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Microgrid Protection Issues – A Case Study

B. Koti Reddy

Scientific Officer, Heavy Water Plant, Dept of Atomic Energy, Manuguru, India
kotireddy1965@gmail.com

Abstract: Today's electrical power system is facing a number of challenges which includes age old equipment, continuous growing demand, demand for electrification of remote areas and conservation of natural resources. Microgrid is one of the solution for these challenges which meets the local demands through Distributed Generations and is parallel with utility grids if exists. There are certain technical and regulatory issues to be considered in Microgrid systems. One of the major technical issues will be of electrical protection which needs to be analysed in Microgrids. The protection issues of microgrid are case studied in this paper including simulation with a software and a conclusion is arrived.

Keywords: Microgrid, Protection System Management, PV system, Distributed Energy Resource, Relay Coordination.

I. Introduction

The ongoing demand for continuous qualitative electrical power from the consumers as well as electricity in remote areas opened the doors for de-regulated electricity markets and many innovations. Microgrid is one of the ideas developed to meet these demands. Even though it is at an infant stage, it will be a quick alternate to the existing power system problems of Reliability, Stability and Efficiency(RSE). A microgrid is a group of interconnected loads and Distributed Energy Resource (DER) within a clearly defined electrical boundary that acts as a single controllable entity with respect to the grid [1]. It can connect or disconnect from the grid to enable it to operate in both grid-connected or island (standalone) mode. A simple model of microgrid is shown in Fig.1 [2] which is self explanatory.

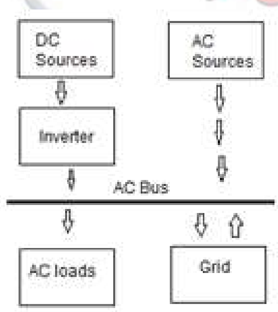

Fig. 1. Microgrid Concept

Microgrids are distribution grid sections that host production capacities, controllable loads and storage facilities with the rollout of more and more DERs. With the advancements in Power electronics, Microgrids are set to grow in a fast phase in coming years [3]. There are many benefits with microgrids:

- Reduced transmission & Distribution losses.
- Useful to serve remote places.
- Improved energy delivery locally.
- Provides clean and cheap energy from DERs
- Improves stability of existing grids
- Meets statutory requirements of renewable energy by respective Governments
- Offers different service options to customers.
- Reduces grid congestion and peak load shedding.
- It not only saves money but generates revenue also.
- Helps in reducing the carbon emissions.
- Makes the area energy secure.

II. Challenges

Microgrid introduces many operational challenges viz. Technical, Financial and Legal issues which must be addressed by utilities while adopting microgrids. The main Technical issues are synchronism, voltage stability, fault currents, protection, safety [4] and communications [5]. The other main challenges are the cost of DERs, lack of user-friendly technology, retrofits/renovations [6], cost of new protection and communication equipment, skill development, storage issues, advanced infrastructure like SCADA costs etc. The scope of this paper is restricted to protection issues and will be discussed in subsequent paragraphs. The future DERs, Storage devices and Loads can be added without any hurdles like adding RAM or Hard Disk to the existing system in a desktop.

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III. MICROGRID CATEGORIES

Microgrids are classified into various categories, as shown in table I, based on their power rating, and control [7]. Other than above classification, these are other varieties based on mode of operation like grid-connected and island and AC/DC & AC-DC types. This classification is of more important while dealing with stability and protection issues.

TABLE I
CLASSIFICATION OF MICROGRIDS

Category	A	B	C	D
Segment	LV Segment	MV Segment	MV Feeder	Primary station
Rating	<2 MW	<5 MW	<20 MW	>20 MW
Applicat-ion	Small individual facilities like Schools & Hospitals with SPV.	Smaller to large, SPV and Wind power.	Smaller to large, SPV Wind power and storage facility.	Mini grid, Solar PV, biomass and Wind power for large industries.
Control	A switch for isolation.	Switches for isolation.	Switch to kept OFF the feeder.	Controls substation with transform-ers

IV. PROTECTION

A Microgrid is a customer group of controllable play-and-play micro-DERs and storage devices which are placed optimally closer to customer. The Protection System Management (PSM) in microgrids is very challenging due to two-way or bi-directional power flow and device adequacy. The protection system has to isolate the microgrid from utility grid in case of fault on either side. It should protect existing system &devices and grid when fault occurs on either side. Hence a properly co-ordinated protection system is required in microgrids network with strict control of isolations. The protective relays shall be time-graded for over current and earth faults [8]. It is proposed to take case study of known microgrid and perform all the checks like load flow, fault currents and relay co-ordination with the help of e-tap software. ETAP Power station is the most sophisticated engineering power system analysis tool on the market now supports around 10,000 IEEE Bus projects. The main work models of e-tap are shown in Fig 2.

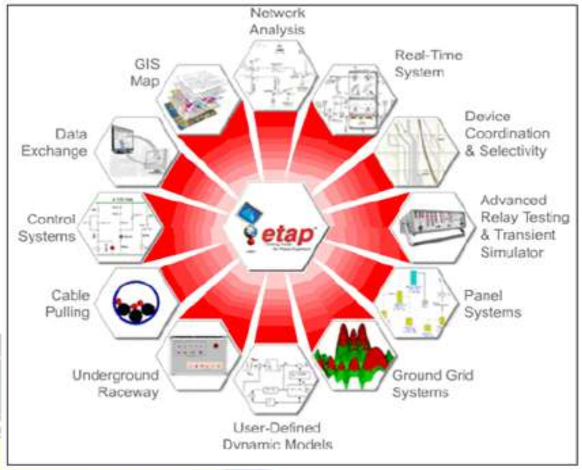

Fig. 2. e-tap components

V. CASE STUDY

One of a known existing mini-grid is shown in Fig 3 which is self explanatory. With the addition of 100 KWp Solar Photo Voltaic (SPV) power plant with a battery storage system (not shown in fig), the same has become as a microgrid, as shown in Fig 4. Here the CB 1 and T1(250 KVA, 6.6/0.433 KV) are for extension of power supply from utility grid. At the point of common coupling (PCC), the CB2 with relay R2 isolates the microgrid from utility grid in case of fault on either of the side. CB5 & 6 is controlling SPV plant, CB4 is for 75 KW water Pump Motor and CB3 is controlling the lumped load (100 KVA) of the selected area. Simulations are done with the help of e-tap software for

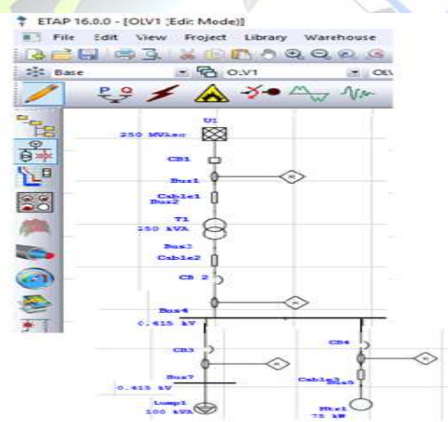

Fig. 1. Existing mini-grid

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the following scenarios:

1. Pre and post-Microgrid load flow.
2. Pre and post-Microgrid fault current estimations for a three phase bolted fault at grid side and load side.
3. Pre & post-Microgrid Relay coordination for above faults.
4. Inference of results.

1. Pre and post-Microgrid load flow: Screenshot (with current in Amps) of pre and post-microgrid simulation result are shown in Fig. 5 and 6 respectively.

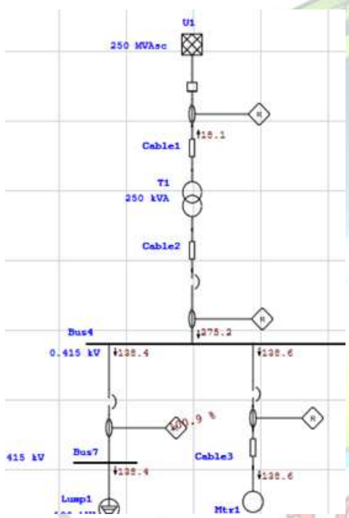

Fig. 5. Load flow in Pre-Microgrid

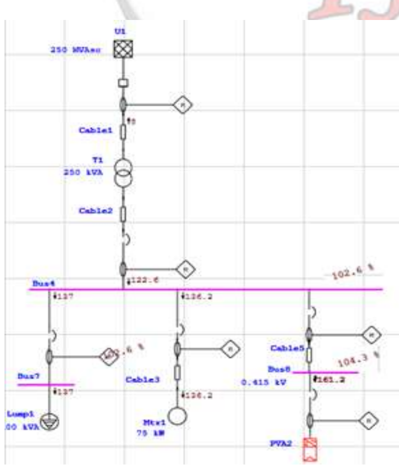

Fig. 6. Load flow in post-Microgrid

2. Pre and post-Microgrid fault current estimations, as per IEC 60909, are shown in fig 7 and 8 respectively.
3. Pre & post-Microgrid Relay coordination: Simulations are done for pre and post-Microgrid fault at PCC and result sheets are shown in Fig 9 and 10 respectively.
4. Inference of results: All the simulation results of relays operation time are shown in table II.

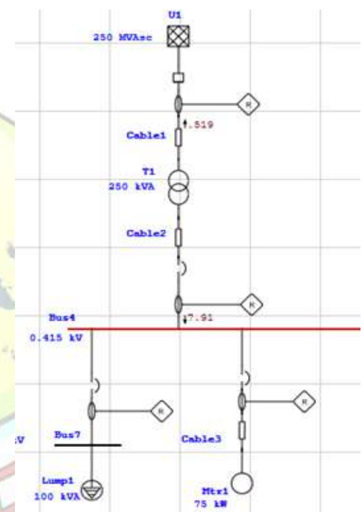

Fig. 7. Fault current in Pre-Microgrid

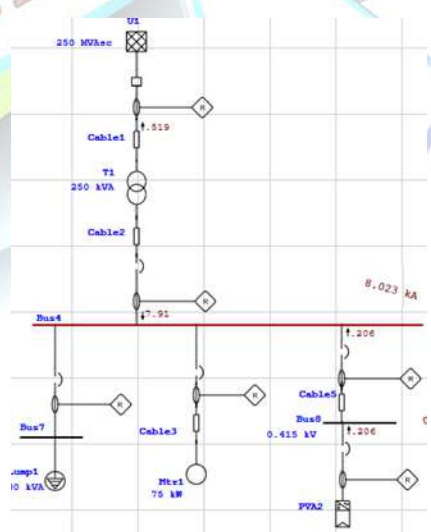

Fig 8 Fault current in Post-Microgrid

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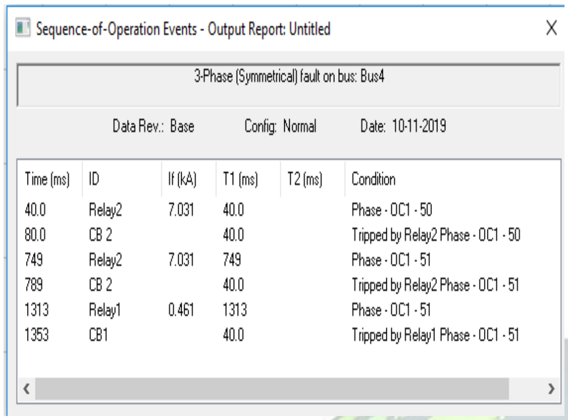
Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on bus: Bus4

Data Rev.: Base Config: Normal Date: 10-11-2019

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
40.0	Relay2	7.031	40.0		Phase - OC1 - 50
80.0	CB 2		40.0		Tripped by Relay2 Phase - OC1 - 50
749	Relay2	7.031	749		Phase - OC1 - 51
789	CB 2		40.0		Tripped by Relay2 Phase - OC1 - 51
1313	Relay1	0.461	1313		Phase - OC1 - 51
1353	CB1		40.0		Tripped by Relay1 Phase - OC1 - 51

Fig. 9. Relays Operation in Pre-Microgrid

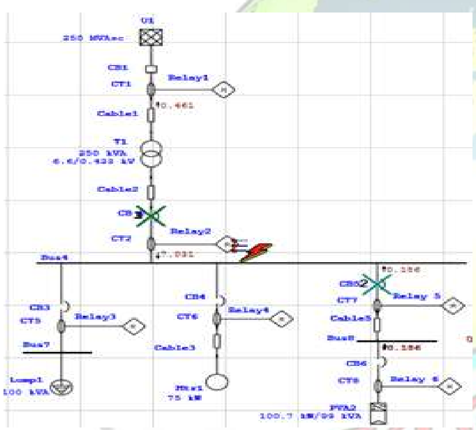

Fig. 10. Relays Operation in Post-Microgrid (Screen shot)

From the results shown in table 2, it is evident that the addition of DERs particularly SPVs will not cause much change in fault currents and relay coordination. The impact of DER at PCC is to be checked with the help of Stiffness Ratio (SR) [9] which is used to evaluate the impact of DERs on system fault levels.

SR = System fault current including DER/DER fault current

As a general rule, if SR of more than 50, DERs are less likely to create any voltage problem on grids.

In our case study, SR= 8.023/0.206=39 which is reasonable and controllable.

VI. Conclusion

Micrograds have remarkable importance on existing electrical power system market. They shall be encouraged fully so as to harness the renewable energy resources like Sun and Wind as long as the sun shines and wind blows on earth. It is concluded that for grid side faults, all the DERs to be preferably isolated to protect them as well as reduce their contribution to fault currents. It is also to be ensured that the grounding system at microgrid area shall be perfect for better safety of the system.

TABLE II
SIMULATION RESULTS

Simulation	Pre-Microgrid at PCC	Post-Microgrid From Grid at PCC	Post-Microgrid From SPV at PCC	Remarks
Load flow(A)	275.2	122.2	161.2	Load is shared.
Fault current (KA)	7.91	7.91 (total=8.02 KA)	0.206	Marginal increase with SPV.
Relay operation for fault at (CB-Relay-Time in Mille seconds)				
PCC	CB2- R2- 80 CB1-R1-1353	CB2- R2- 80 CB1-R1-1353		Nil
Lump load	CB3-R3-50 CB2-R2-80 CB1-R1-1353	CB3-R3-50 CB2-R2-80 CB1-R1-1353		Nil
Pump Motor	CB4- R4- 60 CB2-R2-80	CB4- R4- 60 CB2-R2-80		Nil
SPV	NA	CB5- R5- 40 CB2-R2-80		Nil

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