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Determining the Spinning Reserve In Power Systems By Corrected Recursive PJM Method

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Abstract

Security for grids in the electric industry is very important to the power system. Dispatching a consistent high quality to customers is the main goal. There is a need for balance in power generation and power consumption.

Consumption forecasts do not meet load amounts and it tolerates consumption loads beyond actual amounts to be sure the spinning reserve is necessary not only in order to be secure but also because of need for accurate calculating.
In this research the amount of the Spinning Reserve in an instant system by PJM method will be determined and then, with an innovative recursive model, optimize and correct the determined spinning reserve.

Introduction

Available generation capacity in the system contains the difference of generation and consumption. The adequate spinning reserve is one of the main parameters to supply the security of the power system operation. [1], in order for available risk in the system to be minimized and supply the security of the system to minimize the cut off in system which is caused by unsecured forecast of load and exiting the units out of circuit by accidental event. [2] there are many ways to determine the reserved power in the system.
1- Pennsylvania, New Jersey, Maryland
2- Capacity Outage Probability Table
3- Forced outage rate
4- Outage replacement rate
5- Large
In the LU method, capacity of reserved power is being selected according to the largest unit of system capacity [3].
In this way in some articles for more security it is being selected even two times more than the largest unit capacity [4]. In the LU+PL method the reserved power is being

selected by a certain percentage of annual peak load added by the largest unit in the system [3]. In SCR the scenario is being defined and the reserved power is selected in order for the system to be able to withstand an accident. The LU and PL+LU methods must both do the same. At the certain method for the same size systems with different parameters a unit criterion exertion in determines the capacity of system reserve an equal reserve will be achieved which is certainly incorrect.

Meanwhile some of the stochastic methods are available, in which we can calculate the security ability of a system properties. One of these stochastic methods to calculate the spinning reserve is a method based on the risk calculation.Risk is being estimated by the probability of when the system can not supply intended load[6]. In this research one of the stochastic methods have been used in order to determine the spinning reserve which is based on the assessing the reliability of the system. This method is being done with the COPT table production and determining the amount of system risk compared with the allowed risk amount. This method is a suitable and flexible one in determining the spinning reserve. The system and its allowed risk amount tolerance and the amount of the spinning reserve is being determine.

In this research in order to determine the amount of available risk in the system, software has been defined and a correction has been applied into the PJM method. In the second part of this article the methods of determining the spinning reserve will be covered. The PJM method will be explained. In the 3rd part the amount of spinning reserve based on the mentioned method by the produced software for an instance grid will be determine. At the 4th part the way of dispatching the spinning reserve onto an instance grid's units will be calculated and presented. The result will be assessed in the 5th part. Finally, in the 6th part the conclusion and suggestion will be presented.

Determining the Spinning Reserve by PJM method and Markova model [9]

For each unit in this model there are 2 states. The unit is working with its highest capacity and it is in the circuit or that is out of function and it is out of circuit, they are UP state (or 0) state and down (or 1) state respectively.

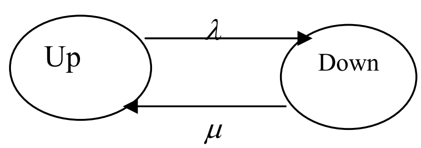


Figure1: the two states model for a unit

Now according the upper definition the below equation is achievable:

$$P_{down} = \frac{\lambda}{\lambda+\mu} - \frac{\lambda}{\lambda+\mu} e^{-(\mu+\lambda)t} \quad \textbf{(1)}$$

General Conceptual Title for FOR, ORR

FOR represents unintended exit speed

ORR represents replacing the exiting objects speed. If the time of the equation in Figure1. assume to be ∞, Pdown will be posed for programming and called FOR (unintended exit speed) and the Pdown formula turns into the formula below:

$$P_{down} = FOR = \frac{\lambda}{\mu + \lambda} \quad \textbf{(2)}$$

Pi(t) represents probability of the system to be in position i in time t.
T represents lead time.
λ represents being out of function speed for a generation unit speed
μ represents repairing speed (transition from being out of function into safe)
At the operation time because of none-availability of repairing this amount will be assumed to be zero ($\mu \to 0$) and its name is ORR. The Pdown (or ORR) formula is below.

$$P_{down} = 1 - e^{-\lambda T} \quad \textbf{(3)}$$

Because of λ is a very small in lead time this abstracted equation is in mind:

$$P_{down} = ORR = \lambda T \quad \textbf{(4)}$$

Equation 4 is known as ORR and shows the probability of not to replace the out of function unit in the lead time (T).

Determining the Spinning Reserve Power Value by Copt Table

The first column of output capacity, the second column of capacity in the system, the third column of capacity output probability, and the forth column of total probabilities are the system risk, and in the line where CAP.IN value equals load. The risk amount is obtained as per load and production value. To find total probabilities, forth column, the following formula can also be used.

P(X) = (1-U) P'(X) =UP'(X-C) **(5)**

P'(X) = assembling probability value
P(X) = assembling probability value (risk)
U =FOR or ORR value
X = output megawatt value
C = last output capacity value in each step

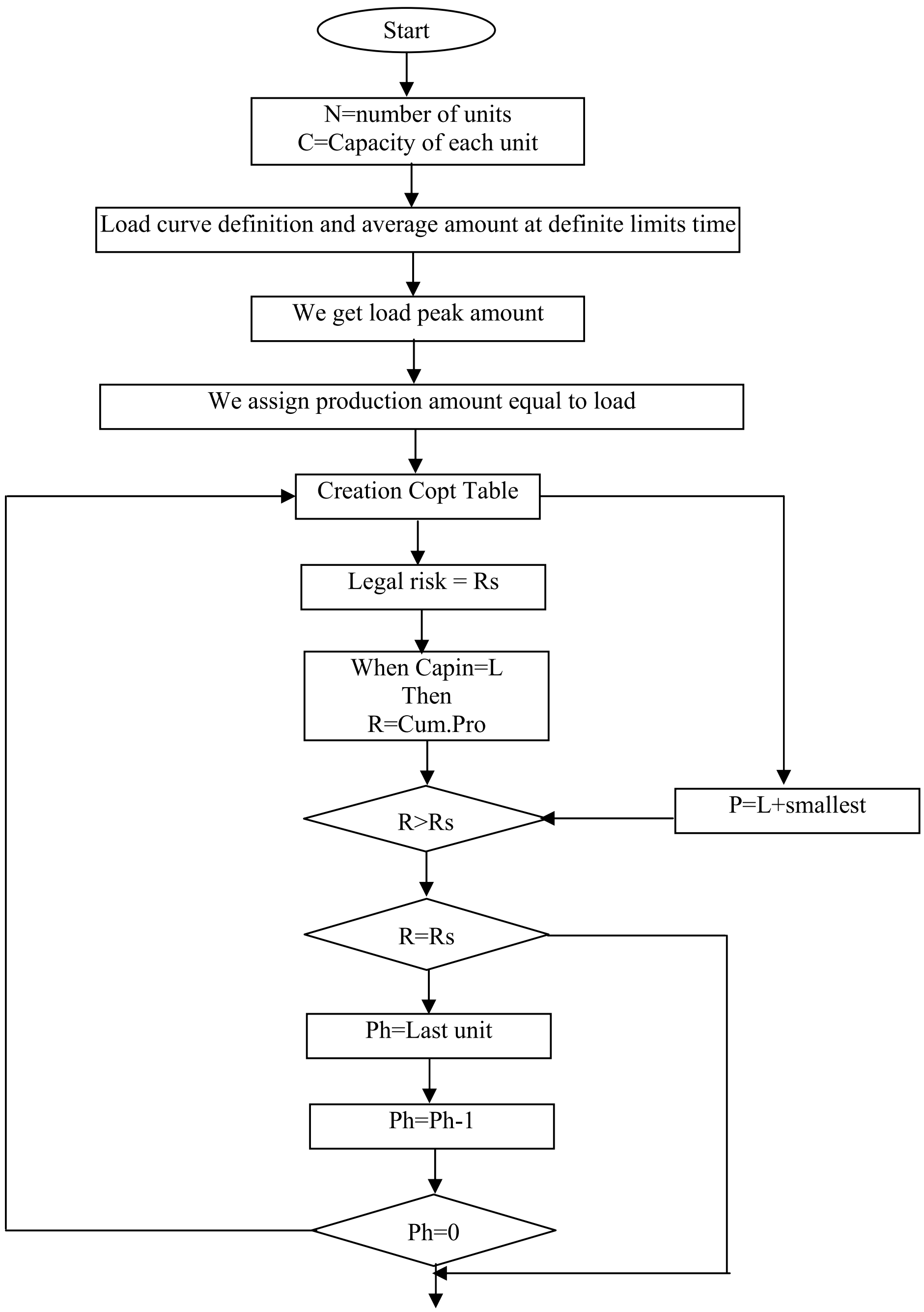
Table 1 COPT models parameter

CAP.OUT	CAP. IN	PROBABILITY	CUM.PRO
A_1	B_1	P_1	$P_1+P_2+P_3+P_4$
A_2	B_2	P_2	$P_2+P_3+P_4$
A_3	B_3	P_3	P_3+P_4
A_4	B_4	P_4	P_4

In the beginning, if output power is x ≤ 0, then P'(X) will be 1 and if P'(X) is 1 and x>0, then P'(X will be 0. If x=0, then P'(X) is one and if x>0, P(X) from previous stage will be replaced with P'(X), and if there is no X from previous stage, P'(X) will be 0.[7]

The Suggested Algorithm for Determining Reserve Power Amount

Since the obtained risk value may be too much largest unit is output as single megawatt by ready software until the risk in that production becomes the proper confidence capacity can be obtained in the system by less production and reserve. The flow table of applied algorithm will be draw and shown in next part.



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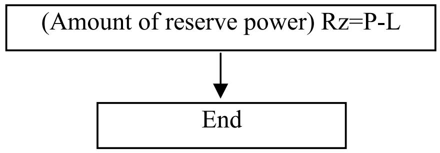

Figure 2: The suggested algorithm for determining reserve power amount by applying Copt table

Assimilation of Sample Network

The existing sample network is confidence capacity test (RTS) in IEEE [9] the single line diagram of which is indicated in figure 3. The system has 2(PV) generator bases, four (PQ) load bases, 9 transferring lines, and 11 production units. The least producing unit is 5MW and the most one is 40MW. The voltage level of system transfer lines in 230 KV and voltage changes is between 0.97-1.05PU. The most load system is 185MW, and the production installed capacity is 240MW. The other features are as follows:

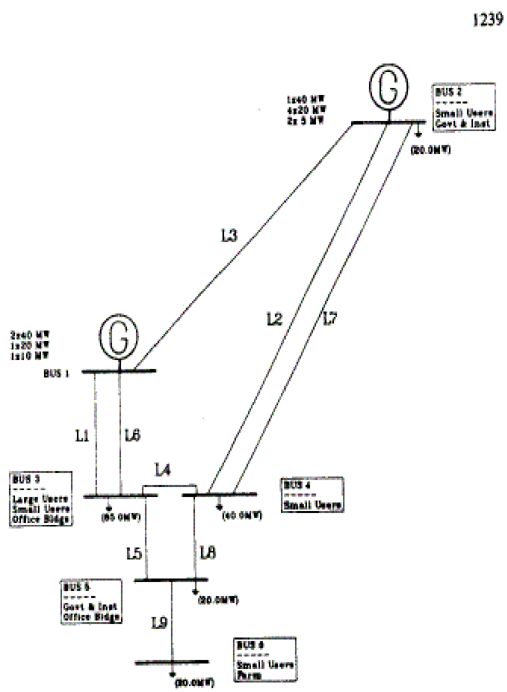

Figure 3: single line diagram of sample network

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Table 2- destruction rate of sample network units

Destruction rate per year	Obligation destruction rate	Number of each unit	Type	Unit size (MW)
2	0.010	2	Aqueous	5
4	0.020	1	Thermal	10
2.4	0.015	4	Aqueous	20
5	0.025	1	Thermal	20
3	0.020	1	Aqueous	40
6	0.030	2	Thermal	40

$$\lambda = \frac{\text{Destruction rate per year}}{8760}$$

Risk Amount as Per Production

The more the production, the less the risk. Figure 4 shows network risk upon production value. Copt table of productions from which the diagram numbers are extracted are calculated by software, and the amount of proper production per allowable risk [4] is 230 MW. By applying suggested method in this article with proper confidence capacity, the optimum calculated reserve power is reduced to 225 MW.

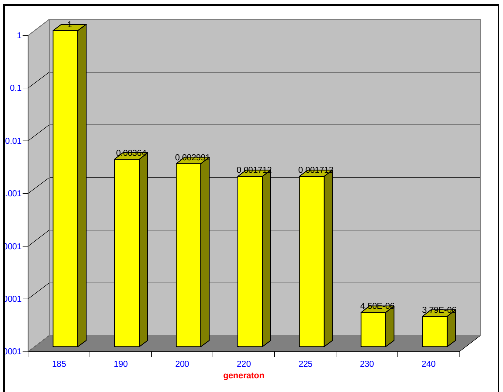

Figure 4: Risk amount as per production

Determining Reserve Power Value as Per Risk

By changing figurative risk amount of the system we may consider various we may reserves for system regarding the circumstances and destruction reply rate of sample network units according to values in table 4. The different values are shown in figure 5.

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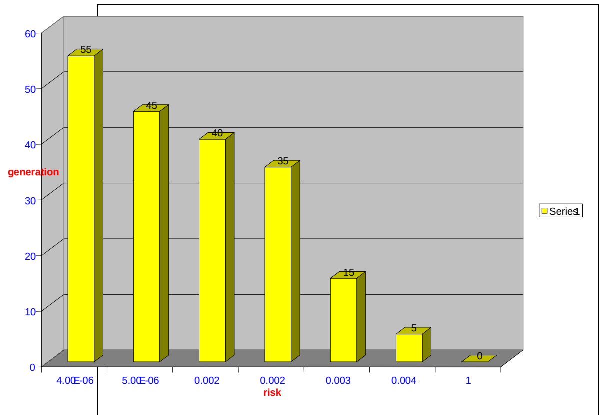

Figure 5: Reserve power value as per risk

The Method of Distributing Spinning Reserve Power in the System

Here, the amount of production led to proper risk for the system is considered. By considering 185 MW loads in system, load is performed on that part, so regarding the empty capacity remained for the units, the reserve amount is found. The reserve amount on each unit is also obtained as per reply rate of each unit. Finally, the most proper reserving distribution is the one that presents more reserve amount and less rely risk.

Table 3- Copt table for 185 MW

Cumulative	**In**	**Out**
1	185	0
0.002918	180	5
0.002691	165	20
0.001028	160	25
0.001028	145	40
2.18E-06	140	45
1.94E-06	125	60
2.36E-07	120	65
2.35E-07	105	80
4.44E-10	100	85
3.91E-10	85	100
3.41E-13	80	105
2.52E-13	65	120
1.37E-16	60	125
7.95E-17	45	140
3.04E-20	40	145
1.23E-20	25	160
3.56E-24	20	165
7.54E-25	5	180
1.72E-28	0	185

Table 4- Destruction reply rate of sample network units

MW/min reply rate	**Destruction probability with in 5 minutes**	**Number of units**	**MW**
20	0.0000190	2	5 (hyd.)
1	0.0000381	1	10 (th.)
20	0.0000228	4	20 (hyd.)
1	0.0000476	1	20 (th.)
20	0.0000285	1	40 (hyd.)
1	0.0000571	2	40 (th.)

$$\text{Destruction possibility Within 5 minutes} = \frac{5 \times \lambda}{8760 \times 60}$$

Studying the Results

To achieve proper confidence capacity and not have more reserve than necessary 225MW production is obtained in this research, 40 MW of which is for reserve power. This method delivers more accurate reply for reserve in the network compared to defined methods. It also supplies system confidence capacity and prevents extra reserve amounts in the system resulting in revenue expense increases. The method of distributing reserve power into the sample network is suggested in the appendix. It should be mentioned that the proper reserve distribution is the one that gives more required reserve amount with better reply risk. Table (5) is the most proper reserve power distribution for a sample network.

Conclusion

As it was seen, spinning reserve power value was calculated by one of the probable methods in this research .First the spinning reserve power amount was found by PJM method. Then regarding the fact that reserve power amount should not be surplus in the system for an economic exploitation, it is exited there from by single end software as a single MW, at first place where the obtained risk amount is less than allowable risk.

Regarding the advantages of this method, it is suggested that such a method is used for determining spinning reserve power amount of system in long term planning. It can also be applied in daily exploitations in an online way, especially in electricity market systems in order to find spinning reserve power amount for the system.

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Appendix

The tables (5) to (9) on appendix show distribution of spinning reserve on sample network units.
L: Load in island system,
G_i: Total capacity of system in situation i,
R: Reserve

G	(hyd.) 5	(hyd.) 5	(hyd.) 20	(hyd.) 20	(hyd.) 20	(hyd.) 20	(th.) 20	(hyd.) 40	(th.) 40	(th.) 35
L	5	5	0	0	20	20	20	40	40	35
R	0	0	20	20	0	0	0	0	0	0

G	(hyd.) 5	(hyd.) 5	(hyd.) 20	(hyd.) 20	(hyd.) 20	(hyd.) 20	(th.) 20	(hyd.) 40	(th.) 40	(th.) 35
L	5	5	20	20	20	20	20	0	40	35
R	0	0	0	0	0	0	0	40	0	0

G	(hyd.) 5	(hyd.) 5	(hyd.) 20	(hyd.) 20	(hyd.) 20	(hyd.) 20	(th.) 20	(hyd.) 40	(th.) 40	(th.) 35
L	5	5	20	20	20	20	20	40	0	35
R	0	0	0	0	0	0	0	0	5	0

G	(hyd.) 5	(hyd.) 5	(hyd.) 20	(hyd.) 20	(hyd.) 20	(hyd.) 20	(th.) 20	(hyd.) 40	(th.) 40	(th.) 35
L	5	0	20	20	20	20	20	40	40	0
R	0	5	0	0	0	0	0	0	0	5

G	(hyd.) 5	(hyd.) 5	(hyd.) 20	(hyd.) 20	(hyd.) 20	(hyd.) 20	(th.) 20	(hyd.) 40	(th.) 40	(th.) 35
L	5	5	0	20	20	20	0	40	40	35
R	0	0	20	0	0	0	5	0	0	0

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