Space weather
In a power system perspective

Bertil Kielén 2017-11-10

- Something about Svenska Kraftnät and the transmission system
- ”Track record”
- How are we effected by space weahter
- Can we do anything to it?
- Do we need forecasts?
- ?

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Svenska Kraftnät

Swedish National Grid

- **We are responsible for the national grid**
  - **400 and 220 kV lines in Sweden and connections to the neighboring countries, in some cases through HVDC-lines**
- **We balance production and consumption in the electricity system**
- **We ensure that the electricity supply can handle serious strains**

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THE NORDIC/NATIONAL GRID

The Swedish national grid for electricity consists of 15,000 km of power lines, 160 substations and switching stations and 16 overseas connections.

VOLTAGE	OVERHEAD POWER LINE	CABLE
400 kV AC	11 010 km	8 km
220 kV AC	3 550 km	29 km
High Voltage DC (HVDC)	100 km	885 km

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What have happened

- Beginning in 1958 there have been noticable effects at 1-2 occasions per solar cycle. Last time this year (2017-09-08)
  - Fluctuating voltage. Transformers saturated by GIC takes more reactive power
  - Line and transformer trips. False trips from sensitive earth fault protections
  - No damaged equipment
  - Often possible to reconncet within a minute
  - No severe problems to keep the system stable
    - No customers without electricity but in Malmö 2003

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What have happened

- Transformer failures?
  - No, we have not noticed any immediate transformer failure or shortened life time
- Problems with satellites?
  - No, we don’t use GNSS in critical systems and has an atomic clock to control our computer networks
  - We don’t use satellite communication to control the system

What if …

- Transformer failure is possible
- Several lines out at the the time could result in a blackout
- Voltage problems might jeopardize system stability
- Or a combination of the above
  - Blackout to larger areas

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What do we do about it?
Planning

- Protections less sensitive to GIC and harmonics
  - Yes, much better now compared to 1980’s but ”false” tripping´s could still happen
- We always buy 3-phase 3-limb transformers which can withstand 200 A DC current in the neutral connection for 10 minutes
  - Now about 2/3 of all HV-transformers are 3-phase 3 limbed
  - Next version of our guideline will insted refer to IEEE-standard, Std C57 163-2015
  - Exceptions, a few new installations with single phase units are equipped with neutral resistors to reduce the flow of GIC

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What do we do about it?
Planning

- Communiction through optical fibers
  - Power Line Carrier, Radio links and hard wires are phased out
- Measurements of GIC
  - Not implemented yet
  - But better measurements of voltages and harmonics

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What do we do about it?
Planning

- Restoration plan
  - A partial or total blackout might happen for different reasions
    - Heavy ice, hurricane, technical failures…. or *space weather*
  - We do have a plan how to restore the system even from a total blackout
  - Operators have simulator training

What do we do about it?
Operational procedures

- Warnings and alerts from UK Met office via SMHI
- **At NOAA G4**
  - Raised awarness in the control center, any voltage deviation?
  - Watch out for new information, contact with IRF

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What do we do about it? Operational procedures

- **At NOAA G5**
- Reduced transfer limits (however if the planned transfer is above the new limit we don’t change the schedule)
- Test of protection, communication equipment and circuit breakers abandoned. No new test started
- If its possible to take outaged lines, transformers, generators, protection into service, do so. Don’t start any new outages
- If it is’nt very costly or mess up other plans for the future (this is often the case)
- Series compensation should be in service
- Keep normal voltage

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What do we do about it? Operational procedures

- **At NOAA G5+** = much more than just at the threshold for G5
- As above plus:
- Bring in more people to the control center
- Keep transfer within limits = counter trade

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Forecasts

- To reduce transfer with the normal market mechanism we would need a notice 40 hours in advance
  - The local short time Dst in Sweden will reach 100 nT/min [+/- x nT] Monday 13/11 at 20:20 CET [+/- y hours]
  - Reliable and precise both in timing and strength
  - Otherwise used to raise awareness in the control center and possibly postpone works
- Forecasts 1-40 hours ahead
  - Same requirements
  - Handle by Svk with special power transactions

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Forecasts

- Short time forecast
  - E-field could be used to calculate the GIC and the reaction in the transformers
  - A network model with (near) real time topologi should be used
  - Power generators with very short time to start could be used (gas turbines)
  - Some swithing operations possible
  - But less than 1 hour is to short to do any serious action/decision
- Real time measurements, Dst, E-field, GIC
  - Used to verify if an event is caused by space weahter or not
  - Model verification

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