DISTRIBUTION SYSTEMS AND DISTRIBUTED GENERATION

SOME THOUGHTS

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Distribution Systems- An Introduction

- Radial system
  - To reduce complexity in planning and operation
    - Low fault levels
    - Simple protection system
    - Low cost
- Reliability is low vis-a-vis transmission system

Transmission Systems-Design

- Meshed system
- n-1 or even n-2 secure
- Transports larger MWs, hence higher kV level

TRANSMISSION VS. DISTRIBUTION SYSTEMS

S. No.	Transmission Systems	Distribution Systems
1	Technical losses 1-5%	6-8%
2	X/R ratio > 1	X/R ratio <1
3	Mesh operation	radial operation
4	Unbalance in network and load is low	unbalance in network and load is high
5	Generation penetration is high	generation penetration is low
6	Reactive power control is complex	reactive power control is simple

Reliability Study in Distribution System

System Attributes and Reliability Indices for Indian Urban Electric Distribution Utilities (Yr. 2009-10) and ConEdison, New York

Sr. No.	Parameters		Rinfra-D, Mumbai	Tata Power, Mumbai	BEST, Mumbai	Torrent Power Ahmed-abad	Torrent Power Surat	ConEdison, New York
1	Reliability indices	SAIFI (E/Y/C)	8.57	1.77	4.38	8.8	8.89	0.02 (2003-2007 average)
		CAIDI (M/E)	36	25.18	31.99	76.43	20.85	14.8 (2003-2007 average)
		SAIDI (M/Y/C)	307.8	44.33	140.10	678	185.4	0.296
2	System attributes	Customers (million)	2.7	0.05	0.9	1.26	0.52	3.2
		Area (sq.km)	384	459	69	356	52	1709.39
		Load density (VA/sq.m)	4.01	0.72	11.59	3.37	10.88	8.42 (till 2008)
		Peak demand (MVA)	1538	330	800	1200	566	13141 (till 2008)

Reliability Study in Distribution System (cont.)

- ConEdison (a distribution system in New York) network has mesh system at LT level. It provides (n-2) reliability.
- Typical reliability index values for US utilities based on 2005 IEEE survey data. Quartiles refer to the minimum value for a utility to fall in the top 25% of utilities (first quartile), next top 25% of utilities (second quartile) and so forth. Results are presented for all events included

Quartile	SAIFI(E/Y/C)	SAIDI(M/Y/C)	CAIDI (M/E)
1	1.25	128.4	101.4
2	1.63	216.5	134.1
3	2.13	366.0	179.8
4	7.25	2091.1	760.0

- Network reliability targets in the Europe are very stringent. For example, in Finland

Criteria	City	Urban area	Rural area
Total interruption time	1 hour in a year at max.	2-3 hours in a year at max	4-6 hours in a year at max.
Number of short interruptions ($<$ 3 min)	No short interruptions	$\leq$ 10 interruptions in a year	$\leq$ 60 interruptions in a year

- Reliability of distribution must be improved if DG have to be connected to it.

Some Measures to Improve Reliability of Distribution Systems

- Make the network underground
- Operate in open ring configuration
- Mesh LT network
- Use on-line network load alleviation tool by integrating with SCADA.
- Auto recloser
- Provide redundancy at transformer level

Some Measures to Improve Reliability of Distribution Systems (cont.)

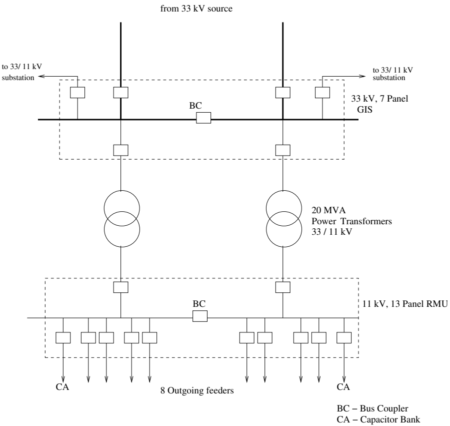


FIGURE: Redundancy at transformer level

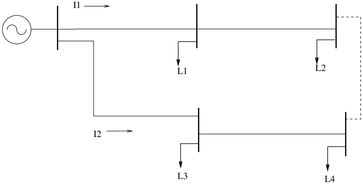


FIGURE: Open Ring Configuration

Protection System Issues

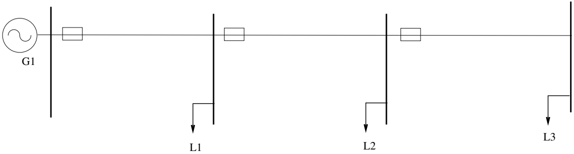


FIGURE: Single Source Model of Distribution System

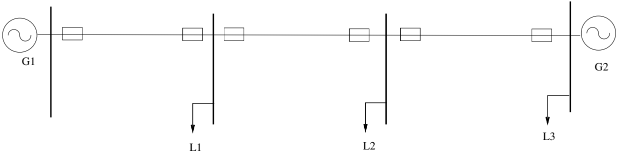


FIGURE: Distribution System with Distributed Generation

PROTECTION SYSTEM ISSUES (CONT.)

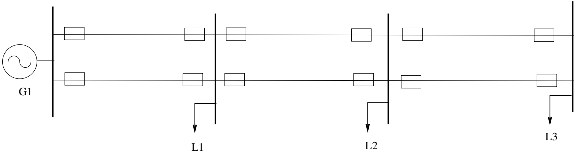


FIGURE: Parallel Lines with Single Source Model

Remark: Protection system will have to be upgraded and made directional.

DRE Grid Interconnection Requirements

Requirements of Grid Operators

Introduction of the DRE in the network should not lead to massive change in the already installed network (Otherwise it defeats the whole purpose of installing DRE). It should not adversely effect the reliability of network and safety of personnel and customers.

Requirements for DRE Operators

The Grid should provide a reliable means to distribute the generated power in such a manner that optimal utilization of the DRE is achieved. At same time the reliability of power for DRE customer is not adversely effected.

Basically both the Grid Operators and DRE Operators have certain expectations and obligations from/to each other that are addressed through interconnection guidelines.

Major requirements of the Grid Operators

- Introduction of DRE should not cause the exceeding the limits of protection devices like circuit breakers.
- The protection system coordination must be maintained. A reasonable setting changes may be acceptable but not protection philosophical changes.
- DRE should not cause increase in frequency of operation of any protection or switching devices.
- The voltage levels in the feeders should not be adversely effected. i.e. the voltage in feeders should not drop or even rise above the standard limits.
- The power quality parameters of the feeders should not be adversely affected.
- DRE should not cause safety hazard for the Grid operating personnel.

Major requirements of the Grid Operators

Most of the requirements get translated into guidelines for un-intentional islanding operation

- When the supply from the grid side is interrupted for some reason, the DRE should get disconnected from the Grid (within 2 sec. as per IEEE Std.1547) and remain disconnected until the Grid supply is restored and is normal state for at least 5 minutes.

- If DRE remain active in islanded condition the restoring of the Grid supply can cause damage to the circuit breaker as well as the DRE itself due to non-synchronous closing. The circuit breakers in distribution system don't have synchronism checking devices and are not designed for such operation.

Major requirements of the Grid Operators

- Isolated network fed from a weak source can cause overvoltages (ferroresonance) in network, that can cause damage to consumer equipment.

- Presence of active source on a faulty network is safety hazard as the fault current persists and may cause fire.

- It also safety hazard to the operating personnel who require completely isolated network before performing any maintenance work.

Major Requirements from DRE Operators

- As the DRE cannot operate in islanded conditions, it is required that the Grid availability is maintained at all the time.
- Frequent un intentional switching of Grid must be avoided.
- The Grid should also provide the power within the prescribed power quality standards.
- Large fluctuations in voltage and frequency causes unnecessary DRE islanding.
- Switching and Lightning surges from Grid may cause damage to sensitive DRE interface devices like inverters.
- As far as possible the Grid operator should not impose any reactive power absorption/delivery requirements on DREs.

Meeting points of Grid and DRE Requirements

- As a regulatory requirements the Grid operators should declare a *de minimus* power limit for DRE. Any DRE below this limit should not require any permission to connect to Grid and start operating as long as it meets the standard inter connectivity requirements.

- For connecting DRE above the *de minimus* limit, a Grid impact study should be done to ascertain that no adverse impact is caused on Grid by DRE.

- Grid should be bound by contract to maintain a minimum standard of performance with respect to availability and quality of Grid supply.

SMART METERS

STEP 1 Automatic meter reader (AMR)

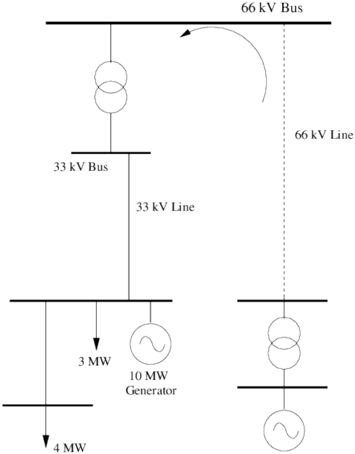
STEP 2 Bidirectional meters

STEP 3 Dynamic pricing (to improve load elasticity)

Learning from Shalivahan Green case

- 10 MW biomass generator was tripping frequently
- 33 kV feeder availability was suspected but was subsequently found to be above 98.5%
- Protection settings were found to be incorrect
  - Generator overvoltage settings were found to be improper. As per IEEE standard an instantaneous setting of 130% and 110% with a 10 sec time delay was recommended
  - A vector surge relay was provided. This relay is prone to mal operation and was recommended to be replaced by an under-frequency + rate of change of frequency relay.
- One of the conclusions of the study was that a protection system audit of the DRE should be carried out before granting permission for grid connectivity.
- Role of OLTC
- Reactive power obligation
- The utility in this case MSEDCL preferred on providing connectivity at sub transmission level (66 kV) instead of distribution level (33 kV). This would mean that benefit of counterflow would be lost, as will demonstrated by the subsequent example

Learning from Shalivahan Green case (cont.)

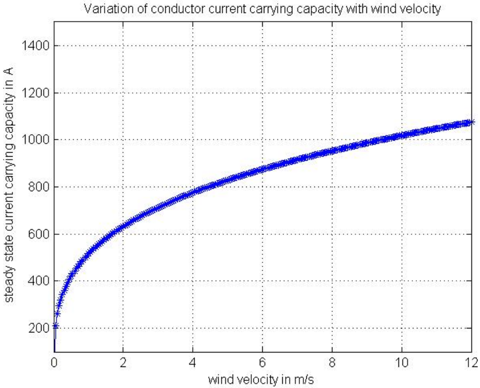


COLLECTOR SYSTEM FOR WIND FARM

- Located at Samana, Gujarat
- Installed capacity of 462 MW
- Radial network
- Wind farms are owned by various investors
- Loss of a line may result in huge economic loss if plant load factor is higher
- Average plf is 0.25
- Investment cost in n-1 reliability by open ring can be recovered in two years (based on historical wind profile)
- It is affordable
- Line loading varies with the wind speed for the collector system. It should be considered while planning the network with minimum reliability investments.
  - Under normal conditions, the network should be operated on economic loading.
  - In case of line contingency, the network can be operated as per thermal loading.

Collector System for Wind Farm (cont.)

The relation of line loading w.r.t. wind speed for PANTHER conductor is shown in the following figure.



CONCLUSION

Distribution Systems should be improved if they are going to transport power from distributed generation resources

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THANKS