Distributed Generation & Hosting Capacity

Need for stochastic analysis

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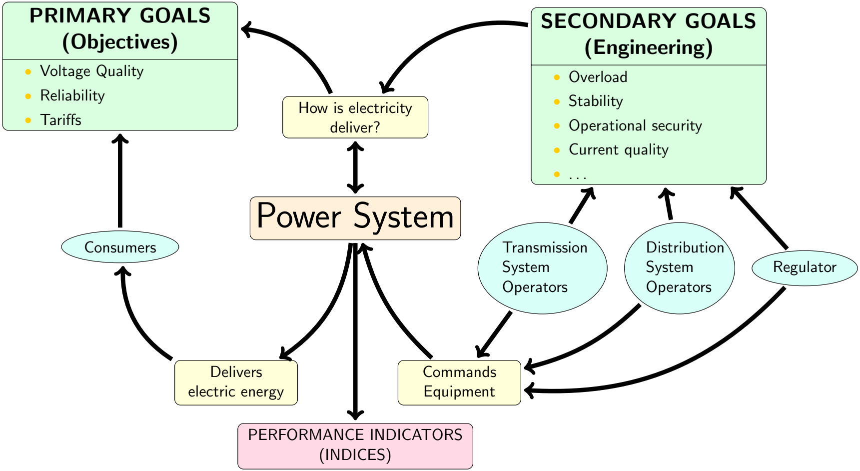
Goals for Delivering Electric Energy



Performance Indicators

Indices

Voltage

1. Overvoltage
2. Undervoltage
3. Voltage distortion
4. Imbalance
5. Flicker

Power

1. Overloded equipment
2. Losses

Current

1. Ampacity in cables
2. Harmonic distortion

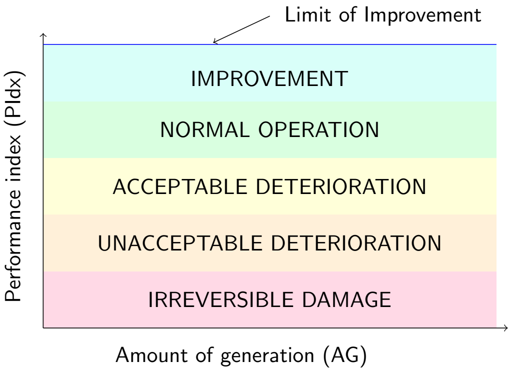
Frequency

1. Overfrequency
2. Underfrequency

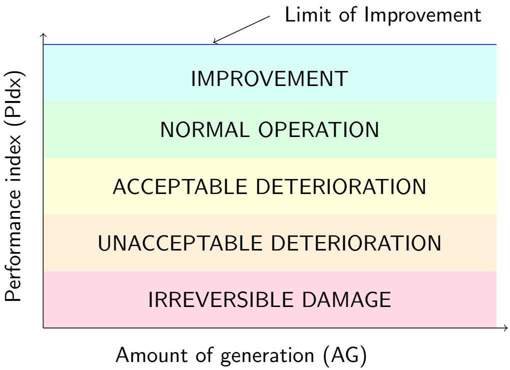
Reliability

1. Number of Outages
2. Number of voltage sags
3. Number of failures in equipment

Hosting capacity



Hosting capacity



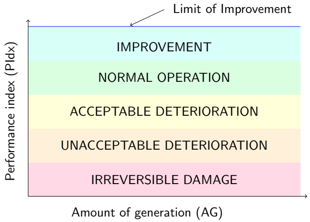
Definition

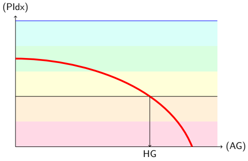
The amount of distributed generation for which the performance becomes unacceptable.

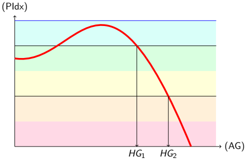
Hosting capacity

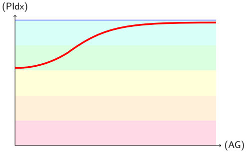
Definition

The amount of distributed generation for which the performance becomes unacceptable or does not improve.

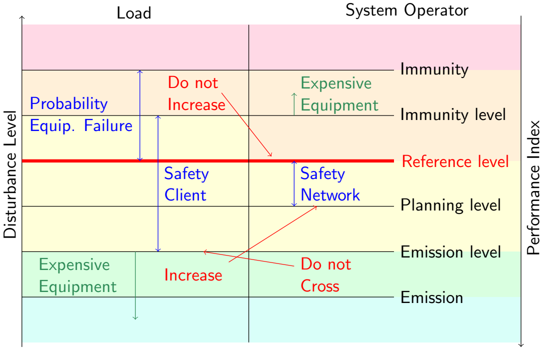








Disturbance levels



- Reference level: The probability of equipment failure is low. International standards.
- If the Reference level is moved there are no incentives to improve the network.
- $\Uparrow$ Planning Level $\longrightarrow$ $\Uparrow$ Hosting Capacity $\longrightarrow$ $\Uparrow$ Emissions $\longrightarrow$ $\Uparrow$ Risk System Operator

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Overloading

Feeder

No Distributed generation

$$P_{consumed} = P_{LB} + P_{LC}$$

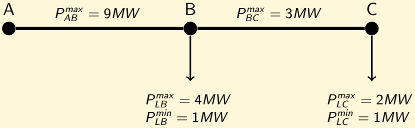
$$P_{deliverd} = P_{AB} + P_{BC}$$

No overload conditions

$$P^{max}_{deliverd} < P^{max}_{LB} + P^{max}_{LC} \Leftarrow Consumers$$

$$P^{max}_{deliverd} < P^{max}_{AB} + P^{max}_{BC} \Leftarrow Ampacity$$

Example



Hosting capacity

$$P_{deliverd} = P_{consumed} - P_{generated}$$

$$P^{max1}_{delivered} = P^{max}_{consumed} - P^{min}_{generated} \Leftarrow \text{Same case that no generation}$$

$$P^{max2}_{delivered} = P^{max}_{generated} - P^{min}_{consumed} \Leftarrow \text{Change direction of power flow}$$

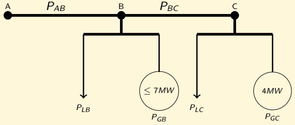
$$P^{max}_{generated} = P^{max2}_{delivered} + P^{min}_{consumed}$$

No overload conditions

$$P^{max}_{generated} < P^{max}_{consumed} + P^{min}_{consumed} \Leftarrow 1^{st}\text{Hosting capacity (HC1)}$$

$$P^{max}_{generated} < P^{max}_{feeder} + P^{min}_{consumed} \Leftarrow 2^{st}\text{Hosting capacity (HC2)}$$

Example



$$P^{HC1}_{AB} = (4 + 2) + (1 + 1) = 8MW$$

$$P^{HC1}_{BC} = (2) + (1) = 3MW$$

$$P^{HC2}_{AB} = (9) + (1 + 1) = 11MW$$

$$P^{HC2}_{BC} = (3) + (1) = 4MW$$

Managing the risk

- Limits are deterministic.
- Minimum consumption is only a few hours per year.
- Maximum production occurs over a fraction of time.
- Probability of reaching the worst case scenerio (maximum production, minimum load) is very low.
- Stochastic approach
  - Measurement: Accurate data of consumer patterns.
  - Consumer: Acknowledge possible interruptions.
  - System Operator: Penalties for interruptions.

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Voltage regulation

Parameters

- Cross-section (A)
- Length, location (l)
- Reactance (α)
- Power factor (k)
- Nominal voltage (U)

Definition

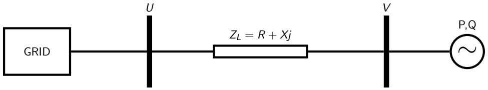
$$R = \rho \frac{l}{A}$$

$$\alpha = \frac{X}{R}$$

$$k = \frac{Q}{P}$$

$$Z_L = R + Xj = R(1 + \alpha j)$$

$$I = \frac{1}{V}(P + Qj) = \frac{P}{V}(1 + kj)$$



Equations

$$\Delta V = |U - V| = |Z_L I|$$

$$\Delta V = |R(1 + \alpha j)\frac{P}{V}(1 + kj)|$$

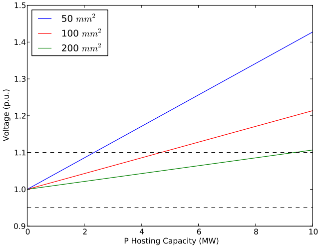
$$\Delta V = \frac{PR}{V}|1 - \alpha k + (\alpha + k)j|$$

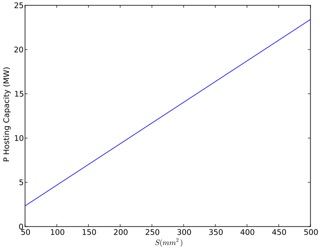
$$\frac{\Delta V}{V} = \frac{PR}{V^2}\sqrt{(1 - \alpha k)^2 + (\alpha + k)^2}$$

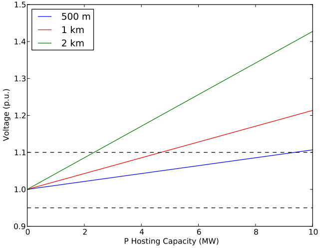
$$P = \frac{\delta V V^2}{R} \frac{1}{\sqrt{(1 - \alpha k)^2 + (\alpha + k)^2}}$$

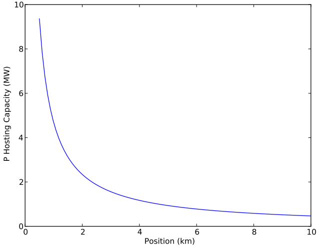
Voltage regulation

Cross-section & Length









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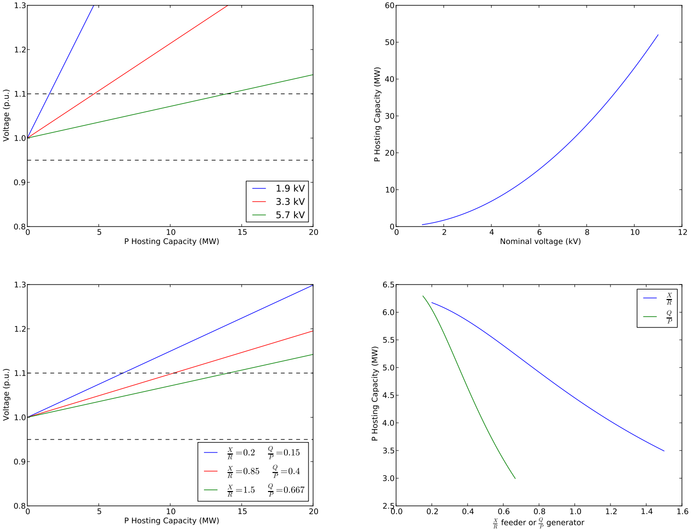
Voltage regulation

Nominal Voltage & Reactive power



Voltage regulation

implications

Factors

- HC $\propto$ cross-section.
- HC $\propto$ 1/location.
- HC $\propto$ voltage level.
- HC $\propto$ $\frac{X}{R}$ and Q.

Stochastic approach

- The deterministic method:
  - Overvoltage: Lowest consumption and maximum production.
  - Probability of suffering overvoltage or undervoltage is zero.
- Worst-case scenerio is highly unlikely.
- Voltage regulators decrease HC, and increase uncertainty.
- Risk analysis. Immunity level is high: Probability of failure is low.

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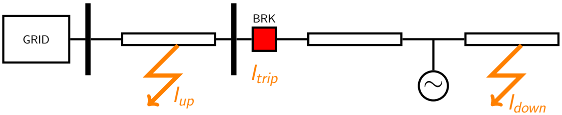
Hosting Capacity & Protection

Margin of coordination



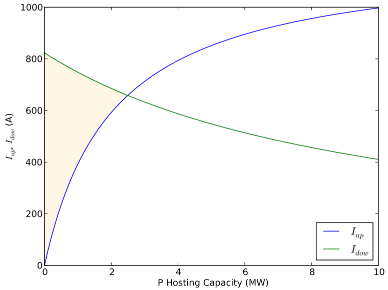
Coordination

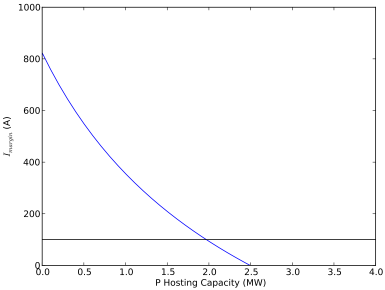
No generation

$$I_{down}^{min} > I_{trip} \qquad I_{up} = 0$$

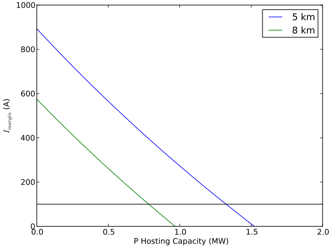
Generation

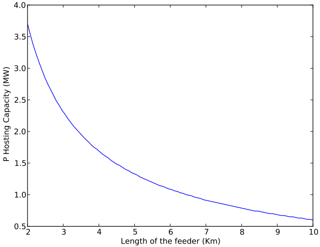
$$I_{down}^{min} > I_{trip} > I_{up}^{max}$$

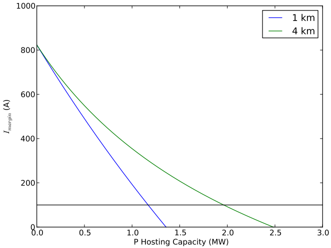


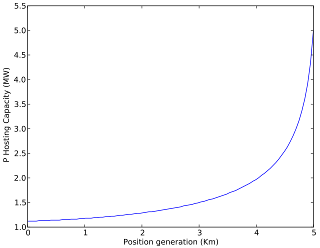


Hosting Capacity & Protection









Summary

- $\Uparrow$ Generation $\Longrightarrow$ Uncoordination.
- $\Uparrow$ length feeder $\Longrightarrow$ $\Downarrow$ HC.
- Generation far from substation $\Longrightarrow$ $\Uparrow$ HC .
- Current protection is not a solution when the penetration is high.

Stochastic approach

- Different type of generation $\Longrightarrow$ Different contributions of faulty currents.
- Generation is not present in the system at all times.
- $\Uparrow$ # trips $\not\Longrightarrow$ $\Uparrow$ # failures loads.
- Controlled island operation $\Uparrow$ reliability.

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conclusions

Hosting capacity calculation

- The Hosting capacity concept can be applied to any other performance index that can be measured in the network such as harmonics (THD, TDD,. . .), imbalance, reliability (voltage sags, outages. . .). . .
- A deterministic approach to calculate the hosting capacity underestimates the potential of the current distribution system to integrate distributed generation in most of performance indecies.

Bibliography

- J. Deuse, S. Grenard, and M.H.J. Bollen."EU-DEEP integrated project - technical implications of the "hosting-capacity" of the system for DER". International Journal of Distributed Energy Resources, 4(1) : 17-34, 2008.
- Bollen, M.H. and Hassan, F. "Integration of Distributed Generation in the Power System". Wiley-IEEE Press. 2011.
- Etherden, N. and Bollen, M.H.J.. " Increasing the hosting capacity of distribution networks by curtailment of renewable energy resources", PowerTech, 2011 IEEE Trondheim, 2011.

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Thank you for your attention.

Are there any Questions?