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Future Power
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MVDC for Utility Scale Power Distribution and Control

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Motivation

Electrification of heat and transport along with significant increases in distributed energy resources pose challenges for distribution network operators (DNOs) as they evolve into distribution system operators (DSOs). Issues may include capacity constraints, voltage excursions, lower supply security and reduced power quality. A method of addressing these matters whilst unlocking capacity is therefore required.

Medium Voltage DC (MVDC)?

MVDC networks (operating in the range of 5-50 kV) represent a candidate technology to release capacity of existing assets without increasing system fault level.

Fig 1. Example of a 4 kV MV machine drive of 7 MW.

MVDC faces similar challenges to HVDC in the sense that semiconductor devices must withstand voltages that are not readily handled by single devices. However, a simple down scaling of HVDC is unlikely to yield the optimal solution as priorities for cost, volume, reliably and functionality are different.

MVDC converters for grid applications reside between MV machine drives (used within wind turbines, traction, mining etc. generally between 2-14 kV rating) and HVDC operating at hundreds of kV. Although the power ratings of MV machine drives (typically 1-80 MVA) are similar to that which an MVDC network solution will take, the voltage capability of such converters needs to be increased to reduce resistive losses.

Increasing power densities of power electronics and their reducing cost through market volume makes the prospect of reinforcing the conventional ac grid with dc elements more appealing.

Power Flow Studies

This poster considers the case for the selective interconnection of grid supply points (GSP) and primary substations via fully controllable power electronic links. An existing 33 kV distribution network (Fig. 2.) is used. Power flows for a conventional network will be benchmarked before assessing the potential capacity release created by delivering energy from multiple substations via controllable interconnection. Substation loading is presented in Table 1.

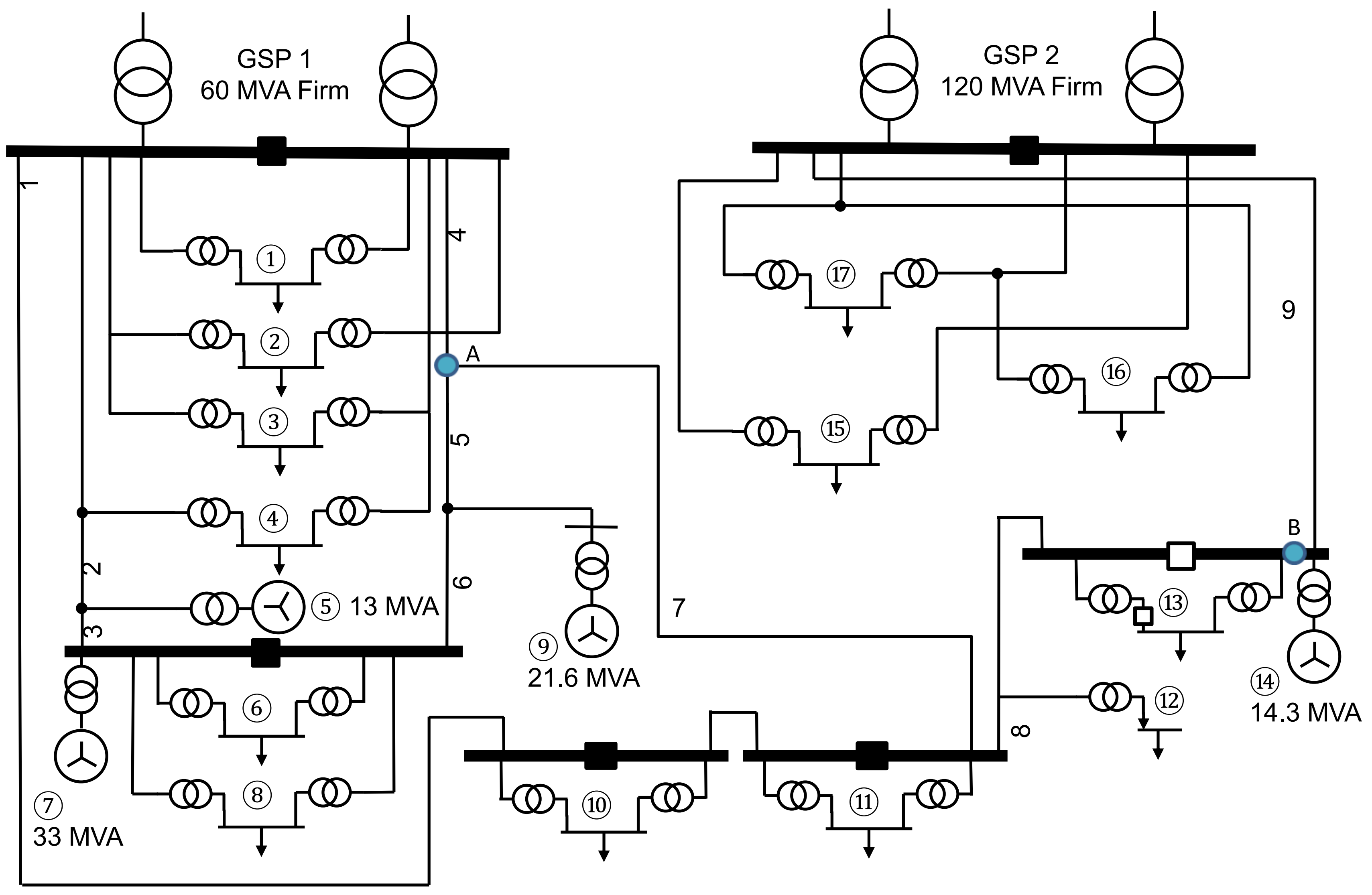

Fig 2. 'Real world' 33 kV network with significant levels of embedded generation.

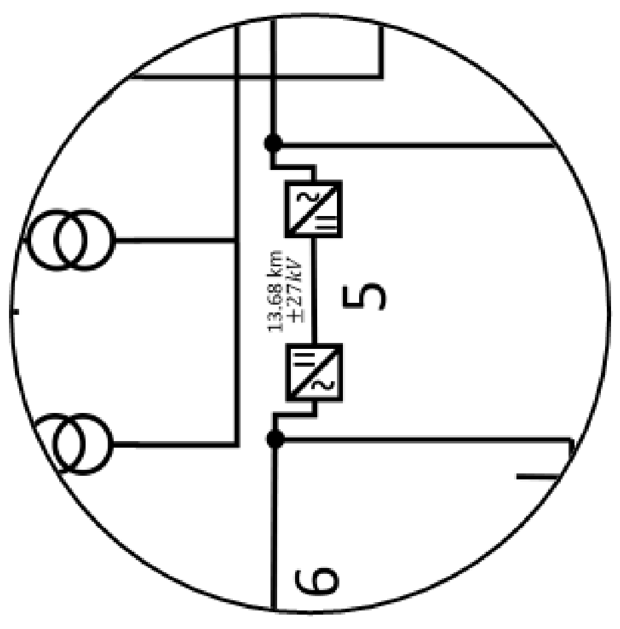

Fig. 3. Embedded MVDC network link operating at ± 27 kV (repurposing of Line 5).

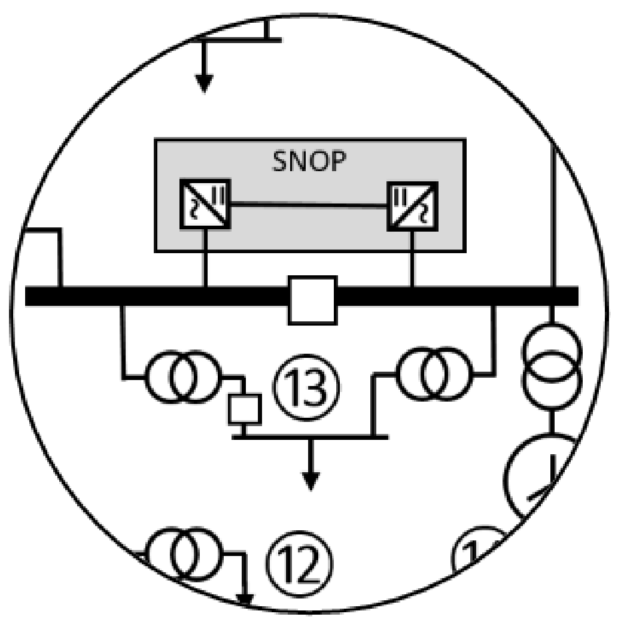

Fig. 4. Soft Normally Open Point (SNOP) connected across bus-coupler.

Table 1. Substation and GSP maximum and minimum loadings. [* Indicates generation node]

ID	*Firm Capacity (MVA)*	*S Max (MVA)*	*S Min (MVA)*	*PF*
GSP1	60	43.49	10.87	
GSP2	120	33.47	8.37	
①	10	4.08	1.02	1
②	2	12.6	3.15	0.7
③	5	2.32	0.88	1
④	24	9.55	2.39	0.9
⑤*	13			
⑥	5	2.78	2.39	0.8
⑦*	33			
⑧	10	4.74	1.19	1
⑨*	21.6			
⑩	10	6.7	1.67	1
⑪	10	5.7	1.44	1
⑫	10	1.9	0.47	1
⑬	24	5.86	1.46	1
⑭*	14.3			
⑮	40	4.54	1.14	1
⑯	21	13.35	3.34	1
⑰	24	15.14	3.79	1

Results

Table 2 shows line loading results. Red highlights line overloads. Yellow highlights lines loaded to >90% of thermal rating.

For maximum demand, the MVDC link removes the immediate thermal overload but creates a new one elsewhere for minimum demand.

A SNOP solves this problem even with a 34 MVA increase in generation.

Line capacities were not altered when repurposing ac conductors to dc.

Table 2. Results from simulations under various loading scenarios and dc deployments
'DC+' = SNOP & MVDC line 5
'Base' = Network 'as is'
'Gen ↑' = Increase in DG of 19 MVA @ A and 15 MVA @ B

			Loading (%)							
		Scenario	Base		DC Line 5		DC+		↑ Gen Base	↑ Gen DC+
		Demand	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Min*	*Min*
Line ID	**Rating (MVA)**	**Length (km)**								
1	20.86	8.01	42	37	24	20	38	22	54	45
2	38.81	8.48	60	60	92	139	92	92	65	92
3	41.2	0.01	26	27	53	98	53	54	30	54
4	38.81	6.29	70	83	35	55	17	29	118	96
5	29.43	13.68	132	143	84	99	84	84	138	84
6	20.86	0.025	76	92	23	42	23	22	83	22
7	20.86	6.25	59	47	55	36	90	66	66	33
8	24.63	12.56	8	2	8	2	64	44	2	41
9	20.86	0.21	40	59	40	59	88	98	124	81

Conclusion & Future Work

Power flow analysis has highlighted that assets are stressed in places yet underutilised elsewhere, suggesting that rebalancing and rerouting or power is required.

It has been shown that dc technologies can be effective in alleviating problems – in this case, conversion of one line to dc and use of a SNOP has the potential to reduce congestion and to make better use of existing line assets.

The analysis has focussed on keeping within thermal limits and in that context results are encouraging. Power quality and security factors have not yet been addressed and neither have the relative costs compared to conventional ac reinforcement. An important consideration is the availability and maturity of the relevant dc technologies.

Practical implementation considerations (including protection, control and operational aspects) will be considered in the subsequent months.

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