Dynamic Restoration Strategy for Distribution System Resilience Enhancement

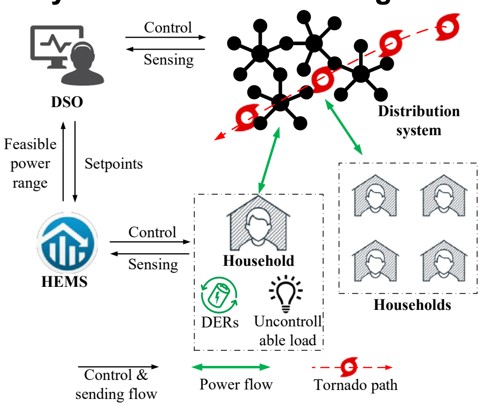
Weijia Liu, Fei Ding, and Changhong Zhao

National Renewable Energy Laboratory

Abstract

In electric power distribution systems, distributed energy resources (DERs) can act as controllable power sources and support utility operators to minimize power outages after extreme weather events (e.g., hurricane, earthquake, wildfire) and thus help enhance the grid's resilience. Meanwhile, the influences of extreme events and the capabilities of DERs are dynamic and difficult to predict. Hence, the desired distribution system restoration strategy should be able to evolve according to real-time fault/disturbance information and the availability of DERs. In this paper, we propose a new dynamic restoration strategy for distribution systems to enhance system resilience against potential hazards. An efficient reconfiguration algorithm is developed to eliminate the use of integer variables to relieve the computational burden. Model predictive control is implemented to adjust the system topology and DER operation set points based on the updated fault information and DER forecasts. The effectiveness of the proposed restoration model in enhancing distribution system resilience is validated through an IEEE 123-bus test system. Simulation results also validate that the proposed restoration model can mitigate the occurrence of unexpected events and the fluctuations of DERs.

Dynamic Restoration Diagram

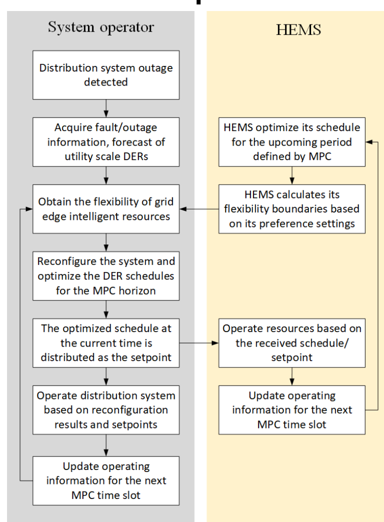


Heuristic Reconfiguration Algorithm

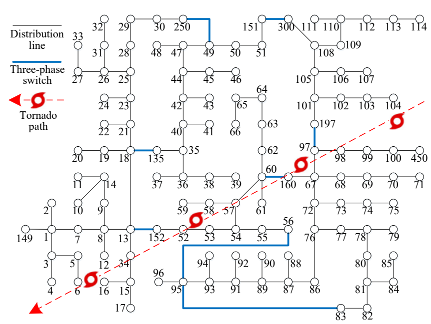
- A three-phase optimal power flow (OPF) model is difficult to solve with Boolean variables denoting switch status.
- An efficient heuristic algorithm is employed to obtain a good approximate solution.

Step	Description
1	Identify connected subnetworks after an outage.
2	Solve three-phase OPF model for each subnetwork with all switches closed.
3	From the solution of Step 2, identify and open the **openable** switch with the minimum active power flow. An **openable** switch is a switch, by opening which, the subnetwork remains connected.
4	Repeat Step 2 and Step 3 until the subnetwork becomes radial.
5	Run the OPF model to obtain the optimal dispatch strategies for all radial subnetworks.

MPC-Based Dispatch Flowchart



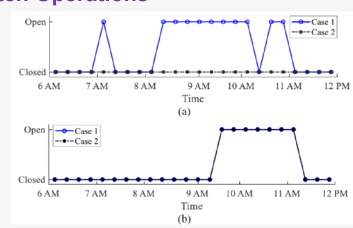
Test Case



Simulation Results

Case	Description
1	A tornado hits the test system at 6 a.m.
2	A tornado hits the test system at 6 p.m.

➢ Switch Operations

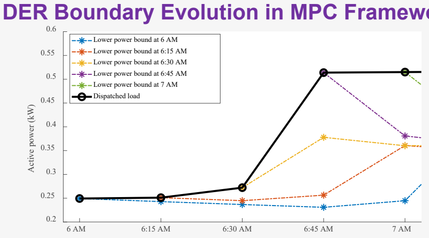


(a) switch 18-135; (b) switch 56-95

➢ Statistics

	Case 1 Phase [A, B, C]	Case 2 Phase [A, B, C]
Total load supply (MWh)	[2.57, 2.01, 2.04]	[2.33, 1.77, 1.84]
Minimum voltage (p.u.)	[0.994, 0.992, 0.996]	[0.993, 0.992, 0.997]

➢ DER Boundary Evolution in MPC Framework



With updated data, a gradual increase in the lower boundary is observed in MPC because more power is needed to satisfy the comfort settings of the customer.

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by NREL's Laboratory Directed Research and Development Program. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

2020 IEEE ISGT North America
Washington, D.C.
February 17–20, 2020
NREL/PO-5D00-76078