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ENERGY COMMITMENT: A PLANNING OF ENERGY CARRIER BASED ON ENERGY CONSUMPTION

Purpose. Energy consumption is one of the criteria for determining the quality of life in a country. Continued supply of energy and the possibility of long-term access to resources require a comprehensive plan. One of the key issues in the field of energy planning is energy carriers. In this paper, a new theory is introduced to energy network studies for planning of energy carriers called Energy Commitment. In this theory, an appropriate planning is applied for energy carriers based the final energy consumption. Energy carriers are available either naturally or after the energy conversion process. Energy commitment is modeled on an energy network with the presence of electrical energy, gas energy, transportation section, agriculture section, industrial section, residential section, commercial section, and general section. References 25, tables 3.

Key words: **energy, energy commitment, energy carrier, energy consumption, unit commitment.**

Цель. Потребление энергии является одним из критериев определения качества жизни в стране. Непрерывные поставки энергии и возможность долгосрочного доступа к ресурсам требуют комплексного плана. Одним из ключевых вопросов в области энергетического планирования являются энергоносители. В данной статье в исследования энергетических сетей для планирования энергоносителей вводится новая теория под названием Energy Commitment («энергетическое обязательство»). В этой теории для энергоносителей применяется соответствующее планирование на основе конечного потребления энергии. Энергоносители доступны либо естественным путем, либо после процесса преобразования энергии. Energy Commitment моделируется в энергетической сети с учетом электрической энергии, энергии газа, транспортной отрасли народного хозяйства, сельскохозяйственной отрасли, промышленного сектора экономики, жилищно-коммунального хозяйства, реального сектора экономики и прочих видов экономической активности. Библ. 25, табл. 3.

Ключевые слова: **энергия, энергетическое обязательство, энергоноситель, энергопотребление, единичное обязательство.**

Introduction. Energy consumption is one of the criteria for determining the level of development and quality of life in a country [1]. If energy used properly and reasonably, it can in any country make progress in the science, technology and welfare of its people. Otherwise, it will cause irreparable economic losses and a massive economic downturn [2]. The energy consumption trend has been very fast and critical in recent years. Continued supply of energy and the possibility of long-term access to resources require a comprehensive energy planning, which is why energy planning is indisputable economic, national and strategic imperatives. One of the key issues in the field of energy planning is energy resources.

Many studies is done on the power system such as: transformers [3], battery energy storage [4], distributed generation [5], energy [6]. One of the most important studies of electric power network is the issue of Unit Commitment (UC) [7]. UC is to determine the most appropriate electrical power generation pattern at power plants, firstly, to meet technical requirements, and then to be the most economical [8]. UC has been studied using various methods. The priority list method and dynamic programing are the first methods in UC [9]. In the Lagrange method, equal and unequal constraints were added to the objective function [10]. In [11] UC problem is investigated the in presence of FACTS devices and energy storage. In [12] UC problem is studied under cyber-attacks. In addition, evolutionary methods have been used for solving UC in recent years. In [13] a method is proposed based on the classical genetic algorithm. Integer-coded genetic algorithm in [14] is proposed. Researchers have also used other methods to solve the UC problem such as: Particle Swarm Optimization (PSO) [15], Teaching Learning Based Optimization (TLBO) [16], Gravitational Search Algorithm (GSA) [17] , Water Cycle Algorithm (WCA) [18] and Grey Wolf Optimization (GWO) [19], Whale Optimization Algorithm (WOA) [20]. Other algorithms are also suggested for UC solving [21-24].

Energy Commitment (EC) is to determine the most appropriate pattern for using energy resources to meet energy demand, firstly, to meet technical requirements, and secondly, to be the most economical. In other words, energy sources should be used as much as needed, if the energy sources are in line with the demand peak it will cost a lot. Therefore, EC reduces energy supply costs.

This problem can be articulated mathematically, so that a function called F is defined as the objective function, which is equal to the total cost of supplying energy demand. In this case, the problem is to minimize F. Note that losses are discarded and there is no explicit mention of any exploitation restrictions in the issue. So:

$$F = F_1\left(E_{s_1}\right) + F_2\left(E_{s_2}\right) + F_3\left(E_{s_{13}}\right) + \\ + \ldots + F_{N_s}\left(E_{s_{N_s}}\right) = \sum_{i=1}^{N_s} F_i\left(E_{s_i}\right), \tag{1}$$

where F is the objective function, F_i is the cost of i-th source, E_{s_i} is the i-th kind of energy demand and N_s is the number of energy carriers.

The above issue is an optimization problem that can be examined using appropriate methods.

Problem Formulation. Energy grid modelling. The energy network consists of the following sections: transportation, agriculture, industrial, residential, commercial and general.

In the energy grid, energy demand is calculated as a sum of sub networks of the grid:

$$EC_f = EC_1 + EC_2 + \ldots + EC_N = \sum_{i=1}^{N} EC_i, \tag{2}$$

where EC_f is the final energy consumption, N is the number of different sections of energy consumption and EC_i is the energy consumption of i-th section.

Firstly, the final energy consumption matrix based on different sections is determined as

$$E_1 = \left[EC_1\ EC_2\ \dots\ EC_i\ \dots\ EC_N\right]^T, \tag{3}$$

where E_1 is the final energy consumption matrix based on different sections.

Now final energy consumption matrix based on different energy carriers is determined as

$$E_2 = T_{1,2} \times E_1, \tag{4}$$

where E_2 is the final energy consumption matrix based on different energy carriers and $T_{1,2}$ is the transpose matrix of different sections to different energy carriers.

Energy losses is modeled as

$$E_3 = T_{2,3} \times E_2, \tag{5}$$

where E_3 is the final energy consumption based on different energy carriers considering losses and $T_{2,3}$ is the efficiency matrix.

At this stage, electrical energy is converted into energy carriers. The electrical energy of different power plants is determined as

$$E_u = T_u \times E_e, \tag{6}$$

where E_u is the electrical energy of different power plants, T_u is the separation matrix of electricity generation by different power plants and E_e is the total electricity demand.

Input fuel for different power plants is determined as

$$E_{e_1} = T_{u,f} \times E_u, \tag{7}$$

where E_{e_1} is the input fuel for different power plant and Electrical manufacturer carriers is determined as

$$E_{e_2} = T_{f,c} \times E_{e_1}, \tag{8}$$

where E_{e_2} is the electrical manufacturer carriers and $T_{f,c}$ is the conversion matrix of input fuel to energy carriers.

After simulation of electrical energy, final energy consumption is calculated as

$$E_4 = E_3 + E_{e_2} - E_e, \tag{9}$$

where E_4 is the final energy consumption after conversion of electrical energy.

At this stage, the process of refining crude oil is simulated as

$$E_{p_1} = T_p \times E_p, \tag{10}$$

where E_{p_1} is the energy carriers produced by refining, T_p is the separation matrix of produced products from refining crude oil and E_p is the maximum capacity of refineries.

After simulation of process of refining crude oil, final energy consumption is calculated as

$$E_5 = E_4 + E_p - E_{p_1}, \tag{11}$$

where E_5 is the final energy consumption after refining crude oil. Actually E_5 determines energy carriers in order to supply of energy demand.

Test energy grid. EC is applied to energy grid with 10 power units. Electrical network information is adapted from [25].

Simulation. After modeling the energy network, EC is simulated on energy grid.

The simulation results of EC on the energy grid studied are presented in Tables 1-3.

In Table 1, dynamic scheduling results are presented with equal paths to the maximum number of states per hour of the study. The second path, (S2) is identified as an appropriate strategy. The cost of EC in this path is equal by 8,554,182 USD. The need for energy carriers to provide final energy consumption is specified in Table 2. The result of economic distribution of electrical energy is presented in Table 3.

Table 1

The output result of dynamic planning in ten unit energy grids

Strategy						Hour
S6	S5	S 4	S3	S2	S1	
2	2	2	2	2	2	The initial state
3	3	3	3	3	3	1
3	3	3	3	3	3	2
3	3	3	3	3	3	3
3	3	3	3	3	3	4
3	3	3	3	3	3	5
4	4	4	4	4	4	6
4	4	4	4	4	4	7
9	9	9	9	9	9	8
9	9	9	9	9	9	9
9	9	9	9	9	9	10
10	10	10	10	10	10	11
10	10	10	10	10	10	12
10	10	10	10	10	10	13
9	9	9	9	9	9	14
9	9	9	9	9	9	15
9	9	9	9	9	9	16
9	9	9	9	9	9	17
9	9	9	9	9	9	18
9	9	9	9	9	9	19
9	9	9	9	9	9	20
9	9	4	4	4	4	21
9	6	4	4	3	3	22
7	6	4	4	3	3	23
7	6	5	4	3	2	24
8,557,932	8,557,192	8,557,153	8,554,502	8,554,182	8,555,398	Cost (USD)

Table 2

The need of energy carriers in ten unit energy grids

8	7	6	5	4	3	2	1	Hour
3721.1	3721.1	3721.1	3721.1	3721.1	3721.1	3721.1	3721.1	Petroleum
51.78965	44.67028	37.55091	23.31218	16.19281	1.95407	–12.2847	–19.404	Liquid gas
–350.552	–365.265	–354.657	–429.906	–466.355	–539.254	–612.154	–647.68	Fuel oil
–11.7441	–61.1345	–123.351	–210.1	–253.46	–340.182	–426.903	–470.252	Gas oil
17.72885	1.640607	–14.4476	–46.6241	–62.7124	–94.8888	–127.065	–143.154	Kerosene
405.1893	363.9642	322.7392	240.289	199.0639	116.6137	34.16357	–7.06152	Gasoline
53.06305	50.85209	48.64113	44.2192	42.00824	37.58632	33.1644	30.95344	Plane fuel
4380.603	4190.728	3988.239	3615.204	3432.123	3065.959	2699.796	2519.415	Natural gas
26.60254	25.4941	24.38566	22.16878	21.06034	18.84346	16.62658	15.51815	Coke gas
58.79772	56.34781	53.89791	48.9981	46.54819	41.64838	36.74857	34.29867	Coal
16	15	14	13	12	11	10	9	Hour
3721.1	3721.1	3721.1	3721.1	3721.1	3721.1	3721.1	3721.1	Petroleum
30.43155	51.78965	66.02839	80.26713	94.50586	87.3865	80.26713	66.02839	Liquid gas
–459.901	–350.552	–275.868	–198.861	–135.511	–158.969	–198.861	–275.591	Fuel oil
–141.826	–11.7441	74.99814	161.7678	260.843	205.169	161.7678	75.0014	Gas oil
–30.5359	17.72885	49.90533	82.0818	114.2583	98.17004	82.0818	49.90533	Kerosene
281.5141	405.1893	487.6395	570.0897	652.5398	611.3148	570.0897	487.6395	Gasoline
46.43017	53.06305	57.48497	61.90689	66.32881	64.11785	61.90689	57.48497	Plane fuel
3831.358	4380.603	4751.988	5130.168	5531.033	5323.32	5130.168	4752.798	Natural gas
23.27722	26.60254	28.81941	31.03629	33.25317	32.14473	31.03629	28.81941	Coke gas
51.448	58.79772	63.69753	68.59734	73.49714	71.04724	68.59734	63.69753	Coal
24	23	22	21	20	19	18	17	Hour
3721.1	3721.1	3721.1	3721.1	3721.1	3721.1	3721.1	3721.1	Petroleum
–5.1653	9.073439	37.55091	66.02839	80.26713	51.78965	37.55091	23.31218	Liquid gas
–595.486	–548.095	–423.452	–275.868	–198.861	–350.552	–423.452	–496.351	Fuel oil
–370.456	–277.548	–98.4652	74.99813	161.7678	–11.7441	–98.4652	–185.186	Gas oil
–110.977	–78.8006	–14.4476	49.90533	82.0818	17.72885	–14.4476	–46.6241	Kerosene
75.38865	157.8388	322.7392	487.6395	570.0897	405.1893	322.7392	240.289	Gasoline
35.37536	39.79728	48.64113	57.48497	61.90689	53.06305	48.64113	44.2192	Plane fuel
2913.867	3278.051	4014.44	4751.988	5130.168	4380.603	4014.44	3648.277	Natural gas
17.73502	19.9519	24.38566	28.81941	31.03629	26.60254	24.38566	22.16878	Coke gas
39.19848	44.09829	53.89791	63.69753	68.59734	58.79772	53.89791	48.9981	Coal

Table 3

The electrical energy economical distribution within the energy grid

Unit 10	Unit 9	Unit 8	Unit 7	Unit 6	Unit 5	Unit 4	Unit 3	Unit 2	Unit 1	Hour
0	0	0	0	0	0	0	129.9054	150	420.9897	1
0	0	0	0	0	0	0	130	165.9591	455	2
0	0	0	0	0	0	0	130	266.087	455	3
0	0	0	0	0	0	0	130	366.2149	455	4
0	0	0	0	0	0	0	130	416.2788	455	5
0	0	0	0	0	0	61.40668	130	455	455	6
0	0	0	0	0	0	111.4706	130	455	455	7
0	54.94904	10	25	78.91501	25	20	129.9395	403.1555	454.5755	8
0	54.92522	38.19602	25	79.91727	25	40.51524	129.8847	454.393	453.831	9
0	54.99011	46.54565	75.69185	79.97855	25	129.9675	129.966	454.8779	454.8368	10
55	55	55	85	80	51.98213	130	130	455	455	11
55	55	55	85	80	157.1164	130	130	455	455	12
31.11385	55	55	85	80	25.80435	130	130	455	455	13
0	55	46.5999	25.09276	80	25.18803	130	130	455	454.9096	14
0	50.46745	10	25	42.35772	25	20	129.0834	452.7482	446.8778	15
0	54.57776	10	25	75.61226	25	20	129.572	260.4829	451.0978	16
0	54.58248	10	25	75.74856	25	20	129.4813	209.902	451.5645	17
0	55	10.06585	25.04071	80	25.08315	20.12963	130	401.2152	455	18
0	55	46.61355	25.03679	80	25.13997	130	130	455	455	19
0	53.36535	10	25	79.89353	25	70.70835	129.7906	454.3342	453.5704	20
0	0	0	0	0	0	61.40668	130	455	455	21
0	0	0	0	0	0	0	130	316.1509	455	22
0	0	0	0	0	0	0	130	216.023	455	23
0	0	0	0	0	0	0	130	216.023	455	24

Conclusions.

Energy Commitment (EC) was introduced as a planning of energy carrier based on energy consumption. EC is to determine the most appropriate pattern for using energy resources to meet energy demand, firstly, to meet technical requirements, and secondly, to be the most economical.

The energy grid including different sections was modeled in matrix form. EC was simulated on the one energy grid with ten power plants and result was presented. Different combinations of power plants are available to provide final energy consumption. Due to the different fuel inputs to each power plant, there are different combinations of energy carriers. The proper combination of energy carriers is determined to provide final energy consumption using the dynamic programming method.

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