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EFFECT OF LOSS PENALTY FACTOR ON UNIT COMMITMENT

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Abstract- Minimizing the cost of production is very important for generating companies. Considering all the influential factors for seeking a correct solution for the unit commitment (UC) problem to minimize the generation cost is of great importance and plays an undeniable role in this case. Considering the losses and its distribution in a power system is one of the important factors in solving the UC problem. There are different methods to explain the losses in the system. One of the best methods is the use of Loss Penalty Factor (LPF). This article is to offer an easy and quick way for calculating LPF. Approximations used in this article highlight this article by far from accuracy and response time perspective. Consequently, it leads to obtain LPF of generating units accurately and in a very short time. The effects of these coefficients in solving the UC problem on the IEEE118 sample network have also been searched.

Keywords: Loss Penalty Factor (LPF), Transmission Loss, Unit Commitment (UC).

I. INTRODUCTION

In fact the purpose of unit commitment is to minimize the cost function of electrical energy production and consequently solve the cost function by applying mathematical methods. It could be specified that hydro or steam power plants should be committed in a specific period of time. This cost function that from now on is called the objective function, is dependent on output power of each generating unit and its production cost curve [1].

Nowadays, in most countries, electrical industry in all its aspects, from generation to selling energy to retailing customer, is operated by private companies. In this environment decreasing production cost as much as possible is of greater importance [2, 3]. For this purpose, correct explanation of UC problem and considering most of the affecting items which are not often considered in the UC is energy loss in the network. Energy loss, in the transmission line is of special importance in Economic Dispatch (ED) and it is known that Economic Dispatch is the main core in solving the UC problem [1, 4].

The importance of energy loss in the network is more obvious when it is observed during solving of UC problem, because considering this item, it is possible that some generating units go from off state to on state or vs. This has a direct impact on the coefficients of LPF and also LPF has direct impact on Economic Dispatch that also again has direct impact on UC problem in the net period and this cycle will continue for a complete period of UC problem and major changes in result are probable [5].

In this article, first UC problem is expressed and then the easiest method of calculating LPFs is proposed. In order to simplify the calculation of LPF some cases are considered whose impacts on the real amount of LPF are deal with in the fourth section. Then the effects of arrival or exit or changes in output power of a unit on the LPF are shown and finally the results of solving UC on a test system with and without considering LPF are presented.

II. UC PROBLEM AND LPF CALCULATION METHOD

A power network usually includes many water and steam power plants and in every moment it should be able to provide the whole load of net. In every network, in addition to existing load, there should be some percentage of loads as reserve power, i.e. the producing units should be ready to produce this amount of load in every moment. Expense function of produced energy in the interval is obtained by the Following relation [5, 6].

$$C=\sum_{t=1}^{T}\sum_{i=1}^{I}(C_{ti}(P_{ti}(t))+S_{ti}(t)+\sum_{j=1}^{J}S_{hj}(t) \quad (1)$$

$$\sum_{i=1}^{I}P_{ti}(t)+\sum_{j=1}^{J}P_{hj}(t)=P_d(t),\quad t=1,2,...T \quad (2)$$

$$\sum r_{ti}(P_{ti}(t))+\sum r_{hj}(P_{hj}(t))\geq P_r(t),\quad t=1,2,..T \quad (3)$$

The equations are usually considered in most of the methods of UC solving; but the power losses in the transmission network should be added to these relations. Equation (2) is also rewritten as follows:

$$\sum_{i=1}^{I}P_{ti}(t)+\sum_{j=1}^{J}P_{hj}(t)=P_d(t)+P_l(t),\quad t=1,2,...T \quad (4)$$

Now the purpose is the calculating of LPF. Considering the following equations, which are related to Economic Dispatch subject [6, 7, 8].

$$\lambda_i = \frac{1}{1-LPF_{th,t}} \cdot \frac{\partial C}{\partial P_{ti}(t)} \quad (5)$$

$$LPF_{th,t} = \frac{\partial P_l(t)}{\partial P_{ti}(t)} \quad (6)$$

The λ is used in Economic Dispatch subject. In the last equation the relation between losses of the system and LPF is shown. Values of LPFs in each system are dependent to state of that system and the configuration of generating units.

Because of high capacity and also too many problems for turning off, the hydro power plants are rarely exited from the system completely. On the other hand, their efficiency, even in so low power, is very high and they don’t have any additional cost for working in low power. So in solving the UC problem the hydro power plants are removed completely because it is clear that in order to minimize the production cost, hydro power plants should work with their maximum capability. For this reason, LPF subject is only related to thermal power plants.

For computing the coefficient of losses the following algorithm can be used: one bus in the system is selected as the reference bus and its power amount is changed a little. With these changes, there will be a change in production share of all units. LPFs are resulted from the flowing relation [3].

$$LPF_{th,t} = \frac{\partial P_l(t)}{\partial P_{hi}(t)} \approx 1 + \frac{\Delta P_r}{\Delta P_{th}} \quad (7)$$

To compute the ΔP_{th}, change in the output power of every generator as a result of every little change in the power of the reference bus, a power flow analysis should be done over the system.

There are various methods for power flow analyses. Newton-Raphson’s method can offer proper responses with match care. An appropriate way to decrease calculation time is to ignore voltages of buses in Jacobean set, for this purpose, the voltage of all buses is considered equal to the reference voltage. In this article the Fast-decoupled method is used for power flow analysis and voltage of all buses are assumed to be equal. In the next season the errors resulting from this simplification are going to be discussed.

III. TEST SYSTEM

In order to consider the effect of performed simplifications and also to analyze the impact of LPF on UC, power system is considered as the example. The test system used in this article is based on the modified IEEE118 system, which is obtained from reference [9]. Table 1 shows system demand data and Table 2 explains generator characteristic. The line flow limits for all lines are set to 300 MW. The voltage magnitude at each bus is bounded from 0.9 to 1.1 pu.

Table 1. System demand data

Hour	D^t	R^t	Hour	D^t	R^t
1	4242	211	13	4895	245
2	3916	196	14	4786	239
3	3698	185	15	4732	237
4	3589	179	16	4732	237
5	3481	174	17	4950	247
6	3484	174	18	5438	272
7	3589	179	19	5385	269
8	3807	190	20	5276	264
9	4351	218	21	5112	256
10	4786	239	22	5003	250
11	4895	245	23	4732	237
12	4950	247	24	4406	220

Table 2. Generator characteristic

No	α_{i0}	α_{i1}	α_{i2}	P_{max}	P_{min}
1	0.02533	25.5472	24.3891	12	2.40
2	0.01561	37.9637	118.9083	20	4.00
3	0.01359	37.7770	118.4576	20	4.00
4	0.01161	37.9637	118.9083	20	4.00
5	0.01059	38.7770	119.4576	20	4.00
6	0.01199	37.5510	117.7551	20	4.00
7	0.01261	37.6637	118.1083	20	4.00
8	0.00962	13.5073	81.8259	20	4.00
9	0.00876	13.3272	81.1364	76	15.20
10	0.00895	13.3538	81.2980	76	15.20
11	0.00932	13.4073	81.6259	76	15.20
12	0.00623	18.0000	217.8952	100	25.00
13	0.00599	18.6000	219.7752	100	25.00
14	0.00612	18.1000	218.3350	100	25.00
15	0.00588	18.2800	216.7752	100	25.00
16	0.00598	18.2000	218.7752	100	25.00
17	0.00578	17.2800	216.7752	100	25.00
18	0.00698	19.2000	218.7752	100	25.00
19	0.00473	10.7154	143.0288	155	54.25
20	0.00481	10.7367	143.3179	155	54.25
21	0.00487	10.7583	143.5972	155	54.25
22	0.00259	23.0000	259.1310	197	68.95
23	0.00260	23.1000	259.6490	197	68.95
24	0.00263	23.2000	260.1760	197	68.95
25	0.00264	23.4000	260.5760	197	68.95
26	0.00267	23.5000	262.1760	197	68.95
27	0.00261	23.0400	260.0760	197	68.95
28	0.00150	10.8416	276.0575	350	140.00
29	0.0153	10.8616	177.0575	350	140.00
30	0.00143	10.6616	176.0575	350	140.00
31	0.00163	10.9616	177.0575	350	140.00
32	0.00194	7.4921	310.0021	400	100.00
33	0.00195	7.5031	311.9102	400	100.00
34	0.00196	7.5121	312.9102	400	100.00
35	0.00197	7.5321	314.9102	400	100.00
36	0.00199	7.6121	313.9102	400	100.00

IV. ERROR RESULTED FROM SIMPLIFICATIONS USED IN POWER FLOW METHOD

The results of calculations on the test system are shown in Figures 1 and 2. In Figure 1 the effect of simplifications on all the buses is shown. As it can be seen, in this condition the error of 45% of calculations coefficient is less than 2%; more than 20% of calculated coefficient have an error less than 3%; and nearly non of the calculated coefficients have an error more than 5%, that could be acceptable in regards to the decreased volume of calculation and time of calculation.

The conspicuous note about simplifications is indicated in Figure 2. It should be noted that only LPFs of the buses which contain thermal units are considered. Figure 2 shows the percentage error related to these buses. It can be seen that more than 50% of these calculations have the error less than 2% and nearly no calculated parameter has an error more than 4% from its real value that shows the accomplished simplifications don't decrease accuracy a lot. Although for the calculation of these coefficients a bus is selected as the reference bus, the researches show that the selection of reference bus doesn't have much effect on the values of LPFs. With a very excellent approximation, it can be supposed that with the change of the reference bus, all calculated factors would be multiplied by a same coefficient [7, 8].

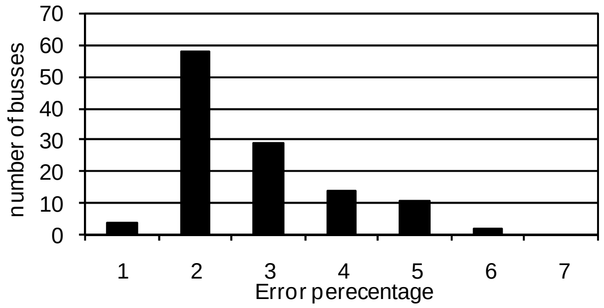

Figure 1. The error percentage resulted from simplifications in all buses

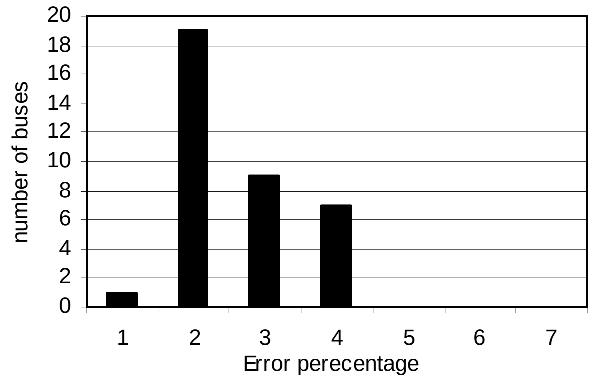

Figure 2. The error percentage resulted from simplifications in the buses contained thermal generator

V . IMPACT OF LPF ON THE PRODUCTION SHARE OF GENERATING UNITS AND UC

There is an important point in the calculations of LPFs and the use of it in programming of generation units, and it is the change of LPF of a unit due to the change in its output power or the change in the output power of other units.

During load change of a unit, LPF of that unit increases progressively and with high gradient and also other units encounter the increase of LPF whit a gradient less than the gradient related to the major unit. In Figure 3 LPF of a sample unit (the generator no 32) in the network subject for load change from no load (0%) to full load (100%), has been shown that is indicator of an increase about 40% from the zero loads till the name load.

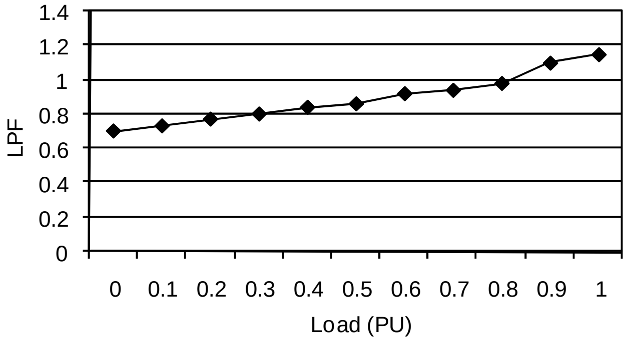

Figure 3. The change of LPF of a unit from no load to full load

The change of the LPF of the units is an important subject in the solving of UC problem considering the arrival or the exit of a unit to and from the network resulted in great changes of the LPF of the all units. So in the arrival of a unit all the units encounter with load changes, specially, the units which are connected to many lines or the high impedance lines are faced with the great load change. Therefore, it is possible for them to encounter a big load fall and exit from the pivot. According to the previously presented facts, for the solving of UC problem and with considering all the cases, the following algorithm is proposed:

1. Default values are allocated to thermal generating units as LPFs. This quantity can be a fix assumed one like 0.9 but it is better to use from previous amounts of LPFs as primary amounts of each new step.
2. For a possible condition of arrangement of generating units and based on the LPF of previous phase Economic Dispatch is accomplished.
3. With the obtained amount for the power of each unit and according to the method stated in the first section, the new values of LPFs are calculated.
4. With the new value of LPF again Economic Dispatch is accomplished in order to find the production share of each generation unit.
5. All the above processes are repeated for all the possible conditions.
6. The obtained values for the output power of units are given to the program of solving the UC problem until with the aid of a heuristic method the best condition is selected.

This algorithm is the least work to get the solution. If the processes in the items 2 and 3 are repeated more, the obtained solution for the power of each unit and the value of LPF will be better and more accurate.

In order to analyze change results in the impact of LPF of unit commitment, the offered algorithm was applied to the IEEE118 test system and for the hour of 18-19. Figures 4 and 5 show the results of these analyses representing the state of 36 generating unit during the period from 18-19. In these figures the horizontal axis shows the unit number and the vertical axis shows the state of the unit during this period. Figure 4 shows the result obtained from the performance of unit commitment without consideration of LPF [7] as well as Figure 5 shows the result with due regard to LPF.

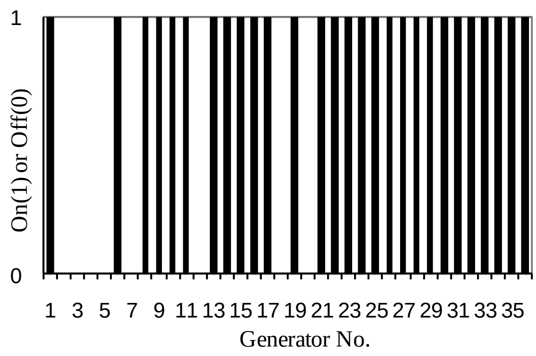

Figure 4. UC without consideration of LPF on hour 18-19

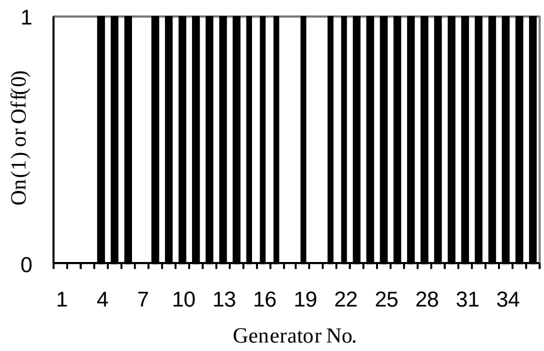

Figure 5. UC with consideration of LPF on hour 18-19

Hence the initial states of both conditions (with LPF and without LPF) become the same and with the comparison of external results for the hour 18-19, the importance LPF application could be realized. As it is perceived with due regard of LPF, unit No. 1, that is a small unit (with the power of 2.4-12MW), should not be turned on and instead, units No. 4 and No. 5 should be turned on. Of course it is clear that the production share of all on-units will be involved in some changes.

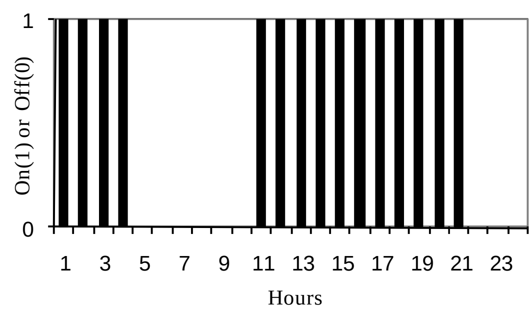

Figure 6. UC without consideration of LPF on 1 day (Generator 17)

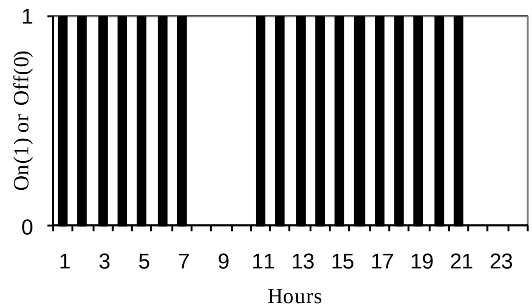

Figure 7. UC with consideration of LPF on 1 day (Generator 17)

The analysis shows that unit 17 has the largest change in its output power, Figure 6 and 7 represent this change for unit 17 as well. In these figures the horizontal axis indicates 24 hours period of time and the vertical axis shows the state of the unit (up or down). When the value is 1 it means that the unit is on during the related hours and if the value is 0 it means the unit is off during the related period.

As it can be seen during the period from 7 till 24 the results are the same. If LPFs are not considered then unit 17 should be on in the duration from 1 till 7. But without considering LPFs unit 17 should be kept on from 1 till 7. It should be pointed out that this change in the arrangement is not only because of considering the losses, but also the way the losses are distributed within the network.

VI. CONCLUSIONS

Whereas the purpose of the performance of the Unit Commitment and Economic Dispatch program is to utilize the network in the most possible economic condition, it is necessary to consider all the parameters, which somehow have an influence on the economical condition of system. One of These parameters is the amount of losses in the network which depends on the factors such as topology of the network and arrangement of generation units. With the change in the output power of the generators in the network, the transmitted power through the lines, and as a result, the amount of the losses of the system will change.

Consequently there is the possibility that with due regard to the losses of the transmission system a different unit commitment schedule is reached. In this research the study is done on the IEEE118 test system and it was observed that the obtained program with due regard to the losses is different from when the losses are not considered.

NOMENCLATURES

I : The number of gas and heat units
J : The number of water units
C : The whole production expense
$C_{ti}(P_{ti}(t))$: The fuel expense of its unit
$P_d(t)$: The load of net in t moment
$P_r(t)$: The cycling reserve load
$P_{ti}(t)$: The production power of i heat unit
$P_{hj}(t)$: The production power of j water unit
$r_{ti}(P_{ti}(t))$: The reserve power of i water unit
$r_{hj}(P_{hj}(t))$: The reserve power of j water unit
$S_{ti}(t)$: The starting expense of i heat unit
$S_{hj}(t)$: The starting expense of j water unit
t : The subtitle related to interval
T : The time of a complete period under consideration

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BIOGRAPHIES

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