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EVALUATION OF THE POWER TRANSACTION CONSIDERING THE TRANSMISSION USE OF SYSTEM CHARGES AND SYSTEM CONSTRAINTS

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Abstract. *In general, the optimal power transaction is expressed using a total operating cost for the joined generating units while the power delivery is dispatched using a power schedule commitment. These financial aspect and power participation are used to measure all technical processes during providing and selling energy to customers. Moreover, the power delivery to the energy user is also constrained by transmission capabilities associated with transmission charges at all operators. Recently, the power system deregulation leads to sectional charges of the system. In addition, the power system should be operated in the feasible lowest cost under economic and environmental penetrations. To cover both penetrations and technical constraints, artificial bee colony algorithm and artificial salmon tracking algorithm are used to find out the optimal power composition considering transmission charges, generating costs, and pollutant compensations. Results show that the total minimum cost depends on technical factor schemes. Various combined power portions also give numerical implications on the economic operation, power production, and power transaction. In particular, generated powers lead to the total cost and the total pollutant discharge for each generating unit. Power delivery on the system conducts to the delivery fee as the transmission use of system charges.*
Keywords: Artificial bee colony, Artificial salmon tracking, Economic dispatch, Power transaction, Transmission charge

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1. **Introduction.** Nowadays, the power system becomes huge networks to cover various energy providers. This system connects generating units, power lines, and final utilities as power system enterprises and transmission operators [1,2]. These integrated networks can be divided commonly into subsections covered in terms of generation, transmission, distribution, and utilization with own functions in interconnected networks [3-8]. Practically, the power system structure is used to deliver electric energy from generator sites to load demand areas. This network is operated in the least cost strategy for the optimal power transaction (OPT). This operation is also depended on power system enterprises based on the export-import (EXIM) power rate in the energy market [9-12]. The power import transaction (PIT) is needed to fulfill the total power production considering a negotiable rate of the EXIM power. On the other hand, the power export transaction (PET) is delivered from the higher area producer with a reasonable rate for the power selling. The cheaper operation is subjected to all power plants productions and power delivery processes.

Operationally, the power system is supported by various types of generating units which are integrated into an existing system [3,13]. The optimal cost of the generating unit is used to measure its operation throughout an economic dispatch (ED) to meet a total load demand. Transmission and distribution lines also become attracting operators to cover the power delivery to the load center [10,14]. In recent years, Kyoto Protocol has forced many processes to control environmental effects [14,15]. By considering this issue, an emission dispatch (EmD) of the power system operation should be decreased to keep the pollutant discharge from firing thermal power plants [13,16-19]. Moreover, the power system should be operated economically in suitable combinations to cover the OPT, ED, and EmD problems. One of the strategies is approached using a single economic problem (SEP) which can be optimized using many methods considering the transaction between energy sellers and buyers [20,21]. Technically, these studies will gain the power transaction and lead to the management strategy for the enterprises and operators. These works also focus on the power transaction problem with exploring artificial bee colony algorithm (ABCA) and introducing artificial salmon tracking algorithm (ASTA) as new opportunities to determine optimal power productions and transactions. In these studies, the problem is also addressed to observe several schemes of transmission use of system (TUoS) charges and enterprises rates. By considering technical conditions, these works flow in a problem statement and applied procedures, the conclusion preceded the discussion. Each part of the section is concerned in the main discussion.

2. **Problem Statement.** In general, the power system is required by normal state conditions presented in a set of equality, and inequality constraints [15,16]. The intrinsic requirements include generator output limits, and transmission maximum power flows, while the operation includes the bus voltage magnitude limits [3,4,17-22]. Financially, the operating cost function faces to the fuel consumption cost and emission compensation, while the operation exists. These functions can be presented by Equations (1) and (2) for the ED and EmD, respectively. Referring to these problems, the single objective function is presented by Equation (3), while the equality constraints are presented by Equations (4) to (6), and the inequality constraints are presented by Equations (7) to (10). The power fee for a transaction between buses m and n is also referred to the TUoS charges considering the PIT and PET as presented by Equation (11).

$$F_i(P_i) = c_i + b_i P_i + a_i P_i^2 \tag{1}$$

$$E_i(P_i) = \gamma_i + \beta_i \cdot P_i + \alpha_i \cdot P_i^2 \tag{2}$$

$$\min \Phi_T = \min \left\{ \omega_{eco} \sum_{i=1}^{n_{gen}} F_i(P_i) + \omega_{emi} h \sum_{i=1}^{n_{gen}} E_i(P_i) \right\} \tag{3}$$

$$\sum_{i=1}^{n_{gen}} P_i - \sum_{i=1}^{n_{dem}} P_{D_i} - \sum_{m=1}^{n_{line}} \sum_{n=1}^{n_{line}} P_{L_{mn}} = 0 \quad (4)$$

$$PG_m = P_{D_m} + V_m \cdot \left[\sum_{n=1}^{n_b} V_n \left(G_{mn} \cdot \cos(\theta_{mn}) + B_{mn} \cdot \sin(\theta_{mn}) \right) \right] \quad (5)$$

$$QG_m = Q_{D_m} + V_m \cdot \left[\sum_{n=1}^{n_b} V_n \left(G_{mn} \cdot \sin(\theta_{mn}) + B_{mn} \cdot \cos(\theta_{mn}) \right) \right] \quad (6)$$

$$P_i^{\min} \leq P_i \leq P_i^{\max}; \quad i = 1, 2, \ldots, n_g \quad (7)$$

$$Q_i^{\min} \leq Q_i \leq Q_i^{\max}; \quad i = 1, 2, \ldots, n_g \quad (8)$$

$$V_j^{\min} \leq V_j \leq V_j^{\max}; \quad j = 1, 2, \ldots, n_b \quad (9)$$

$$S_{mn} \leq S_{mn}^{\max}; \quad m \;\&\; n = 1, 2, \ldots, n_{line} \quad (10)$$

$$PT_{mn} = pr_{mn} PF_{mn} \quad (11)$$

where P_i is output power of the ith generating unit, $F_i(P_i)$ is fuel cost of the ith generating unit for P_i, a_i, b_i, c_i are coefficients of quadratic fuel cost function by the ith generating unit, $E_i(P_i)$ is emission of the ith generating unit for P_i, α_i, β_i, γ_i are the coefficients of the emission characteristics by the ith generating unit, ω_{eco} and ω_{emi} are weighting factors, P_{D_i} is total power load, $P_{L_{mn}}$ is transmission loss, PG_m and QG_m are power injections of load flow at bus m, P_{D_m} and Q_{D_m} are load demands of load flows at bus m, V_m is a voltage at bus m, $P_i^{\min}$ and $Q_i^{\min}$ are minimum limits of the ith generating units, $P_i^{\max}$ and $Q_i^{\max}$ are maximum output powers of the ith generating unit, $V_j^{\min}$ and $V_j^{\max}$ are voltage limits at bus j, S_{mn} is power delivery between buses m and n, PT_{mn} is a power transaction bus p and q (\$), pr_{mn} is a transmission transaction charge between buses m and n, and PF_{mn} is power import between buses m and n.

As mentioned before that many evolutionary methods have been used to solve technical problems, such as genetic algorithm, evolutionary programming, particle swarm optimization, neural network, harvest season artificial bee colony, and thunderstorm algorithm [13,22-24]. In these studies, ABCA is applied to solving the OPT under several constraints. In detail, ABCA has three types of bee covered employed bees, onlooker bees and scout bees [20,21,25,26]. In particular, ASTA is compiled using its procedures based on the exploring and surviving steps. The exploring step is used to search out a mouth river for guiding a desired possibility selection. The surviving step is used to find out the returning destination to track the desired solution at all various branches.

3. **Applied Procedures.** For determining the best combination of generating units, the OPT is designed based on the fuel cost, emission reduction, enterprise rate, and TUoS charge. The power production is optimized using ABCA and ASTA. Moreover, the system is evaluated using the Newton Raphson method for determining performances. Technically, power plants in one area are operated by the single enterprise as same as transmission lines based on the TUoS charges which are also provided by the single operator. In these works, the IEEE-30 bus system is selected as a sample system. In detail, Figure 1 is used to illustrate procedures for solving the OPT covered ED and EmD problems using ABCA where procedures of ASTA are illustrated in Figure 2. In these studies, technical data are detailed in Table 1, Table 2, and Table 3. In particular, transaction charges accompanied by ABCA and ASTA parameters are listed in Table 4.

As illustrated in Figure 1 and Figure 2, ABCA and ASTA are programmed using pseudo-codes for searching the best solution [20,25,27-30]. The ABCA uses parameters as listed in Table 4 covered for colony size, food source, limit food source, foraging cycle, and runtime. This table also presents the ASTA covered in salmon number, surviving factor, mouth river, tracking round, migrating period. In particular, these works also use an equality scenario for the OPT considering the PIT and PET aspects while the system's charges are also listed in Table 4.

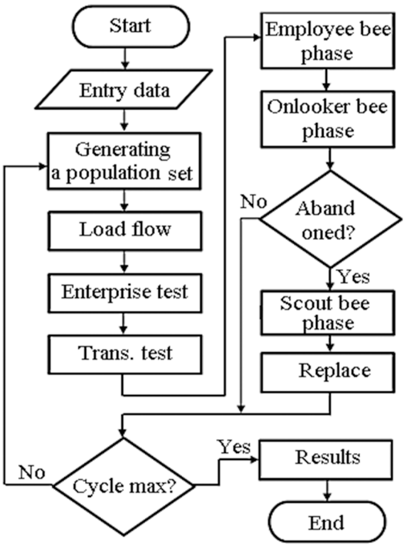

FIGURE 1. Flowchart of the ABCA phases

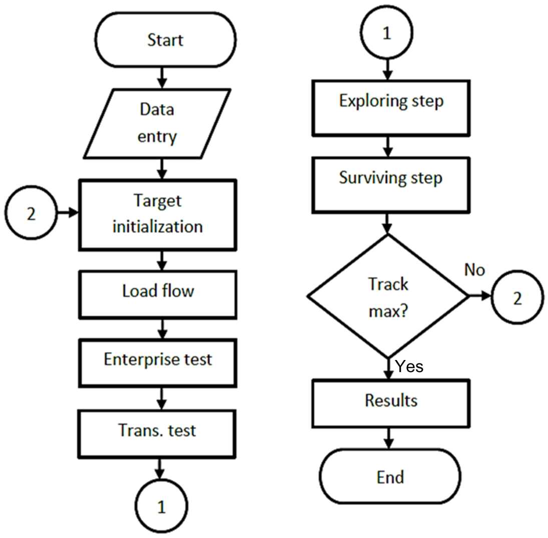

FIGURE 2. Flowchart of the ASTA steps

TABLE 1. Enterprises power limits and generating coefficients

Power Enterprises	Gen	Power limit				Coefficient cost			Coefficient emission		
		P^{min}	P^{max}	Q^{min}	Q^{max}	a	b	c	α	β	γ
Area 1	G5	10	30	−10	50	0.02500	3.00	0	0.0290	−0.0040	24.7000
Area 2	G3	15	50	−15	80	0.06250	1.00	0	0.0270	−0.0100	25.5050
	G6	12	150	−15	120	0.02500	3.00	0	0.0271	−0.0055	25.3000
Area 3	G1	50	200	0	0	0.00375	2.00	0	0.0126	−1.1000	22.9830
	G2	20	80	−20	75	0.01750	1.75	0	0.0200	−0.1000	25.3130
	G4	10	125	−15	90	0.00835	3.25	0	0.0291	−0.0050	24.9000
P: MW, Q: MVar, a: \$/MW^{2}h, b: \$/MWh, α: kg/MW^{2}h, β: kg/MWh , γ: kg/h											

TABLE 2. Area load demands

Area 1			Area 2			Area 3		
Bus	MW	MVar	Bus	MW	MVar	Bus	MW	MVar
19	19.50	9.40	1	54.20	14.00	3	32.40	11.20
20	0.00	0.00	2	21.70	12.70	6	22.80	10.90
21	0.00	0.00	4	7.60	1.60	7	0.00	0.00
22	17.50	11.20	5	0.00	0.00	8	30.00	13.20
23	3.20	1.60	9	6.20	1.60	12	0.00	0.00
24	0.00	0.00	10	5.80	2.00	13	11.20	7.50
25	23.20	16.70	11	0.00	0.00	16	3.50	1.80
26	3.90	2.30	14	0.00	0.00	17	0.00	0.00
27	9.00	5.80	15	8.20	2.50	18	3.70	0.90
28	2.20	0.70	–	–	–	–	–	–
29	12.40	0.90	–	–	–	–	–	–
30	10.60	1.90	–	–	–	–	–	–
Total	101.50	50.50	Total	103.70	34.40	Total	103.6	45.5

Table 3. Line data of the system

Track	Fr	To	Z (%)	Track	Fr	To	Z (%)	Track	Fr	To	Z (%)
1	1	2	0.06	14	14	15	0.24	26	23	24	0.30
2	2	3	0.18	15	15	16	0.14	27	25	10	0.20
3	4	1	0.19	16	16	7	0.28	28	25	9	0.21
4	4	5	0.19	17	16	8	0.03	29	25	26	0.47
5	6	3	0.04	18	16	12	0.30	30	26	16	0.21
6	7	8	0.56	19	17	13	0.21	31	26	20	0.03
7	9	4	0.20	20	17	18	0.08	32	26	22	0.21
8	10	4	0.04	21	19	11	0.17	33	26	27	0.24
9	10	5	0.13	22	19	20	0.17	34	26	28	0.37
10	10	11	0.28	23	21	22	0.26	35	27	28	0.47
11	12	6	0.09	24	22	16	0.23	36	28	29	0.68
12	13	8	0.12	25	23	17	0.09	37	29	23	0.38
13	14	12	0.22					38	29	30	0.51

Table 4. Transaction charges, ABCA and ASTA parameters

Provider	Charge ($/MW)	ABCA	Value	ASTA	Value
Operator 1	3	Colony size	100	Salmon number	100
Operator 2	2.5	Food source	50	Surviving factor	0.25
Operator 3	3	Limit food source	100	Mouth rive	100
Enterprise 1	4.5	Foraging cycles	100	Tracking round	100
Enterprise 2	5.5	Run time	1	Migrating period	1
Enterprise 3	2.5	Solution population	50	Solution population	50

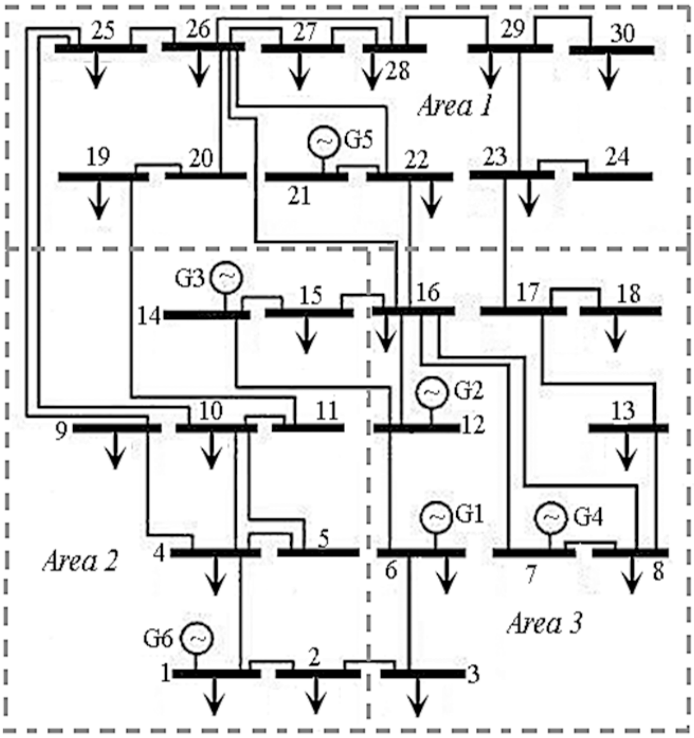

Figure 3. Modified IEEE 30 bus system

4. **Result and Discussions.** In this section, the IEEE-30 bus system is modified into 3 areas as illustrated in Figure 3 where load demands are distributed in Area 1 of 101.50

MW and 50.50 MVar, Area 2 of 103.70 MW and 34.40 MVar, and Area 3 of 103.60 MW and 45.50 MVar. By considering this model, these works are addressed to assess the OPT based on the SEP using technical constraints, transmission charges, and power rates. Figure 4 illustrates a computational characteristic of ABCA and ASTA for carrying out the SEP considering all requirements. This figure is performed using 0.5 of an equality weighting factor and the optimal solution is obtained in 25 iterations of ABCA and 17 of ASTA. The optimal solution of the SEP is given in Table 5 considering 308.80 MW of the load distributed in 101.5 MW for Area 1, 103.7 MW for Area 2, and 103.6 MW for Area 3. Moreover, the individual loading bus is detailed in Figure 5. Thus, the power loss on the EXIM track is given in Figure 6 for the 17 lines while the loading buses are given in Figure 5.

From Table 5, it is known that the ED produces 309.7 MW of ABCA and 309.8 MW of ASTA. Moreover, the ABCA discharges 809.6 kg/h while it is allowed in 262.5 kg/h. In contrast, the ASTA has 724.3 kg/h of the produced emissions and 263.2 kg/h of the

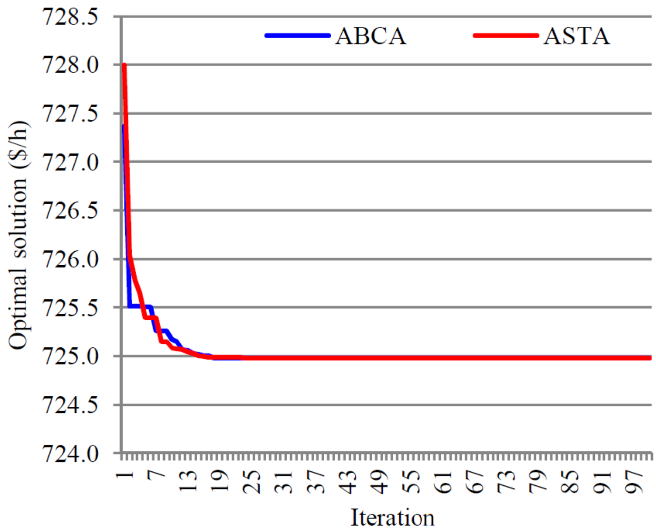

FIGURE 4. Convergence speed of the SEP

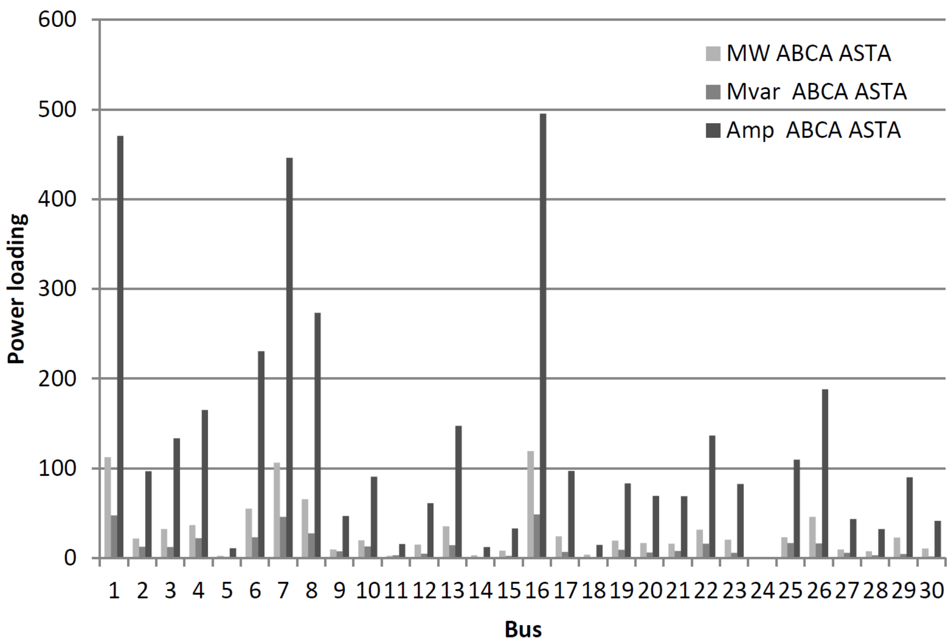

FIGURE 5. Bus power loading

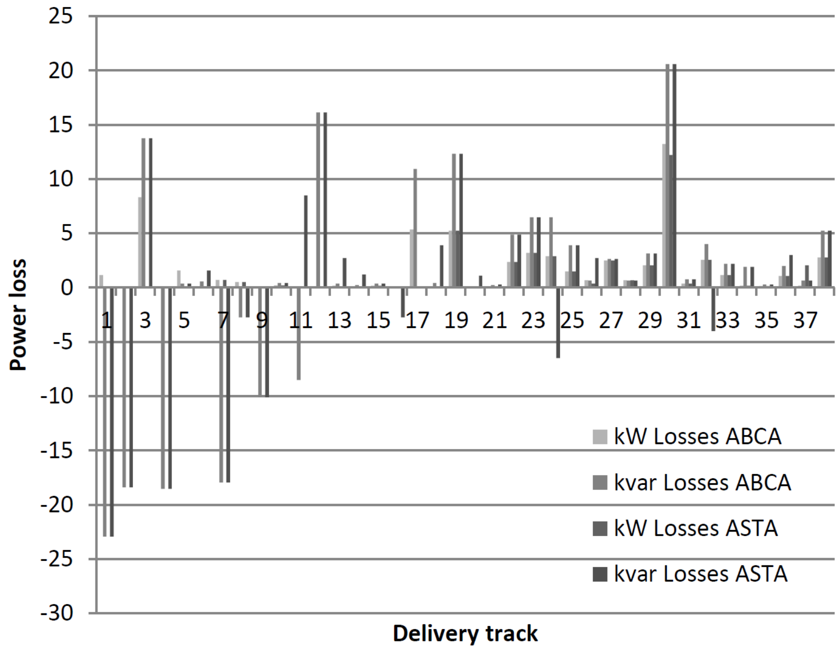

Figure 6. Power loss tracking

Table 5. Individual power productions and pollutant discharges of power plants

Unit	ABCA					ASTA				
	MW	MVar	Emission Discharge (kg/h)	Permitted Discharge (kg/h)	Over Emission (kg/h)	MW	MVar	Emission Discharge (kg/h)	Permitted Discharge (kg/h)	Over Emission (kg/h)
G5	16.1	7.9	32.1	13.7	18.5	18.1	9.9	34.1	15.4	18.7
G3	4.1	0.9	25.7	2.6	23.1	7.1	0.9	26.8	6.0	20.8
G6	112.7	47.7	368.7	95.8	272.9	104.4	43.7	320.2	88.8	231.5
G1	55.3	23.2	0.7	47.0	less	56.3	13.2	1.0	47.8	less
G2	15.2	4.7	28.4	12.9	15.5	25.3	16.7	35.6	21.5	14.1
G4	106.3	46.0	354.0	90.5	263.6	98.6	46.0	306.6	83.7	222.9

Table 6. Individual emission compensations and operating costs of power plants

Unit	ABCA				ASTA			
	Over Emission (kg/h)	Emission Charge ($/h)	Fuel cost ($/h)	Total cost ($/h)	Over Emission (kg/h)	Emission Charge ($/h)	Fuel cost ($/h)	Total cost ($/h)
G5	18.5	13.1	54.7	67.8	18.7	13.3	62.4	75.7
G3	23.1	16.4	3.6	869.1	20.8	14.8	10.2	775.2
G6	272.9	193.8	655.3		231.5	164.3	585.9	
G1	less	no	122.0	791.2	less	no	124.4	749.1
G2	15.5	11.0	30.6		14.1	10.0	55.4	
G4	263.6	187.1	440.5		222.9	158.3	401.0	

discharge limitation. Economically, the lowest operating cost is 1,728.1 $/h for the ABCA different with the ASTA of 1,600.0 $/h as detailed in Table 6. Referring to Table 2, the EXIM power transaction is listed in Table 9. By considering the OPT, PIT, and PET, Area 1 imports the power from Area 2 and Area 3 to cover the load demand where the power wheeling and system performances are detailed in Table 8 and Table 7.

Table 7. Local bus voltage variations of the system

Bus	kV	% var	Bus	kV	% var	Bus	kV	% var
1	150.00	0.00	11	149.88	−0.08	21	150.00	0.00
2	149.99	−0.01	12	150.00	0.00	22	149.96	−0.03
3	149.99	−0.01	13	149.96	−0.03	23	149.90	−0.07
4	149.91	−0.06	14	150.00	0.00	24	149.90	−0.07
5	149.91	−0.06	15	149.99	−0.01	25	149.87	−0.09
6	150.00	0.00	16	150.00	0.00	26	149.91	−0.06
7	150.00	0.00	17	149.91	−0.06	27	149.90	−0.07
8	149.99	−0.01	18	149.91	−0.06	28	149.90	−0.07
9	149.88	−0.08	19	149.88	−0.08	29	149.90	−0.07
10	149.91	−0.06	20	149.91	−0.06	30	149.84	−0.11

Table 8. Power wheeling transaction on transmission lines

Route		Power		Current	Route		Power		Current	Route		Power		Current
Fr	To	MW	MVar	A	Fr	To	MW	MVar	A	Fr	To	MW	MVar	A
1	2	21.62	11.62	94.49	14	15	3.05	0.94	12.28	23	24	0.00	0.00	0.00
2	3	0.07	1.08	4.15	15	16	5.15	1.56	20.72	25	10	11.33	7.81	53.00
4	1	36.84	22.05	165.30	16	7	104.02	43.94	434.60	25	9	3.37	5.91	26.20
4	5	2.48	1.45	11.07	16	8	63.09	25.50	261.90	25	26	8.46	2.96	34.52
6	3	32.47	12.26	133.60	16	12	15.17	4.69	61.10	26	16	31.94	11.42	130.50
7	8	2.42	2.08	12.28	17	18	3.70	0.90	14.65	26	20	16.92	6.22	69.40
9	4	9.56	7.51	46.83	17	13	24.31	6.87	97.26	26	22	14.09	5.02	57.57
10	4	17.19	11.52	79.72	19	11	2.56	3.17	15.69	26	27	9.72	3.27	39.50
10	5	2.48	1.46	11.09	19	20	16.91	6.22	69.40	26	28	7.01	1.67	27.76
10	11	2.56	3.17	15.69	21	22	16.07	7.87	68.88	27	28	0.73	−2.52	10.11
12	6	0.00	0.00	0.02	22	16	15.51	8.35	67.80	28	29	5.55	−1.55	22.19
13	8	35.51	14.38	147.50	23	17	20.61	5.95	82.63	29	23	17.41	4.35	69.14
14	12	0.00	0.00	0.00						29	30	10.58	1.90	41.41

Table 9. Export import power transaction for all areas of the sub-systems

Location		ABCA						ASTA					
		Enterprises (MW)						Enterprises (MW)					
		G5	G3	G6	G1	G2	G4	G5	G3	G6	G1	G2	G4
Area 1	Power	16.1	–	12.7	–	–	73.0	18.1	–	7.5	–	–	76.2
	Fee ($)	–	–	70.0	–	–	182.5	–	–	41.1	–	–	190.6
Area 2		–	–	4.1	99.9	–	–	–	–	7.1	96.9	–	–
Area 3		–	–	–	–	55.3	15.3	33.3	–	–	–	56.3	25.3
Provider		TUoS charges ($)						TUoS charges ($)					
		G5	G3	G6	G1	G2	G4	G5	G3	G6	G1	G2	G4
Area 1, Operator 1		48.2	–	38.2	–	–	219.0	54.2	–	22.4	–	–	228.7
Area 1, Operator 2		–	–	31.8	–	–	182.5	–	–	18.7	–	–	190.6
Area 1, Operator 3		–	–	–	–	–	219.0	–	–	–	–	–	228.7
Area 2, Operator 2		–	10.1	249.9	–	–	–	–	17.6	242.4	–	–	–
Area 3, Operator 3		–	–	–	165.8	45.8	100.0	–	–	–	168.8	75.8	67.0
User		Area 1		Area 2		Area 3		Area 1		Area 2		Area 3	
Load (MW)		101.5		103.7		103.6		101.5		103.7		103.6	
Loss (MW)		0.3		0.3		0.3		0.3		0.3		0.3	
Demand (MW)		101.8		104.0		103.9		101.8		104.0		103.9	

5. **Conclusion.** This paper presents an application of ABCA and ASTA for evaluating power selling and transmission use aspects based on IEEE-30 bus model. These works demonstrate that ABCA and ASTA have a smooth convergence speed with quick characteristic to select the optimal solution, while the transmission and power rates affect the operating cost of enterprises. The power production of enterprises leads to the export and import power transaction, whereas, the system is run well in different performances. A revealing convergence and a real sample system are devoted to the future works.

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