Power System Security Using Contingency Analysis For Distributed Network

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- ***Abstract-** As the power systems continue to increase in size and complexity, including the growth of smart grids, larger blackouts due to cascading outages becomes more likely. Grid congestion is often associated with a cascading collapse leading to a major blackout. Such a collapse is characterized by a self-sustaining sequence of line outages followed by a topology breakup of the network. This thesis addresses the implementation and testing of a process for contingency analysis and sequential cascading outage simulation in order to identify potential cascading modes. A modeling approach described in this paper offers a unique capability to identify initiating events that may lead to cascading outages. It predicts the development of cascading events by identifying and visualizing potential cascading tiers. The proposed approach was implemented using a 12-bus simplified distribution network. The results of the study indicate that initiating events and possible cascading chains may be identified, ranked and visualized. This approach may be used to improve the reliability of a transmission grid and reduce its vulnerability to cascading outages.*

Keywords: power system operations, power flow, transmission access, etap 11.

I. INTRODUCTION

In a three phase ac power system active and reactive power flows from the generating station to the load through different networks buses and branches. The flow of active and reactive power is called power flow or load flow. Power flow studies provide a systematic mathematical approach for determination of various bus voltages, there phase angle active and reactive power flows through different branches, generators and loads under steady state condition. Power flow analysis is used to determine the steady state operating condition of a power system. Power flow analysis is widely used by power distribution professional during the planning and operation of power distribution system.

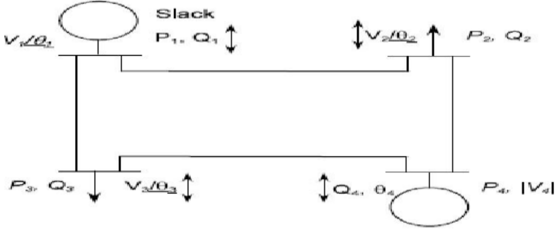

Fig 1.1

There three methods for load flow studies mainly
#Gauss siedel method
Newton raphson method
Fast decoupled method.

1.1 OBJECTIVE OF LOAD FLOW STUDY

- Power flow analysis is very important in planning stages of new networks or addition to existing ones like adding new generator sites, meeting increase load demand and locating new transmission sites.
- The load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting power channels
- It is helpful in determining the best location as well as optimal capacity of proposed generating station, substation and new lines.
- It determines the voltage of the buses. The voltage level at the certain buses must be kept within the closed tolerances.
- System transmission loss minimizes
- Economic system operation with respect to fuel cost to generate all the power needed
- The line flows can be known. The line should not be overloaded, it means, we should not operate the close to their stability or thermal limits.

1.2 BUS CLASSIFICATION

A bus is a node at which one or many lines, one or many loads and generators are connected. In a power system each node or bus is associated with 4 quantities, such as magnitude of voltage, phage angle of voltage, active or true power and reactive power in load flow problem two out of these 4 quantities are specified and remaining 2 are required to be determined through the solution of equation. Depending on the quantities that have been specified, the buses are classified into 3 categories.

VARIABLES AND BUS CLASSIFICATION

Buses are classified according to which two out of the four variables are specified

- **Load bus**: No generator is connected to the bus. At this bus the real and reactive power are specified.it is desired to find out the volatage magnitude and phase angle through load flow solutions.It is required to specify only Pd and

Qd at such bus as at a load bus voltage can be allowed to vary within the permissible values.

- **Generator bus or voltage controlled bus**: Here the voltage magnitude corresponding to the generator voltage and real power Pg corresponds to its rating are specified.It is required to find out the reactive power generation Qg and phase angle of the bus voltage.

- **Slack (swing) bus**: For the Slack Bus, it is assumed that the voltage magnitude |*V*| and voltage phase *Θ* are known, whereas real and reactive powers P_g and Q_g are obtained through the load flow solution.

Impacts of Distributed Generation

The increasing concerns related to the global warming process determined the shifting towards the use of distributed generation (DG) designed to meet the environmental restrictions. The increasing penetration rate for the DG in the energy systems is raising technical and non technical problems that must be quickly solved in order to deeply exploit the opportunities and benefits offered by the DG technologies. This chapter gives an overview of the impacts of distributed generation on the distribution network. Both technical and the economic impacts are discussed in detail.

Technical Impacts of Distributed generation on the Distribution System

For the last 50 years distribution systems have been designed to receive power at a high voltage and to supply it to consumers‟ loads. The introduction of distributed generation presents a new set of conditions to the networks. Many technical issues need to be addressed when considering the connection of distributed generation. This section of the thesis will examine the impact of the effects of DGs on the network‟s power flows, steady state voltage variations and network power losses.

Power Flows

To have a better understanding on the effects of DGs on a power system, it is necessary to know the factors influencing the transfer of power between sections of a system. A power flow, sometimes known as Load Flow, will be used to evaluate these transfers and to check the normal operating conditions of an electrical power network. Therefore, this section will briefly highlight factors influencing power transfer and will explain the basic principles involved in the load flow technique.

Reverse Power Flows

Modern distribution systems have been designed to accept bulk power from the High voltage (HV) transformers and to distribute it to customers. Thus the flow of P and Q has always been from higher to lower voltage levels. However, the significant penetration of distributed generation reverses the power flow and the network is no longer a passive circuit supplying loads. It becomes an active system with power flows and voltages determined by the generation as well as the loads. In these cases, the generator exports more than enough power to supply all the loads on the system to which it is connected. The surplus power is transferred back through the distribution transformer, and is fed into a higher voltage system. The possibility of reverse power flows in transformers can sometimes present a problem with the operation of automatically controlled tap changers, which are fitted to the transformers to provide voltage regulation on the low voltage side of the transformer.

Transfer of Power between Active Sources

This section aims to highlight the factors that influence the transfer of P and Q between two sections of a network. Consider the one-line diagram of a power system shown in Figure 2.7.

Figure 2.7 One-line Diagram of a power system

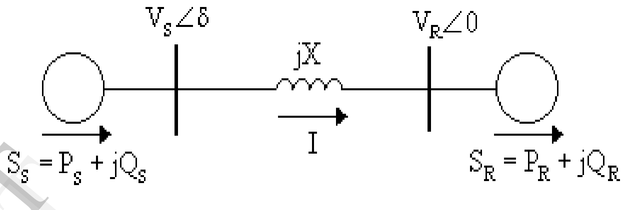

Figure 2.7 shows two active sources connected by a transmission line,

Which is represented by a purely inductive reactance? This is because impedances representing transmission lines, transformers and generators are predominantly inductive. The effects of shunt capacitance of the transmission lines have been included in the net transmitted Q [13]. The subscript "S" symbolizes the sending-end parameters and the subscript "R" symbolizes the receiving-end parameters.

From Figure 2.7, the complex power at the receiving end is

Voltage Profile

The popular saying "the customer is always right," still carries a lot of truth, especially in the utility industry. As industry has advanced from manufacturing largely by hand to producing precision parts and equipment with machines, the importance of having high-quality and consistent power has grown along with it, which makes power quality an issue for both the utility customer and the utility itself. Since voltage quality is directly associated with power quality and all distribution systems contain at least some voltage drop somewhere in the system, voltage profile and measures to improve it are both important. The generally accepted steady-state range for bus voltages on any power system is 0.95-1.05 per unit (put.), meaning that the voltage at the bus is between 95- 105% of the nominal voltage of the bus.

Distributed generators are used less frequently to address voltage profile deficiencies than voltage regulators and capacitors, but there have been several recent studies on DG's possibilities of improving the profile. Distributed generation generally offers the best voltage regulation and voltage profile improvement when operated as a voltage-controlled generator, but most forms of DG are operated as a power factor controlled generator to maximize the power output as most generators operate are most efficient at peak power outputs. However, this maximization of output and efficiency can come at the cost of creating over-voltages at the point of common coupling (PCC) and surrounding buses.

In radial networks, bus voltages decrease as the distance from the distribution transformer increases, and may become lower than the minimum voltage permitted by the utility. Utilities usually combat this problem by increasing the tap ratio of the distribution transformer, and/or by switching on the shunt capacitors. By providing a portion of energy on site, DG systems reduce branch currents, which in turn lead to reduced losses and increased voltage throughout the feeder.

In a well-behaved power system where reactance (X) is significantly higher than resistance (R), the voltage drop is fundamentally dependent of its reactive power flows. A typical X/R ratio for a 275kV network is between 5 and 10. However, in 11kV distribution network the ratios are lowers than 1 . Therefore, distribution networks are more prone to voltage variations due to both active and reactive power flows. The operation of a DG will tend to push up local voltage levels on the network to which it is connected, especially if the generator is connected to a voltage-regulated circuit. This can conflict with the convention of having the steady-state voltage of systems between 1kV and 132KV to be maintained within ± 6% of the nominal voltage. For systems above 50V and below 1kV, variations of between +10% and –6% of nominal voltage are permitted. However, to accommodate developing trends in the Power systems industry, it has been proposed that, with effect from January 2003, the permitted voltage variations for systems 50V and 1kV will change to ± 10%.

For networks where X>>R, the bus voltage magnitude increases as reactive power at the same bus is increased. If an adjacent load absorbs the output from an embedded generator, then the impact on the distribution network voltage is likely to be advantageous. However, if it is necessary to transmit the power through the network then steady-state voltage variations may adversely become excessive. Operating the embedded generator at a leading power factor, which absorbs reactive power, acts to reduce the voltage rise. However, this increases the network losses. The losses are considerably reduced if the generation is much closer to the load. Further reduction in losses and improvement in the voltage profile can be achieved if the embedded generator produces some reactive power. To achieve this, the embedded generator must be operated at a lagging power factor.

Local generation may exceed local consumption if DG continues to produce at its rated power during periods of minimum loads. Consequently, the power flows are reversed and the distribution network injects power into the grid. The source generator absorbs the excess generation but continues to supply the necessary reactive power to the system. However, it must be noted that voltage regulated systems, usually distribution networks, can only accommodate relatively small amounts of distributed generation. Significant penetrations of embedded generators may disturb the operation of systems fitted with Line Drop Compensations.

The starting of DG can cause step changes of voltage levels in the distribution network. These step changes are caused by the inrush currents, which may arise when transformers or induction generators are energized. Synchronous generators do not induce inrush currents themselves, but their transformer may do so if they are energized. Step voltage changes can also occur whenever a generator is suddenly disconnected from the network due to faults or other occurrences.

Network Losses

Distributed generation will also impact losses on the network. The strategic placement of EG on the network can reduce losses normally seen by the system while improper placement may actually increase the network losses. Proper placement can also free available capacity for transmission of power and reduce equipment stress.

Siting of DGs to minimize losses is like siting capacitor banks for loss reduction. The only difference is that DG will impact both real power and reactive power flow, whereas capacitors only impact the reactive power flow. A small penetration of a strategically placed DG with an output of just 10-20% of the feeder demand can have a significant loss reduction benefit for the system.

Although system losses are not directly a power quality issue, the losses in a system are usually related to the voltage profile of the system. One study found that active power losses are reduced under heavy loading conditions, but losses are actually increased under light loading conditions. This was possible because the distributed generator removed congestion on lines during heavy loading periods, but during lighter loading conditions the DG reversed power flow rather than reduce line loading. An increase in system losses is especially noticeable with voltage-controlled synchronous generators as this type of generator will begin to “motor” and absorb reactive power produced on the system to regulate voltage. Another study found that the location of the distributed generation is important in reducing system losses and that increasing the sizing of distributed generation generally results in fewer losses, but the gains slowly diminish. An additional study confirmed the results of the sizing study and also found that increasing penetration and power output of DG can result in increased system losses.

For a particular bus, as the size of DG is increased, the losses are reduced to a minimum value and then increased, beyond a size of DG (i.e. the optimal DG size) at that location. If the size of DG is further increased, the losses starts to increase and it is likely that it may overshoot the losses of the base case (system without DG). Also notice that location of DG plays an important role in minimizing the losses.

Power System Security

Economical operation of every power system is the major concerned. An equally important factor in the power system is the desire to maintain system security. System security involves practices suitably designed to keep system operating when components fail. An operationally secure power system is one with low probability of blackout or equipment damage. If the process of cascading failures continues, the system as a whole or its major parts may completely collapse. This is normally referred to as system blackout. All these aspects require security constrained power system optimization.

So the final aim of economy is the security function of utility company. The energy management system (EMS) is to operate the system at minimum cost, with guaranteed alleviation of emergency conditions. The emergency condition will depend on the severity of violations of operating limits (branch flows and bus voltages). The most severe violations results from Contingencies. A particular system said to be secure only with reference to one or more specific contingency cases, and a given set of quantities monitored for violation.

System security can be said to be comprise of three major functions that are carried out in an energy control centre:

(1) System monitoring
(2) Contingency analysis
(3) Corrective action analysis

System Monitoring:

It supplies the power system operators or dispatchers with pertinent up-to-date information on the conditions of the power system on real time basis as load and generation change.Telemetry system measure, monitor and transmit data, voltages, currents, currents flows and status of circuit breakers and switches in every substation in transmission network. Further, other critical and important information such as frequency, generator outputs and transformer tap positions can also be telemetered.

Contingency Analysis:

Modern operation computers have contingency programs stored in them. These foresee possible system troubles before they occur. They study outage events and alert the operators to any potential overloads or serious voltage violations. Thus contingency analysis carries out emergency identification and “what if” simulations.

Corrective action analysis:

It permits the operator to change the operation of the power system if a contingency analysis program predicts a serious problem in the event of the occurrence of a certain outage. Thus this provides preventive and post-contingency control.

Contingency Selection:

Direct Methods:

These involves screening and direct ranking of contingency cases. They monitor the appropriate post-contingent quantities (flows, voltages). The severity measure is often a performance index.

Indirect Method:

These give the values of the contingency case severity indices for ranking, without calculating the monitored contingent quantities directly.

Concept and Algorithm-

Overview

Based on the active or reactive branch flows from a solved power flow or state estimation computation, the proposed method organizes the busses and branches of the network into homogeneous groups according to a few concepts which are introduced below. Once this organization is complete, it is possible to answer questions such as” how far does the power produced by this unit go?” or “which generators are supplying this load?’ It is also possible to represent the state of the system by a directed, acyclic graph. Further processing of this graph provides the answer to questions such as ’how much use is the generator making of this line?” or”what proportion of the system losses is produced by that generator?’. This method is applicable independently to both active and reactive power lows. In the following description, the tam power” can be replaced by either” active power” or “reactive power” depending on the desired application.

Contingency analysis

In the past many widespread blackouts have occurred in interconnected power system. Therefore it is necessary to ensure that power systems should be operated more economically such that power is delivered reliably. Reliable operation implies that there is adequate power generation and the same can be transmitted reliably to the loads. Most power systems are designed with enough redundancy so that they can with stand all major failure events. Here we have studied the possible consequences and remedial actions required by two main failure events: line outages and generating unit failure.

It is important to know which line or unit outages will render line flows or voltages to cross the limit. To find the effects of outages, contingency analysis techniques are employed. Contingency analysis models single failure event or multiple failure events one after another until all “credible outages” are considered. For each outage, all lines and voltages in the network are checked against their respective limits. Flowchart illustrating a simple method for carrying out contingency analysis.

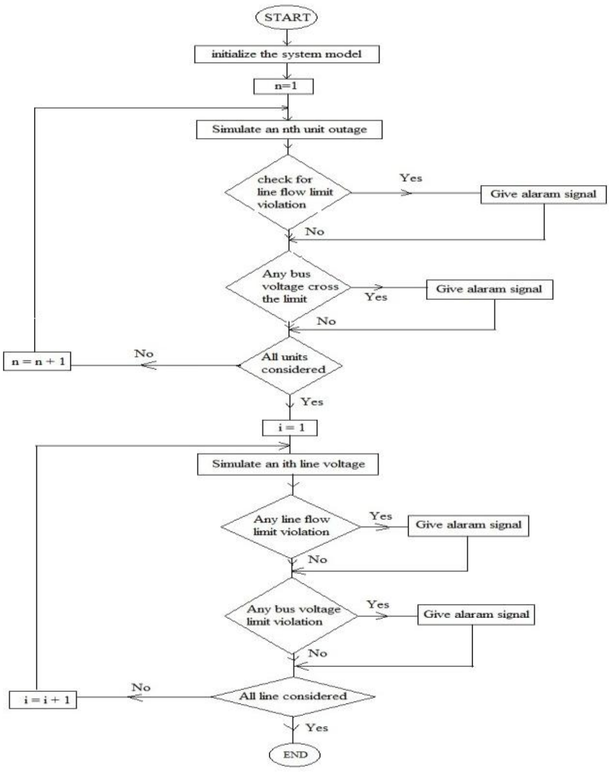

Fig 1. Flow chart for contingency analysis.

Table 1: Generator data for contingency analysis of power system:

Identity	Type	KV	MVA	MW
Gen1	Swing	66	470.58	400
Gen2	Load	66	352.94	300
Gen3	Load	66	294.11	250

Table 2: Bus and Load data for contingency analysis of power system during normal load flow through system:

Identity	KV	Load across bus(MW)	Load current (A)
Bus1	66	170	1487
Bus2	66	50	437.4
Bus3	66	100	859.9
Bus4	66	80	686.2
Bus5	66	70	599.7
Bus6	66	20	172.1
Bus7	66	70	598.2
Bus8	66	20	171.4
Bus9	66	45.2	388.7
Bus10	66	60	514
Bus11	66	30	256.3
Bus12	66	90	767.6

Table 3: Branch date for 66 KV, 12 –bus distribution system:

From Bus	To Bus	R_{pu}	X_{pu}	B/2	X^1
1	2	0.01837	0.1125	0	1
1	3	0.0313	0.1875	0	1
2	3	0.025	0.15	0	1
2	6	0.0063	0.0375	0	1
3	4	0.0125	0.075	0	1
3	5	0.0187	0.1125	0	1
4	5	0.025	0.15	0	1
4	8	0.0187	0.1125	0	1
5	7	0.0187	0.1125	0	1
6	8	0.0125	0.075	0	1
6	9	0.0063	0.0375	0	1
7	11	0.0125	0.075	0	1
8	10	0.0063	0.0375	0	1
8	11	0.0187	0.1125	0	1
11	12	0.0125	0.075	0	1

Single Line Diagram For Power System Distributed Network

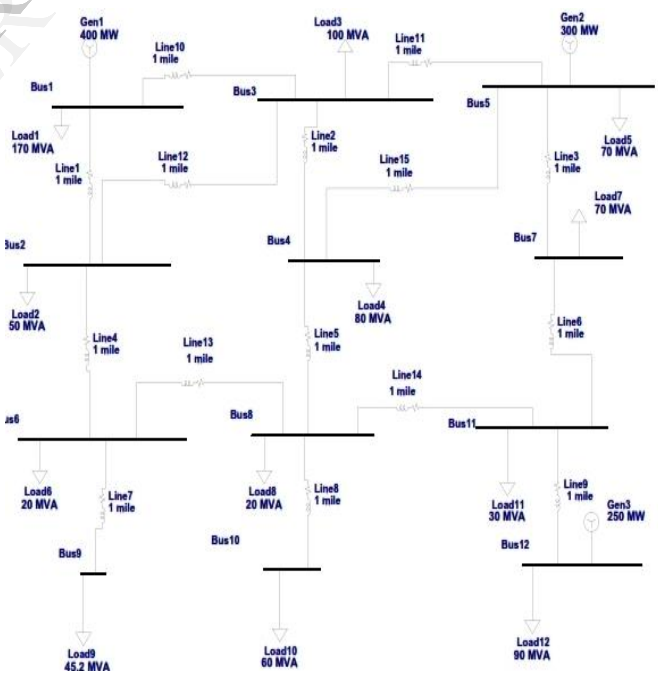

Table 4: Data for during lines outages:

S.No.	ID	Voltage Profile											
		Line 10		Line 11		Line 12		Line 13		Line 14		Line 15	
		%mag	%angle	%mag	%angle	%mag	%angle	%mag	%angle	%mag	%angle	%mag	%angle
1	Bus 1	100	0	100	0	100	0	100	0	100	0	100	0
2	Bus 2	97.16	-5.9	98.53	-3.53	98.72	-3.12	98.75	-2.85	98.62	-3.28	98.62	-3.43
3	Bus 3	96.09	-9	98.3	-4.16	98.1	-4.87	97.76	-5.23	98.12	-4.55	98.3	-4.37
4	Bus 4	95.98	-9.36	97.84	-5.53	97.9	-5.51	97.24	-6.75	97.89	-5.25	98.08	-5.06
5	Bus 5	95.84	-9.82	97.38	-6.97	97.78	-5.92	97.16	-6.99	97.5	-6.28	97.86	-5.75
6	Bus 6	96.75	-7	98.22	-4.4	98.4	-4.02	98.68	-3.06	98.4	-3.92	98.36	-4.19
7	Bus 7	95.7	-10.3	97.26	-7.37	97.57	-6.58	96.76	-8.27	96.89	-8.11	97.64	-6.44
8	Bus 8	96.14	-8.8	97.76	-5.74	97.94	-5.39	96.81	-8.09	98.1	-4.76	97.99	-5.31
9	Bus 9	96.17	-7.15	98.17	-4.55	98.36	-4.17	98.64	-3.21	98.35	-4.06	98.32	-4.34
10	Bus 10	96.07	-8.91	97.71	-5.93	97.88	-5.59	96.76	-8.29	98.04	-4.96	97.94	-5.5
11	Bus 11	95.73	-10.16	97.31	-7.18	97.57	-6.57	96.64	-8.66	96.65	-8.89	97.64	-6.45
12	Bus 12	95.56	-10.75	97.14	-7.77	97.4	-7.16	96.47	-9.25	96.48	-9.48	97.47	-7.04

Conclusion-

In this analysis of load flow during contingency when all the buses outage from the network one by one there is no case of unbalance of system network, but when line 10,line 11,line 12,line 13,line 14,and line 15 outages from the network it causes unbalance of network. One another factor is found that the line 10 is the most critical line of the network it causes maximum unbalance of all the buses. So protection of the line 10 most important factor than other lines.

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