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Z-Statistic Method for Estimating Resource Peak Load Carrying Capability[1]

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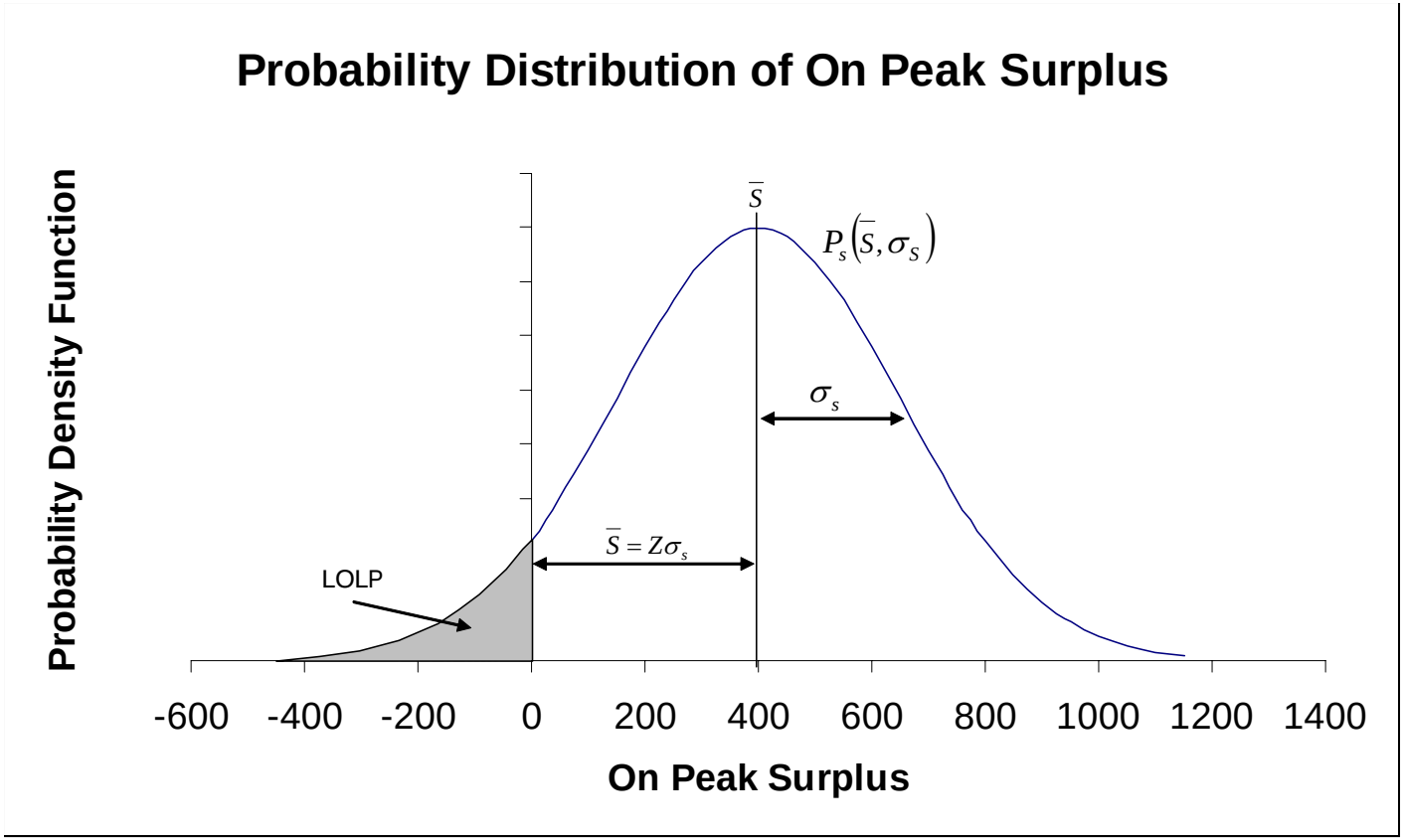
[1]Concepts taken from "Z Method for Power System Resource Adequacy Applications", Dragoon and Dvortsov, submitted for publication IEEE Transactions on Power Systems, June 20, 2005.

On-Peak Surplus Capacity

- Form a stochastic variable of surplus generating capability, assuming all operable units are made available over on-peak hours

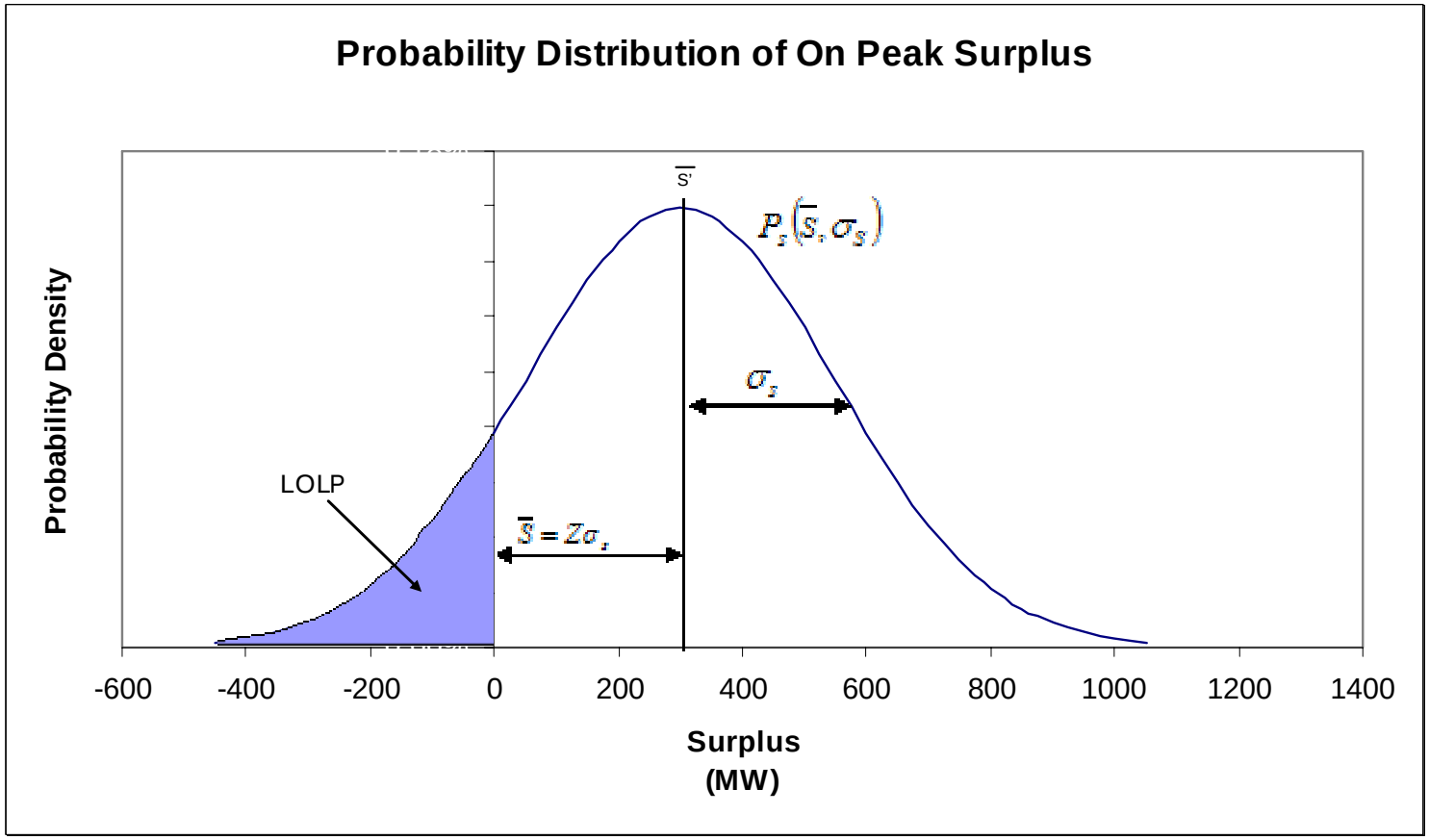
$$S_i = R_i - L_i$$

$$Z = \frac{\overline{S}}{\sigma_s}$$



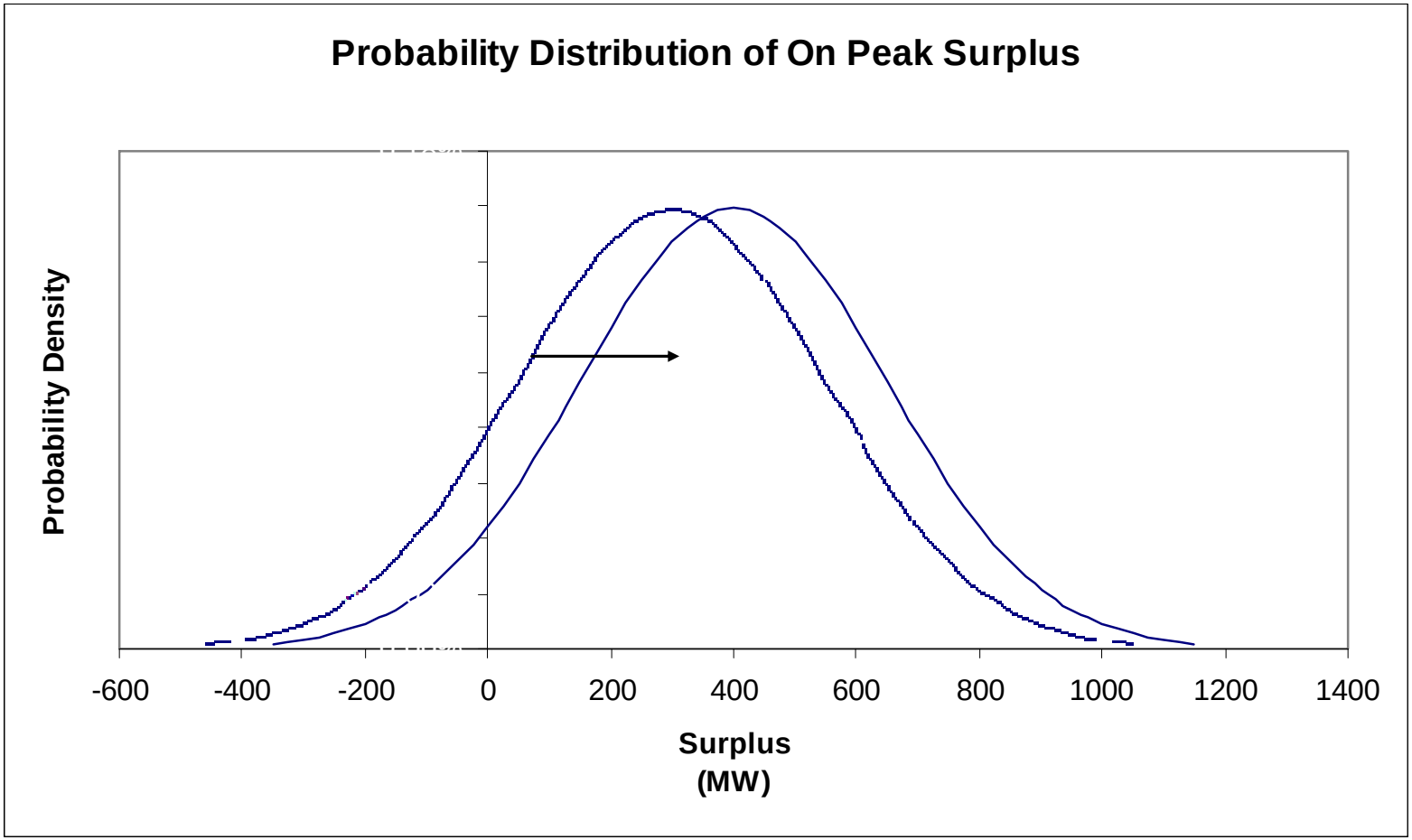
Adding Peak Load

- Distribution of S moves to left



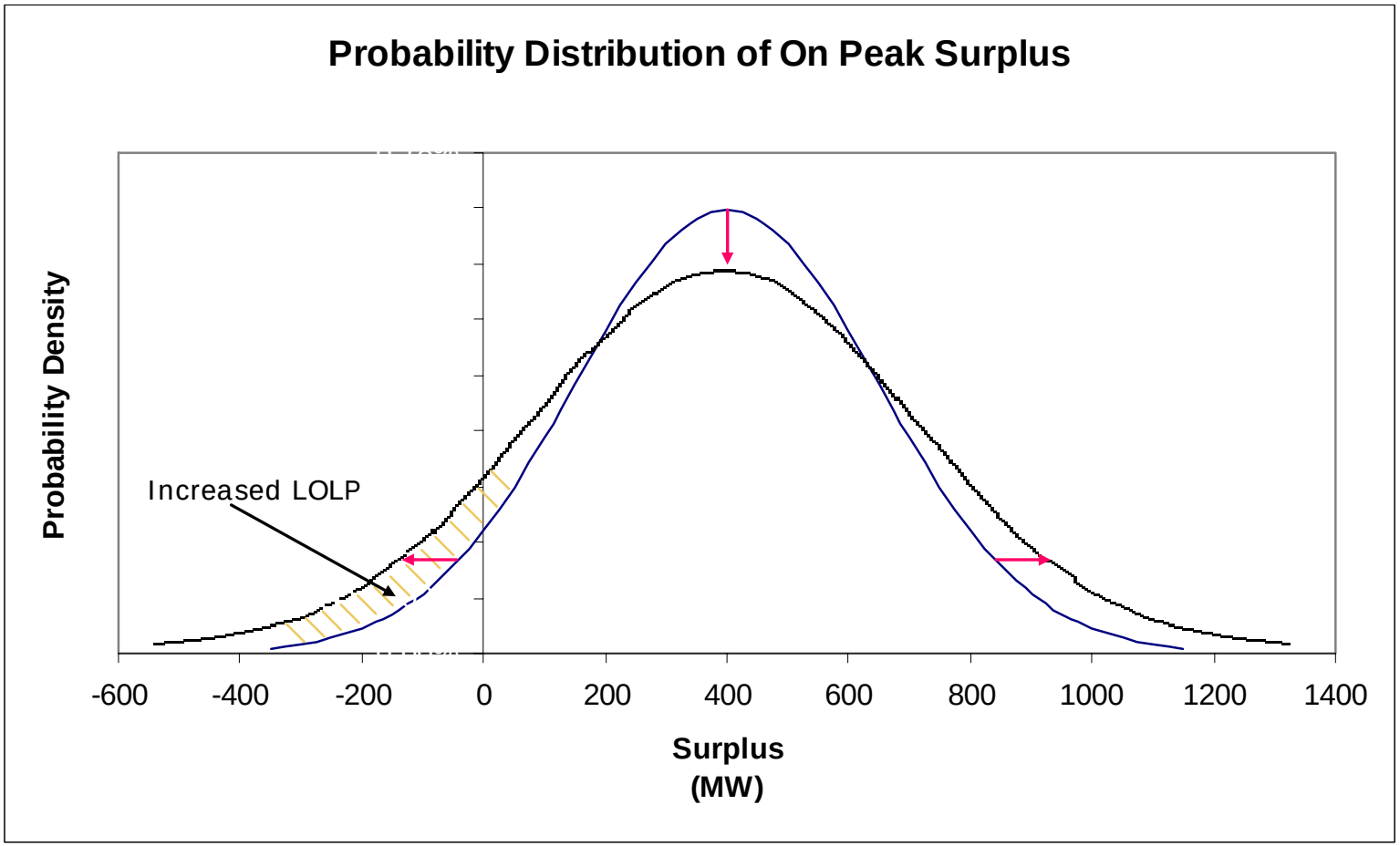
Adding generation moves it back

- Distribution of S moves to Right



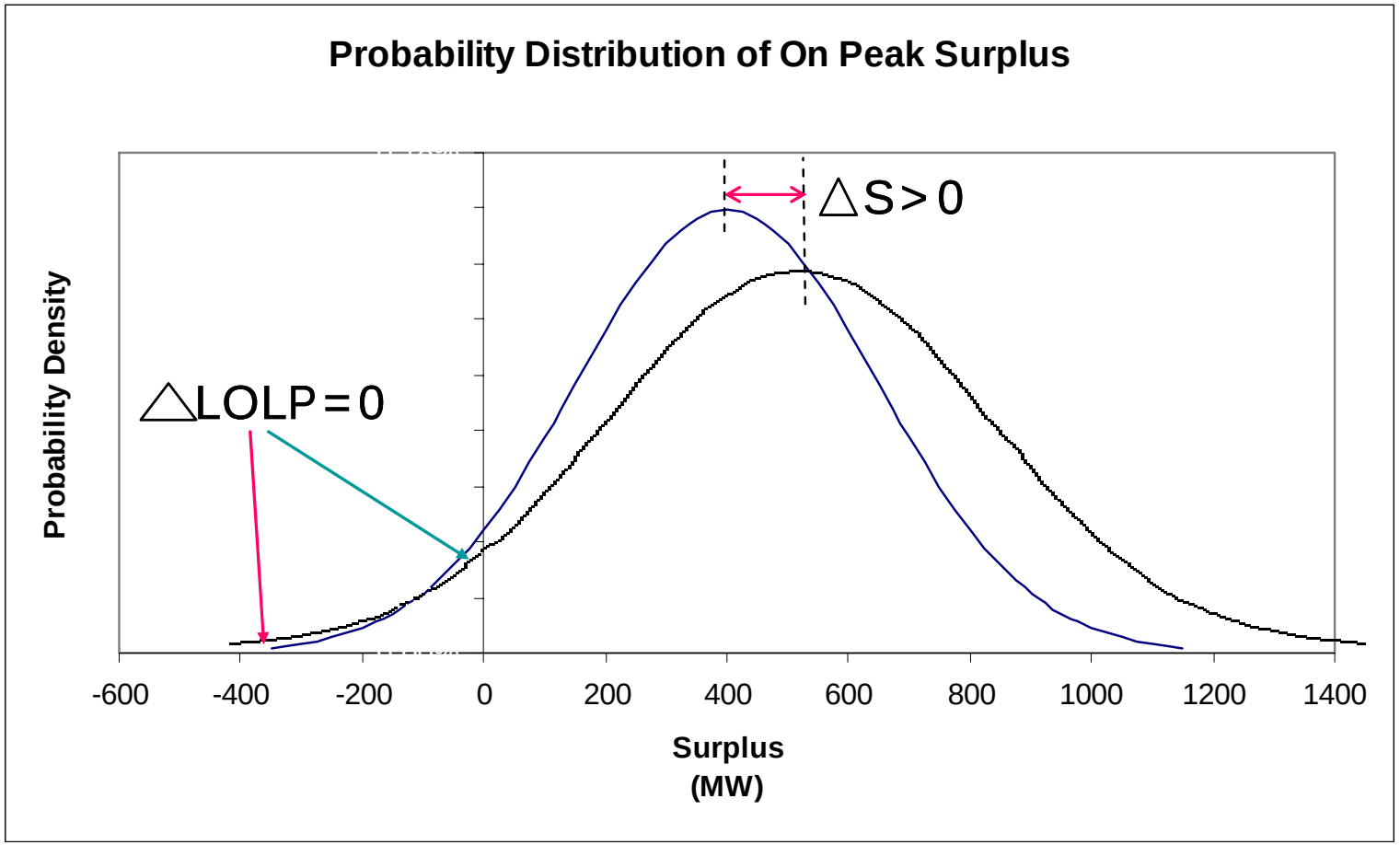
Balancing Expected Peak Growth with Expected Capacity is Insufficient

- The surplus distribution broadens with real (ie, not 100% reliable) generation and load growth, and LOLP grows



Expected Surplus Must Increase to Maintain LOLP

- One way to estimate the needed increment is to maintain the Z-statistic in the expanded system



Adding Generation to Balance Load

- Generation offsets load directly if the added generation and load are fixed
  - For real (not 100% reliable) loads and resources, the distribution of surplus broadens
- Expected on-peak generation must be greater than the increase in expected load growth, or LOLP will grow
- The incremental surplus can be estimated by requiring the Z-statistic to remain constant under system expansion

Z-Statistic Method

- Holding Z constant approximates holding LOLP constant for real distributions of on-peak surplus distributions
  - Holding Z constant holds LOLP exactly constant for normally distributed surpluses
  - Normality is NOT a requirement – just a sufficient condition
    - More work needed to identify limiting conditions on the method
    - Application to a stochastic model with a non-normal tail found the method accurate to within the stochastic model's capability of measuring it, after 65,000 samples.

Calculating Needed Surplus Increment to Keep Z Constant

- Assumptions:
  - Incremental surplus is small compared to existing surplus
  - Incremental sigmas small compared to existing surplus sigma

$$Z_1 = \frac{\overline{S}_1}{\sigma_{S_1}}$$

$$Z_2 = \frac{\overline{S}_2}{\sigma_{S_1}} = \frac{\overline{S}_1 - \overline{L} + \overline{R}}{\sqrt{\sigma_{S_1}^2 + \sigma_L^2 + \sigma_R^2}} \approx Z_1 - \overline{L} + \overline{R} - Z_1 \frac{\left(\sigma_L^2 + \sigma_R^2\right)}{2\sigma_{S_1}}$$

$$Z_2 \geq Z_1 \Rightarrow$$

$$\overline{R} - \overline{L} \geq Z_1 \frac{\left(\sigma_L^2 + \sigma_R^2\right)}{2\sigma_{S_1}}$$

Needed Incremental Expected Surplus to Keep LOLP Constant.

Conclusions

- Peak Load Carrying Capability (PLCC) of incremental units can be computed without iteratively running stochastic computer models
- Z-Statistic provides powerful method for quickly and simply calculating PLCC and trading-off unit sizes and outage rates
  - Methodology is not limited to normally distributed surplus distributions
  - Can be used in conjunction with capacity expansion modules