OKG

OKG is part of the Sydkraft group which is the second largest utility in Sweden. OKG operates 3 NPPs in south-east Sweden and produce approximately 10% of the electricity in Sweden. Vattenfall is the biggest utility and Svenska Kraftnät is the owner and operator of the 400 and 220 kV system.

Kraftnätet i Nordvästeuropa

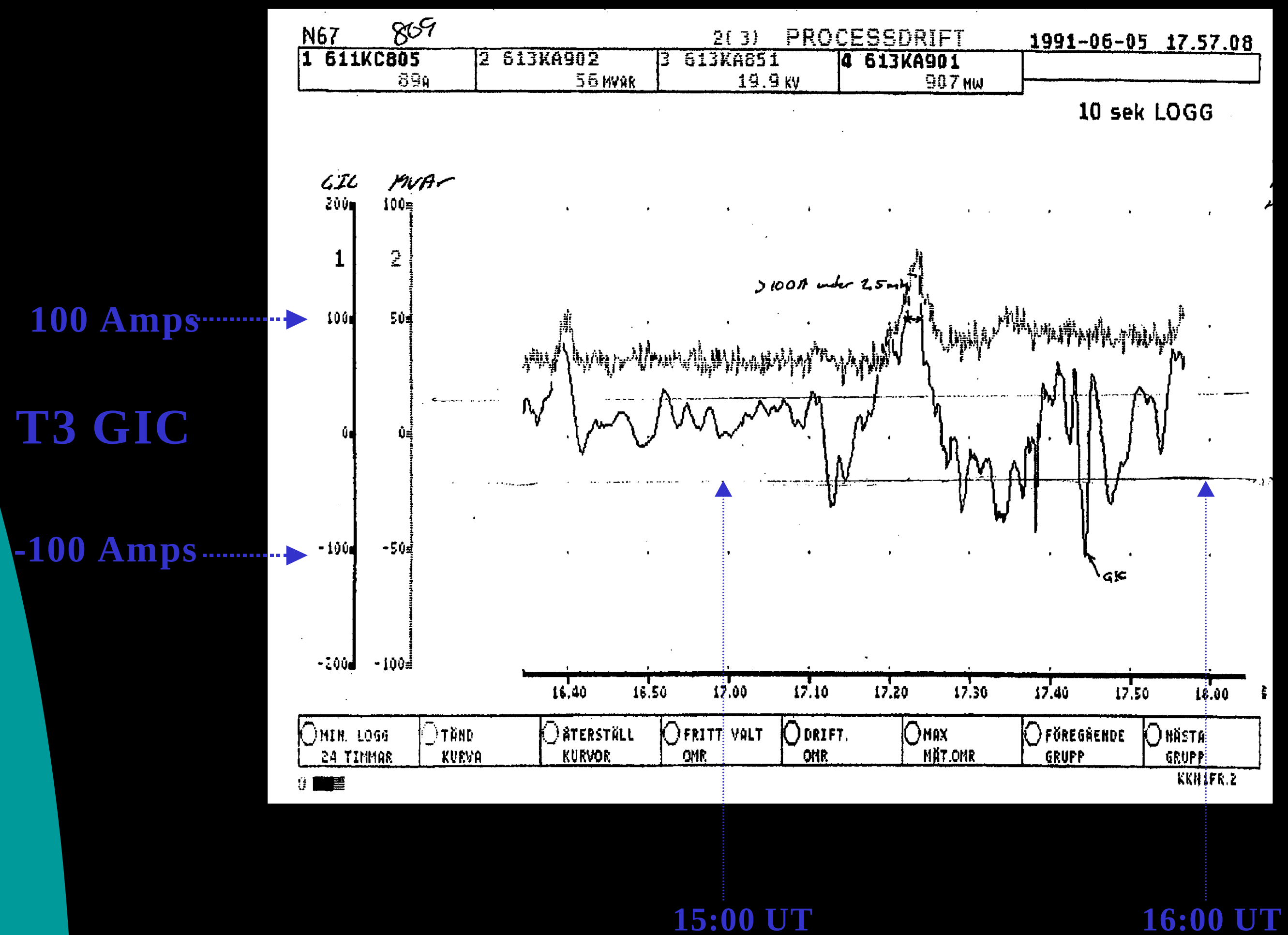
Det svenska stamnätet omfattar huvudsakligen kraftledningar för 400 och 220 kV, ställverk, transformatorstationer m.m. samt utlandsförbindelser för växel- och likström.

Omfattning 1999	Friledning	Kabel
400 kV växelström	10573 km	4 km
275 kV växelström	75 km	–
220 kV växelström	4295 km	
130 kV växelström	–	7 km
Högspänd likström (HVDC)	115 km	236 km

Background

- OKG first experienced GIC 1986
- Some minor measures where taken including a continuous GIC monitoring system
- 1998 We analysed the risk for severe consequences
  - The analyses indicated that additional measures where needed
  - Some transformers world-wide has broken down from GIC
  - IRF in Lund where contracted on R&D basis to produce a prediction system for GIC in one transformer
  - A co-operation with Svenska Kraftnät (SvK) where initiated
  - Metatech where contracted to help evaluate the vulnerability of the Swedish and Norwegian networks

GIC disturbance



GIC disturbances in the Swedish grid

- 1960 30 lines tripped
- 1982 4 transf and 15 lines tripped
- 1986 5 occasions, 1-3 lines tripped at each occasion
- 1986 O3, minus sequence start, high temperatures in G3. O3 has since then suffered several GIC´s and been in fieldcurrent mode several times
- 1989 5 130 kV lines tripped
- 1991 1 transf and 9 lines tripped
- 1991 1 220 kV line tripped
- 1999 Radio communication for protection lost. O3 in fieldcurrent regulation for 1 h
- 2000 O3 in fieldcurrent regulation for 7 h, registered voltage drop on the 400 kV system

GIC has however so far not caused any customers to be out of power

Effects From GIC on T3/G3 at OKG

- Overheating in mainly GSU T3 (GIC sensitive type of transformer)
- Increase in reactive power consumption in mainly T3
- Harmonics from T3 produces high temperatures in G3
- Unstable operation of G3 makes it necessary to use field current regulation
- Possible trip from minus sequence or earth-fault relay or reduction of output power
  - Possible breakdown of G3/T3

Performed OKG / Svenska Kraftnät Investigations:

- Rearrangement of the connections to the grid
- Installation of blocking device
- Installation of a neutral resistor in T3
- Installation of series capacitors
- Transformer neutral not connected to ground
- Influence on the relay protection system
- Measurements to investigate the different flows of GIC
- Calculating the equivalent dc-resistance (part of the system)
- Sunburst (monitoring)

Measurements

- Simultaneous measurements of GIC and harmonics in 6 transformer neutrals OVT T1, T2, T3 and SVP T7, AVA, KID and GLN
- Measurements during 1 month 1998
- Measurements at different connections to the grid
- Disconnection of one pole of the dc-cable to gotland created a potential difference (DC current)
  - During the measurements at least 3 events was recorded
  - GIC was found also in other transformers

Possibility to predict DC-currents

- An R&D-project with the ambition to develop predictions of GIC in T3 is performed by IRF. It is also possible to receive predictions from Metatech
- From NPP point of view predictions are not enough, we will hopefully avoid damaged apparatus but will suffer from loss of production. From network point of view we will investigate if there is enough possible actions that could be triggered from predictions

  It is crucial that predictions deliver information that is understandable to operators. It seems like the translation from space matters to utility matter must be solved in co-operation between space researchers and electric utilities.

Today

- To reduce the effects at one site (O3) a neutral resistor has been installed
- One additional transformer at OKG has been equipped with continuous GIC monitoring
- OKG, SvK and Vattenfall together with Statnett and Metatech performed a risk analyses of GIC influences on the grid via modelling
  - This work utilised an evaluation of the effects of neutral resistors
  - Risks for the grid was revealed
  - Risks for Power plants was revealed
  - Possible actions could and can be tested in the model

Specification, neutral resistor

- Resistance at 20 °C 2,4 Ω +/-5%
- U_m (kV) 24
- Rated initial current (A) 14000
- Rated peak withstand current (A) 28600
  waveform according to appendix 1
- Operating time (s) 1
- Current after 0,5 s (A) 6000
- Final current after 1 s (A) 5400
- Continuous current (A) 50
- Rated insulation class (kV) 36
- Test voltage, 50 Hz and 60s (kV) 70
- LI terminal to ground (kV) 170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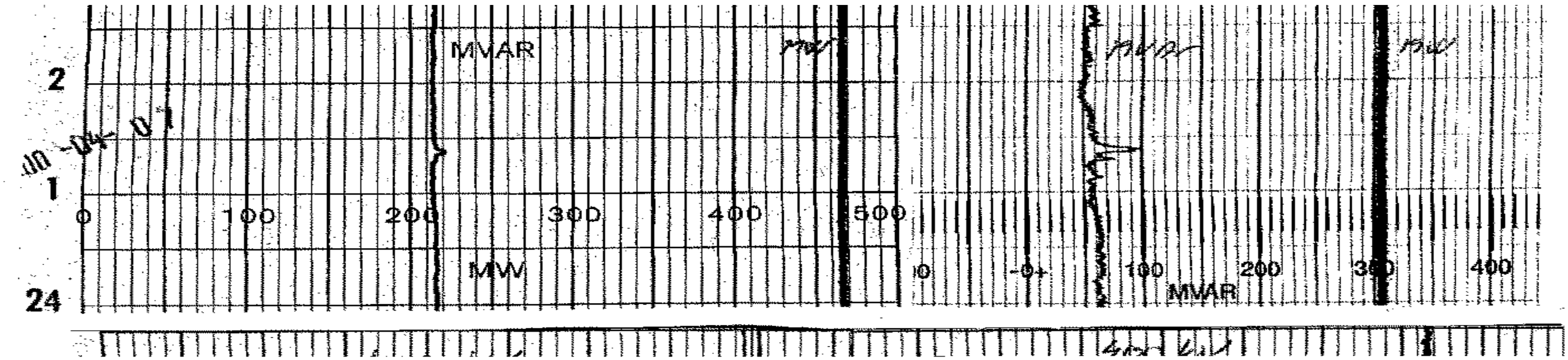
Högspänd likström (HVDC) 115 km 236 km
Vattenkraftstation
Värmekraftstation
Transf. el kopplingsstation
750 kV ledning
400 kV ledning
275 kV ledning
220 kV ledning
Samkörningsförbindelse för lägre spänning än 220 kV
Planerad/under byggnad
Sverige
Norge
Finland
Estland
Ryssland
Lettland
Litauen
Kaliningrad
Polen
Vitryssland
Danmark
Tyskland
1
2
3
4
5
0 100 200 km


2
1
24
0
100
200
300
400
500
MVAR
MW
0
100
200
300
400
MVAR

Recommendations/Future work

* Verification of GIC-levels, MVAr, voltage
* Investigation of Harmonic immunity
* Transformer Design
* Possible actions if predictions are available
* Predictions / Forecasting