Campus Microgrid: High Reliability for Active Distribution Systems

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***Abstract*— Campus microgrid is composed of distributed energy resources (DER) including distributed generation (DG), controllable loads, and storage. In this paper, the role of high reliability distribution system (HRDS) in microgrid operations is evaluated. The HRDS implemented at Illinois Institute of Technology (IIT) is used as a case study along with DER to increase the load point reliability and decrease the operation cost of the microgrid.**

I. Summary

In this paper, HRDS is introduced and applied to the IIT microgrid and the improvements on reliability indices are evaluated. The proposed indices include the system average interruption frequency index (SAIFI), system average interruption duration index (SAIDI), customer average interruption duration index (CAIDI), customer average interruption frequency index (CAIFI), expected energy not supplied (EENS) and loss of load expectation (LOLE). The results show that the integration of HRDS switches will help improve the reliability indices in a microgrid.

Figs. 1 and 2 show the third at IIT loop with and without HRDS switches. It is also assumed that the redundant cables in Figs. 5 and 6 will be available when the primary feeding cable has failed. The demand at Perlstein and Alumni Hall are aggregated as the Perlstein Hall load. In Fig. 1, a failure mode will result in downstream load curtailments until the manual switching restores the loads. Since the transfer switches are manually operated, the estimated time for manual source transfer at the building feeder is about three hours. In Fig 2, the HRDS switches at load points provide uninterruptable load serving capability. In order to calculate the interruption indices in the system the buildings are referred as customers throughout the paper. Hence there are four customers in the third loop.

II. Simulation of Microgrid Operation

The microgrid operation cost includes the cost of energy trade with the main grid, cost of microgrid energy supply, and curtailment costs (value of lost load.) The operation cost of battery in a microgrid is assumed negligible. When the hourly price of energy at the main grid is higher than the marginal cost of microgrid generation, the microgrid could supply the excess energy to the main grid in real-time for reducing the operation cost. The main grid electricity price is procured based on the historical residential real-time electricity price of ComEd which is applicable to commercial customers [20].

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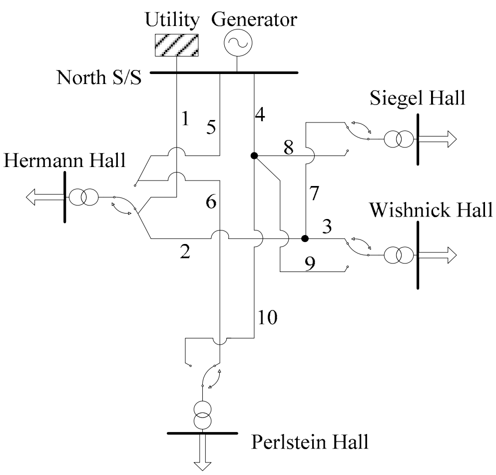

Fig. 1 Third loop layout without HRDS switches

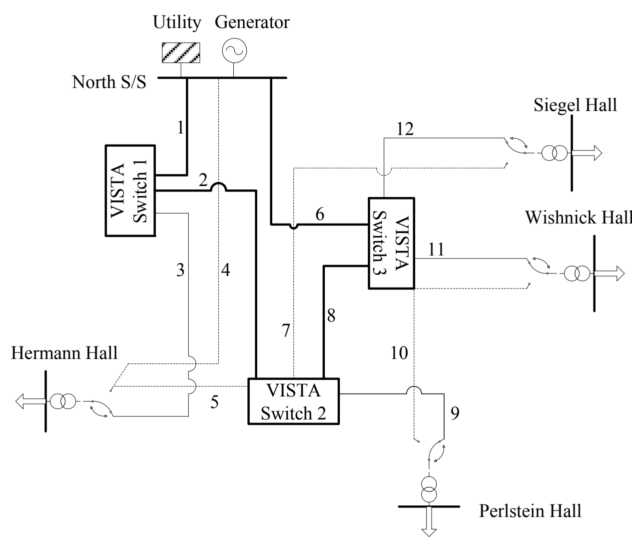

Fig. 2 Third loop layout with HRDS switches

The microgrid outages could result in the loss of revenue estimated at 80$/kWh (value of lost load) which covers the replacement cost of damaged equipment (campus facilities as well as research), personnel and administrative cost of reinitiating and sustaining key research experiments, cost of aggravation associated with disrupted academic classes, laboratories, and any other major campus events such as open houses and conferences interrupted by microgrid outages.

The annual operation cost is 140,497$/yr. The HRDS implementation would reduce the operation cost to

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126,644$/yr. The storage will further reduce the annual operation cost to 119,236$/yr by performing demand response and taking the advantage of daily market price fluctuations. The lost loads in the three Cases are 173.236, 0, and 0 kWh/yr, respectively.

Fig. 3 shows the energy flow to the microgrid on the 23rd day of the year. Here the energy drawn from the main grid (hours 4, 5, 16 and 17) is stored at the microgrid when the energy price at the main grid is low and deployed once the main grid price is high (hours 10, 11, 19 and 20.) Here, the main grid price is not high enough to trigger the microgrid generation. The lowest price of energy at the microgrid occurs at hours 4 and 5 (2.4 ¢/kWh) and increases to 3.5 and 3.6 ¢/kWh at hours 10 and 11 respectively. This cycle is repeated at hours 16-17 and 19-20.

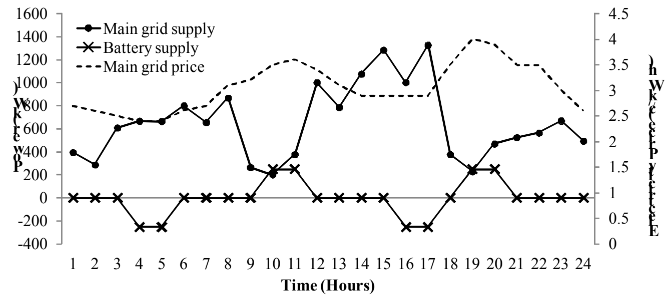

Fig. 3 Battery and main grid supply to the microgrid in 23rd day.

There are four customers in the third loop. Three cases are shown in Table I. In Case 1 (without HRDS) , there is a single load interruption in Perlstein Hall so SAIFI and CAIFI are 0.25 (interruptions/customer.yr) and 1 (interruptions/affected customer.yr) respectively. The outage duration is 3 hours and SAIDI and CAIDI are 0.75 (hrs/customer.yr) and 3 (hrs/customer interruption.yr) respectively. In Case 2 (with HRDS), no outages occur in the microgrid which decreases SAIFI, CAIFI, SAIDI and CAIDI to zero. Likewise, in Case 3 (with HRDS and battery), SAIFI, CAIFI, SAIDI and CAIDI are zero. In both Cases 2 and 3, the customer outage duration is zero hours.

Table I. Annual energy not supplied at load points

	Hermann Hall (kWh/yr)	Siegel Hall (kWh/yr)	Wishnick Hall (kWh/yr)	Perlstein Hall (kWh/yr)
Case1	0	0	0	173.236
Case 2	0	0	0	0
Case 3	0	0	0	0

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