Short Term Schedule of Economic Dispatch and Emission of Hydrothermal System

Vann Sak Ky[1], Zhijun Qin [2]
[1] School of Electrical Engineering, [2]Guangxi University, 530004, Nanning, China
3483572017@qq.com, zjqin@gxu.edu.cn

ABSTRACT

The overall goals of paper will be improved he financial and environmental benefits of the combined operation of hydro and thermal power plant. Considering both of reduction fossil fuel usage and the power generation cost by coal-fired units, the power generation scheduling problem of the power system with cascade hydropower three stations. The schedule of this problems of cascade hydropower stations are the power generation, the hydropower water consumption, the thermal power generation pollutant emissions, and the total thermal power cost. The schedule dispatch model established by this can not only determine the best output of thermal power and the best water storage and release strategy of hydropower, but also describe the complementary effects of hydropower and thermal power, and fully reflect the concept of energy conservation and benefit. So Genetic Algorithm has been applied to find out the solution of pollutant and economic of hydrothermal plant dispatch. The short term scheduling is determined for studying and to calculate the hydro and thermal power plants. Some of thermal restrictions and hydro restrictions are considered in the processing such as storage limitation, discharge limitation of the reservoir and generation of each unit limitation. The hydrothermal short term schedule calculation has been included 3 hydro units and 3 thermal units from power system. The study case has been gotten the data and the situation in Cambodia.

Keywords
Economic dispatch and emission, Genetic algorithm, System constraints.

Article Received: 10 August 2020, Revised: 25 October 2020, Accepted: 18 November 2020

Introduction

In general, economic emission dispatch (EED) concept and summarizes EED models in an electricity network and multiple energy system (MES). Moreover, the illustrative studied cases are presented to show the embedded flow of economic and emissions in real power systems. The EED model can effectively quantify economic emission footprints of energy systems, providing better results. The EED analysis provides useful and reasonable advice for mitigating global climate change [1].

Greenhouse Gas emissions in Cambodia according to the World Resources Institute Climate Analysis Indicators Tool (WRI CAIT), in 2013 Cambodia's GHG emissions dominated from the land-use change and forestry (LUCF) sector for 47.6% of the total emission in the country, agriculture (36.4%), Energy (14.1%), industrial processes (1.2%) and waste (0.7%,) [2]. The emission reduction targets need be set and allocated not only in Cambodia but also to others countries involved in climate change negotiations. The case study results indicate that a considerable amount of emissions flow EF among countries. Many countries that exported the energy should take additional emission responsibility according to the international energy system trade. Without considering EF, emissions can be attributed only to energy production, and thus, the evaluation results will be unfair to energy export countries. To this end, the EF model would facilitate rational and equitable agreement in climate change negotiations by reasonably attributing economic and emissions.

The Cambodia annual plan constitutes of energy supply and demand & supply plan. The core of energy supply plan is hydropower and coal fired thermal unit operation plan. Especially, hydropower units are the center of it. This is

because of the viewpoints of (a) Effective use of hydropower generation capacity to minimize expected discharged overflow water from reservoirs during rainy season. (b) Effective use of expected unused generation energy (=defined as “extra energy”) based on unused retained water in hydropower plants and effective use of coal fired thermal power plants whose generation cost is low and competitive. (c) Maximizing efforts on export energy increase and distribution consumption expansion (such as housing complexes construction) using (b) in cooperation with other related departments. (d) Rational promotion and suggestion on hydropower plants' construction plan from the viewpoints of (b), (c) and system demand increase situation. A huge amount of water is still kept on being thrown away as discharged overflow water from reservoirs for any minutes during rainy season. (e) Water saving hydropower generation on planning basis while supplying required amount of electricity during the time period from mid-November to December in preparation for dry season and during dry season when almost no rainfall is expected. Proper operation planning of generating units considering effective and efficient use of hydropower generation, and proper estimation of extra generation energy from hydropower plants and coal fired thermal power plants will facilitate realistic export energy increase negotiation and distribution energy consumption expansion planning and will contribute to finding one of the deciding factors of timely power plants construction in terms of contribution to Ministry's Grand Policy [3].

In these works, Cambodia network system is adopted as a sample system for the simulations. In Cambodia Transmission System, Peak load of weekday occur at daytime and nighttime for holiday. In dry season, the monthly peak system demand (MW) dramatically increases while hydropower plants have to be operated at minimum output at the peak time. Fuel power plants shall be kept as standby units so that coal power plants, import power from Vietnam, and hydropower plants are the major supplies for Cambodia Transmission System (CTS). Based on this reason, CTS network configuration shall leave some load supplied from Thailand system.

Function Dispatch of Economic and Emission

Dispatch Definition Economic and Emission

The dispatch economic and emission purpose are to focus on the minimize fuel cost and reduction greenhouse emission with the restriction are considered.

A. Objective function and constraints

The work issue of hydrothermal power system (HPS), such as economic, emission, have considered as the problem of multi-objective optimization, that the purpose is to minimize of each objective function of the system, also satisfying to both equality and inequality constraints. The HPS constraints of N_i thermal plants and N_h hydro power plants in K time sub-intervals will be included.

1. Modeling of Fuel Cost

The modeling of fuel cost function of each power plants are demonstrated as the quadratic equation (1) [4] [5] [6].

$$C(P_{ki}) = a_i + b_i P_{ki} + c_i P_{ki}^2 (\$/h) \qquad (1)$$

where P_{ki} generated power i^{th} generator; a_i, b_i,c_i:coefficients of the cost curve; $C(P_{ki})$:cost of generating P_{ki} by i^{th} unit. So sum of generation cost has calculated by equation (2) below [7]:

$$F = \sum_{i=1}^{N} a_i + b_i P_{ki} + c_i P_{ki}^2 \ (\$/h) \qquad (2)$$

Where *F*: sum of generation cost, *N*: number of generation in operation.

The solution of problem for this paper is considered both the economic and emission.

2. Economic Dispatch

Economic function *Ec*: the thermal generator cost is profoundly nonlinear; the cost equation is more reasonable signified as a portioned piecewise nonlinear equation instead of a single quadratic equation. The overall fuel cost can be precisely signified in term of genuine power output as a non-smooth cost equation (3) [8]:

$$E_c = \sum_{k=1}^{K} \sum_{i=1}^{N_i} T_k [a_i + b_i P_{ki} + c_i P_{ki}^2] (\$) \qquad (3)$$

Where E_c is overall generation cost equation, T_k is the duration sub-interval generation, P_{ki} power generated by i^{th} thermal plant in k^{th} sub-interval.

3. Emission Dispatch

In this model, the sum of transmitted CO2 is taken as the chosen file from the viewpoint of natural preservation. The pollutant from each generator is given as a work of its yield, which is the entirety of a quadratic and an exponential equation the pollutant objective can be numerically modeled as (4) [9][10]:

$$E_m = \sum_{k=1}^{K} \sum_{i=1}^{N_i} T_k [\alpha_i + \beta_i P_{ki} + \gamma_i P_{ki}^2] (\text{kg/h}) \qquad (4)$$

4. Characteristics equation of Hydro Power plant is absolutely related to the water discharge variable (D_h), water storage variable (S_h) and the coefficient of the hydro reservoir. (5) [11].

$$P_{hik} = A_{11i}(S_{hik})^2 + A_{22i}(D_{hik})^2 + A_{33i}(S_{hik})(D_{hik}) + A_{44i}(S_{hik}) + A_{55i}(D_{hik}) + A_{66i} \quad (5)$$

The hydro power generation value P_{hik} is based on the constraints of water availability in N_h equalities, $A_{11}, \dots$ and A_{66} are the coefficients of h^{th} hydro power plants, S_h and D_h are storage and discharge with i^{th} (unit and reservoir) at k^{th} available time interval of water of h^{th} hydro power plant.

5. Economic and Emission Combination Dispatch (EECD)
The EECD objective model have been changed to a single objective equation by using penalty factor (*pf*) approach as (6) [12] [13].

$$Ptc = Ec + pf * Em \quad (6)$$

where the total pure cost in the system execution is *Ptc*. And to provide a minimization of emission and fuel cost (6) should be formed as (7) [14]:

1. $$Tc = wt * Ec + (1\text{-}wt) * pf * Em \quad (7)$$

where *wt* is the specifies optimization type weight factor; in case *wt* = 1, the model is economic load dispatch (ELD); in case *wt* = 0, the model is emission dispatch (EmD); and in case *wt* = 0.5, the model have been called EECD [15].

By the taking after these step, *pf* for indicated power demand can be calculated:

Step 1: h_i of each unit could be calculated:

$$\frac{Ec(P_i^{max})}{Em(P_i^{max})} = h_i \text{ , } i\text{: is counting number } (\$/kg) \quad (8)$$

2. Step 2: h_i value will be sorted as ascending.

Step 3: Include the output (max) of each one at a time beginning from the unit with littlest h_i until $\sum P_i^{max} \geq P_D$

Step 4: h_i related with the final unit is *pf* for the given power demand.

6. System Constraints
The balance power and equation of water availability constraint of the hydrothermal power system are:

$$\sum_{i=1}^{N_i} P_{ki} + \sum_{h=1}^{N_h} P_{kh} = P_{kD} + P_{kL} \text{ , } \quad k = 1, \dots, K \quad (9)$$

The balance power constraints are K equalities, P_{kh} is the power produced by h^{th} hydro power plant in k^{th} sub-interval, and P_{kD} is the full demand in k^{th} sub-interval.
For this model P_{kL} have not included, (9) equation becomes as below (10):

$$\sum_{i=1}^{N_i} P_{ki} + \sum_{h=1}^{N_h} P_{kh} = P_{kD} \text{ , } \quad k = 1, \dots, K \quad (10)$$

3. The imbalance constraints for hydrothermal power system unit output were respectively as the form below [16][17]:
   - Thermal power generation limit P_{th} : Produced the power with the specified of the generations limits.

4.
$$P_{th}^{min} \leq P_{th} \leq P_{th}^{max}$$

5.
   - Hydro power generation limit P_h: Produced the power with the specified of the generations limits

$$P_h^{min} \leq P_h \leq P_h^{max}$$

6.
   - Hydro Reservoir Storage S_h: The reservoir has to kept the available volume of water for every hour.

7.
$$S_{hij}^{min} \leq S_{hij} \leq S_{hij}^{max}$$

   - Hydro Reservoir Discharge D_h: The reservoir discharge should lie in between specified limits.

$$D_{hij}^{min} \leq D_{hij} \leq D_{hij}^{max}$$

Genetic algorithm

The Genetic Algorithm fundamentals were the first propped by Holland. Genetic algorithm was primarily according to mechanics of natural selection that belong to the larger class of

evolutionary, it is a part of evolutionary algorithm [18].
Apply GA for EED:
1. Read all related data of system such as coefficients, population size, power demand then creates the initial population randomly.
2. Check the any constraints, evaluate fitness function and determine the total cost of generation with satisfied variables.
3. Apply operators of GA.
4. Check for conditions, if the conditions not satisfied, GA will not print the solutions, if the conditions satisfied, GA will print the solutions [19].

system studying

The hydrothermal system has 3 thermal power generation units and 3 hydro power generation units. The coefficients and any data of hydrothermal to solve the problem have been defined in the Table I to IV below including generation limit, storage limit, and discharge limit for hydro reservoir.

Table I
Generation limit, water storage limit and water discharge limit

Unit	P_{min}	P_{max}	S_{min}	S_{max}	D_{min}	D_{max}
Ph1	0	246	51.00	102.00	5.10	12.75
Ph2	0	338	85.00	204.00	8.50	12.50
Ph3	0	400	59.50	136.00	11.05	21.25

Table II
Hydro power generation coefficients

Unit	A_{11}	A_{22}	A_{33}	A_{44}	A_{55}	A_{66}
Ph1	-0.0046	-0.34500	0.01725	1.3110	10.925	-80.50
Ph2	-0.00184	-0.34500	0.01610	0.6325	6.3250	-46.0
Ph3	-0.00345	-0.3565	0.0315	1.656	16.100	-103.5

Table III
Economic coefficients and thermal limitation

Thermal	a	b	c	P_{min}	P_{max}
C1	1661.05685	36.38229	0.02114	140.00	408.00
C2	1358.69399	38.32781	0.01802	135.00	400.00
C3	452.00199	46.22844	0.10603	75.00	237.00

Table IV
Emission coefficients and limits of thermal generation

Unit	α	β	γ	P_{min}	P_{max}
C1	57.84325	-0.51197	0.00461	140.00	408.00
C2	42.95984	-0.51197	0.00461	135.00	400.00
C3	9.88009	0.32819	0.00421	75.00	237.00

Results and Discussion

Normally, in Cambodia the operation of power generation is according the seasons, initial production cost of power plant, low cost energy in which time subinterval (daytime and nighttime) in this country. During dry season the power generation thermal power plant is the priority power generation source and hydro power plant is to adjust to the total power load consumption, and during raining season in the power generation is depended on the hydro power generation sources and others power thermal and any exports energy sources are to adjust to the total load consumption. In this case study the result not focus on dry season or raining season, the solution is operated thermal and hydro power generation simultaneously. According to initial data from power plant and national control center (NCC), the total load demand in this case divide in 24 subinterval k for every one hours. In this case study consists of three thermal and three hydro power generation units. In table V, by considering compositions of Ec=1,278,293.50($) and Em=97,653.58(kg), the minimum total cost is received EECD=1,211,014.81($) by using weight factor *wt* = 0.5 and the penalty factor pf for 24 hours. And Fig.1 Hydrothermal generation sharing during subinterval, Fig.2 Reservoir storage of hydro power plant.
Table V

Hydro and thermal plant generation

TK	Pd	Thermal Generation			Hydro Generation		
		C1	C2	C3	Ph1	Ph2	Ph3
1	891	268.00	135.00	131.60	84.55	17.23	254.52
2	860	234.45	177.51	104.00	88.66	58.40	196.67
3	842	268.00	135.00	102.20	76.91	16.87	243.35
4	841	268.00	135.00	101.60	68.24	47.52	220.70
5	854	268.00	135.00	109.40	60.31	67.45	214.01
6	891	240.15	152.77	141.56	82.18	67.26	206.92
7	1031	192.34	294.06	131.79	72.83	64.54	275.41
8	1225	233.43	343.99	157.57	106.51	68.35	315.61
9	1300	193.32	399.01	186.99	117.78	98.30	304.16
10	1339	274.74	320.04	208.61	134.63	141.40	259.89
11	1255	378.14	219.80	154.59	51.97	123.66	325.94
12	1176	256.72	281.12	167.71	80.90	114.31	275.39
13	1244	280.80	299.22	166.29	44.08	120.40	333.14
14	1331	372.49	258.79	167.32	84.83	101.00	346.55
15	1327	353.42	233.81	208.87	116.60	97.19	317.53
16	1201	289.27	245.84	185.43	90.54	137.42	252.36
17	1096	268.00	227.60	162.00	94.46	111.47	232.82
18	1101	268.00	230.60	162.00	70.75	87.65	281.80
19	1124	268.00	244.40	162.00	77.88	96.92	274.93
20	1075	202.37	314.77	127.36	107.10	31.94	290.88
21	1078	268.00	216.80	162.00	66.63	115.45	249.25
22	1012	286.30	158.57	162.76	124.97	73.90	205.58
23	954	241.61	145.06	185.36	102.10	35.70	243.62
24	898	142.05	180.14	217.04	88.23	15.92	255.26
Economic Dispatch (Ec) 1278293.50($)							
Emission Dispatch (Em) 97653.58(kg)							
EECD 1211014.81($)							

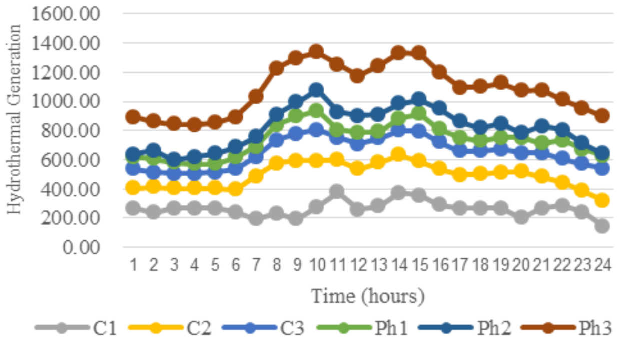

Fig.1 Hydrothermal generation sharing during subinterval

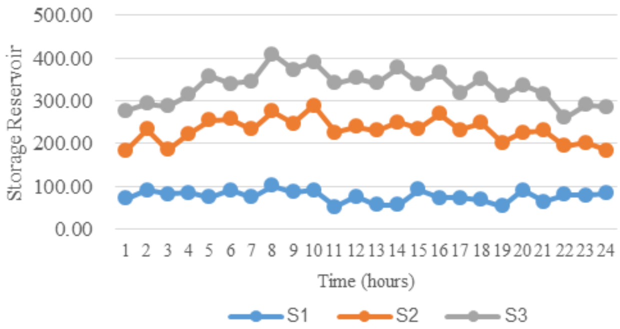

Fig.2 Reservoir storage of hydro power plant

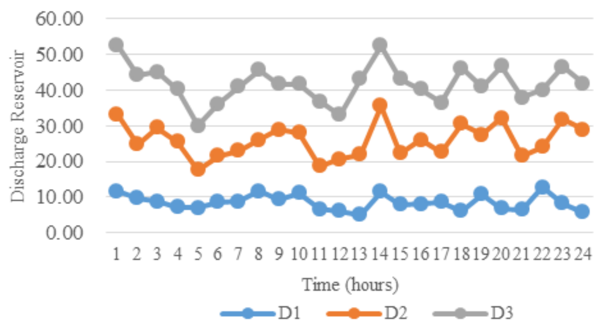

Fig3. Reservoir discharge of hydro power plant

Conclusion

This paper proposes genetic algorithm to reduce the financial dispatch and the pollutant dispatch of thermal power system, which considering generator characteristics nonlinear, such as limitation of power thermal generation, power hydro generation, limitation of hydro reservoir storage, limitation of hydro reservoir discharge. The execution of the proposed model is illustrated on 3 units of thermal power generation and 3 units of hydro power generation. The result appears that the model can look the best arrangement, autonomous of the number of generator, request conditions and able to handle the function restriction effectively. It can be watched that utilities ought to not continuously go for ideal assignment of generation cost, pollutant cost, and that value will give the effective dispatch of the system operation.

ACKNOWLEDGMENT

I would like to thank to my advisor Prof. Qin Zhijun for his persistent direction throughout the research process, precious time and concerned he devoted all through this work. And also, thankful the financial sponsor (Electricite du Cambodge (EDC) and China Sothern Power Grid company) for giving me this opportunity. This work is supported by Natural Science Foundation of China under Grant 51767001.

REFERENCES

[1] Agrawal S P, Porate K B. Economic dispatch of thermal units with the mpact of wind power plant[C].2010 3rd International Conference on merging Trends in Engineering and Technology, IEEE, Goa, India,2010.

[2] USAID, Greenhouse Gas Emissions in Cambodia, Cambodia, 2017.

[3] Annual Energy Supply and Demand & Supply Plan for the Year 2017, National Control Center, Electricite du Cambodge.

[4] Serdar ÖZYÖN1, Celal YAŞAR, Hasan TEMURTAŞ. A Novel Hybrid Algorithm for Nonconvex Economic Power Dispatch Problems[J]. IOSR Journal of Electrical and Electronics Engineering, 2016 11(6): 92-101.

[5] Ray S. Economic Load Dispatch Solution using Interval Gradient Method[J]. Advanced Research in Electrical and Electronic Engineering, 2014, 1(4): 55-58.

[6] Daryani N, Zare K. Multiobjective power and emission dispatch using modified group search optimization method[J]. Ain Shams Engineering Journal, 2018, 9(3): 319-328.

[7] Srikanth K S, Kishore D R, Muni T V, et al. Economic load dispatch with multiple fuel options using GA toolbox in Matlab[J]. Journal of Science and Technology, 2016, 1(1): 17-24.

[8] Khan N A, Awan A B, Mahmood A, et al. Combined emission economic dispatch of power system including solar photo voltaic generation[J]. Energy Conversion and Management, 2015, 92:82-91.

[9] Foroud A A, Soleymanpour H R. Solution of Short-term Economic-Emission Hydrothermal Generation Scheduling by an Efficient Particle Swarm Optimization technique[C]. 2010 18th Iranian Conference on Electrical Engineering, IEEE, Isfahan, Iran, 2010.

[10] Basu M. Economic environmental dispatch of hydrothermal power system[J]. International Journal of Electrical Power & Energy Systems, 2010, 32(6): 711-720.

[11] Normansyah, Akhdiyatul, Erick Radwitya, Hardiansyah, Cuckoo Search Algorithm for Environmental/Economic Dispatch Problem[J]. IOSR Journal of Electrical and Electronics Engineering, 2017, 12(5): 59-63.

[12] Damodaran S K, Kumar T K S. Combined Economic and Emission Dispatch Using a Classical Technique[J]. IFAC Proceedings Volumes, 2014, 47(1): 1049-1053.

[13] Rezaie H, Kazemi-Rahbar M H, Vahidi B, et al. Solution of combined economic and emission dispatch problem using a novel chaotic improved harmony search algorithm[J]. Journal of Computational Design and Engineering, 2019, 6(3): 447-467.

[14] Liang H, Liu Y, Li F, et al. A multiobjective hybrid bat algorithm for combined economic/emission dispatch[J]. International Journal of Electrical Power & Energy Systems, 2018, 101: 103-115.

[15] F. N. Al Farsi, M. H. Albadi, N. Hosseinzadeh, A. H. Al Badi. Economic Dispatch in Power Systems A comparison between vertically integrated and liberalized markets[C]. The 8th IEEE GCC Conference and Exhibition, Muscat, Oman, 2015.

[16] Xie M, Ji X, Hu X, et al. Autonomous optimized economic dispatch of active distribution system with multi-microgrids[J]. Energy, 2018, 153: 479-489.

[17] Ashfaq A, Khan A Z. Optimization of economic load dispatch problem by linear programming modified methodology[C]. 2nd International Conference on Emerging Trends in Engineering and Technology (ICETET'2014). IIE, London, UK, 2014.

[18] Dasgupta K , Banerjee S . An analysis of economic load dispatch using different algorithms[C]// 2014 1st International Conference on Non Conventional Energy (ICONCE). IEEE, 2014.

[19] Liu J, Luo X J. Optimal economic emission hydrothermal scheduling based on black hole theory and annual profit analysis considering FGD[J]. 2011.