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The Penetration of Pollutant Productions on Dynamic Generated Power Operations Optimized Using a Novel Evolutionary Algorithm

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***Abstract*—At Present, the environmental protection penetrates public awareness to decrease atmospheric emissions as important efforts for increasing living quality in air from various gaseous effects. Technically, it has forced industrial sectors to control pollutant productions while operating machineries of engineering processes to keep all contaminant materials. This condition has also forced the power system operation to modify operational strategies of thermal power plants considered pollutant productions from combustions of fossil fuels for reducing emissions. This paper demonstrates new approaches for measuring pollutant penetrations embedded in the single priority function considered an emission standard, a dynamic penalty factor, and Thunderstorm Algorithm (TA). By considering the IEEE 62-bus system model, results obtained show that the hourly computation has different performances for the 24 hours operation. It also indicates that pollutant discharges are dominated gradually by higher contributors associated with scheduled power plants. The convergence speed of TA is smooth and fast for determining the optimal solution, which are ranged in 6-20 for the cycle and 1.8-3.8 s for the time consumption. Moreover, the 24 hours operation is powered totally in 60,826.10 MW for feeding the total load of 56,820.50 MW. This operation also spends in 291,870.60 $ for the fuel procurement and 83,233.70 $ for the compensation of the pollutant production during existing 19 generating units. In total, the accumulation of pollutant discharges from 19 power plants is 68,012.20 kg.**

***Keywords*—economic operation; emission dispatch; penalty factor; power system; thunderstorm algorithm**

I. INTRODUCTION

Recently, energy consumptions become more important issues to keep sustainable providers from various natural primary resources as long as customer usages for their utilities. The energy consumption also steers up the electric energy to drive many industrial sectors for supplying power demands and also provides for various load demands. In general, electric energy is produced at power generations corresponded to the power system operation under technical conditions to maintain daily operations. In fact, demands are progressed gradually hour to hour affected dynamically to the operation to serve energy customers. In addition, the operation becomes a dynamic power system operation (DPSO) with its possibility fluctuations to face many problems while producing and transmitting power outputs at potential sections, such as generating units, transmission and distribution limits, loads and utilities.

Nowadays, the DPSO has also met a global warming change issue as an effort for controlling pollutant impacts in air from the fossil fuel combustions [1-5]. Regarding in this issue, the environmental protection is also considered on the DPSO to present public awareness and to decrease atmospheric emissions during producing energy at power stations. Furthermore, this problem is recommended to manage correctly in order to select the decision within suitable ranges of constraints and requirements associated with emission standards and operational conditions [5-11]. One of the most important problems in the DPSO is to reduce emission discharges from fossil fuel combustions at generating units during existing thermal power plants (TPPs) for producing electric energy. This problem has forced to modify operational strategies of TPPs considered decreasing air contaminants from the DPSO, such as CO; CO_2; SO_x; and NO_x [2-3], [12-14].

In particular, the DPSO needs to pay double attention on the management system to face the complexity operational problems and to cover the environmental protection requirement. In these aspects, the atmospheric emission reduction becomes one of popular issues on the DPSO presented in an emission dispatch strategy for the decreasing percentage contribution as well as the financial charge of an environmental compensation [1-6], [15-17]. Moreover, a conventional strategy cannot meet environmental protection requirements because it only considers minimized fuel costs to treat pollutant productions [12], [17-20].

To cover this condition, an optimization strategy is very important for minimizing emission discharges subjected to maintain the optimal committed power outputs [21-22]. Practically, the DPSO is operated within 24 hours for the given loads as long as its fluctuation from present hour to next hour. This condition is also used to treat the dynamic financial charge (DFC) at every hour related to the individual generating fuel cost and used to monitor the dynamic pollutant production (DPP) inline the DPSO for 24 hours [1-7], [9-12]. By considering financial and pollution aspects, these problems become a crucial task to select the combined generating units based on the balance of dynamic problems throughout a dynamic operational problem (DOP) considered demand changes under operational constraints the environmental requirement [5-7].

As one of the important issues on the DPSO, the pollutant reduction is an interesting topic to evaluate from a different view as presented in this paper with introducing a new approach for evaluating the produced pollutant domination of TPPs. As the novel approach, it is applied to the IEEE's model to search the balance between DFC and DPP problems solved using a new evolutionary algorithm.

II. MATERIAL AND METHOD

A. Dynamic Representation

Concerning in the DOP, demand changes are very important for every hour corresponding to ramp limits to allow generation sites within permitted power changes at the whole operating period with considering technical and pollutant limits [5-7]. These constraints are used to pose desired solutions at feasible ranges for the optimal performance. Moreover, the DOP is advanced from a classical dispatch with integrating an environmental aspect on TPPs for decreasing pollutant productions together with the fuel consumption presented in the total operating cost through a dynamic economic dispatch (DED).

For performing the DED problem at over all intervals, it is computed using Equation (4) and it is required by several constraints in terms of an equality power of the load demand and committed generating units, power flows with embedding losses for the lines, capacity limits of powers, each voltage at each bus, power transfer capability limits, and ramp limits. Matheatically, the DED and its limitations for these works are presented as follows:

$$\sum_{t=1}^{T} \mathrm{DFC}_{\mathrm{total}}^{t} = \sum_{t=1}^{T} \sum_{i=1}^{ng} \left(c_i + b_i . P_i^t + a_i \left(P_i^t\right)^2 \right) \tag{1}$$

$$\sum_{t=1}^{T} \mathrm{DPP}_{\mathrm{total}}^{t} = \sum_{t=1}^{T} \sum_{i=1}^{ng} (\gamma_i + \beta_i . P_i^t + \alpha_i (P_i^t)^2) \tag{2}$$

$$\sum_{t=1}^{T} \Phi_{\mathrm{total}}^{t} = \\ w.\left(\sum_{t=1}^{T} \mathrm{DFC}_{\mathrm{total}}^{t}\right) + (1-w).\left(\sum_{t=1}^{T} h^t . \mathrm{DPP}_{\mathrm{total}}^{t}\right) \tag{3}$$

$$\text{DOP dispatch} = \text{minimize} \sum_{t=1}^{T} \Phi_{\mathrm{total}}^{t} \tag{4}$$

$$\sum_{i=1}^{ng} P_i^t = PD_i^t + PL_i^t \tag{5}$$

$$P_i^{min} \le P_i^t \le P_i^{max} \tag{6}$$

$$Q_i^{min} \le Q_i^t \le Q_i^{max} \tag{7}$$

$$V_p^{min} \le V_p^t \le V_p^{max} \tag{8}$$

$$S_{pq}^{t} \le S_{pq}^{max} \tag{9}$$

$$P_i^t - P_i^{(t-1)} \le UR_i \tag{10}$$

$$P_i^{(t-1)} - P_i^t \le DR_i \tag{11}$$

where t is period intervals of time (t=1, 2, 3, …, T), T is a total time operation, DFC^{t}_{total} is total financial charge for the fuel consumption of generating units ($/hr) at t^{th} of time, P_i^t is output power of i^{th} generating unit during time interval t (MW), ng is total number of generating units, a_i, b_i, c_i are fuel cost coefficients of i^{th} generating unit, DPP^{t}_{total} is total pollutant production of generating units (kg/hr) at t^{th} of time, α_i, β_i, γ_i are emission coefficients of i^{th} generating unit, Φ^{t}_{total} is DOP ($/hr) at t^{th} of time, h^t is a penalty factor at t^{th} of time, w is a compromised factor, PD^t is power load demand during interval t, PL^t is transmission loss during time interval t, PG_p^t and QG_p^t are power injection of load flow at bus p during time interval t, PD_p^t and QD_p^t are load demand of load flow at bus p during time interval t, V_p^t and V_q^t are voltage at bus p and q during time interval t, P_i^{min} is minimum output power of i^{th} generating unit, P_i^{max} is maximum output power of i^{th} generating unit, Q_i^{max} and Q_i^{min} are maximum and minimum reactive power of i^{th} generating unit, Q_i^t is reactive power output of i^{th}generating unit during time interval t (Mvar), V_p^{max} and V_p^{min} are maximum and minimum voltage at bus p, S_{pq}^t is power transfer between bus p and q during time interval t (Mvar), S_{pq}^{max} is limit of power transfer between bus p and q, UD_i is the up ramp limit of i^{th} generating unit and DR_i is the down ramp limit of i^{th} generating unit.

B. Dynamic Factor

Focused on power productions, generating units will be constrained by ramp limits for increasing and decreasing power productions [5-7]. At the same time, the environmental requirements also force TPPs for reducing pollutant discharges in air together with fuel consumptions. Meanwhile, the DED consists of DFC and DPP problems with the individual portion of fuel consumptions and pollutant productions. It becomes main contributors for the DPSO in accordance to power output productions at generating units [5-7], [11-12], [14]. In particular, TPPs discharge different amounts of the emission related to the own hourly power output to meet demand changes.

In this section, the domination of TPPs is presented in a new penalty factor approach for integrating DPP and DFC problems as a dominant penalty factor (DPF). The DPF assumes that pollutant discharges are dominated by larger emission producers exceeded the allowed emission (AllwEmi). To show involvements of larger contributors, it is introduced an over rate emission coefficient (OREC) associated with the produced emission (ProdEmi) and the AllwEmi as given in Equation (12). For each hour, it is performed using following expressions:

$$\mathrm{OREC}_z^t=\frac{\sum_{tu=1}^{gu}\mathrm{TPE}_{zs}^t-\sum_{tu=1}^{gu}\mathrm{TAES}_{zs}^t}{\mathrm{nG}_z^t\sum_{tu=1}^{gu}\mathrm{TPE}_{zs}^t} \tag{12}$$

$$\mathrm{h}_z^t=\{\mathrm{hG}_{zs}^t\} \tag{13}$$

$$\mathrm{dh}_z^t=\mathrm{OREC}_z^t.\mathrm{rh}_z^t \tag{14}$$

where OREC_z^t is the over rate emission coefficient at the t^th hour of the z^th iteration; TPE_{zs}^t is the total produced emission at the t^th hour of the s^th generating unit of the z^th iteration (kg/h); TAES_{zs}^t is the total allowed emission at the t^th hour of the s^th generating unit of the z^th iteration (kg/h); gu is the number of generating units at the t^th hour of the z^th iteration; nG_z^t is the number of generating units at the t^th hour of the z^th iteration exceeded the allowed emission; t is period intervals of time (t=1, 2, 3, …, T), T is a total time operation; h_z^t is a penalty factor set at the t^th hour of the z^th iteration ($/kg); hG_{zs}^t is the individual penalty factor at the t^th hour of the s^th generating unit exceeded the allowed emission of the z^th iteration step ($/kg); dh_z^t is the dominant penalty factor at the t^th hour of the z^th iteration ($/kg); and rh_z^t is the selected hG_{zs} at the t^th hour of the z^th iteration for the highest TPE_{zs}.

C. Thunderstorm Algorithm

To evaluate the DOP as presented in the DED based on DFC and DPP problems, this aspect is addressed to generating units online the system. In this section, a new evolutionary computation will be explored to carry out the DED. In general, this method will be detailed as an evolutionary algorithm which is constructed from a natural inspiration [6]. The natural process is selected as the new inspiration for attempting a new evolutionary algorithm from thunderstorms.

Several years ago, Benjamin Franklin was demonstrated early to test the theory of lightning practiced his idea of a flying object using a kite. Nowadays, it is known that the lightning is considered as an atmospheric discharge which typically occurs during thunderstorms or other possibility factors such as volcanic eruptions or dust storms [23-24]. In particular, many studies of thunderstorms have rapidly advanced during the past century and many efforts have been made toward for understanding the multiple lightning, thunderstorms, and their consequences [23-25].

In this section, these mechanisms are adopted to become an intelligent computation using several stages and procedures as the thunderstorm algorithm (TA) for mimicking natural processes of the thunderstorm. In particular, the searching mechanism of TA for selecting a solution is conducted to the striking processes using Equation (16). Moreover, TA also consists of various distances of the deployed streamer by a hazardous factor for spreading positions of the striking points.

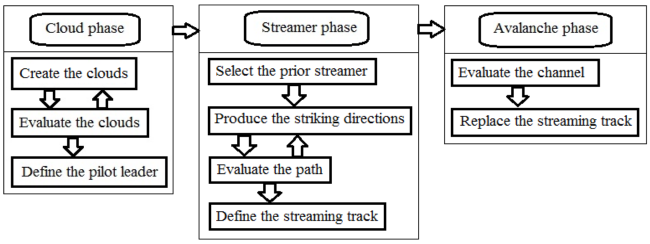

Fig. 1 Hierarchy processes of thunderstorm algorithm

In principle, the sequencing order of TA is given in several procedures as the pseudo-codes in terms of Cloud Phase, Streamer Phase, and Avalanche Phase [26-27]. In detail, these mechanisms are provided in Figure 1. Mathematically, main functions are presented as follow:

$$\text{Cloud charge: } \mathrm{Q}_{sj}^{m}=(1+\mathrm{k.c}).\mathrm{Q}_{midj}^{m} \tag{15}$$

$$\text{Striking path: } \mathrm{D}_{sj}^{n}=(\mathrm{Q}_{sdep}^{n}).\mathrm{b.k} \tag{16}$$

$$\text{Probability charge: } \mathrm{probQ}_{sj}\begin{cases}\dfrac{\mathrm{Q}_{sj}^{m}}{\sum \mathrm{Q}_{s}^{m}} \text{ for m}\\ \dfrac{\mathrm{Q}_{sj}^{n}}{\sum \mathrm{Q}_{s}^{n}} \text{ for n}\end{cases} \tag{17}$$

where Q_{sj} is the current charge, Q_{midj} is the middle charges, s is the streaming flow, D_{sj} is the striking charge's position, Q_{sdep} is the deployed distance, n is the striking direction of the h^th, k is the random number with [-1 and 1], c is the random within [1 and h], h is the hazardous factor, b is the random within (1-a), j ∈ (1,2,..,a), a is the number of variables, m is the cloud size.

D. System Model

In these works, the DPSO is simulated using the IEEE-62 bus system as many previous studies adopted the standard models. The IEEE-62 bus system is structured using 62 buses; 89 lines; and 32 load buses as detailed in References [12], [20]. Furthermore, technical data for these works are given in following tables.

TABLE I
POWER AND RAMP LIMITS

Gen	P_{min} (MW)	P_{max} (MW)	Q_{min} (MVar)	Q_{max} (MVar)	DR_i (MW)	UR_i (MW)
G1	50	300	0	450	65	102
G2	50	450	0	500	65	153
G3	50	450	-50	500	65	153
G4	0	100	0	150	25	34
G5	50	300	-50	300	65	102
G6	50	450	-50	500	65	153
G7	50	200	-50	250	65	68
G8	50	500	-100	600	65	170

G9	0	600	-100	550	75	204
G10	0	100	0	150	25	34
G11	50	150	-50	200	65	51
G12	0	50	0	75	25	17
G13	50	300	-50	300	65	102
G14	0	150	-50	200	75	51
G15	0	500	-50	550	75	170
G16	50	150	-50	200	65	51
G17	0	100	0	150	25	34
G18	50	300	-50	400	65	102
G19	100	600	-100	600	130	204

TABLE II
HOURLY POWER DEMANDS

Hour	MW	MVar	Hour	MW	MVar
01.00	1,701.7	741.3	13.00	2,691.6	1,173.1
02.00	1,828.1	796.8	14.00	2,221.2	968.1
03.00	2,165.0	943.5	15.00	2,391.1	1,041.8
04.00	2,221.2	968.1	16.00	2,426.2	1,055.8
05.00	2,466.2	1,074.8	17.00	2,466.2	1,074.8
06.00	2,221.2	968.1	18.00	2,542.0	1,107.8
07.00	2,316.0	1,009.5	19.00	2,691.6	1,173.1
08.00	2,391.1	1,041.8	20.00	2,771.6	1,208.2
09.00	2,476.0	1,079.0	21.00	2,601.7	1,133.8
10.00	2,836.9	1,236.3	22.00	2,263.3	986.3
11.00	2,912.0	1,269.3	23.00	1,926.4	839.6
12.00	2,766.7	1,206.1	24.00	1,525.5	805.2

TABLE III
FUEL COST COEFFICIENTS OF GENERATORS

Gen	a (kg/MWh^2)	b (kg/MWh)	c
G1	0.0070	6.80	95
G2	0.0055	4.00	30
G3	0.0055	4.00	45
G4	0.0025	0.85	10
G5	0.0060	4.60	20
G6	0.0055	4.00	90
G7	0.0065	4.70	42
G8	0.0075	5.00	46
G9	0.0085	6.00	55
G10	0.0020	0.50	58
G11	0.00450	1.60	65
G12	0.00250	0.85	78
G13	0.00500	1.80	75
G14	0.00450	1.60	85
G15	0.00650	4.70	80
G16	0.00450	1.40	90
G17	0.00250	0.85	10
G18	0.00450	1.60	25
G19	0.00800	5.50	90

TABLE IV
EMISSION COEFFICIENTS OF GENERATORS

Gen	α (\$/MWh^2)	β (\$/MWh)	γ
G1	0.018	-1.81	24.30
G2	0.033	-2.50	27.02
G3	0.033	-2.50	27.02
G4	0.014	-1.30	22.07
G5	0.018	-1.81	24.30
G6	0.033	-2.50	27.02
G7	0.013	-1.36	23.04
G8	0.036	-3.00	29.03
G9	0.040	-3.20	27.05
G10	0.014	-1.30	22.07
G11	0.014	-1.25	23.01
G12	0.012	-1.27	21.09
G13	0.018	-1.81	24.30
G14	0.014	-1.20	23.06
G15	0.036	-3.00	29.00
G16	0.014	-1.25	23.01
G17	0.014	-1.30	22.07
G18	0.018	-1.81	24.30
G19	0.040	-3.00	27.01

E. Procedures of Simulations

In these studies, the problem is simulated using hourly demands as listed in Table II and it is conditioned using limitations in Table I. In detail, these works are also simulated using 10% of the loss limit, 0.5 of the weighting factor, and 0.85 kg/h of the emission standard. Moreover, the function problem is also conditioned by other operational constraints as presented in Equations (5) to (11) in order to search the solution in suitable operational ranges as desired in ± 5% of voltage violations, 95% of the power transfer capability, banded on upper and lower power limits included ramp limits for the increasing and decreasing powers.

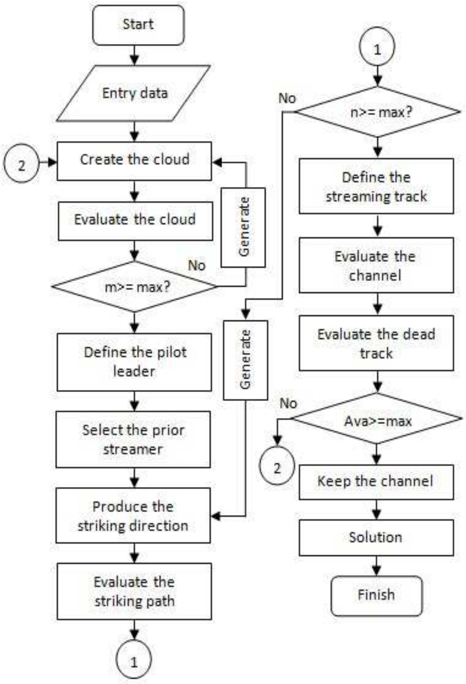

Fig. 2. Sequencing order of TA

Refer to Figure 1, TA is executed using several programs covered in the main program, evaluate program, cloud charge program, streamer program, avalanche program and dead track program. The programs are developed to cover sequencing processes of TA. These procedures are conducted to the Figure 2 for expressing the mechanism to search the optimal solution as detailed in pseudo-codes. These programs are run in 1 of the avalanche, 50 of the cloud charge, 100 of the streaming flows, 4 of the hazardous factor, and 200 of the cloud size.

III. RESULTS AND DISCUSSIONS

The simulation results are given in several performances to show algorithm's abilities for solving the DOP as presented in the DED with considering operational constraints to schedule committed power outputs of generating units associated with DFC and DPP aspects. According to designed programs for 24 hours, results are presented respectively in several indicators as illustrated in following figures and tables for the computation abilities and the dynamic operations. Table V shows computational performances for determining optimal solutions within 24 hours for each individual power demand obtained in different iterations as streaming flows (Str) with captived characteristics as illustrated in Figure 3. On the other hand, the optimal solution comes from various striking points (Sp) for each hour.

TABLE V
COMPUTATIONAL PERFORMANCES

Hour	Str	Sp	Time (s)	Hour	Str	Sp	Time (s)
01.00	20	3	2.5	13.00	15	1	1.7
02.00	19	1	2.2	14.00	17	3	2.0
03.00	19	3	1.9	15.00	19	1	2.5
04.00	20	3	3.0	16.00	20	1	2.4
05.00	6	1	2.0	17.00	29	1	1.8
06.00	16	4	1.9	18.00	30	1	2.0
07.00	11	3	2.0	19.00	31	2	1.7
08.00	11	4	1.8	20.00	16	2	2.2
09.00	6	2	2.0	21.00	22	4	3.5
10.00	8	2	2.0	22.00	18	1	3.2
11.00	15	1	1.8	23.00	24	3	2.4
12.00	15	3	2.1	24.00	15	2	3.8
Str: streaming flow, Sp: striking point							

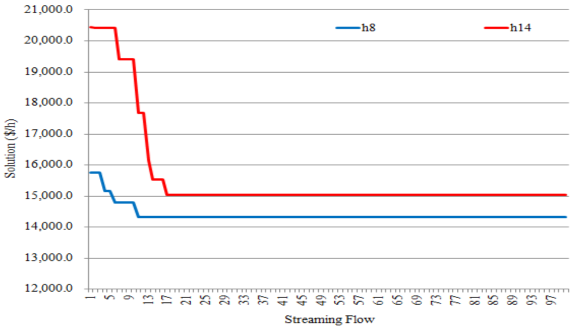

Fig. 3 Convergence speeds of the 8th and 14th hours

TABLE VI
EMISSION PRODUCTIONS

Hour	PP	AD	Hour	PP	AD
01.00	2,888.7	1,597.0	13.00	10,190.4	2,393.8
02.00	1,796.8	1,644.7	14.00	3,609.2	2,017.7
03.00	6,228.7	1,966.5	15.00	5,573.3	2,141.6
04.00	6,136.6	1,972.0	16.00	5,812.9	2,156.2
05.00	7,824.2	2,281.4	17.00	8,162.2	2,256.2
06.00	4,252.6	2,075.0	18.00	5,536.6	2,263.3
07.00	4,022.1	2,091.5	19.00	8,136.1	2,473.3
08.00	6,872.7	2,209.6	20.00	9,473.0	2,547.6
09.00	6,054.1	2,213.9	21.00	6,820.2	2,362.7
10.00	14,830.4	2,635.6	22.00	4,279.5	2,021.3
11.00	10,449.2	2,609.1	23.00	3,048.5	1,759.9
12.00	14,089.4	2,582.0	24.00	1,531.0	1,430.4
PP: Pollutant Production, AD: Allowed Discharge					

Captured within 100 streaming flows at 08:00 and 14:00, the running outs are given in Figure 3 as the convergence speeds for determining the optimal solution in smooth and fast as detailed in Table V for all streaming flows. By considering 24 hours, Table V also provides time consumptions for searching the optimal solution. In particular, hourly pollutant penetrations are given in Table VI covered in the pollutant production (PP) and the allowed discharge (AD). According to this table, it is known that all of the operation for 24 hours, power plants produce higher emissions over the standard. The illustration for this penetration is performed in Figure 4 associated with the OREC at 23.00 and 24.00, as the samples for all period time operation included the dominant penalty factor (dh).

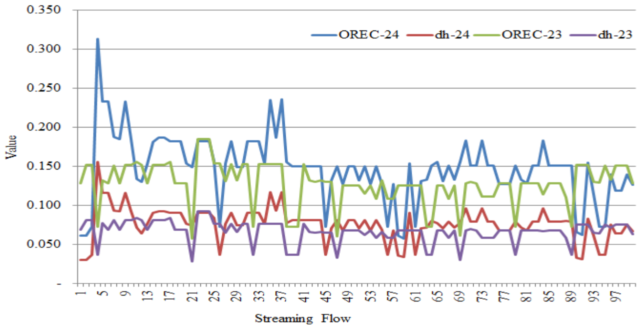

Fig.4 OREC and dh of the 23rd and 24th hours

TABLE VII
OPERATIONAL PERFORMANCES

Hour	Load (MW)	Gen. (MW)	Loss (MW)	Fuel costs ($)	Emi. costs ($)
01.00	1,701.7	1,878.9	177.2	9,290.6	1,384.6
02.00	1,828.1	1,934.9	106.8	8,120.3	333.8
03.00	2,165.0	2,313.5	148.5	11,915.8	3,550.6
04.00	2,221.2	2,320.0	98.8	11,427.3	3,397.1
05.00	2,466.2	2,684.0	217.8	12,725.2	4,254.4
06.00	2,221.2	2,441.1	219.9	11,170.8	1,885.7
07.00	2,316.0	2,460.5	144.5	11,690.2	1,705.6
08.00	2,391.1	2,599.5	208.4	11,914.9	3,719.6
09.00	2,476.0	2,604.6	128.6	11,803.0	3,086.1
10.00	2,836.9	3,100.7	263.8	16,005.9	8,994.8
11.00	2,912.0	3,069.5	157.5	15,081.4	5,789.6
12.00	2,766.7	3,037.7	271.0	15,856.1	8,539.6
13.00	2,691.6	2,816.3	124.7	14,832.5	5,891.3
14.00	2,221.2	2,373.8	152.6	10,695.6	1,425.2
15.00	2,391.1	2,519.6	128.5	11,447.1	2,828.8
16.00	2,426.2	2,536.7	110.5	11,805.7	2,941.7
17.00	2,466.2	2,654.3	188.1	13,416.1	4,495.5
18.00	2,542.0	2,662.7	120.7	12,833.4	2,600.4
19.00	2,691.6	2,909.8	218.2	13,639.6	4,310.2
20.00	2,771.6	2,997.2	225.6	14,916.6	5,171.4
21.00	2,601.7	2,779.7	178.0	12,788.3	3,471.7
22.00	2,263.3	2,377.9	114.6	11,672.4	1,884.9
23.00	1,926.4	2,070.4	144.0	9,604.0	1,327.9
24.00	1,525.5	1,682.8	157.3	7,217.8	243.2

Technically, generated power operations are listed in Table VII for describing operational performances on the optimal solutions considered the pollutant penetration at each generating units. These results show that the balance of power productions and demands covers the power loss for 24 hours. In detail, this table also provides operating costs of fuel consumptions for integrating all power plants. The pollutant penetration during the power production process is also listed in this table as the financial compensation for the environmental protection for each hour.

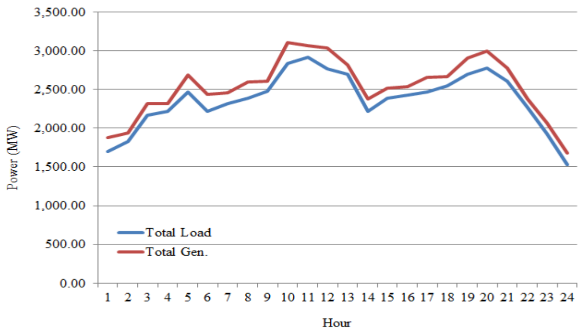

Fig. 5 Hourly power productions

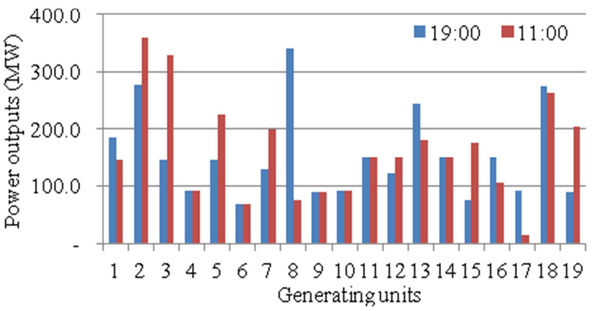

Fig. 6 Power outputs at the 19th and 11th time

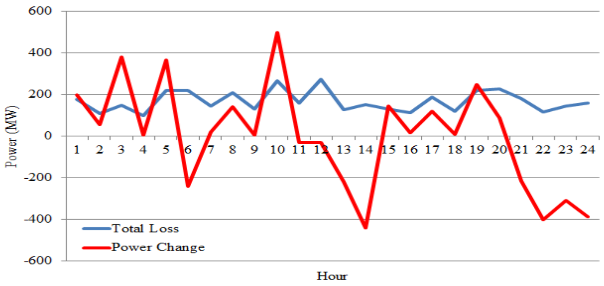

Fig. 7 Hourly progressing operations

In particular, hourly total power outputs of generations are given in Figure 5 for the balance of the total power usages and the power serves with the power production is higher than the power demand. From this figure, it is illustrated that the generation system must cover the total power loss at the network during supplying the total load, which is depicted in Figure 7 for the fluctuated total power loss. Furthermore, the individual contribution of the power output is illustrated in Figure 6 for 19 power plants selected at 19.00 and 11.00 for describing the peak conditions. These productions are also performed in Figure 7 for the hourly progressing operations of the total power productions. From this figure, it is known that both power outputs and the loss are fluctuated following ramp limits and the total loss requirement. This figure also informs, the produced power changed of the committed power generation is changed from the present hour to the next hour with different capacity for the decreasing or increasing power production.

IV. CONCLUSIONS

This paper presents new methods for measuring pollutant penetrations covered in dominated producers throughout the OREC technique and the dominant penalty factor. This paper also explores thunderstorm algorithm to solve the DOP considered the DED problem and various technical constraints. Results show that pollutant productions penetrate dynamically to the power productions for 24 hours. These penetrations also affect to the emission compensations as the environmental fee included in the operating cost together with the fuel cost. From these works, the real implementation to the large system is devoted to the future studies with various parameter combinations.

REFERENCES

[1] Yunzhi Cheng, Weiping Xiao, Wei-Jen Lee and Ming Yang, "A new approach for emissions and security constrained economic dispatch," in *Proc. NAPS IEEE Conference*, 2009, pp. 1-5, Starkville, USA.

[2] R. Gopalakrishnan, A. Krishnan, "A novel combined economic and emission dispatch problem solving technique using non-dominated ranked genetic algorithm," *European Journal of Scientific Research*, vol. 64, no. 1, pp. 141-151, Nov. 2011.

[3] Mukesh Garg, Surender Kumar, "A survey on environmental economic load dispatch using lagrange multiplier method," *International Journal of Electronics & Communication Technology*, vol. 3, no. 1, pp. 43-46, March 2012.

[4] M.A. Abido, "A survey on environmental economic load dispatch using lagrange multiplier method," *International Journal of Electronics & Communication Technology*, vol. 18, no. 4, pp. 1529-1539, March 2003.

[5] A.N. Afandi, "Optimal scheduling power generations using HSABC algorithm considered a new penalty factor approach," in *Proc. IEEE Conference on Power Engineering and Renewable Energy*, 2014, pp. 13-18, Bali, Indonesia.

[6] A.N. Afandi, Irham Fadlika, Andoko, "Comparing performances of evolutionary algorithms on the emission dispatch and economic dispatch problem", *Telkomnika*, vol 13, no 4, pp. 1187-1193, December 2015.

[7] Devendra Bisen, Hari Mohan Dubey, "Dynamic economic load dispatch with emission and loss using GAMS," *International Journal of Engineering Research & Technology*, vol. 1, no. 3, pp. 1-7, May 2012.

[8] Kamran Hafeez, M.A.U Khan, "Application of geographic information system for the installation of surge arrestors on over head 132 k-v power line", *International Journal on Advanced Science Engineering Information Technology*, vol. 2(6), pp. 6-8, 2016

[9] Mohd Khairuzzaman Mohd Zamani, Ismail Musirin, Saiful Izwan Suliman, Muhammad Murtadha Othman, Mohd Fadhil Mohd Kamal, "Multi-area economic dispatch performance using swarm intelligence technique considering voltage stability", *International Journal on Advanced Science Engineering Information Technology*, vol. 7(1), pp. 1-7, 2017

[10] X.S. Han, H.B. Gooi, D.S. Kirschen, "Dynamic economic dispatch: Feasible and optimal solutions," *IEEE Trans. Power Systems*, vol. 16, no. 1, pp. 22-28, Feb. 2001.

[11] R.H. Liang, "A neural based redispatch approach to dynamic generation allocation," *IEEE Trans. Power Systems*, vol. 14, no. 4, pp. 1388-1393, Nov. 1999.

[12] A.N. Afandi, "Optimal solution of the EPED problem considering space areas of HSABC on the power system operation," *International Journal of Engineering and Technology*, vol. 7, no. 5, pp. 1824-1830, May 2015.

[13] A. Eskandari, M. Jahangiri, M. Anbia, “Effect of particle size of NaX zeolite on adsorption of CO2/CH4, ” *International Journal of Engineering*, vol. 29, no. 1, pp. 1-7, Jan. 2016.

[14] K. Sathish Kumar, V. Tamilselvn, N. Murali, R. Rajaram, N. Shanmuga Sundaram and T. Jayabarathi, “Economic load dispatch with emission constraints using various DPSO algorithm, ” *WSEAS Transaction on Power System*, vol. 9, no. 3, pp. 598-607, Sept. 2008.

[15] Nur Husna binti Azizul, Abdullah bin Mohd Zin, Elankovan Sundararajan, “The design and implementation of middleware for application development within honeybee computing environment”, *International Journal on Advanced Science Engineering Information Technology*, vol. 6(6), pp. 9137-945, 2016

[16] S. Kouhi, M.R. Ranjbar, M. Mohammadian, M. Khavaninzadeh, ”Economic aspect of fuel cell power as distributed generation,” *International Journal of Engineering*, vol. 27, no. 1, pp. 57-62, Jan. 2014.

[17] M. M. Lotfi, S. F. Ghaderi, “Short-term price-based unit commitment of hydrothermal gencos: A pre-emptive goal programming approach,” *International Journal of Engineering*, vol. 26, no. 9, pp. 1017-1030, Sept. 2013.

[18] P. Panciatici, M.C. Campi, S. Garatti, S.H. Low, D.K. Molzahn, A.X. Sun, L. Whenkel, “Advanced optimization methods for power systems,” in *Proc. Power System Computation Conference*, 2014, pp. 1-18, Wroclow, Poland.

[19] Bommirani B., Thenmalar K., “Optimization technique for the economic dispatch in power system operation,” *International Journal of Computer and Information Technology*, vol. 2, no. 1, pp. 158-168, Jan. 2013.

[20] A.N. Afandi, Hajime Miyauchi, “Improved artificial bee colony algorithm considering harvest season for computing economic dispatch on power system,” *IEEJ Transactions on Electrical and Electronic Engineering*, vol. 9, no. 3, pp. 251-257, Apr. 2014.

[21] T. Taleshian, A. Ranjbar, R. Ghaderi, “Using modified IDPSO-SQP algorithm to solve nonlinear time optimal bang-bang control problem,” *International Journal of Engineering*, vol. 26, no. 11, pp. 1307-1322, Nov. 2013.

[22] S. Deepa, S. Rajesh Babu, M. Ranjani, “A robust STATCOM controller using particle swarm optimization,” *International Journal of Engineering*, vol. 27, no. 5, pp. 731-738, May 2014.

[23] T. J. Lang, S. A. Rutledge, and K. C. Wiens, “Origins of positive cloud-to-ground lightning flashes in the stratiform region of a mesoscale convective system,” *Geophys. Res. Lett*., vol. 31, no. 10, May 2004.

[24] L. D. Carey, S. A. Rutledge, and W. A. Petersen, “The relationship between severe storm reports and cloud-to-ground lightning polarity in the contiguous united states from 1989 to 1998,” *Mon. Wea. Rev.*, vol. 131, pp. 1211–1228, July 2003.

[25] C.P.R Suanders, H. Bax-Norman, E.E. Ávila, and N.E. Castellano, “A laboratory study of the influence of ice crystal growth conditions on subsequent charge transfer in thunderstorm electrification,” *Q. J. R. Meteorol. Soc.*, vol. 130, pp. 1395–1406, Apr. 2004.

[26] A.N. Afandi, “Thunderstorm algorithm for assessing thermal power plants of the integrated power system operation with an environmental requirement, ” *International Journal of Engineering and Technology*, vol. 8, no. 2, pp. 1102-1111, Apr. 2016.

[27] A.N. Afandi, Hajime Miyauchi, “Solving combined economic and emission dispatch using harvest season artificial bee colony algorithm considering food source placements and modified rates”, *International Journal on Electrical Engineering and Informatics*, vol. 6, no. 2, pp. 266-279, June 2014.