System planning, EG2050 Probabilistic production cost simulation of electricity markets – L12

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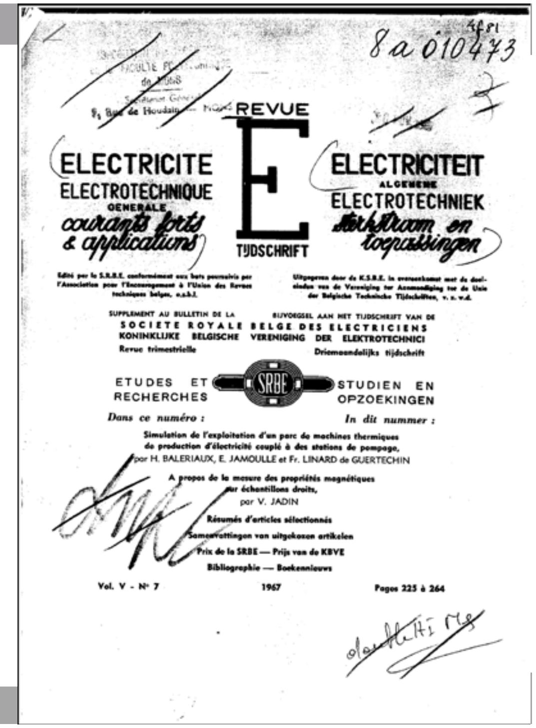
Probabilistic production cost simulation (PPC)

- Development started in the late 1960:th
- Analytical calculations
- A fast method but limitations concerning possibilities to include market details.



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Résumés d'articles sélectionnés

Samenvattingen van uitgekozen artikelen

Prix de la SRBE — Prijs van de KBVE

Bibliographie — Boekennieuws

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PPC model

Assume

- Perfect competition
- Perfect information
- Load is not price sensitive
- Neglect grid losses and limitations
- All scenario parameters can be treated as independent

Some of these assumption can be treated with some specific methods.

Calculation of system index - Basic idea

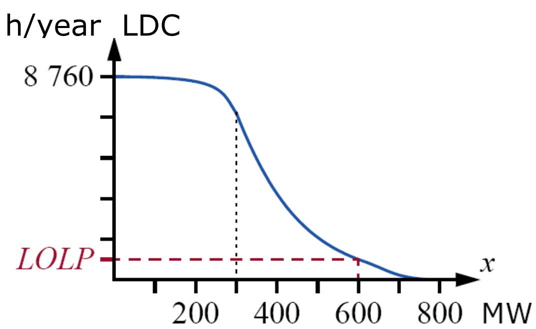
- Assume a system where all power plants are 100 % available.
- In this system it is easy to calculate the system indeces from the load duration curve, LDC

<u>Example</u>

- Load duration curve, LDC
- Two power stations (300 MW, always avialable, incremental operation cost β_1 and β_2 respectively, $\beta_1 \leq \beta_2$)

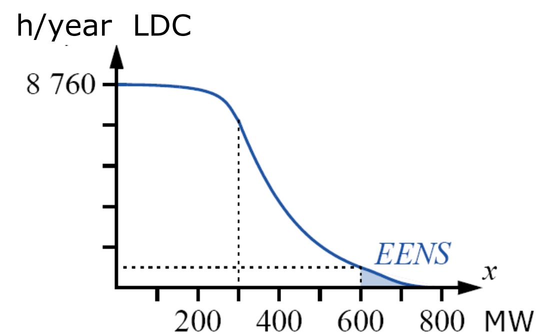
Calculation of system index - Basic idea

LOLP = LDC(600) = 876 h/year = 10%



Calculation of system index - Basic idea

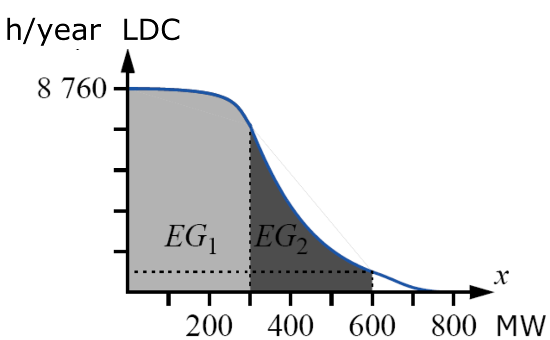
$$EENS = \int_{600}^{\infty} LDC(x)dx$$



Calculation of system index - Basic idea

$$ETOC = \beta_1 EG_1 + \beta_2 EG_2$$

Perfect competition ⇒ Unit 1 is used first, since $\beta_1 \leq \beta_2$



Load model

- We only study the total load in the system
- We assume that the load is price independent
- The load is represented by a scenarioparameter, D, which has a probability distribution which is data for the simulations
- In probabilistic simulation (PPC) the load is represented with the load duration curve.

Load model

- How to determine the load duration curve?
- It can not be calculated but it has to be estimated from historical data and forecasts.

- Alternative 1: Select a standardized function (e.g. normal distribution) and fit historical data + forecast to this one.
- Alternative 2: Calculate an LDC directly from available data + forecasts.

Load model – Alternative 2

- ***Definition 6.11.*** The load curve, $D(k)$, states the mean load per hour during a specified time period: $k = 1, \dots, T$.

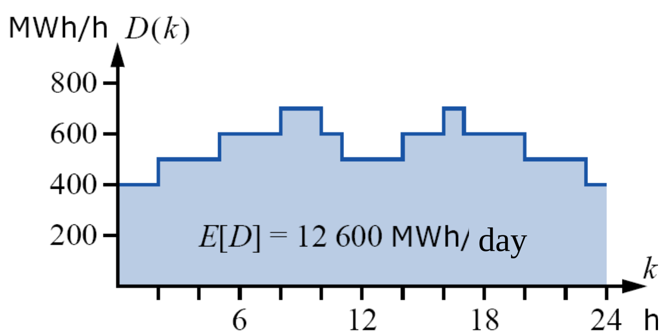
  D(k) = load hour k [MWh/h]

- ***Definition 6.12.*** The real load duration curve, $LDC_R(k)$, states the load level which is exceeded during k hours.

  LDC_R(K) = load level that is exceeded during k hours [MWh/h]

Load model – Alternative 2

Example 6.7

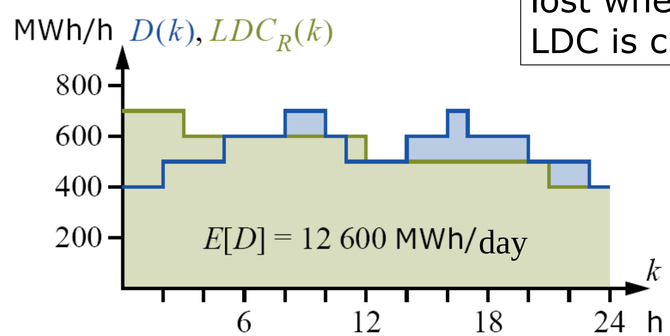


The expected value of the load corresponds to the area below the curve

Load model – Alternative 2

Example 6.7

Information is lost when an LDC is created!



The area below the real LDC is as large as the area below the load curve

Load model – Alternative 2

- ***Definition 6.13.*** The inverted load duration curve, *LDC*(*x*), states how many hours a certain load level *x* is exceeded.

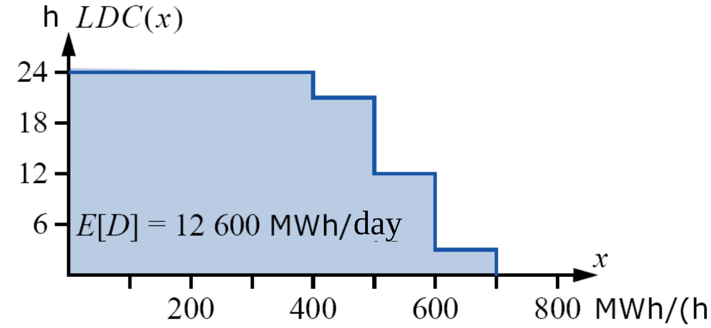
  LDC(x)=number of hours when the load level x is exceeded [h]

  By dividing LDC(x) with the length of the studied time period, the normalized LDC is obtained.

  The normalized LDC shows the probability distribution of the load during the studied period.

Load model – Alternative 2

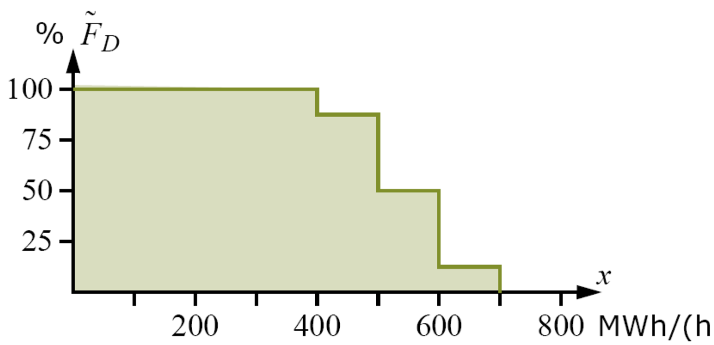
Example 6.8:



The area below the curve is still the same since only axes are changed

Load model – Alternative 2

Example 6.8:

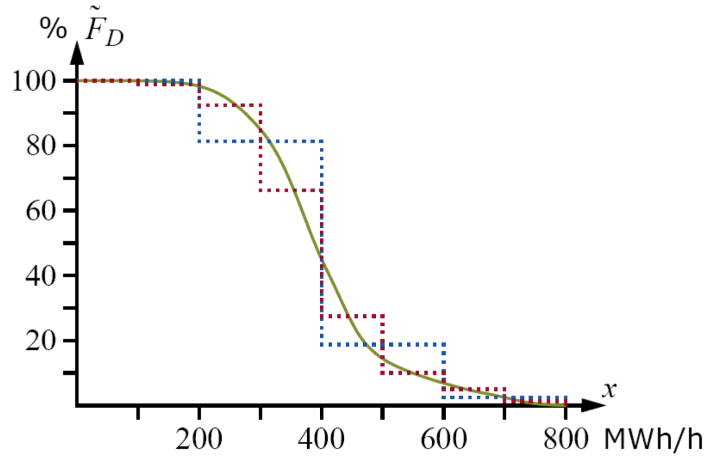


The area is now changed since the y-axes is divided with T. To get the correct expected value, the area has to be multiplied with T.

Load model – Practical aspect

- In reality the load is a continous stochastic variable
- To be able to calculate expected energy values, it is necessary to integrate the load duration curve, which means that some numerical methods have to be applied
- It is therefore suitable to use a discrete approximation of the LDC.

Load model – Practical aspect



Thermal power station model

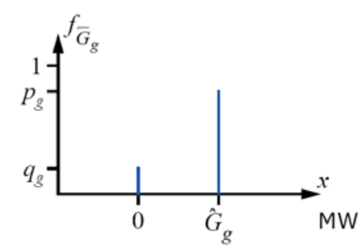
The model of the thermal power stations include:

- Installed capacity, $\hat{G}_g$.
- Production cost, $C_{Gg}(G_g) = \alpha + \beta G_g$. This means that we assume that the incremental production cost is independent of the production level, i.e., constant efficiency.
- Availability, p_g.

Thermal power station model

- A thermal power station is represented by a scenario parameter, $\overline{G}_g$ (available production capacity), with a distribution which is used as data for the simulation
- In probabilistic simulation a two state model is used for available capacity.

Thermal power station model



- The availability of a thermal power station can not be calculated, but has to be estimated from historical data and forecasts of the future.

Thermal power station model

- Estimation of availability

Definition 6.14. The Mean Time To Failure is calculated by

$$MTTF = \frac{1}{K}\sum_{k=1}^{K} t_u(k),$$

where K is the number of periods when the power plant is available and $t_u(k)$ is the duration of each of these periods.

Thermal power station model

- Estimation of availability

Definition 6.15. The Mean Time To Repair is calculated by

$$MTTR = \frac{1}{K}\sum_{k=1}^{K} t_d(k),$$

where K is the number of periods when the power plant is not available and $t_d(k)$ is the duration of each of these periods.

Thermal power station model

- Estimation of availability

Definition 6.16. The failure rate λ is the probability that an available unit will fail. The failure rate can be estimated as

$$\lambda = \frac{1}{MTTF}.$$

Thermal power station model

- Estimation of availability

Definition 6.17. The repair rate μ is the probability that an unavailable unit will be repaired. The repair rate can be estimated as

$$\mu = \frac{1}{MTTR}.$$

Thermal power station model

- Estimation of availability

Definition 6.18. The availability is the probability that a power plant is available. This probability can be estimated as the part of a longer period that the unit is available:

$$p = \frac{MTTF}{MTTF + MTTR} = \frac{\mu}{\mu + \lambda}.$$

Thermal power station model

- Estimation of availability

Definition 6.19. The unavailability is the probability that a power plant is unavailable, which can be estimated by

$$q = 1 - p = \frac{MTTR}{MTTF + MTTR} = \frac{\lambda}{\mu + \lambda}.$$

Thermal power station model

- Estimation of availability

Example 6.11 (availability in a power plant). Table 6.4 shows the operation log of a power plant. Calculate the failure rate, repair rate and unavailability of this unit.

Table 6.4 Example of operation log of a power plant.

Event	Time [week]								
Failure		20		60		70		101	
Repair	0		23		62		74		104

Thermal power station model

- Practical considerations

- How the availability is estimated depends on available data. Is, e.g., MTTF and MTTR available or not?
- Remember that **availability** is not the same as **utilization**! If a power plant is available, does **not** mean that it is used! A plant is only used when it is available **and** needed! Needed means that the load is high enough and the plant is competitive.