International Studies about the Grid Integration of Wind Generation

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Internation Studies About Grid Integration of Wind Generation

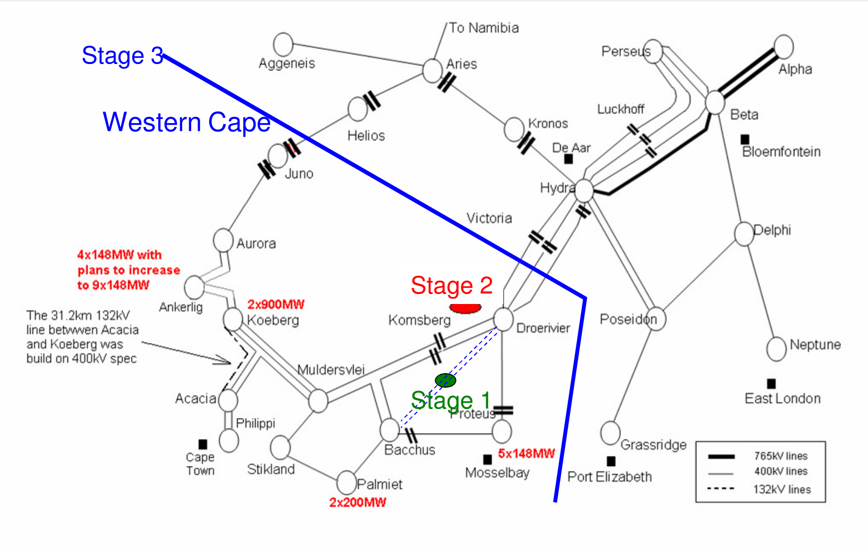
- Grid Integration of Wind Generationin South Africa:
  - The GIZ/DEA&DP Grid Study for the Western Cape/South Africa
  - GIZ/DOE/ESkOM: Capacity Credit of Wind Generation in South Africa
- "DENA-II-Study"
  Integration of Renewable Energies into the German electricity transmission system during the time frame 2015-2020 with an outlook until 2025

Results of the GTZ/DEA&DP Grid Study for the Western Cape/South Africa

Situation in South Africa

- Since 2009: Feed-in tariff scheme is in place (1,25ZAR/kWh around 0,14USD/kWh)
- Only a few test turbines in operation (end of 2009)
- Wind farm developments in the Cape (Western and Eastern Cape) started.
- High uncertainty about the overall amount of wind generation that will get a permission to connect to the grid.
- The grid study (2009) represents an initial feasibility study looking at the high voltage transmission system.
- The capacity credit study (2010) looks at the contribution of wind generation to the equivalent firm capacity and system operational aspects.

The South African Transmission System

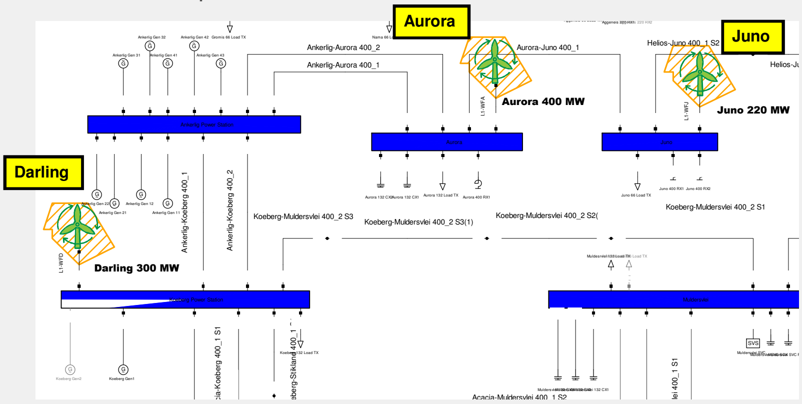


The GTZ/DEA&DP Grid Study - Approaches

- Consideration of all wind farms in the Western Cape, for which application existed by end of March 2009 (2798MW)
- High level feasibility studies considering the existing ESKOM transmission grid (excluding subtransmission, <=132kV)
- Constraints:
  - No major network upgrades (such as new lines)
  - Minor network upgrades, such as additional var-compensation is possible.
- System 2009 (not considering network extensions that are planned for the next 10 years.)

The GTZ/DEA&DP Grid Study - Approaches

- Required grid reinforcement at subtransmission levels (132kV) out of the scope of this study
- Lumping all wind farms in a specific region together and modelling them as an equivalent infeed into the nearest 400kV substation



The GTZ/DEA&DP Grid Study - Approaches

- Definition of credible worst-case scenarios:
- Analysed cases:
  - High load, 1 Koeberg (nuclear power plant) units in
  - High load, 2 Koeberg units in
  - Low load, 1 Koeberg unit in
  - Low load, 2 Koeberg units in
- Generation Balancing – High Wind Scenarios:
  - Reduction of Gas Turbine Generators (running in SCO mode where possible)
  - Reduction of pump storage generation at Palmiet
  - Reduction of coal power plants outside the Cape
- Load flow and contingency analysis studies looking at thermal and voltage aspects only.

2800MW in the Western Cape – Summary of Results

- Up to 1000MW of export from the Cape to the North under Low load – High Wind conditions (without wind, the Cape system has rather an import problem).
- No violation of thermal limits under n-1 conditions in all scenarios.
- Voltages can be maintained within appropriate limits, without any additional reactive power compensation in the Western Cape.
- The general feasibility of the integration of up to 2800MW of wind generation in the Western Cape, with regard to the impact on the transmission grid, could be demonstrated.
- However:
  - Operation of the system with considerable export from the Cape to the North must be studied in further detail.
  - More detailed studies are required for confirming these results.

Integration of Wind Energy into the Western Cape System - Summary

Western Cape transmission system – excellent for wind integration:

- Cape system currently has an import problem (no export problem). Power import will be reduced during times of high wind generation.
- Large number of fast acting peak load units available that can be used for balancing wind variations.
- Pump storage can be used for supporting the balancing of wind variations.
- Some GTGs allow for SCO-operation – no need for additional dynamic reactive power compensation (SVC).

At subtransmission levels (<=132kV), transmission capacity will be limited in some cases.

What else needs to be done

- Additional, more detailed studies at transmission levels, including additional generation-load scenarios and alternative wind generation scenarios.
- Stability studies under various operating scenarios.
- Wind farm connection studies for every wind farm application.
- Studies related to transmission system operation under situations, in which the Cape exports power to the rest of the system
- Studies related to the expected total power variations of wind generation (variations, ramp-up and ramp-down speeds) for identifying additional reserve requirements have to be carried out.

Capacity Credit of Wind Generation in South Africa

Markus Pöller/DIgSILENT GmbH

Capacity Credit Studies for South Africa

- Studies commissioned by:

energy Department: Energy REPUBLIC OF SOUTH AFRICA

Eskom

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

- Studies executed by:

DIgSILENT

- With contributions from:

Eskom

windlab

Scope of Work

- South African system
  - 2015: installed capacity: 52537MW, peak demand: 40582 MW
  - 2020: installed capacity: 59753MW, peak demand: 48315MW
- Part1: Assessment of capacity credit of wind generation in South Africa for the following scenarios
  - Sc1: 2015: 2000MW of wind generation
  - Sc2: 2020- low wind: 4800 MW of wind generation
  - Sc3: 2020- high wind: 10000MW of wind generation
- Part2: Impact on residual load variations

Methodology - Summary

- Capacity Credit calculated based on LOLP at daily peak loads.
- Evaluation of Capacity Credit is based on the increase of available reserve at given confidence level.
- Dispatchable units modelled by 2-state Marcov models and deterministic maintenance plan
- Load modelled by daily peak loads
- Wind generators modelled by wind speed time series and generic power curve.
- Approach considers:
  - Correlation of wind speeds with seasonal load variations.
  - Correlation of wind speeds with daily load variations.
  - Correlation between wind speeds at different sites.
  - Correlation of planned outages with load (maintenance schedule).

Study Results – SC1 - 2015

- Installed Conventional Capacity: 52 537MW
- Yearly Peak Demand: 40 582MW

- Equivalent Firm Capacity: 535 MW
- Capacity Credit: 26,8%
- Corrected CC: 30,0 %

- Average capacity factor of wind generation: 27,2%
- Average capacity factor during full load hours: 30,0%
- Capacity reduction factor CR: 0,89

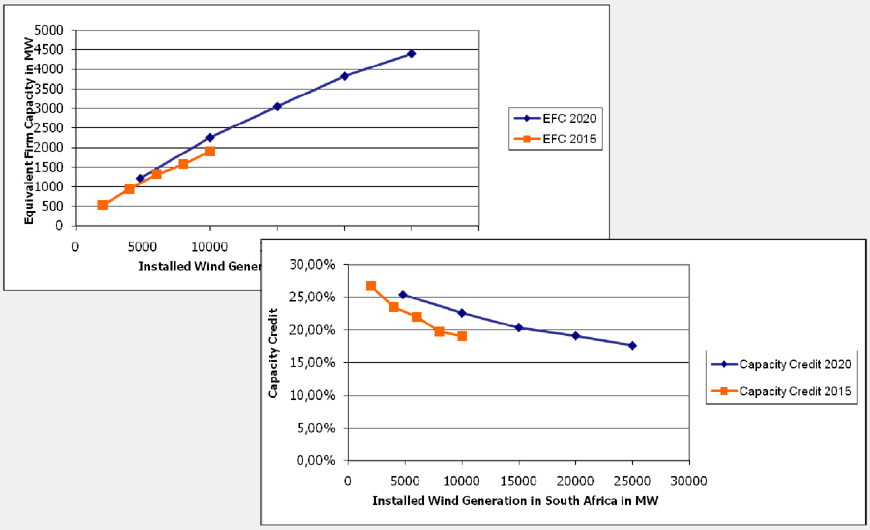
Study Results – SC2 – 2020-Low

• Installed Conventional Capacity:	59 743MW
• Yearly Peak Demand:	48 315MW
• Equivalent Firm Capacity:	1218 MW
• Capacity Credit:	25,4%
• Corrected CC:	28,2 %
• Average capacity factor of wind generation:	30,6%
• Average capacity factor during full load hours:	34,4%
• Capacity reduction factor CR:	0,74

Study Results – SC2 – 2020-High

• Installed Conventional Capacity:	59 743MW
• Yearly Peak Demand:	48 315MW
• Equivalent Firm Capacity:	2256 MW
• Capacity Credit:	22,6%
• Corrected CC:	25,1 %
• Average capacity factor of wind generation:	32,0%
• Average capacity factor during full load hours:	35,8%
• Capacity reduction factor CR:	0,63

Sensitivity Studies – Up to 25 000MW of Wind Generation



Capacity Credit Studies - Summary

- Capacity credit of wind generation in South Africa will be between 23% and 27% for installed wind capacities up to 10 000MW until 2020.
- With increasing penetration levels, capacity credit of wind generation is generally reducing.
- In the presented studies, the 2020 wind farm sites have better wind conditions, therefore capacity credit remains high, also in 2020 scenarios.
- Considering the limited availability of coal fired power plants (90%), the effect on generation adequacy is equivalent to coal fired power stations with an installed capacity between 25% and 30% of the installed wind capacity.

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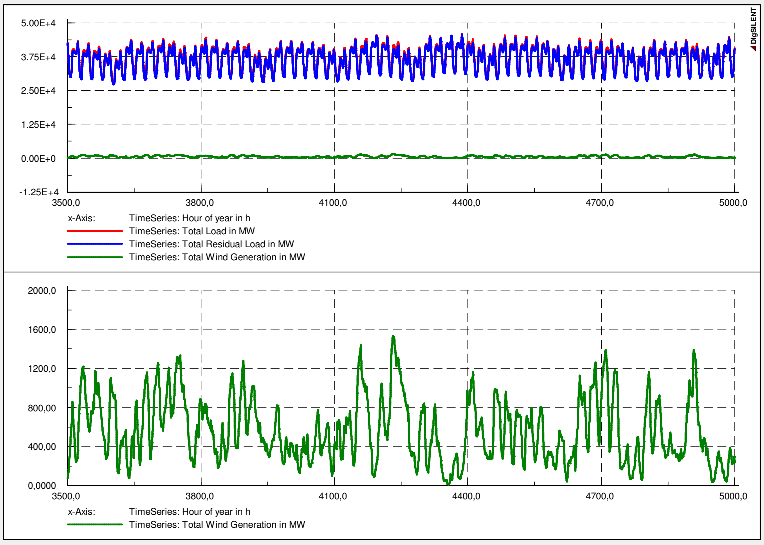
Part 2: Impact of Wind Generation on Operational Aspects

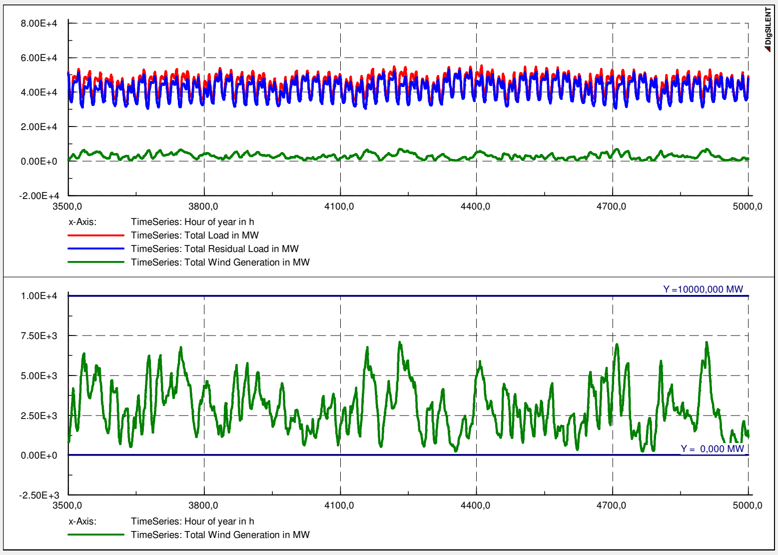
Purpose and Scope of Studies

- Visualisation of typical variations of wind generation
- Identification of worst-case situations with regard to
  - Ramp-up and ramp-down situations
  - Peak load situations
  - Situations with minimum load
- Input data:
  - Time series of wind speeds (hourly resolution, same as capacity credit)
  - Generic power curve
  - Forecast of time series of the load for 2015 and 2020 (hourly resolution)

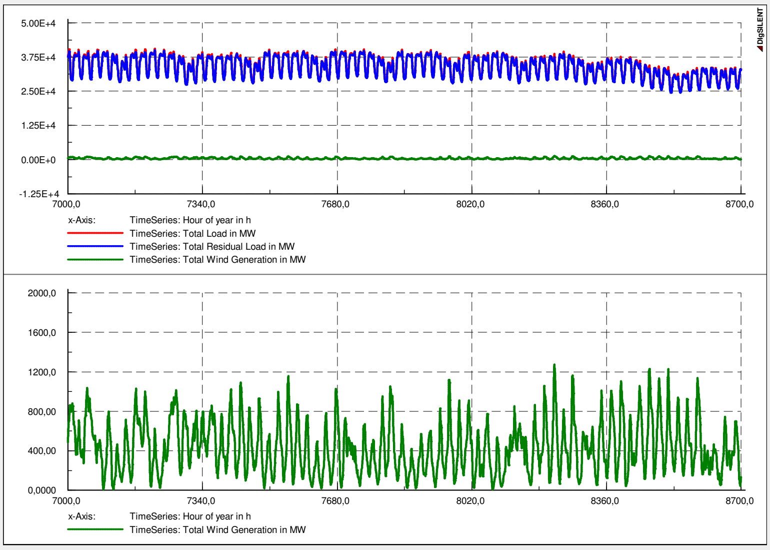
Typical Situation in Winter 2015



Typical Situation in Winter 2020-High (10000MW int. Wind)



Typical Situation in Summer 2015



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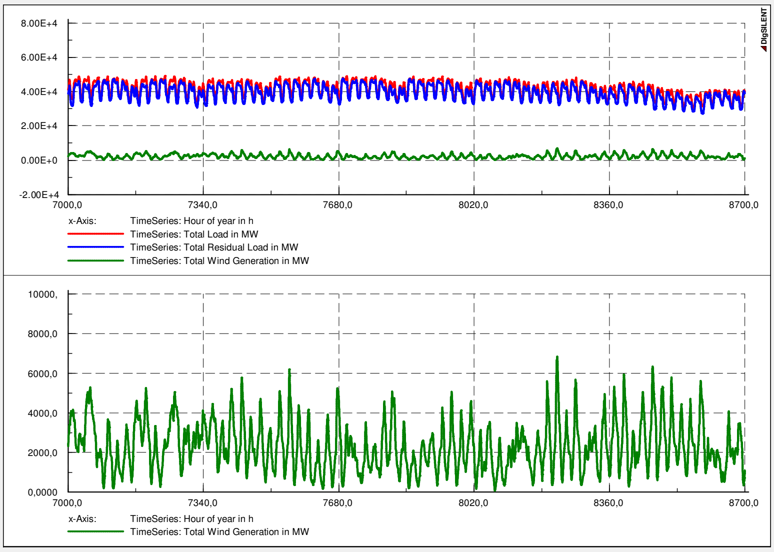
Typical Situation in Summer 2020-High (10000MW int. Wind)



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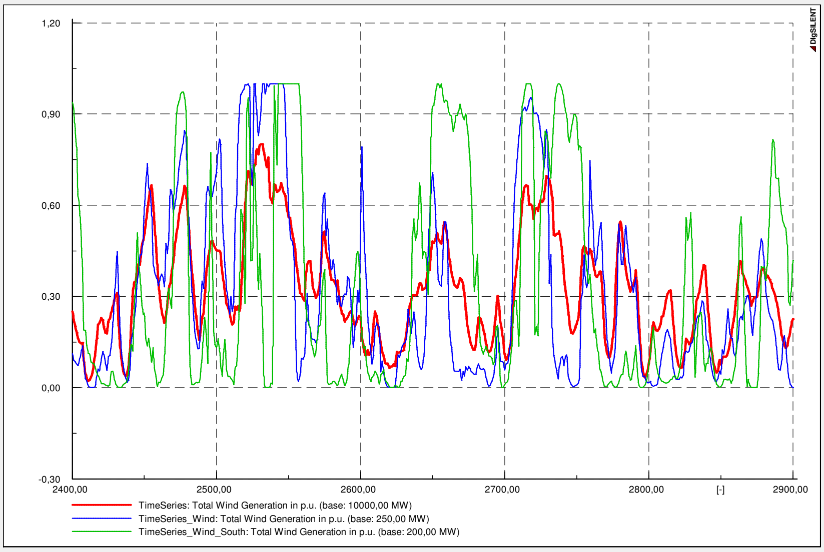
Individual vs. Global Wind Generation (2020-High)



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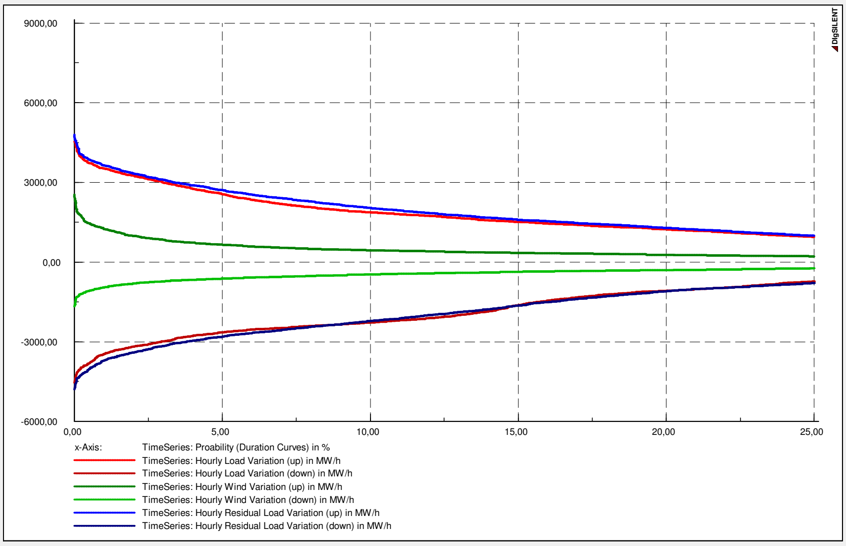
Scenario 3 – 2020/High Wind – Ramp Rates



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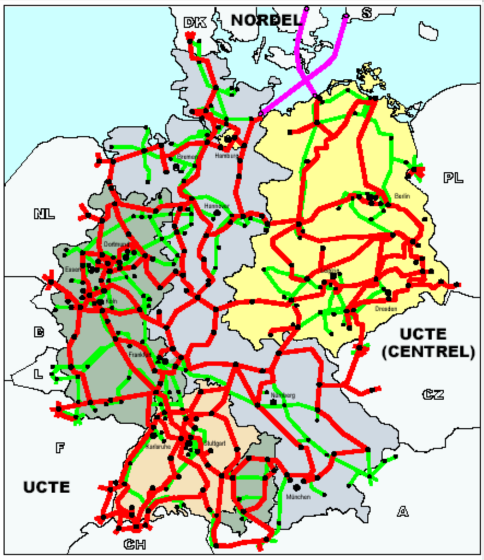
Studies – Summary and Conclusions

- Capacity credit of wind generation in South Africa can be expected to be in a range of around 25% or higher depending on results of studies that are currently under way.
- Hourly ramp-up and ramp-down rates of the residual load are comparable to the corresponding ramp-rates of the system load (without wind generation).
- There are no considerably increased dynamic performance requirements for the existing thermal power plants in South Africa resulting from wind generation with up to 10000MW of installed capacity.
- Main impact on system operation will result from limited predictability not from actual load or wind variations. Corresponding studies are recommended.

"DENA-Grid-Study" (Dena 1 – Study)

Integration of Onshore and Offshore Wind Energy into the German Power System – Planning Study 2003 - 2020

German Power Transmission System



Dena II-Study (Released 11/2010)

- Studied time frame: 2015-2020
- Study execution time: 2007-2011
- Assumptions mainly based on 2007/2008, some of them not valid any more (e.g. solar power, time frame for nuclear power face-out)
- Main assumptions:
  - Load decreases by 8% until 2020
  - Installed onshore wind capacity 2020: 37 000MW
  - Installed offshore wind capacity 2020: 14 000MW
  - Installed PV capacity 2020: 17 900MW
  - Total contribution of renewable energies to electricity demand 2020: 39%
- All references: Final report Dena II study.

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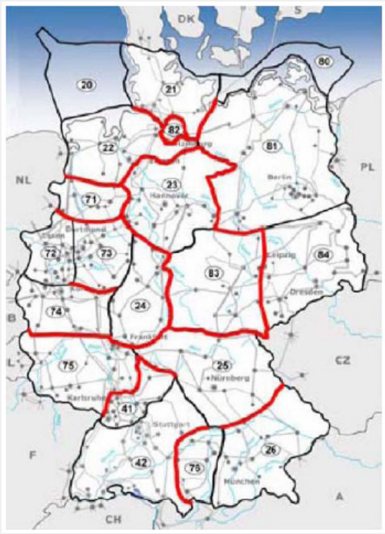
Dena 2 - Scope of Work

- Assessment of required grid expansion
- Use of high temperature conductors
- Use of temperature monitoring
- Demand-side management
- Benefits of the use of storage

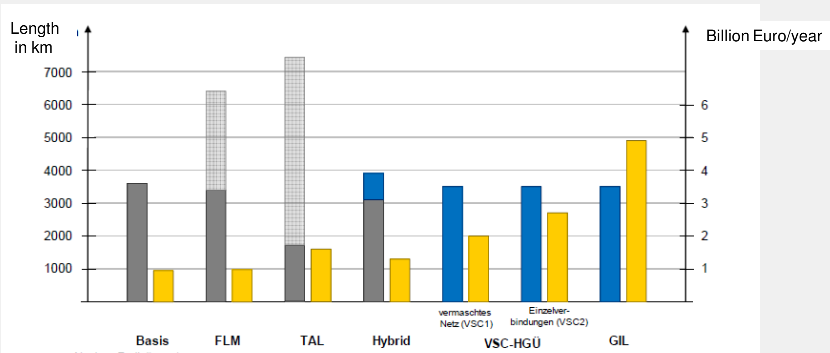
Methodology

- Definition of three base scenarios with regard to storage
- Definition of three scenarios considering different conductor technologies.
- Time series of wind generation with regional resolution and 15min time resolution.
- Market model for calculating unit commitment and economic dispatch.
- Simplified load flow analysis based on regional model and PTDFs

Methodology – regional model for network analysis



Required Grid Expansion (and cost)



- Grey: Required length of new overhead lines
- Blue: Required length of new underground cables
- Yellow: Annualized costs
- FLM: With temperature monitoring
- TAL: High temperature conductors
- Hybrid: Overhead lines/underground cables
- HGÜ-VSC: HVDC-VSC
- GIL: Gas insulated lines

Other Results and Observations

- Storage for reducing required grid expansions:
  - No significant benefit if storage is operated according to existing market rules.
- Use of DSM:
  - Significant reduction of required load following reserve (by up to 60% max. reserve power)
  - Reduction of required peak capacity (e.g. gas turbines): around 800MW
- Increase of load following reserve:
  - Because of improved wind prediction, the required load following reserve will not considerably increase until 2020.

Outlook: Determination of the Maximum Possible Installed Wind Generation Capacity in the System of Panama (Start: 2011)

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Studies for Panama – Scope of Work

- DIgSILENT is contracted by the ministry of energy of Panama and ETESA (TSO).
- Studied time frame: until 2021
- Phase 1: Grid integration studies
  - Steady state (load flow/short circuit)
  - Dynamic studies (Transient, oscillatory and frequency stability studies)
- Phase 2: System performance:
  - Capacity credit
  - Impact on required spinning reserve
- Status: studies have just started

Thank You

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