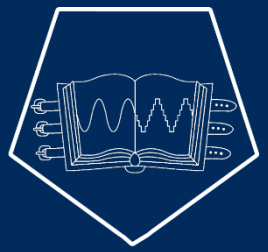


Future Power Networks & Smart Grids Centre for Doctoral Training

Medium Voltage DC

Freeing up latent grid capacity quickly and affordably

Lewis Hunter

SC B4 - HVDC and Power Electronics

(PS 2 / MVDC / LVDC and Power Electronics for Distribution Systems)

University of Strathclyde Glasgow

EPSRC

Engineering and Physical Sciences Research Council

Imperial College London

Contents

- Motivation
- Introduction to UK Distribution
- What is MVDC?
- Trial Network
- Future Work
- Conclusion

University of Strathclyde Glasgow

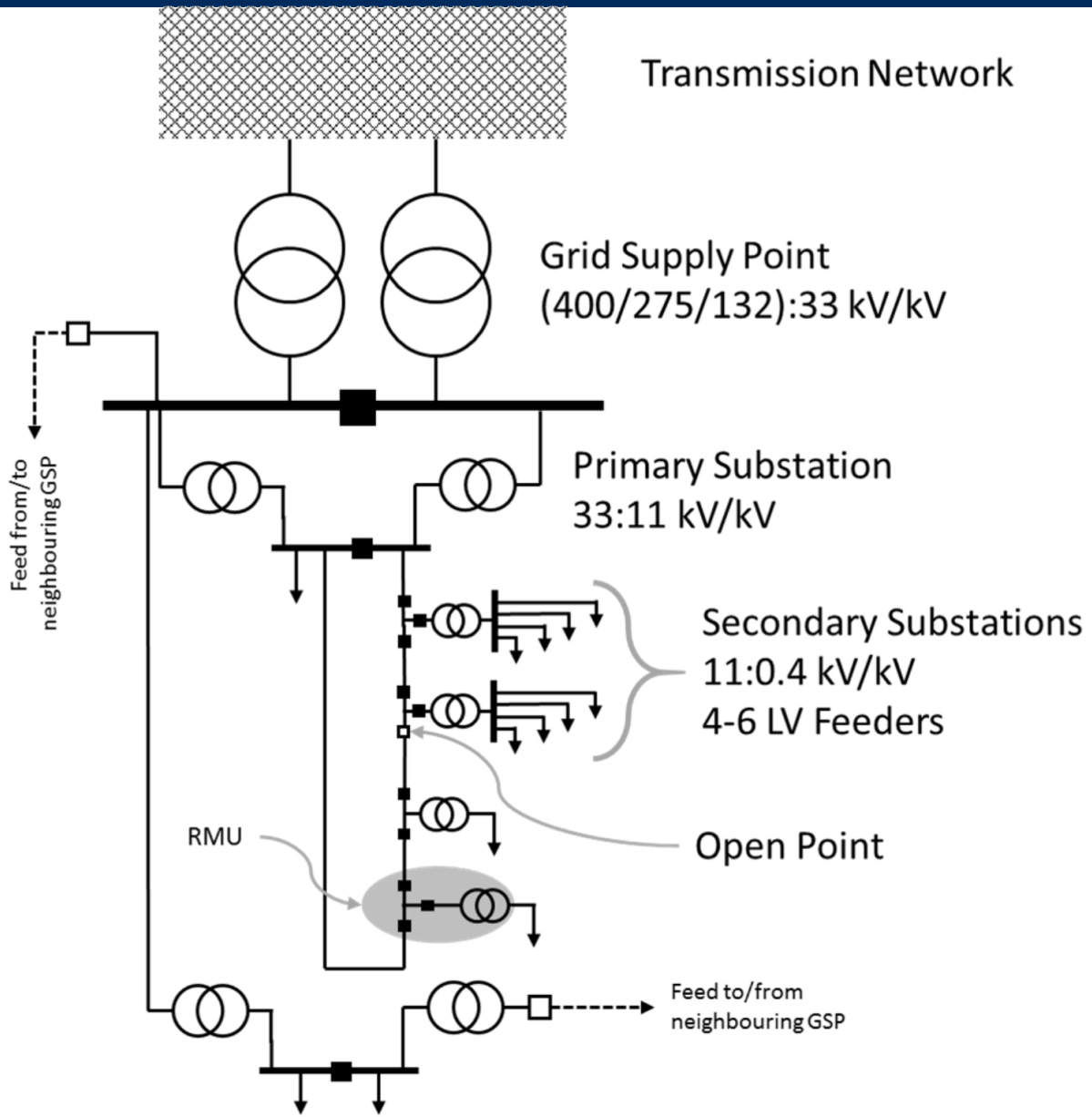
The Future ?!

Imperial College London

University of Strathclyde Glasgow

Network Support

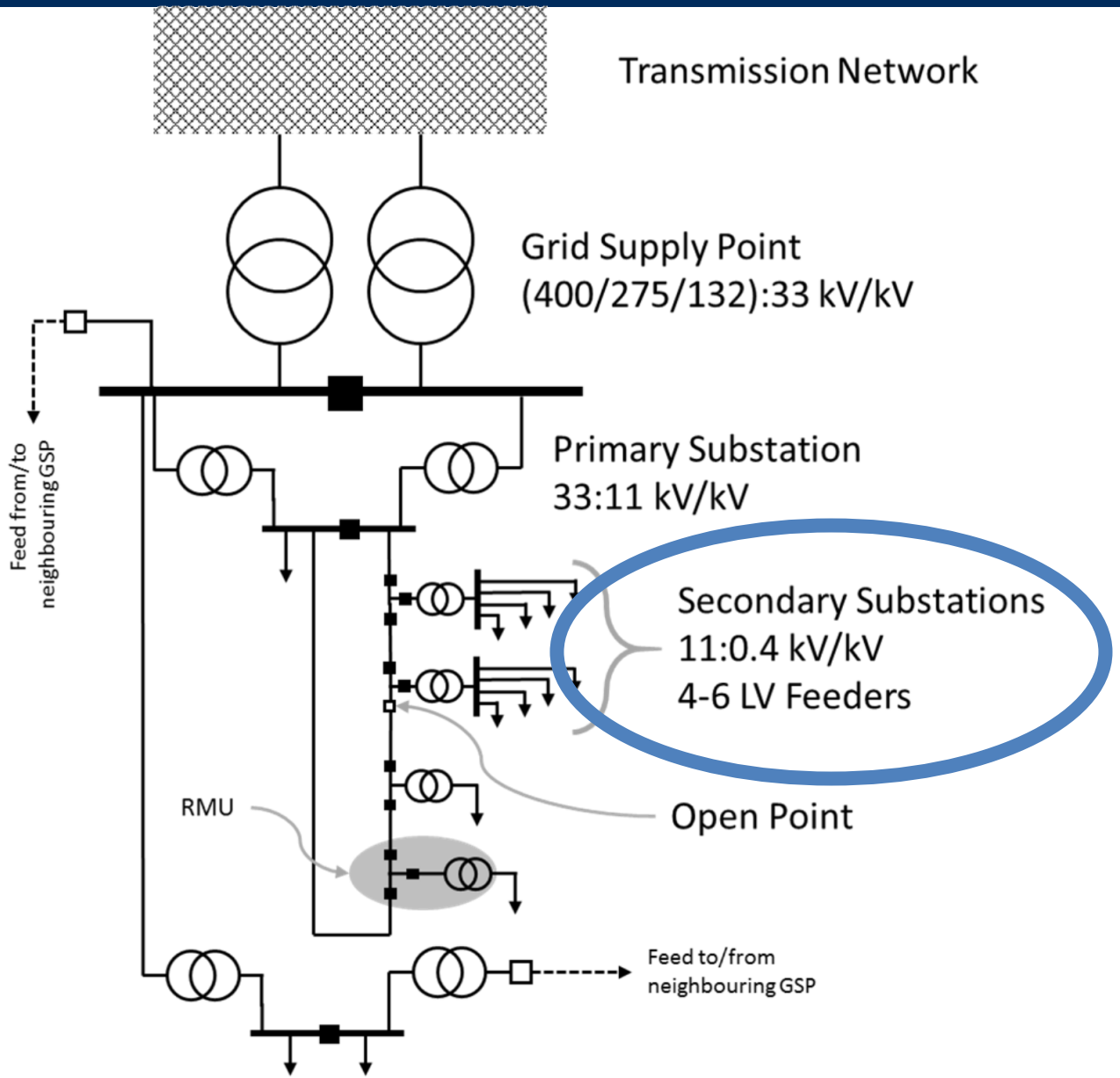
Imperial College London



University of Strathclyde Glasgow

Network Support

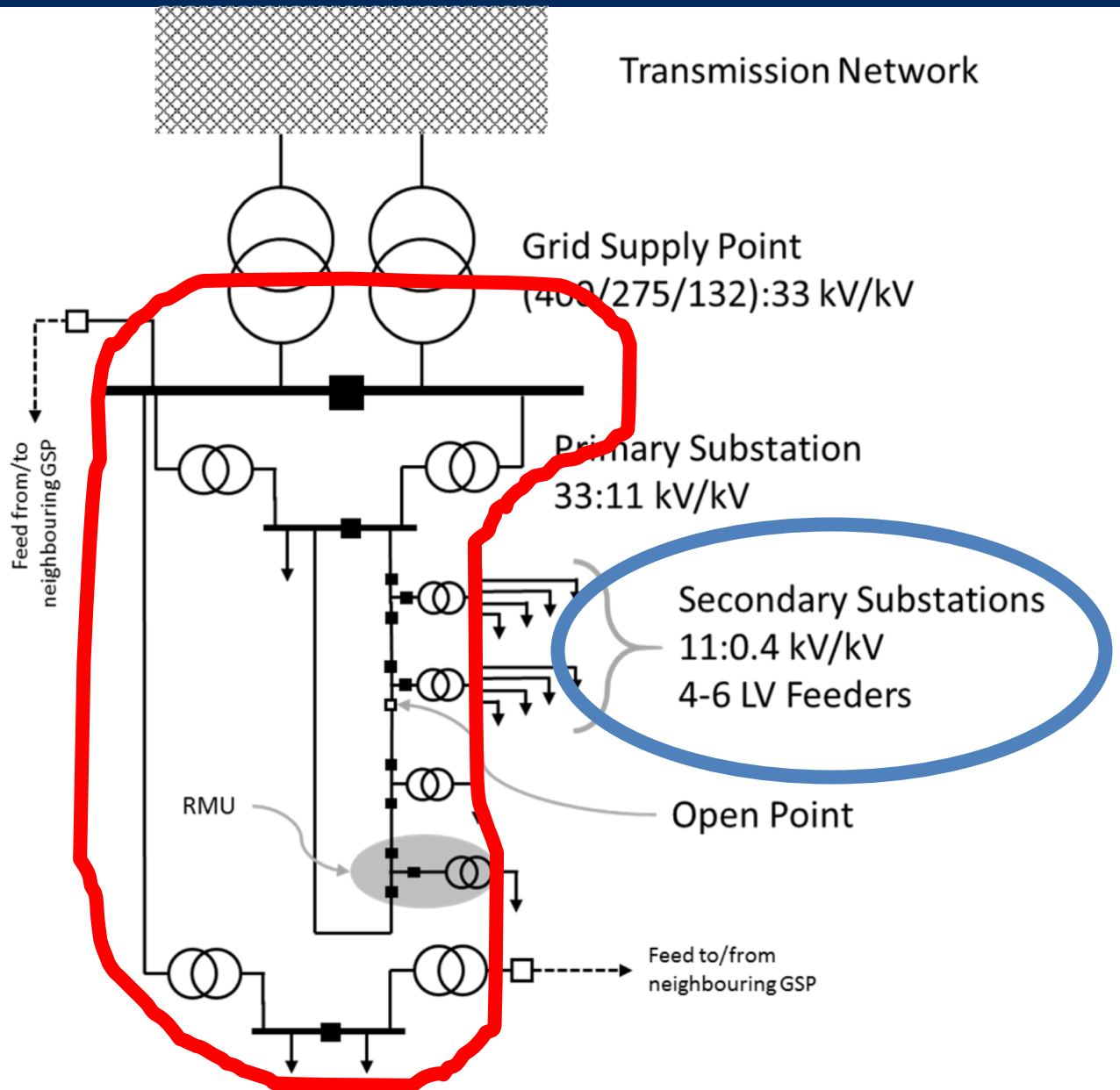
Imperial College London



University of Strathclyde Glasgow

Network Support

Imperial College London



How can we support increasing low carbon technology:

sustainably,

securely,

cost effectively?

University of Strathclyde Glasgow

MVDC?

Imperial College London

- Power ratings 10-100 MVA
  - Wind
  - Machine Applications
- Voltage range 5-50 kV
  - Beyond single power electronic device rating

MVDC?

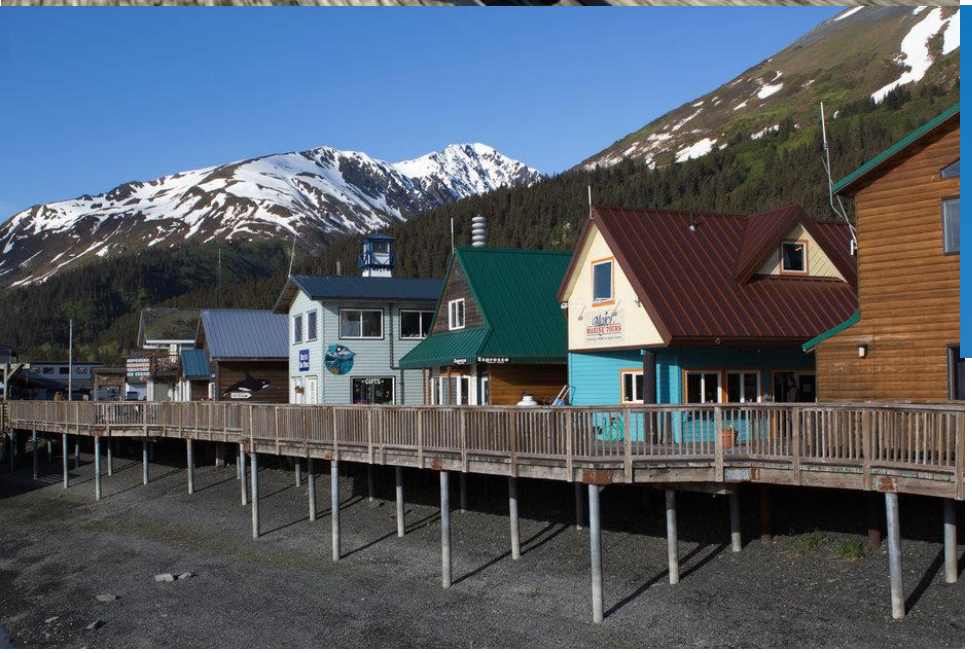
- Power ratings 10-100 MVA
  - Wind
  - Machine Applications
- Voltage range 5-50 kV
  - Beyond single power electronic device rating

Issue!

University of Strathclyde Glasgow

MVDC Activity

Imperial College London

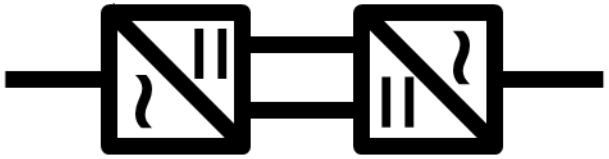


Scottish Enterprise

ANGLE-DC

cigré
INTERNATIONAL COUNCIL
ON LARGE ELECTRIC SYSTEMS

Network Converters



Soft Open Point

(Back to Back converter)

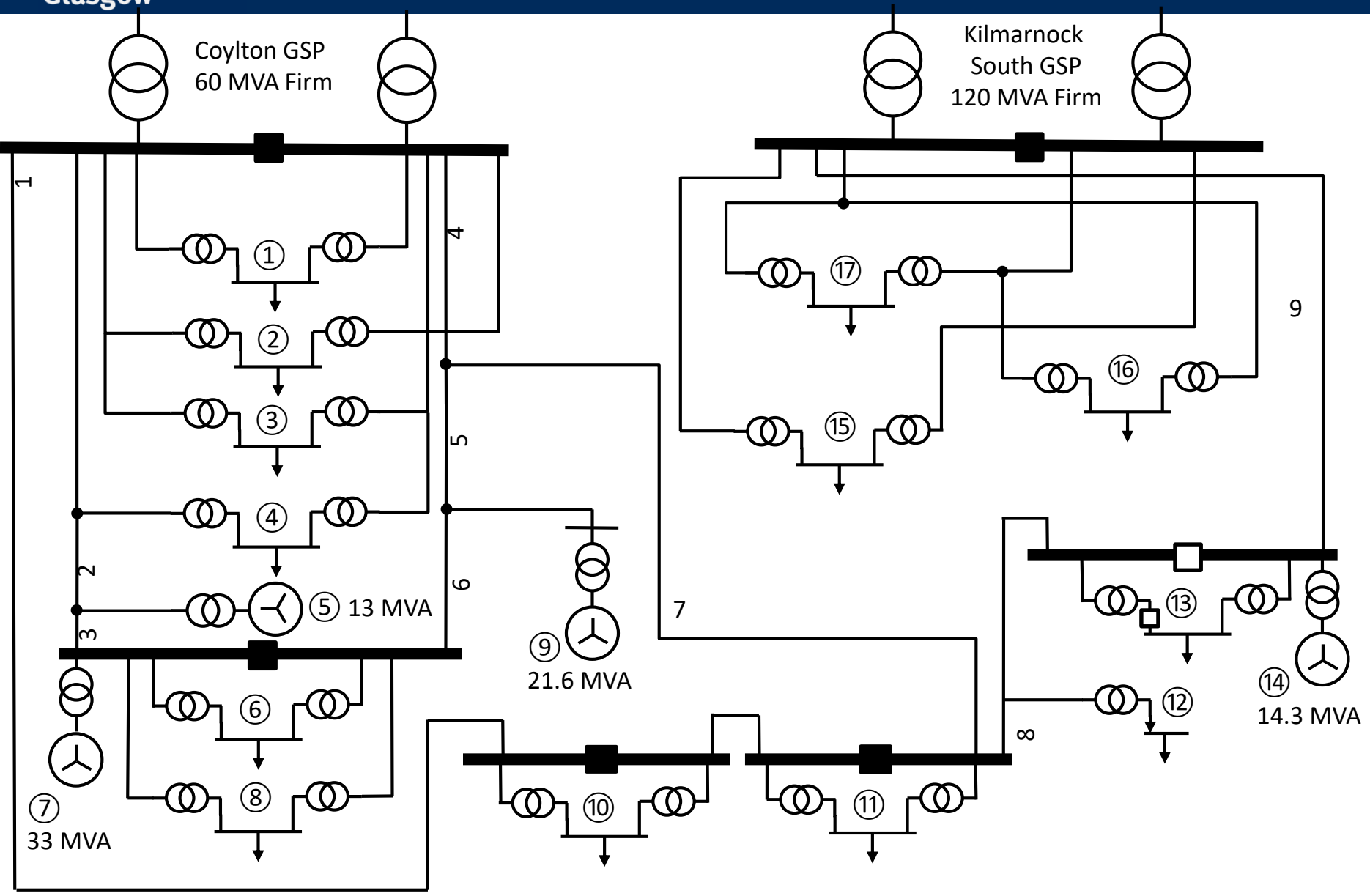
Interconnects adjacent feeders

DC Bus Voltage c. 750 → 1200 V

MVDC

DC Bus Voltage c. 5 → 50 kV (± 27 kV)

EMBEDDED MVDC LOAD FLOW STUDIES


Coylton GSP
60 MVA Firm
Kilmarnock
South GSP
120 MVA Firm
1
2
3
4
5
6
7
8
9
① ② ③ ④
⑤ 13 MVA
⑥ ⑧
⑦
33 MVA
⑨
21.6 MVA
⑩ ⑪
⑫ ⑬
⑭
14.3 MVA
⑮ ⑯ ⑰

University of Strathclyde Glasgow

Network Parameters

Imperial College London

ID	Name	Firm Capacity MVA	Pmax MVA	Pmin MVA
GSP1	Coylton	60	43.49	10.87
GSP2	Kilmarnock South	120	33.47	8.37
⑤*	Harehill WF	13		
⑦*	Harehill WF (ext)	33		
⑨*	Gallowrig WF	21.6		
⑭*	Bankend Rig WF	14.3		

Line	Rating (MVA)	Distance (km)
1	20.86	8.01
2	38.81	8.48
3	41.2	0.01
4	38.81	6.29
5	29.43	13.68
6	20.86	0.025
7	20.86	6.25
8	24.63	12.56
9	20.86	0.21

Line ratings: 20 → 40 MVA

Line lengths: 6 → 14 km

Primary Substations: 2 → 24 MVA

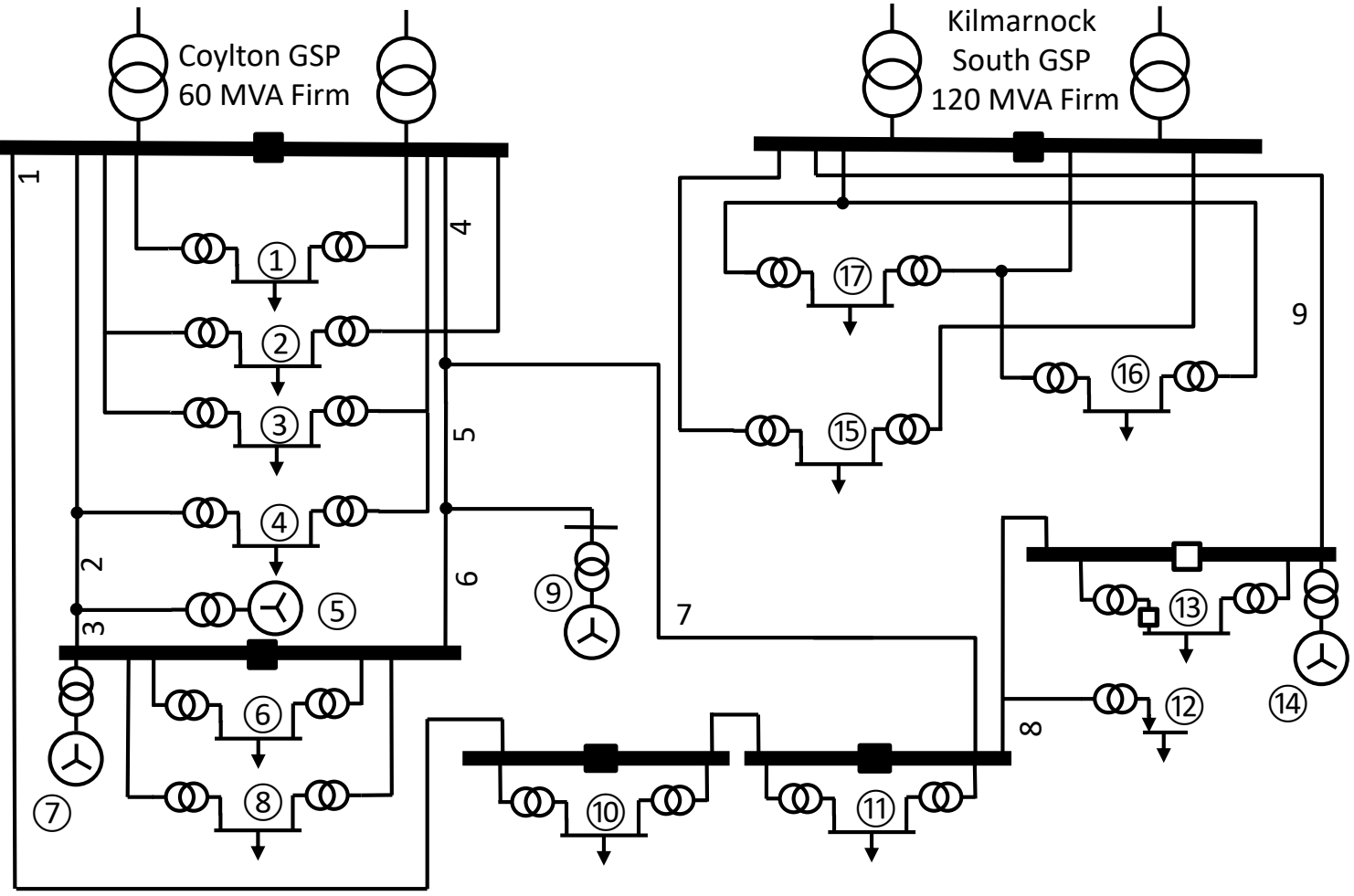
DG (wind): 13 → 33 MVA

Voltage maintained to 1 ± 0.03 pu

University of Strathclyde Glasgow

Base Study

Imperial College London



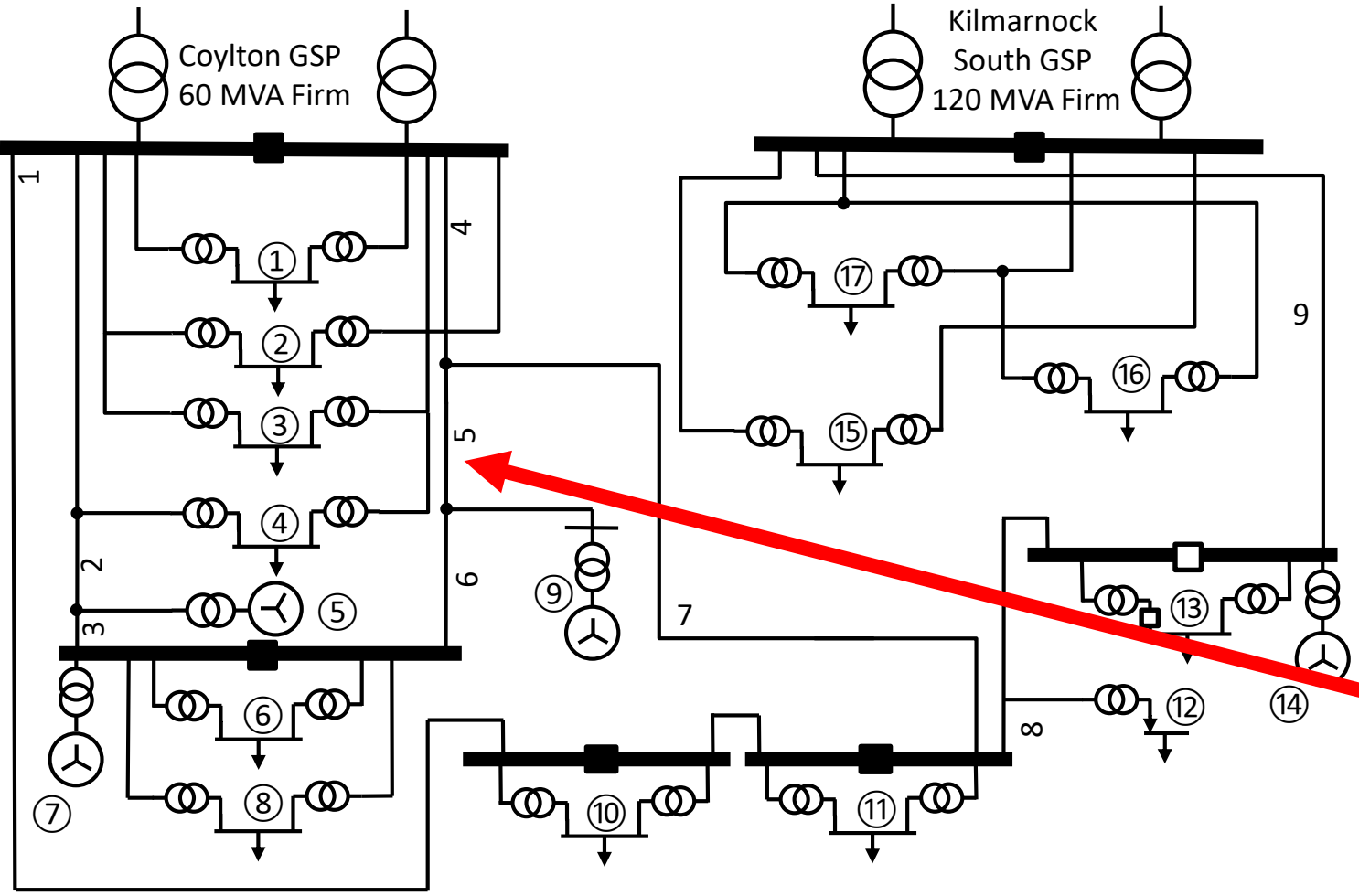
Line	Loading (%)	
	Base Network	
	Max Demand	Min Demand
1	42.2	37.2
2	60.3	60.3
3	25.7	26.6
4	70.4	82.9
5	131.9	142.7
6	75.8	91.8
7	59.2	47.4
8	8	1.9
9	40.4	59.3

* Max DG Power Injections

University of Strathclyde Glasgow

Base Study

Imperial College London



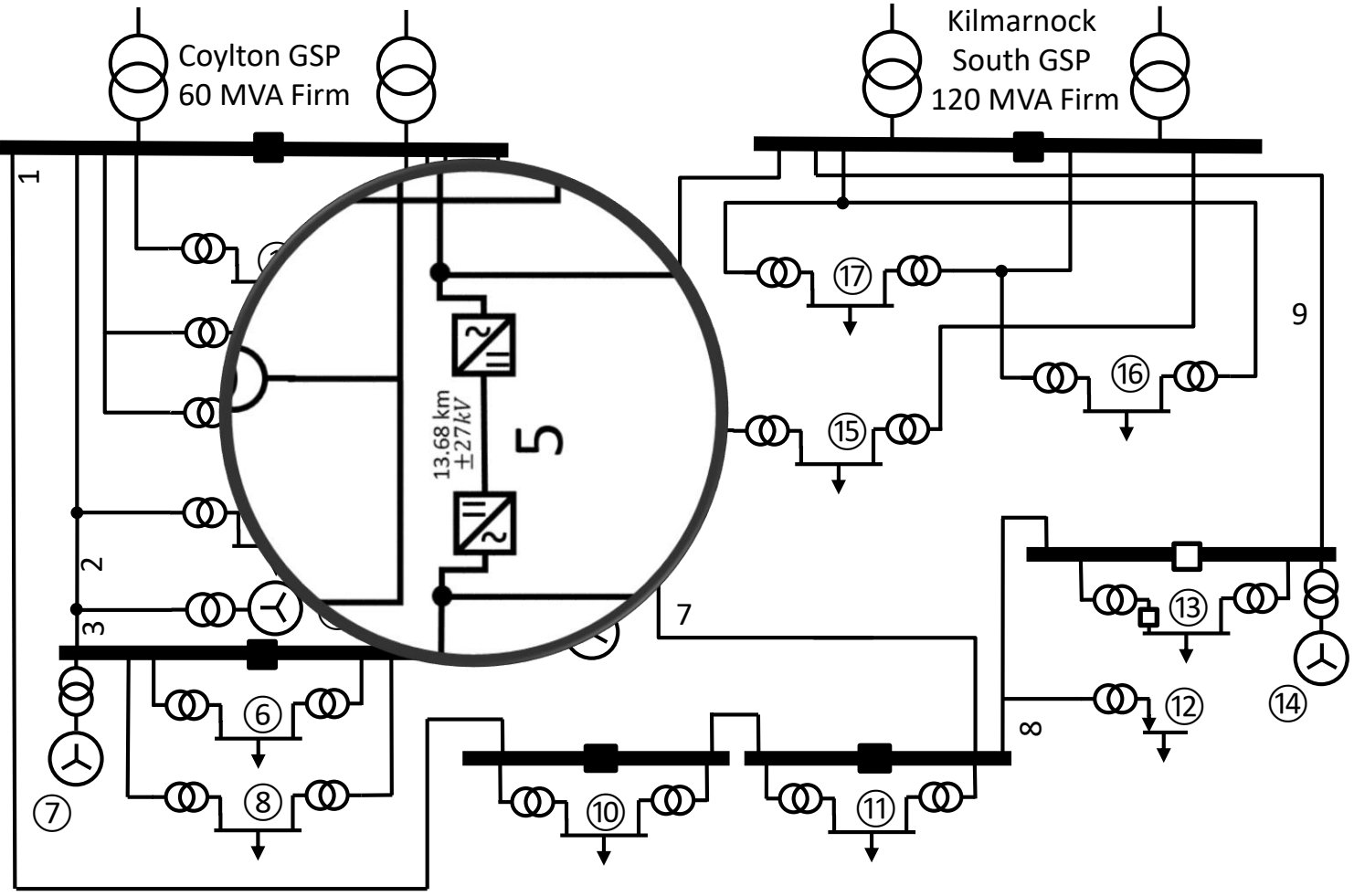
Line	Loading (%)	
	Base Network	
	Max Demand	Min Demand
1	42.2	37.2
2	60.3	60.3
3	25.7	26.6
4	70.4	82.9
5	131.9	142.7
6	75.8	91.8
7	59.2	47.4
8	8	1.9
9	40.4	59.3

* Max DG Power Injections

University of Strathclyde Glasgow

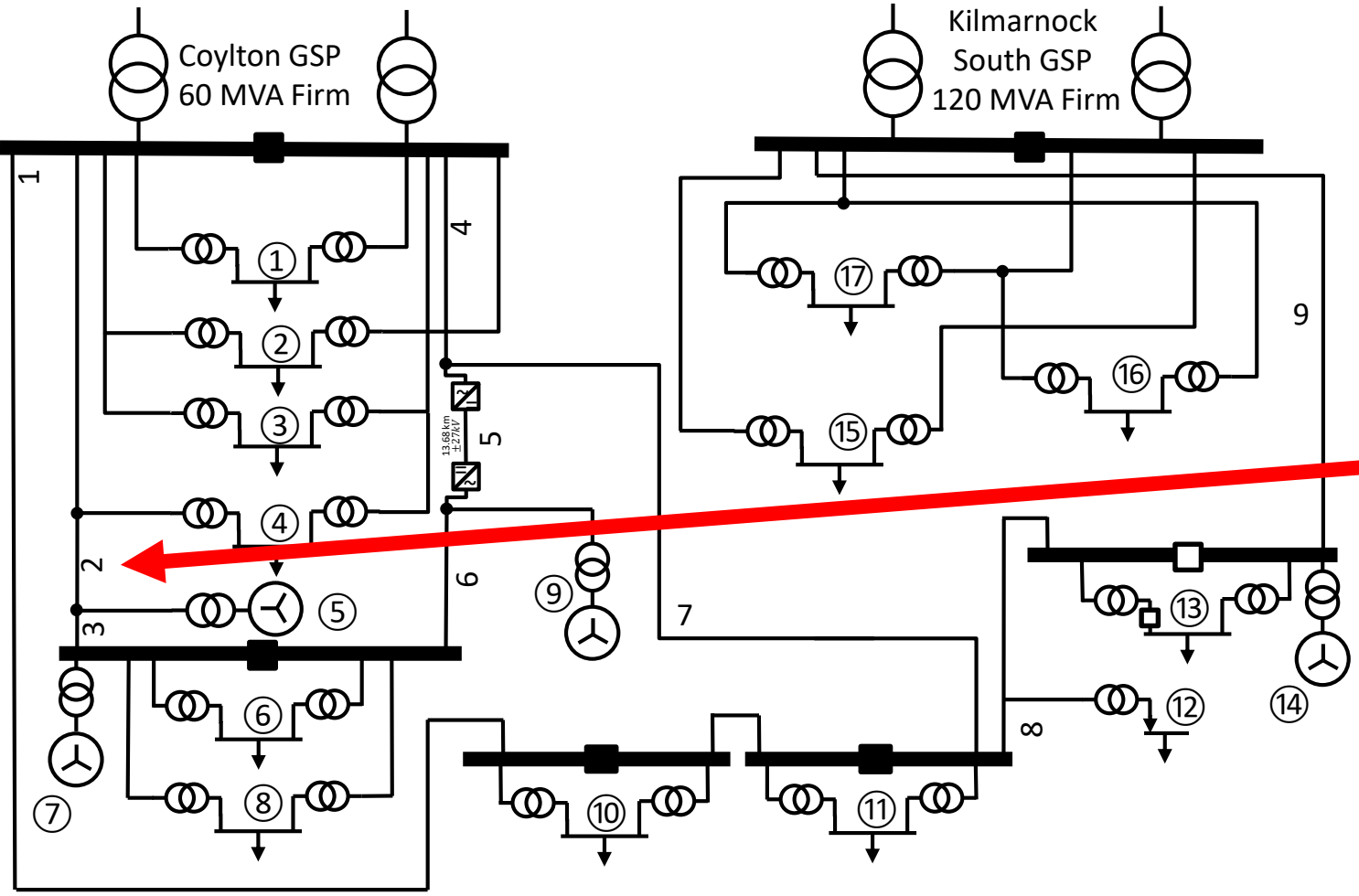
MVDC Embedded Link

Imperial College London



Line	Loading (%)	
	MVDC Line 5	
	Max Demand	Min Demand
1	24.1	20.3
2	91.6	139.3
3	53.3	98.2
4	34.8	55
5	84.3	99
6	22.6	42.2
7	54.9	36.3
8	8.2	1.9
9	40.4	59.3

MVDC Embedded Link

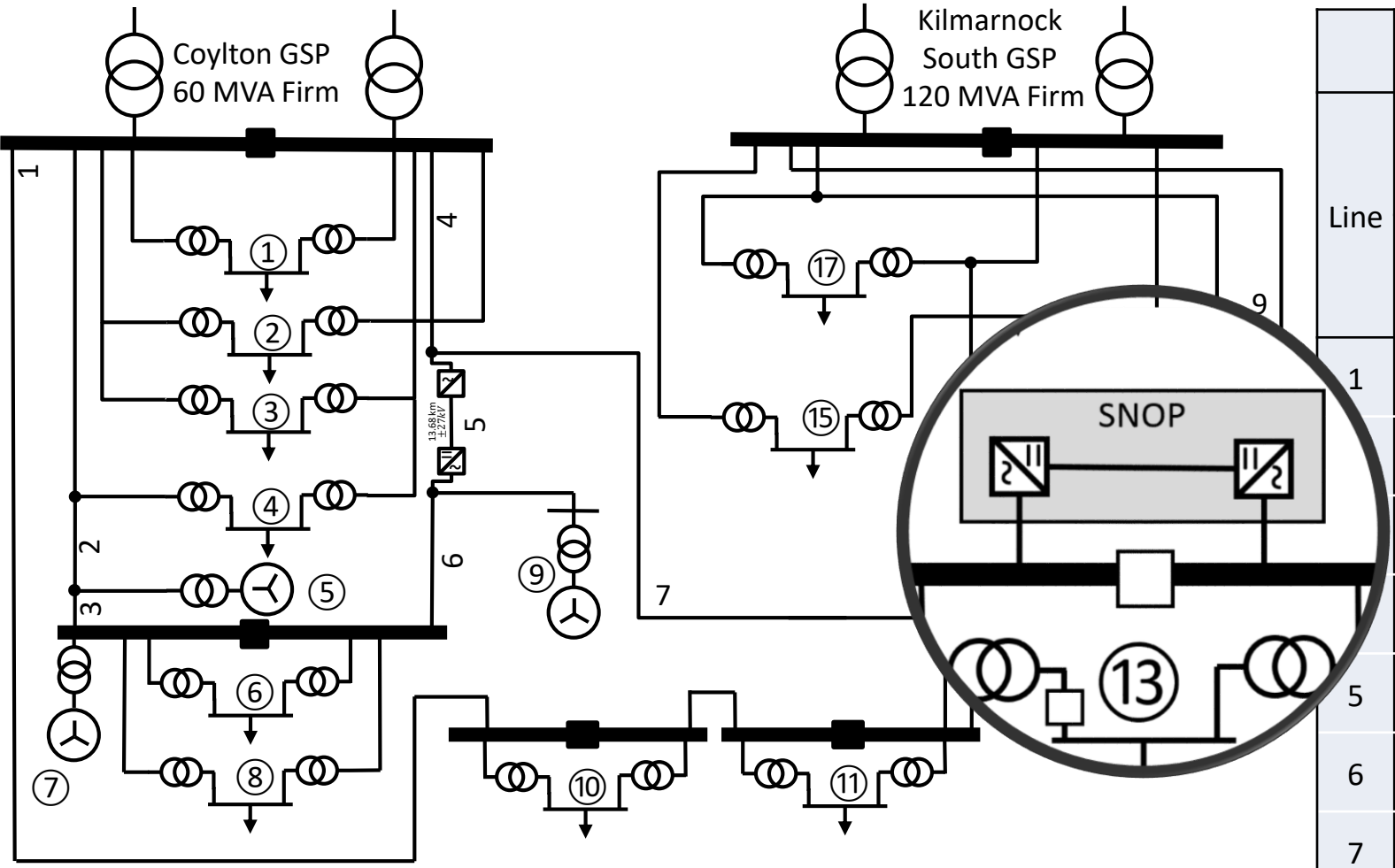


Line	Loading (%)	
	MVDC Line 5	
	Max Demand	Min Demand
1	24.1	20.3
2	91.6	139.3
3	53.3	98.2
4	34.8	55
5	84.3	99
6	22.6	42.2
7	54.9	36.3
8	8.2	1.9
9	40.4	59.3

B2B Converter (SNOP) Addition

University of Strathclyde Glasgow

Imperial College London

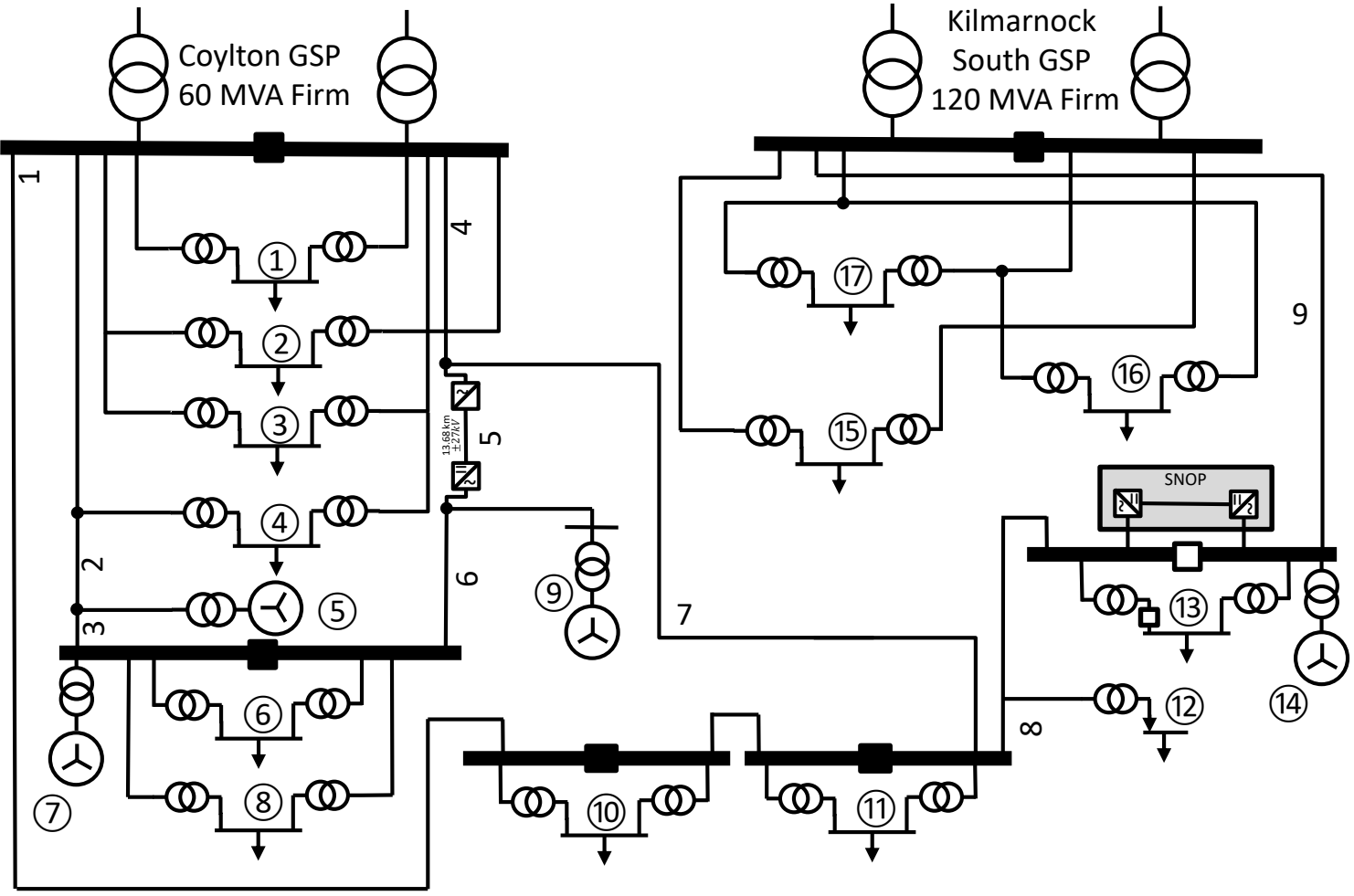


Line	Loading (%)	
	SNOP & MVDC L5	
	Max Demand	Min Demand
1	37.5	21.5
	91.6	92.4
	53.3	54.4
	17.3	29
5	84.3	84.3
6	22.6	22.4
7	89.7	66.4
8	64.4	44.2
9	88	97.7

B2B Converter (SNOP) Addition

University of Strathclyde Glasgow

Imperial College London

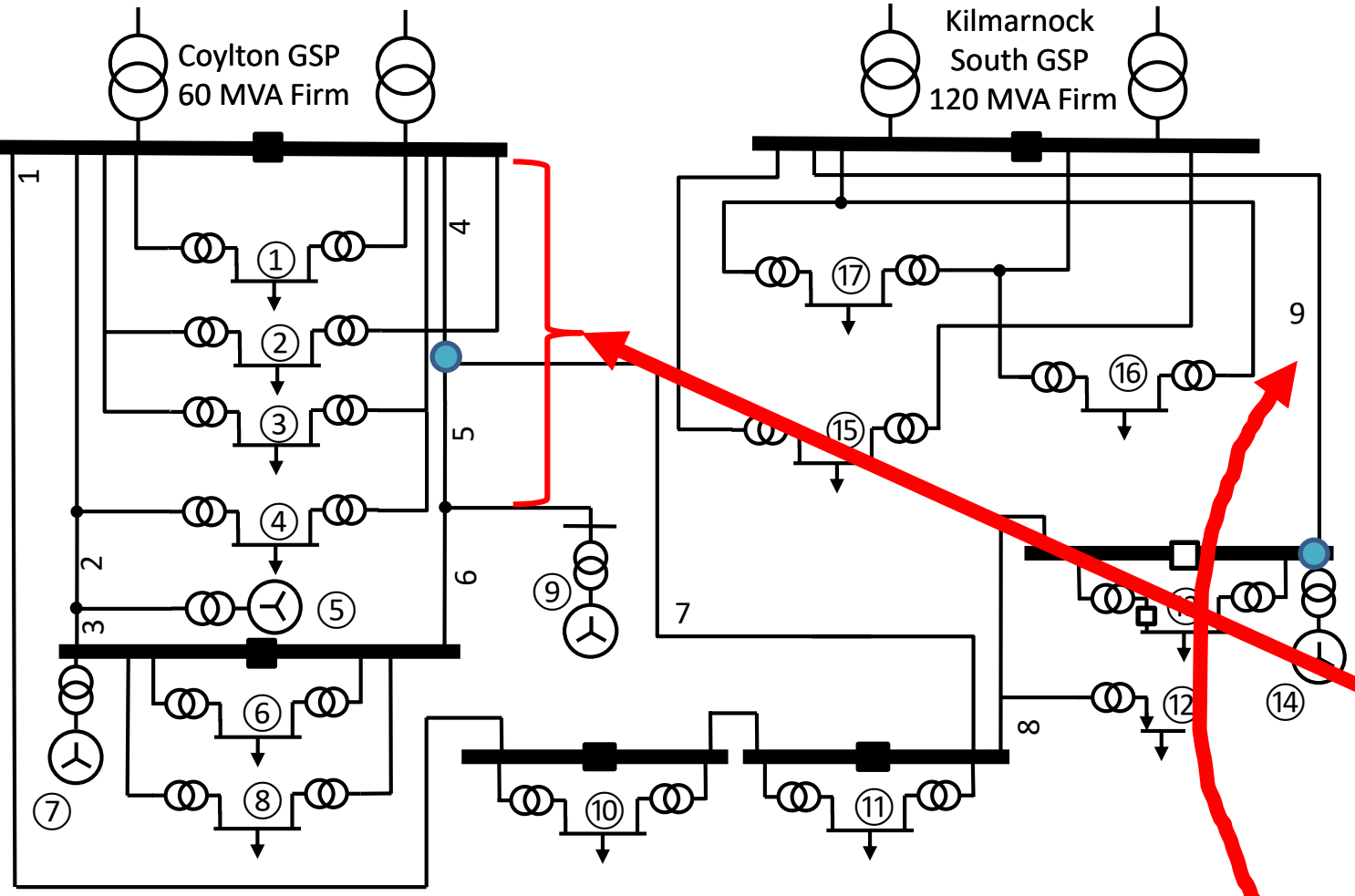


Line	Loading (%)	
	SNOP & MVDC L5	
	Max Demand	Min Demand
1	37.5	21.5
2	91.6	92.4
3	53.3	54.4
4	17.3	29
5	84.3	84.3
6	22.6	22.4
7	89.7	66.4
8	64.4	44.2
9	88	97.7

University of Strathclyde Glasgow

Increased DG

Imperial College London



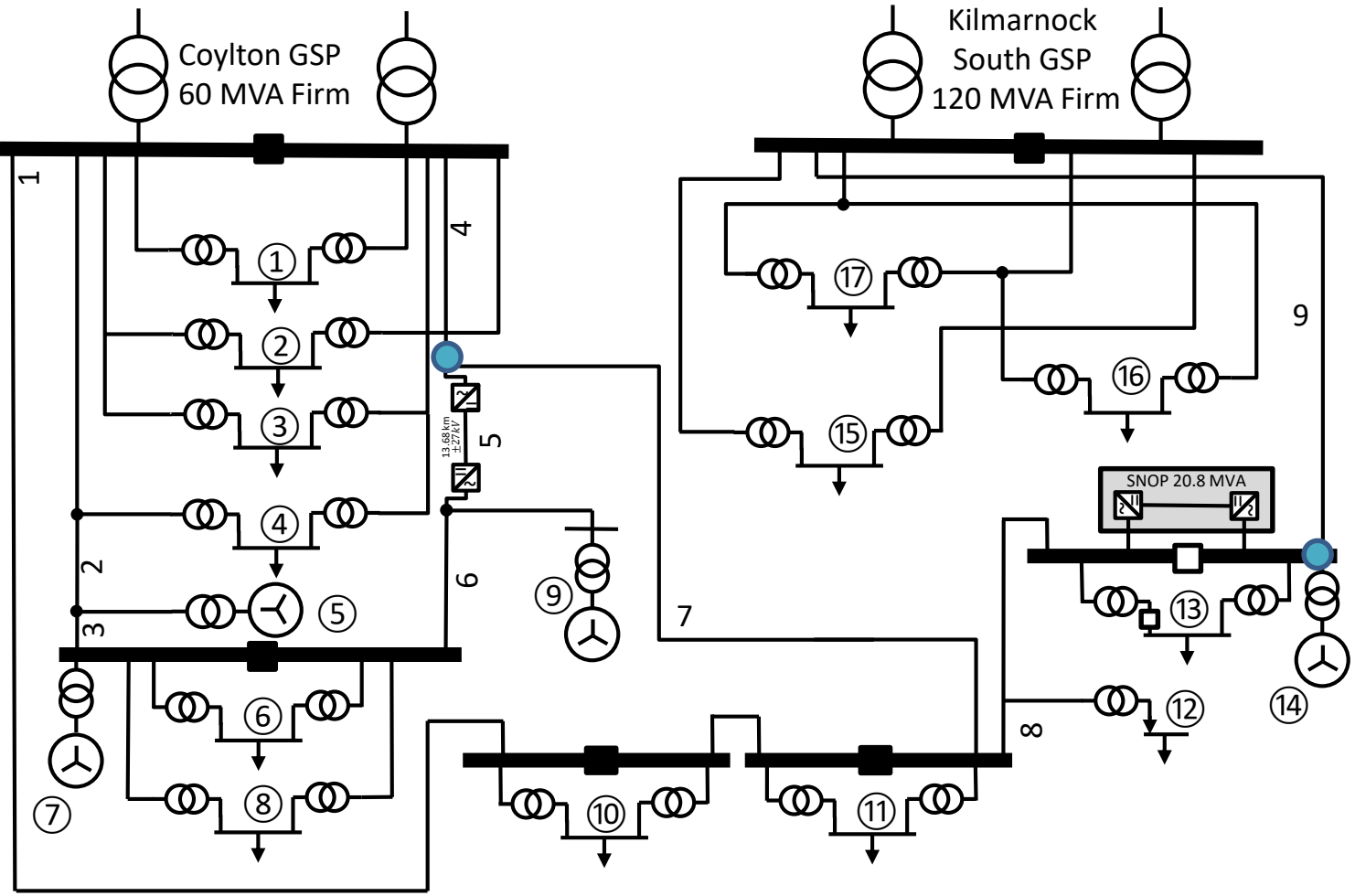
Line	Loading (%)	
	Increased RE (min load)	
	No DC (as is)	DC +
1	53.7	
2	64.6	
3	30.3	
4	118.3	
5	137.5	
6	83	
7	65.9	
8	1.9	
9	124.2	

GSP	FirmCap	Connected (MW)	Increase (MW)
Coylton	60	72.35	+ 19.25
Kilmarnock	120	16.10	+ 14.3

University of Strathclyde Glasgow

Increased DG

Imperial College London



GSP	FirmCap	Connected (MW)	Increase (MW)
Coylton	60	72.35	+ 19.25
Kilmarnock	120	16.10	+ 14.3

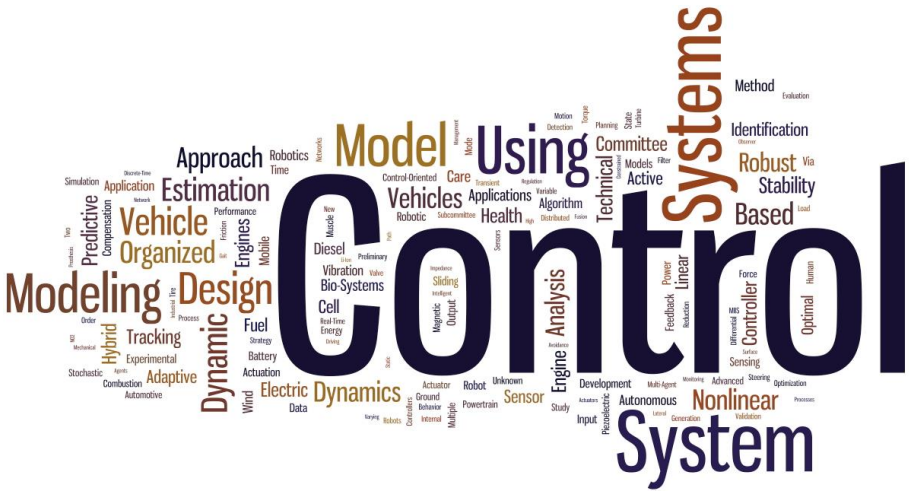
Line	Loading (%)	
	Increased RE (min load)	
	No DC (as is)	DC +
1	53.7	44.6
2	64.6	92.4
3	30.3	54.4
4	118.3	95.6
5	137.5	84.3
6	83	22.4
7	65.9	32.6
8	1.9	41.1
9	124.2	81.4

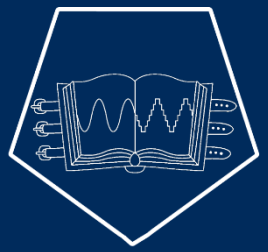
Future Work & Opportunities

- Protection
  - Weak grid fault studies & minimum protection requirements
  - Line repurposing considerations
- Control
  - DC links (operation mode? changing mode?)
  - How do we set link transfers with limited network information. Setting multiple links?
- Stability
  - Oscillation (DC links and/or embedded PE)
  - Recirculation of power?

Conclusion

- Drivers, barriers, TRL for MVDC identified
- Case study
  - Small amounts of control have big capacity release
  - Increasing line capacity isn't always the answer
- Future work areas and opportunities for further research





Future Power Networks & Smart Grids Centre for Doctoral Training

Questions?

Lewis Hunter
University of Strathclyde, Glasgow, Scotland
lewis.hunter.100@strath.ac.uk

EPSRC
Pioneering research and skills

Imperial College London