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Contingency Screening Using Risk Factor Considering Transmission Line Outage

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***Abstract*—**Power system security analysis is the most time demanding process due to large number of possible contingencies that need to be analyzed. In a power system, any contingency resulting in security violation such as line overload or low voltage may occur for a number of reasons at any time. To efficiently rank a contingency, both probability and the extent of security violation must be considered so as not to underestimate the risk associated with the contingency. This paper proposed a contingency ranking method that take into account the probabilistic nature of power system and the severity of contingency by using a newly developed method based on risk factor. The proposed technique is implemented on IEEE 24-bus system.

***Keywords*—**Line overload, low voltage, probability, risk factor, severity.

I. Introduction

In a power system, any contingency resulting in security violation such as line overload or low voltage may occur for a number of reasons at any time. To limit the consequences of such events, power system operators usually maintain a deterministic security margin that takes into account only a limited set of contingency normally referred as critical contingencies. A typical set of critical contingency consists of a list of contingencies with severe impact, while the other possible contingencies are neglected. However, several recent major blackouts reported in Denmark, Sweden, Italy and United Kingdom have shown that deterministic security margin based on critical contingencies do not always prevent customer outage and system collapse [1].

The basic analysis method for contingency screening involves evaluation of security of a power system by using the complete AC power flow calculations considering all possible contingencies [2]. However, this method cannot satisfy the real-time demand due to the computation time constraints. A very well accepted contingency analysis procedure is by dividing the contingencies into a set of critical and non-critical contingencies [3]. In 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 [4]. Then, contingency screening based on the severity towards security violation is calculated.

Performance Index (PI) is the most commonly used indicator in contingency screening [7]. PI quantify the severity of contingency calculated using information obtained from power flow. However, if the probability of the transmission line outage is low, then the risk resulting from this contingency becomes relatively small, and in some cases it can be neglected [5]. Contingency screening using probabilistic concept has the ability to capture the probabilistic nature of contingency as well as its severity. In [5], research has shown that severe contingency might not be critical if the probability of occurrence of that particular contingency is low.

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This paper proposed a contingency screening and selection using risk factor in which both likelihood and severity of the contingency are taken into consideration. Result obtained from the proposed method is compared with the conventional screening method (i.e. using PI). The proposed method for screening and selecting the critical contingency is tested on the IEEE 24-bus power system.

II. Performance Index

In this study, the PI is calculated based on the continuous severity function associated with security violation. A transmission line outage is classified as critical if its PI is greater than the PI base case. Description of continuous severity function for low voltage and line overload are explained in the subsequent section. For fair comparison, the PI will be normalized between 0.1 to 0.9.

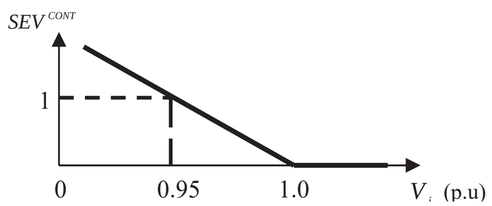

Fig. 1 Continuous severity function for low voltage

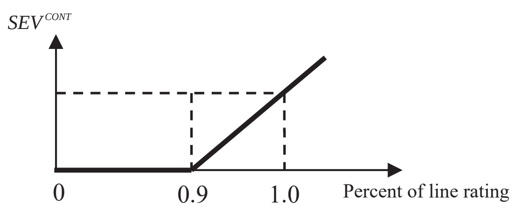

Fig. 2 Continuous severity function for line overload

III. Risk Factor

The probability of transmission line outage is assumed to follow Poisson distribution function and is written as [5]:

$$\Pr(E_i) = \lambda e^{-\lambda} \quad (1)$$

where λ is the failure rate of the transmission line.

The extent of security violation is measured by using severity function shown in Figs. 1 and 2 [6].

To screen the critical transmission line outages, the probability of transmission line outage and the severity of low voltage and line overload condition must first be computed. The probability and severity values are then normalized between 0.1 and 0. The normalized values of probability of transmission line outage and its severity are then classified into low, medium or high. Each class in the probability of transmission line outage is assigned a probability factor (PF) value of 1, 2 or 3 corresponding to low, medium or high probability of occurrence correspondingly. Similarly, each class in the severity function value is assigned a severity factor (SF) value. The classification of probability of transmission line outage and severity function value is shown in Tables I and II respectively. Based on the definition of risk, the risk factor (RF) is defined as,

$$\text{RF} = \text{Probability Factor} \times \text{Severity Factor} \quad (2)$$

TABLE I
CLASSIFICATION OF PROBABILITY OF TRANSMISSION LINE OUTAGE

Range	Class	PF
$0.1 \le \mathbf{Prob}_{norm} \le 0.36$	Low (L)	1
$0.36 < \mathbf{Prob}_{norm} \le 0.62$	Medium (M)	2
$0.62 < \mathbf{Prob}_{norm} \le 0.9$	High (H)	3

TABLE II
CLASSIFICATION OF SEVERITY FUNCTION VALUE

Range	Class	SF
$0.1 \le \mathbf{SEV}_{norm} \le 0.4$	Low (L)	1
$0.4 < \mathbf{SEV}_{norm} \le 0.8$	Medium (M)	2
$0.8 < \mathbf{SEV}_{norm} \le 0.9$	High (H)	3

TABLE III
RISK FACTOR VALUES ASSOCIATED WITH PROBABILITY FACTOR AND SEVERITY FACTOR

PF	SF	RF
1 (L)	1 (L)	1
	2 (M)	2
	3 (H)	3
2 (M)	1 (L)	2
	2 (M)	4
	3 (H)	6
3 (H)	1 (L)	3
	2 (M)	6
	3 (H)	9

Table III shows all possible risk factor values associated with the probability factor and severity factor. A transmission line outage is classified as critical if its risk factor value is greater than 1. A risk factor of 1 is chosen as the threshold for critical and non-critical contingency since the risk resulting from a transmission line outage with a risk factor of 1 is relatively small. This is due to the fact that the transmission line outage is a rare event and its probability is usually in the range of 10^{-7} to 10^{-5}, and the severity of a security violation can be as small as 10^{-2}, thus by multiplying a low probability event with low severity of security violation, the risk of transmission line outage will become even smaller. Therefore, the risk of transmission line outage with low probability of occurrence and low severity of security violation can be discarded since its risk is insignificant. Therefore, only transmission line outage with significant contribution to the risk index is considered for further analysis.

Depending on the type of security violation considered, the severity of a transmission line outage is computed and classified into L, M or H according to the classification table shown in Table III. Then, the risk factor of each transmission line outage towards low voltage and line overload are computed. The transmission line outage is considered critical if the risk factor is greater than 1. The critical transmission line outages associated with low voltage and line overload is stored in each respective contingency list. These procedures are carried out for all transmission line outages considered in the study.

IV. RESULTS AND DISCUSSION

Power flow simulations were performed using the PSAT software to examine the bus voltage magnitudes and power flows during transmission line outages. To screen the critical transmission line outages, the probability of transmission line outage calculated using (1) and severity associated with security violation must first be computed and then normalized between 0.1 to 0.9. The risk factor with respect to low voltage and line overload associated to line outage is calculated by using (2). Line outage event is considered to be critical if the risk factor associated to the line outage is more than 1.

From the calculation, the base case PI for low voltage and line overload is 0.107 and 0.100 respectively. Table IV shows the normalized PI, probability factor, severity factor, risk factor and risk values for each transmission line outage associated with low voltage where “c” and “nc” represents critical and non-critical line outage.

From the results presented in Table IV, both the PI and the proposed contingency screening methods indicate that only five out of 33 transmission line outages events are classified as non-critical line outages. However, it is noted that there are differences in the critical transmission line outages identified by both methods. This is due to the fact that the PI based method only evaluates the severity of a transmission line outage regardless of its probability of occurrence while the proposed critical line outage screening method considers both probability and severity factor values. In the proposed line outage screening method for low voltage, the transmission line outage with low probability and low severity factor values is discarded from further analysis since the risk of low voltage associated with these line outages is comparatively small.

TABLE IV
RESULT OF LINE OUTAGE SCREENING FOR LOW VOLTAGE

Line Outage			PI	Proposed Method			Risk
Line #	from bus	to bus		PF	SF	RF	(x10^{-5})
L1	1	2	1.52				0.697
L2	1	3	2.31	3	1	3	2.588
L3	1	5	2.09	2	1	2	1.381
L4	2	4	3.06	3	1	3	2.461
L5	2	6	1.89	3	1	3	1.959
L6	9	3	1.73	2	1	2	1.346
L7	4	3	3.17	1	1	1	0.108
L8	9	4	1.71	2	1	2	1.251
L9	0	5	1.48	2	1	2	1.014
L10	0	6	7.05	2	3	6	4.650
L11	7	8	4.10	2	2	4	2.422
L12	9	8	1.61	3	1	3	1.504
L13	10	8	1.77	3	1	3	1.653
L14	11	9	2.51	1	1	1	0.085
L15	12	9	2.92	1	1	1	0.100
L16	11	10	1.89	1	1	1	0.064
L17	12	10	1.88	1	1	1	0.064
L18	13	11	2.38	3	1	3	1.978
L19	14	11	1.72	3	1	3	1.385
L20	13	12	2.31	3	1	3	1.918
L21	23	12	2.33	3	1	3	2.676
L22	13	23	2.17	3	1	3	2.320
L23	16	14	3.29	2	1	2	2.568
L24	16	15	1.67	2	1	2	1.100
L25	21	15	1.49	3	1	3	1.276
L26	15	24	4.82	3	2	6	4.119
L27	17	16	1.63	2	1	2	1.150
L28	19	16	1.92	2	1	2	1.312
L29	18	17	1.57	2	1	2	0.998
L30	22	14	1.54	3	1	3	1.854
L31	18	21	1.53	2	1	2	1.083
L32	19	20	1.52	2	1	2	1.186
L33	23	20	1.51	2	1	2	1.033

From Table IV, lines L1, L9, L25, L32 and L33 are classified as non-critical based on the PI method but these line outages are considered critical based on the risk factor. The severities of these line outages (L1, L9, L25, L32 and L33) are considered low and their PI values are less than the base case PI, nonetheless their probability of occurrence cannot be neglected. Due to the high probability (L25) and medium probability (L1, L9, L32 and L33) of these lines outage, the risk of transmission line outage associated with low voltage contributed by those lines outage are prominent. On the other hand, lines L7, L14, L15, L16 and L17 are deemed to be critical based on the PI method but non-critical based on the proposed method. Both severity and probability factor of these lines outage events (L7, L14, L15, L16, and L17) are in the low range, therefore their resulting risk of transmission line outages associated with low voltage are relatively small. it is noted that the PI based method overlooked the effect of the probability of line outage in which the line outage event that is deemed to be non-critical has reasonably high risk values whereas the proposed screening method accurately screen the non-critical line outages due to the low risk values. Thus, the proposed screening method has the ability to efficiently screen only the high risk of transmission line outage associated with low voltage.

The result of transmission line outage screening associated with line overload is illustrated in Table V.

TABLE V
RESULT OF LINE OUTAGE SCREENING FOR LINE OVERLOAD

Line Outage			PI	Proposed Method			Risk
Line #	from bus	to bus		PF	SF	RF	(x10^{-5})
L1	1	2	0.00				0.000
L2	1	3	0.00	3	1	3	0.000
L3	1	5	0.00	2	1	2	0.000
L4	2	4	0.00	3	1	3	0.000
L5	2	6	1.12	3	3	9	1.163
L6	9	3	0.00	2	1	2	0.000
L7	4	3	0.72	1	2	2	0.025
L8	9	4	0.05	2	1	2	0.034
L9	0	5	0.00	2	1	2	0.000
L10	0	6	0.00	2	1	2	0.000
L11	7	8	0.00	2	1	2	0.000
L12	9	8	0.00	3	1	3	0.000
L13	10	8	0.00	3	1	3	0.000
L14	11	9	0.00	1	1	1	0.000
L15	12	9	0.00	1	1	1	0.000
L16	11	10	0.00	1	1	1	0.000
L17	12	10	0.00	1	1	1	0.000
L18	13	11	0.00	3	1	3	0.000
L19	14	11	0.00	3	1	3	0.000
L20	13	12	0.00	3	1	3	0.000
L21	23	12	0.00	3	1	3	0.000
L22	13	23	0.00	3	1	3	0.000
L23	16	14	0.00	2	1	2	0.000
L24	16	15	0.00	2	1	2	0.000
L25	21	15	0.00	3	1	3	0.000
L26	15	24	0.72	3	2	6	0.616
L27	17	16	0.00	2	1	2	0.000
L28	19	16	0.00	2	1	2	0.000
L29	18	17	0.00	2	1	2	0.000
L30	22	14	0.00	3	1	3	0.000
L31	18	21	0.00	2	1	2	0.000
L32	19	20	0.00	2	1	2	0.000
L33	23	20	0.00	2	1	2	0.000

From the results shown in Table V, lines, L5, L7, L8, and L26 have normalized PI values greater than 0.100, and these lines are considered as critical line outages based on the PI method. The screening of critical transmission line outages that result in line overload obtained using the proposed line outage screening method indicated that 29 transmission line outages have been identified as critical towards line overload.

The most severe transmission line outage associated with line overload is the outage of line L5 with severity factor value of 3. Based on the proposed method, despite the low severity factor values, the transmission line outages are still considered critical if the probability factor values of these transmission line outages are not in the low range. The proposed screening method does not only screen line outage with medium and high severity value but it also screens line outage with medium and high probability of occurrence. For example, outage of line L14, L15, L16, and L17 are not considered critical based on the proposed method since the probability of occurrence is low when compared with the other line outages.

V. Conclusion

The proposed line outage screening based on risk factor which takes into account probability and severity of line outage. Comparing the result of the transmission line outage screening based on the proposed screening method and the PI based method, it is shown that the PI method result in unnecessary computational burden because it overlooked the effect of the probability of line outage, hence the line that is classified as critical by using PI method may have a very low risk.

References

[1] Kirschen, D. S. & Jayaweera, D.," Comparison of risk-based and deterministic security assessments," *IET Generation Transmission Distribution,* vol. 1, No. 4, pp. 527-533. July 2007.

[2] Sidhu, T. S. & Cui, L.,"Contingency Screening for Steady-State Security Analysis by Using FFT and Artificial Neural Networks," *IEEE Transaction on Power Systems,* vol. 15, pp.421-426. August 2002.

[3] Castro, C. A., Bose, A., Handschin, E & Hoffmann, W.," Comparison of different screening techniques for the contingency selection function," *International Journal of Electrical Power & Energy Systems,* vol. 18, pp. 425-430. October 1996.

[4] Srivani, J. & Swarup, K. S.,"Power system static security assessment and evaluation using external system equivalents," *International Journal of Electrical Power & Energy Systems,* vol. 30, pp.83-92, 2008.

[5] Hazra, J. & Sinha, A. K.," A risk based contingency analysis method incorporating load and generation characteristic," *International Journal of Electrical Power & Energy Systems,* vol.32, pp.433-442, June 2010.

[6] Ni, M. , McCalley, J. D., Vittal, V. & Tayyib, T.," Online Risk-Based Security Assessment," *IEEE Transactions on Power Systems*, vol.18, pp.258-265, February 2003.

[7] J. Srivani & K.S. Swarup, "Power system static security assessment and evaluation using external system equivalents", Electrical Power and Energy Systems, Vol. 30, pp. 83-92, 2008.