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Transmission Network Expanssion Planning Using Contingency Analysis

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Abstract. The purpose of a power transmission network is to transfer power from generation plants to load centers securely, efficiently, reliably and economically. Any practical transmission network is ever expanding and thus, the transmission expansion planning (TEP) problem is identifying where to construct new transmission lines in future so that the growing load demand can be met by transfer of power from existing and upcoming generation in a given time horizon. In this paper a methodology is proposed for choosing the best transmission expansion plan. Contingency analysis is used to evaluate potential transmission connections and aid selection of those that best plan for overall system security. A ranking method is also demonstrated to prioritize transmission planning

Keywords: Transmission network expansion planning, Contigency analysis, system security, overload

1. Introduction

Due to the exponential load growth, the electrical power systems are continuously expanding in size all over the world. Owing to the high degree of interconnection, analyses of power systems have become increasingly more complex. Power system deregulation has increased the complexity and size to a larger extent. Taking into account the future load growth, to plan the use of existing transmission facilities and its further expansion emerges an issue with prime importance.

Various techniques, including branch and bound, sensitivity analysis, Bender decomposition, simulated annealing, genetic algorithms, Tabu search, and greedy randomized adaptive search procedure (GRASP) have been used to study the problem[1-8]. Since it is difficult to obtain the optimal solution for a realistic system considering both generators and transmission lines simultaneously, transmission expansion planning is usually performed after generation expansion planning. Typically, deterministic reliability criteria such as the (N-1) or (N-2) contingency criteria and load balance constraints are used in practice for transmission expansion planning because they are computationally tractable. In a typical power system planning problem, adequacy or security standards may be used initially in order to select the reasonable plans from draft scenarios suggested from the view point of strategic policy is called a first macro stage[9]. More detail technical analysis, which is mainly contingency analysis, fault analysis, and stability analysis, are applied in order to check the engineering feasibility of the plans. This is called a second micro stage. In this paper a methodology is proposed for choosing the best transmission expansion plan using contingency criterion.

2. Contingency Analysis

Contingency analysis is abnormal condition in electrical network. It put whole system or a part of the system under stress .Contingency evaluation is one of the most important tasks encountered by planning and operation engineers of bulk power systems. In planning, contingency analysis is used to examine the performance of a power system and the need for new transmission expansion due to load growth or generation expansion.

Contingency analysis provides tools for managing, creating, analyzing, and reporting lists of contingencies and associated violations. In general, the state of a power system is determined based on its ability to meet the expected demand under different contingency levels.

Contingency analysis is used as a study tool for the off-line analysis of contingency events, and as an on-line tool to show operators what would be the effects of future outages. This allows operators to be better prepared to react to outages by using pre-planned recovery scenarios. Some important points which are worthy of noting :

- Security is determined by the ability of the system to withstand equipment failure.
- Weak elements are those that present overloads in the contingency conditions (congestion).
- Standard approach is to perform a single (N-1) contingency analysis simulation

2.1 Contigency Selection & Screening

As various probable outages compose a contingency set, some cases in the contingency set may lead to transmission line over loads or bus voltage limit violations during power system operations. Such critical contingencies should be quickly identified for further detailed evaluation or, where possible, corrective measures taken. The process of identifying these critical contingencies is referred to as "contingency selection". The traditional procedure of contingency selection is based on the results of a full AC load flow solution. In order to cope with the computational burden, current practice is to perform contingency analysis in two phases: contingency selection (or screening) and contingency evaluation. In the contingency selection phase, the original list of contingencies is screened to a shorter list by eliminating large number of cases expected to have no violation. In the contingency evaluation phase, full ac power flow analysis is performed on the potentially severe cases selected by the contingency selection phase.

2.2 Classification of Contigencies

Contingency analysis is abnormal condition in electrical network. It put whole system or a part of the system under stress.

It occurs due to

- Sudden opening of a transmission line.
- Generator tripping.
- Sudden change in generation.
- Sudden change in load value.

In this paper contingencies that are occurring due to Sudden opening of a transmission line are considered and overload violations are checked.

2.3 Evaluating Transmission Security

Steady-state system security typically requires no loss of load, bus voltages within power quality bands, transmission flows within thermal limits, and system operation at a safe margin from static voltage collapse. Contingency analysis during periods of high demand drives the long-term design of system expansion, as other considerations are typically addressed over shorter planning horizons. Contingency analysis enables determination of quasi-optimal transmission topologies. NERC requires that systems be designed and operated to withstand *N*–1and certain critical *N*–2 or greater contingencies. A ranking method will be demonstrated to prioritize transmission planning[12].

3. Case study with a Seven Bus System

Here a 7 bus system is created and run in power world simulator .The seven bus system shown in figure 1, was selected to demonstrate the use of screening method using load flow to calculate severity of ranking with single line under base case operating condition. The system consists of 7 buses, 5 of them are generator buses and 11transmission lines. The AC load flow using NR Method is carried out .

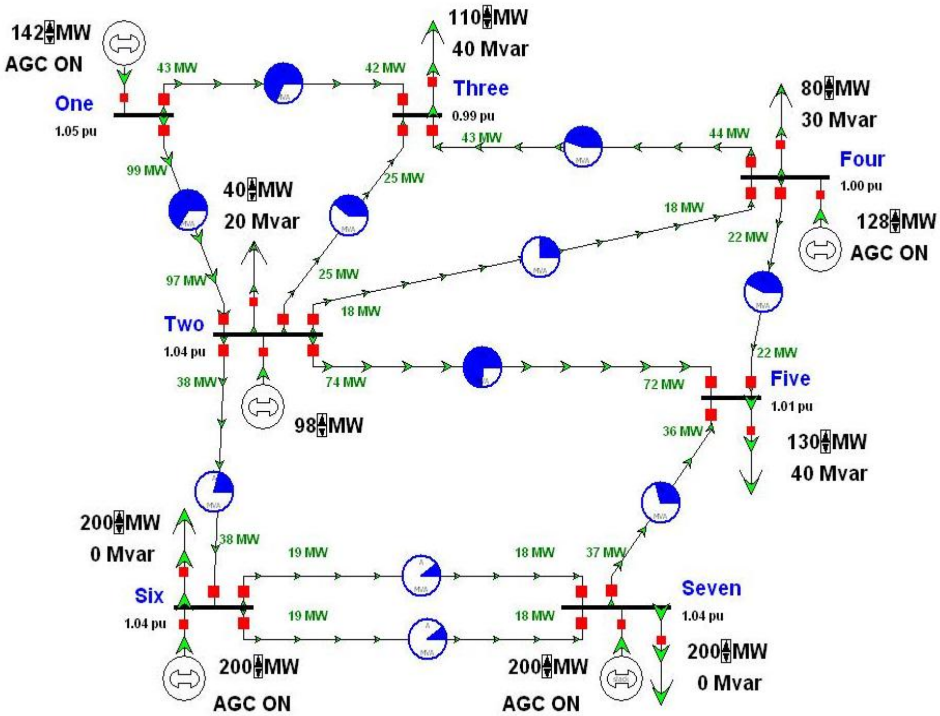

Fig 1 Base case seven bus system before running contingency analysis

The Comparison of the overloaded lines obtained by load flow methods is given in table1. A load flow based ranking method is used to prioritize transmission planning. The most severe contingencies are those that causes maximum overloaded lines & higher percentage of overload. Total eleven contingencies are inserted and contingency analysis is performed taking outage on each line .

Table 1 The Comparison of the overloaded lines and ranking obtained by load flow methods

Sr No	Contingency cases considered (‘from’ and ‘to’)	Overloaded Lines (‘from’ and ‘to’)	Percentage Overload	Ranking of Contigency
1	Line 1-2	Line 1-3	218	1
2	Line 1-3	Line 1-2	96	5
3	Line 2-3	Line 1-3	81	9
4	Line 4-3	Line 1-3	98	4
5	Line 2-4	0	0	6
6	Line 2-5	Line 4-5	90	3
7	Line 2-6	Line 2-5	101	4
8	Line 6-7	Line 2-5	82	7
9	Line 5-7	Line 2-5	111	2
10	Line 6-7	Line 2-5	82	8
11	Line 4-5	Line 2-5	89	8

To enhance system security, new lines should be added to produce counter-flows on overloaded or weak lines [12]. Studying the results of contingency analysis

Table 2.List &Priority of new lines added to mitigate counter flow to release overloaded lines or weak elements

Priority of adding line	1	2	3	4
List new lines considered (‘from’ and ‘to’)	Line 1-3	Line 2-5	Line 4-5	Line 1-2

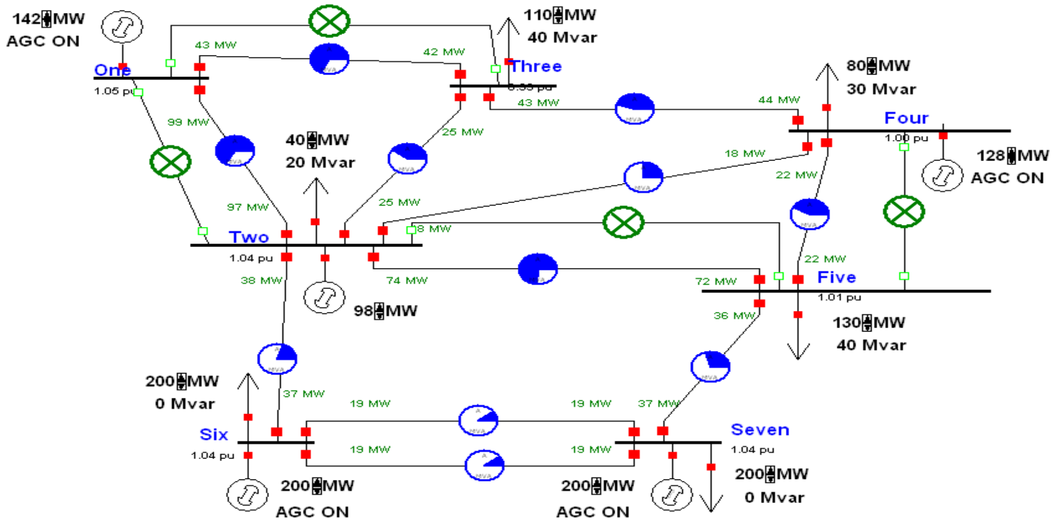

Figure 2Showing location of new lines can be inserted to release overload

Contingency Analysis is carried out after addition of four lines .It is seen that no overload happens for N-1 check is conducted by removing single line according to the contingency list and computing the overload each time. Addition of Line 1-3,Line 2-5,Line 4-5 and Line 1-2 is chosen as best plan to enhance system security. Table3 shows Contigency results showing how addition of lines removes overloading of lines.

Table3: Contigency Analysis results showing before and after addition of lines:

Contigency Name	**Before addition of lines**			**After addition of lines**		
	Violations	Aggregate MVA	%Max Branch Overload	Violations	Aggregate MVA	%Max Branch Overload
L_000007Seven-000005FiveC1	**1**	**0.7**	**100.7**	0	0	0
L_000006Six-000007SevenC2	0	0	0	0	0	0
L_000006Six-000007SevenC1	0	0	0	0	0	0
L_000004Four-000005FiveC1	0	0	0	0	0	0
L_000003Three-000004FourC1	0	0	0	0	0	0
L_000002Two-000006SixC1	**1**	**1.2**	**101.2**	0	0	0
L_000002Two-000005FiveC1	0	0	0	0	0	0
L_000002Two-000004FourC1	0	0	0	0	0	0
L_000002Two-000003ThreeC1	0	0	0	0	0	0
L_000001One-000003ThreeC1	0	0	0	0	0	0
L_000001One-000002TwoC1	**1**	**94.5**	**218.1**	0	0	0

4. Conclusion

A TEP methodology for choosing the best transmission expansion plan using contingency analysis is used to evaluate potential transmission connections and aid selection of those that best plan for overall system security. The expansion plan obtained from the case study may contain insecure configurations. To ensure the system reliability, the expansion plan is assessed by a list of credible single line outages, i.e. the "*N-1*" criteria, using a base case AC load flow[12]. Should overload happen in any transmission line, best location from the rest of the possible are selected to reinforce the network. The security assessment is repeated until no overloading happens in the system and the optimal expansion plan is finalized. Three steps of the security assessment involve contingency screening, N-1 checking, and selection of extra line for reinforcement. Finally, the best lines to enhance security are selected from the rest of the possible lines.

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