THE IMPACT OF LOAD AND DISTRIBUTED ENERGY RESOURCES MANAGEMENT ON MICROGRID RELIABILITY

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ABSTRACT

Microgrids have control facilities which provide for the operator, the ability of performing some particular managements to improve reliability indices. For this, by a day-ahead scheduling, DERs generations at 24 hours can be obtained; then two suggested management methods are implemented and the results are compared. It can be seen that reliability indices decrease; therefore, offered managements have positive effect on microgrid reliability.

INTRODUCTION

Microgrids are low voltage (LV) networks which consist of loads and Distributed Energy Resources (or DERs that consist of Distributed Generations (DGs) and storage devices) and can operate in two modes: connected to the upstream network and isolated from it. In a connected mode, microgrids are connected to the distribution network and import or export energy from/to network. They can also provide ancillary services. Isolated mode takes place, when a fault occurs in the upstream network or there is a problem in power quality. In such a case, microgrids can operate isolated from the distribution network, changing from power control mode to frequency control mode and shedding load if necessary. These two modes require suitable control devices and a communication system. Control equipments include: Microgenerator Controller(MC) which controls active or reactive power generation of DGs and storages, Load Controller(LC) which controls loads by shedding them when necessary, and Central Controller(CC) which manages microgrids by setting the set-points of MC and LC in such a way that they provide a suitable economical and technical operation.[3] This process needs a communication system between CC, MC and LC.

One of the most important benefits of microgrids is the improvement of the distribution network reliability. This improvement is felt by consumers inside microgrids and in some situations by some consumers outside microgrids. The evaluation of the impact of microgrids on the individual and the system reliability indices is important in the development of suitable regulations for the operation of microgrids. The basis of this evaluation is the advantages which microgrids provide for reliability of the system. With determining this advantages, it becomes possible to divide the cost of the microgrid construction among different agents that benefit from its development.

The papers which investigate the microgrid reliability mostly study a grid which has no optimized power generation. In [1] with the method that is presented in [2] reliability indices are evaluated and loads supplied via a connection matrix and prioritization in the grid. [4] surveys the reliability evaluation of the microgrid in two scales of low voltage(LV) and medium voltage(MV) considering ampacity constraint and the impact of inside generations and loads rate on reliability indices. With a multi-objective economic dispatch in [5], the microgrid operation is optimized and expected reliability limitation is considered in a constraint of objective function. In this paper, a sample microgrid in LV network is used. at first a day-ahead scheduling is run in order that loads can be supplied from both the inside generation and the main grid; then the Monte Carlo simulation calculates the reliability indices with the use of optimized generations of DERs and the main grid in 24 hours. Finally, with management of storage power, and with interruption of uncritical loads when necessary, the reliability indices will be compared.

RELIABILITY ANALYSIS

For analysis of reliability, some indices like failure rate, repair time and unavailability of loads are required. These indices will be obtained via studying faults in components and summarizing results by the Monte Carlo Simulation method.

Figure.1 is considered as a sample microgrid that has 2 feeders. In this paper, after scheduling, studying contingencies at 24 hours and then failure rate, repair time and unavailability was calculated by the obtained data from previous stage. In this case, the failure rate (λ_L^t) and unavailability (U_L^t) for each load L in feeder f at hour t are given by:

$$\lambda_L^t = \sum_{c\in f} \lambda_c + \lambda_{Grid} \times x^t \tag{1}$$

$$U_L^t = \sum_{c\in f} \lambda_c r_{c/isolate} + \lambda_{Grid} r_{Grid} \times x^t \tag{2}$$

where λ_c is the failure rate of component c in feeder f in which load L stands. $r_{c/isolate}$ shows the repair time or isolation time of component c. r_c is used when the required time to restore load L lasts until component c is repaired, and when load L is restored after the isolation of the faulted component c, $r_{isolate}$ is used. λ_{Grid} and r_{Grid} are numbers of interruptions and repair time of the main grid, respectively. x^t is a binary number which determines the interruption status of loads in the isolated mode. When a fault occurs in the main grid, the microgrid goes into the isolated mode. Therefore, if the internal generation of the microgrid is greater or equal to demands, x^t becomes zero; otherwise, x^t becomes 1.

$$x^t = \begin{cases} 0 & \sum_{i \in \mu G} P_i^t \geq \sum_{L \in \mu G} LP_L^t \\ 1 & otherwise \end{cases} \tag{3}$$

Here P_i^t is the generated power of resource i in the microgrid and LP_L^t is the demand power of load point L at hour t.

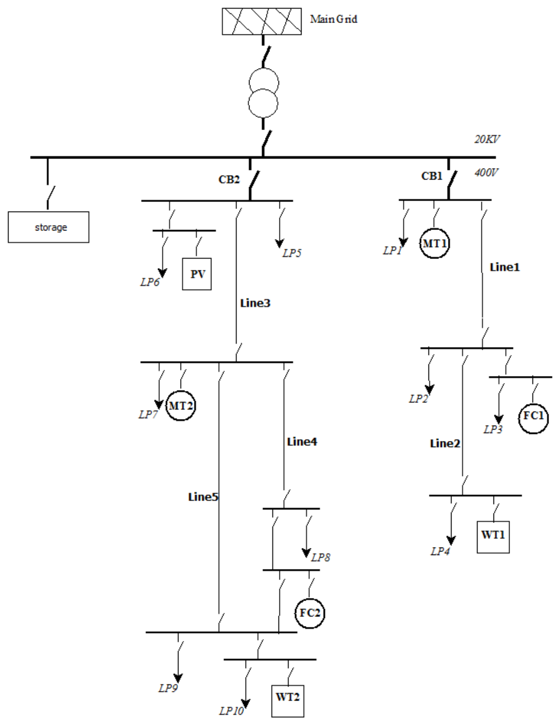

Fig.1 A sample microgrid

In this paper, it is supposed that each fault affects the loads of the faulted feeder; however, some reasons such as the power rating of the transformer(20kv/400v), which limits the amount of imported power from the main grid, causes interrupting loads of non-faulted feeders, too.

System reliability indices in hour t are calculated from failure rate (λ_L^t) and unavailability (U_L^t).

$$SAIFI^t = \frac{\sum_{L=1}^{l} \lambda_L^t \times N_L^t}{\sum_{L=1}^{l} N_L^t} \tag{4}$$

$$SAIDI^t = \frac{\sum_{L=1}^{l} U_L^t \times N_L^t}{\sum_{L=1}^{l} N_L^t} \tag{5}$$

$$ENS^t = \sum_{L=1}^{l} U_L^t \times LP_L^t \tag{6}$$

Where l is the number of loads in the microgrid and LP_L^t is the demand power of load L in hour t.

OPERATION STRATEGY

From an economical point of view, the optimization of the microgrid operation is important. It means that, each DER in each hour produces the power which minimizes the operation cost. When microgrids are operated in the connected mode, the energy is traded off between the upstream network and microgrid. Therefore, it is possible that while the open market price is low the distributed system operator (DSO) buys the energy from the main grid and saves it in storage devises and while the open market price is high DSO supplies their loads by inside generations and storage devices, even selling the power to the main grid.

Management

Control facilities of the microgrid (CC, MC and LC) are unique capabilities which provide the possibility of the definition of the type of operation in the microgrid. Therefore, in some situations it is possible to change the microgrid management in order to improve weaknesses of the grid.

For this, after scheduling of the microgrid, contingencies in the microgrid are investigated. Then the best management method to minimize the effects of the contingencies is found.

According to the sample microgrid in figure.1, to improve the reliability indices, the two following methods are suggested for altering the microgrid management when necessary:

1) Changing the state of charge of the storage and using all energy stored in the storage.

2) Shedding uncritical loads.

When a fault happens in the line 1, all loads in that feeder would interrupt because circuit breaker1 (CB1) would open. Loads of another feeder would not interrupt if the main grid could support that feeder after the fault. Ordinarily, Loads of the faulted feeder are restored after isolating the fault if there is enough capacity of the DERs in that point. It means, after isolating line1, fuel cell1 and wind turbine1 must have sufficient capacity for supplying the load point 2, 3, 4 (LP2, LP3, LP4). Otherwise, by shedding uncritical loads as a management method by DSO other load points would be supported. As a result, repair time decreases to the isolating time of faulted component. Load shedding can be implemented one by one in such a way that, first the LP3 is shed and if there is no balance between loads and

generations again, LP4 is shed, too. As a result, for line faults, it can decrease repair time but not the failure rate.
When the microgrid is operated in the isolated mode, at some hours, according to the day-ahead scheduling, inside generations of the microgrid would not be sufficient to supply microgrid loads. Therefore, these two management methods are implemented to decrease both failure rate and repair time. In this mode, the first method makes use of the whole capacity of the storage at that time; then if there is still no balance, the shedding of loads is performed one by one.
Yet there is no suitable management method when a fault in DERs occurs.

CASE STUDY

To study the impact of load and DERs management on reliability fig.1 was considered as a sample microgrid. The information of DERs are in table.1 and the bidding of generators, operation costs and open market price [6,7] at each hour is given in fig.2. The maximum power that can be imported from the main grid was supposed of as 1MW and failure rate and repair time of the main grid as 0.001 f/hour and 2 hours respectively. Failure rate of other components is shown in table.2. This microgrid consists of ten loads. LP1, LP2, LP5, LP8, LP9 are respectively uncritical loads and LP3, LP4, LP6, LP7, LP10 are critical loads. The isolating time of each fault is 0.5 hour.

Table.1 DERs data

	Min Power (KW)	Max Power (KW)	Start Up/Down Cost ($)	λ (f/hr)	r (hr)
MT1	20	400	0.14	0.0002	2
MT2	20	400	0.14	0.0002	2
FC1	10	300	0.24	0.0003	2
FC2	10	150	0.18	0.0003	2
Storage	-150	150	0	0.0001	2
PV	0	30	0	0.00035	2
WT1	0	50	0	0.0004	2
WT2	0	50	0	0.0004	2

Table.2 Fault rate and repair time

	Line1	Line2	Line3	Line4	Line5	Storage
λ (f/hr)	0.0001	0.0001	0.00015	0.00015	0.0005	0.0001
r (hr)	2	2	2	2	2	2

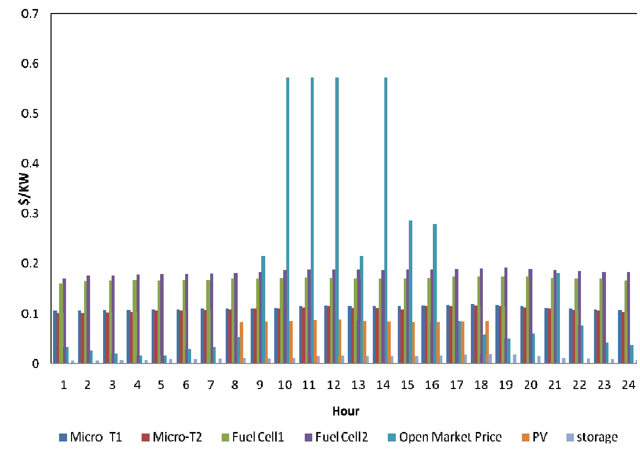

Fig.2 Biddings and operation costs

Table.3 Power range of loads

	LP1	LP2	LP3	LP4	LP5
Power range (KW)	100-210	120-215	10-150	10-150	75-200
	LP6	**LP7**	**LP8**	**LP9**	**LP10**
Power range (KW)	10-150	15-205	90-210	85-200	15-205

Power range of each load is presented in table.3. The number of customers in each load point is equal to the amount of power (KW) loads at each hour.

RESULTS AND DISCUSSION

As mentioned, first a day-ahead scheduling is performed for attaining optimized generations of DERs at 24 hours. The solution was obtained using mixed-integer linear programming in GAMS and the result is shown in fig.3. As can be seen, when the open market price is lower than operation cost of DERs, microgrid loads are mainly supplied by the main grid and when the open market price is high, the generation power of DERs are not only supported by microgrid loads but also exported to the main grid.

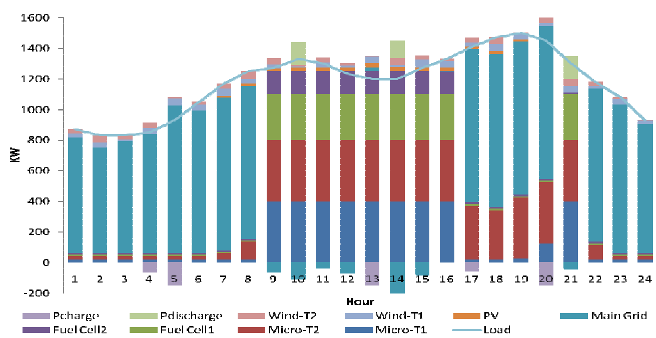

Fig.3 Day-ahead scheduling of the microgrid

Then by the use of obtained data from scheduling and calculating the load reliability indices at each hour and then by using each hour data, reliability indices of loads and system reliability indices are calculated for a day. The reliability indices of the system are shown in table.4 and the reliability indices of loads in table.5.

Table.4 system reliability indices

	Without Management	With Management
SAIFI(int/day and customer)	0.0675	0.0568
SAIDI(hr/day and customer)	0.0606	0.0482
ENS(KWh/day)	69.9809	54.8226

Table.5 Loads reliability indices

Load Point	Indices	Without management	With Management
1	λ(f/day)	0.0448	0.0414
	U(hr/day)	0.0464	0.0432
	r(hr)	1.0357	1.0435
2	λ(f/day)	0.0448	0.0414
	U(hr/day)	0.0499	0.0467
	r(hr)	1.1127	1.1268
3	λ(f/day)	0.0448	0.0264
	U(hr/day)	0.0499	0.0134
	r(hr)	1.1127	0.5057
4	λ(f/day)	0.0448	0.0264
	U(hr/day)	0.0514	0.0148
	r(hr)	1.1462	0.5625
5	λ(f/day)	0.0818	0.0714
	U(hr/day)	0.0649	0.0582
	r(hr)	0.7935	0.8151
6	λ(f/day)	0.0818	0.0564
	U(hr/day)	0.0649	0.0282
	r(hr)	0.7935	0.5
7	λ(f/day)	0.0818	0.0564
	U(hr/day)	0.0692	0.0282
	r(hr)	0.8458	0.5
8	λ(f/day)	0.0818	0.0714
	U(hr/day)	0.0692	0.0625
	r(hr)	0.8458	0.875
9	λ(f/day)	0.0818	0.0694
	U(hr/day)	0.0692	0.0578
	r(hr)	0.8458	0.8329
10	λ(f/day)	0.0818	0.0564
	U(hr/day)	0.0692	0.0282
	r(hr)	0.8458	0.5

As can be seen by applying management methods failure rate (λ) and unavailability (U) both improve in either critical loads or uncritical loads. Average repair time a day for critical loads decreases; though, for some uncritical loads it increases. Totally, after management, system reliability indices (SAIFI, SAIDI and ENS) decrease which show the positive effect of applying management methods on microgrid reliability. However, the operation cost might increase because of the changing of the microgrid scheduling, yet the load interruption cost might decrease since the energy not supply has been decreased.

CONCLUSION

Consequently, with finding weak points of the microgrid and implementing some suitable management methods for those weaknesses, it is possible to improve the microgrid performance. Here, by attending to reliability indices and the type of loads, two management methods have been suggested. In fact, for other cases such as voltage problems similar technique can be used. Incorporating restriction of imported power from the main grid is proposed for future work.

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