# Very low likelihood of a power grid black-out in Belgium during an extremely severe geomagnetic storm

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## Context & Aims

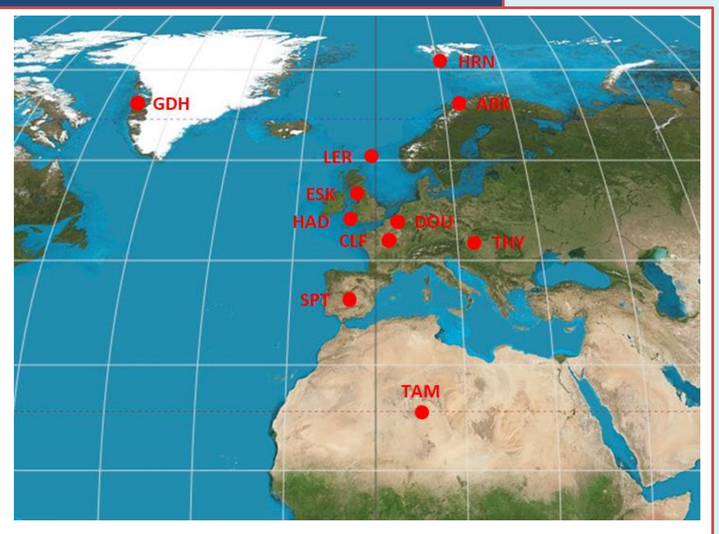
- Regular questions from broad public and space weather (SWx) end users on the probability of a power grid black-out in Belgium during a strong geomagnetic storm, similar to 13-14 March 1989 and 29-30 October 2003.
- In a recent report[1], Elia, Belgium's main high-voltage transmission system operator, mentioned not a single SWx-related power grid event during the period 1977-2017, mild fluctuations at most.
- This study compares the variations in the magnetic field in Belgium during strong geomagnetic storms with those from other magnetometer stations in the European sector, putting them in perspective against events known to have caused great disturbances in the power grid.
- [1] Source: https://www.elia.be/nl/publicaties/brochures


## 1. Selection of strong geomagnetic storms

- Period: 1996 – 2017
- Source data: Kyoto WDC (http://wdc.kugi.kyoto-u.ac.jp/)
- Criteria: Kp ≥ 7- and Dst ≤ -100 nT and AE ≥ 1200 nT (most intense value on daily base)
- Completed if only one criterium was missing
- Completed if 2 criteria missing and Dst ≤ -125 nT or AE ≥ 1400 nT
- Total number of strong geomagnetic events: 179 storm days

## 2. Selection of magnetometer stations

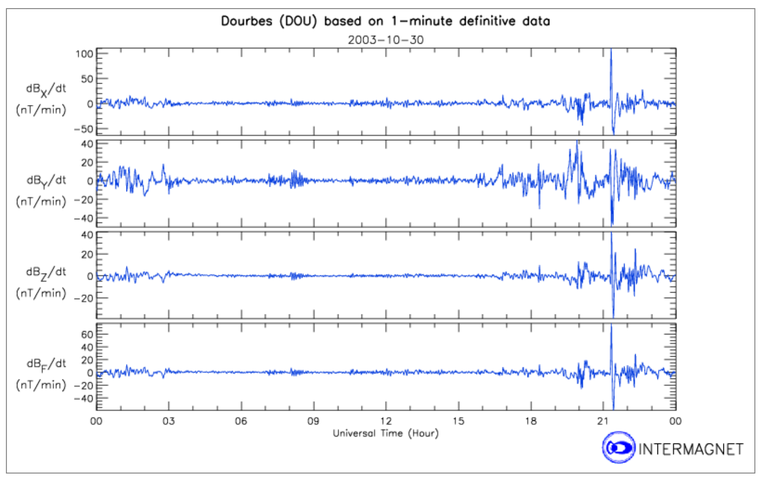
- 10 magnetometer stations in the European sector (from 76E to 124E)
- About evenly spread (about 4° to 6°) in geomagnetic latitude (74N to 24N)
- Belgium represented by Dourbes (51N geomagn. lat.)




- Godhavn (78N, 34E) added to have station within the auroral oval
- Choice of stations also determined by availability of data during the period (Intermagnet)

## 3. Data handling

- dB/dt generally considered as a good proxy for Geomagnetically Induced Currents (GIC, SWx cause for power grid disturbances)
- For each event day and at each location, maximum (dBx/dt) and maximum (dBy/dt) were manually determined from graphs at Intermagnet (http://www.intermagnet.org/)
- Maximum absolute value was taken, i.e. max(abs(dBi/dt))
- Data binned and averaged per Kp level (e.g. Kp = 8 combines 8-, 8o and 8+)
- However, Kp = 9- and Kp = 9o were kept apart



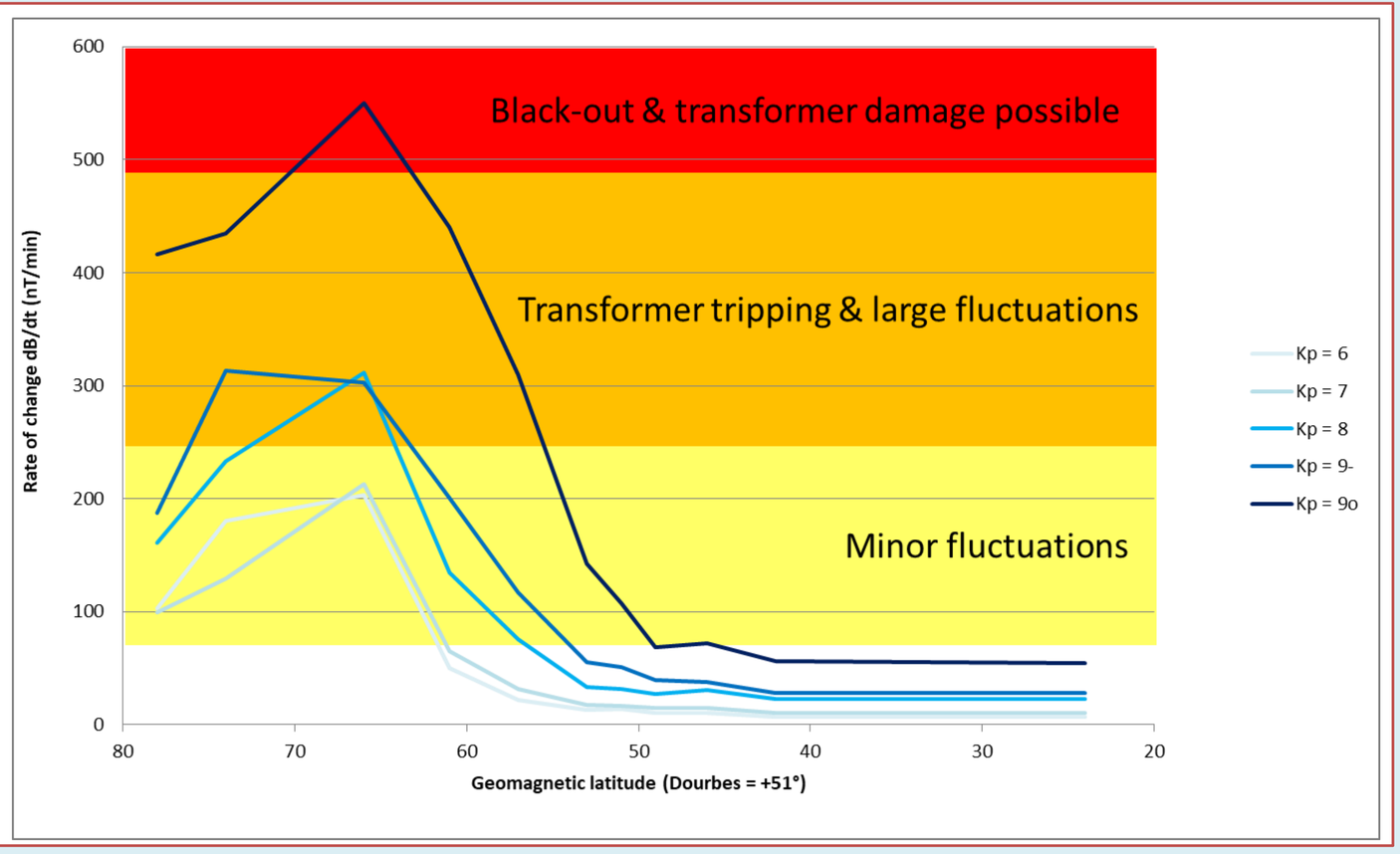

## 4. Selection of incidents

- Period 1972–2017
- Binned i.a.w. severity incident
- *Sources: Boteler et al. (1999), Odenwald (2000), Weaver et al. (2004), Kappenman (2005), Wik et al. (2009), Stauning (2013), Liu et al. (2016), Knipp et al. (2018), Private comm. with Elia on 2003 event for Belgium, Intermagnet data for relevant stations*

| Date | Location | Incident | (dBi/dt)max in nT/min | Geomagn. Lat. | Kp |
|---|---|---|---|---|---|
| 4 Aug 1972 | Manitoba, Canada | Transformer damage | 800-2000 | 61N | 9 |
| 13-14 Mar 1989 | Québec, Canada | Black-out | 600-900 | 55N | 9 |
| 29-30 Oct 2003 | Malmö, Sweden | Black-out | 500 -1200 | 55N | 9 |
| 24 Mar 1991 | Sweden | 9 220 kV lines & 1 transfo tripped | 450 | 58N | 9- |
| 9 Nov 1991 | Sweden | 1 220 kV line tripped | 430 | 58N | 9- |
| 6-7 Apr 2000 | Southern Sweden | Largest GIC ever recorded in transfo (~300 A) | 400 | 55N | 9- |
| 8 Nov 2004 | Southern Sweden | GIC of 100 A in 1 transformer | 130 | 55N | 9- |
| 29-30 Oct 2003 | Belgium | Mild fluctuations | 110 | 51N | 9 |
| 22 Jun 2015 | China | Fluctuations in Railways | 80 | 26N | 8+ |

## 5. Results

- This graph combines the 4 foregoing steps:
  - The horizontal axis represents the geomagnetic latitude for the 11 magnetometer stations
  - The vertical axis represents the average of the maximum rate of change (dB/dt) binned over Kp
  - The 5 curves are for each separate Kp
  - In general, standard deviations were about half the average values
  - The background colors reflect the intensity of the power grid disturbance
- Catastrophic failures occur between mostly 60-70°
- Note the steep drop-off in GIC effects outside this zone towards geomagnetic equator
- Note relatively large difference in GIC effects between Kp = 9- and Kp = 9o storm days
- Dourbes (51N) is at the very low end of the minor effects region, even during strong storms (Kp = 9)
- GIC effects are clearly not 0 for equatorial locations during strong storms




## 6. Main conclusion

- Belgium has a near zero probability for a power grid failure similar to Québec in 1989. Maximum dBi/dt values in Dourbes should be at least 4 to 5 times higher than those recorded during the Halloween storms in October 2003, i.e. 550 nT/min vs. the recorded 110 nT/min.

## 7. Contact

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