Workshop on transmission network security standards

Modelling and analysis in support of the fundamental review of GB SQSS

G Strbac

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    - Shift in network design philosophy: from peak demand security to economic efficiency
  - SQSS and TAR
  - Key questions for fundamental review of SQSS
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- Probabilistic Cost-Benefit Analysis
- Initial illustrative case studies: assessing the efficient existing network capability
  - Impact of constraint costs, weather condition, intertrip, line construction)
- Observations

Shift in network investment and operation from reliability to economic efficiency

- Historically, reliability driven design of transmission network to meet peak demand requirements, was considered to deliver economically efficient solution (limited constraints).
- How does a significant penetration of wind power changes this approach?
  - Ability of generation to secure load during peak condition is critical for determining transmission requirements associated with that source
  - The ability of wind generation to displace capacity of conventional plant is the key to answering the question as to how much transmission should be built for it (capacity value of wind 10%-20%)
  - Wind has a limited contribution to security of supply and hence, from the reliability perspective, drives much less transmission than conventional plant

	Low penetration	High penetration
Low diversity	**35%**	**20%**
High diversity	*45% - 50%* *(N/A)*	**30%**

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Economic efficiency is dominant driver for future transmission investment

- In systems with wind generation, economic efficiency drives larger transmission capacities than reliability considerations
  - Cost-benefit analysis: balancing cost of transmission investment against the reduction of constraint costs over the life span of the investment (it is generally not economic to constrain off wind power significantly)
  - Optimal network is significantly more constrained
  - Developed model to inform economic efficiency driven investment
- Large capacity margins in systems with significant contribution of wind generation
  - Example: 60GW peak demand supplied with 72 GW of conventional generation =>20% capacity margin); add another 30GW of wind (that displaces say 3GW of conventional plant); installed capacity 99 GW to supply 60GW of peak demand =>about 60% capacity margin
- Network capacity should be shared between wind and conventional generation: SEDG provided evidence to 2006 Energy Review and White Paper highlighting the deficiencies in GB access arrangements and supported call for TAR

Importance of GB SQSS for TAR

- TAR: network users to choose between (i) using the existing network capacity (non-firm access) or (ii) support building of new network capacity (firm access)
  - But what is the capacity of the existing network?
  - What is the efficient capacity of the existing network that should be released to network users?
  - What rules are used to determine how much capacity should be made available to network users?
  - What is the basis of these rules?
  - Are the rules efficient? Do these provide the right balance between costs and benefits?

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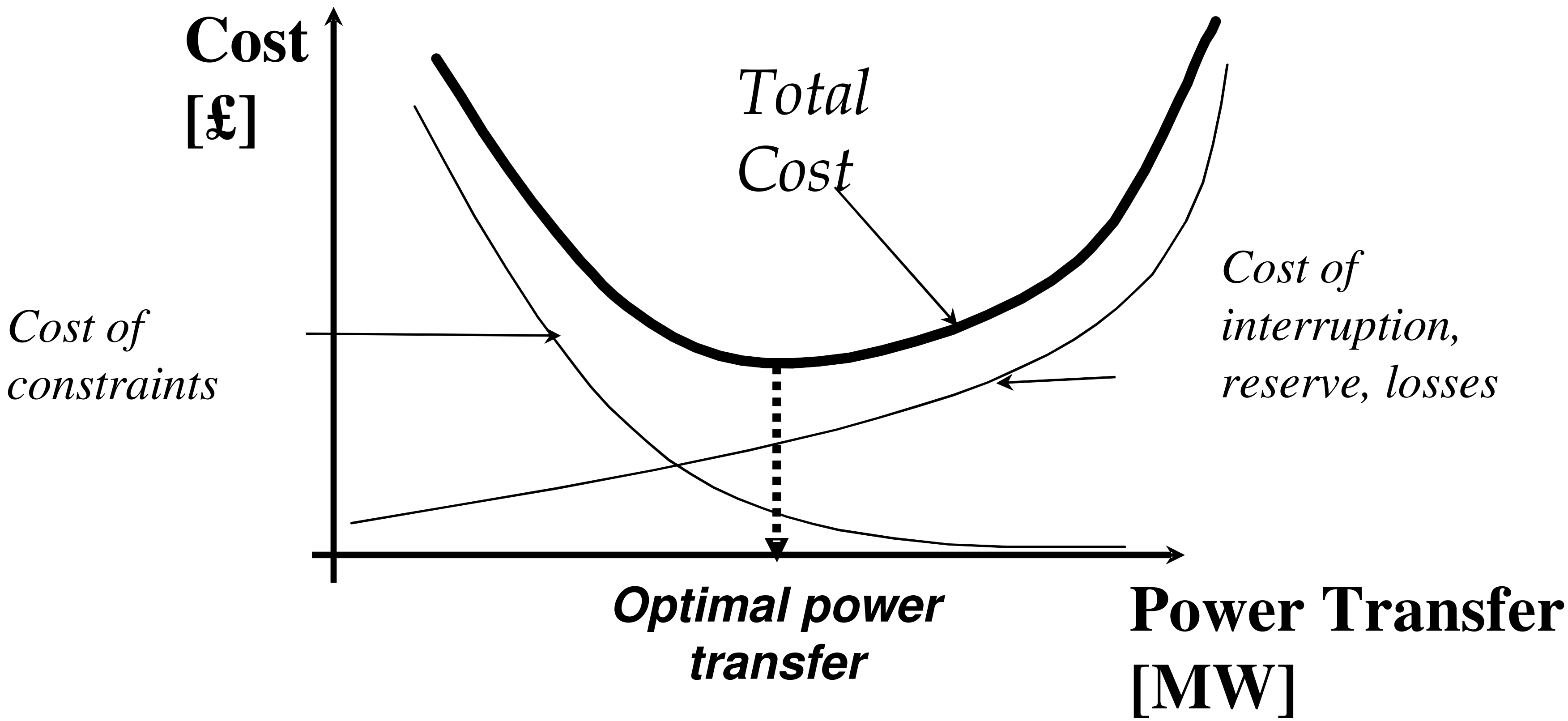
Two key questions for the fundamental review of the GB SQSS

- Is the present network standard barrier for efficient operation of the electricity market, i.e. barrier for competition in generation and supply?
- Is the present standard delivering maximum value to network users, i.e. provides the right balance between costs involved (paid by the users) and benefits that users derive from it?

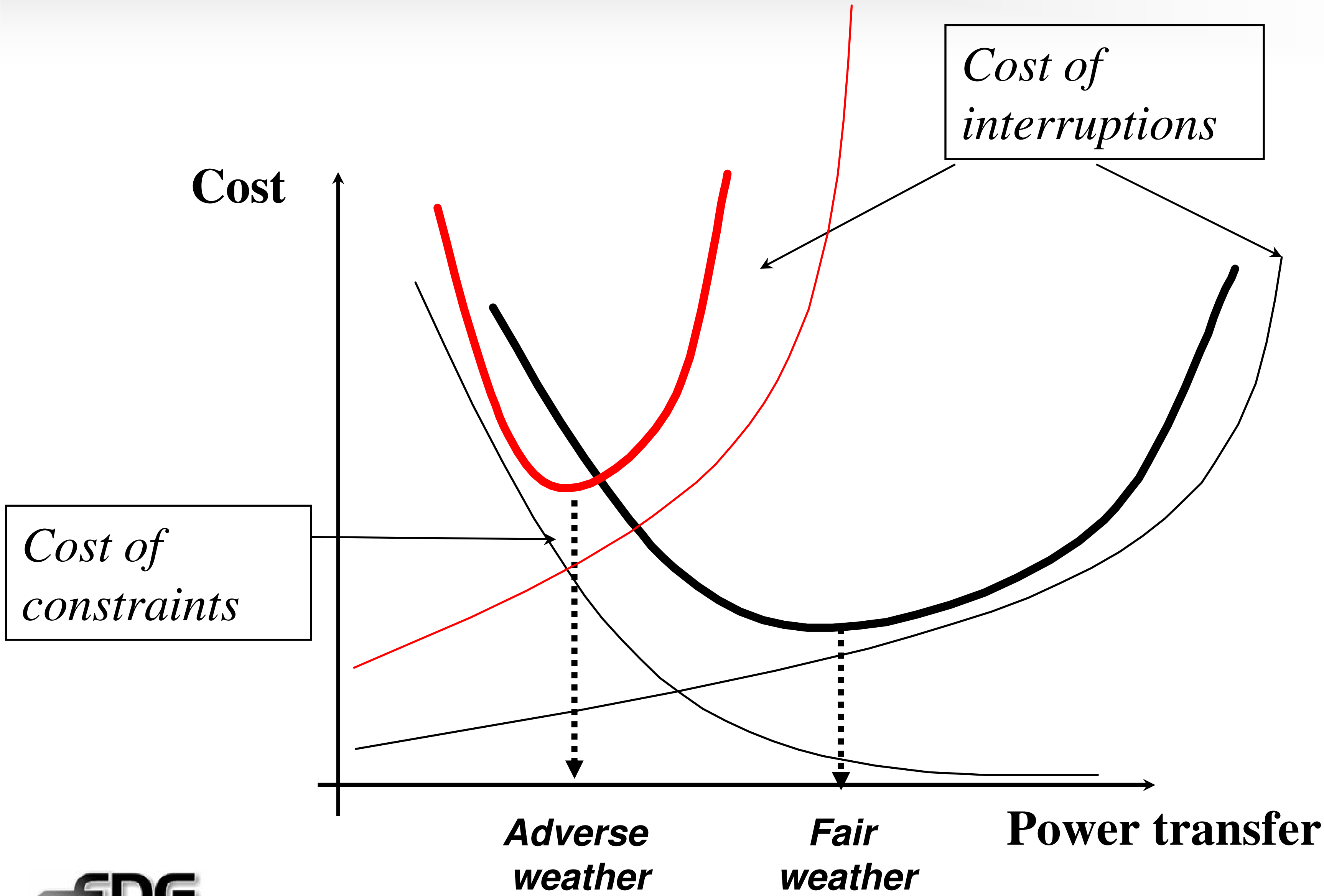
Some issues of concern

- Binary approach to risk is fundamentally problematic
  - “no” risk at all if the occurrence of any selected (single or double) contingency does not violate the operational limits
  - “unacceptable” risk if the occurrence of a credible contingency would cause some violations of operating limits
- Failure rates of individual circuits are very different and can vary significantly with weather condition
- The degree of security provided is unlikely to be optimal in any particular instance (might be good on average but it would not be appropriate for any individual case).
  - the cost of providing the prescribed level of security (in both operational and planning timescales) is not compared with the reliability benefit delivered
- Non-network solution to network problems

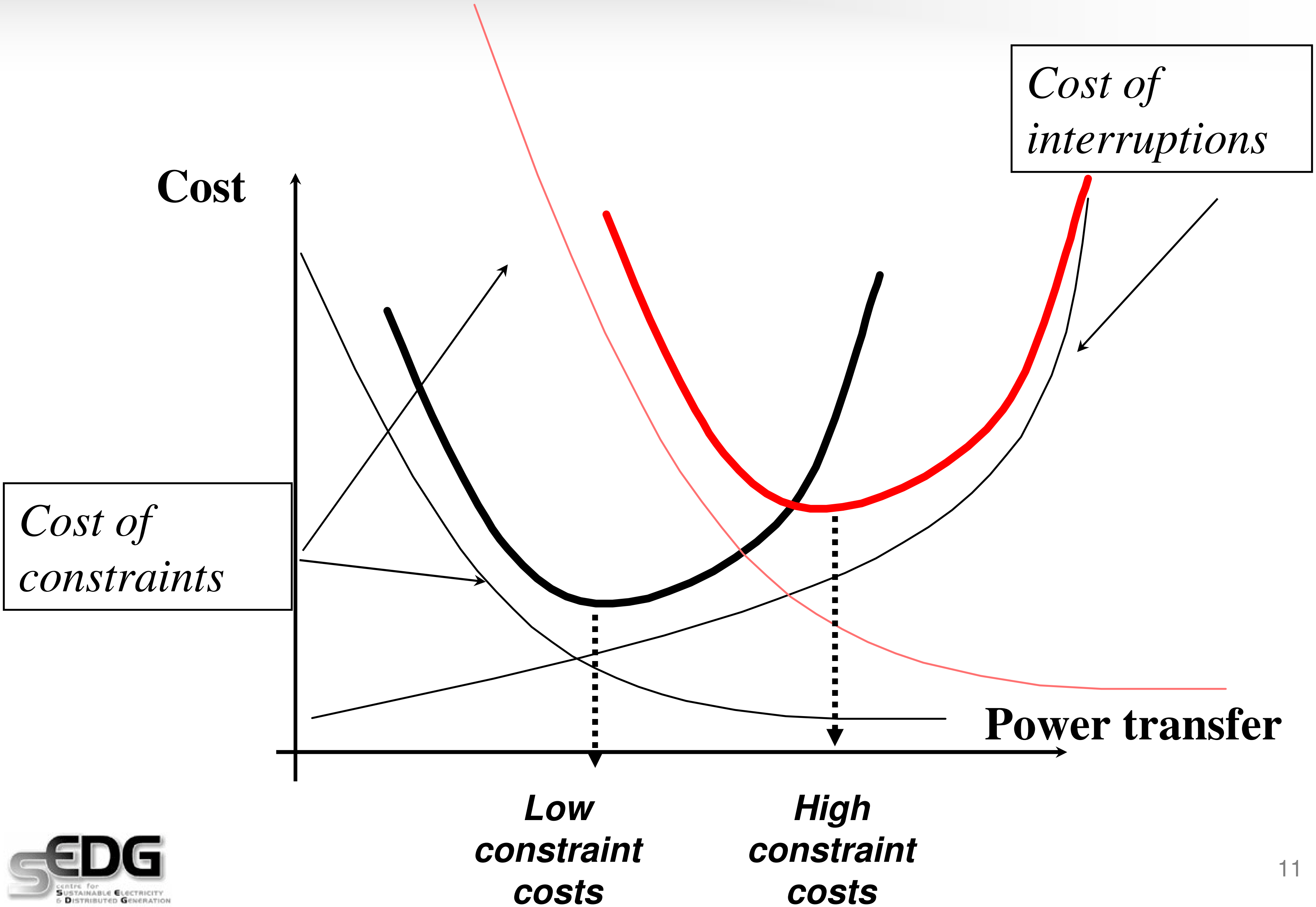
Determining the optimal transfer capability of the existing network: probabilistic CBA



Impact of weather condition



Impact of costs of constraints



Modelling of network boundary transfer capability

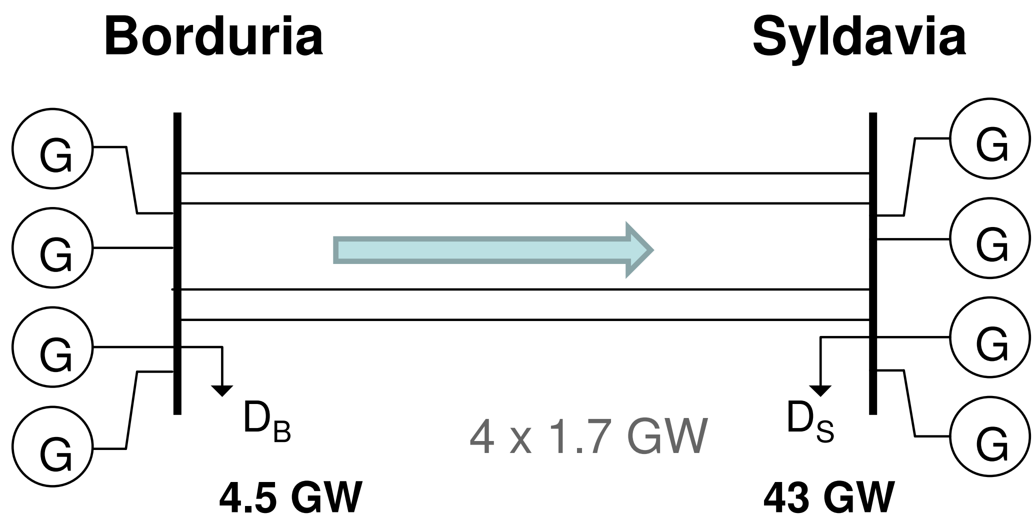
- Pre-fault, Intact system
  - Supply and demand balance
  - Reserve and response constraints
  - Pre fault capability
  - No load curtailment
- Post fault automatic
  - Supply and demand balance (response, intertrips, load curtailment)
  - Response $\leq$ pre-fault committed response
  - Intertrip $\leq$ pre-fault committed intertrip capacity
  - Short term post fault rating
- Post fault manual
  - Supply and demand balance (BM, intertrip, load curtailment)
  - Generators on forced outage cannot be synchronised back
  - Ramp rate limits
  - Medium term post fault flow limit

Probabilistic CBA:

Illustrative initial studies on the boundary of Borduria – Syldavia

Any similarity to Scotland – England (B6) boundary is entirely coincidental

Borduria - Syldavia systems….



- Significant interest in wind power in Borduria, about 10GW of wind power by 2020
- Borduria and Syldavia connected via 2 double circuits: East and West circuits, with 2 x 2 x 1.7GW = 6.8 GW

Generation in Borduria and Syldavia

Technology	Borduria[MW	Syldavia [MW]
CCGT	-	23,228
OCGT & Oil	1,450	4,437
Coal	3,456	24,485
Nuclear	2,440	8,300
CHP	120	1,756
Biomass	69	150
Interconnector	-	1,976
PS	700	1,560
Wind	10,000	1,661
Other renewables	1,600	2,026

TOT	21,872	69,579

TOT B&S system	89,451

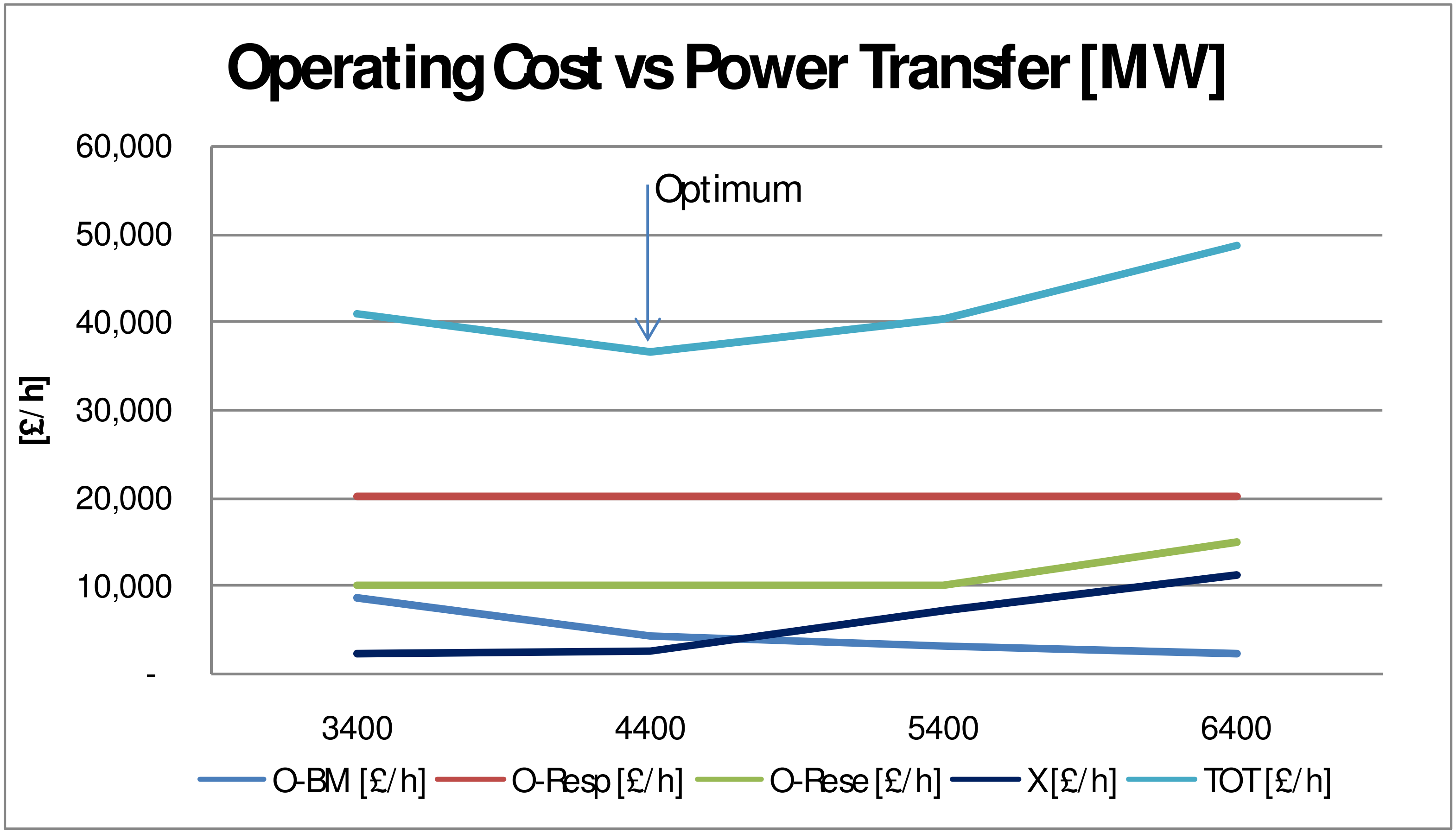
Technology	CFuel £/MWh	CBid £/MWh	COffer £/MWh
CCGT	44	44	44
OCGT & Oil	114	113	114
Coal	53	53	53
Nuclear	-	- 10,000	10,000
CHP	-	- 1,000	1,000
Biomass	28	- 24	28
Interconnector	60	60	60
PS	100	100	100
Wind	-	- 34	-
Other renewables	-	- 34	0

-Reserve cost: 10 £/MW/h

-Response cost: 20 £/MW/h

-VOLL: 30,000 £/MWh

Base case (wind generation output in Borduria 4.5GW)



Optimal transfer is 4.4 GW: (N-2) 2 x 1.7GW + 1GW intertrip

Optimal power transfer will depend on weather conditions

Weather condition	Single fault probability	Common mode fault probability	Expected Outage costs [£/h]	Transfer [MW]
Adverse	0.094610	0.009461	2,308	**4400**
Favourable (adverse/32)	0.002927	0.000293	2,502	**6100**

Fair weather condition transfer of 6.1GW:
(N-1) 3x1.7 GW+ 1GW intertrip

Contrast to the present GB SQSS with fixed boundary capabilities

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Optimal power transfer will depend on wind conditions

Wind output in Borduria [MW]	Response [MW]	Reserve [MW]	Boundary Flow [MW]
4500	1000	1000	**4400**
7000	1000	1400	**6000**
9200	1700	1700	**6800**

Stark contrast with the present GB SQSS with fixed boundary capabilities

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Impact of cost of intertrip

Intertrip cost [£/MW/h]	Transfer [MW]
0	4400
5>	3400

- Is charging for arming an intertrip cost reflective?
- Intertrip costs contribute significantly to constraint costs
- Administered intertrip cost? Intertrip as a grid code requirement?

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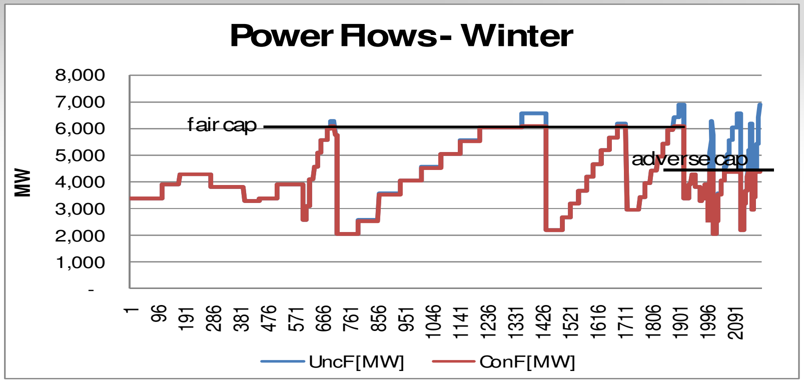
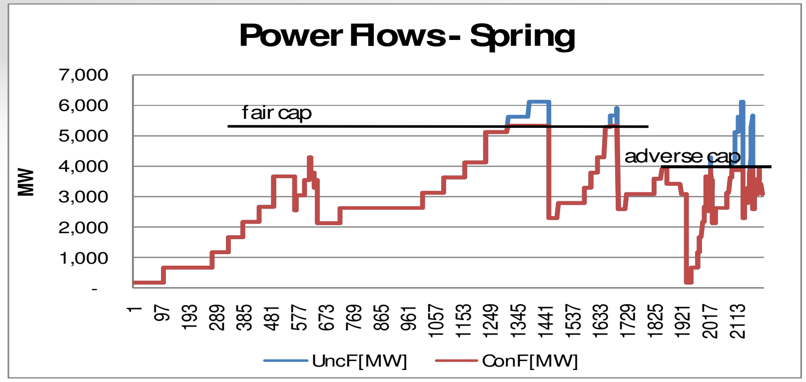
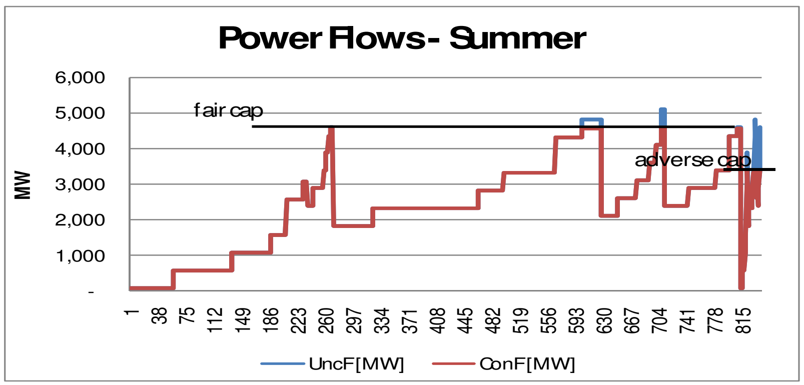
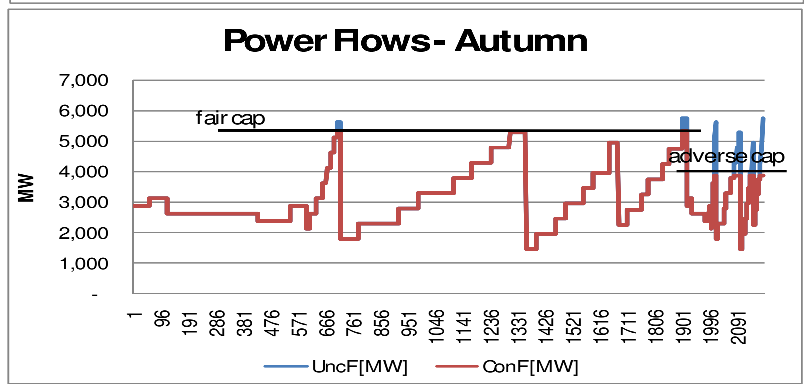
Impact of common mode failure

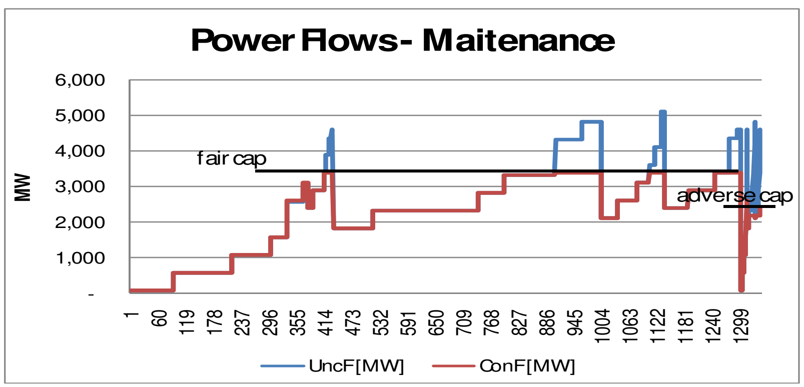
Circuit Construction	Transfer [MW]
4 individual circuits	5600
2 double circuits	4400











Illustrative year-round analysis: constrained and unconstrained power transfers during different operating conditions

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Conclusions and observations

- Fundamental review of GB SQSS: a unique opportunity develop a new transmission operation framework for future GB electricity supply system that would
  - provide basis for efficient network operation and development
  - ensure that network delivers maximum value to network users
- Cost effective network operation framework essential for success of TAR
- Potentially significant benefits from the departure from the existing deterministic to a probabilistic SQSS: releasing latent network capacity?
  - Immediate opportunity:
    - Network capacity to be optimised with weather condition
    - More efficient constraint costs management
    - Intertrip to be made cost reflective
  - Additional opportunities: incorporate advances in technology
    - Post fault rating, dynamic line rating, coordinated SPS, coordinated voltage control, application of advanced ICT for coordinated real time control, modern system management tools…
    - Application of responsive demand and distributed generation
    - Modern maintenance techniques

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Modelling and analysis to support the development of a new GB SQSS

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