Study Committee C6

Active distribution systems and distributed energy resources

Paper ID_10280

Demonstration of Distribution Network Reconfiguration to Increase the Hosting Capacity of Renewable Energy based on Multiple Constraint Considerations

S. M. CHO, H. J. LEE, W.W. JUNG, C.H. SHIN
Korea Electric Power Corporation Research Institute
Republic of Korea

J.Y. KOO
Hanyang University
Republic of Korea

Motivation

- The cost of reinforcing lines to accommodate renewable energy is rapidly increasing.
- Distribution network reconfiguration (DNR), an NWA, involves changing the distribution system's configuration by closing normally opened switches, and by opening other switches to maintain a radial structure
- Since KEPCO installed ADMS in the Chungbuk area, an environment to demonstrate DNR was established.

Distribution Network Reconfiguration(DNR)

- Distribution systems typically have a radial structure.
- Normally opened switches are configured to supply power to a detour route when a failure occurs in the feeder.
- By closing a normally opened switch and by opening another switch, the distribution system's structure can be changed while maintaining its radial structure.
- DNR can be used as a means to increase the hosting capacity of DER.

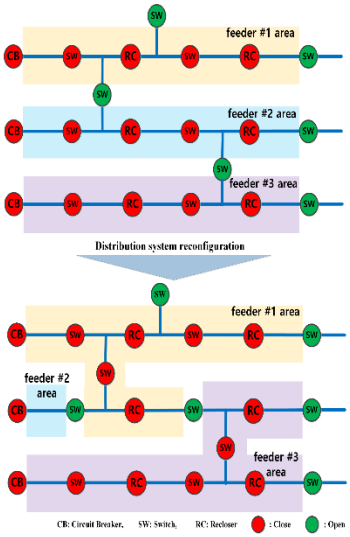

Fig1. Distribution network reconfiguration

Minimum Hosting Capacity

- Hosting capacity refers to the DER capacity that can be accommodated in the range wherein the performance index of the power distribution system does not exceed the limit value.
- The minimum hosting capacity(MHC) was calculated as the accommodatable capacity within the range where the DER concentrated at the end of the feeder does not cause overvoltage and overcurrent in order to assume the worst-case condition and used in the DNR objective function.

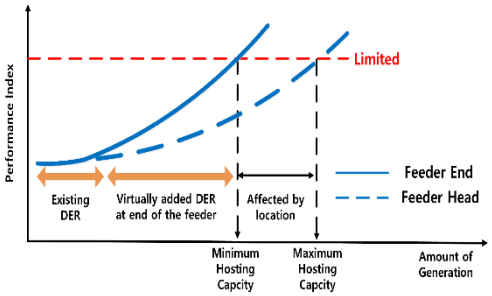

Fig2. Definition of minimum hosting capacity

- This study calculated the hosting capacity by adding a single virtual DER to the feeder's end and continuously increased the capacity in fixed step units, as shown in the figure below.
- Finally, MHC of all feeders was summed and calculated as an objective function of DNR. In this paper, 200kW was used for the fixed step.

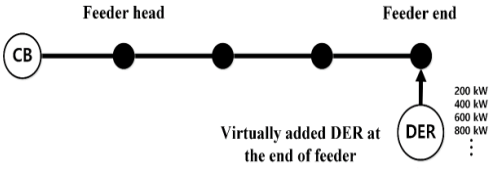

Fig3. Virtually added DER concept

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Distribution Network Reconfiguration Objective function

- The DNR objective function maximizes the sum of the MHC of all feeders as explained above.
- In the equation below, N is the total number of feeders used for the reconfiguration, and MHC_i is the MHC of the *i*th feeder.

$$\text{Maximize} \sum_{i=1}^{N} MHC_i$$

Optimization Solution for DNR

- The DNR in Korea's ADMS uses a parallel computing-based genetic algorithm. Genetic algorithms are extremely good at finding global optimal solutions, easy to implement, and allow constraints to be flexibly configured. However, they require extensive computation time.
- To address this drawback, this study applied a master–slave parallel genetic algorithm (MSPGA) with parallel computing technology

Distribution Network Reconfiguration Constraints

- Voltage and overcurrent were applied as necessary DNR constraints.
- The nominal voltage of feeders in Korea is 22.9 kV and the allowable range ranges from 0.96 p.u. to 1.02 p.u. below Equation defines the allowable voltage range of node *i*.

$$V_{min} \le V(i) \le V_{max}$$

- For the feeder overcurrent, the standard value considering the operating margin in the thermal allowable capacity was applied.

$$I_{ij} \le I_{ij\_limit}$$

Demonstarion area

- We installed the KEPCO-developed ADMS in Chungbuk, South Korea and analyzed the effects of reconfiguration to increase MHC in this distribution operating environment.

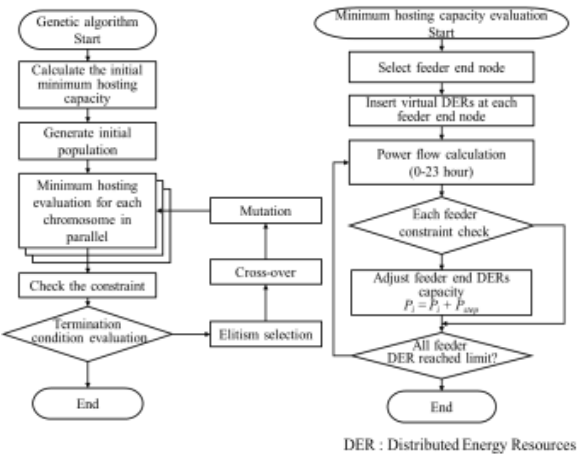

Fig 4. Optimization algorithm and flow charts used for the evaluation of objectives

Table 1. Areas to which the distribution network reconfiguration was applied

	Urban area (Bong-Myeong)	Rural area (Yeong-Dong)
Main transformer capacity	45/60 MVA × 7 bank (total 420MVA)	45/60 MVA × 4 bank (total 240MVA)
Feeder No.	29	12
Peak load	90.2 MW (5 pm)	46.03 MW (8 am)
Average load	76.6 MW	33.3 MW
Existing DER output	1.3 MW (1 pm)	31.41 (12 pm)
Feeder length sum	115.69 km	263.41 km
Average feeder length	3.7 km/feeder	21.9 km/feeder

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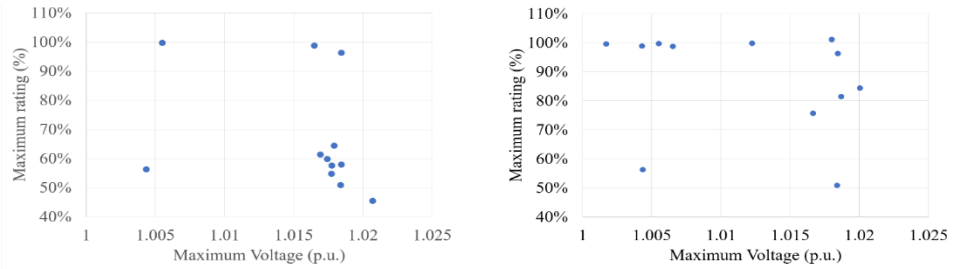
Demonstration result

- As the rural area has a long line length and more protective devices than the urban area, this indicates that the reconfiguration results are greatly influenced according to whether the movement of protective devices is included in the constraints.

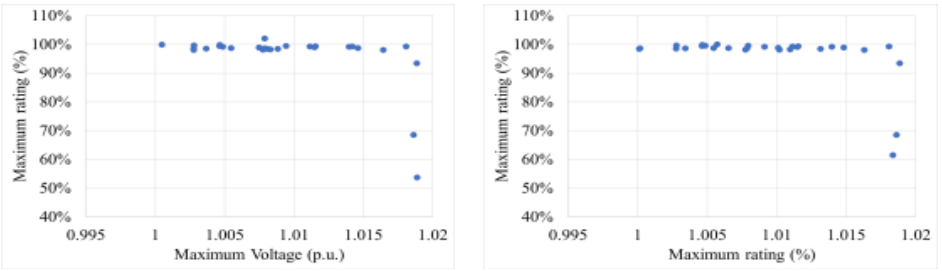
Table 2. Reconfiguration result as a function of the applied area and constraint

	Urban area	Rural area
Initial configuration MHC	322.3 MW	82.01 MW
MHC in the reconfiguration condition (protection design maintained)	327.7 MW (1.7%↑)	83.61 MW(2.0%↑)
MHC in the reconfiguration condition (protection design changed)	332.5 MW (3.2%↑)	104.61 MW(27.6%↑)



(a) (b)

Fig 5. Maximum voltages and thermal ratings of feeders in the rural area case (a) before reconfiguration and (b) after reconfiguration



(a) (b)

Fig 6. Maximum voltages and thermal ratings of feeders at urban area case (a) before reconfiguration and (b) after reconfiguration

Conclusion

- As a result, overvoltage due to DERs can easily occur in the rural area. use bullet points with clear statements
- Consequently, the MHC values for most feeders in the rural area were determined by overvoltage, while those in the urban area were determined by the thermal capacity.
- DNR did not have a large effect in the urban area because the DER capacity was limited by the thermal capacity in the cases of most feeders
- future studies will apply DNR to additional target areas and various conditions not covered in this study