CIRED 21-22 SEP 2022 SHANGHAI , CHINA

Fault Incidence Matrix based Reliability Evaluation Method for the Smart Distribution System with High Penetration of Distributed Generation

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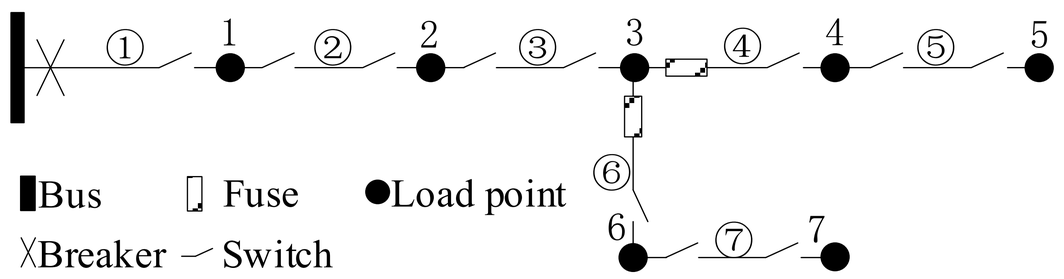
Abstract

A reliability evaluation method for the smart distribution system with high penetration of distributed generation (DG) based on the fault incidence matrix is proposed in this paper, considering the intermittency and islanding operation strategy of DG. Firstly, the power supply path matrix (PSPM) of DG is obtained by inversing the node-branch incidence matrix of the network. Then, the DG's islanding range matrix (IRM) is established based on the PSPM for the maximum load restoration. Finally, the system reliability indexes are explicitly expressed by the algebraic operation among the IRM, the fault element parameter vectors and the fault incidence matrix (FIM). The method proposed in this paper is applied in IEEE RBTS Bus6 system to verify its effectiveness. The sensitivity analysis is also carried out with respect to the DG access location and DG capacity, which can provide the reference for the DG planning and reliability improvement of the smart distribution system.

Fault Incidence Matrix



FIM-A

	1	2	3	4	5	6	7
①	1	1	1	1	1	1	1
②	0	1	1	1	1	1	1
③	0	0	1	1	1	1	1
④	0	0	0	1	1	0	0
⑤	0	0	0	0	1	0	0
⑥	0	0	0	0	0	1	1
⑦	0	0	0	0	0	0	1

FIM-B

	1	2	3	4	5	6	7
①	0	0	0	0	0	0	0
②	1	0	0	0	0	0	0
③	1	1	0	0	0	0	0
④	0	0	0	0	0	0	0
⑤	0	0	0	1	0	0	0
⑥	0	0	0	0	0	0	0
⑦	0	0	0	0	0	1	0

Reliability Calculation Model for the Smart Distribution System with DG

The DG islanding range matrix (IRM) ***R*** is defined to describe the DG's islanding range under different fault events. The row and column number of ***R*** corresponds to the fault prone branch number and load point number respectively. The elements in ***R*** is '1' or '0'. The element '1' represent the load point can be restored by DG under the branch fault with the corresponding row number, that is, this load point is within the DG islanding range. Otherwise, the element '0' means the load point can't be restored by DG. The IRM ***R*** can be calculated as:

$$\mathbf{R} = \mathbf{A} - \mathbf{A} \cap \mathbf{S}^{\mathrm{mod}}$$

$$\mathbf{A} = \begin{bmatrix} 1&1&1&1&1&1&1 \\ 0&1&1&1&1&1&1 \\ 0&0&1&1&1&1&1 \\ 0&0&0&1&1&0&0 \\ 0&0&0&0&1&0&0 \\ 0&0&0&0&0&1&1 \\ 0&0&0&0&0&0&1 \end{bmatrix}$$

$$\mathbf{S}^{\mathrm{mod}} = \begin{bmatrix} 0&0&0&0&0&0&0 \\ 1&0&0&0&0&0&0 \\ 1&1&0&0&0&0&0 \\ 1&1&1&0&0&1&1 \\ 0&0&0&0&1&0&0 \\ 0&0&0&0&0&1&1 \\ 0&0&0&0&0&0&1 \end{bmatrix}$$

$$\mathbf{R} = \begin{array}{c} \\ ① \\ ② \\ ③ \\ ④ \\ ⑤ \\ ⑥ \\ ⑦ \end{array} \begin{array}{c} \begin{array}{ccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 \end{array} \\ \begin{bmatrix} 1&1&1&1&1&1&1 \\ 0&1&1&1&1&1&1 \\ 0&0&1&1&1&1&1 \\ 0&0&0&1&1&0&0 \\ 0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0 \end{bmatrix} \end{array}$$

Conclusion

(1) The access of DG improves the system reliability to some extend but the improvement varies with DG's characteristic and islanding operation strategy.

(2) The intentional islanding operation strategy can improve SAIFI. If all the dispatchable DGs are forbidden from forming the intentional island, the load points will suffer the same outage event as the system without DG.

(3) The dispatchable DG can make more improvement on the reliability indexes than the undispatchable DG.