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TRANSMISSION NETWORK EXPANSION WITH TRANSMISSION LOADING RELIEF

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Abstract- Transmission planning should seek to maintain or improve system security over time and facilitate robust wholesale power markets by improving transmission capacity for bulk power transfers across wide regions It includes finding the optimal plan for the electrical system expansion, it must specify the transmission lines and/or transformers that should be constructed so that the system to operate in an adequate way and in a specified planning horizon. In this paper a methodology is proposed for choosing the best transmission expansion plan using Transmission security based on contingency analysis. A procedure using sensitivity analysis is used to evaluate potential transmission connections and that provide the most improvements to overall system security .The methodology is applied to a six bus Garver system The result obtained with the proposed method are validated with the results reported in the earlier research papers.

Keywords- *TNEP, Security Constraints Contingency analysis, AMVACO, TLR*

I. INTRODUCTION

Transmission network expansion planning (TNEP) is a basic part of power system planning that determines where, when and how many new transmission lines should be installed. Its goal is to minimize the network construction and operational cost, while meeting imposed technical, economic and reliability constraints. [1,2] The most researched planning is called basic planning in which the security constraints are not considered. In other words, in this planning, the optimal expansion plan is determined without considering the contingencies caused by transmission-line outages. [3,4].

Generally, transmission network expansion planning can be classified as static or dynamic. Static expansion determines where and how many new transmission lines should be installed up to the planning horizon. If in the static expansion the planning horizon is separated in several stages we have dynamic planning [5,6]. The majority of the generating plants are located far from the load centers Thus the investment for transmission network is huge. Due to this fact static transmission network expansion planning (STNEP) problem should be evaluated carefully.

II. OVERVIEW OF THE PLANNING METHODS

The TNEP can be stated as a large-scale, non-linear, integer-mixed, non-convex optimization problem and it requires the use of heuristic and combinatorial optimization algorithms because they are able to find better solutions compared with those that are obtained when classical techniques of mathematical optimization are used[7,8].

Transmission expansion planning with open access to the grid has become a hot issue in the electric utility industry in recent years. However, the basic objective of strengthening a transmission grid is relevant for most countries. The blackouts that have occurred in countries worldwide and in India suggest that more reliable grid structures may be needed to establish successful deregulated electricity markets. These incidents call for the development of new tools that can address system uncertainties and significantly enhance the effectiveness of transmission planning[9,10,11].

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[12,13].

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. 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. A deterministic reliability criterion such as load balancing constraints (adequacy) is often used in the first stage. Here a methodology is proposed for choosing the best transmission expansion plan using an adequacy-based security criterion based on an contingency criterion done by eliminating contingencies with probabilities lower than a prescribed probability limit. Weighted transmission loading relief (TLR) analysis and other linear techniques are used to quickly estimate the impacts of a large number of potential transmission lines on transmission system security.

The transmission network expansion planning problem consists of defining when and where new circuits should be installed to serve, in an optimal way, the growing electric energy market, subject to a set of electrical, economic, financial, social and environmental constraints. Such a problem has a dynamic nature, since the requirements of transmission facilities (lines or power transformers) should be defined over time within a given horizon. In fact, this problem consists in the execution of two successive tasks, the first one corresponds to the definition of the set of candidate transmission routes whereas the second one, corresponds to the selection of the best subset of circuits among the set of options found before[14,15]. Our work is addressed to this second task.

In developing countries like India, the TNEP problem requires a careful evaluation. Transmission will represent about 40% of the total investment in the electric energy sector during the next five years, which is calculated at about US$ 30 billion. Therefore, any effort for reducing the cost of the transmission system expansion by some fraction of a percent, allows savings of a significant amount of capital.

III.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–1 and certain critical N–2 or greater contingencies [16].

Contingency analysis is an energy management system application that analyzes the security (i.e. the safe & stable operation) of a power system. It identifies & prioritizes the current & power flow overload in equipment.. Power World Simulator’s Contingency Analysis tools provide the ability not only to analyze a power system in its base case topology, but also to analyze the system that results from any statistically likely contingent scenario. Industry planning and operating criteria often refer to the n-1 rule, which holds that a system must operate in a stable and secure manner following any single transmission or generation outage.

A. Selection of number of lines

However, the option to consider a very large number of new transmission connections adds complexity to the planning and selection process. Suppose n substations are candidates for new transmission connections. The number of possible new transmission lines is given by:

$$= \frac{n!}{(n-2)!\,2!} \qquad (1)$$

Evaluating the impacts of such a large number of transmission connections requires tools for screening the list to determine which transmission upgrades would provide the most cost-effective benefits. We uses weighted transmission loading relief (TLR) analysis and other linear techniques to quickly estimate the impacts of a large number of potential transmission lines on transmission system security[17].

B. Aggregate Contingency overload

One measure of system security is the amount of thermal overloading that occurs during a set of simulated contingencies or forced outages. The level of contingent overloading may be expressed as the sum of MVA overloads across all monitored transmission elements and simulated contingencies, or the Aggregate MVA Contingency Overload (AMVACO), defined as follows :

$$AMVACO = \sum_{c \in CONT} \sum_{ij \in Branch} (MVAij - RATI) \Big|_{\text{MVA j > Rating 2i}} \qquad (2)$$

Thus for a given line ij and contingency c, the contribution to the AMVACO would be the amount of MVA that the flow on line ij exceeded its emergency limit or contingency rating. If the line operates within its limits for all contingencies, then its contribution to AMVACO is zero. A desirable goal of any transmission upgrade or expansion would be to improve the system security as measured by the AMVACO [17].

D. Transmission relief.

The bus Transmission Loading Relief (TLR) describes how an incremental power injection at a given bus k (ΔPk) impacts power flow (ΔPij) on a transmission branch between bus i and bus j:

$$TLR = \frac{(\Delta Pij)}{(\Delta Pk)} \qquad (3)$$

ΔPij is positive if the incremental power flow is positive from bus i to bus j, and negative otherwise. From this, the Weighted Transmission Loading Relief (WTLR) value is defined to represent the impact of an incremental power injection on all contingent overloaded branches. It expresses the expected system AMVACO change of an injection at the corresponding bus, where the impact on each overloaded line is weighted by the total MVA overload on the line.

$$WTLR = \frac{N_{cont}}{sysAMVACO} \times \sum \left[CODir_{BRANCHij} \times TLR_{BUSk,BRANCHij} \times AMVACO_{BRANCHij} \right] \quad (4)$$

$CODir_{BRANCHij}$ reflects the direction of the contingent overloading, relative to the branch reference direction (from bus i to bus j). It is equal to +1 if the contingency overloading occurs in the direction of bus i to bus j and -1 if the contingency overloading occurs in the direction of bus j to bus i. Thus the product of $TLR_{BUSk,BRANCHij}$ and $CODir_{BRANCHij}$ is negative if the flow (ΔPij) imparted by the incremental power injection at bus k (ΔPk) alleviates the contingency overloading. The bus WTLR value can thus be applied to each end of a proposed transmission line to linearly estimate the total expected AMVACO change expected from the addition of a new transmission branch. To enhance system security, new lines should be added to produce counter-flows on lines and transformers that experience contingency overloads as illustrated in Fig 3.1

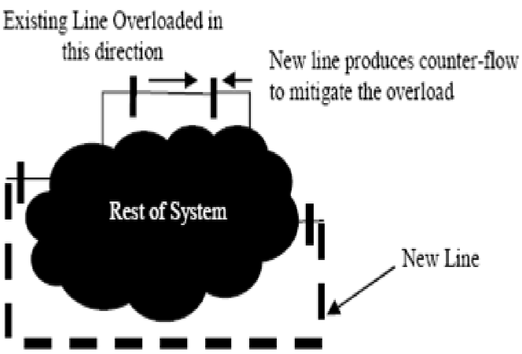

Fig 3.1: Transmission relief

E. Security Enrichment Factor

Assume the flow expected in the direction of bus k toward bus m is Pkm. If one approximates the system as loss less and linear within a range defined by the incremental flow on the proposed line, then adding the proposed line is equivalent to placing a generator at bus k with output -Pkm and a generator at bus m with output +Pkm, as illustrated Figure 3.2.

The impedance parameters of the proposed line have a significant effect on the value of Pkm in that a lower per unit impedance yields a larger Pkm.

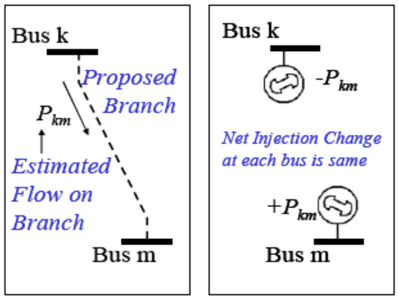

Figure 3.2: Network equivalents

The bus-based WTLR values may then be applied to estimate the AMVACO impact or Security Enrichment Factor (SEF):

$$SEF = P_{km} (-WTLR_k + WTLR_m) \quad (5)$$

F. Cost impact

The SEF by itself does not take into account the feasibility or cost of adding in the potential new transmission line. Also, the SEF may be biased toward capital intensive higher voltage connections as the corresponding lower impedance yields higher post-closure flow on the branch. Cost considerations, including capital investment and right-of-way acquisition, may be incorporated by dividing capital and other implementation costs by the SEF for each proposed line. A cost-security ratio (CSR) may be defined as follows:

$$CSR = \frac{Cost}{SEF} \quad (6)$$

The CSR approximates the investment required per unit reduction in expected AMVACO. Lower CSR represents a greater cost effectiveness of the proposed line in improving system security and relieving contingency overloading

IV.ALGORITHM

Perform contingency analysis and calculate MVACO.

1) Calculate bus-based transmission loading relief.
2) Calculate flow Pkm on candidate lines.
3) Calculate line-based SEF.
4) Calculate Cost/Security Ratio for each candidate line.
5) Insert line with best Cost/Security Ratio.
6) Repeat the process until security criteria is met.

V. TEST AND RESULTS

A. TNEP: WITH 6 BUS GARVER SYSTEM

Garver's network is used as a test system to demonstrate the effectiveness of the proposed idea [12]. The configuration of this network before expansion is shown in Fig. 5.1. The power flow limit of possible corridors and construction cost of the lines i.e. initial topology and electrical system data can be found in [6],[2]. Substations 1, 3 and 6 are generator busses that their generation limit are 100 MW, 250 MW and 450 MW respectively. This system has six buses, 15 candidate branches, a total demand of 760 MW and maximum possible number of added lines per corridor equal to five.

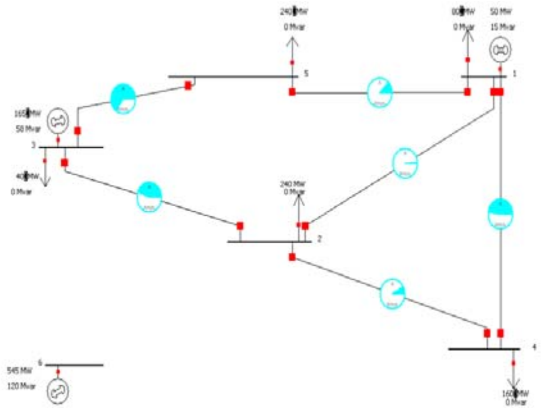

Fig 5.1: 6 bus Garver base case system

The 6 bus Garver system is designed and simulated in PowerWorld simulator. The expansion plan is obtained by applying proposed algorithm and by obtaining AMVACO, WTLR, SEF and CSR. The optimal solution to the expansion planning problem for two cases without and with security constraints is found out.

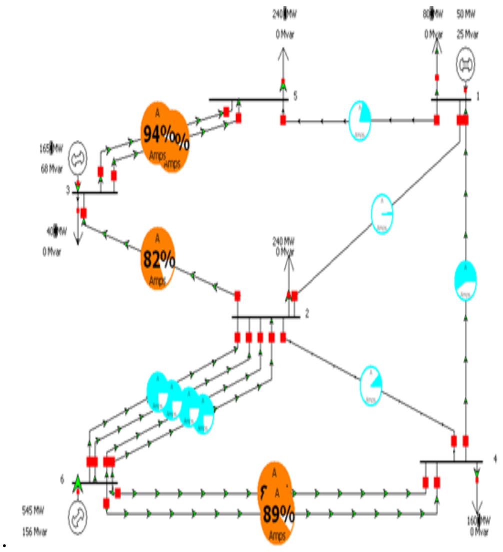

Fig 5.2: Expanded system without security

B. Transmission Network Expansion Planning Without Security Constraints.

The objective is to minimize the total investment cost of the new transmission lines to be constructed, satisfying the constraint of real power flow in the lines of the network. The optimal solution obtained without security constraints is shown in fig. 5.2. This include a total investment cost of US\$ 200×10^3 with the addition of following seven lines, $n_{3\text{-}5}$=1, $n_{6\text{-}4}$=2, $n_{2\text{-}6}$=4. This results are shown in Table 1 and are exactly matching with the one reported by specialized GA[17].

C. Transmission Network Expansion Planning With Security Constraints.

The objective is to minimize the total investment cost of the new transmission lines to be constructed, satisfying the constraint of real power flow for the base case and N-1 contingency cases. It ensures that the system will be secured even after any single line outage. The optimal solution obtained for the expansion planning problem with security constraints is shown in table 2 .It results in a total investment cost of US\$ 270×10^3 with the addition of following ten lines, $n_{3\text{-}5}$=2, $n_{6\text{-}4}$=3, $n_{2\text{-}6}$=4, $n_{3\text{-}2}$=1.

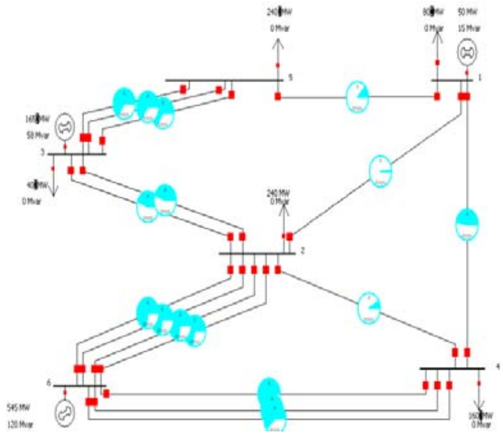

Fig 5.3: Final expanded system

The results for TNEP with the proposed method without and with security constraints are presented in Table 3. The results are matching with the results reported with specialized GA [6] and basic binary GA[[16,17].Comparing the results obtained without and with security constraints it can be observed from that cost of expansion plan with security constraints increases by US\$ 70,000 with the addition of three new lines namely $n_{3\text{-}5}$=1, $n_{6\text{-}4}$=1, $n_{3\text{-}2}$=1. The expansion cost incurred with proposed method for TNEP with security constraints is lesser when compared to the one reported in [16]. The proposed methodology is simple, fast and efficientin computation.

Table.1: IEEE 6 bus Garver system status and AMVACO (without security constraint).

	line inserted	Circuit no.	System status	AMVACO
without security	0	0	blackout	nil
	$n_{6\text{-}4}$	1	blackout	nil
	$n_{6\text{-}4}$	2	blackout	nil
	$n_{6\text{-}2}$	1	blackout	nil
	$n_{6\text{-}2}$	2	blackout	nil
	$n_{6\text{-}2}$	3	blackout	nil
	$n_{6\text{-}2}$	4	blackout	nil
	$n_{3\text{-}5}$	1	stable	377.815
	Total numbers of line inserted			7
	Investment cost (US\$ 10^3)			200

Table.2: TNEP with security constraint for IEEE 6 bus Garver system.

	Overloaded Line	Candidate Lines	SEF	Cost/SEF	Line Selected	AMVACO
with security	3-5	3 TO 5	49.05	0.4	3 TO 5	128.77
		3 TO 6	10.85	4.4		
		3 TO 2	5.6	3.6		
	6-4	6 TO 4	-8.06	-3.72	6 TO 4	32.76
		3 TO 6	-11.52	-4.16		
		6 TO 2	-6.2	-4.834		
	3-2	3 TO 2	0	0	3 TO 2	0
	Total numbers of line inserted					10
	Investment cost (US$ 10^3)					270

Table.3: Comparison of TNEP with and without security constraint for Garver system for different Methods of Expansion

Comparison of TNEP	TNEP withproposed method		TNEP with Genetic Algorithm	
Type of Case Study	TNEP Without security constraints	TNEP With security constraints	TNEP Without security constraints	TNEP With security constraints
Transmission Expansion Plan	n_{3-5}=1 n_{6-4}=2 n_{2-6}=4	n_{3-5}=2 n_{6-4}=3 n_{2-6}=4 n_{3-2}=1	n_{3-5}=1 n_{6-4}=2 n_{2-6}=4	n_{3-5}=2 n_{6-4}=3 n_{2-6}=4 n_{3-6}=1
Total number of lines added	7	10	7	10
Investment cost [10^3 US$]	200	270	200	298

VII .CONCLUSIONS

In this paper, very simple and efficient algorithms for static transmission network expansion planning with and without security constraints are presented. First the algorithm for base case transmission expansion planning with in load specifications has been presented. Then the algorithm has been extended to include security constraints.

The methodology is simple and computationally efficient because it utilizes line addition method and simulation of system after each addition of line one by one. It provides a good enough solution with minimum investment cost and maximum security with sufficient line insertion for system expansion, thus confirming the excellent quality of the solution provided by the proposed method. Garver 6 bus system gets secured by reducing the system AMVACO to zero and methodology is equally efficient with greater real time system.

Thus the TLR-based transmission line selection process described herein enables fast screening of many combinations of potential new transmission lines.

REFERENCES

[1] H. Shayeghi, M. Mahdavi, H. Haddadian. ‘DCGA Based-Transmission Network Expansion Planning Considering Network adequacy’, International Journal of Information Technology, vol 4(4) 2008

[2] M. Parsa Moghaddam, H. Abdi, and M. H. Javidi, ‘Probabilistic OPF Approach for Transmission Expansion Planning in Restructured Power Systems’, Iranian Journal Of Electrical And Computer Engineering, Vol. 7(1), Winter-Spring 2008.

[3] I. de J. Silva, R. Romero, C. A. Murari, ‘Transmission Network Expansion Planning Considering Uncertainness in Demand’, Proceeding of IEEE Power Engineering Society General Meeting, vol. 2, pp. 1424-1429, June 2005

[4] Rajeev Kumar Gajbhiye, Student Member, IEEE, Devang Naik, Sanjay Dambhare, and S. A. Soman, Member, IEEE, ‘An Expert System Approach for Multi-Year Short-Term Transmission System Expansion Planning: An Indian Experience.’, IEEE Transactions on Power Systems, vol 23(No. 1), February 2008.

[5] Gerardo Latorre, ‘Classification of Publications and Models on Transmission Expansion Planning’, IEEE Transactions On Power Systems, Vol. 18(2), May 2003

[6] Ali Khajeh Kazerooni, Member, IEEE , and Joseph Mutale, Senior Member, IEEE Transmission Network Planning Under Security and Environmental Constraints, IEEE Transactions on Power Systems, Vol. 25, No. 2, May 2010.

[4] A. R. Abdelaziz, ‘Genetic Algorithm Based Power Transmission Expansion Planning’, Proceedings of the 7th IEEE International Conference on Electronics, Circuits and Systems, vol. 2, pp. 642-645, December 2000.

[5] Gerardo Latorre, ‘Classification of Publications and Models on Transmission Expansion Planning’, IEEE Transactions On Power Systems, Vol. 18(2), May 2003

[6] Zhao Xu,Zhao Yang Dong,Kit Po Wong, ‘Multi-objective Transmission Planning’, IEEE ,2009

[7] S. Binato, M. V. F. Periera, S. Granville, ‘A New Benders Decomposition Approach to Solve Power Transmission Network Design Problems’, IEEE Transaction on Power System, vol. 16(Issue 2), pp. 235-240, May 2001.

[8] S. Jalilzadeh, M. Mahdavi and H. Hadadian, ‘A GA Based Transmission Network Expansion Planning Considering Voltage Level, Network Losses and Number of Bundle Lines’, Department of Technical Engineering, University of Mohaghegh Ardabili, Ardabil, Iran

[9] "Report of the Enquiry Committee on Grid Distubance in Northern Region on 30th July 2012 and in Nothern, Eastern & North-Eastern Region on 31st July 2012". http://www.powermin.nic.in.+16 August 2012.

[10] S. Binato, G. C. de Oliveira, A Greedy Randomized Adaptive Search Procedure for Transmission Expansion Planning, IEEE Transaction on Power System, Vol.16(Issue 2), pp. 247-253, May 2001

[11] Armando M. Leite da Silva, Luiz A. F. Manso, ‘Transmission Expansion Planning: A Discussion on Reliability and “N-1” Security Criteria’, IEEE, 2010 [12] R. Romero, A. Monticelli, A. Garcia and S. Haffner., ‘Test systems and mathematical models for transmission network expansion planning’, IEE ProcmLp.s online no. 2W20026, 2002.

[13] Tawfiq Al-Saba, Ibrahim El-Amin., ‘The application of artificial intelligent tools to the transmission expansion problem’, Electric Power Systems Research, Elsevier Science, vol 62, 2002.

[14] Jaeseok Choi, Trungtinh Tran, ‘A Method for Transmission System Expansion Planning Considering Probabilistic Reliability Criteria’, IEEE Transactions On Power Systems, vol. 20(3), August 2005.

[15] R. Romero, C. Rocha, J.R.S. Mantovani and I.G. Sanchez, ‘Constructive heuristic algorithm for the DC model in network transmission expansion planning’, IEE Proc..Transmission. Distribution., vol. 152(2), March 2005.

[16] Ashu Verma, P.R. Bijwe and B. K. Panigrahi., ‘Heuristic method for Transmission Network Expansion Planning with Security constraints and Uncertainty in load specifications.’ IEEE, T&D Asia,2009.

[17] Scott R. Dahman, ‘Advanced Sensitivity Analysis for Long-Range Transmission Expansion Planning,’, Proceedings of the 41st Hawaii International Conference on System Sciences 2008, 2008