
Uticaj vjetra i PV na sigurnost sistema u buducnosti
Dr. Ervin Spahic, Head of Future Technologies,
Siemens, GP EPC TS PLM
cigre
Crna Gora

1


SIEMENS
Ingenuity for life.
Uticaj vjetra i PV na sigurnost sistema u buducnosti
Wind and PV impact on secure system operation in future
Dr. Ervin Spahic, Head of Future Technologies, EM TS PLM
Intern © Siemens AG 2019
siemens.com

2

Trends in the world Examples of Germany, Ireland…

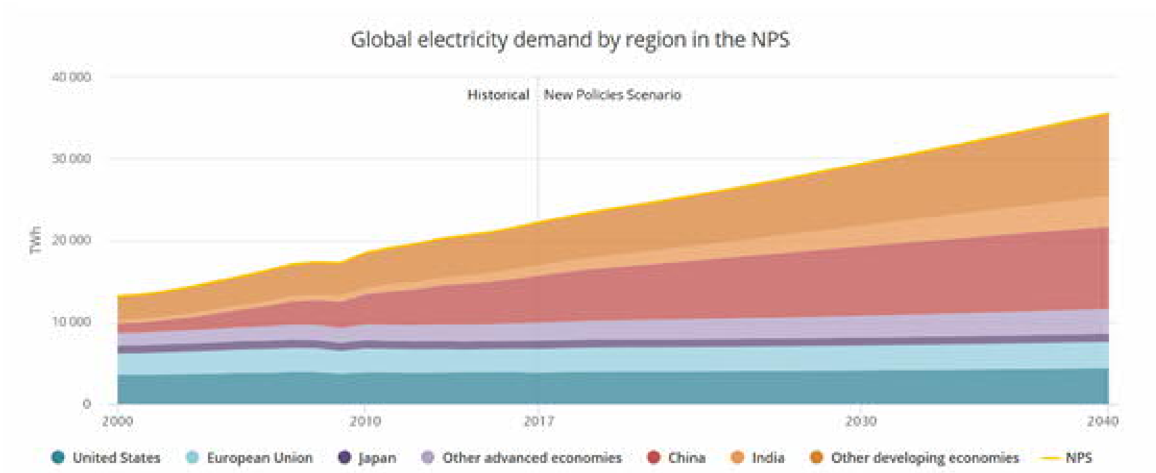
SIEMENS
Ingenuity for life.

3

Global future electricity demand

cigre Crna Gora

SIEMENS
Ingenuity for life.

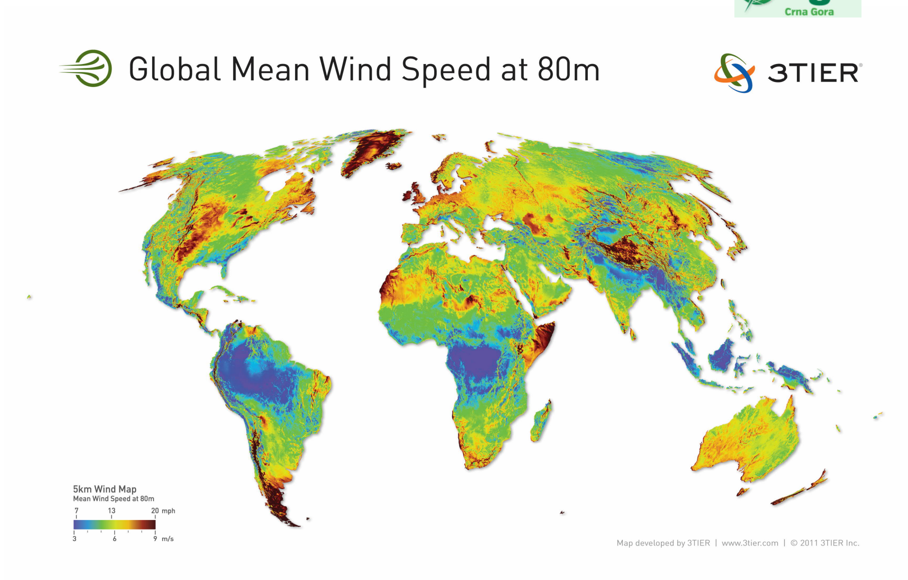


Quelle: https://www.iea.org/weo2018/electricity/

Siemens AG 2019
Page 4 May 2019 Dr. Ervin Spahic / EMTS PLM

4

Wind potential - onshore

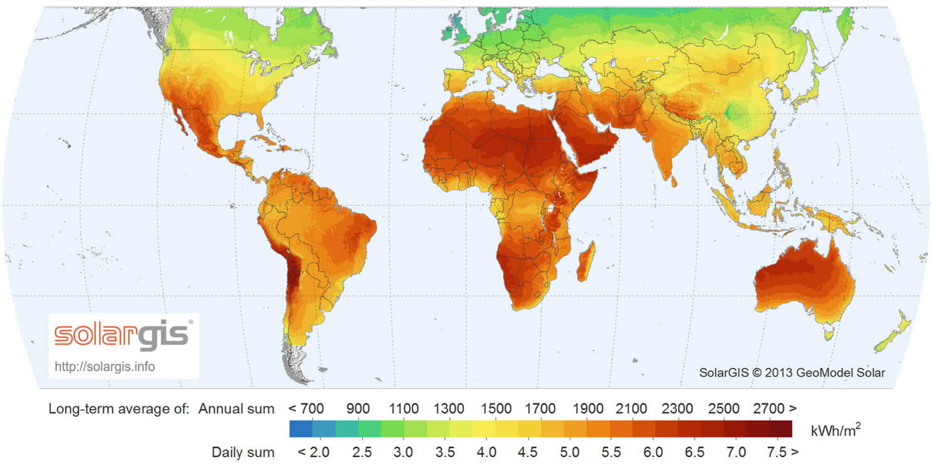


Siemens AG 2019

Page 5 May 2019 Dr. Ervin Spahic / EMTS PLM

5

Solar potential

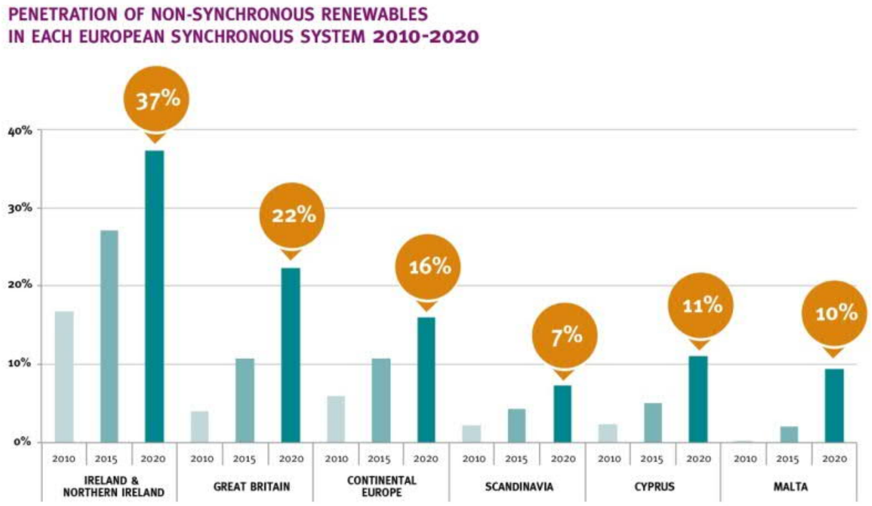


Siemens AG 2019

Page 6 May 2019 Dr. Ervin Spahic / EMTS PLM

6

Feed in tariffs at the beginning
Today – auctions

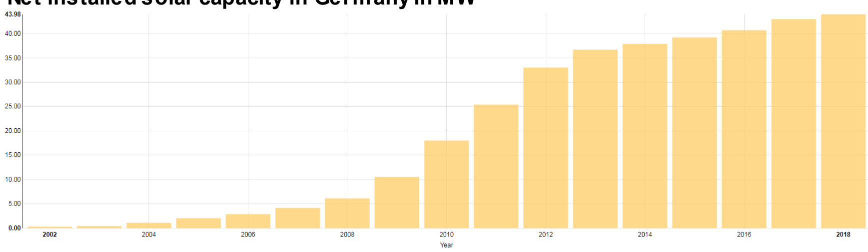


Source: The National Renewable Energy Action Plans (NREAP)

7

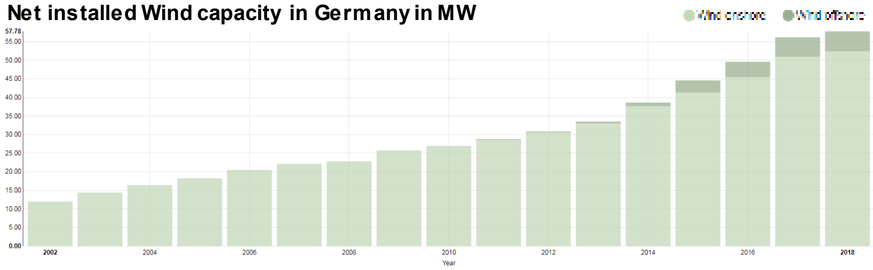
Development of PV and wind energy in Germany

Net installed solar capacity in Germany in MW



Datasource: AGEE, BMWi, Bundesnetzagentur
Last update: 02 Jul 2018 17:39

Net installed Wind capacity in Germany in MW



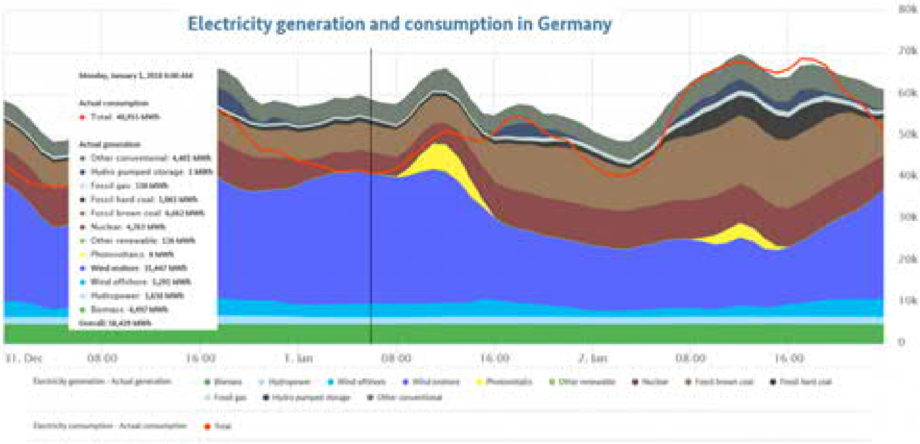
Datasource: AGEE, BMWi, Bundesnetzagentur
Last update: 02 Jul 2018 17:39

8

Renewable’s already today at 100% of load

cigre Crna Gora

SIEMENS
Ingenuity for life.



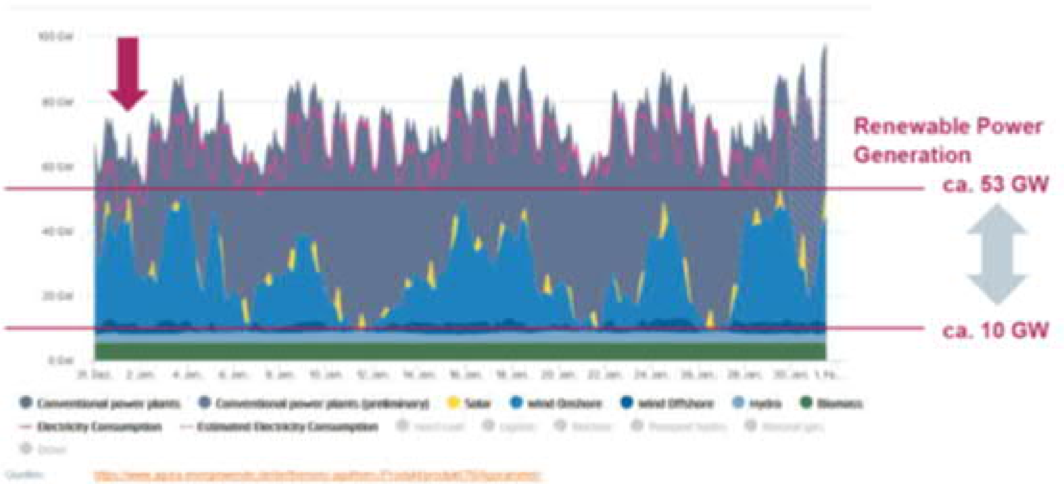
- Germany on 01.01.2018 100% renewable generation
- Ireland on 10.01.2017 60% wind power generation

9

Renewable’s already today at 100% of load

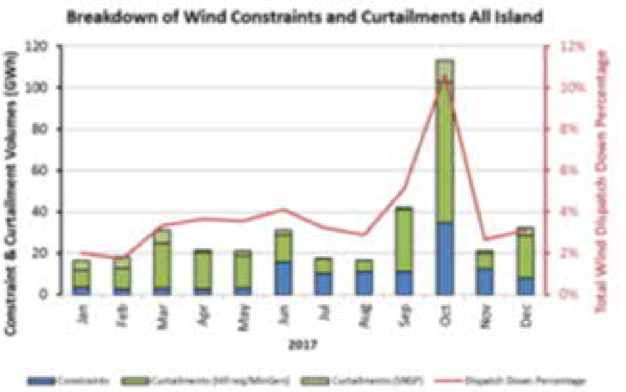
cigre Crna Gora

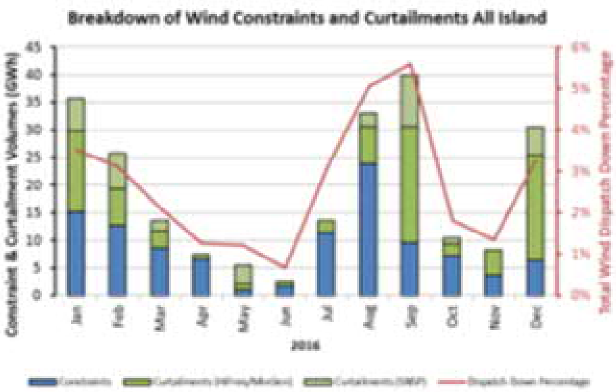
SIEMENS
Ingenuity for life.



10

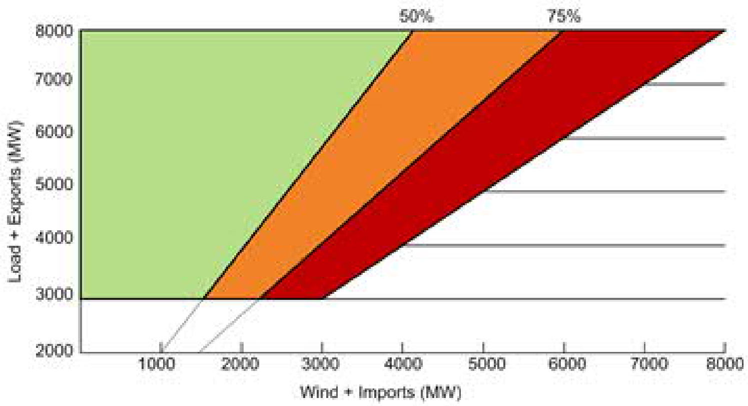
Redispatch costs
Ireland example





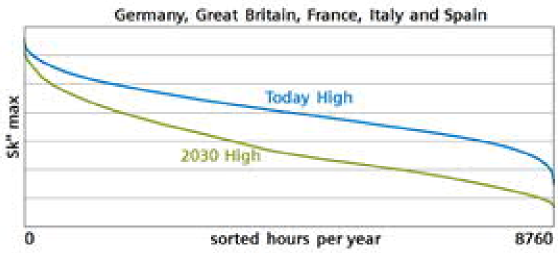
Source: Eirgrid

Renewable portion in Ireland
Depends on the operating point



Source: Eirgrid

Short circuit power in selected countries of Europe

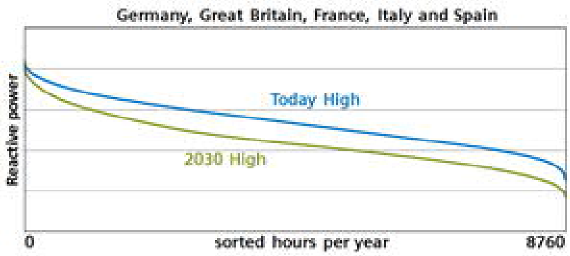


- Significant decrease of short circuit power in future
- Short circuit power needed for protection

Siemens AG 2019
Page 13 May 2019 Dr. Ervin Spahic / EMTS PLM

13

Reactive power* in selected countries of Europe



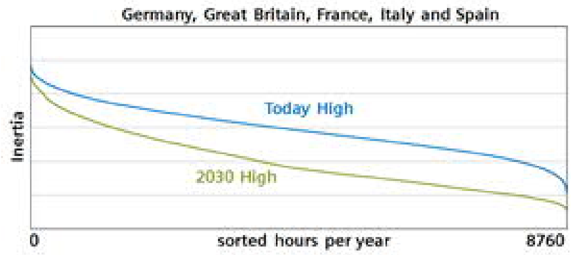
- Decrease of reactive power, although not as severe as short circuit power or inertia.
- However, reactive power support is a local issue and detailed analyses have to be made. Cases like e.g. Great Britain, Ireland or Italy are showing large demand for reactive power.

* Here only inductive power shown. Capacitive reactive power also calculated. Similar trend, however not that severe.

Siemens AG 2019
Page 14 May 2019 Dr. Ervin Spahic / EMTS PLM

14

Inertia in selected countries of Europe

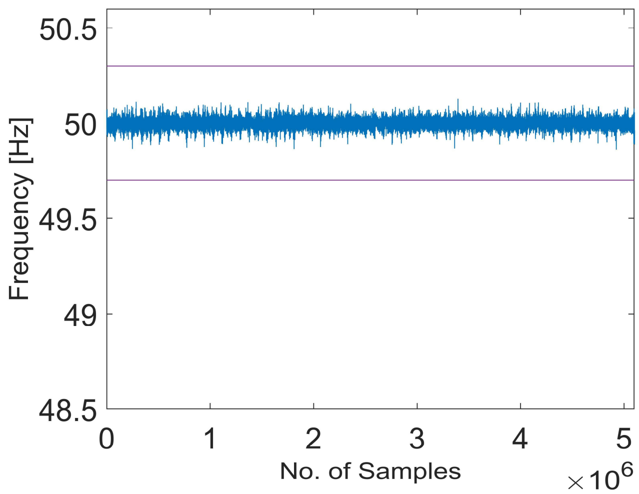


- Significant decrease of inertia!
- Inertia and fast frequency response needed asap!
- Market and grid mechanism needed.

Siemens AG 2019
Page 15 May 2019 Dr. Ervin Spahic / EMTS PLM

15

Frequency pattern for two months Germany

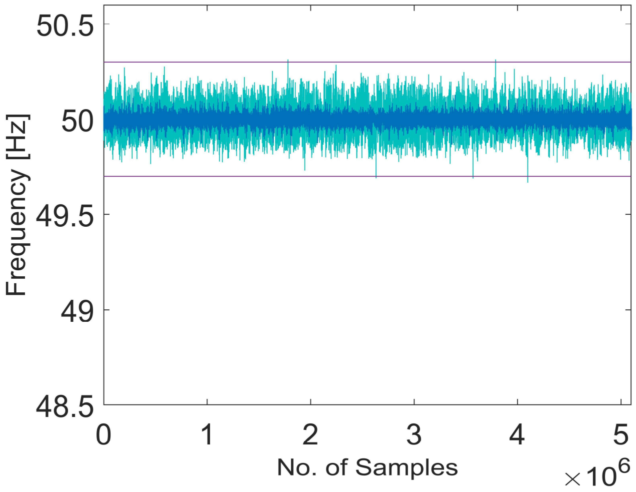


	# Frequency > 50.3 Hz	# Frequency < 49.7 Hz
Germany	0	0

Siemens AG 2019
Page 16 May 2019 Dr. Ervin Spahic / EMTS PLM

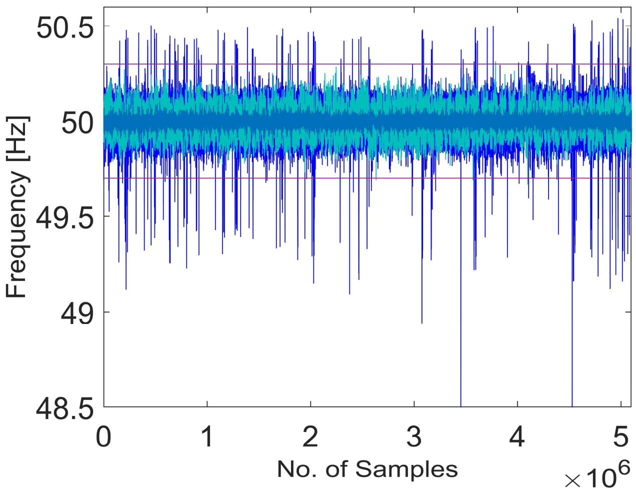
16

Frequency pattern for two months
Germany & UK



	# Frequency > 50.3 Hz	# Frequency < 49.7 Hz
Germany	0	0
UK	2	3

Frequency pattern for two months
Germany & UK & Tasmania



	# Frequency > 50.3 Hz	# Frequency < 49.7 Hz
Germany	0	0
UK	2	3
Tasmania	183	235

SIEMENS
Ingenuity for life.

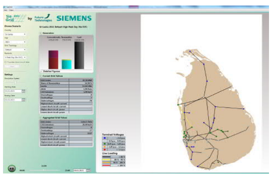
SieGrid
Tool for grid analysis

19

Siegrid

SIEMENS
Ingenuity for life.

- Estimate the optimal operation and placement of HVAC/HVDC/GIL lines, FACTS (incl. SynCon and storage) and power plants
- Show customers that we understand their needs and offer them solutions – focus on the future development i.e. impact of renewables.



Phase 1
Data gathering

- Grid data:
  - Transmission lines, transformers, substations (type, length, size…)
  - Generation units (type, power, CO2…)
  - Loads
- Operation data:
  - Price indicators conventional' s
  - Generation profiles from renewables
  - Load profiles
- Study case definition

Phase 2
Grid analysis and results

- Power plant scheduling (depending on generation costs)
- Load flow calculations
- Simulations for one year with an hourly resolution (15 min or other also possible) .
- Results incl. visualization:
  - Losses
  - Line loadings
  - Voltage profiles
  - CO2-emissions
  - Generation cost
  - Inertia
  - Short circuit power
  - - …

Phase 3
Technical optimization

- Impact / advantages of HVDC, FACTS, GIL, SynCon, storage and other components from TS portfolio on the grid.
- Main focus on technical improvements: losses, line loadings, costs, voltage…
- Exact studies to be done e.g. from Siemens PTI

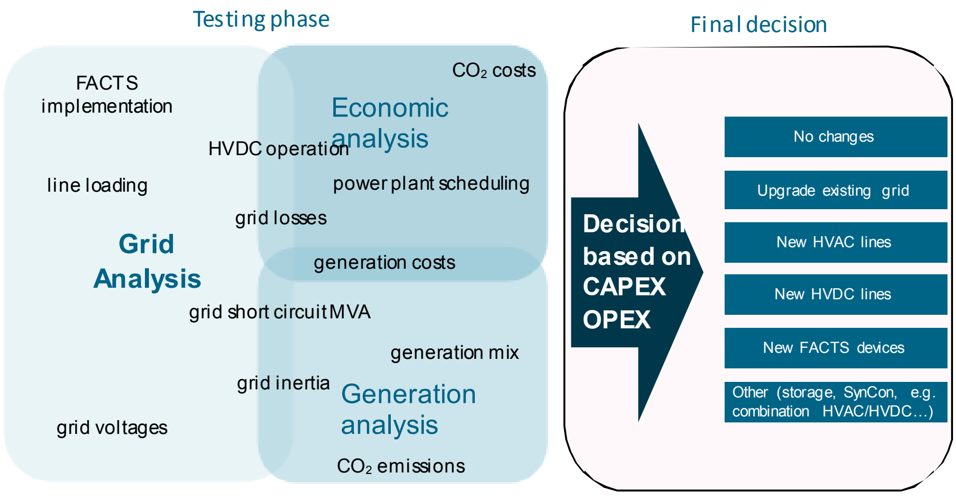
Economic analysis
(CAPEX, OPEX, etc.)

- implement CAPEX and OPEX for different possible solutions
- Benchmarking
- Specific projects
- Future developments (prices, market…)
- Graphical presentation of results –> no calculations needed, results can be handled differently

Siemens AG 2019
Page 20 May 2019 Dr. Ervin Spahic / EMTS PLM

20

What can SieGrid do?



Siemens AG 2019
Page 21 May 2019 Dr. Ervin Spahic / EMTS PLM

21

Phase 1
Data gathering

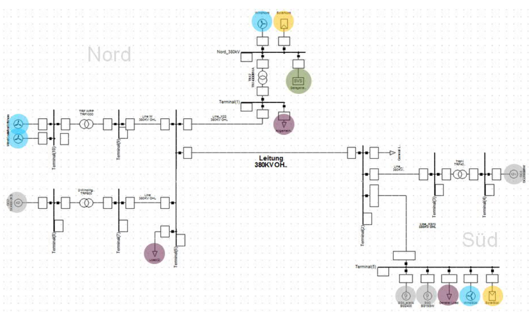
Required input

Grid topology
- Lines / Substations / Transformers
- Generation
  - Fossil power plants
  - Renewable capacities
- Demand / Exchange

Operation data
- Price indicators conventional' s
- Generation profiles renewables (hourly / 15min resolution)

Study cases
- Future scenarios on grid and generation

Simulation environment
- DigSilent / Power Factory*



Fossil generators
Loads
Wind generators
FACTS
PV generator

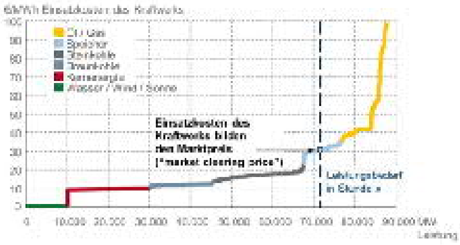
* Similar to NEPLAN, PSS/E etc.

Siemens AG 2019
Page 22 May 2019 Dr. Ervin Spahic / EMTS PLM

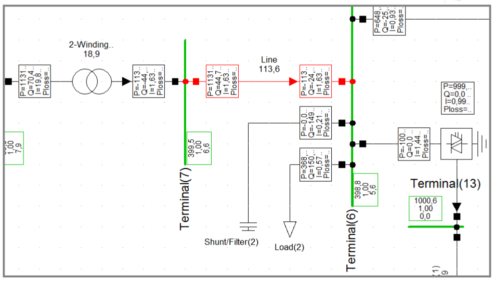
22

Phase 2
Grid calculations and results

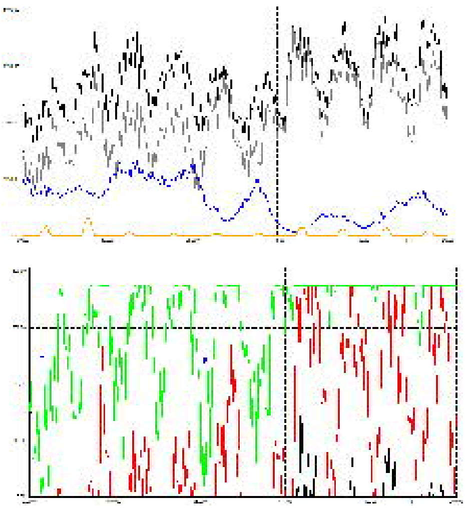
Power plant scheduling -> load flow
- Calculation of residual load
- Sorting generators according to cost
- Simulation of e.g. one year with hourly resolution (15 min also possible)

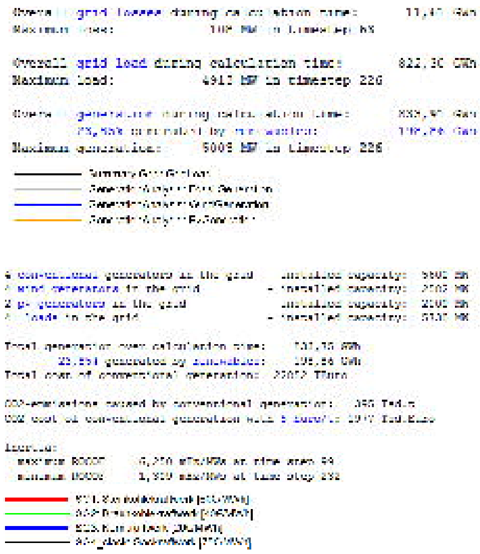


Calculations and results
- Visualization of results, such as line loading, grid losses, voltages, CO_2-emissions, short circuit power, costs, inertia-impact…

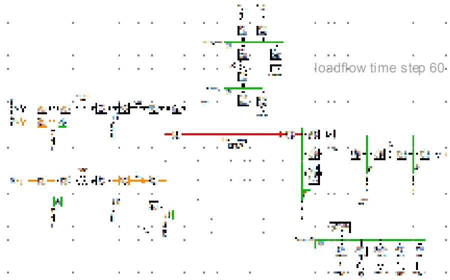


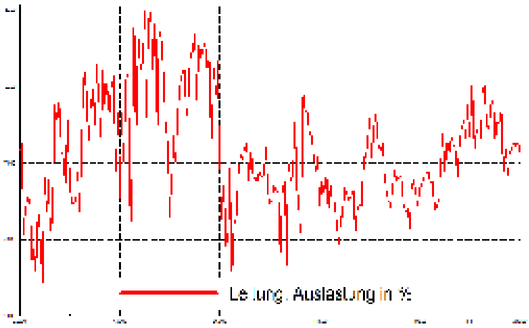
SieGrid model testing
Example: generation analysis





SieGrid model testing
Example: line loading





Loading of more than 100% is considered as overload

Number of overloaded lines: 1
Lines on average overloaded in 36 out of 241 hours.

Line with maximal loading:
[illegible]
Maximal loading of 1309 occured during time step 60

Most frequently overloaded lines:
[illegible]
Overloaded 36 out of 241 hours.

Siemens AG 2019
Page 25 May 2019 Dr. Ervin Spahic / EMTS PLM

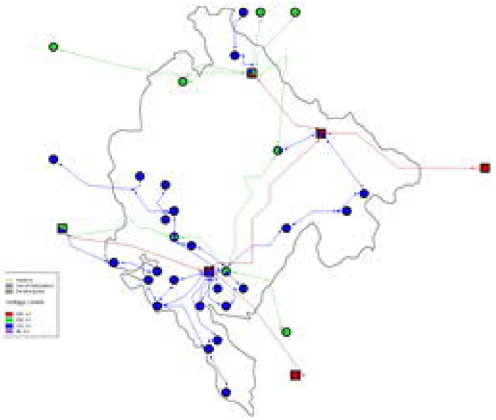
25

Montenegro Transmission system overview

26

Transmission grid of Montenegro Overview 2017

CIGRE Crna Gora — SIEMENS Ingenuity for life.



Follow ing voltage levels are modelled:

- 400 kV – 5 Lines
- 220 kV – 10 lines
- 110 kV – 35 lines + 2 cables

Lines w ere modelled according to the data from CGES and ENTSO-e

Total installed generation: 953,5 MW

Peak load: 653,4 MW

All dates are from CGES Operating Statement and ENTSO-e

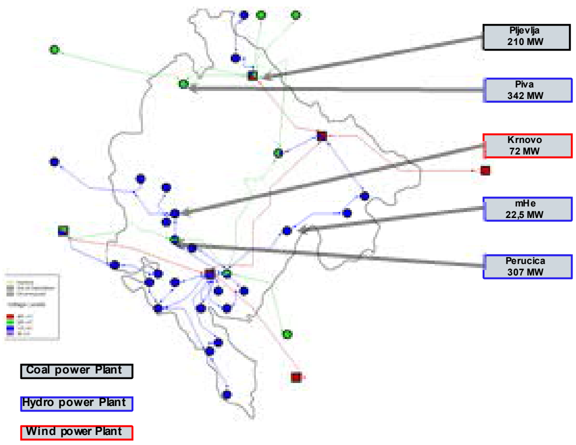
https://www.cges.me/en/documents/reports „Operating Statement for the year 2017"

Siemens AG 2019
Page 27 May 2019 Dr. Ervin Spahic / EMTS PLM

27

Electricity generation of Montenegro

CIGRE Crna Gora — SIEMENS Ingenuity for life.



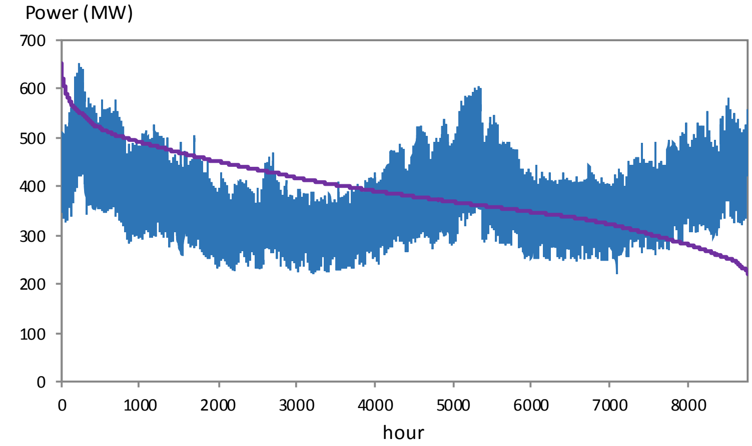
Generators	Voltage Level [kV]	Installed power [MW]
Pljevlja	220	210
Piva	220	342
Perucica	110	307
Krnovo	110	72
mHe	110	22,5

https://www.cges.me/en/documents/reports „Operating Statement for the year 2017"

Siemens AG 2019
Page 28 May 2019 Dr. Ervin Spahic / EMTS PLM

28

Load profile 2017



Peak: 653,4 MW (10.01.2018 17:00)

Low : 221,0 MW (23.10.2018 03:00)

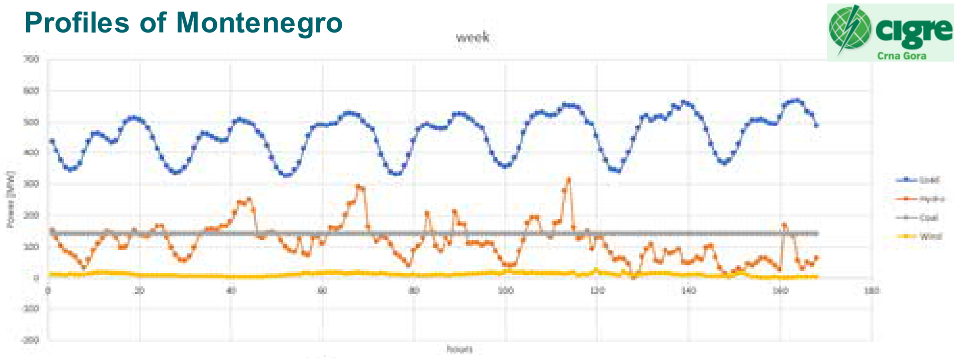
Energy: 3416 GWh

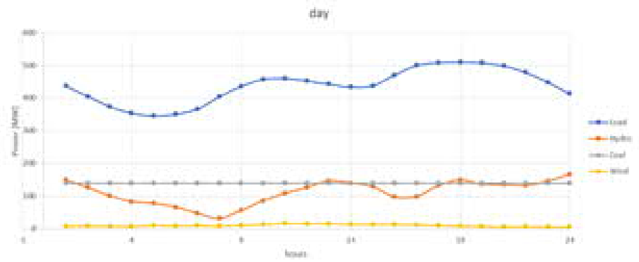
Siemens AG 2019

Page 29 May 2019 Dr. Ervin Spahic / EMTS PLM

29

Profiles of Montenegro





Siemens AG 2019

Page 30 May 2019 Dr. Ervin Spahic / EMTS PLM

30

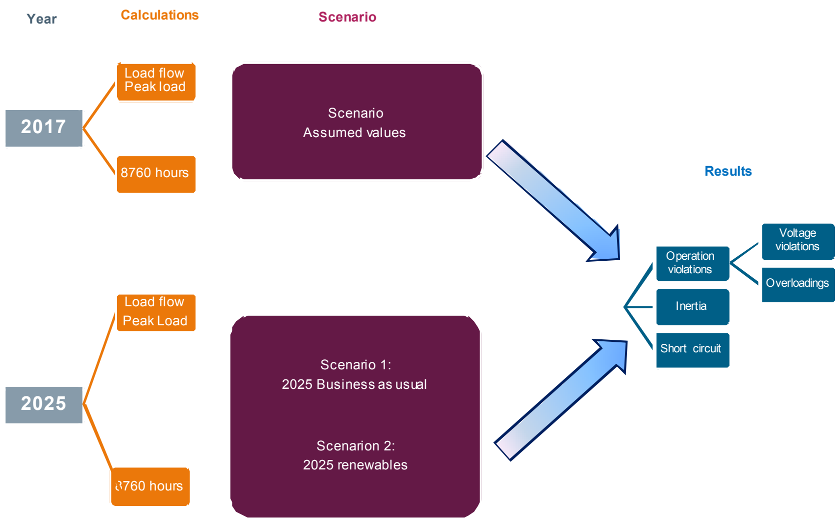
SIEMENS
Ingenuity for life.

Description of calculated scenarios

31

Overview of calculated scenarios

SIEMENS
Ingenuity for life.



Scenarios 2025
HVDC 500 MW – export
No peak load increase
Grid development at 400 kV and 110 kV level

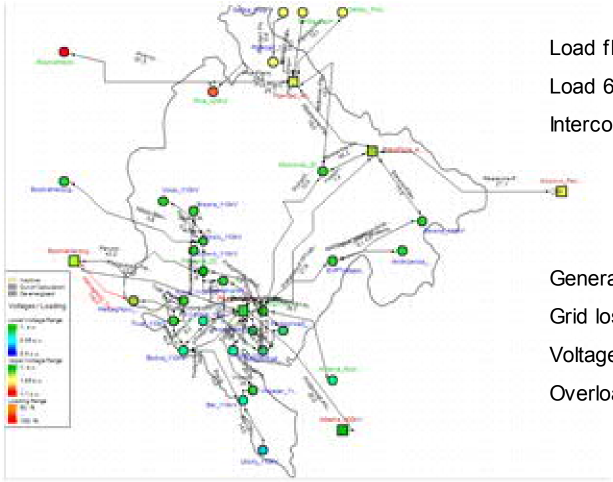
Scenario 1 Business as usual:
50 MW wind farm at Mozura
50 MW PV farm in Ulcinj

Scenario 2 Renewables:
200 MW Wind in Budva (WPD)
150 MW additional PV in Ulcinj
Disconnection of coal power plant Pljevlja

32

Load flow results 10.01.2017 at 17:00

SIEMENS
Ingenuity for life.



Load flow results on 10.01.2017:

Load 653 MW. Cos φ for all loads: between 0,89 ind. And 0,95 ind.

Interconnectors:

- MNE – ALB -97 MW
- MNE – BiH +263 MW
- MNE – SRB -145 MW

Generation: 835,8 MW

Grid losses: 86,7 MW

Voltage violations: 0 (400 kV), 3 (220 kV), 4 (110 kV)

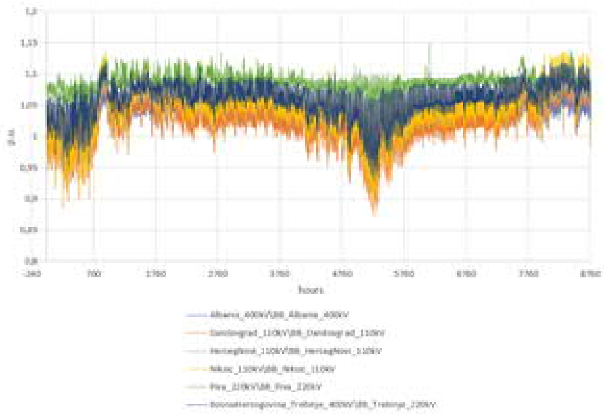
Overloading violations: 4

33

Transmission grid of Montenegro Voltage violations 2017

cigre Crna Gora

SIEMENS
Ingenuity for life.



Total number of busbars: 73

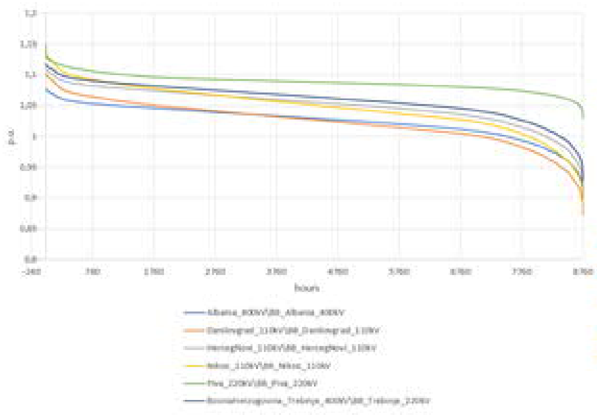
Total violations: 2599

Percentage of violations: 0,4%

Busbar / Concept	N° Violations	Max. Volt [p.u.]	Min. Volt [p.u.]	Exceeded Lim. [% ts]
Albania_400kV\BB_Albania_400kV	1	1,078	0,899	0,01%
Danilovgrad_110kV\BB_Danilovgrad_110kV	32	1,1	0,87	0,36%
HercegNovi_110kV\BB_HercegNovi_110kV	110	1,11	0,91	1,3%
Niksic_110kV\BB_Niksic_110kV	398	1,13	0,89	4,54%
Piva_220kV\BB_Piva_220kV	1308	1,15	1,02	14,9%
BosniaHerzogovina_Trebinje_400kV\BB_Trebinje_220kV	247	1,12	0,93	2,8%

34

Transmission grid of Montenegro
Voltage violations 2017 - sorted



Total number of busbars: 73

Total violations: 2599

Percentage of violations: 0,4%

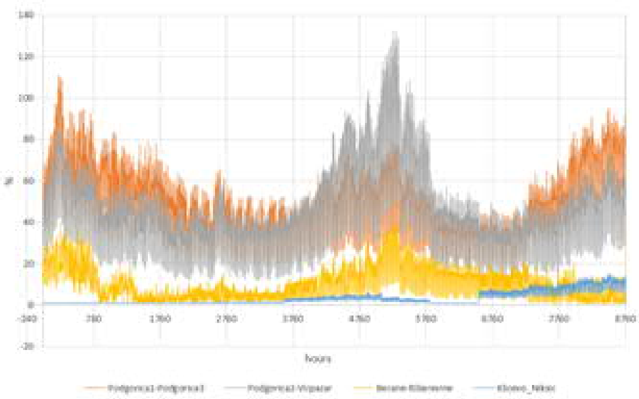
Busbar / Concept	N° Violations	Max. Volt [p.u.]	Min. Volt [p.u.]	Exceeded Lim. [% ts]
Albania_400kV\BB_Albania_400kV	1	1,078	0,899	0,01%
Danilovgrad_110kV\BB_Danilovgrad_110kV	32	1,1	0,87	0,36%
HercegNovi_110kV\BB_HercegNovi_110kV	110	1,11	0,91	1,3%
Niksic_110kV\BB_Niksic_110kV	398	1,13	0,89	4,54%
Piva_220kV\BB_Piva_220kV	1308	1,15	1,02	14,9%
BosniaHerzogovina_Trebinje_400kV\BB_Trebinje_220kV	247	1,12	0,93	2,8%

Siemens AG 2019

Page 35 May 2019 Dr. Ervin Spahic / EMTS PLM

35

Transmission grid of Montenegro
Overloadings 2017



Number of Lines: 50

Number of overloaded lines: 6

Total violations: 5265

Percentage of violations: 1,2%

Line / Concept	N° Violations	Max. Loading	Exceeded Lim. [% ts]
Podgorica1-Podgorica3	35	111%	3,57%
Podgorica2-Virpazar	153	132%	2,77%
Berane-Ribarevine	0	39%	0,30%
Klicevo_Niksic	0	6%	0,14%

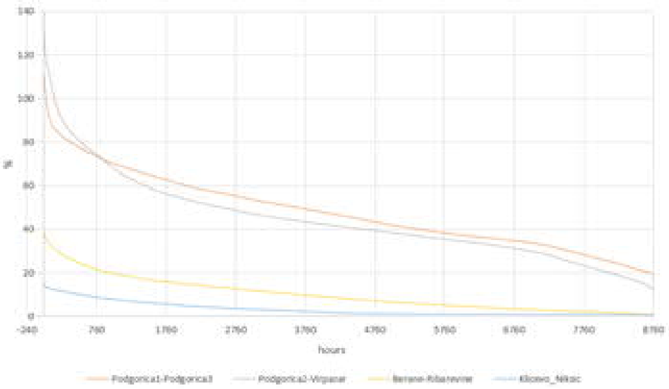
Siemens AG 2019

Page 36 May 2019 Dr. Ervin Spahic / EMTS PLM

36

Transmission grid of Montenegro Overloadings 2017 - sorted

SIEMENS
Ingenuity for life.



Number of Lines: 50

Number of overloaded lines: 6

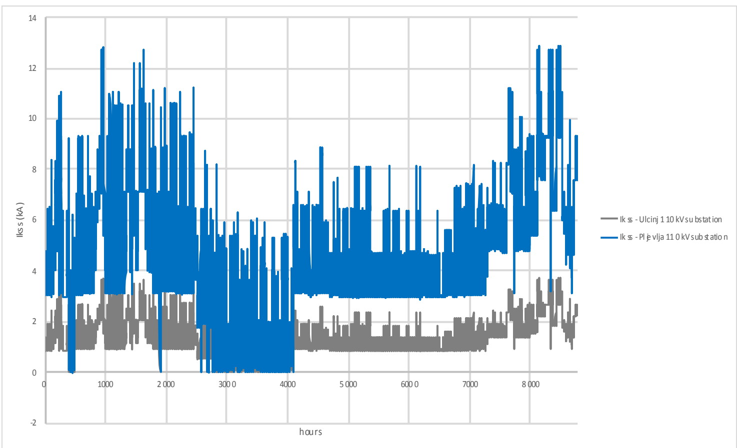
Total violations: 5265

Percentage of violations: 1,2%

Line Concept	N° Violations	Max. Loading	Exceeded Lim. [% ts]
Podgorica1-Podgorica3	35	111%	3,57%
Podgorica2-Virpazar	153	132%	2,77%
Berane-Ribarevine	0	39%	0,30%
Klicevo-Niksic	0	6%	0,14%

Transmission grid of Montenegro Short circuit current 2017

SIEMENS
Ingenuity for life.

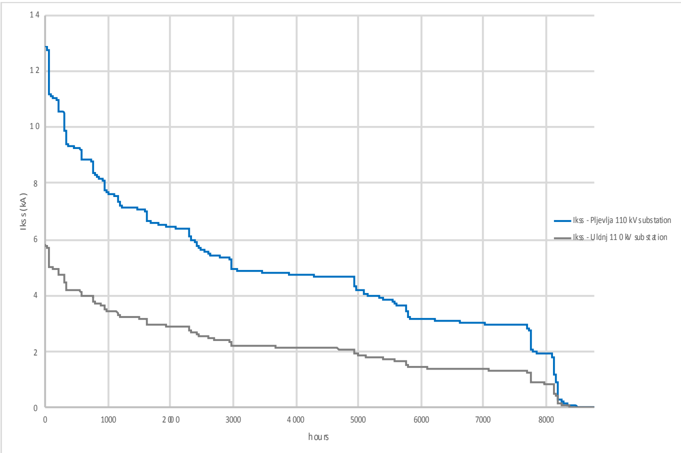


Pljevlja1 (north)

Ulcinj (south)

Big differences showing that short circuit current lower in south

Transmission grid of Montenegro
Short circuit current 2017 - sorted

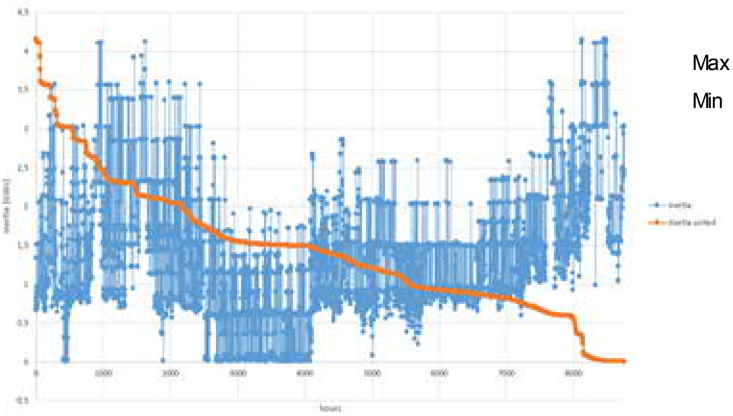


Pljevlja1 (north)

Ulcinj (south)

Big differences showing that short circuit current lower in south

Transmission grid of Montenegro
Inertia 2017



Max inertia 19th December 9pm: 4,1 GWs

Min inertia 22th April 10 pm: 0,1 GWs

SIEMENS
Ingenuity for life.

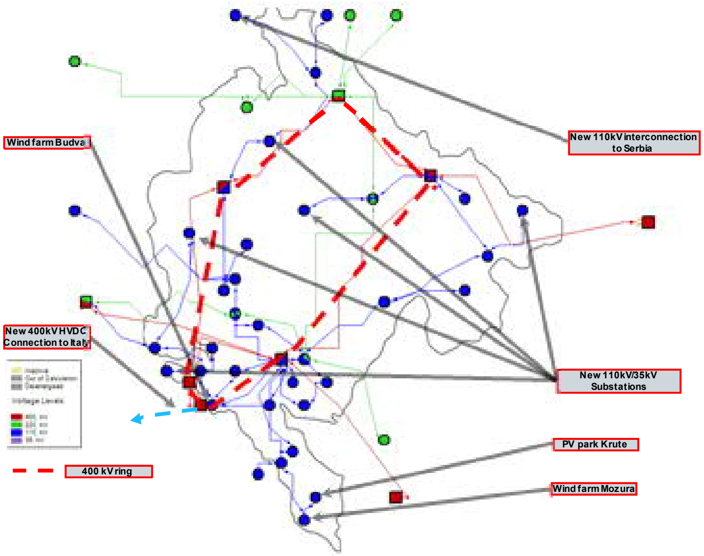
Future scenarios
Year 2025

41

Development of the grid

cigre Crna Gora

SIEMENS
Ingenuity for life.



Generators	Voltage Level [kV]	Installed power [MW]	
Pljevlja	220	210/**0***	Coal
Piva	220	342	Water
Perucica	110	307	Water
Krnovo	110	72	Wind
mHe	110	22,5	Water
Krute	110	50/200*	PV
Mozura	110	50	Wind
Budva	110	200*	Wind

** Scenario 2*

Scenario 1 2025 Business as usual: Grid development at 400 kV and 110 kV level, HVDC connection 500 MW, 50 MW wind farm at Mozura, 50 MW PV farm in Ulcinj

Scenario 2 2025 Renewable: 200 MW Wind in Budva (WPD), Additional 150 MW PV in Ulcinj, disconnection of coal power plant Pljevlja

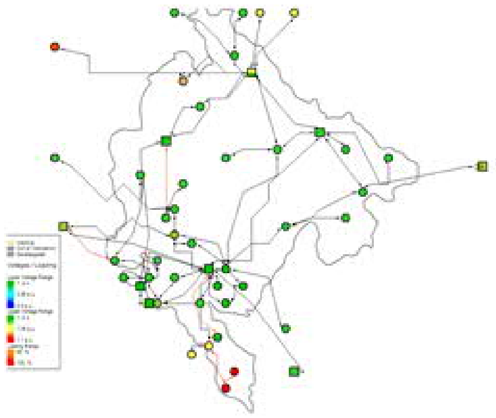
Siemens AG 2019

Page 42 May 2019 Dr. Ervin Spahic / EMTS PLM

42

Results for 8760 load flow calculations
Preliminary

SIEMENS
Ingenuity for life.



	Scenario 1 Business as usual	Comment	Scenario 2 Renewable	Comment
Over / undervoltages	Reduced (-15 %) +	Improvements in south	Increased (12 %) –	Issues in north
Overloadings	Reduced (-11 %) +	Improvements in south, higher transit	Increased (25 %) –	South and transit
Short circuit power*	Similar (+2 %)		Reduced (-21%) –	Reduced (TE Pljevlja out of operation)
Inertia*	Similar (+2 %)		Reduced (-20 %) –	

Siemens AG 2019
Page 43 May 2019 Dr. Ervin Spahic / EMTS PLM

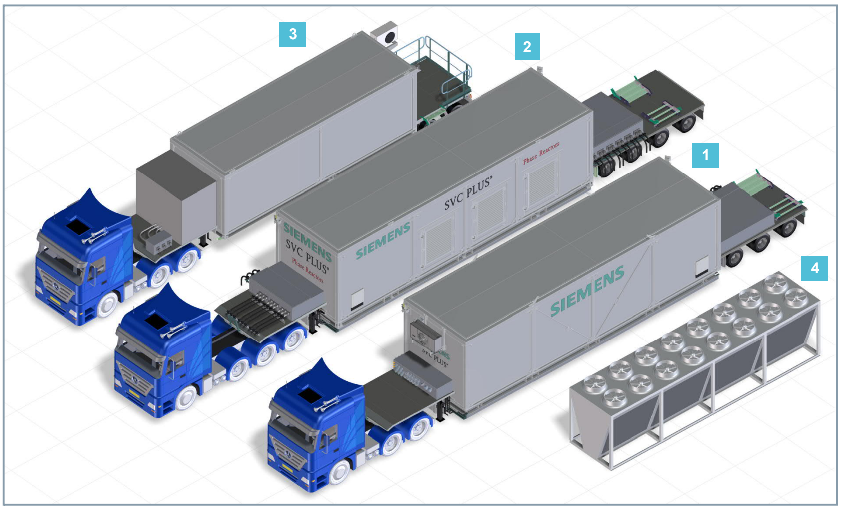
43

SIEMENS
Ingenuity for life.

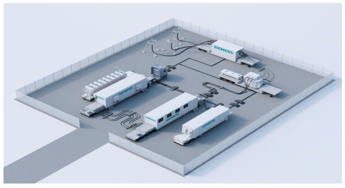
Solutions facing challenges

44

Challenge: flexibility
Mobile STATCOM



1 SVC PLUS Container
2 Phase Reactors
3 Auxiliary Container
4 Air Cooler
Mobile Transformer[1)]
Mobile GIS[1)]

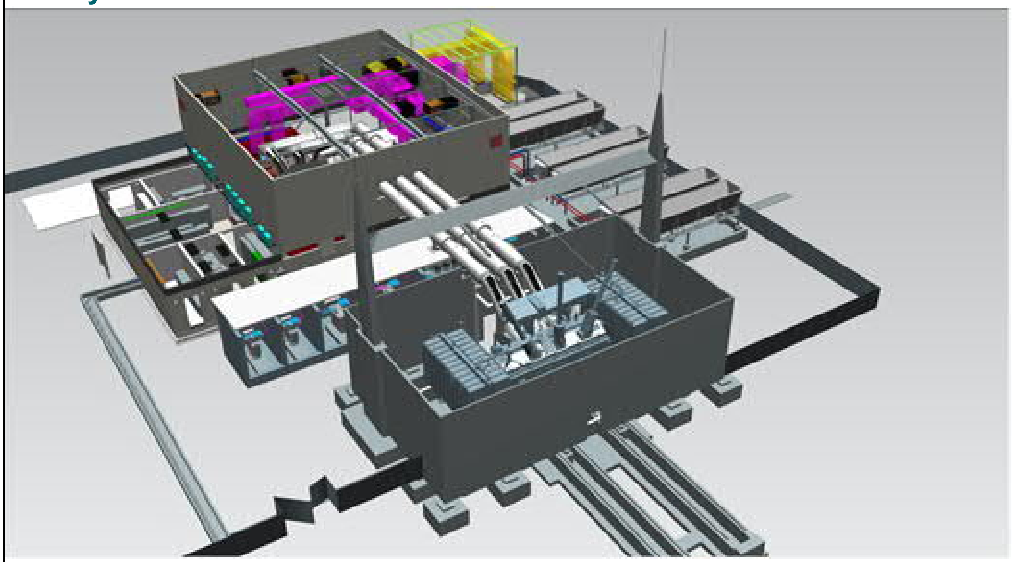


1) Not shown here – further details on request

Siemens AG 2019
Page 45 May 2019 Dr. Ervin Spahic / EMTS PLM

45

Challenge: weaker grids
Synchronous condenser

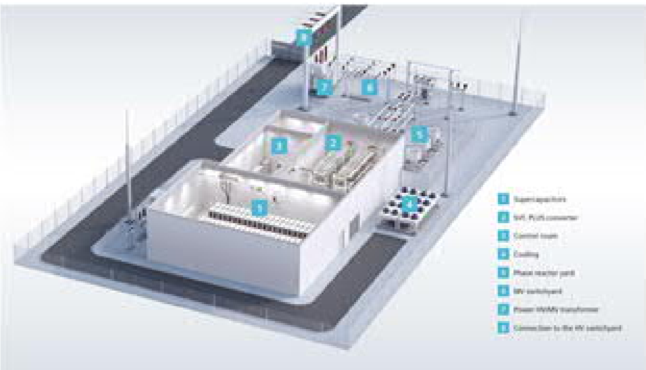


Siemens AG 2019
Page 46 May 2019 Dr. Ervin Spahic / EMTS PLM

46

Challenge: Fast frequency response
SVC PLUS Frequency Stabilizer

SIEMENS Ingenuity for life.



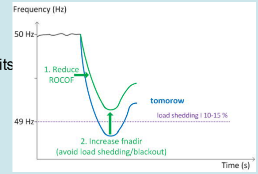
- +/- 70 Mvar continuous
- +/- 50 MW for several seconds
- Footprint app. 2700 m2

Solution

- New modular technology with active power up to several seconds
- Using proven multilevel STATCOM
- Improving grid performance in steady and dynamic states in case of voltage issues
- Providing virtual inertia to the grid and therewith improve frequency stability of the system
- Proven high-end technology SVC PLUS and innovative application of supercaps

Customer benefits

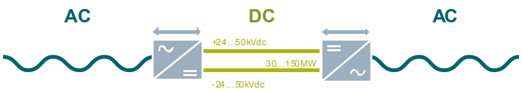
- Grid stability improvement
- STATCOM operation
- Reduced need for "must run" units
- Reduced losses
- Reduced CO_2 emission
- Preventing black-outs
- Improved grid availability

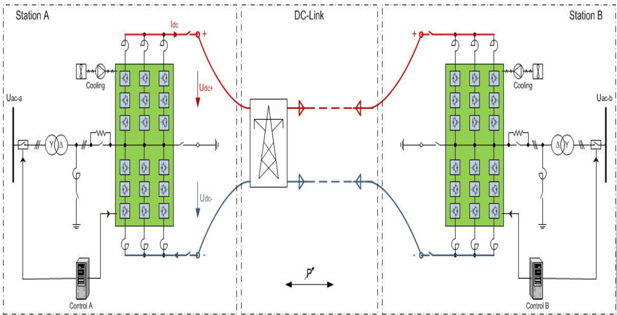


Challenge: flexibility
MVDC PLUS®

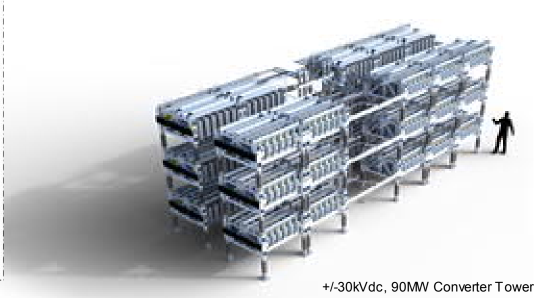
SIEMENS Ingenuity for life.

1. Symmetrical Monopole Configuration
2. Modular Multilevel IGBT Voltage Sourced Converter
3. Bi-directional Power Flow
4. DC-Link Over-headline (OHL) and/or Cable





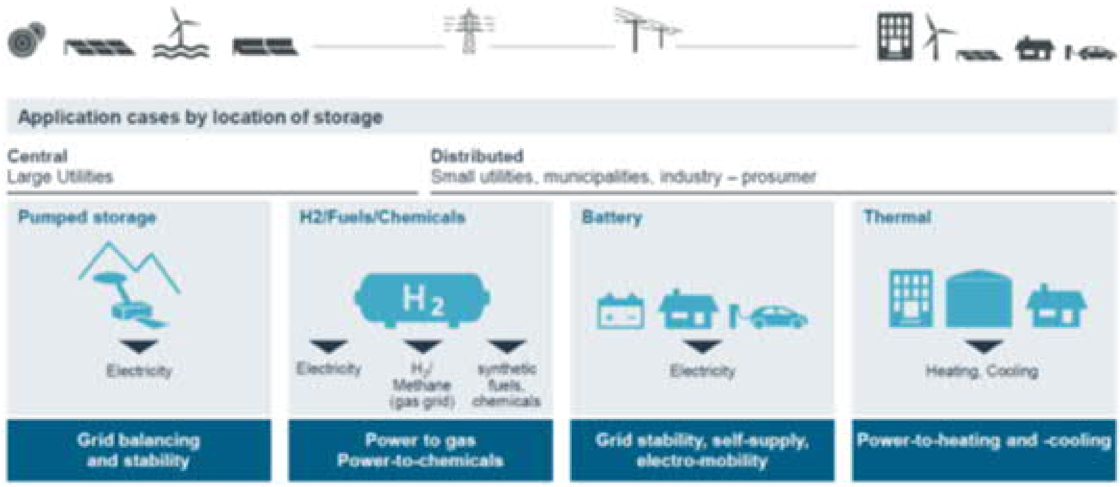
DC System: Symmetrical Monopole



+/-30kVdc, 90MW Converter Tower

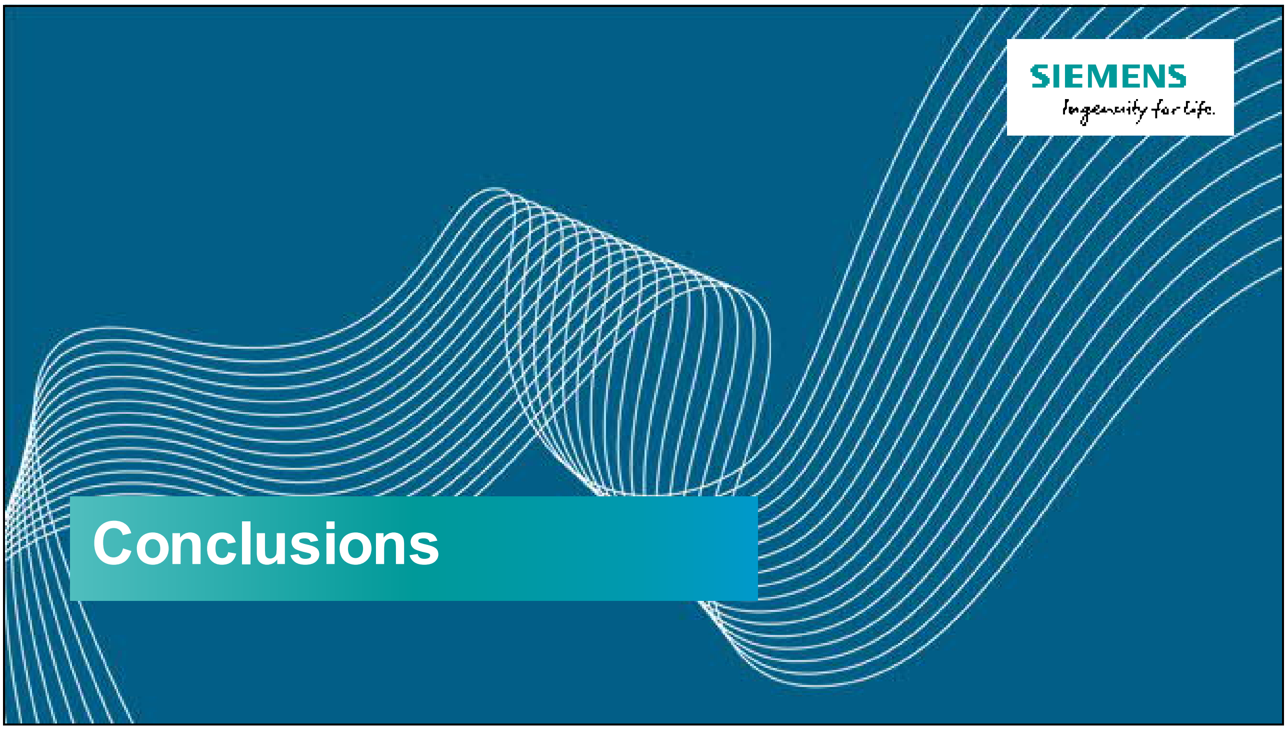
Challenge: flexibility
Storage technologies

cigre Crna Gora | SIEMENS Ingenuity for life.



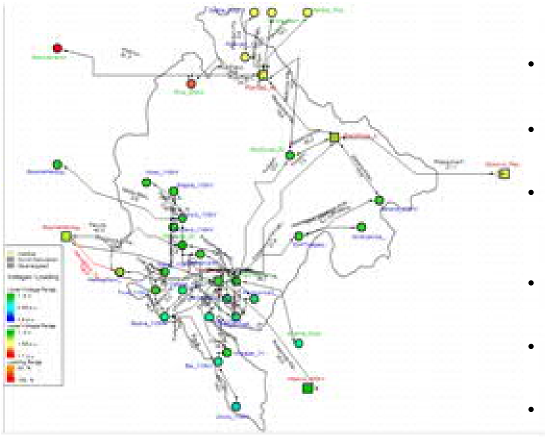
Siemens AG 2019
Page 49 May 2019 Dr. Ervin Spahic / EMTS PLM

49



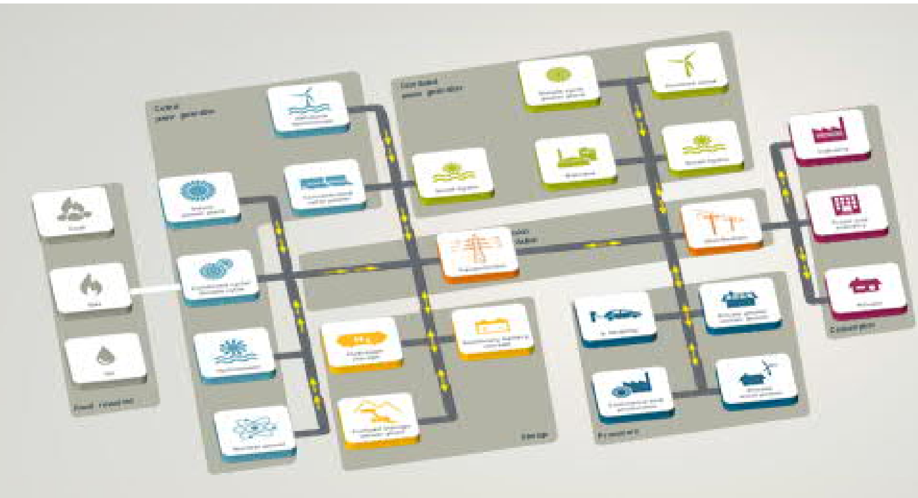
50

Conclusions



- Worldwide very good experience with the renewables and their integration. Renewables can have positive impact -> changes of grid code requirements needed.
- Montenegro has a compact and robust system (coal and hydro generators) and is a part of ENTSO-E.
- In a business as usual – the performance of the system even better – concerns during times when Pljevlja in maintenance.
- In case of renewable scenario the challenges in the system increase – especially the system short circuit power and inertia, overloading's in south and partly undervoltage in north.
- Reduced short circuit ratio could have impact on the secure operation of renewables and HVDC.
- However, with few "small" flexible solutions and few line reinforcement i.e. new lines no significant issues.
- Detailed analysis on possible scenarios and, especially, neighboring countries shall give more precise results.

Thanks for Your attention!



Dr. Ervin Spahic
Head of Future Technologies
Transmission Solutions
GP EPC TS PLM

Siemens AG

Freyeslebenstr. 1
91058 Erlangen

Phone: +49 (9131) 17 38272
ervin.spahic@siemens.com