Study Committee C6

Active Distribution Networks and Distributed Energy Resources

Paper 10826

CONGESTION MANAGEMENT IN DISTRIBUTION NETWORKS WITH LARGE PRESENCE OF RENEWABLE ENERGY SOURCES

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Background

- The rapid expansion of variable renewable energy sources (RESs) increases the risk of congestion in distribution networks at times of coinciding large generation and small demand.
- In parallel, the reactive power flows in distribution networks are changing due to the increased RES production. Also contributing is the rising number of consumer electronics with non-linear load characteristics. For distribution system operators (DSOs), minimizing undesired reactive power flows at the connection point to the transmission system is key to meet inter-network requirements.
- The use of flexibility resources in the network has the potential to quickly boost network capacity and allows for safe integration of additional renewable energy sources while network reinforcement can be deferred or eliminated.

Objectives

- Development of an active network management (ANM) algorithm for use of flexibility in distribution networks for congestion management and control of reactive power at the TSO/DSO interface.
- Coordination of all types of local flexibility resources: converter-interfaced RESs for control of active and reactive power, also loads, BESS, EV charging.
- Demonstrate implementation process of algorithm for deployment in real network environment.

Control Algorithm Overview

1. Configuration of flexibility resources

   Data on resource availability (real-time or predefined) is collected.

2. Bottleneck detection

   Real-time measurements from monitored lines are evaluated against operational limits.

3. Centralized control response

   PI controllers determines response at each monitored network component.

4. Flexibility dispatch

   The controller responses are distributed as set point updates to available flexibility resources. Set point conflicts are resolved through worst-case prioritization.

5. Distribution of set points

   Central controller communicates set point updates to local flexibility resources.

Case Study

Simulations using the algorithm in the CIGRE European MV benchmark system. Network model implemented in PowerFactoy.

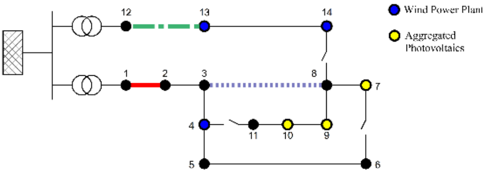


Figure 1. Topology of CIGRE European MV benchmark. Feeder 1 and feeder 2 are connected to separate 110/20 kV transformers. Loads are connected to all feeder nodes. Coloured lines are monitored for congestion.

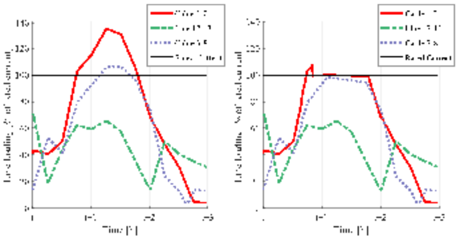


Figure 2. Loading of monitored overhead lines during simultaneous peak PV production, moderate WPP production, and low demand. A three-hour period simulated for uncontrolled network operation (left), congestion management algorithm active (right).

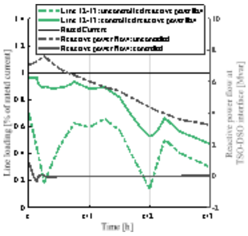
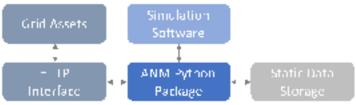


Figure 3. Loading of monitored overhead line at feeder 2 (in green) and reactive power flow at TSO-DSO interface (in grey).

Deployment

Development of a digital toolbox to facilitate integration with existing DSO and customer interfaces, as well as standard communications protocols.



Conclusion

- Proposed algorithm manages congestion and reactive power flow in distribution network using flexibility resources. Successful demonstration of functionality in simulations.

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Active Network Management Algorithm

- The algorithm consists of five successive modules: configuration of available flexibility, bottleneck detection, determination of appropriate control actions, flexibility dispatch, and distribution of new set points.

Feedback Controller

- Time-discrete PI controllers determine the amount of flexibility (active or reactive power) instantaneously required at the monitored location.

$$u(t_k) = u(t_{k-1}) + K\left(e(t_k) - e(t_{k-1}) + \frac{T}{T_I}e(t_k)\right).$$

- Controller output is limited to network constraint violations.
- Anti-windup scheme to prevent controller saturation from imposed limits.

Flexibility Dispatch Process

- Dispatch process converts controller outputs to set point updates to individual flexibility resources.
- Management of bottlenecks is prioritized over reactive power control.
- The algorithm is neutral to the choice of strategy for allocation of flexibility to resources. Two options are presented in the paper: merit order and weighted allocation of set points.
- Merit order dispatch assigns flexibility according to a resource ranking list. Using weighted allocation, flexibility is distributed among all available resources.

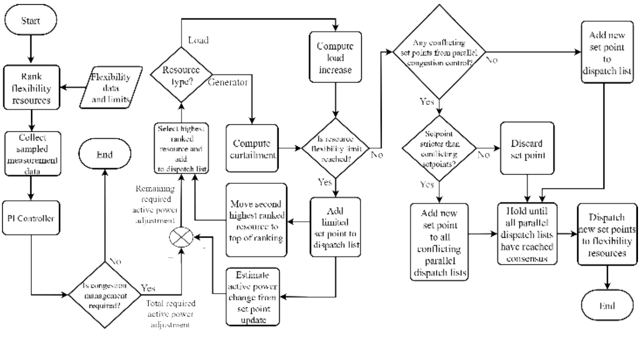

Figure 4. Merit order dispatch algorithm for congestion management. The flow chart represents a single measurement sampling instance, a potential control response, and dispatch of new set points to available flexibility resources. At each sample, the resulting setpoint changes are obtained by traversing the ranking list until the total volume reaches that determined by the PI controller.

Case Study: flexibility usage

Using merit order dispatch for congestion management in feeder 1 of the the CIGRE European MV benchmark system.

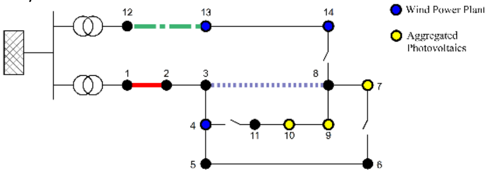

Table 1. Ranking list for flexibility resources (loads excluded) based on power transfer distribution factors (PTDFs). The PTDF is interpreted as the change in power flow in MW in a line caused by a 1 MW change at the power injected at the respective node.

#	Resource Name	Rated Power [MW]	PTDF ($\Delta P^{line}/\Delta P^{node}$)	Flexibility Limit [% of rated power]
1	WPP-4	4.0	0.902	70
2	PV-8	1.0	0.892	20
3	PV-9	1.5	0.890	50
4	PV-7	1.5	0.887	40
5	PV-10	1.0	0.887	40
6	PV-11	1.5	0.886	40

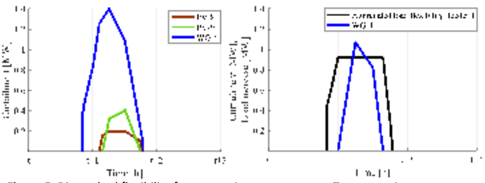

Figure 5. Dispatched flexibility for congestion management. Two scenarios are presented: a) only generation flexibility active, b) both load and generation flexibility active.

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