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This contribution addresses question 2.9: 'What new or additional tools will Power System Operators need to be able to foresee, prepare, and react to extreme operating conditions?

Background

Traditionally, 'normal' transmission constraint identification and response looks at paths identified from power flow analysis on a 'complete' system. With changes to load flows resulting from increases in DER, many systems are operated at the limits of their capability with little or no headroom.

We illustrate an additional technique applied to look for other constraint relief by considering topology changes that maintain security requirements as specified but allow the system topology to be changed by, for instance, opening a circuit breaker elsewhere deep in the system. This can provide additional transfer capacity and a greater margin at these extreme boundary conditions.

Topology changes, which may be non-intuitive, can enable power flows to be rerouted across the network and relieve constraints caused by a range of extreme operating conditions. This software-based technique has been on trial in the UK. In another session, (Paper C1-10226) we report that they have been applied as part of Grid Enhancing technologies in the Southwest Power Pool (USA), releasing additional grid capacity by relieving constraint limits.

Effectively, this is an extra step in optimising the network topology. We evaluate how changes are implemented by altering topology within the normal security boundaries by implementing changes deep within the system that then provide pathways for additional power flows. A simple analogy is how Google maps can divert traffic around constraints in the road network when some routes have become congested, allowing drivers to reach their destination faster and safely.

This contribution provides examples of the application of the technique currently under trial in the UK, where congestion from renewables has been relieved by implementing day-ahead topology change studies. These provide the control room with potential congestion reduction through non-intuitive changes to topology that meet security and other criteria.

The software tool allows the selection of the range of reliability, security and operational standards and criteria that the System Operator wishes to apply. For instance, criteria can include N-1 security, no load radialisation, generation constraints, the maximum number of reconfiguration actions, minimum relief achieved by action, and provide topology reconfiguration options that meet these criteria.

It provides potential operational changes to the network that the System Operator can choose to reduce constraint loading, such as the opening of circuit breakers, changes to phase shifting transformer settings and the incremental benefits of implementing the changes. These changes are evaluated using standard techniques for determining that transient and voltage stability are maintained, which is a regular part of control room operations. It provides the operators with possible reconfigurations if despatch on the day intersects with constraint boundaries, and there are economic advantages in relieving them.

Example of Deep Topology Optimisation

In this short contribution, we illustrate that opening 4 circuit breakers in various parts of the network can change system flows and increase boundary transfers by 12.3% or 1289MW over the initial 10,500 MW normal transfer limits. The optimisation achieves this by identifying the critical thermal limit components, exploring topology changes, and optimising these to reduce the flows in critical circuits while maintaining reliability criteria. It does so in seconds to minutes.

National Grid ESO is using the new technology on a trial basis. So far, it has demonstrated that when constraints are identified through standard techniques, there is often another layer of improvement that can be made through deep network topology changes.

Many options can be evaluated. Selected solutions must be practical and implementable.

We have limited the evaluated options for the UK system based on system operator criteria:

- Ensured no load is radialised, i.e. no single end feeding any load.
- Limited the number of changes to six, e.g. circuit breaker opening, tap changes etc., to make it practical for the system control room engineer, and
- Required a minimum of 10MW relief for any topology change.

In the UK, as the system operator manages the Transmission system generally from 275kV and 400kV (apart from Scotland, where 132kV is part of Transmission), we have not included Distribution in the trial reconfiguration at lower voltages. In the US, and as reported in paper 10226 at the C1 session, we have identified further options by changes to the Distribution system topology.

Benefits of Topology Optimisation

As you have seen, we have demonstrated that applying our techniques in the actual operational environment can reduce constraints loading, leading to substantial savings of £14-£40M in congestions costs annually and seen demonstrable improvements in the Transfer Capacity of 3-12% across constraint boundaries at the extreme of operating conditions.

For evaluation purposes, we have provided a service to allow cases to be evaluated overnight and identified constraint reductions which are notified to the control room as options for use if 'normal' constraints apply. We envisage that the technique will become an integral part of control room network management tools.

In summary, we anticipate:-

- A future where deep network topology optimisation becomes integral to control room operation to reduce constraints and improve operating margins under extreme boundary operating conditions.

- Topology optimisation maximising the use of the existing Transmission Network, reducing constraint costs and allowing more DER and renewable generation output to be moved between generation and load.

NewGrid innovative topology optimisation has been demonstrated on networks in the UK and the US to relieve boundaries at extreme operating conditions and allow the dispatch of further renewable generation across the boundary. In the case of the UK, optimisation tools have additionally reduced the 'constraining off' payments for generation and provided substantial financial benefit.

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