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Feeder Reconfiguration in Distribution Networks using ETAP

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Abstract—The feeder reconfiguration problem highly nonlinear with multi objective and multiple constrains. It chooses the on/off status of the switches in a distribution network in order to meet one or more objective such as power loss or cost or voltage regulation. It is a mixed-integer nonlinear program and, hence, hard to solve. We proposed an iterative algorithm using ETAP 12 In this paper which follows an ac optimal power flow problem. The algorithm is computationally efficient and scales linearly with the number of redundant lines. It requires neither parameter tuning nor initialization for different networks. It successfully computes an optimal configuration on all four networks we have tested. Problem reduces the losses by 5% compare to the existing methods and improve the voltage regulation. Even during contingencies, the voltage regulation is better and losses are less compare to the conventional methods.

Index Terms—Distribution System, Feeder Reconfiguration, Optimal Switching, ETAP 12.6, Voltage regulation, Losses, Equipment Loading

I. INTRODUCTION

The restoration of a distribution system is an important operation problem in demand side management. Feeder reconfiguration is very important to enhance the quality and reliability of the distribution system. Traditionally, feeder reconfiguration is performed by opening/closing, tie and sectionalizing switches. Feeder reconfiguration is done for system power loss reduction and for load balancing. The phenomenal growth in the micro- and mini-computers, microprocessors and telecommunication technologies provide opportunities for advanced control of electric power systems in general and distribution system automation in particular. At the same time, dependence on power supply has also increased. As demand increases, distribution feeder reconfiguration can be used as a planning as well as a real-time control tool. Especially with the development of semi-automatic/remote control switches, online reconfiguration has become an important component of distribution automation.

Distribution substations (D-substations) are the nodes for terminating the subtransmission lines. The most important equipment of the D-substation is the substation transformers which step down the subtransmission voltage level to the lower distribution voltage level. Some other equipment of D-substation is high and low voltage buses, circuit breakers for both high and low voltage level, metering equipment and the control room. Each D-substation serves one or more primary feeders.

Primary distribution system (PDS) delivers electricity from the D-substation to the distribution transformers and then to feed different types of loads such as industrial, commercial, and residential. A typical PDS will be composed of one or more feeders. A mains or feeder is one of the circuits out of the D-substation. Most PDS voltages are between 3.3 and 33 kV with the major voltage classes 3.3, 6.6, 11, 22 and 33 kV.

Mostly mains or feeders are 3-phase, 3-wire and 3-phase, 4-wire systems and may be that of overhead or underground categories. If the system is 3-phase- 4-wire then the fourth wire is the neutral wire and usually connected to the pole beneath the phase wires and is grounded periodically. Branching, called laterals, from the mains are one or more and branching from the laterals called sub-laterals are also one or more. There are several configurations of the distribution systems which can increase customer service choice.

However, most distribution circuits are radial because of simplicity and cost constraints but have the low reliability.

Secondary distribution system (SDS) is fed by the distribution transformer, which step-down the distribution system voltage level down to secondary distribution level. SDS is usually radial networks and route the power within a close proximity to the customers. The service drop in the SDS connects the energy meter of each customer with the utility supply. In the United States, the majority of SDS are 1-phase and the voltage level is 120/240 volts for 1-phase, 3-wire or 3-phase, 4-wire 120/208V or 3-phase, 4-wire 277/480V. While in European systems, SDS is mostly 3-phase, 4-wire system and the voltage level is usually 220/440 volts or 220/380 volts or 230/400 volts or 240/416 volts. In india Secondary Distribution system is of 3-Phase, 4 Wire System at 415V

II. FEEDER RECONFIGURATION

The main objective in feeder reconfiguration is to restore as much load as possible by transferring essential load of the out-of-service to the nearby healthy feeder. A minimal number of switch operations is required because of switch life expectancy concerns. Under normal operating conditions, distribution engineers periodically reconfigure distribution feeders by opening and closing of switches in order to increase network reliability and reduce line losses. The resulting feeders must remain in radial configuration and meet all load requirements. However, in response to a fault, some of the normally closed switches would be opened in order to isolate the faulted network branches. At the same time, a number of normally open switches would be closed in order to transfer part or all of the isolated branches to another feeder or to another branch of the same feeder. All switches would be restored to their normal positions after removal of the fault.

A whole feeder, or part of a feeder, may be served from another feeder by closing a tie switch linking the two while an appropriate sectionalizing switch must be opened to maintain radial structures. By changing the state of the switches to transfer loads from one feeder to another, the operating conditions of the overall system may be improved significantly. Feeder reconfiguration is an important operation tool as well as a fault management technique. During normal operating conditions, the networks are reconfigured to reduce the system power loss, and to relieve the network from the overloads. During abnormal condition, the network can be re-arranged so that maximum number of customers retains electrical service. To reduce the system real power losses is also referred as network reconfiguration and to relieve overloads is referred as load balancing. The early studies on the network reconfiguration were directed to the planning stage. In planning, the main objective is to minimize the cost of construction. An early work on network reconfiguration for loss reduction was presented by Merlin and Back in 1975. They have developed branch-and-bound type optimization technique to determine the minimum loss configuration.

III. MODELING OF THE SYSTEM

IEEE 33 Bus system is modeled using ETAP. Transmission lines are modeled as Nominal Pi model. Loads are assumed as constant power loads. Distribution system is Radial in nature and hence Current / Power flow is unidirectional from source to load. Fault current – Majorly from Grid and small fault current from motor loads. Failure / loss of any component results in power outage for downstream. Poor availability and reliability is key factor which forces the utilities and distribution companies to implement some initiatives to improve the system performance. Voltage profile degrades from source towards load centers. Current Increases from load to source towards source Higher R/X Ratio signifies that ill conditioned Power System and Conventional load flow techniques fail to solve the load flow.

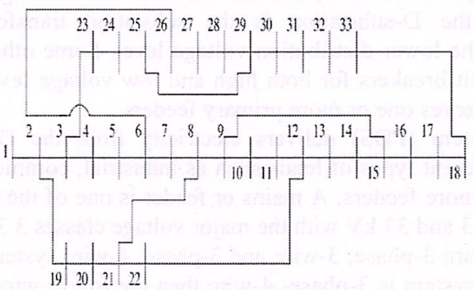

Fig 1. Single Line Diagram

IV. LOAD FLOW AND SHORT CIRCUIT STUDIES

Simulations are carried out for IEEE 33 bus system and it is considered as base case. This case is carried out to verify the optimal reconfiguration schemes carried out in subsequent cases. Voltage profile, Equipment loading and Losses are the key parameters which are monitored in each cases. Both Newton Rapshon as well as Gauss Sideal methods are tried out to verify the results obtained are same. Figure 1 shows the single line diagram for the base case.

Table 1 shows the equipment loading of each branches for Simulation of base case. Results shows that all branch loading are within the limit. Results also prove that the conductor size is increased at source end will result in reduction in losses. Table 2 shows the losses for various cases of feeder open configuration.

Sec.	Sn-Rc End	Abs curr (pu)	Sec.	Sn-Rc End	Abs curr (pu)	Sec.	Sn-Rc End	Abs curr (pu)
1	1-2	4.5204	14	14-15	0.0969	26	26-27	0.6309
2	2-3	3.0385	15	15-16	0.3631	27	27-28	0.5673
3	3-4	1.3567	16	16-17	0.3023	28	28-29	0.5080
4	4-5	1.2100	17	17-18	0.2440	29	29-30	0.9159
5	5-6	1.1418	18	18-19	1.3656	30	30-31	0.3861
6	6-7	0.3933	19	19-20	1.2674	31	31-32	0.2215
7	7-8	0.1642	20	20-21	1.1677	32	32-33	0.1037
8	8-9	0.4132	21	21-22	0.5836	33	8-21	0.4843
9	9-10	0.0283	22	22-23	1.5834	34	9-15	0.3225
10	10-11	0.0373	23	23-24	1.4788	35	12-22	0.4833
11	11-12	0.0928	24	24-25	1.0070	36	18-33	0.1581
12	12-13	0.3189	25	6-26	0.6950	37	25-29	0.5457
13	13-14	0.2469						

Table 1 Simulation Results – Equipment loading for Base case:

Iter. No.	Edge Opened	Real Power Loss (kW)	Iter. No.	Edge Opened	Real Power Loss (kW)
0	Mesh Conf.	123.2859	1	(9,10)	123.2485
2	(32,33)	123.6138	3	(14,15)	123.8109
4	(7,8)	126.542	5	(25,29)	140.1558

Table 2 Simulation Results – Losses for Base case:

Sec.	Sn-Rc End	Abs curr (pu)	Sec.	Sn-Rc End	Abs curr (pu)	Sec.	Sn-Rc End	Abs curr (pu)
1	1-2	4.5629	12	12-13	0.5274	23	23-24	0.9550
2	2-3	3.1025	13	13-14	0.4540	24	24-25	0.4783
3	3-4	1.9548	14	14-15	0.3041	25	6-26	1.4113
4	4-5	1.8079	15	15-16	0.2403	26	26-27	1.3494
5	5-6	1.7401	16	16-17	0.1728	27	27-28	1.2879
6	6-7	0.3840	17	17-18	0.1054	28	28-29	1.2305
7	7-8	0.1702	18	18-19	1.3435	29	29-30	1.0923
8	8-9	0.7885	19	19-20	1.2454	30	30-31	0.5041
9	9-10	0.7228	20	20-21	1.1461	31	31-32	0.3266
10	10-11	0.6568	21	21-22	0.1008	32	32-33	0.0774
11	11-12	0.6004	22	22-23	1.0597	33	8-21	0.9470

Table 3 Simulation Results – Equipment loading for case 2:

Iter. No.	Edge Opened	Real Power Loss (kW)	Iter. No.	Edge Opened	Real Power Loss (kW)
1	(8,21)	158.387	2	(14,15)	152.616
3	(12,22)	142.1622	4	(31,32)	142.5996
5	(25,29)	142.5996	6	(7,8)	142.5996
7	(14,15)	142.5996	8	(9,10)	142.5996

Table 4 Simulation Results – Losses for case: 2

VI. CONCLUSION

Solution is provided for highly nonlinear feeder reconfiguration problem with multi objective and multiple constrains. We proposed an iterative algorithm using ETAP 12 In this paper which follows an ac optimal power flow problem. The algorithm is computationally efficient and scales linearly with the number of redundant lines. Itrequires neither parameter tuning nor initialization for different networks. It successfully computes an optimal configuration on all four networks we have tested. Simulation results shows that the method is superior compare to the existing methods in terms of losses, voltage profile during normal and contingency case.

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