

# **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 grid 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 grid system 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 needed in an instant system using the PJM method will be determined. Then, with an innovative recursive model, optimize and correct the determined spinning reserve.

## **Keywords**

*Power system, spinning Reserve, risk, management, security, Copt table*

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## **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.(Miller, R. 1981). In order to minimize risk in the system, the supply and security of the system is analyzed. To minimize system malfunction, which is caused by unsecured forecast of load and exiting the units out of circuit by accidental event, proper analysis must be done. (Gool, B., Mendes,DP. 1998) There are different methods to determine the reserved power in the system.

- Capacity Outage Probability Table
- Forced outage rate

- Outage replacement rate
- Pennsylvania, New Jersey, Maryland (PJM)
- Large Unit (LU)

In the LU method, capacity of reserved power is being selected according to the largest unit of system capacity.(Fotuhi Firuzabadi, M., Afshar, K. 2003)

In this way: articles for more security are being selected even two times more than the largest unit capacity.(Y.Y.Hsu, Y.Y. Lee, Y., Jien, J.-D.1990) 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.(Fotuhi Firuzabadi, M., Afshar, K. 2003) 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 all be applicable methods. A particular method for the same size systems with different parameters is determined by a unit criterion exertion that determines the capacity of system reserve. With this, an equal reserve will be achieved.

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 cannot supply intended load (Billinton, R. Nurul A. Chowdhury, 1988) 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 along with the amount of the spinning reserve is determined.

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 3<sup>rd</sup> part the amount of spinning reserve based on the mentioned method by the produced software for an instance grid will be determine. At the 4<sup>th</sup> 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 5<sup>th</sup> part. Finally, in the 6<sup>th</sup> part the conclusion and suggestion will be presented.

### **Determining the Spinning Reserve by PJM method and Markova model**

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. (R. Billinton, S. Kumar, N chowdhury, 1989)

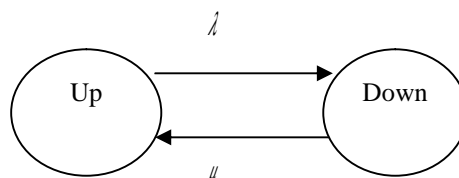


Fig.1: the two states model for a unit

Now according the upper definition the below equation is achievable:

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

***The 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 Fig.1 assume to be  $\infty$ , Pdown will be posed for programming and called FOR (unintended exit speed) and the Pdown formula turns into the formula below:

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

Pi(t) represents probability of the system to be in position i in time t.

T represents lead time.

represents being out of function speed for a generation unit speed

$\mu$  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 ( $\mu \rightarrow 0$ ) and its name is ORR. The Pdown (or ORR) formula is below.

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

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

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

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 fourth 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, fourth column, the following formula can also be used.

$$P(X) = (1-U) P'(X) + UP'(X-C) \quad (5)$$

$P'(X)$  = 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

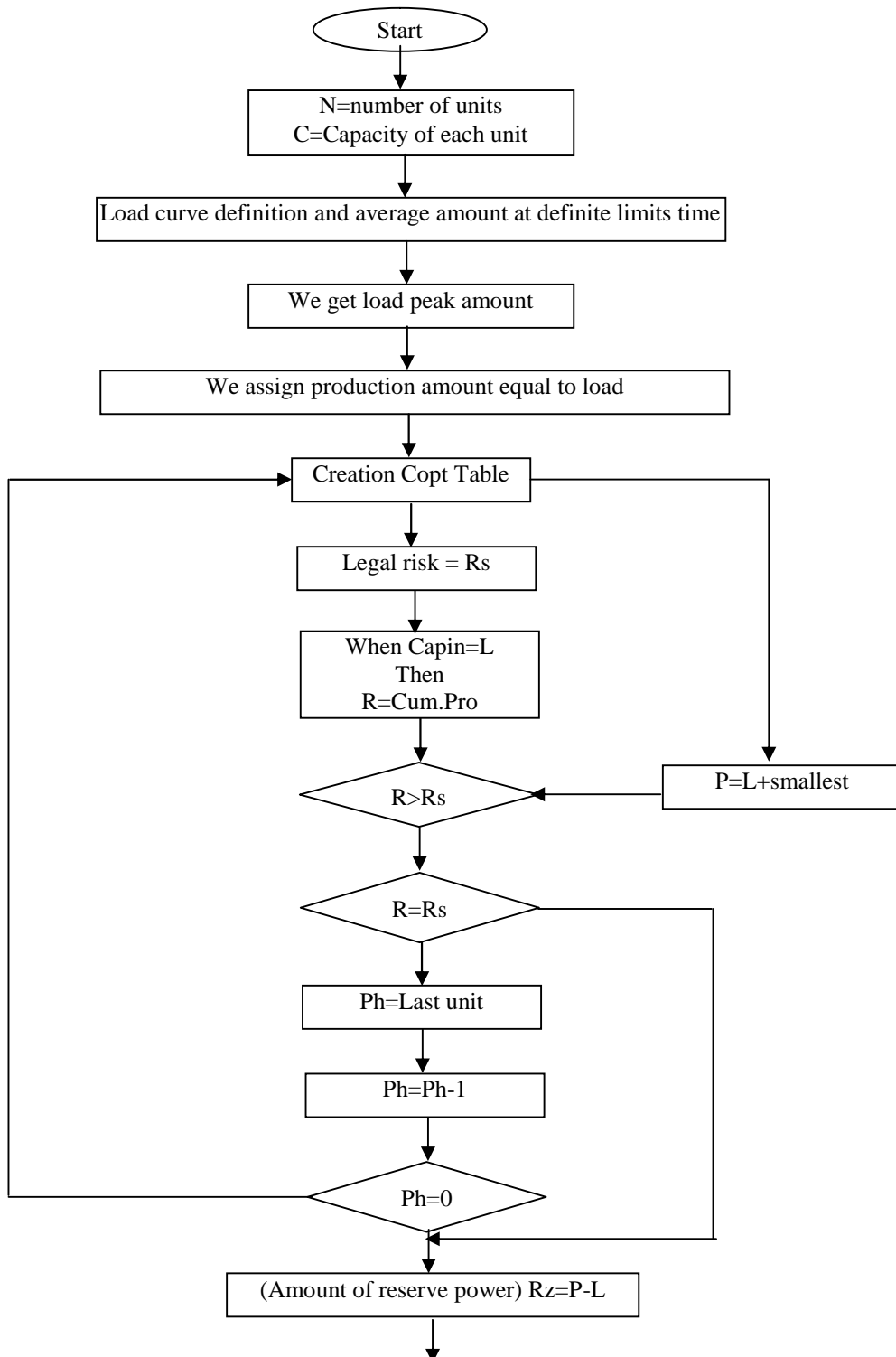
Table 1 COPT models parameter

CAP.OUT	CAP.IN	PROBABILITY	CUM.PRO
A <sub>1</sub>	B <sub>1</sub>	P <sub>1</sub>	P <sub>1</sub> +P <sub>2</sub> +P <sub>3</sub> +P <sub>4</sub>
A <sub>2</sub>	B <sub>2</sub>	P <sub>2</sub>	P <sub>2</sub> +P <sub>3</sub> +P <sub>4</sub>
A <sub>3</sub>	B <sub>3</sub>	P <sub>3</sub>	P <sub>3</sub> +P <sub>4</sub>
A <sub>4</sub>	B <sub>4</sub>	P <sub>4</sub>	P <sub>4</sub>

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. (R. Billinton, R. N. Allan, 1996)

### The suggested algorithm for determining reserve power amount

Since the obtained risk value may be too much, the largest unit output is calculated with software until the risk is reduced to a manageable level. The flow table of applied algorithm is shown below:



End
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Figure 2-The suggested algorithm for determining the reserve power amount is found by applying Copt table

### **Assimilation of sample network**

The existing sample network shows a confidence capacity test (RTS) in IEEE the single line diagram is shown 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:

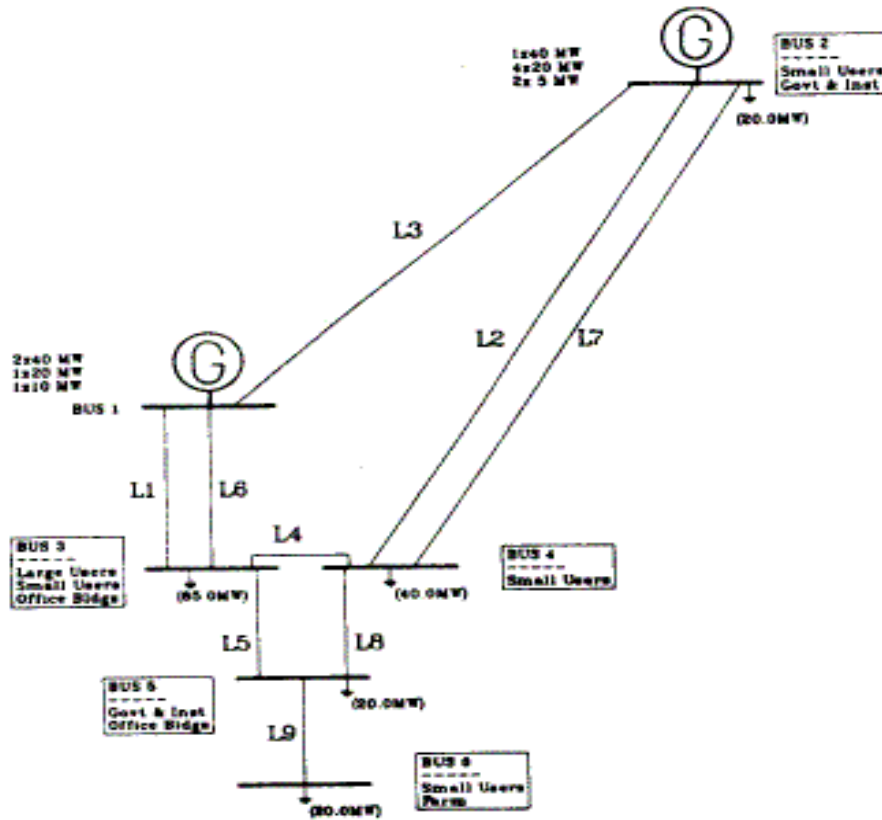


Figure 3- single line diagram of sample network

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

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

**Risk amount as per production**

The more the production, the less the risk. Figure 4 shows network risk versus 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 (Y.Y.Hsu, Y.Y. Lee, Y., Jien, J.-D. 1990) is 230 MW. By applying suggested method in this article with proper confidence capacity, the optimum calculated reserve power is reduced to 225 MW.

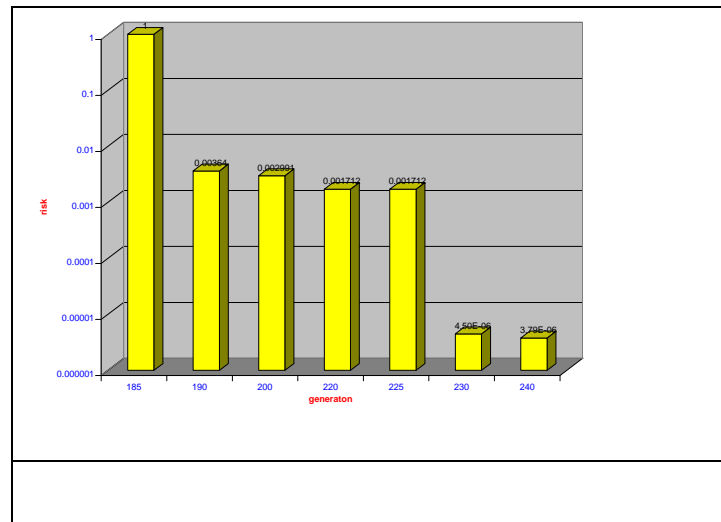


Figure 4- Risk amount as per production

#### *Determining reserve power value as per risk*

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

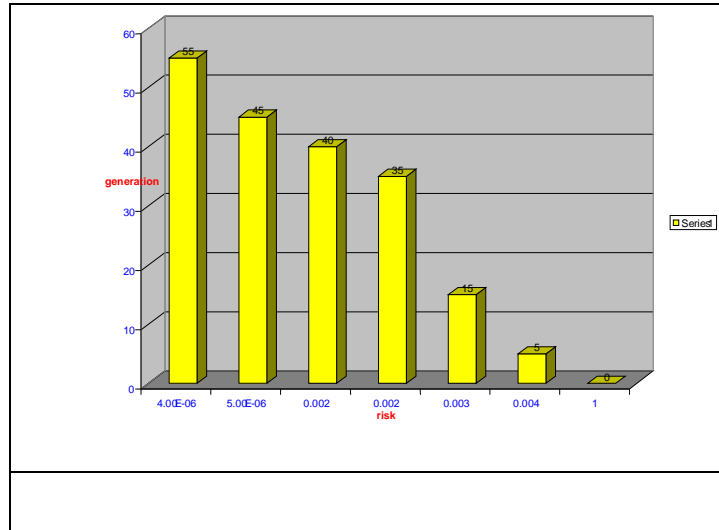


Figure 5- Reserve power value as per risk

### The method of distributing spinning reserve power in the system

Here, the amount of production led those results in proper risk for the system is considered. Considering 185 MW loads on the system, input and output figures are shown below in Table 3. The empty capacity remained for the system and the reserve amount was 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.)

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

### Examination of the results

To achieve proper confidence capacity and not have more reserve than necessary, 225MW production was found to be optimal in this research (40 MW of which is for reserve power). This method delivers efficient value for reserve in the network compared to other 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 a probability method. 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, software is employed is obtained to obtain optimal system values.

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 examinations of power capacity and output that maintains optimal system operation.

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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

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