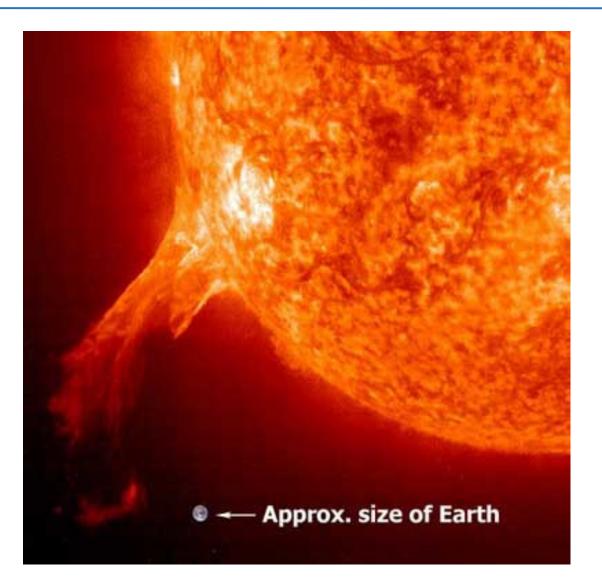
#### Geomagnetic Disturbances Grid Code Review Panel 21 November 2012



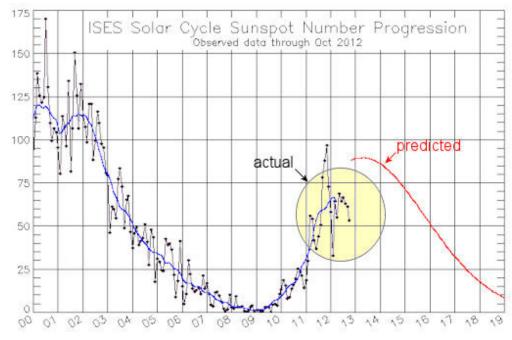
Andrew Richards Severe Risk Analyst National Grid

#### **Coronal Mass Ejection**



#### **Solar Cycles**

- Sun follows a cycle, roughly 11 years
- Number of sunspots indicates how much activity
- Cycle 24 will reach maximum in March 2013
- 2 to 3 years after maximum most active for solar storms
- Cycle 24 was predicted to be weakest for 100 years
- It's turned out even weaker than predicted



#### **Effects on the system**

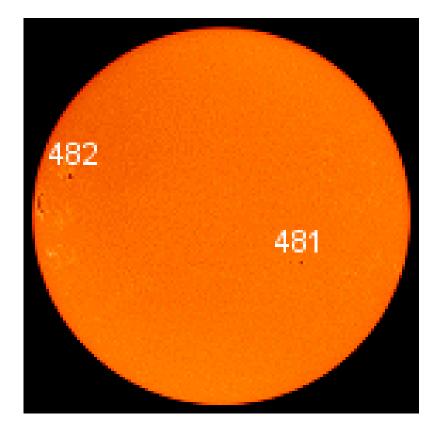
- Magnetic flux leakage from core
  - Overheating, gassing, shutdown
    - Potentially catastrophic failure
- Distorted output waveform
  - Higher harmonics present
  - Protective relays triggered
  - Control assets switched out
- Increased reactive power consumption
  - Voltage instability



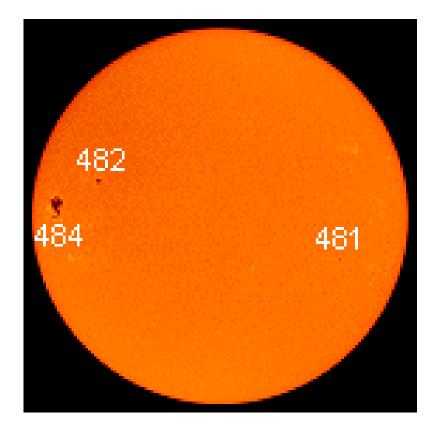
#### **Risk Factors**

- Geographic Location
  - Further north
  - Geological structure down to 500km
- Line length
- Line resistance
- Last two explain why no disturbance ever observed in low voltage network

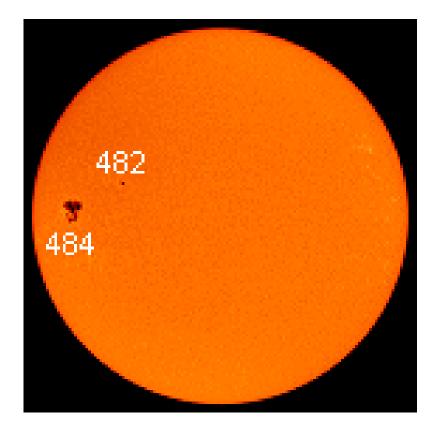
#### **Sunspots**



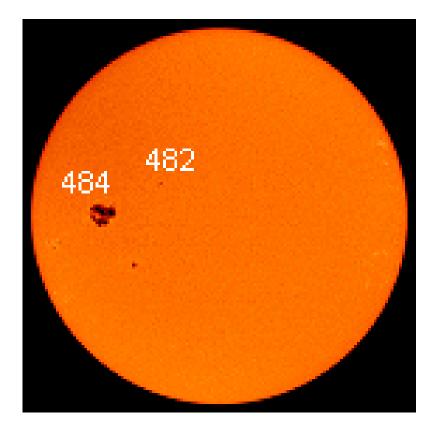
#### **Sunspots**



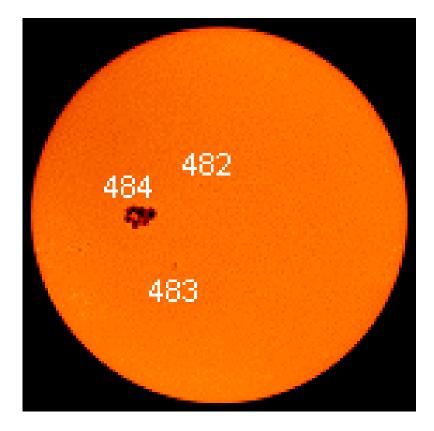
#### **Sunspots**



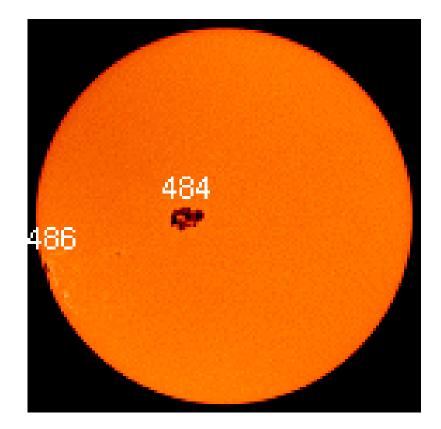
#### **Sunspots**



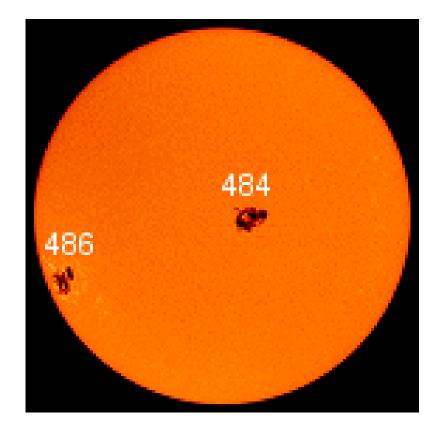
#### **Sunspots**



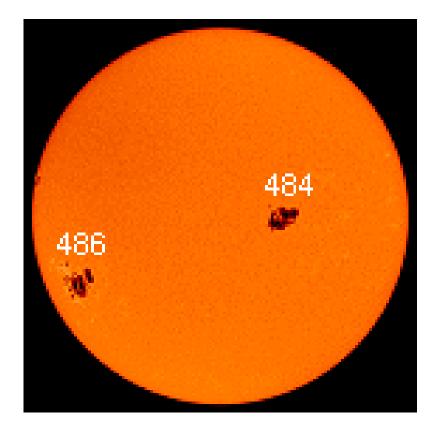
#### **Sunspots**



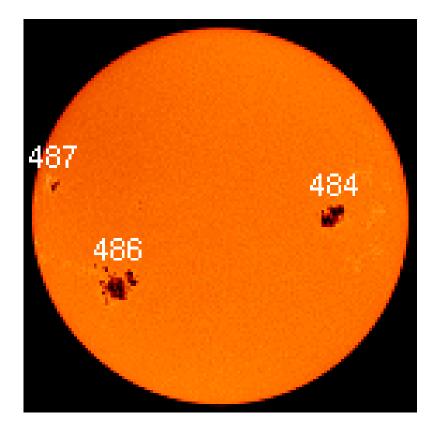
#### **Sunspots**



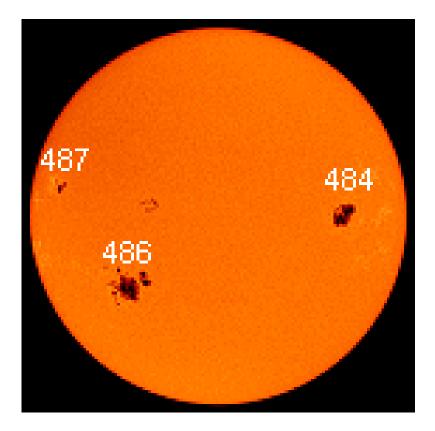
#### **Sunspots**



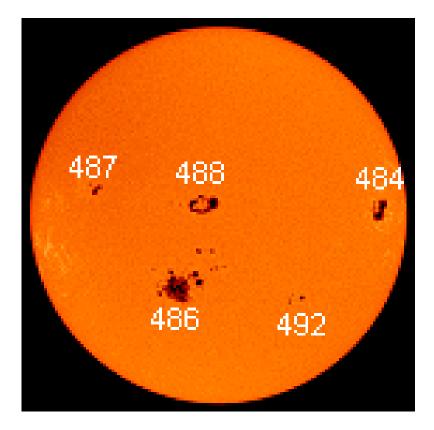
#### **Sunspots**



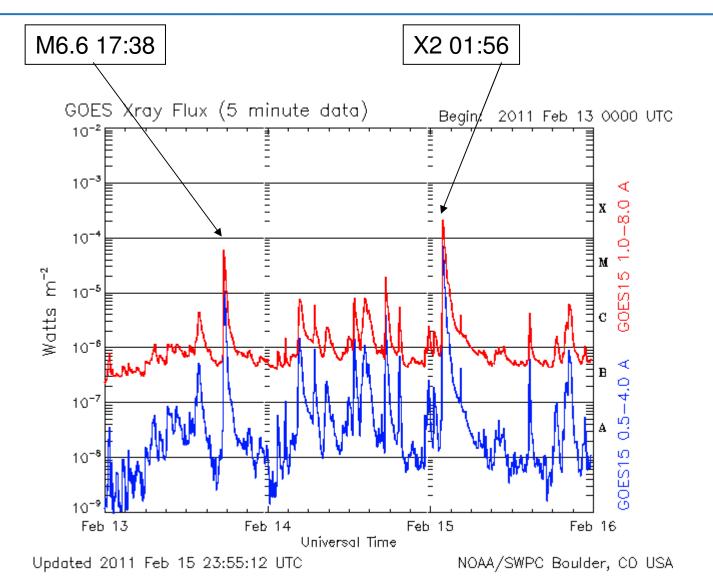
#### **Sunspots**



#### **Sunspots**



#### X-Ray burst from solar flare



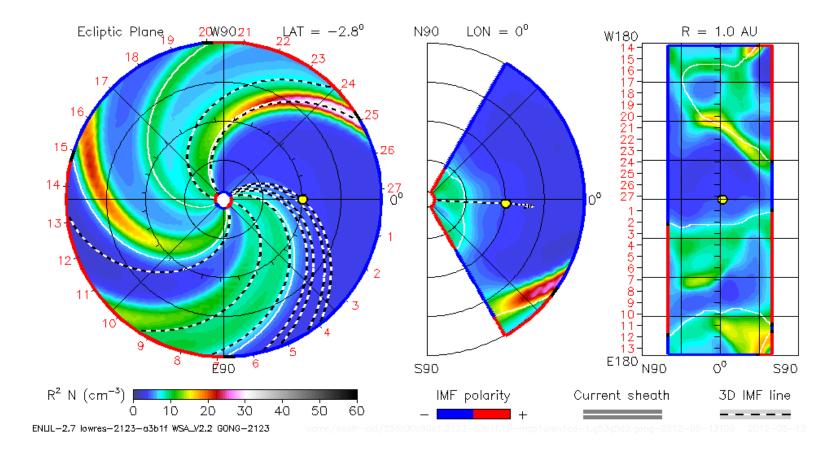
17

#### **ENLIL Model**

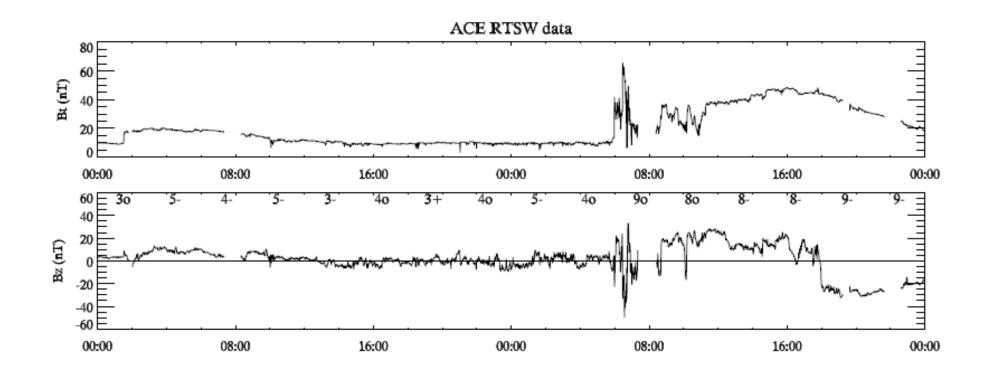
2012-05-13T00:00

2012-05-13T00 +0.00 day

🗢 Earth



#### **CME** arrival at ACE



#### Warning actions

- Day -4 onward
  - Monitor all available space weather sources carefully
- Day -1 Observe CME
  - Issue warning of possible system disturbance
- At T -15 minutes
  - Observe direction of Bz at ACE
  - Reissue warning of system disturbance

### **NG Operational Mitigation**

#### ALL IN:

- All circuits returned to service and switched in
- All Supergrid Transformers connected
- Substations run solid
- Extra generation instructed to synchronise
- Extra reactive support made available
- All monitoring and warning systems utilised

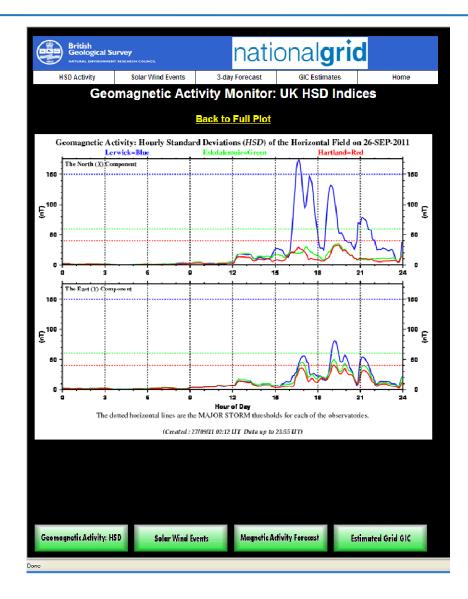
### **Notice of System Disturbance**

- The same as any System Disturbance warning for any other cause
  - Flood, storm, lightning.....
- Continue to follow PNs
- Contribute to system integrity
- Market continues to operate unless......
- National Grid may issue Emergency Instructions to depart from normal Balancing Market Operations in accordance with BC2.9
- Acceptance of an Emergency Instruction counts as acceptance of Bid-Offer Acceptance

### Modelling work for E3C

- Focuses on risk of physical damage to high voltage transformers
- Gives order of magnitude results for a couple of extreme (1 in 100 year) scenarios
- Work requested by E3C includes generator transformers in network model
- Can provide risk to individual transformers at different GIC levels
- Can't be used to identify transformers at risk in any GMD – GIC levels too dependent on individual storm

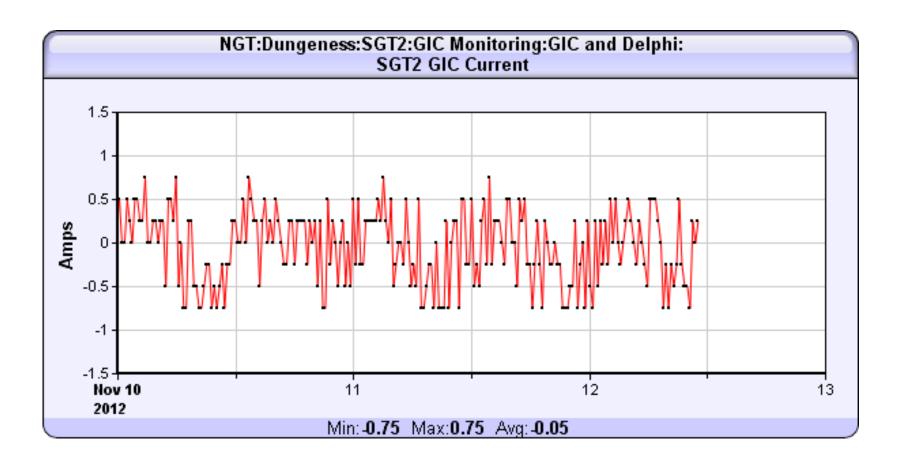
### National Grid / BGS MAGIC Webtool nationalgrid Magnetometer records



# National Grid / BGS MAGIC Webtool nationalgrid Network Model display

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			CLYS21	2.8	13:54	ECCL11	3.5		
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### **GIC Monitoring**



### **Cooperation for Cycle 24**





ELECTRIC POWER RESEARCH INSTITUTE





NOAA NASA NERC (UK) NERC (US)

National Grid UK (4 SUNBURST sensors) National Grid US (2 SUNBURST sensors)





#### Lancaster University Manchester University Cardiff University



Scottish Power DECC Cabinet Office