System Security Review: Credible Event Management

Summary of Findings and Conclusions for Consultation

November 2009

TRANSPOWER

Overview

- Study Objective
- Studies Performed
- Event Management Options
- Costing Methodology
- Study Results
- Conclusions & Recommendations

Study Objective

For the:

- Loss of a Busbar Section; and
- Loss of an Interconnecting Transformer

assess consequence and relative costs of management as a:

- Stability Event;
- Contingent Event; and
- Extended Contingent Event.

Studies Performed

Busbar Studies	*Transformer Studies*	
N-1	N-1	N-1-1
220kV busbars 110kV busbars 66kV busbars connected to core grid	220/110kV interconnecting Transformers 220/66kV interconnecting Transformers	220/110kV Bunnythorpe Transformers 220/110kV Haywards Transformers 220/110kV Otahuhu Transformers 220/110kV Islington Transformers

Event Management Options

- Stability Event Management
  - directly affected load / generation
  - indirectly affected load
    - “Unplanned load shedding”
- Extended Contingent Event Management
  - Pre-arranged post-event load shedding
    - “Planned load shedding”
- Contingent Event Management
  - Pre-event security constraints
    - “Load constrained pre-event”

Event Categories & Backstop Measures

Summary of available and back stop measures

Event Classification	Available Measures	Backstop Measure
Contingent Events	Pre-Contingency Security constraints, planned voluntary load shedding, demand inter-trips, run-back schemes and Automatic Under Voltage Load Shedding (AUVLS).	Pre-contingency security constraints
Extended Contingent Events	Planned involuntary load shedding, Automatic Under Frequency Load Shedding (AUFLS)	Planned involuntary load shedding "*pre-arranged post event load shedding*"
Stability Events	Unplanned involuntary load shedding as necessary to avoid system instability	Unplanned load shedding
Other Events	Emergency load shedding & Restoration	Emergency load shedding & restoration

Load Shedding Measures

Summary of Load Shedding Measures and Application

Load Shedding Measure	Description					Application		
	Planned	Unplanned	Voluntary	Involuntary	Controlled	Contingent	Extended Contingent	Stability & Other
Interruptible Load (IL) Demand Inter-trips Automatic Under Voltage Load Shedding (AUVLS)	✓		✓		✓	✓	✓	✓
Automatic Under Frequency Load Shedding (AUFLS)	✓			✓	✓	∗	✓	✓
Demand Reduction (via DAN) Emergency Demand Shedding		✓		✓	✓		∗	✓

∗ If insufficient reserves to cover a CE event, zero the RAFs and rely on AUFLS for post CE management

∗ If insufficient reserves to cover a CE and ECE event, zero the RAFs and rely on demand reduction for post ECE management

Managing Loss of Generation

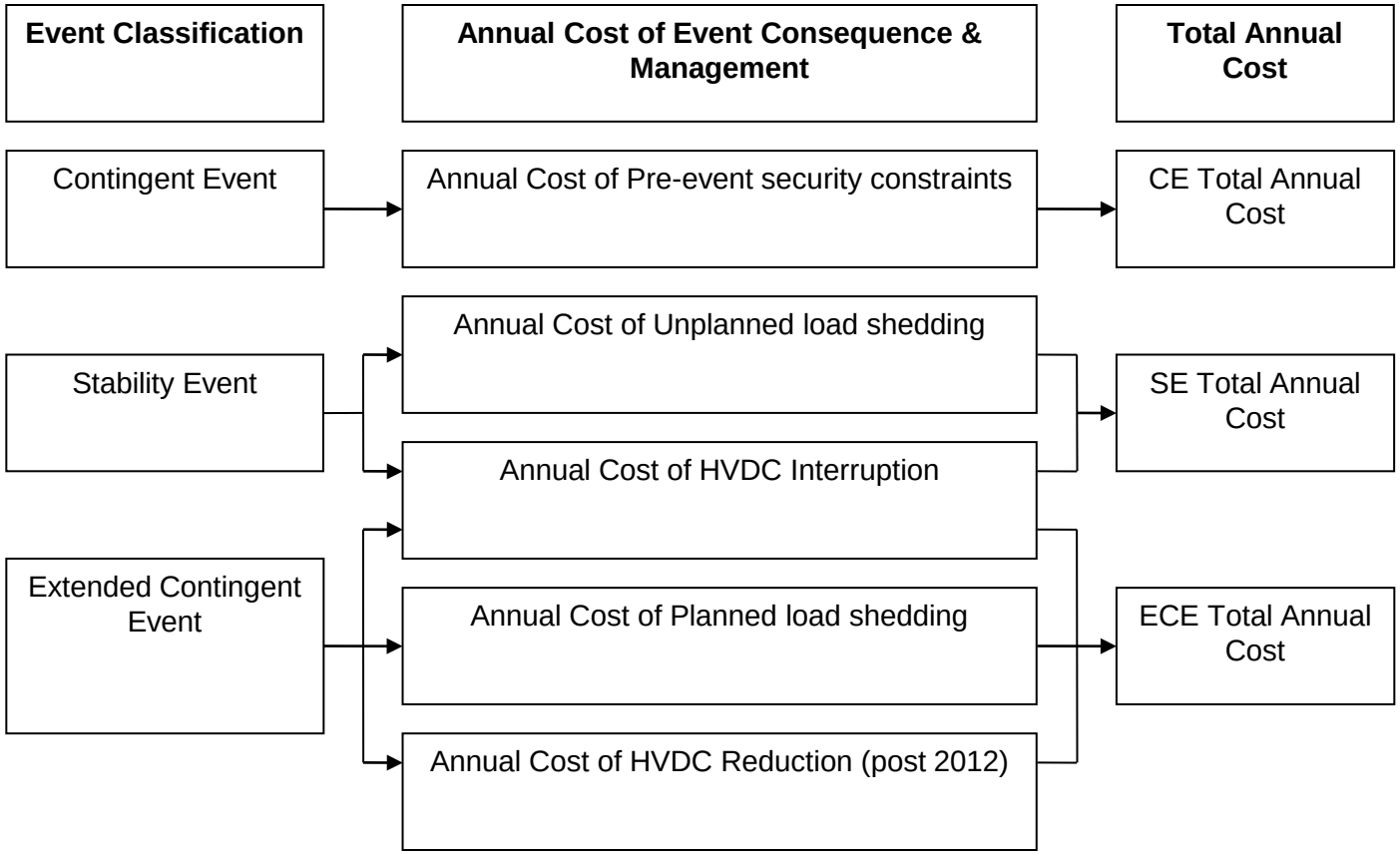
- Stability Event Management
  - directly affected generation
- Extended Contingent Event Management
  - Automatic Under-Frequency Load Shedding (AUFLS)
- Contingent Event Management
  - Procurement of additional reserves

- Cost of managing the loss of generation (discussed later)

Loss of generation following the loss of a busbar section

Loss of a Busbar Section at		Number of generating units	Max. Output
North Island	Huntly	1	390
	Otahuhu	1	380
	Stratford	1	385
South Island	Aviemore	4	220
	Benmore Busbar A	2	180
	Benmore Busbar B	3	230
	Clyde Busbar B	2	216
	Manapouri Busbar A	3	360
	Manapouri Busbar C	3	360
	Ohau A	4	264
	Tekapo B	2	160

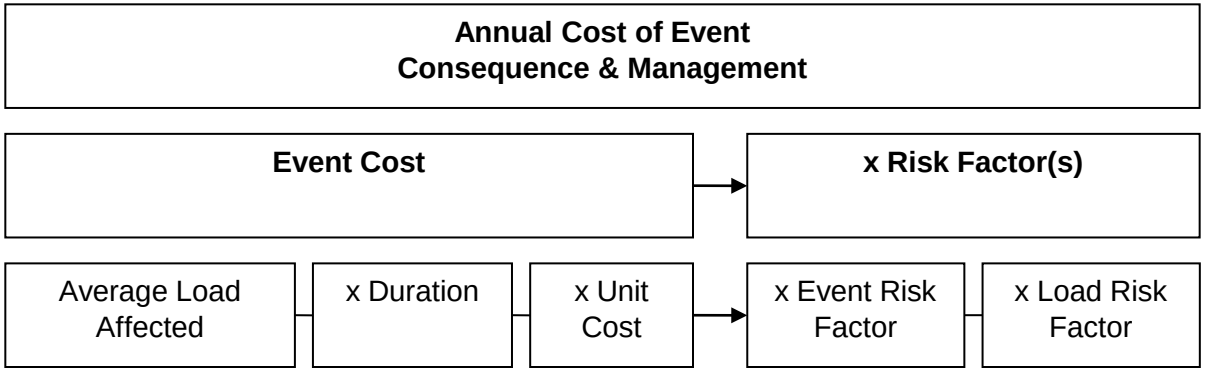
Costing Methodology – Total Annual Cost



Total Annual Cost by Event Classification

Costing Methodology

Annual Cost Calculation



Parameters

Event Risk Factor = $\frac{\text{No of events per year assoc. with element set}}{\text{No of elements in set}}$

Duration = Event duration or
= Max. Duration of load constraint (8760hrs)

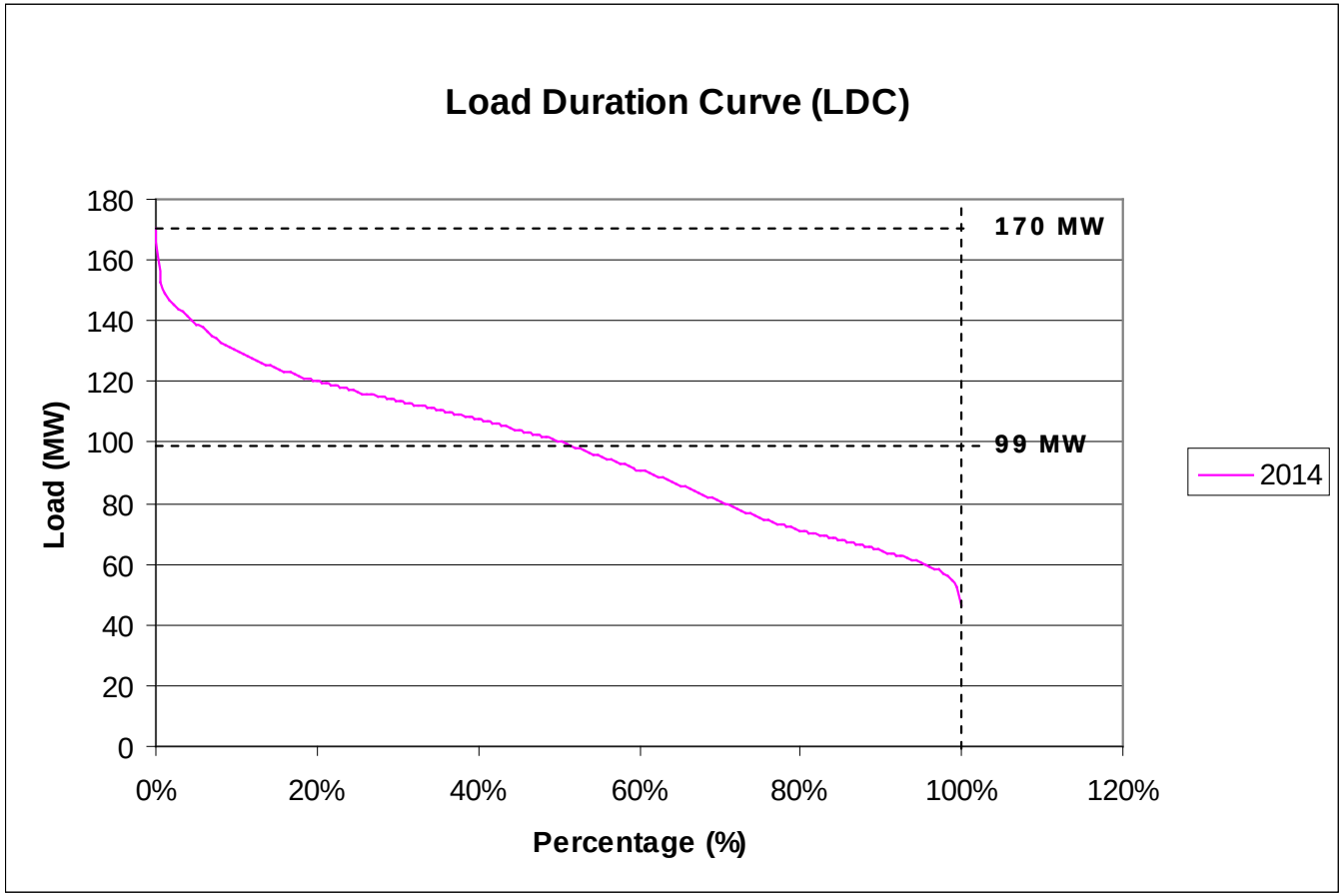
Unit Cost = VoLL $20,000/MW-h (Unplanned Load Shedding)
= VoLL $10,000-$2,000/MW-h (Planned Load Shedding)
= Event Charge $1,250/MW (HVDC Trip)

Average Load Affected = MW of Load Shedding / HVDC Transfer
= Pre-event MW load constraint

Load Risk Factor = Risk period associated with load loss

Load Duration Curves (Ex. 1)

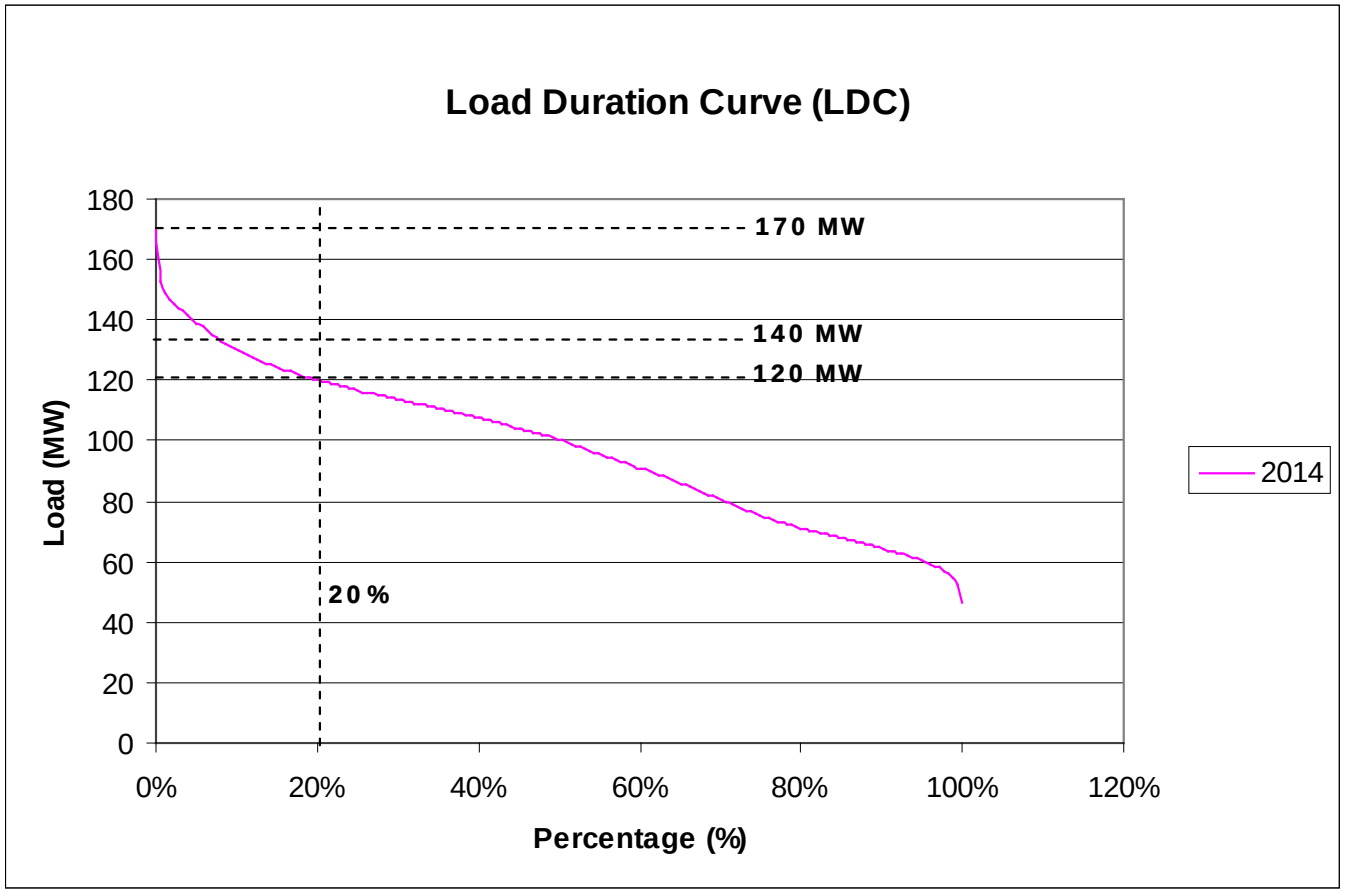
Load Duration Curve: Direct loss of load



Load Risk factor = 1.0 and Average Direct Load Affected = 99MW

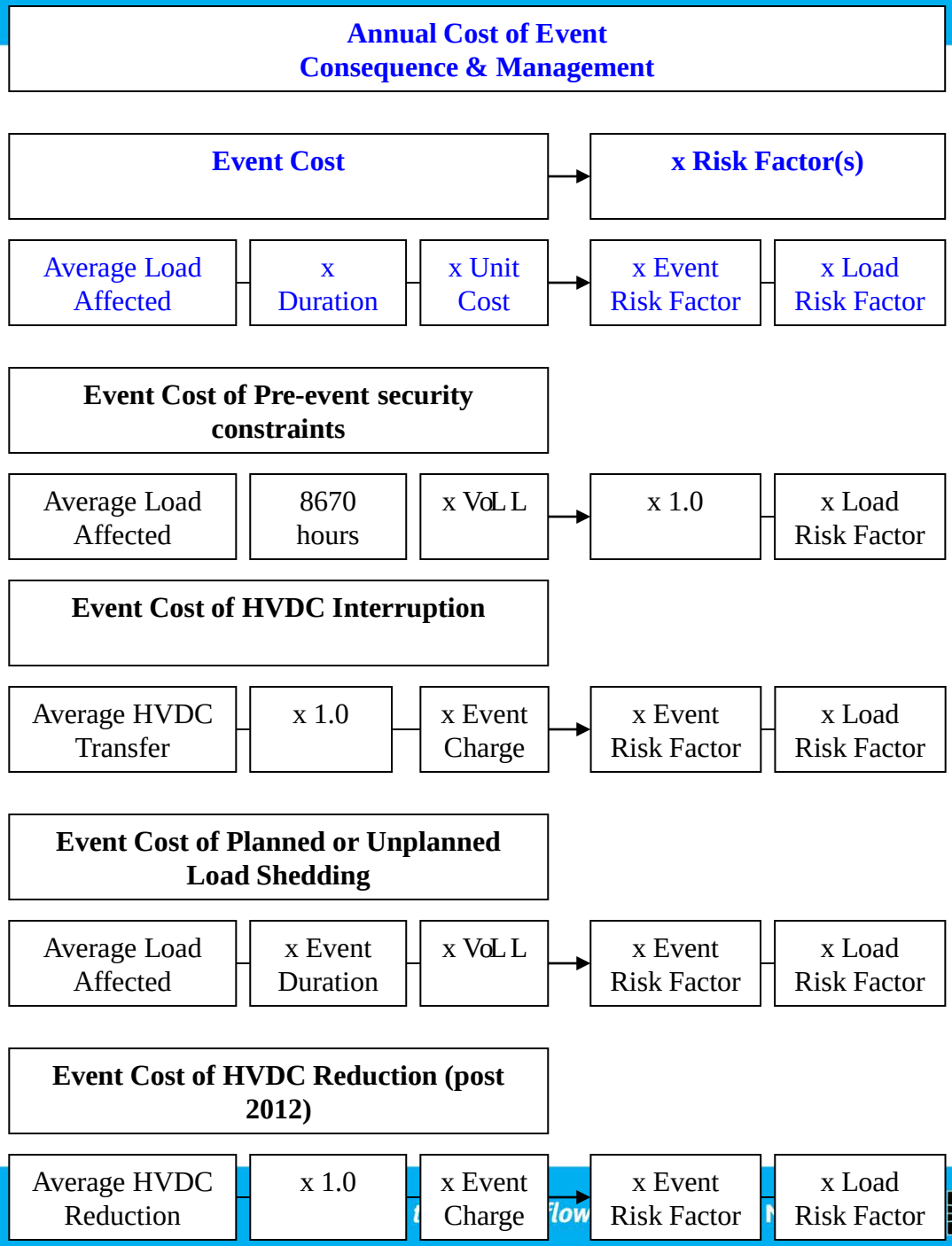
Load Duration Curve (Ex. 2)

Load Duration Curve: Indirect loss of load



Load Risk factor = 0.2 and the Average Load Indirectly Affected during the risk period = 140MW

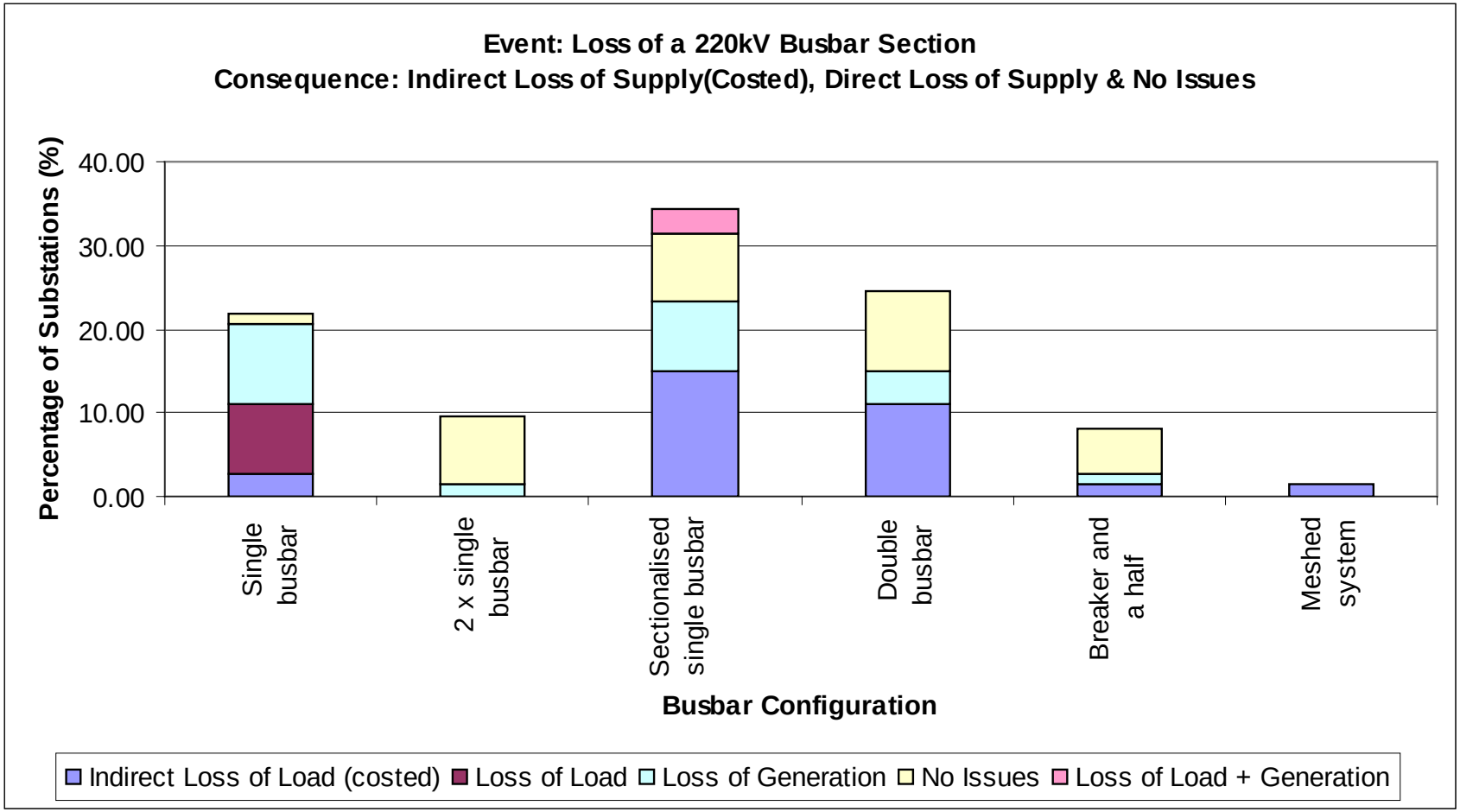
Costing Calculations



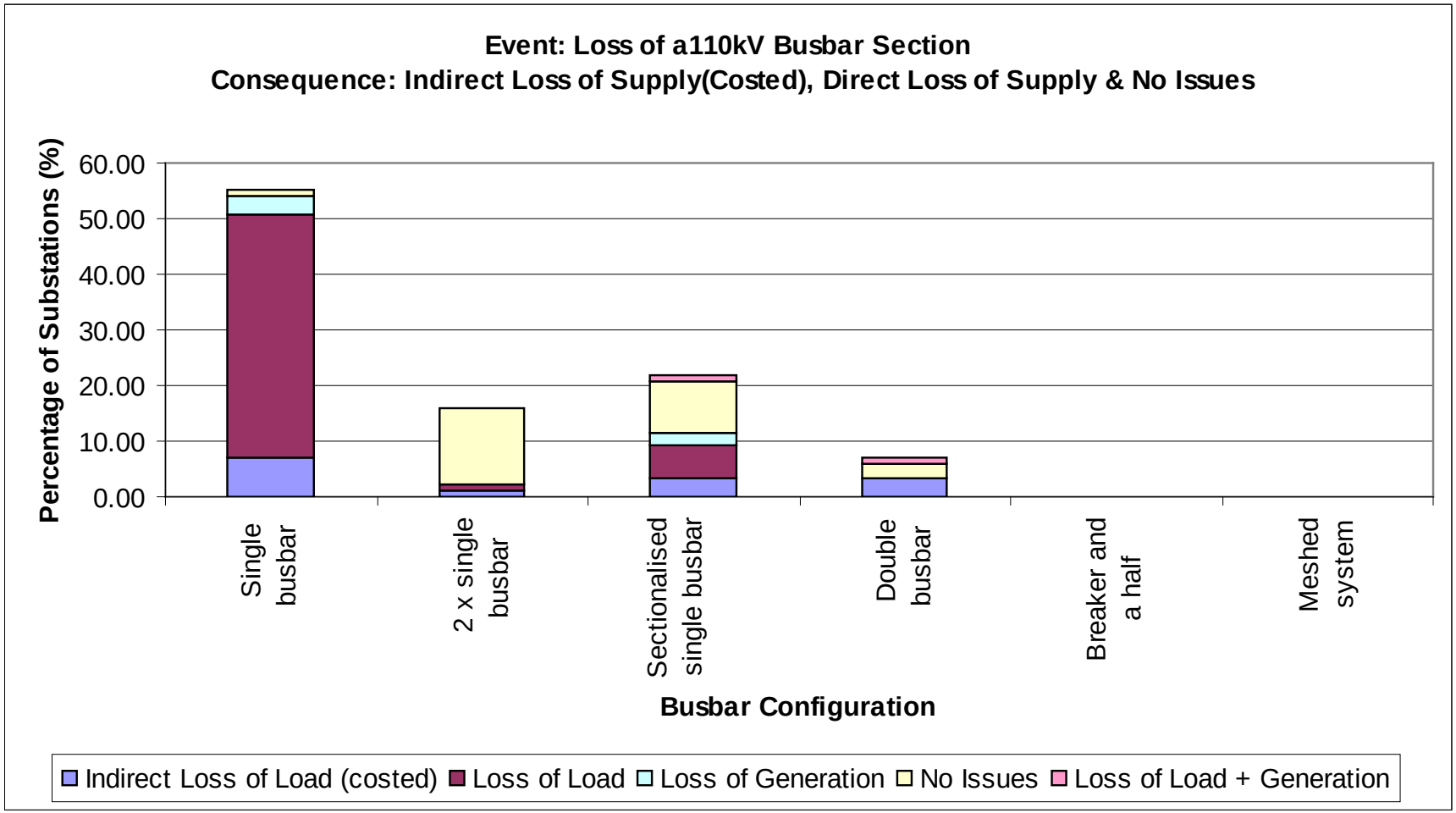
Study Results

- Busbar Configuration
  - CB and disconnector operation
  - BZ protection operation
- Event Consequences
  - No issues
  - Direct loss of load/generation
  - Unplanned load shedding
- Critical Busbars / Transformers
- Optimal management approach

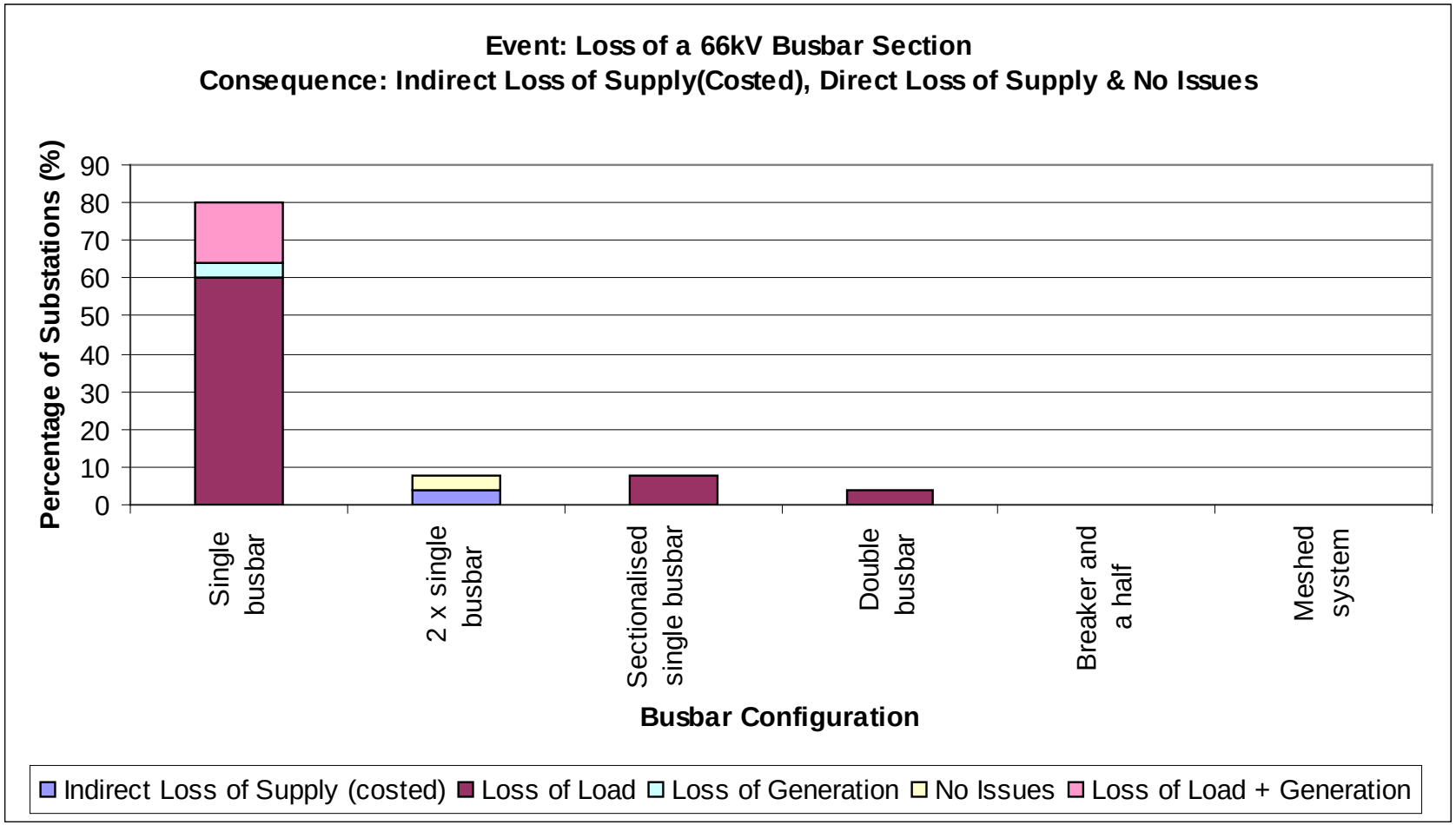
220 kV Busbar Configuration & Event Consequences



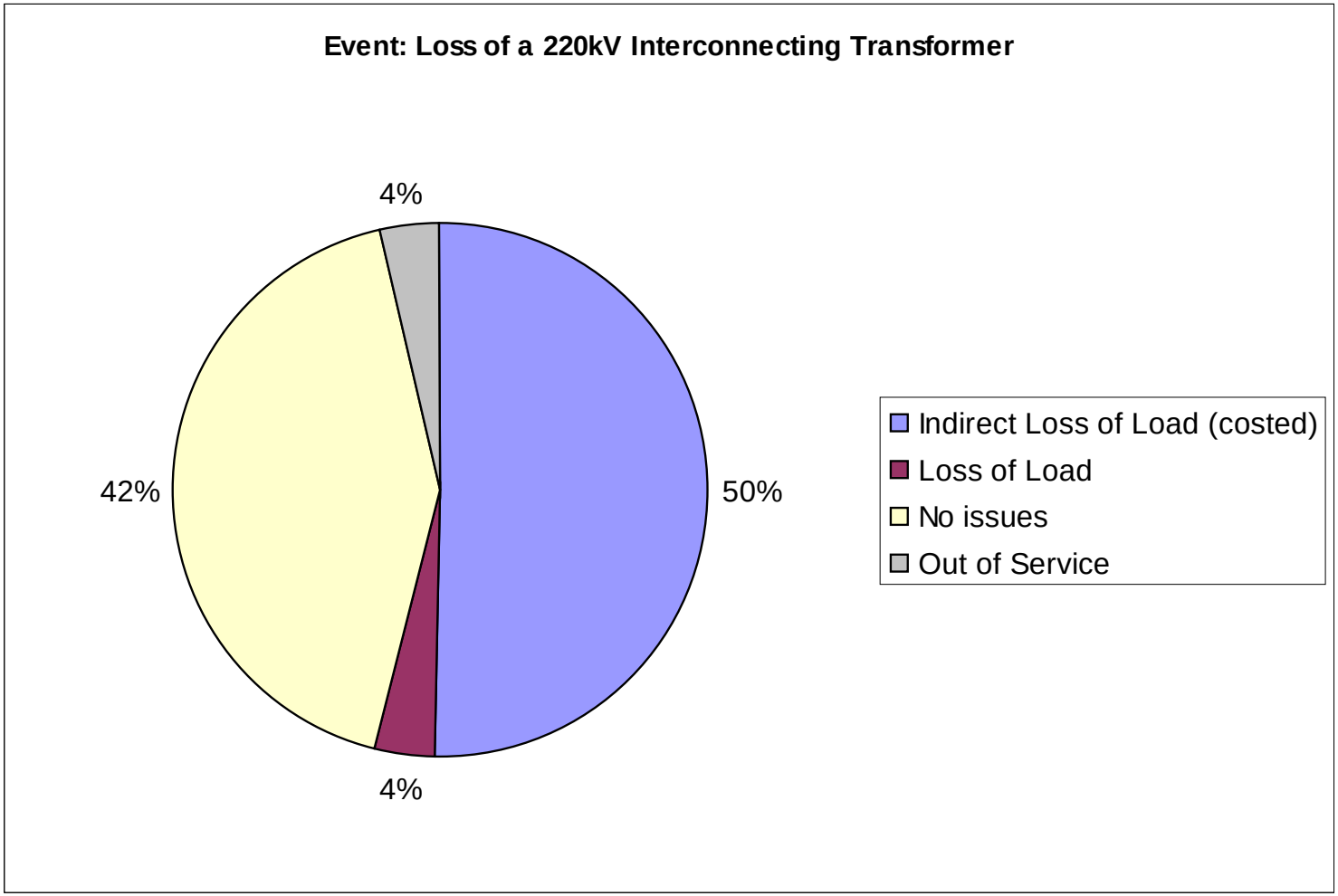
110kV Busbar Configuration & Event Consequences



66kV Busbar Configuration & Event Consequences



220kV Transformer Event Consequences



Busbar Studies: Highest Ranked Events

Busbar Section	*Annual cost associated with event classification ($m)*				
	Stability Event	*Contingent Event*	*Extended Contingent Event*		
			$10k	*$5k*	*$2k*
ASB 220_C	3.245	1102.01	0.0198	0.00991	0.00396
ISL 220_A	2.087	490.56	0.0088	0.004	0.002
ISL 220_B	1.82	409.97	0.0074	0.004	0.001
BPE 220_A1 HVDC South *	1.6582		0.00055	0.00055	0.00055
BPE 220_A2 HVDC South *	1.6582		0.00009	0.00009	0.00009
BPE 220_B HVDC South *	1.6582		0.00009	0.00009	0.00009
TKU_220_1 HVDC South *	1.6582		0.00004	0.00004	0.00004
TKU_220_2 HVDC South *	1.6582		0.00004	0.00004	0.00004
TKB 220	1.639	210.24	0.0038	0.00189	0.00076
KIK 110	1.207	848.84	0.0153	0.008	0.0031
HAY_110_A HVDC North	1.005	10798.44	0.194	0.0097	0.039
HAY_110_A HVDC South *	0.91		0.14	0.009	0.003
ISL 66_C	0.748	59.57	0.0014	0.00071	0.00028
IGH 110	0.687	364.42	0.0066	0.003	0.0013
ISL 220_C	0.638	70.08	0.0013	0.00063	0.00025
KIK 220_A	0.5504	87.6	0.0016	0.001	0.0003
STK 220_A	0.55	91.98	0.0017	0.001	0.0003
BPE 110_A HVDC South *	0.444		0.00073	0.0005	0.00036
BPE 110_B HVDC South *	0.444		0.00004	0.00004	0.00004
ATU 110	0.266	57.82	0.001	0.00052	0.00021

Transformer Studies: Highest Ranked Events

Transformer	*Annual cost associated with event classification ($m)*				
	Stability Event	*Contingent Event*	*Extended Contingent Event*		
			$10k	*$5k*	*$2k*
HWB 220/110 T4	2.51	1676.66	0.303	0.1515	0.0606
STK 220/110/11 T7	2.4898	78.84	0.0143	0.0071	0.0029
HAY 220/110/11 T1 - North	2.17	740.22	0.134	0.067	0.027
HAY 220/110/11 T2 - North	2.17	740.22	0.134	0.067	0.027
HAY 220/110/11 T5 - North	2.17	740.22	0.134	0.067	0.027
ISL 220/66/11 T6	2.0164	50.81	0.0092	0.0046	0.0018
ISL 220/66/11 T3	1.0397	5.26	0.001	0.0005	0.0002
ISL 220/66/11 T7	1.0397	5.26	0.001	0.0005	0.0002
KIK 220/110/11 T2	0.948	39.42	0.0071	0.0036	0.0014
HAY 220/110/11 T1 - South	0.905	183.96	0.034	0.0175	0.0076

Busbar Events Optimal Approach - Relative Costs

Summary of Busbar Cost Analysis

		Annual cost associated with event classification ($m)				
	Busbar Voltage	*Stability Event*	*Contingent Event*	*Extended Contingent Event*		
				$10k	*$5k*	*$2k*
North Island	220kV	9.85	3874.39	0.07	0.04	0.02
	110kV	4.30	16574.69	0.45	0.08	0.07
South Island	220kV	11.25	7024.64	0.13	0.06	0.02
	110kV	2.31	2130.43	0.04	0.02	0.01
	66kV	0.76	90.23	0.00	0.00	0.00
TOTAL Annual Cost ($m)		28.47	29694.38	0.69	0.20	0.12
Δ Annual Cost (%)			104209	-98	-99	-100

Transformer Events Optimal Approach - Relative Costs

Summary of 220kV Interconnecting Transformer Cost Analysis

		Annual cost associated with event classification ($m)				
	Voltage	*Stability Event*	*Contingent Event*	*Extended Contingent Event*		
				$10k	*$5k*	*$2k*
North Island	220/110	12.45	3514.52	0.64	0.32	0.13
South Island	220/110	6.94	2031.43	0.37	0.18	0.07
	220/66	4.10	61.33	0.01	0.01	0.00
TOTAL Annual Cost ($m)		23.49	5607.28	1.02	0.51	0.21
Δ Annual Cost (%)			23772	-96	-98	-99

Conclusions & Recommendations

- Classify the following as Contingent Events:
  - Transmission Circuit
  - Generator
  - HVDC pole
  - Large load / load block
  - Reactive devices
- Classify the following as Extended Contingent Events:
  - HVDC bipole
  - 220kV Interconnecting Transformer
  - 220kV & 110kV Busbar Section
  - 66kV Busbar Section connected to core grid
- Classify the following as Other Events:
  - Multiple Elements
  - 110kV Interconnecting Transformer
  - 66kV Busbar Section not connected to core grid
- Stability Event Classification to be removed. Any credible event may be considered to be a stability event, System Operator may use all measures available to manage transient and stability issues

Questions ?