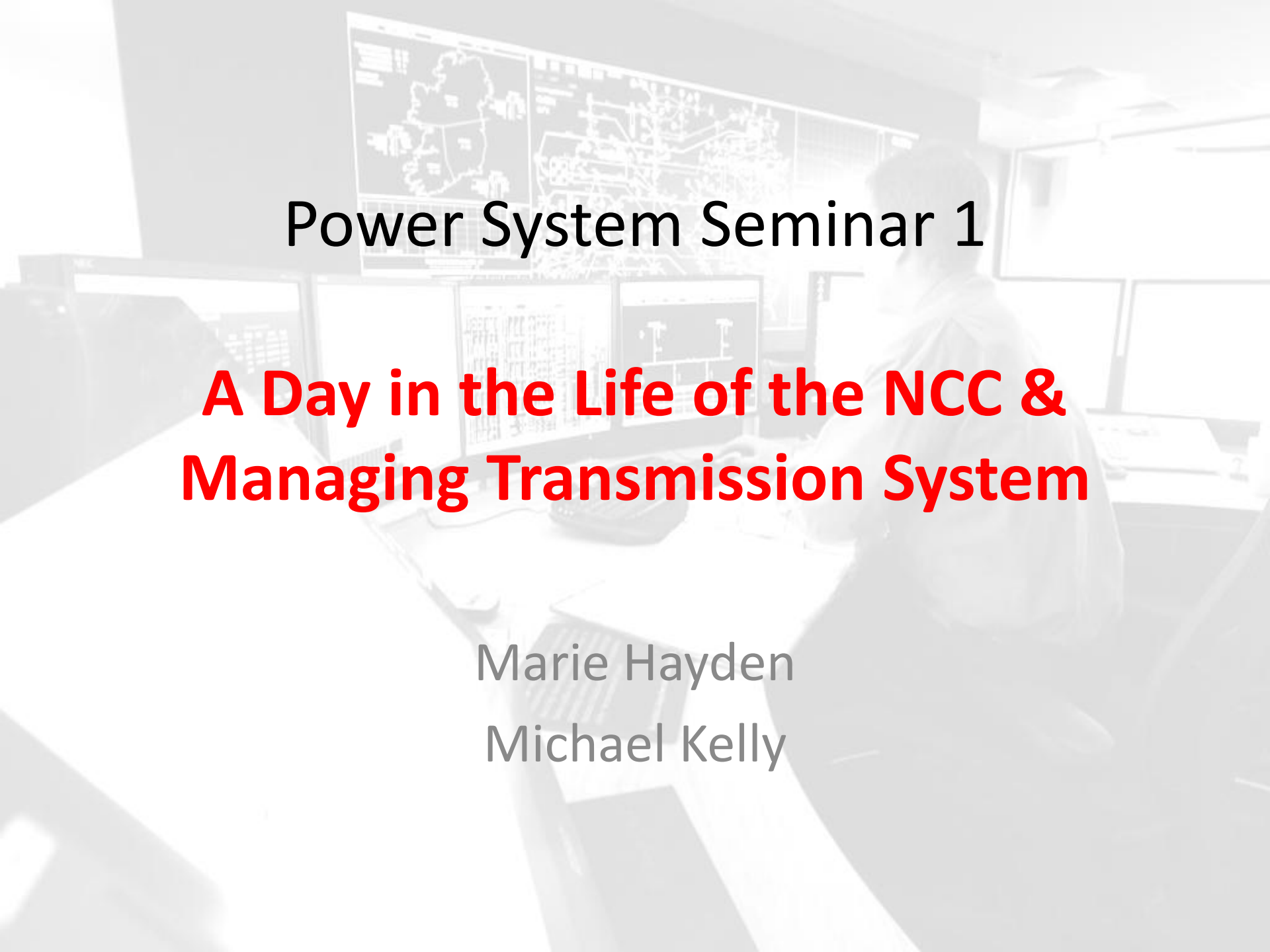


Power System Seminar 1

A Day in the Life of the NCC & Managing Transmission System

Marie Hayden

Michael Kelly

Agenda

- Two Presentations
  - **Marie Hayden: T**he component parts of the transmission system & how it is operated in theory
  - **Michael Kelly:** Real Life – The what and how of transmission system operation in the NCC

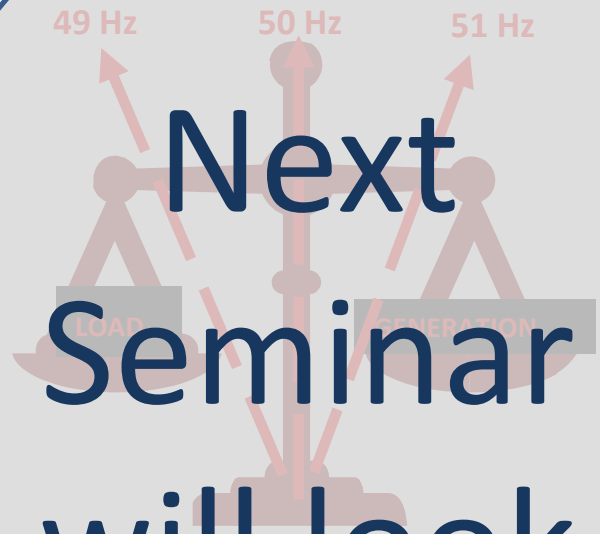
- A visit to the National Control Centre

NCC – What do they do?

LEFT HAND SIDE - TRANSMISSION

- Voltage Control
  - 410–370kV, 240–210kV, 120–105kV
- Monitoring MVA flow on power lines,
  - Redispatch generators
  - Sectionalise stations if necessary
- Remote Control Operations, live switching
- Contingency and Alarm Monitoring
- Transmission Outage Management
- Restoration of plant following disconnection

RIGHT HAND SIDE - GENERATION



- The [illegible] instructs the generators to maintain a balance
  - Gen Deficit, f ↓ Excess Gen, f ↑
- Ensure enough plant for next peak
- Hydro targets, Gas Indicative Schedule
- Maintain Reserve Sharing with SONI
- Wind/ Load Forecast - RCUC

Next Seminar will look at this side

The Theory Presentation

- Overview of the Transmission System
- Differences between the Distribution System and the Transmission System
- The component parts of the Transmission system
- Voltage Control Theory
- Power Flow Control Theory
- Theory of the Meshed Network and N-1 Security

The High Voltage Transmission System

A transport network not unlike a road network

Motorway
National Roads
Regional Roads

_____

Streets

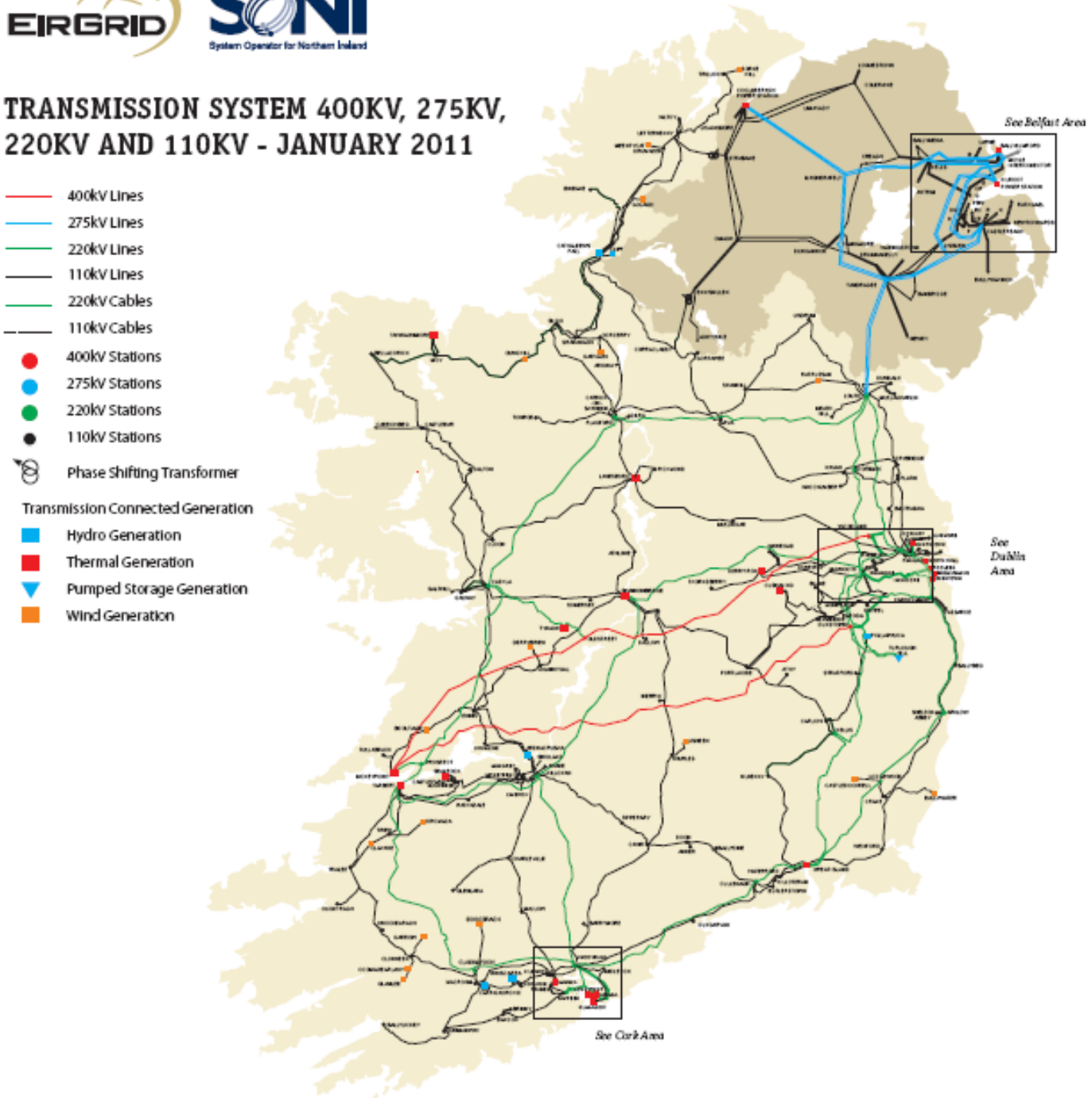
400KV
220kV
110kV

_____

Distribution

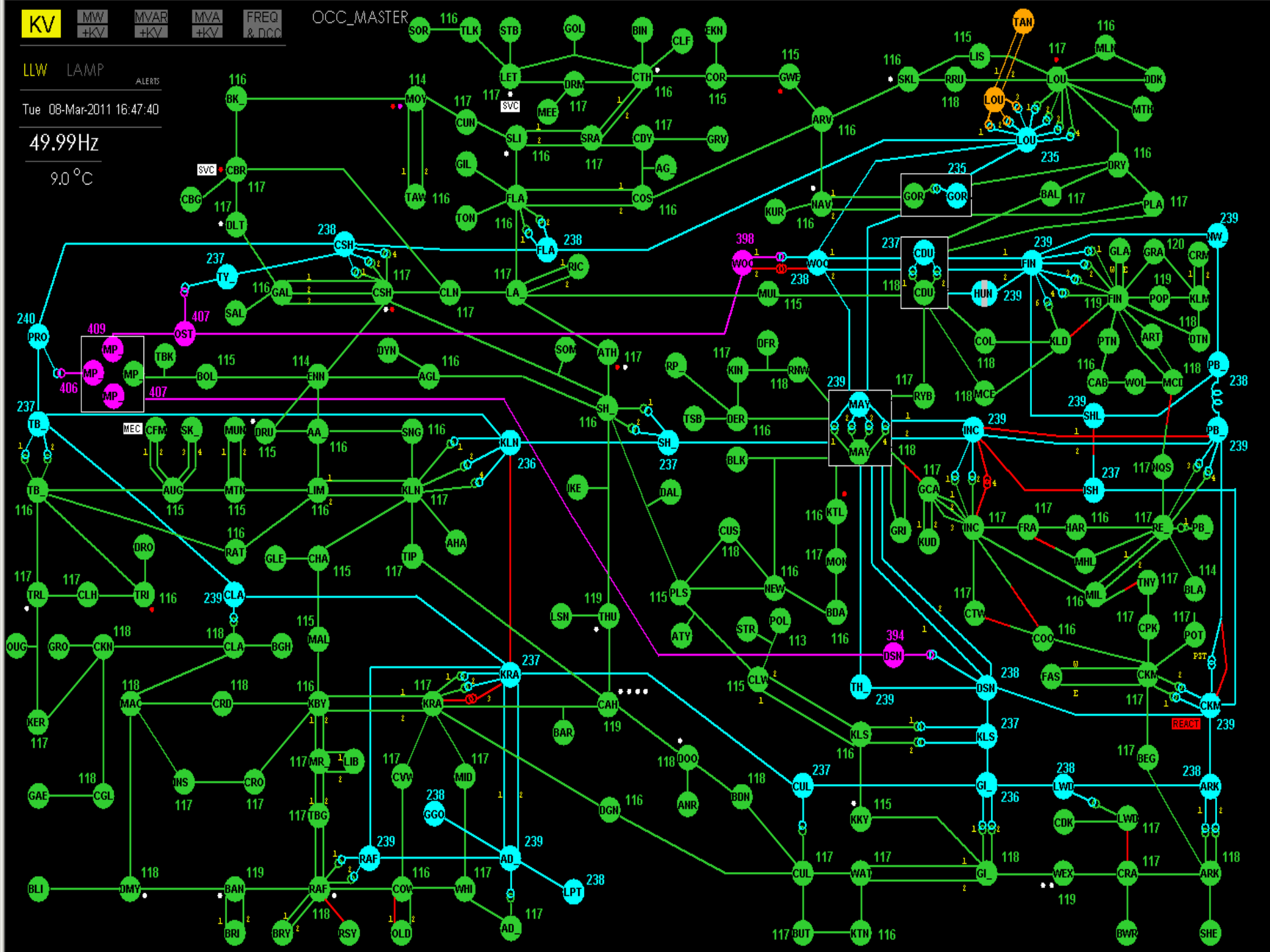
Roads Transport Cars – Power Lines Transport Electricity

TRANSMISSION SYSTEM 400KV, 275KV, 220KV AND 110KV - JANUARY 2011



Today you will see a few times the NCC Schematic Representation of the transmission system.

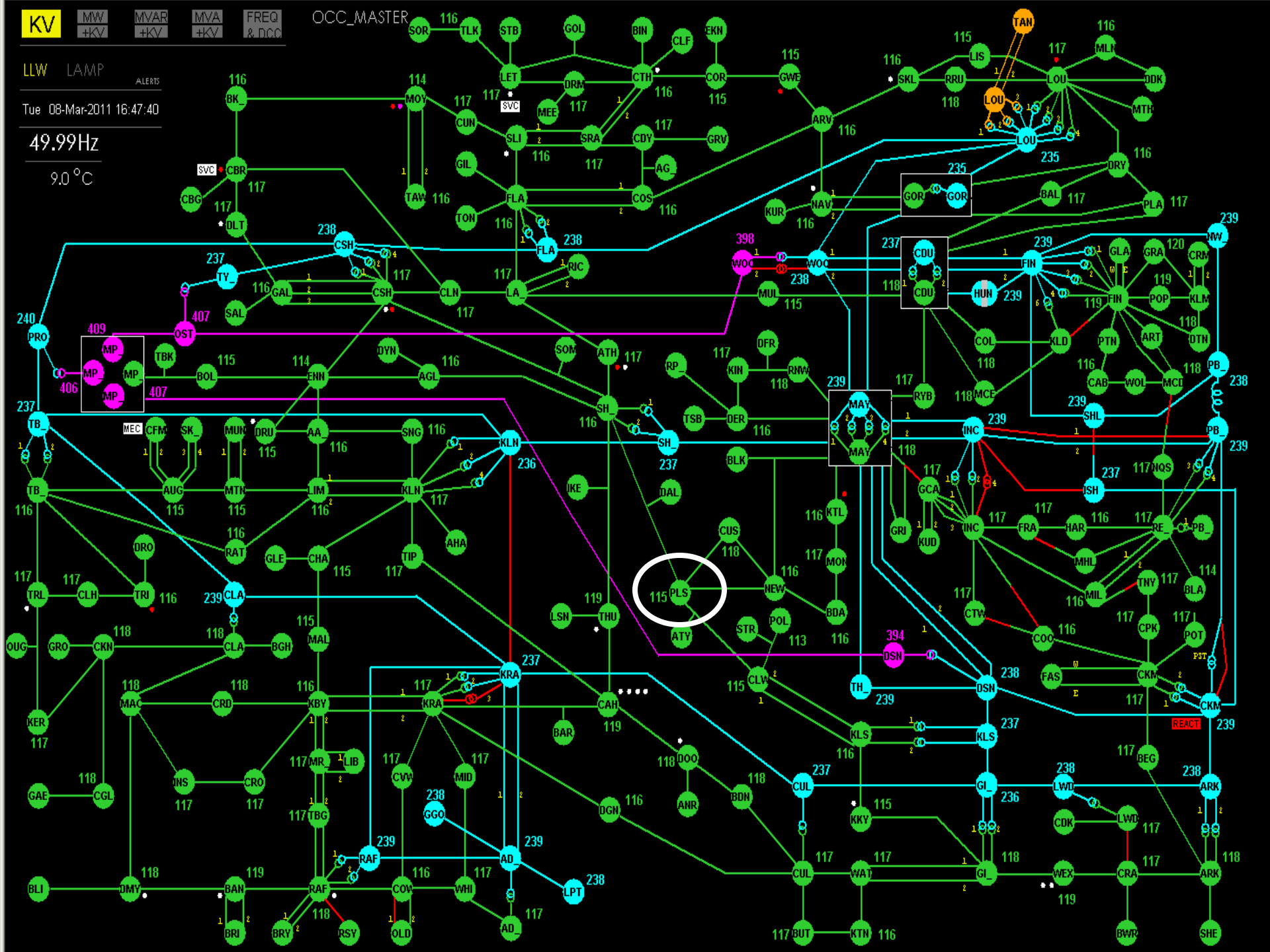
Let me talk through it briefly with you.


KV
MW +KV
MVAR +KV
MVA +KV
FREQ & DCC
OCC_MASTER
LLW
LAMP
ALERTS
Tue 08-Mar-2011 16:47:40
49.99Hz
9.0 °C

DISTRIBUTION V TRANSMISSION

Transmission Versus Distribution

- Principle Differences between Transmission and Distribution are:
  - Meshed V Radial Networks
    - When a transmission line trips power is re-routed to the station from other lines automatically without interruption
    - Example – Portlaoise had 4 lines feeding it
  - Size
    - More Customers are fed at each Transmission Station


KV
MW +KV
MVAR +KV
MVA +KV
FREQ & DCC
OCC_MASTER
LLW
LAMP
ALERTS
Tue 08-Mar-2011 16:47:40
49.99Hz
9.0 °C
SOR
TLK
STB
GOL
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GIL
TAW
FLA
COS
TON
CBR
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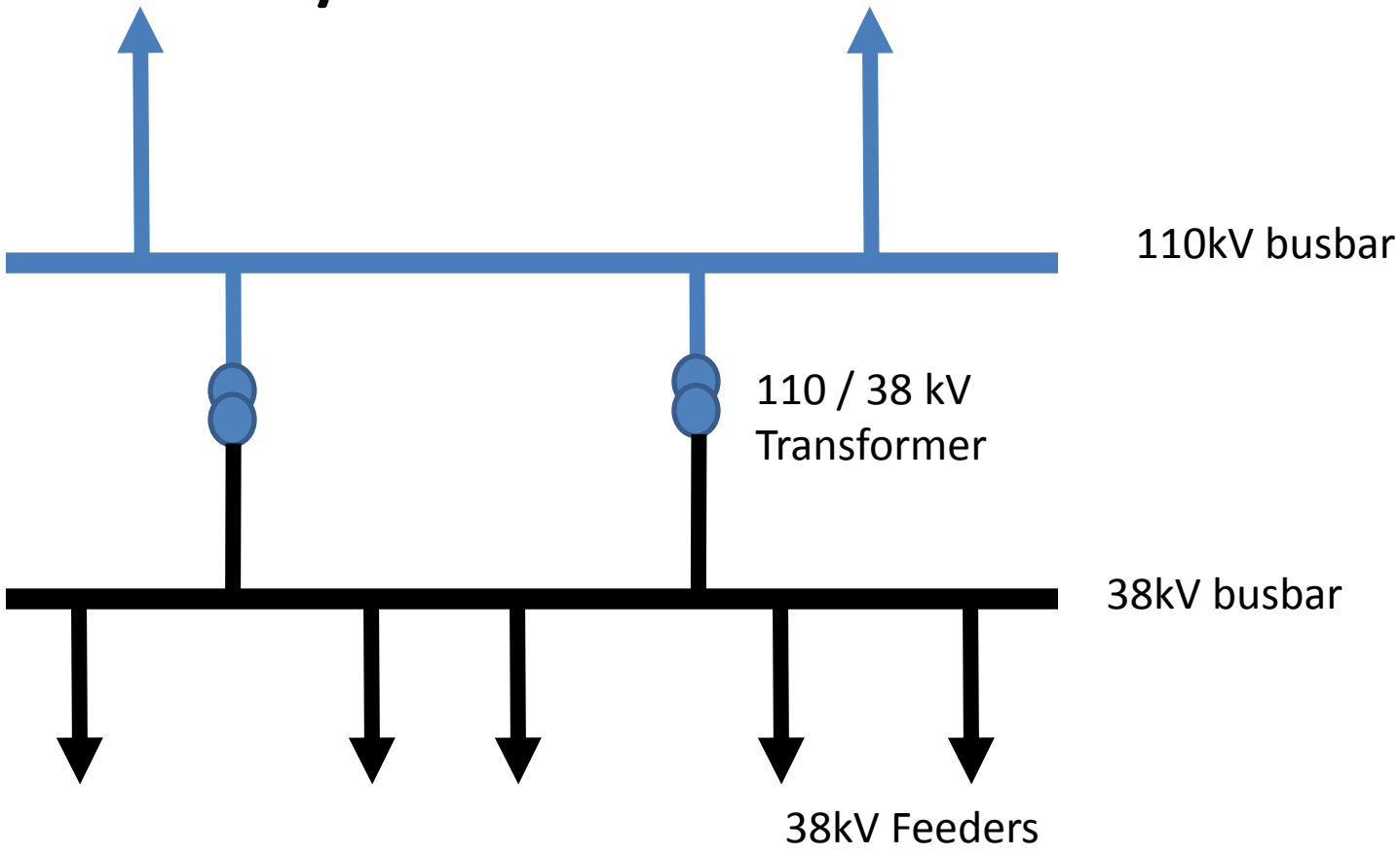
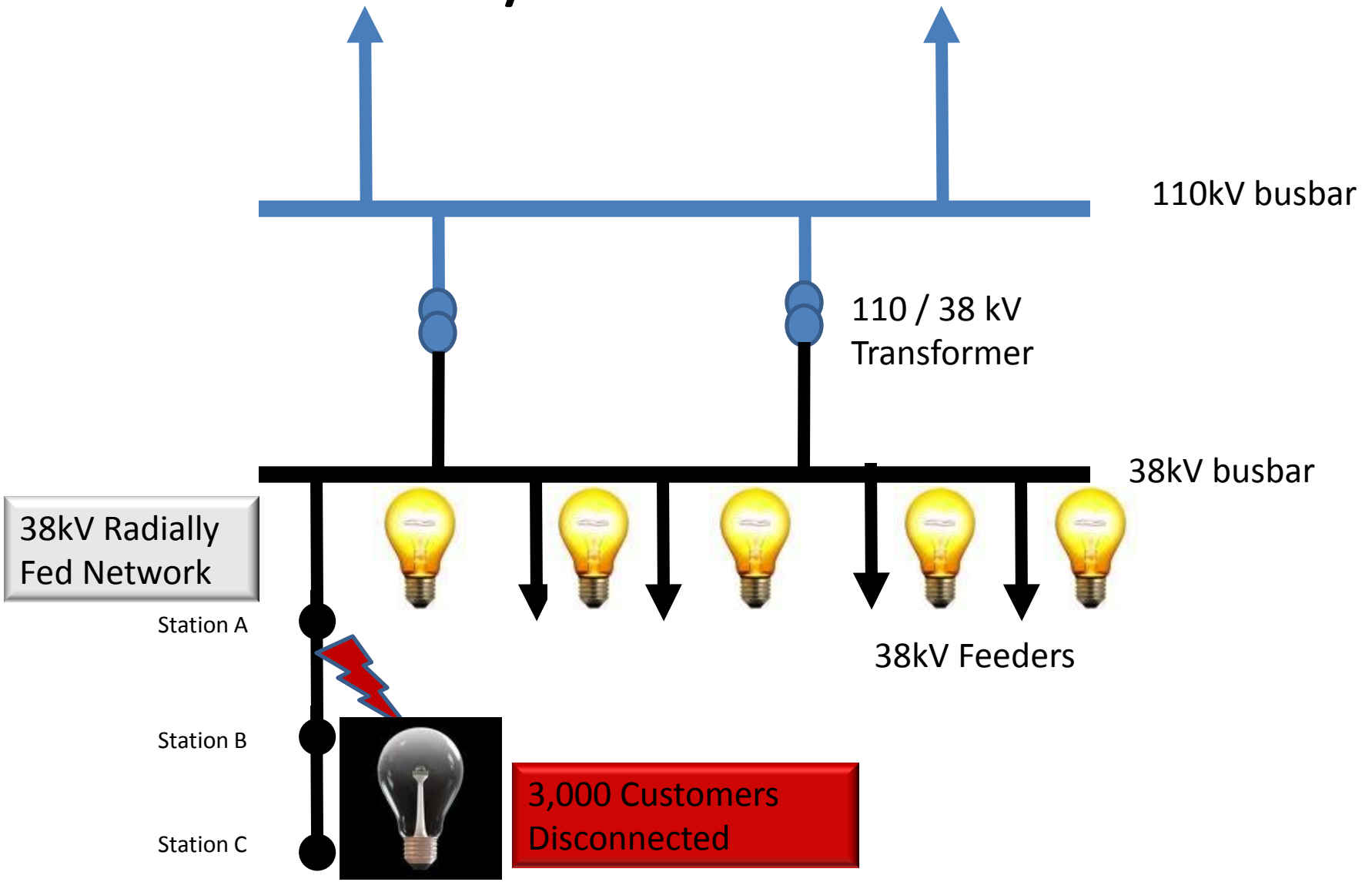
119

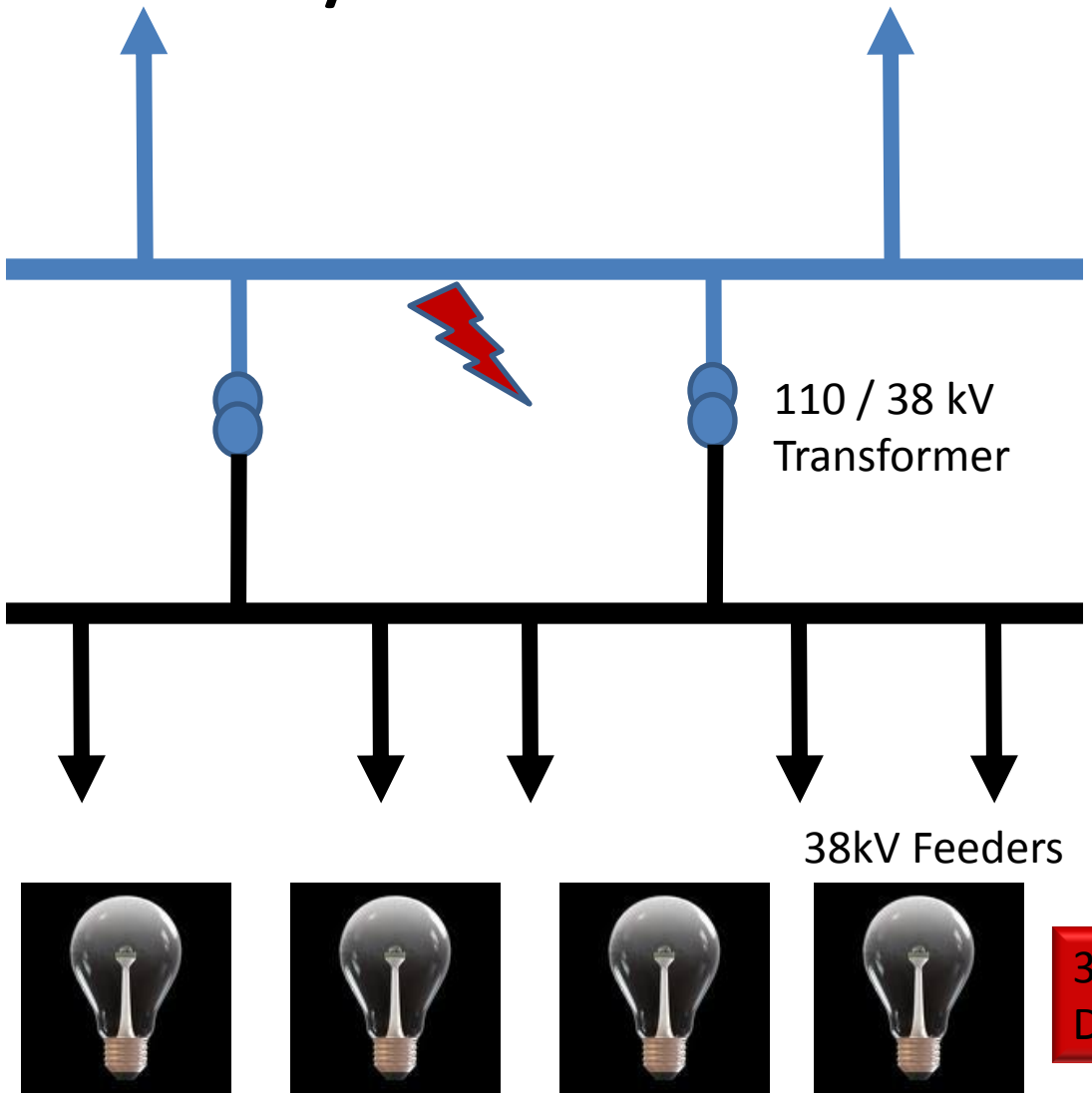
110 / 38kV Station



110 / 38kV Station



110 / 38kV Station



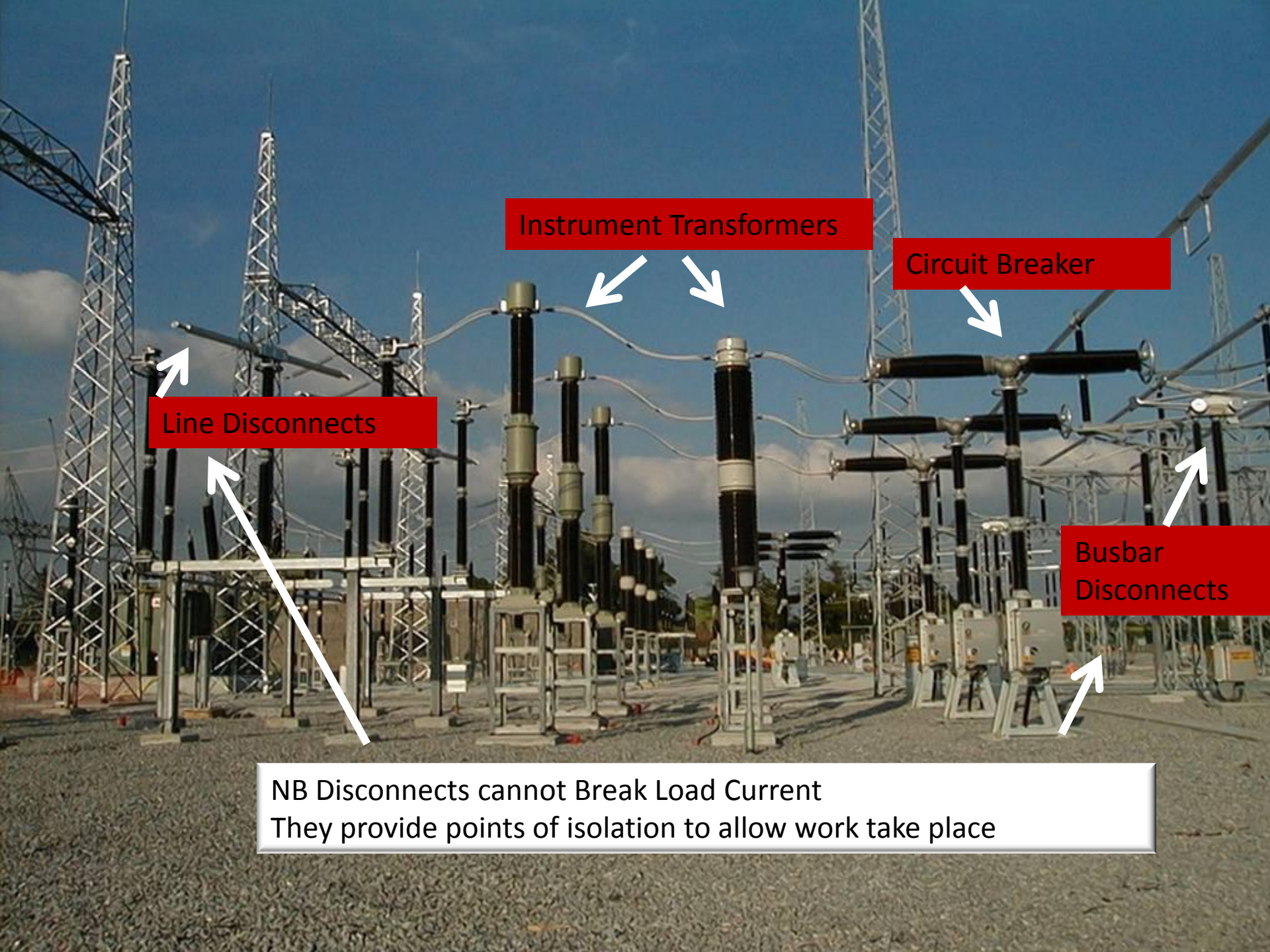
30,000 Customers
Disconnected

COMPONENT PARTS OF THE TRANSMISSION SYSTEM

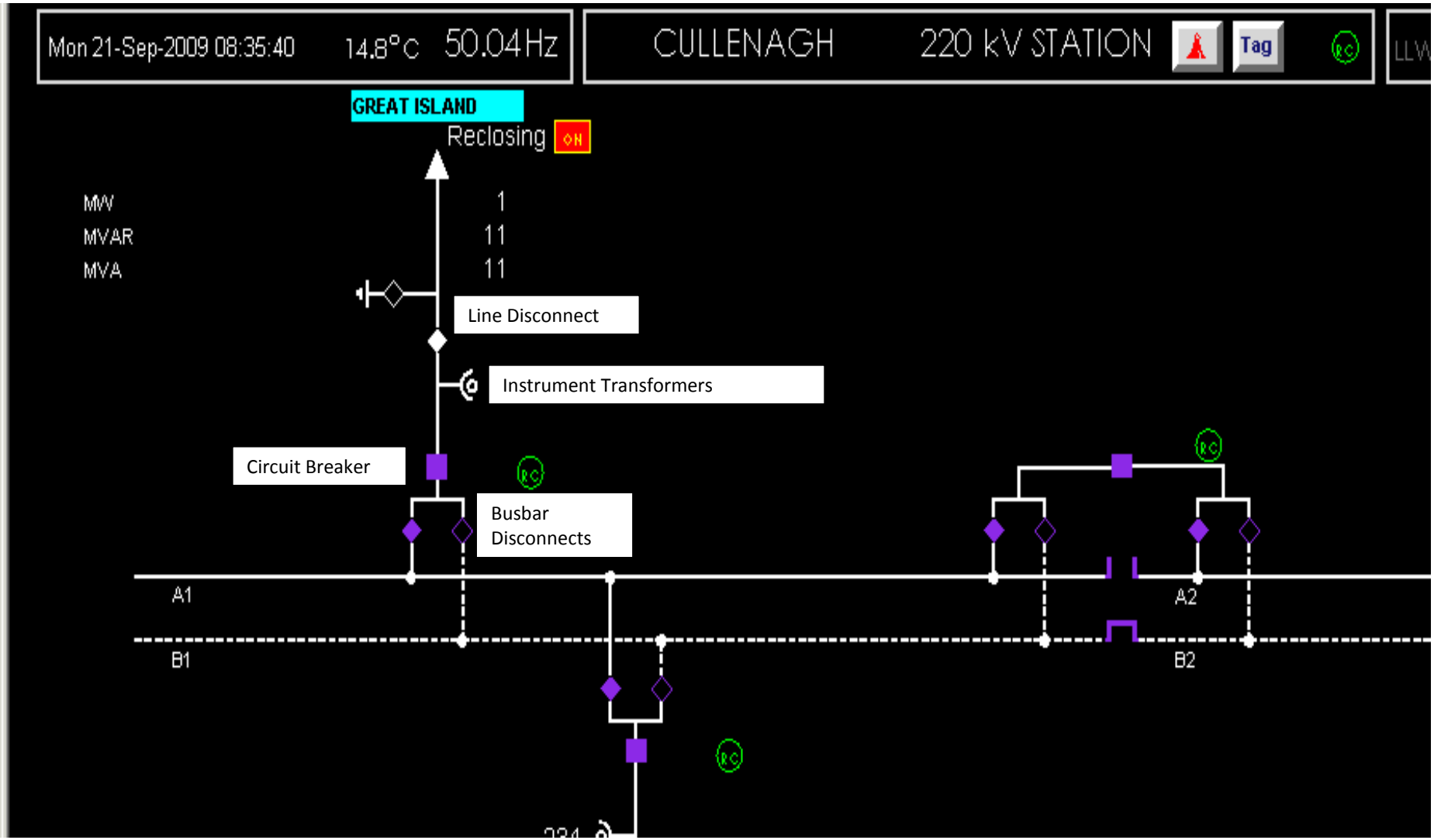
Overhead Lines

Underground Cables

220kV Tubular Busbar with Pantograph Disconnects


Instrument Transformers
Circuit Breaker
Line Disconnects
Busbar Disconnects
NB Disconnects cannot Break Load Current
They provide points of isolation to allow work take place

In NCC all of this is represented as follows



Rating of Equipment

- As shown a Circuit is made up of
  - The Line or Cable
  - The circuit breaker
  - Disconnects
  - Instrument transformers
- Each of these has a rating above which it cannot be operated
- All of these items must be maintained
- A fault on any of these items will cause the circuit to trip and possibly more than just that circuit

THEORY OF VOLTAGE CONTROL

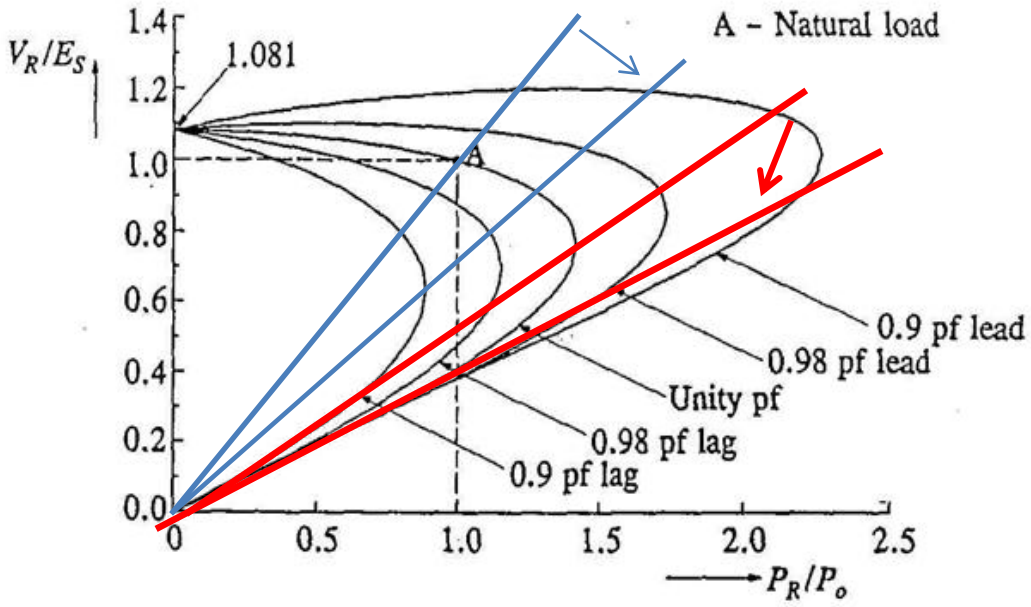
Voltage and Power Flow Control

- As demand for real power (MW) increases so does demand for reactive power
- If reactive power demand is not carefully managed over-voltages or under-voltages can occur
- Voltage Control is a steady state and a dynamic problem

Steady State

- Reactive Power can be supplied by
  - Generators
  - Capacitors / Reactors
  - Transmission Lines & Cables
- Controller must manage MVAR across the system to maintain voltages within allowable limits
- Not as easy as it sounds - much harder than MW control
- If NCC do not constantly manage voltage the voltage can collapse very rapidly

Voltage Collapse



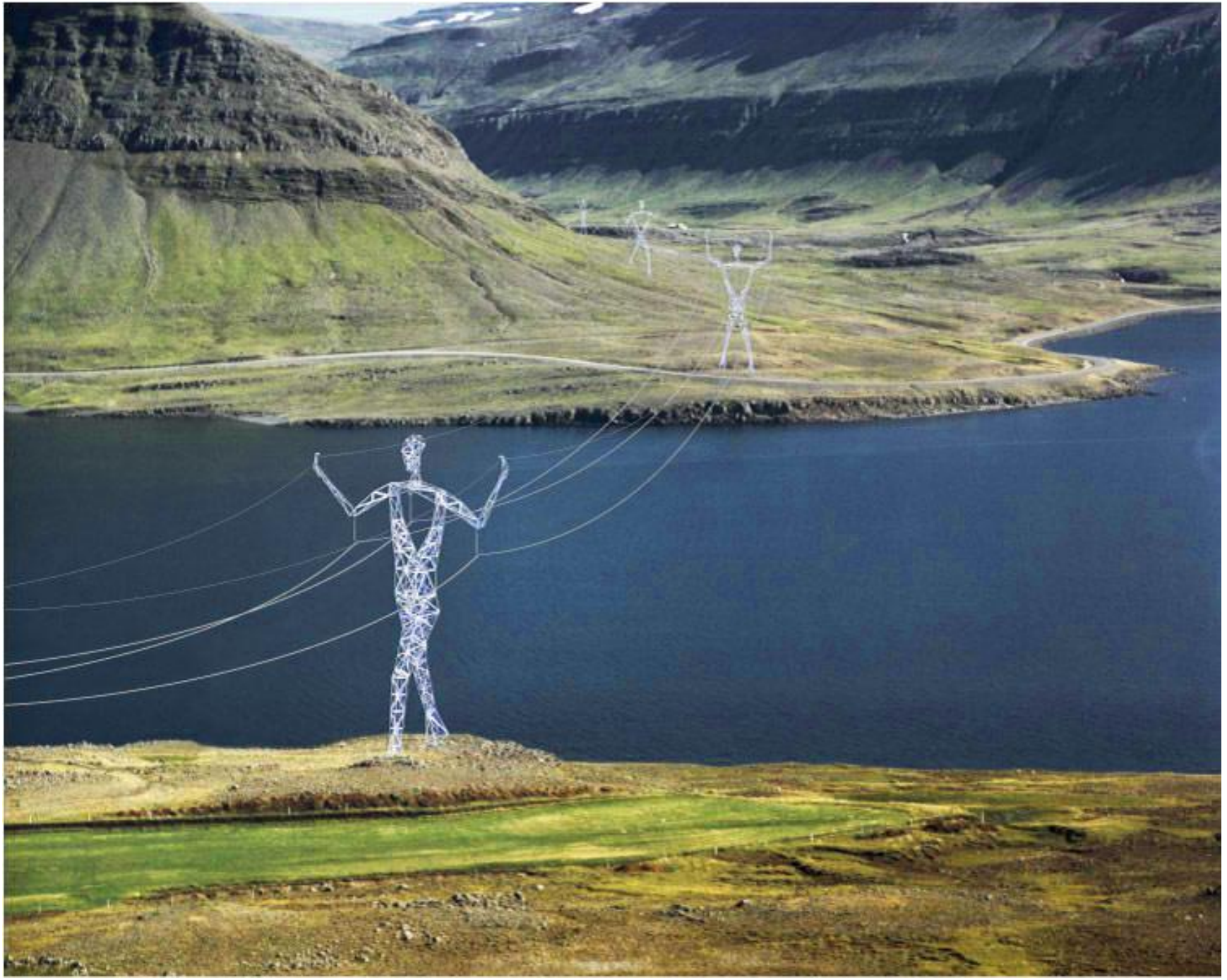
- Voltage Collapse can happen in a matter of minutes
- It has been the cause of wide-scale blackouts in other countries

THEORY OF OVERLOAD CONTROL

Transmission Plant Ratings

- All items of plant are designed to operate at a specific temperature.
- For overhead power lines the actual conductor temperature is influenced by
  - the current flowing down the line ***and***
  - ambient conditions such as wind, temperature, sunlight.
- Static Ratings reflect the allowable power flow for a given ambient conditions
- EirGrid is trialling Dynamic Line Rating Equipment at the moment
- Power lines carrying too much current will sag and could come into contact with earth.

This is not what I mean by sag!!



OPERATING A MESHED GRID: N-1 SECURITY

Meshed Grid Operation

- Power flows on lines varies in proportion to the impedance of the lines
- If a line is switched out power automatically re-routes down other in service lines
- This means there are no supply interruptions when a line is our for maintenance or trips….but
- NCC must ensure that ***resulting*** power flows are within acceptable limits

4 Bus System: Not N-1 Secure…Why?

- All lines operating within their design rating of 120MVA
- One generator on load
- Second unit off load

N-1 Event

- Line A- B Trips
- Power automatically re-routes
- Line A- D is overloaded

Unsecure Network

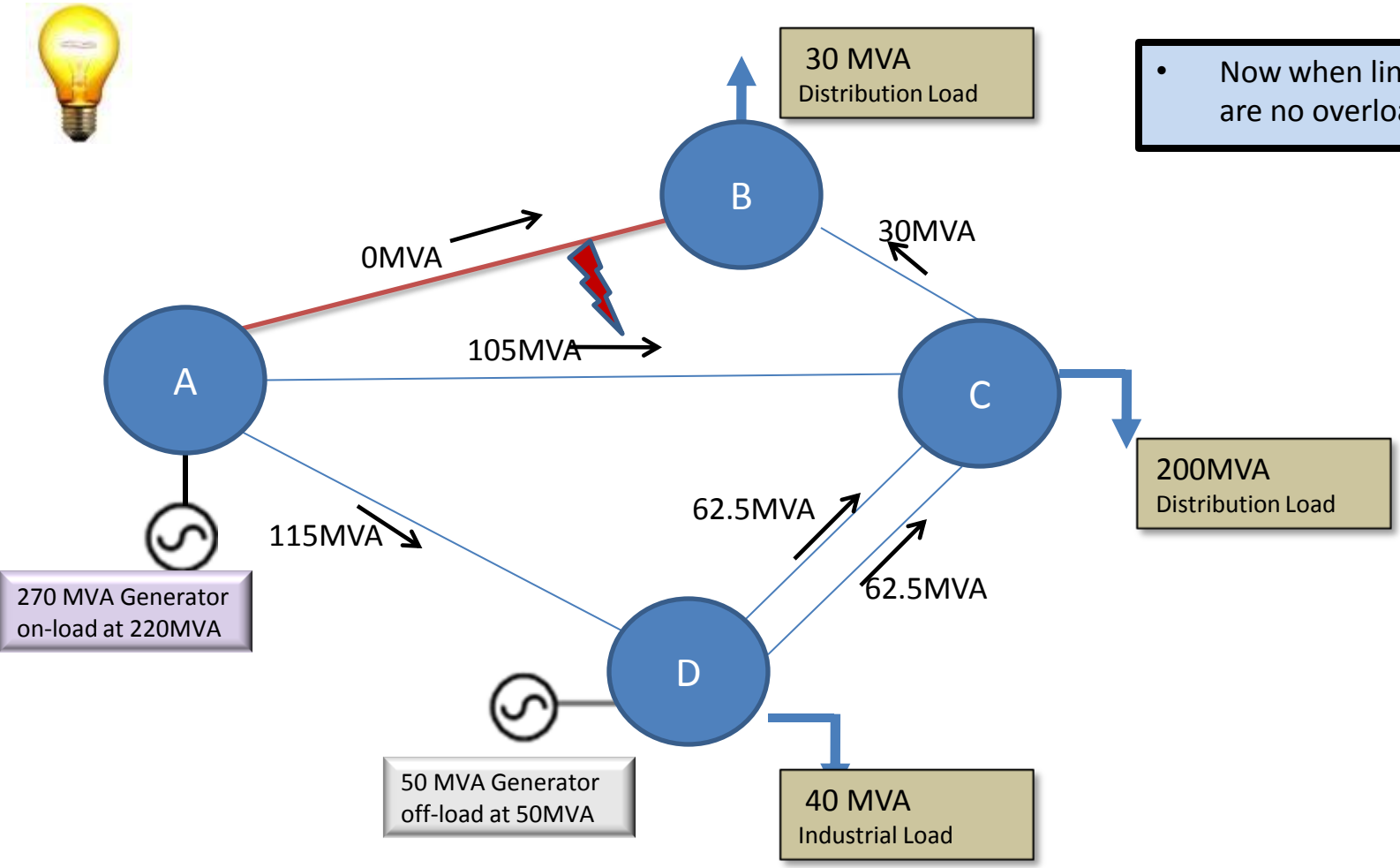
- Line A- D Burns down and trips
- Power automatically re-routes down line A-C overloading it

Blackout

- Line A- C Burns down and trips
- No more Power

What should have happened
N – 1 Secure

- NCC realise that if Line A-B trips the results are catastrophic
- NCC dispatches on load Unit at station D even though it is more expensive than Unit at station A



- Now when line A-B trips there are no overloads

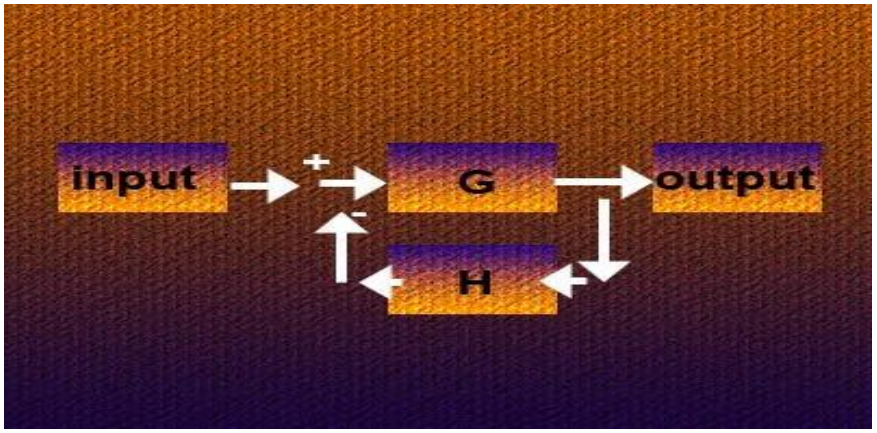
Enough Theory

Transmission Engineer

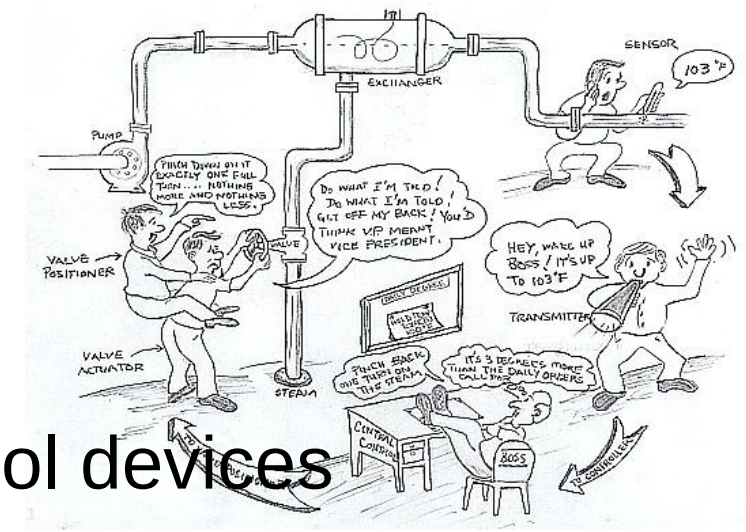
- Monitors and controls voltage
- Monitors and controls power flows
- Responds to system alarms and events
- Monitors the dynamic stability of the system
- Operational switching
  - Remote control
- Manages outages of transmission plant
- System restoration
- Manages connection of new or repaired equipment
  - Declarations of Fitness

VOLTAGE CONTROL

Voltage



- How is it monitored?
  - Set points, targets
  - Assessment tools
  - High visibility

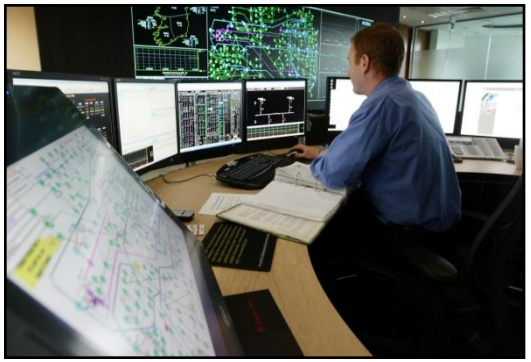


- How is it implemented?
  - Range and scale of control devices

- Steady state v's transient control

Monitoring

- Voltage alarms
  - Trending
  - 4,900 measurement points
- On line voltage stability tool
  - Check voltage as load and topology changes
  - Are you over dependent on one generator?
- Contingency analysis
  - Check voltages as topology changes



Monitored

- Voltage monitored, alarmed and controlled within predefined ranges

Nominal Voltage	Base Case Limits	Post Contingency Limits
400 kV	370 to 410 kV	360 to 420 kV
220 kV	210 to 240 kV	200 to 245 kV
110 kV	105 to 120 kV	99 to 123 kV

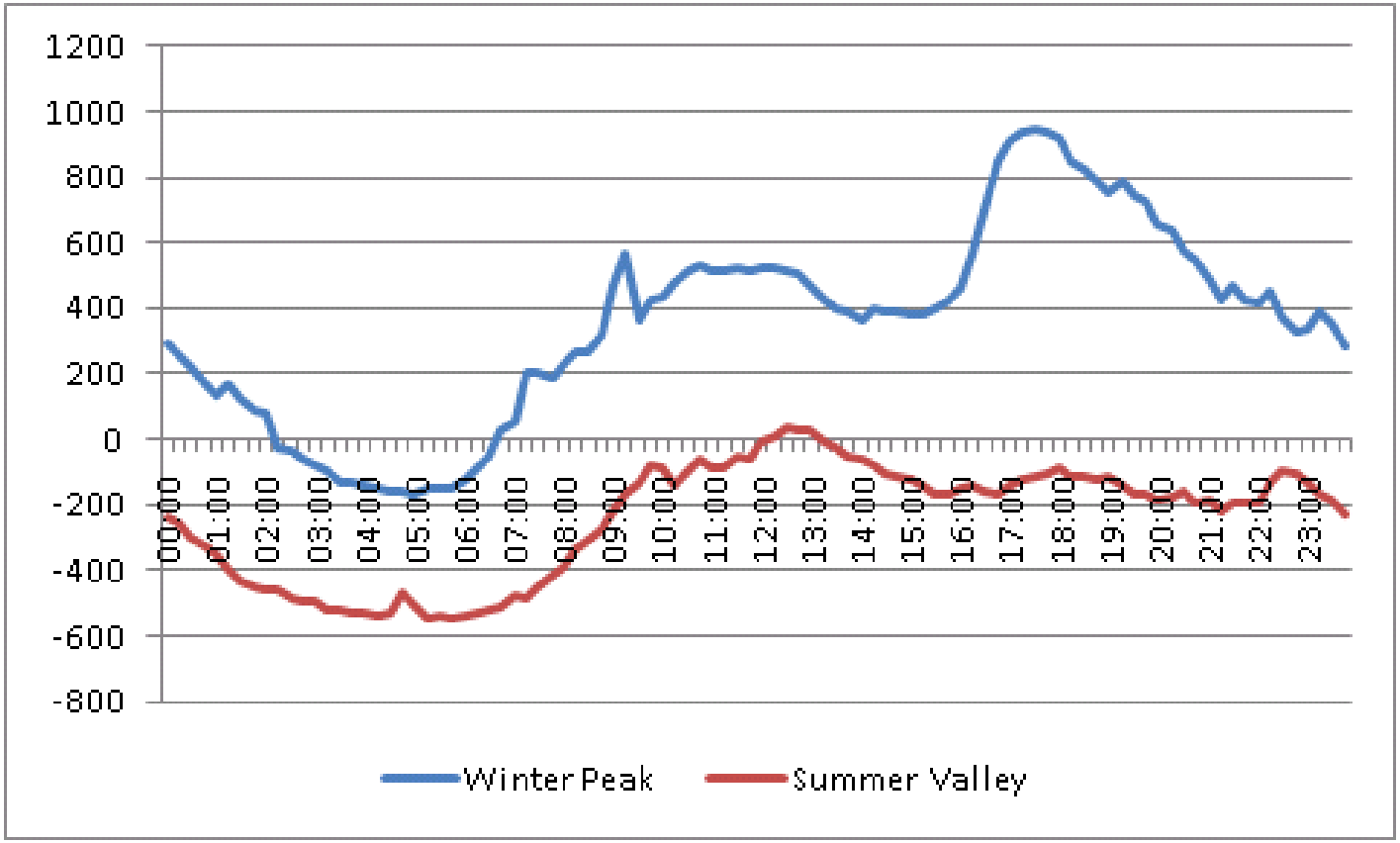
- http://www.eirgrid.com/media/Operational%20Security%20Standards.pdf

EIRGRID

How is voltage controlled

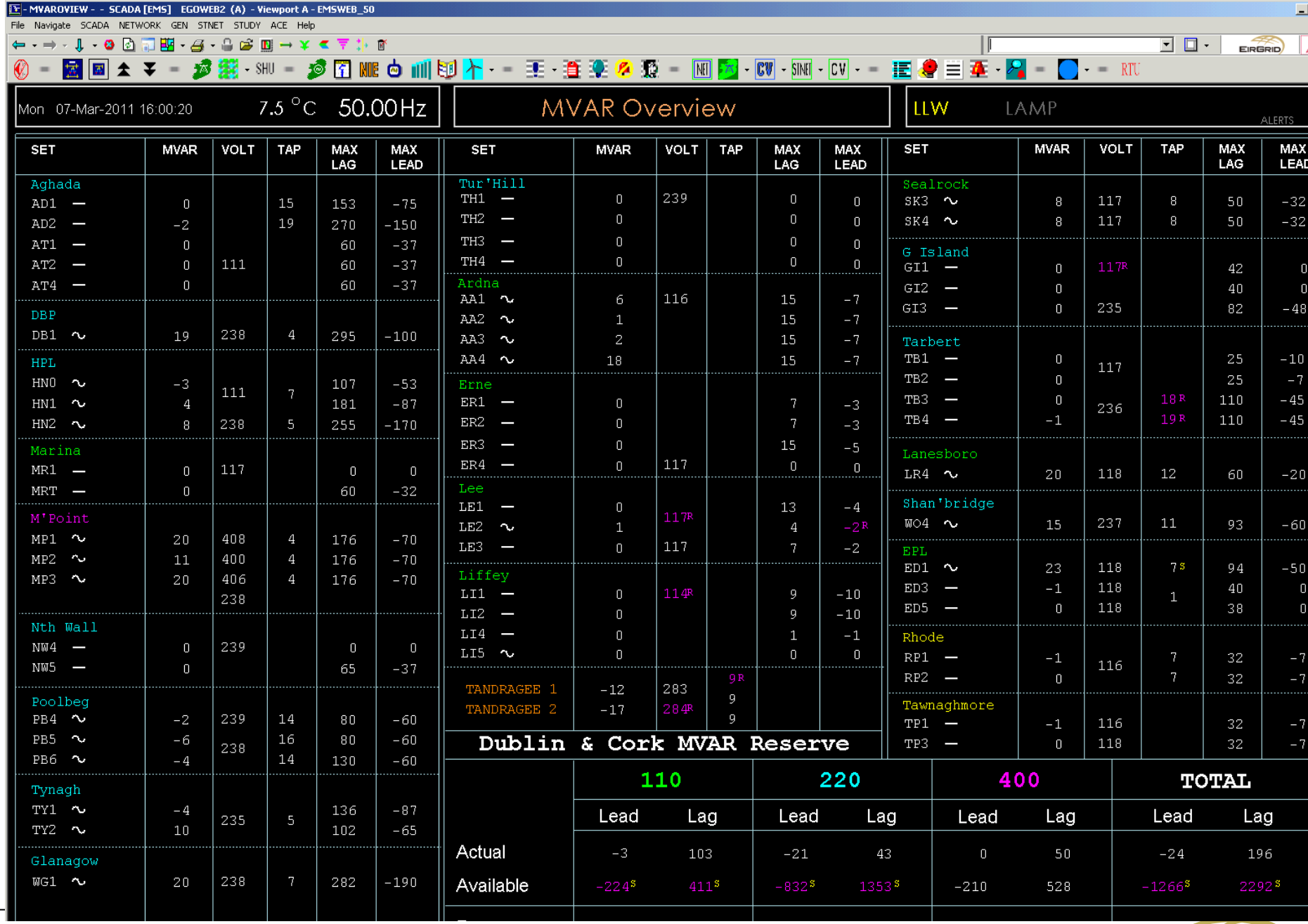
- Generators
  - Dynamic source/sink
- Topology changes
  - Switching out cables
- Tap changing on transformers
  - Remote control
- Static reserve sources
  - Capacitors, Reactors

Reactive Power [MVar] Demand



Capacitive

Reactive



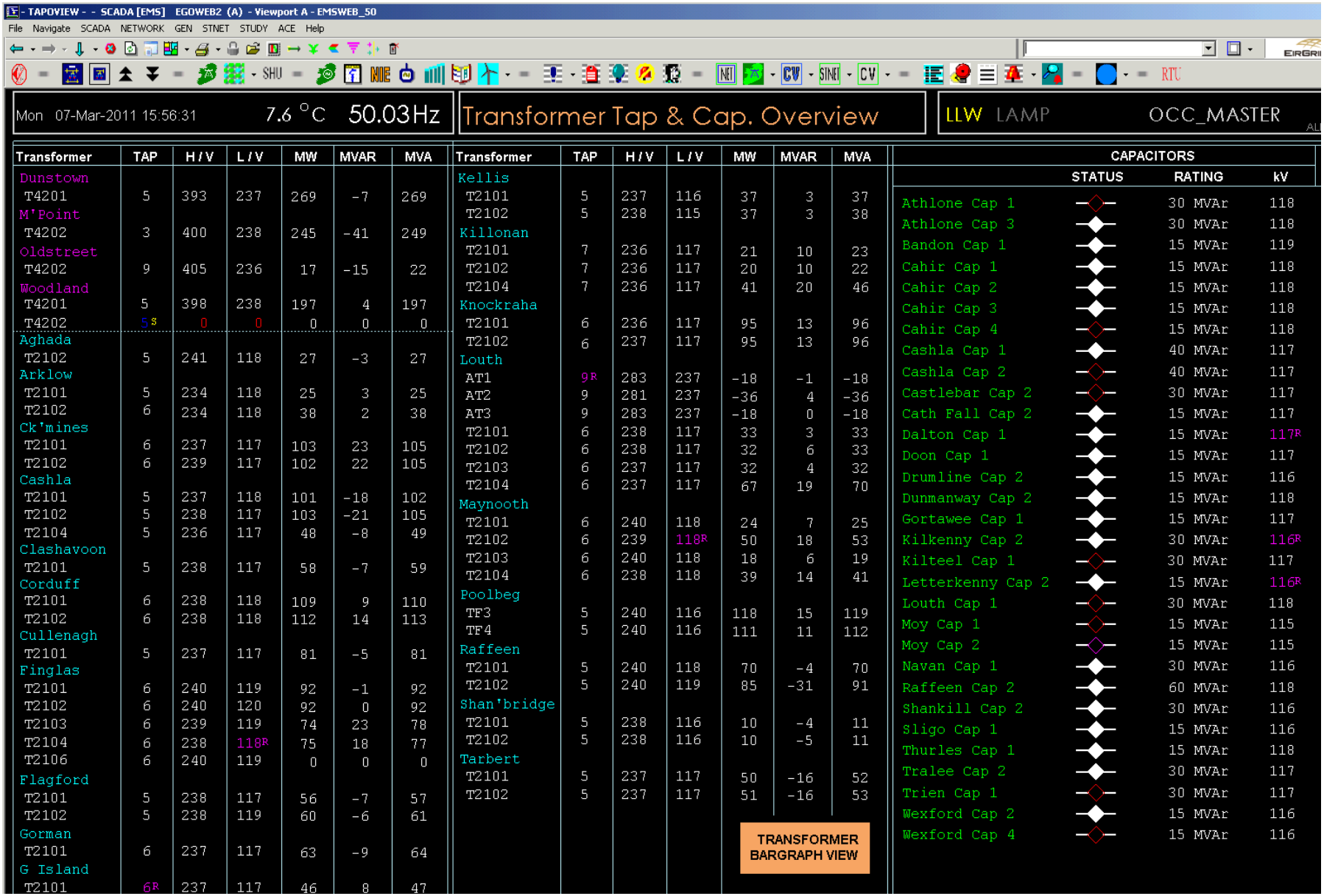
SET	MVAR	VOLT	TAP	MAX LAG	MAX LEAD
Aghada					
AD1 —	0		15	153	-75
AD2 —	-2		19	270	-150
AT1 —	0			60	-37
AT2 —	0	111		60	-37
AT4 —	0			60	-37
DBP					
DB1 ∿	19	238	4	295	-100
HPL					
HN0 ∿	-3	111	7	107	-53
HN1 ∿	4			181	-87
HN2 ∿	8	238	5	255	-170
Marina					
MR1 —	0	117		0	0
MRT —	0			60	-32
M'Point					
MP1 ∿	20	408	4	176	-70
MP2 ∿	11	400	4	176	-70
MP3 ∿	20	406	4	176	-70
		238			
Nth Wall					
NW4 —	0	239		0	0
NW5 —	0			65	-37
Poolbeg					
PB4 ∿	-2	239	14	80	-60
PB5 ∿	-6	238	16	80	-60
PB6 ∿	-4		14	130	-60
Tynagh					
TY1 ∿	-4	235	5	136	-87
TY2 ∿	10			102	-65
Glanagow					
WG1 ∿	20	238	7	282	-190

SET	MVAR	VOLT	TAP	MAX LAG	MAX LEAD
Tur'Hill					
TH1 —	0	239		0	0
TH2 —	0			0	0
TH3 —	0			0	0
TH4 —	0			0	0
Ardna					
AA1 ∿	6	116		15	-7
AA2 ∿	1			15	-7
AA3 ∿	2			15	-7
AA4 ∿	18			15	-7
Erne					
ER1 —	0			7	-3
ER2 —	0			7	-3
ER3 —	0			15	-5
ER4 —	0	117		0	0
Lee					
LE1 —	0			13	-4
LE2 ∿	1	117R		4	-2R
LE3 —	0	117		7	-2
Liffey					
LI1 —	0	114R		9	-10
LI2 —	0			9	-10
LI4 —	0			1	-1
LI5 ∿	0			0	0
TANDRAGEE 1	-12	283	9R		
TANDRAGEE 2	-17	284R	9		

SET	MVAR	VOLT	TAP	MAX LAG	MAX LEAD
Sealrock					
SK3 ∿	8	117	8	50	-32
SK4 ∿	8	117	8	50	-32
G Island					
GI1 —	0	117R		42	0
GI2 —	0			40	0
GI3 —	0	235		82	-48
Tarbert					
TB1 —	0	117		25	-10
TB2 —	0			25	-7
TB3 —	0	236	18R	110	-45
TB4 —	-1		19R	110	-45
Lanesboro					
LR4 ∿	20	118	12	60	-20
Shan'bridge					
WO4 ∿	15	237	11	93	-60
EPL					
ED1 ∿	23	118	7S	94	-50
ED3 —	-1	118	1	40	0
ED5 —	0	118		38	0
Rhode					
RP1 —	-1	116	7	32	-7
RP2 —	0		7	32	-7
Tawnaghmore					
TP1 —	-1	116		32	-7
TP3 —	0	118		32	-7

Dublin & Cork MVAR Reserve

	110		220		400		TOTAL	
	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag
Actual	-3	103	-21	43	0	50	-24	196
Available	-224S	411S	-832S	1353S	-210	528	-1266S	2292S



Transformer	TAP	H / V	L / V	MW	MVAR	MVA
Dunstown						
T4201	5	393	237	269	-7	269
M'Point						
T4202	3	400	238	245	-41	249
Oldstreet						
T4202	9	405	236	17	-15	22
Woodland						
T4201	5	398	238	197	4	197
T4202	5S	0	0	0	0	0
Aghada						
T2102	5	241	118	27	-3	27
Arklow						
T2101	5	234	118	25	3	25
T2102	6	234	118	38	2	38
Ck'mines						
T2101	6	237	117	103	23	105
T2102	6	239	117	102	22	105
Cashla						
T2101	5	237	118	101	-18	102
T2102	5	238	117	103	-21	105
T2104	5	236	117	48	-8	49
Clashavoon						
T2101	5	238	117	58	-7	59
Corduff						
T2101	6	238	118	109	9	110
T2102	6	238	118	112	14	113
Cullenagh						
T2101	5	237	117	81	-5	81
Finglas						
T2101	6	240	119	92	-1	92
T2102	6	240	120	92	0	92
T2103	6	239	119	74	23	78
T2104	6	238	118R	75	18	77
T2106	6	240	119	0	0	0
Flagford						
T2101	5	238	117	56	-7	57
T2102	5	238	119	60	-6	61
Gorman						
T2101	6	237	117	63	-9	64
G Island						
T2101	6R	237	117	46	8	47

Transformer	TAP	H / V	L / V	MW	MVAR	MVA
Kellis						
T2101	5	237	116	37	3	37
T2102	5	238	115	37	3	38
Killonan						
T2101	7	236	117	21	10	23
T2102	7	236	117	20	10	22
T2104	7	236	117	41	20	46
Knockraha						
T2101	6	236	117	95	13	96
T2102	6	237	117	95	13	96
Louth						
AT1	9R	283	237	-18	-1	-18
AT2	9	281	237	-36	4	-36
AT3	9	283	237	-18	0	-18
T2101	6	238	117	33	3	33
T2102	6	238	117	32	6	33
T2103	6	237	117	32	4	32
T2104	6	237	117	67	19	70
Maynooth						
T2101	6	240	118	24	7	25
T2102	6	239	118R	50	18	53
T2103	6	240	118	18	6	19
T2104	6	238	118	39	14	41
Poolbeg						
TF3	5	240	116	118	15	119
TF4	5	240	116	111	11	112
Raffeen						
T2101	5	240	118	70	-4	70
T2102	5	240	119	85	-31	91
Shan'bridge						
T2101	5	238	116	10	-4	11
T2102	5	238	116	10	-5	11
Tarbert						
T2101	5	237	117	50	-16	52
T2102	5	237	117	51	-16	53

110kV profiles - Start: 07-Mar-2011 00:00:00

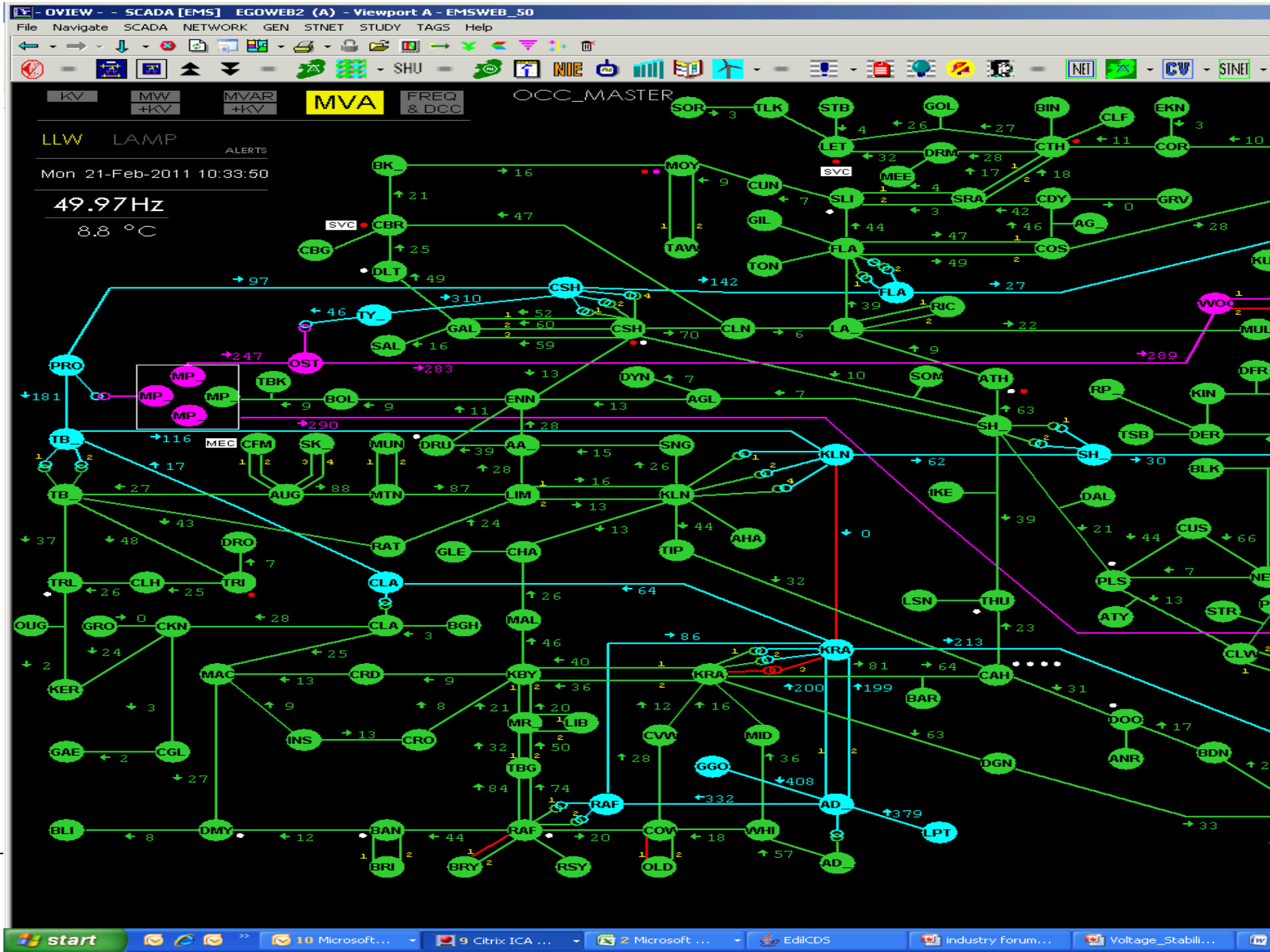
EIRGRID

A SINGLE CABLE FAULT EFFECTS THE ENTIRE SYSTEM

Inchicore – Irishtown 220kV cable fault at 09:28 on 27 January 2007

- Transient voltage response
- Protection operated to clear the fault in 0.05 of a second
- Fault isolated and system integrity preserved
- Over 350 alarms triggered on the EMS System in 10 seconds
- Required on-going operational measures in Dublin (sectionalising and generation re-dispatch)

POWER FLOW


- OVIEW - - SCADA [EMS] EGOWEB2 (A) - Viewport A - EMSWEB_50
File Navigate SCADA NETWORK GEN STNET STUDY TAGS Help
KV
MW +KV
MVAR +KV
MVA
FREQ & DCC
OCC_MASTER
LLW
LAMP
ALERTS
Mon 21-Feb-2011 10:33:50
49.97Hz
8.8 °C
SHU
NIE
NET
CV
STNET
SVC
MEC
SOR
TLK
STB
GOL
BIN
CLF
EKN
LET
CTH
COR
DRM
MEE
BK_
MOY
CUN
SLI
SRA
CDY
GRV
CBR
CBG
TAW
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FLA
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TON
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9 Citrix ICA ...
2 Microsoft ...
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industry forum...
Voltage_Stabili...

Monitoring Power Flows

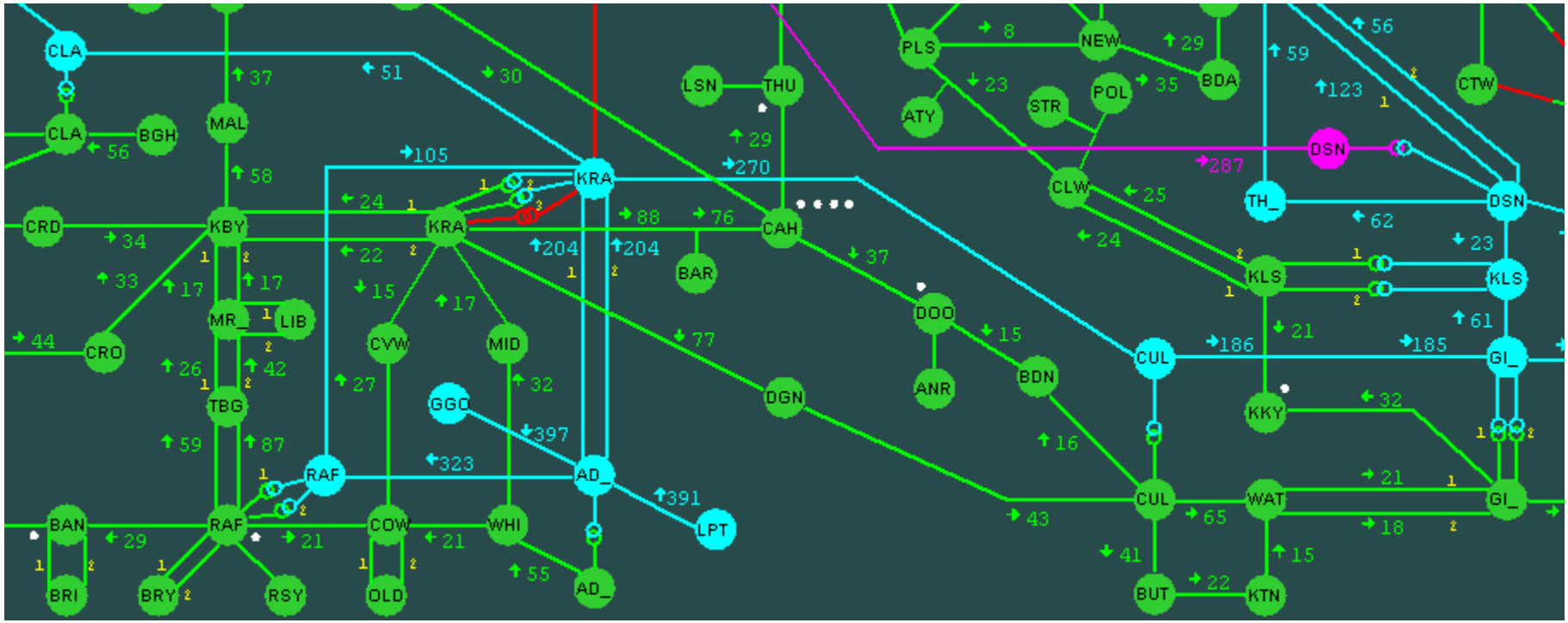
- Line flows alarmed
  - Endangered and Disturbed levels
- Contingency Analysis
  - N-1 analysis
- Study enviroment
  - Can be used to examine future events

EIRGRID

Controlling Power Flow

- Generation commitment and dispatch
  - Out of merit generation required
- Change topology
  - Sectionalise the network
    - Trade off with security
  - Phase shifting transformers
- Load transfer
- Load shedding

Example Case



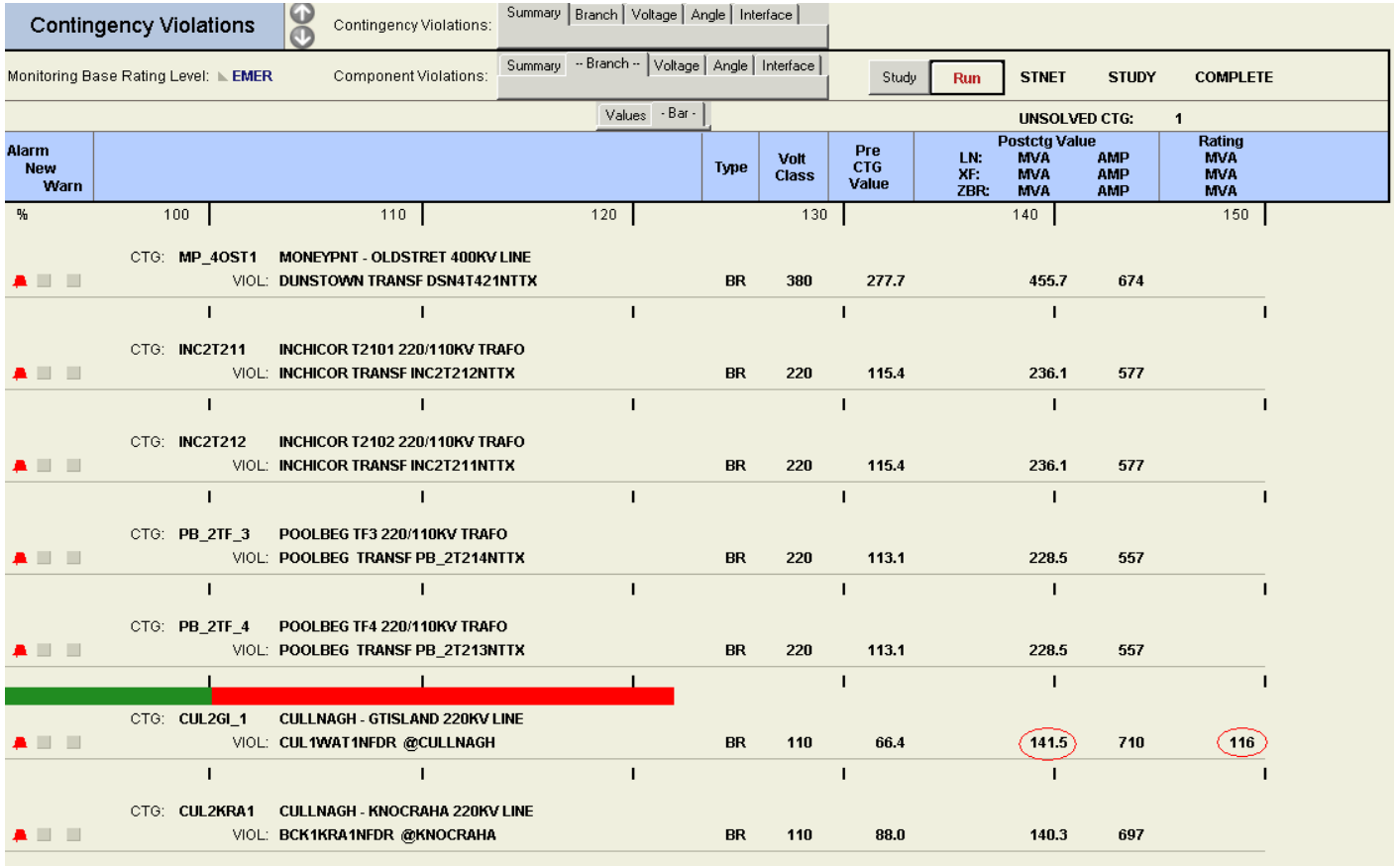
Load 3560 MW (3pm on an average Monday in March)

Medium wind – 251 MW

Cork Generation – 800 MW

Cullenagh – Waterford 110 kV line (rated 116 MVA)

Contingency Violation



Contingency Violations

Contingency Violations: Summary | Branch | Voltage | Angle | Interface

Monitoring Base Rating Level: EMER

Component Violations: Summary | -- Branch -- | Voltage | Angle | Interface

Study | Run | STNET | STUDY | COMPLETE

Values | - Bar -

UNSOLVED CTG: 1

Alarm New Warn		Type	Volt Class	Pre CTG Value	Postctg Value LN: MVA / XF: MVA / ZBR: MVA	Postctg Value AMP / AMP / AMP	Rating MVA / MVA / MVA
%	100 110 120		130		140		150
	CTG: MP_4OST1 MONEYPNT - OLDSTRET 400KV LINE						
	VIOL: DUNSTOWN TRANSF DSN4T421NTTX	BR	380	277.7	455.7	674	
	CTG: INC2T211 INCHICOR T2101 220/110KV TRAFO						
	VIOL: INCHICOR TRANSF INC2T212NTTX	BR	220	115.4	236.1	577	
	CTG: INC2T212 INCHICOR T2102 220/110KV TRAFO						
	VIOL: INCHICOR TRANSF INC2T211NTTX	BR	220	115.4	236.1	577	
	CTG: PB_2TF_3 POOLBEG TF3 220/110KV TRAFO						
	VIOL: POOLBEG TRANSF PB_2T214NTTX	BR	220	113.1	228.5	557	
	CTG: PB_2TF_4 POOLBEG TF4 220/110KV TRAFO						
	VIOL: POOLBEG TRANSF PB_2T213NTTX	BR	220	113.1	228.5	557	
	CTG: CUL2GI_1 CULLNAGH - GTISLAND 220KV LINE						
	VIOL: CUL1WAT1NFDR @CULLNAGH	BR	110	66.4	141.5	710	116
	CTG: CUL2KRA1 CULLNAGH - KNOCRAHA 220KV LINE						
	VIOL: BCK1KRA1NFDR @KNOCRAHA	BR	110	88.0	140.3	697	

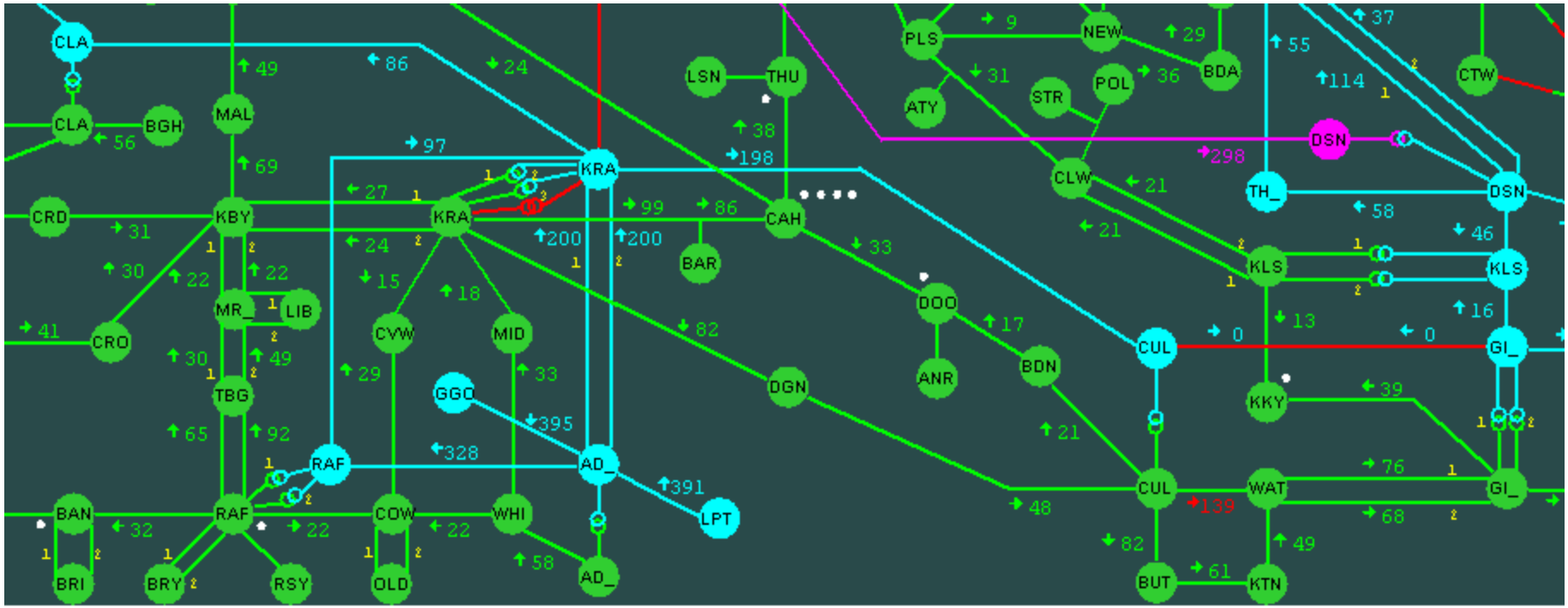
Contingency Analysis Warning

Loss of Cullenagh – Great Island 220 kV line

>121 % overload on Cullenagh – Waterford 110 kV line (rated 116 MVA)

60 MW reduction of Cork generation required to comply with operating standards

East - West Contingency



Tripping of Cullenagh – Great Island 220 kV line

-> 121 % overload on Cullenagh – Waterford 110 kV line

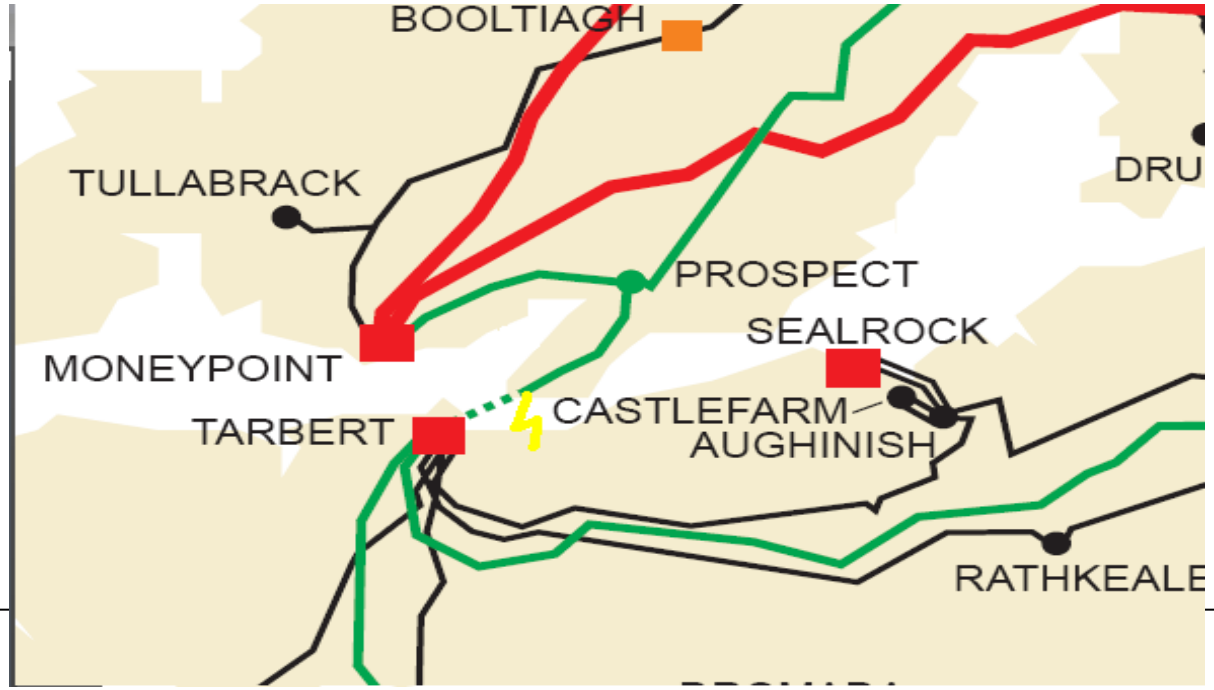
139 MVA flowing on a 116 MVA rated line

REAL LIFE FAULTS

Transmission Fault

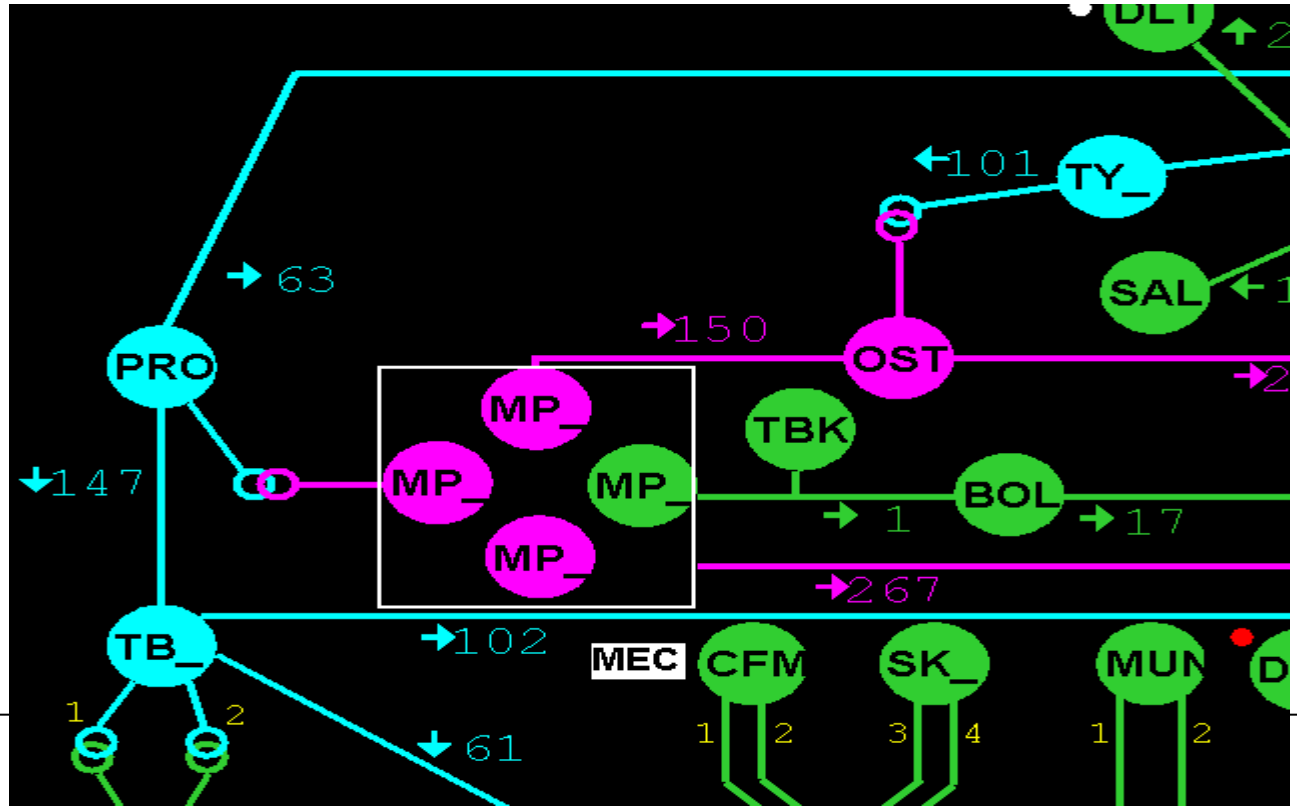
- Prospect Tarbert 220 kV line made up of 7.65 km of 220 kV OHL from Prospect and 2 km UGC under the Shannon to Tarbert

- At 16:00:49 on 4th Feb 2011 - a fault occurred on T phase of the feeder



Pre-fault Operational Info

- 147 MW flowing from Prospect to Tarbert
- 240 kV at Prospect busbar 238 kV at Tarbert busbar



Alarms

- 04-feb-2011 16:00:50 s TRIEN 110KV CLAHANE 1 REL521 DCEF REV PU ON
- 04-feb-2011 16:00:50 s TRIEN 110KV DROMADA 1 7SA612 NEUTRAL PU ON
- 04-feb-2011 16:00:50 s TRIEN 110KV DROMADA 1 7SA612 DCEF REV PU ON
- 04-feb-2011 16:00:51 s AUGHINIS 110KV TARBERT 1 REL DCEF TX ON
- 04-feb-2011 16:00:51 s DROMADA 110KV TRIEN 1 7SA6 NEUTRAL PU ON
- 04-feb-2011 16:00:51 s DROMADA 110KV TRIEN 1 7SA6 DCEF TX ON
- 04-feb-2011 16:00:51 s AUGHINIS 110KV TARBERT 1 REL DCEF TX OFF
- 04-feb-2011 16:00:51 s KILLONAN 220KV TARBERT 1 E/F PU LEVEL ON
- 04-feb-2011 16:00:51 s TRALEE 110KV TARBERT 1 7SN20 EF PU LVL ON
- 04-feb-2011 16:00:51 s CLSHVOON 220KV K'RAHA 1 7SA513 DCEF TRIP ON
- 04-feb-2011 16:00:51 s TYNAGH 220KV: GENERAL STATION ALARM ON
- 04-feb-2011 16:00:51 s SINGLAND 110KV ARDNA 1 REL DCEF REVPU ON
- 04-feb-2011 16:00:51 s DROMADA 110KV TRIEN 1 7SA6 NEUTRAL PU OFF
- 04-feb-2011 16:00:51 s DROMADA 110KV TRIEN 1 7SA6 DCEF TX OFF
- 04-feb-2011 16:00:52 s TRIEN 110KV DROMADA 1 7SA612 DCEF RX ON
- 04-feb-2011 16:00:52 s TRIEN 110KV CLAHANE 1 REL521 DCEF REV PU OFF
- 04-feb-2011 16:00:52 s TRIEN 110KV DROMADA 1 7SA612 NEUTRAL PU OFF
- 04-feb-2011 16:00:52 s TRIEN 110KV DROMADA 1 7SA612 DCEF RX OFF
- 04-feb-2011 16:00:52 s TRIEN 110KV DROMADA 1 7SA612 DCEF REV PU OFF
- 04-feb-2011 16:00:52 s MUINGNAMINNANE CB 20KV T421 CCT BRK STTS OPEN
- 04-feb-2011 16:00:53 s TRALEE 110KV TARBERT 1 7SA511 T PH PU ON
- 04-feb-2011 16:00:53 s TRALEE 110KV TARBERT 1 7SA511 ETH PU ON
- 04-feb-2011 16:00:53 s TRALEE 110KV TARBERT 1 7SN20 EF PT TX ON
- 04-feb-2011 16:00:53 s KILLONAN 220KV TARBERT 1 E/F TRIP LEVEL ON
- 04-feb-2011 16:00:53 s TRALEE 110KV TARBERT 1 7SA511 T PH PU OFF
- 04-feb-2011 16:00:53 s TRALEE 110KV TARBERT 1 7SA511 ETH PU OFF
- 04-feb-2011 16:00:53 s TRALEE 110KV TARBERT 1 7SN20 EF PT TX OFF
- 04-feb-2011 16:00:53 s TRALEE 110KV TARBERT 1 7SN20 EF PU LVL OFF
- 04-feb-2011 16:00:53 s CUNGHILL CB 20KV CAP STEP 1 CCT BRK STTS CLOSED
- 04-feb-2011 16:00:53 s CLSHVOON 220KV TARB'T 1 7SA513 T PH PU ON
- 04-feb-2011 16:00:53 s KNOCKAWARRIGA CB 20KV T421 CCT BRK STTS OPEN
- 04-feb-2011 16:00:53 s SINGLAND 110KV GENERAL STATION ALARM ON
- 04-feb-2011 16:00:53 s SINGLAND 110KV ARDNA 1 REL DCEF REVPU OFF
- 04-feb-2011 16:00:55 s CASHLA 220KV PROSPECT 1 7SA T PHASE PU ON
- 04-feb-2011 16:00:55 s CASHLA 220KV TYNAGH 1 DCEF PU LEVEL ON
- 04-feb-2011 16:00:55 s CASHLA 220KV TYNAGH 1 DCEF TRIP LEVEL ON
- 04-feb-2011 16:00:55 s BALNCOLG NETWORKS 7SA J1 FAULT ON
- 04-feb-2011 16:00:55 s CASHLA 220KV PROSPECT 1 7SA T PHASE PU OFF
- 04-feb-2011 16:00:55 s CASHLA 220KV TYNAGH 1 DCEF PU LEVEL OFF
- 04-feb-2011 16:00:55 s CASHLA 220KV TYNAGH 1 DCEF TRIP LEVEL OFF
- 04-feb-2011 16:00:55 s CASHLA 220KV GENERAL STATION ALARM ON
- 04-feb-2011 16:00:55 s TARBERT 110KV AUGHINIS 1 REL DCEF REV PU ON
- 04-feb-2011 16:00:55 s TARBERT 220KV TRIEN 1 REL521 DCEF REV PU ON
- 04-feb-2011 16:00:55 s TARBERT 220KV PROSPECT 1 EARTH PICKUP ON
- 04-feb-2011 16:00:55 s TARBERT 220KV CLSHVOON 1 S PHASE PICKUP ON
- 04-feb-2011 16:00:55 s TARBERT 220KV CLSHVOON 1 T PHASE PICKUP ON
- 04-feb-2011 16:00:55 s TARBERT 220KV T2101 7SA612 NEUTRAL PU ON
- 04-feb-2011 16:00:55 s TARBERT 220KV T2102 7SA612 NEUTRAL PU ON
- 04-feb-2011 16:00:55 s BALNCOLG NETWORKS 7SA J1 FAULT OFF
- 04-feb-2011 16:00:55 s KILLONAN 220KV TARBERT 1 T PHASE PICKUP ON
- 04-feb-2011 16:00:55 s KILLONAN 220KV TARBERT 1 E/F PER TRP TX ON
- 04-feb-2011 16:00:55 s KILLONAN 110KV SINGLAND 1 REL REV E/F PU ON
- 04-feb-2011 16:00:55 s CLSHVOON 220KV K'RAHA 1 7SA513 EARTH PU ON
- 04-feb-2011 16:00:55 s CLSHVOON 220KV TARB'T 1 7SA513 DCEF TRIP ON
- 04-feb-2011 16:00:55 s CLSHVOON 220KV TARB'T 1 7SA513 EARTH PU ON
- 04-feb-2011 16:00:55 s CLSHVOON 220KV TARB'T 1 7SA513 DCEF PU ON
- 04-feb-2011 16:00:55 s KILLONAN 220KV TARBERT 1 E/F PU LEVEL OFF
- 04-feb-2011 16:00:55 s KILLONAN 220KV TARBERT 1 E/F TRIP LEVEL OFF
- 04-feb-2011 16:00:55 s KILLONAN 220KV TARBERT 1 T PHASE PICKUP OFF
- 04-feb-2011 16:00:55 s KILLONAN 220KV TARBERT 1 E/F PER TRP TX OFF
- 04-feb-2011 16:00:55 s KILLONAN 220KV GENERAL STATION ALARM ON
- 04-feb-2011 16:00:55 s PROSPECT 220KV GENERAL STATION ALARM ON
- 04-feb-2011 16:00:55 s CLSHVOON 220KV K'RAHA 1 7SA513 DCEF TRIP OFF
- 04-feb-2011 16:00:55 s CLSHVOON 220KV K'RAHA 1 7SA513 EARTH PU OFF
- 04-feb-2011 16:00:55 s CLSHVOON 220KV TARB'T 1 7SA513 DCEF TRIP OFF
- 04-feb-2011 16:00:55 s CLSHVOON 220KV TARB'T 1 7SA513 EARTH PU OFF
- 04-feb-2011 16:00:55 s CLSHVOON 220KV TARB'T 1 7SA513 DCEF PU OFF
- 04-feb-2011 16:00:55 s CLSHVOON 220KV TARB'T 1 7SA513 T PH PU OFF
- 04-feb-2011 16:00:55 s KNOCWAGA NETWORKS PROT AC SUPPLY FAIL ON
- 04-feb-2011 16:00:57 s TARBERT CB 220KV PROSPECT 1 CCT BRK STTS OPEN
- 04-feb-2011 16:00:57 s BALLINCOLLIG CB 20KV T421 CCT BRK STTS OPEN
- 04-feb-2011 16:00:57 s BALLINCOLLIG CB 20KV FEEDER 1 CCT BRK STTS OPEN
- 04-feb-2011 16:00:57 s BALLINCOLLIG CB 20KV FEEDER 2 CCT BRK STTS OPEN
- 04-feb-2011 16:00:57 s BALLINCOLLIG CB 20KV FEEDER 3 CCT BRK STTS OPEN
- 04-feb-2011 16:00:57 s PROSPECT 220KV CASHLA 1 7SA T PHASE PU ON
- 04-feb-2011 16:00:57 s PROSPECT 220KV CASHLA 1 REVERSE PICKUP ON
- 04-feb-2011 16:00:57 s PROSPECT 220KV MONEYPNT 1 7SA T PH PU ON
- 04-feb-2011 16:00:57 s PROSPECT 220KV MONEYPNT 1 7SA EF PICKUP ON
- 04-feb-2011 16:00:57 s PROSPECT 220KV MONEYPNT 1 7SA REV IMP PU ON
- 04-feb-2011 16:00:57 s PROSPECT 220KV MONEYPNT 1 7SA DCEF RV PU ON
- 04-feb-2011 16:00:57 s PROSPECT 220KV CASHLA 1 7SA T PHASE PU OFF
- 04-feb-2011 16:00:57 s PROSPECT 220KV CASHLA 1 REVERSE PICKUP OFF
- 04-feb-2011 16:00:57 s PROSPECT 220KV MONEYPNT 1 7SA T PH PU OFF
- 04-feb-2011 16:00:57 s PROSPECT 220KV MONEYPNT 1 7SA EF PICKUP OFF
- 04-feb-2011 16:00:57 s PROSPECT 220KV MONEYPNT 1 7SA REV IMP PU OFF
- 04-feb-2011 16:00:57 s PROSPECT 220KV MONEYPNT 1 7SA DCEF RV PU OFF
- 04-feb-2011 16:00:57 s PROSPECT 220KV TARBERT 1 7SA T PHASE PU ON
- 04-feb-2011 16:00:57 s PROSPECT 220KV TARBERT 1 7SA NEUTRAL PU ON
- 04-feb-2011 16:00:57 s PROSPECT 220KV TARBERT 1 7SA POTT TX ON
- 04-feb-2011 16:00:57 s PROSPECT 220KV TARBERT 1 7SA DCEF RX ON
- 04-feb-2011 16:00:59 s TARBERT 220KV TRIEN 1 REL521 EARTH PU ON
- 04-feb-2011 16:00:59 s TARBERT 220KV PROSPECT 1 T PHASE PICKUP ON
- 04-feb-2011 16:00:59 s TARBERT 220KV CLSHVOON 1 REVERSE PICKUP ON
- 04-feb-2011 16:00:59 s TARBERT 110KV AUGHINIS 1 REL DCEF REV PU OFF
- 04-feb-2011 16:00:59 s TARBERT 110KV AUGHINIS 1 7SA T PHASE PU ON
- 04-feb-2011 16:00:59 s TARBERT 220KV TRIEN 1 REL521 EARTH PU OFF
- 04-feb-2011 16:00:59 s TARBERT 220KV TRIEN 1 REL521 DCEF REV PU OFF
- 04-feb-2011 16:00:59 s TARBERT 220KV PROSPECT 1 T PHASE PICKUP OFF
- 04-feb-2011 16:00:59 s TARBERT 220KV CLSHVOON 1 REVERSE PICKUP OFF
- 04-feb-2011 16:00:59 s TARBERT 220KV CLSHVOON 1 S PHASE PICKUP OFF
- 04-feb-2011 16:00:59 s TARBERT 220KV CLSHVOON 1 T PHASE PICKUP OFF
- 04-feb-2011 16:00:59 s TARBERT 110KV T2101 7SA612 T PHASE PU ON
- 04-feb-2011 16:00:59 s TARBERT 110KV T2101 7SA612 NEUTRAL PU ON
- 04-feb-2011 16:00:59 s TARBERT 220KV T2101 7SA612 T PHASE PU ON
- 04-feb-2011 16:00:59 s TARBERT 220KV T2101 7SA612 NEUTRAL PU OFF
- 04-feb-2011 16:00:59 s TARBERT 220KV T2101 7SA612 REVERSE PU ON
- 04-feb-2011 16:01:00 s PROSPECT CB 220KV TARBERT 1 CCT BRK STTS OPEN
- 04-feb-2011 16:01:01 s TARBERT 110KV AUGHINIS 1 7SA NEUTRAL PU ON
- 04-feb-2011 16:01:01 s TARBERT 110KV T2102 7SA612 T PHASE PU ON
- 04-feb-2011 16:01:01 s TARBERT 110KV T2102 7SA612 NEUTRAL PU ON
- 04-feb-2011 16:01:01 s TARBERT 110KV T2102 7SA612 FWD IMP PU ON
- 04-feb-2011 16:01:01 s TARBERT 220KV T2102 7SA612 T PHASE PU ON
- 04-feb-2011 16:01:01 s TARBERT 220KV T2102 7SA612 REV FLT PU ON
- 04-feb-2011 16:01:01 s KNOCRAHA 220KV CLSHVOON 1 7SA DCEF PU LV ON
- 04-feb-2011 16:01:01 s TARBERT 110KV AUGHINIS 1 7SA T PHASE PU OFF
- 04-feb-2011 16:01:01 s TARBERT 110KV AUGHINIS 1 7SA NEUTRAL PU OFF
- 04-feb-2011 16:01:01 s TARBERT 220KV PROSPECT 1 EARTH PICKUP OFF
- 04-feb-2011 16:01:01 s TARBERT 110KV T2101 7SA612 T PHASE PU OFF
- 04-feb-2011 16:01:01 s TARBERT 110KV T2101 7SA612 NEUTRAL PU OFF
- 04-feb-2011 16:01:01 s TARBERT 110KV T2102 7SA612 T PHASE PU OFF
- 04-feb-2011 16:01:01 s TARBERT 110KV T2102 7SA612 NEUTRAL PU OFF
- 04-feb-2011 16:01:01 s TARBERT 110KV T2102 7SA612 FWD IMP PU OFF
- 04-feb-2011 16:01:01 s TARBERT 220KV T2101 7SA612 T PHASE PU OFF
- 04-feb-2011 16:01:01 s TARBERT 220KV T2101 7SA612 REVERSE PU OFF
- 04-feb-2011 16:01:01 s TARBERT 220KV T2102 7SA612 T PHASE PU OFF
- 04-feb-2011 16:01:01 s TARBERT 220KV T2102 7SA612 NEUTRAL PU OFF
- 04-feb-2011 16:01:01 s TARBERT 220KV T2102 7SA612 REV FLT PU OFF
- 04-feb-2011 16:01:02 s PROSPECT 220KV TARBERT 1 7SA 1P TRIP ON
- 04-feb-2011 16:01:02 s PROSPECT 220KV TARBERT 1 7SA DCEF TRIP ON
- 04-feb-2011 16:01:02 s PROSPECT 220KV TARBERT 1 7SA POTT RX ON
- 04-feb-2011 16:01:02 s PROSPECT 220KV TARBERT 1 7SA DIST TRIP ON
- 04-feb-2011 16:01:02 s PROSPECT 220KV TARBERT 1 7SA T PHASE PU OFF
- 04-feb-2011 16:01:02 s PROSPECT 220KV TARBERT 1 7SA NEUTRAL PU OFF
- 04-feb-2011 16:01:02 s PROSPECT 220KV TARBERT 1 7SA 1P TRIP OFF
- 04-feb-2011 16:01:02 s PROSPECT 220KV TARBERT 1 7SA DCEF TRIP OFF
- 04-feb-2011 16:01:02 s PROSPECT 220KV TARBERT 1 7SA POTT RX OFF
- 04-feb-2011 16:01:02 s PROSPECT 220KV TARBERT 1 7SA POTT TX OFF
- 04-feb-2011 16:01:02 s PROSPECT 220KV TARBERT 1 7SA DCEF RX OFF
- 04-feb-2011 16:01:02 s PROSPECT 220KV TARBERT 1 7SA DIST TRIP OFF
- 04-feb-2011 16:01:07 s KNOCRAHA 220KV CLSHVOON 1 7SA DCEF PU LV OFF

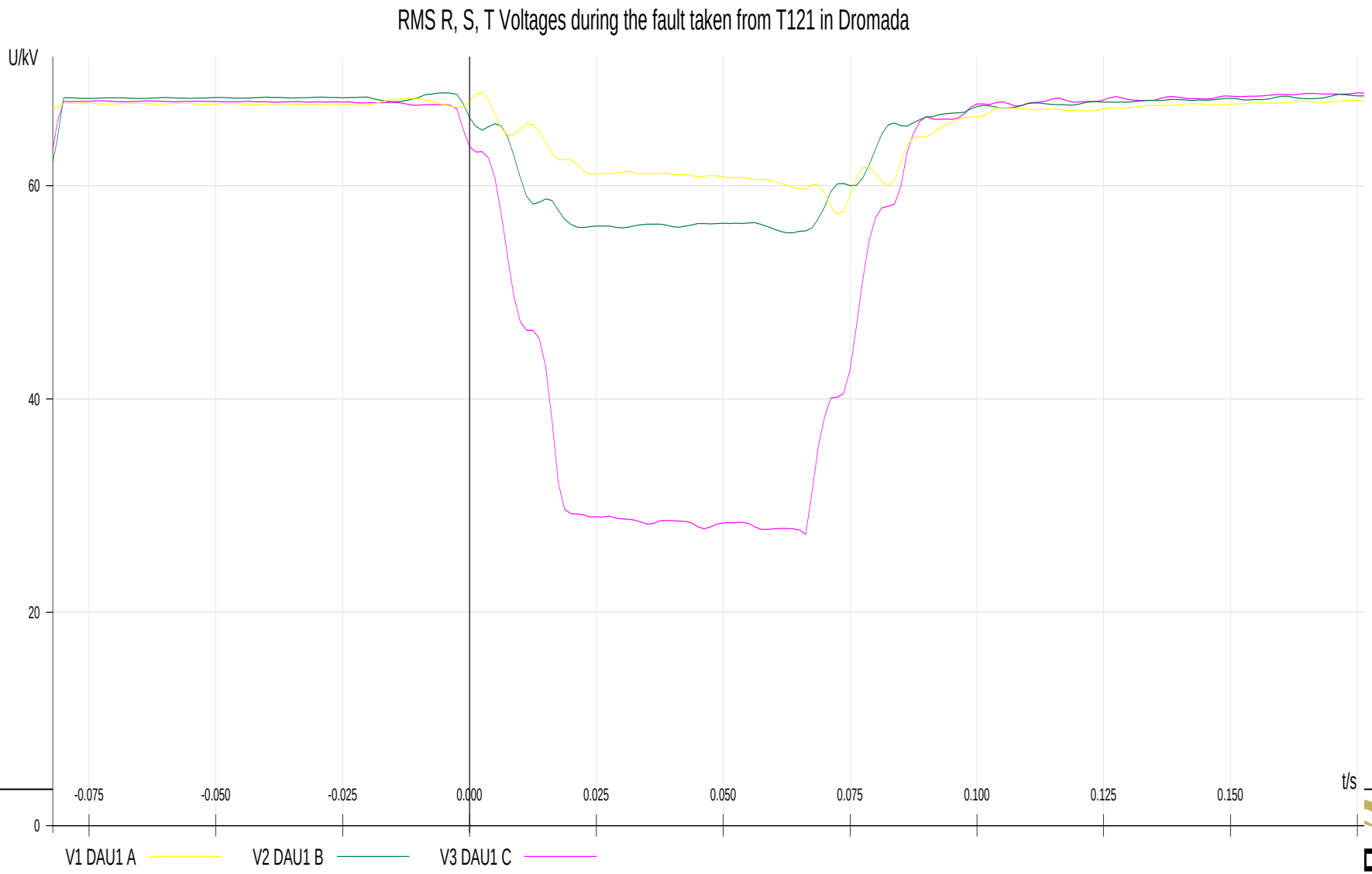
Protection Operations - Prospect

- Total fault clearance time: 80 milliseconds

- The relay in Prospect indicated that the fault was close to or on the cable section of the feeder.
  - Auto restoration is blocked for such faults.

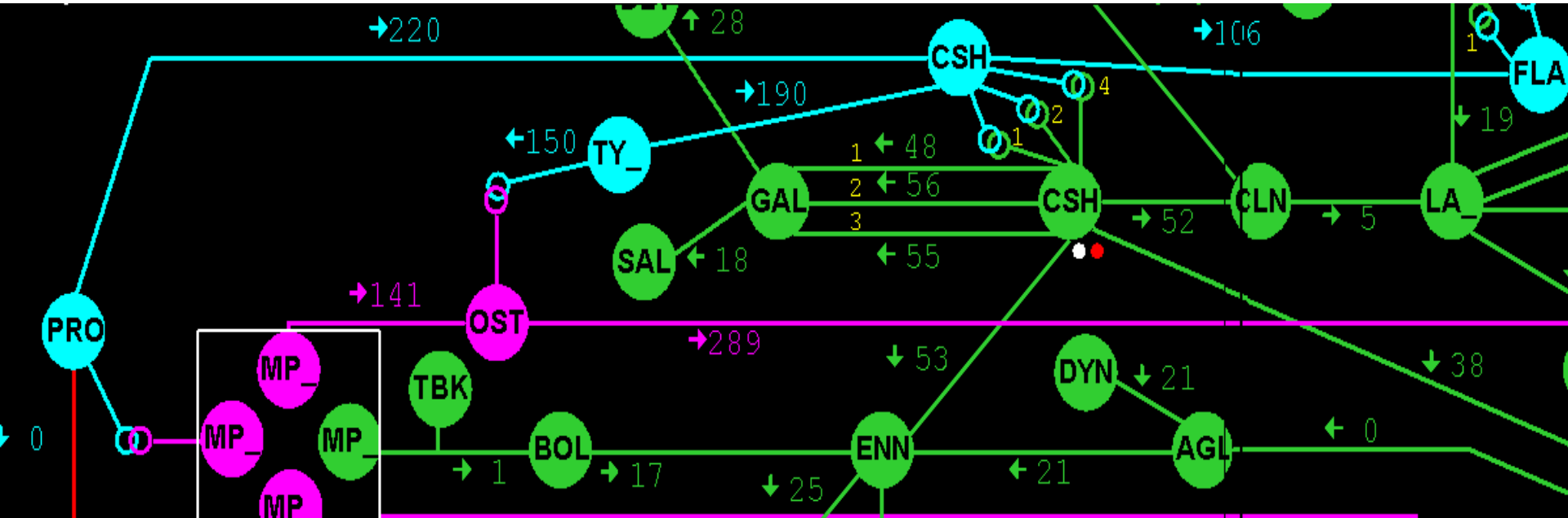
- Follow up inspections indicated
  - No issue with the cable section.
  - A failed surge arrestor at the line/cable interface

Voltage Dip in Dromada 110kV - Kerry



Post-fault Operational

- 147 MW power flow from Moneypoint to Prospect gets redirected to Cashla after the Tarbert line trips
- This was fed back to the south network via the 110 kV lines in Cashla and Flagford
- There was no line overloads as a result of the line tripping



Post Fault Actions

- New surge arresters installed and tested at the line cable interface on 6th of February.

- Feeder was returned to service at 18:53 hours on the 6th of February

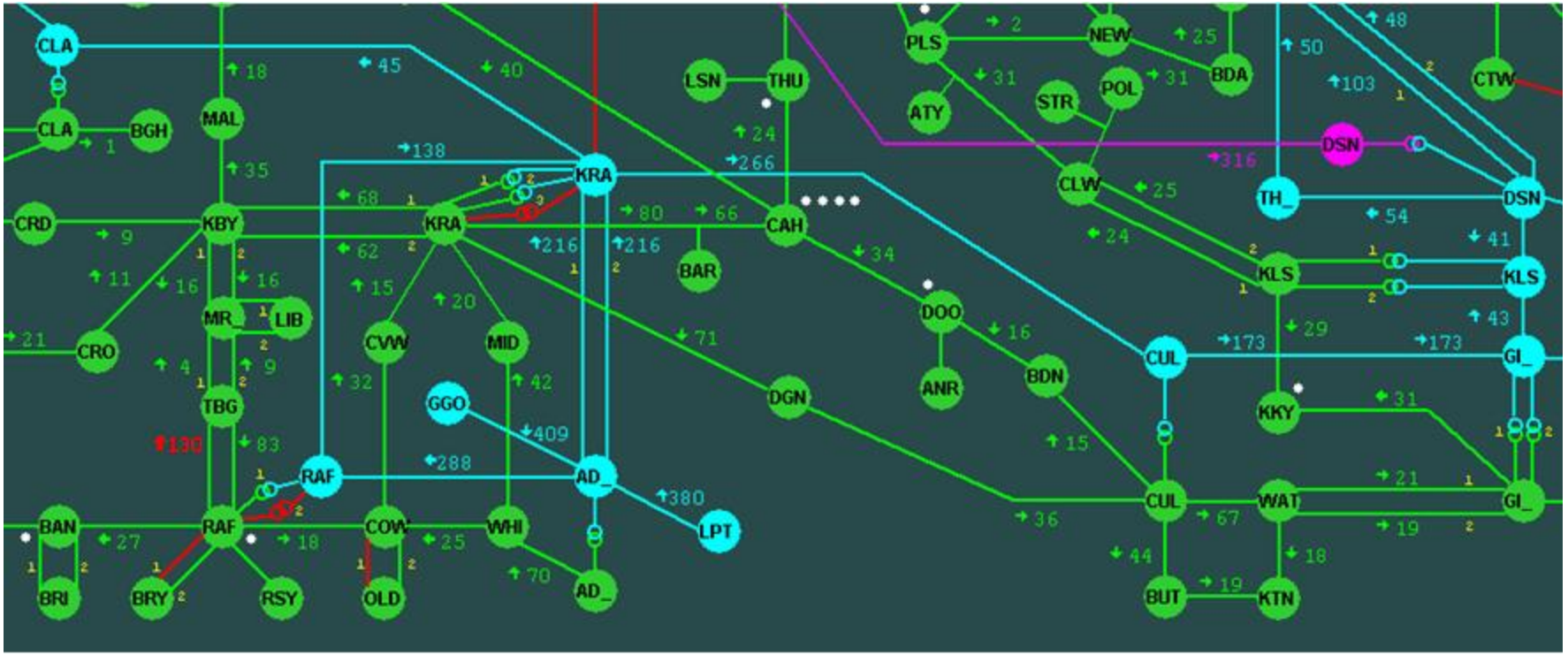
High Impact Low Probability Event

Shannonbridge

27th Feb 2011

End

Cork 110 kV Contingency



Loss of Raffeen T2102 220/110 kV transformer

-> overload on Raffeen – Trabeg 1 (one) 110 kV line

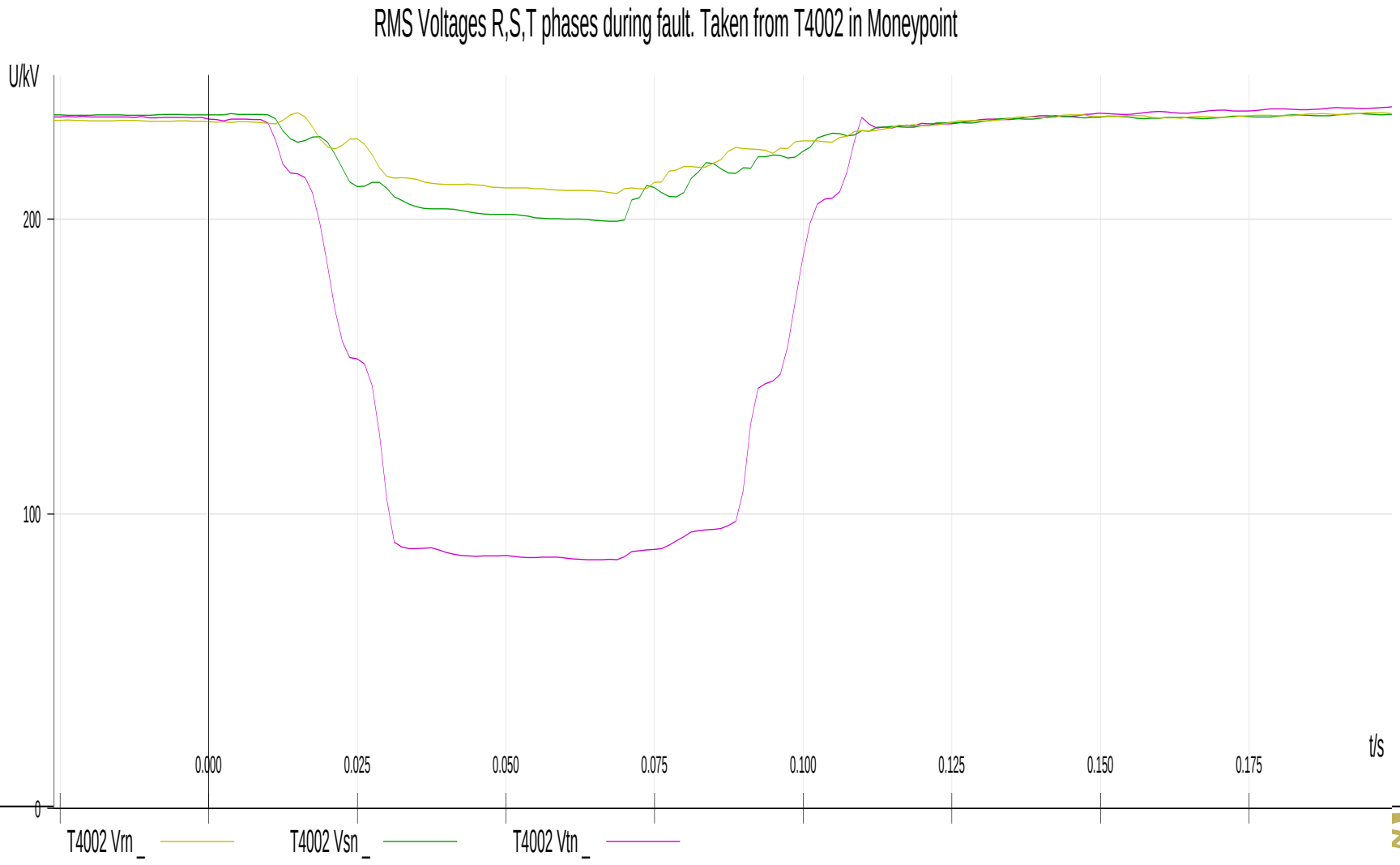
113 % overload on 116 MVA rated line

Voltage dips during the fault

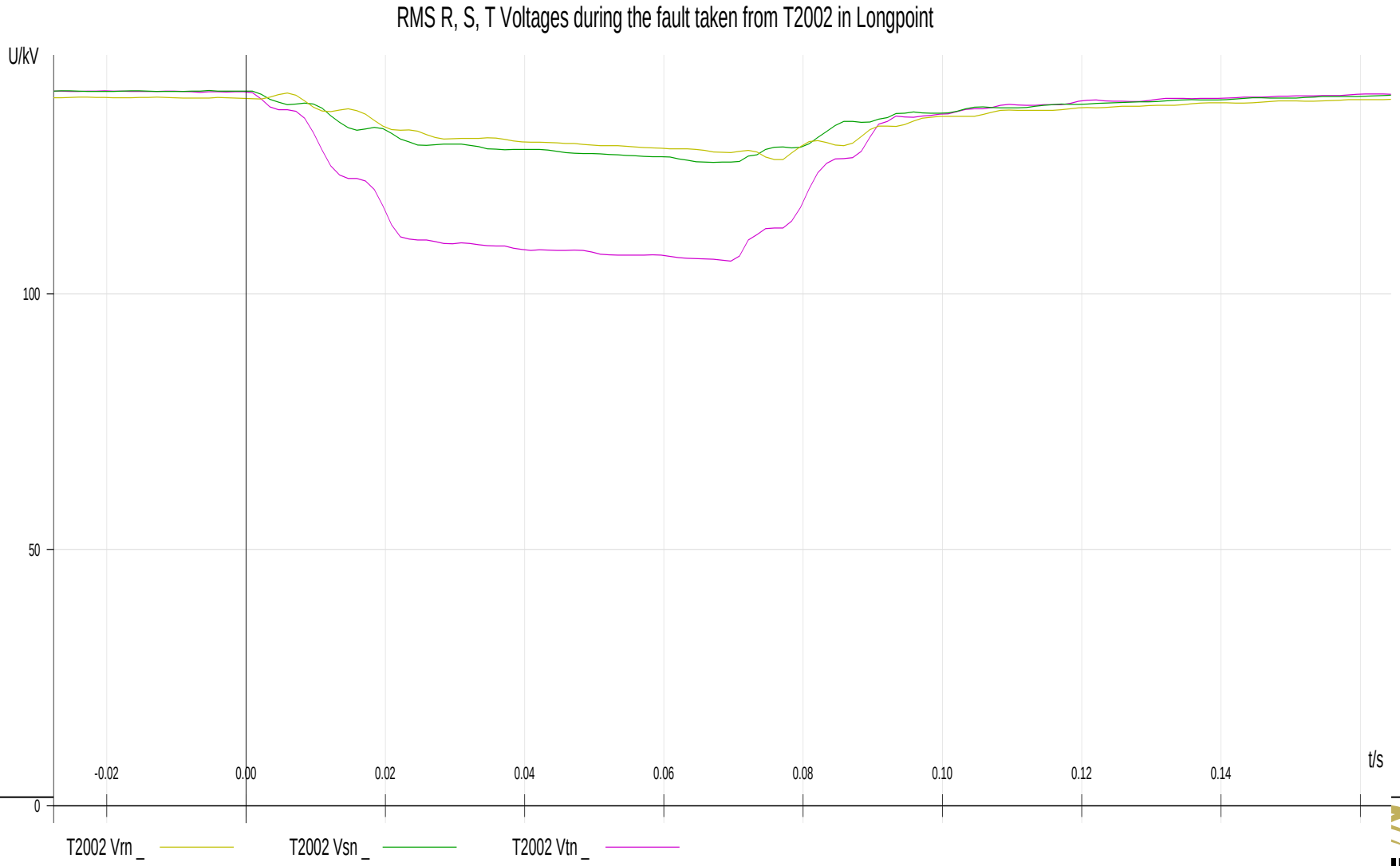
- At the Prospect Side
  - In Moneypoint the 400 kV T phase voltage dipped from 235kV - > 84 kV (35.7 % retained)
  - In Cashla the 220 kV T phase voltage dipped from 138 kV -> 115.7 kV (83.8 % retained)

- At the Tarbert Side
  - In Dromada the 110 kV T phase voltage dipped from 67.9 kV -> 27.4 kV (40.4 % retained)
  - In Clashavoon the 220 kV T phase voltage dipped from 138.9 kV -> 79.2 kV (57 % retained)
  - In Longpoint the 220 kV T phase voltage dipped from 140 kV -> 106 kV (76 % retained)

Voltage Dip in Moneypoint 400kV



Voltage Dip in Longpoint 220kV - Cork



‘System Stats’

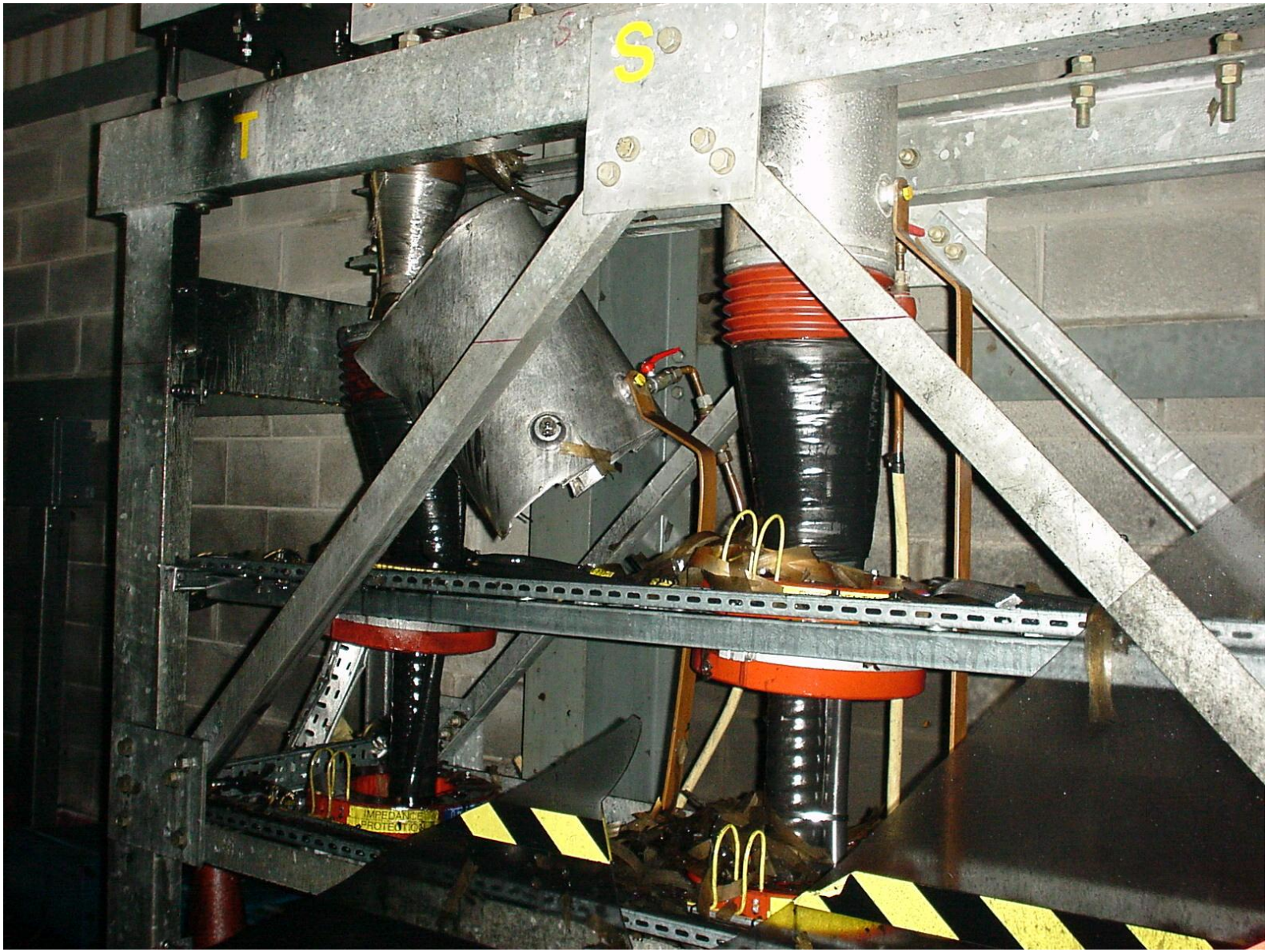
Voltage	No. Stn.	Circuit (km)
400kV	4	440
220kV	31	1830
110kV	159	3850

- 2 x 275kV 600MVA — Tie lines with Northern Ireland
- 2 x 110kV — Tie lines with Northern Ireland

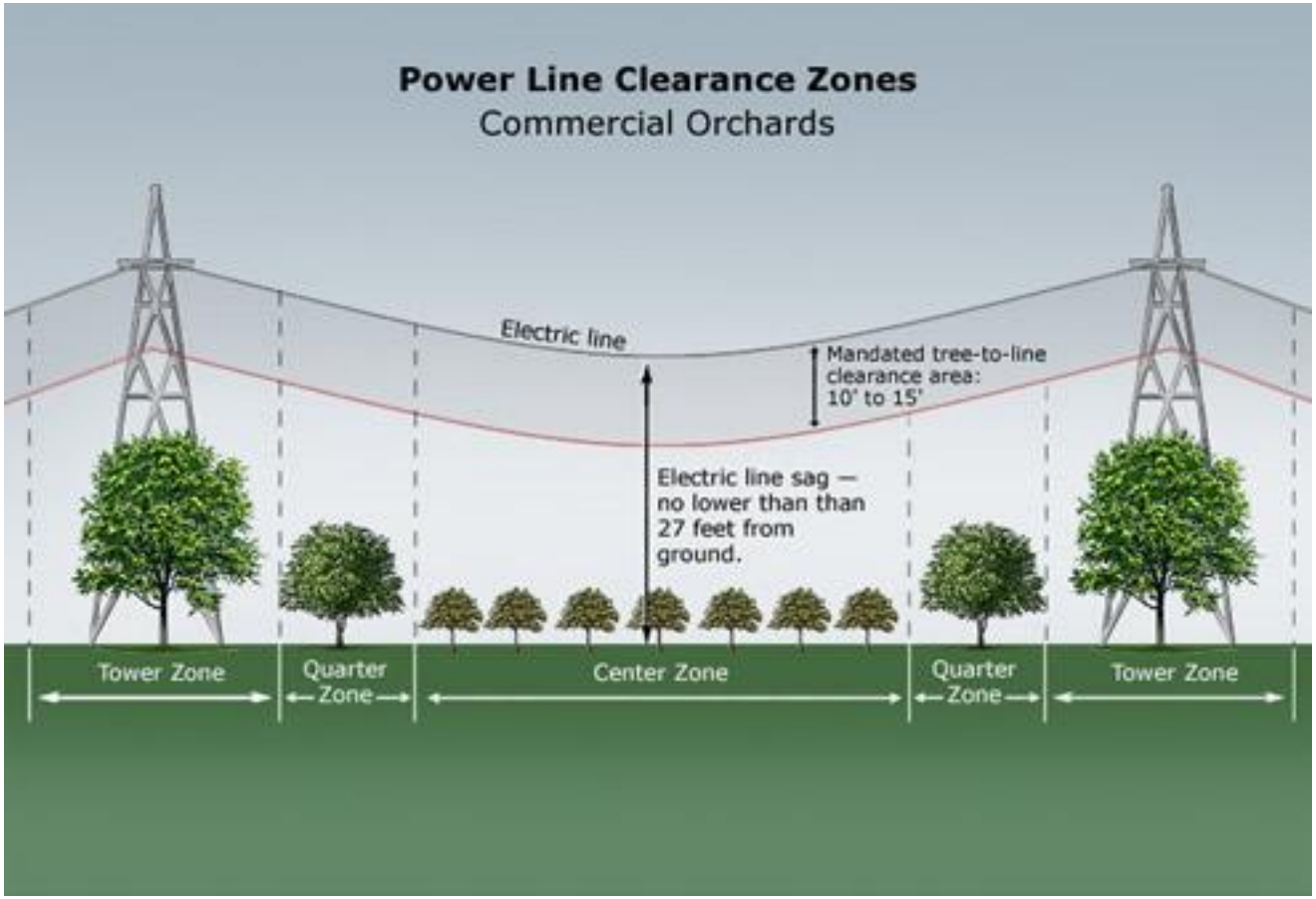
Installed capacity	6,500 MWs	(centrally dispatched)
Installed Wind	1,469 MWs	
Power Stations	21	

Evening Peak	5090 MW	Tues 21/12/2010
Max Wind	1284 MWs	Sat 12/02/2011
Wind as % system demand	50%	Mon 5/04/2010

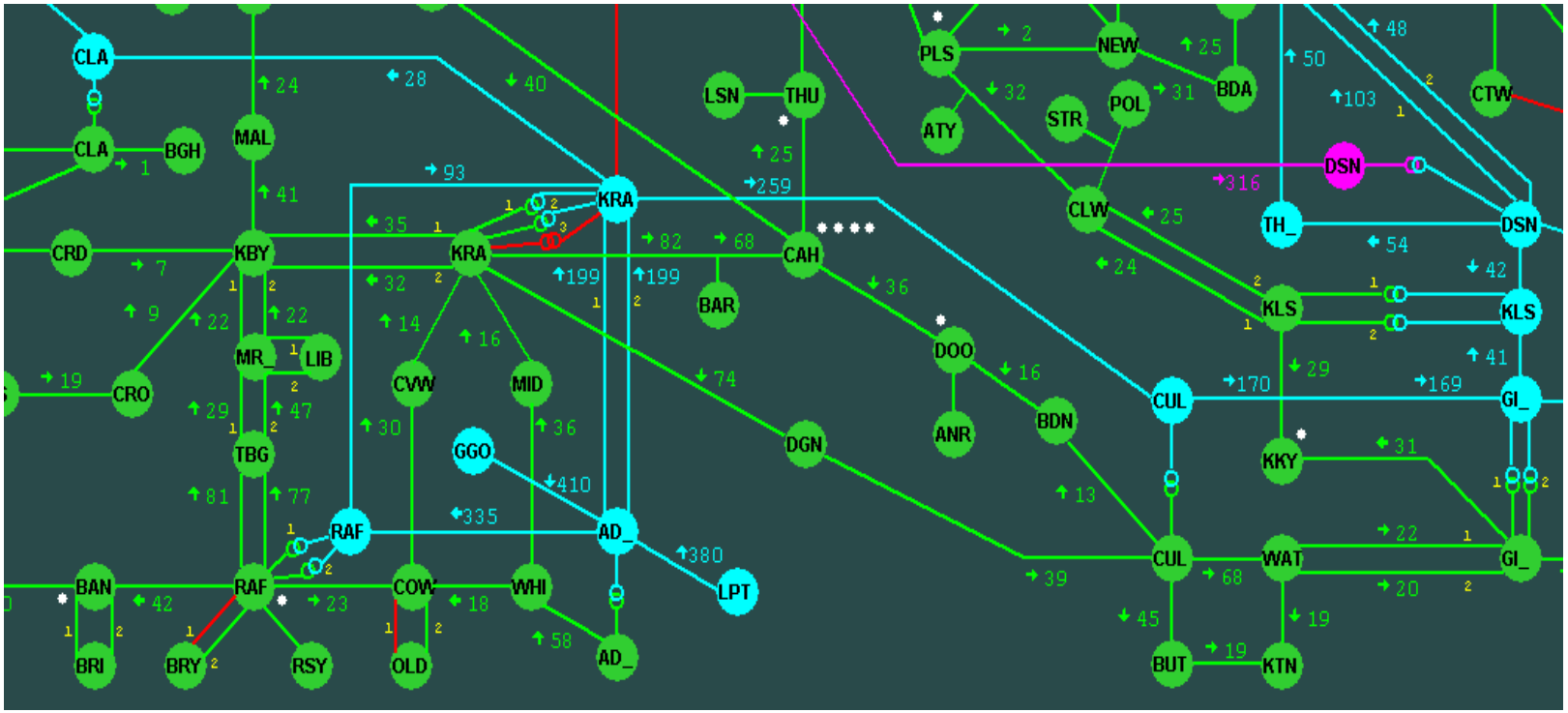
EIRGRID



EIRGRID


Power Line Clearance Zones
Commercial Orchards
Electric line
Mandated tree-to-line clearance area: 10' to 15'
Electric line sag — no lower than than 27 feet from ground.
Tower Zone
Quarter Zone
Center Zone
Quarter Zone
Tower Zone

Example Case



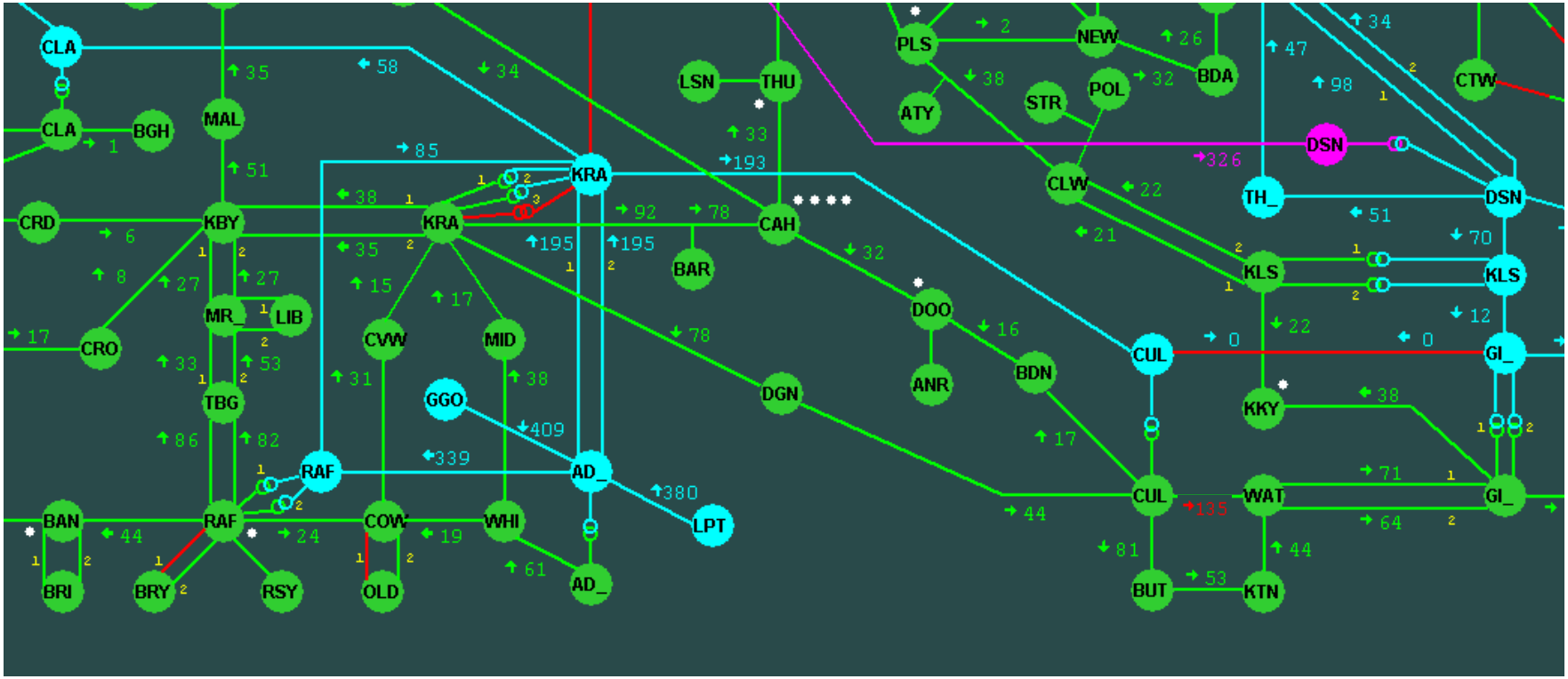
Load 3900 MW

Low wind – 33 MW

Cork Generation – 780 MW

Cullenagh – Waterford 110 kV line (rated 116 MVA)

East - West Contingency



Loss of Cullenagh – Great Island 220 kV line

-> overload on Cullenagh – Waterford 110 kV line

118 % overload on 116 MVA rated line

Power Flow - Why

- Equipment Rating
- Safety
- Secure after n-1

Protection Operations - Tarbert

- In Tarbert: The protection relay detected the fault and issued a 3 pole trip command to the 220 kV circuit breaker on the Prospect line
- The CB opened 69 ms after fault inception. This cleared the fault infeed from Tarbert
- Automatic restoration of the feeder is not in service at the Tarbert end