130	20	232.9904	40	45	35	88.1261	81.3910	59.9701	305.4883	83.1818	63.7500	-14.6910
t17	2050	455	450	130	20	232.9904	40	45	35	87.8378	81.2864	59.0328	307.1662	77.7273	43.6500	99.3766
t18	2120	455	450	130	20	232.9904	40	45	35	87.2315	80.0795	58.0666	308.9502	70.9091	7.3960	52.2729
t19	2070	455	450	130	20	232.9904	40	45	35	86.4987	79.1976	56.8602	310.8166	76.3636	0.0000	70.1121
t20	2050	455	450	130	20	232.2705	40	45	35	62.5277	59.9444	55.5845	312.7425	81.8182	0.0000	-28.5027
t21	1910	455	450	130	20	182.2705	40	45	35	64.2669	65.9564	54.4635	314.7272	81.8182	0.0000	-80.5014
t22	1860	455	450	130	20	181.5505	40	45	35	66.2982	70.5920	55.3070	316.7537	75.0000	0.0000	-90.9958
t23	1850													80.4546	0.0000	-
t24	1800	455	450	130	20	177.7078	40	45	35	68.5250	73.0307	56.6403	309.6374			120.0000
Cost(\$/day)										70.8447	73.9532	56.0600	299.1615	117.2727	0.0000	-93.1543
498290		27.6394				187.2759										

The convergence of objective functions of all cases with iterations using MOPSO algorithm is depicted by Figure.1. It shows that MOPSO converges faster and has got a superior performance. The curve has almost stopped declining since about the 550 th Iterations, it's declines gradually, and it finally achieves the lowest level.

Figure 2 (a)–(d) illustrated pareto front and best solution for all case, respectively. It is able to obtain the optimal pareto-front of the all solution , that are well distributed in the search space.. The cost and emission objectives are actually contradictory and non commensurate in nature. In such problems there is no single optimal

solution to a problem. The best solution out of the Pareto-optimal solutions is a tedious task. In this paper,

a fuzzy ranking method is used for finding the best compromise solution.

Table 2. Best scheduling and dispatching of generation (MW) for case 2 of test system

H	PD	Thermal unit power generation								Hydro power generation				PV Solar	Wind	Pbat
		g1	g2	g3	g4	g5	g6	g7	g8	h1	h2	h3	h4			
t1	1750	299.4152	299.4149	130	20	25	460	45	35	90.6980	66.2000	65.2784	249.37	0.0000	0.0000	-35.3766
t2	1780	299.3701	299.3696	130	20	25	460	45	35	75.4410	49.0000	58.8221	248.6058	0.0000	0.0000	34.3914
t3	1700	299.3939	299.3937	130	20	25	460	45	35	75.7683	50.1640	50.4206	249.3700	0.0000	0.0000	-39.5104
t4	1650	299.3664	299.3661	130	20	25	460	45	35	76.3816	51.2960	49.2708	249.3700	0.0000	0.0000	-90.0509
t5	1670	299.3782	299.3782	130	20	25	460	45	35	76.5683	52.9340	46.8249	249.3700	0.0000	0.0000	-69.4536
t6	1800	326.7483	326.7486	130	20	25	460	45	35	76.4328	57.8209	47.8794	249.3700	0.0000	0.0000	50.1854
t7	1950	367.2091	367.208	130	20	25	460	45	35	75.8246	62.0828	48.2573	251.9118	0.0000	12.3210	67.0004
t8	2010	367.1876	367.1877	130	20	25	460	45	35	75.5910	65.1359	48.9469	257.3005	0.0000	46.6500	120.0000
t9	2090	371.8969	371.9005	130	20	25	460	45	35	75.8431	67.1673	49.3353	262.6068	0.0000	56.2500	92.1174
t10	2080	367.2086	367.2091	130	20	25	460	45	35	76.5029	69.4702	49.3441	267.6977	0.0000	75.4500	86.6361
t11	2100	367.2092	367.2089	130	20	25	460	45	35	77.5578	72.1253	49.0023	272.7105	0.0000	92.5500	117.5388
t12	2150	367.2101	367.2094	130	20	25	460	45	35	78.8815	75.1026	48.6017	277.5559	0.0000	102.9000	66.5220
t13	2110	367.2152	367.2173	130	20	25	460	45	35	80.5094	77.7968	48.1313	282.1581	0.0000	105.4500	-66.5931
t14	2030	358.2016	358.2009	130	20	25	460	45	35	80.8834	79.4939	47.9019	286.5115	60.0000	110.4000	-91.2680
t15	2010	358.1998	358.2007	130	20	25	460	45	35	81.5705	80.9626	48.2393	290.7405	80.4546	87.9000	-27.0551
t16	2060	358.1987	358.1995	130	20	25	460	45	35	82.7148	82.9763	48.2128	294.8213	83.1818	63.7500	-17.7005
t17	2050	358.1982	358.1957	130	20	25	460	45	35	83.4501	84.7835	48.1456	298.5500	77.7273	43.6500	83.5728
t18	2120	358.2016	358.2016	130	20	25	460	45	35	83.8692	85.5297	47.7266	309.5935	70.9091	7.3960	37.5859
t19	2070	358.2074	358.2069	130	20	25	460	45	35	83.0744	84.2795	46.7762	310.5062	76.3636	0.0000	81.4581
t20	2050	358.2058	358.2047	130	20	25	460	45	35	54.7570	49.1257	47.6331	303.7974	81.8182	0.0000	-23.3769
t21	1910	345.8139	345.8121	130	20	25	460	45	35	54.6168	51.5132	49.7135	289.0892	81.8182	0.0000	-56.6231
t22	1860	345.8119	345.8112	130	20	25	460	45	35	54.7050	60.0952	51.9174	268.2824	75.0000	0.0000	-120.0000
t23	1850	343.1922	343.1922	130	20	25	460	45	35	105.9562	80.9790	56.6134	244.6124	80.4546	0.0000	-120.0000
t24	1800	268.6012	268.6008	130	20	25	460	45	35	107.0200	80.9500	59.0053	303.5500	117.2727	0.0000	-35.3766
		Cost(\$/day)								NOx Emission (Ton/day)				SOx Emission (Ton/day)		
		537240								25.8175				195.4521		

Table 3. Best scheduling and dispatching of generation (MW) for case 3 of test system

H	PD	Thermal unit power generation								Hydro power generation				PV Solar	Wind	Pbat
		g1	g2	g3	g4	g5	g6	g7	g8	h1	h2	h3	h4			
t1	1750	50	50	20	130.0000	470	40	223.9319	300	94.3455	67.0229	65.2784	249.3700	0.0000	0.0000	-9.9487
t2	1780	50	50	20	130.0000	470	40	223.9319	300	78.2380	50.1024	46.6694	249.3700	0.0000	0.0000	71.6884
t3	1700	50	50	20	130.0000	470	40	240.8275	300	78.2710	51.2361	45.4993	249.3700	0.0000	0.0000	-25.2038
t4	1650	50	50	20	130.0000	470	40	270.8275	300	77.8388	55.3557	42.4695	249.3700	0.0000	0.0000	-105.8614
t5	1670	50	50	20	130.0000	470	40	300.8275	300	76.9846	59.3841	38.6750	247.5864	0.0000	0.0000	-113.4575
t6	1800	50	50	20	130.0000	470	40	330.8275	300	75.7287	62.3106	38.9801	249.3700	0.0000	0.0000	-17.2169
t7	1950	50	50	20	130.0000	470	40	360.8275	300	75.1310	64.3435	39.9902	249.3700	0.0000	12.3210	88.0169
t8	2010	50	50	20	130.0000	470	40	390.8275	300	75.1255	65.5710	40.5985	249.3700	0.0000	46.6500	81.8576
t9	2090	50	50	20	130.0000	470	40	420.8275	300	75.6783	67.3573	40.9279	249.3700	0.0000	56.2500	119.5891
t10	2080	50	50	20	130.0000	470	40	450.8275	300	76.7489	69.6806	40.9875	249.3700	0.0000	75.4500	56.9355
t11	2100	50	50	20	130.0000	470	40	465.0000	300	78.2267	72.4363	41.1341	249.3700	0.0000	92.5500	41.2829
t12	2150	50	50	20	130.0000	470	40	465.0000	300	80.0093	74.9288	41.3779	249.3700	0.0000	102.9000	76.4139
t13	2110	50	50	20	130.0000	470	40	465.0000	300	80.6720	76.5086	42.0951	249.3700	0.0000	105.4500	30.9042
t14	2030	50	50	20	130.0000	470	40	465.0000	300	81.7382	77.8510	43.6436	249.3700	60.0000	110.4000	-118.0028
t15	2010	50	50	20	130.0000	470	40	444.6615	300	83.1003	79.5671	44.9466	249.3700	80.4546	87.9000	-120.0000
t16	2060	50	50	20	130.0000	470	40	465.0000	300	83.7240	80.7233	46.3704	249.3700	83.1818	63.7500	-72.1194
t17	2050	50	50	20	130.0000	470	40	464.2305	300	84.0245	80.8066	47.5888	249.3700	77.7273	43.6500	-57.3977
t18	2120	50	50	20	130.0000	470	40	434.2305	300	84.1386	79.5897	48.9071	252.216	70.9091	7.3960	82.6129
t19	2070	50	50	20	130.0000	470	40	404.2305	300	84.1728	76.6433	50.2359	257.4446	76.3636	0.0000	60.9093
t20	2050	50	50	20	130.0000	470	40	374.2305	300	54.1800	36.3016	51.2277	272.2420	81.8182	0.0000	120.0000
t21	1910	50	50	20	130.0000	470	40	344.2305	300	54.3018	37.7706	51.7893	271.3174	81.8182	0.0000	8.7722
t22	1860	50	50	20	130.0000	470	40	314.2305	300	54.5202	39.9140	53.5520	278.4032	75.0000	0.0000	-15.6199
t23	1850	50	50	20	130.0000	470	40	284.2305	270	54.7848	48.2396	54.4658	281.9795	80.4546	0.0000	15.8453
t24	1800	50	50	20	127.9714	470	40	254.2305	240	107.0200	80.9500	59.0053	303.5500	117.2727	0.0000	-120.0000
		Cost(\$/day)								NOx Emission (Ton/day)				SOx Emission (Ton/day)		
		581800								44.9267				180.8333		

Economic, NOx emission, SOx emission dispatch and combined problem objectives are minimized using MOPSO. Hydro, wind, PV solar and thermal production from economic optimization, NOx emission optimization, SOx emission optimization and combined problem are given in tables 1-4, respectively. The optimal hourly plant

discharges of four hydro power plants from economic optimization, NOx emission optimization, SOx emission optimization and combined problem are listed in Figure.3 (a)-(d) respectively. Figure 4 (a)-(d) give the reservoir storage volumes of four hydro plants from economic minimization, NOx emission minimization, SOx emission

minimization and combined problem respectively. PV solar and wind power production of total fuel cost for the scheduled day is same for cost optimization, NOx

emission optimization, SOx emission optimization and combined problem.

Table 4. Best scheduling and dispatching of generation (MW) for case 4 of test system

H	PD	Thermal unit power generation								Hydro power generation				PV Solar	Wind	Pbat
		g1	g2	g3	g4	g5	g6	g7	g8	h1	h2	h3	h4			
t1	1750	236.6894	265.8425	130	20	25	460	45	35	113.5000	111.200	65.2784	327.8500	0.0000	0.0000	-85.3603
t2	1780	236.6894	265.8425	130	20	25	460	45	35	99.2594	90.7390	53.8279	327.8500	0.0000	0.0000	-9.2082
t3	1700	236.6894	265.8425	130	20	25	460	45	35	65.0664	52.3960	46.4538	327.8500	0.0000	0.0000	-9.2980
t4	1650	236.6894	265.8425	130	20	25	460	45	35	68.6134	53.4640	42.2005	327.8500	0.0000	0.0000	-59.6598
t5	1670	236.6894	265.8425	130	20	25	460	45	35	69.9897	53.9860	38.6750	326.2912	0.0000	0.0000	-36.4737
t6	1800	275.8046	305.0018	130	20	25	460	45	35	71.7493	53.9860	64.7960	313.6622	0.0000	0.0000	0.0000
t7	1950	327.3480	356.6032	130	20	25	460	45	35	73.7456	54.5000	65.2563	297.5608	0.0000	12.3210	47.6651
t8	2010	327.3480	356.6032	130	20	25	460	45	35	75.8920	55.3712	65.1999	327.8500	0.0000	46.6500	40.0857
t9	2090	327.3480	356.6032	130	20	25	460	45	35	78.1792	58.3533	64.7985	327.8500	0.0000	56.2500	105.6178
t10	2080	327.3480	356.6032	130	20	25	460	45	35	80.5872	63.281	64.0642	327.8500	0.0000	75.4500	69.8163
t11	2100	327.3480	356.6032	130	20	25	460	45	35	81.6939	66.6819	63.1145	312.6642	0.0000	92.5500	84.3444
t12	2150	327.7906	357.0463	130	20	25	460	45	35	82.8588	69.3762	62.1669	312.8612	0.0000	102.9000	120.0000
t13	2110	327.3480	356.6032	130	20	25	460	45	35	84.1791	72.1722	60.8847	313.3428	0.0000	105.4500	75.0199
t14	2030	327.3480	356.6032	130	20	25	460	45	35	84.7666	74.4896	59.4106	314.0983	60.0000	110.4000	-72.1163
t15	2010	327.3480	356.6032	130	20	25	460	45	35	84.6215	75.6597	57.5969	315.0852	80.4546	87.9000	-90.2690
t16	2060	327.3480	356.6032	130	20	25	460	45	35	84.1039	76.0277	55.5740	316.2361	83.1818	63.7500	-17.8246
t17	2050	327.3480	356.6032	130	20	25	460	45	35	83.3398	75.5839	53.3215	317.5573	77.7273	43.6500	-0.1310
t18	2120	327.3480	356.6032	130	20	25	460	45	35	82.4163	75.6471	50.5341	319.0215	70.9091	7.3960	115.1247
t19	2070	327.3480	356.6032	130	20	25	460	45	35	81.8990	77.6974	47.5996	320.6145	76.3636	0.0000	66.8746
t20	2050	327.3480	356.6032	130	20	25	460	45	35	71.3426	70.2885	49.5071	322.3001	81.8182	0.0000	55.7923
t21	1910	303.8319	333.0607	130	20	25	460	45	35	73.1550	73.6817	51.5782	324.0285	81.8182	0.0000	-46.1542
t22	1860	303.8319	333.0607	130	20	25	460	45	35	74.8908	74.7611	52.6030	307.9488	75.0000	0.0000	-77.0964
t23	1850	303.8319	333.0607	130	20	25	460	45	35	76.9298	74.2461	53.0680	290.1583	80.4546	0.0000	-76.7494
t24	1800	271.5165	300.7089	130	20	25	460	45	35	78.0026	77.6232	56.3262	303.5500	117.2727	0.0000	-120.000
		Cost(\$/day)								NOx Emission (Ton/day)				SOx Emission (Ton/day)		
		517530								25.2596				188.8443		

Table 5. Summary results for the test system.

Problem dispatch		Cost (\$/day)	NOx Emission (Ton/day)	SOx Emission (Ton/day)
Economic	Proposed MOPSO	498290	27.6394	187.2759
	NSGA-II [4]	567491	36.0226	194.4046
NOx emission	Proposed MOPSO	537240	25.8175	195.4521
	NSGA-II [4]	582711	35.0342	196.0739
Sox emission	Proposed MOPSO	572230	44.1082	177.8355
	NSGA-II [4]	585235	37.7592	192.8073
Combined Prolem	Proposed MOPSO	517530	25.2596	188.8443
		Total cost : 7140400 (Ton/day)		
	NSGA-II [4]	575566	35.9916	194.4635
		Total cost : ----- (Ton/day)		

Respect the ramp rate constraint equation (5) to solve DEED with the all cases test systems, Figure 5 (a)–(d) show the result.

CONCLUSIONS AND PERSPECTIVES

In this paper, MOPSO applied for CDEEP the combined problem of economical distribution of dynamic emissions with transmission power loss and VPE. To cope with this non-convex problem, linear approximation is employed to transmission power loss and the non-smooth total fuel cost function, and therefore the classical CEED problem is converted to the MOPSO problem. The property of convergence, the computation efficiency and the economic effect of emission are well demonstrated in our present paper. This allows us to say that this MOPSO optimization algorithm is an efficient and robust method which is capable of solving these examples of non-linear multi-objective optimization linked to electrical

networks incorporating renewable energy, hydro and ESS operation and multi area are a future work.

ACKNOWLEDGEMENTS

This work is a part of the Research in Electrical Engineering department of ENIS Sfax University-Tunisia.

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