Vulnerability Study In Power System Transmission

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Abstract—The optimum of the voltage stability is playing a major concern in the power system for the high demanding of the electrical power consumption
Because any failure will caused losses in term of money and productivity at the consumer side. The stability of the system including the generators, transmission lines and also the loads. To predict the probability outages occurred In the system the computer modeling technique is introduced to evaluate the elements of vulnerability in the power system. By applying of this method, the power system provider can determine the limitation of the system and at the same time to provide sufficient information regarding to the measures taken if the voltage collapse occurred. This paper presents the quantitative evaluation of the power system performance is conducted by using the Vulnerable Index (VI) and Margin Index (MI). These indices are used to keep the power system operating in the security level.

Keywords: Voltage stability, Security Level, Vulnerability Index, Quantitative.

I. INTRODUCTION

Due to the complexity and the hugeness of the practical power system network, the stability of power system has been divided into small portion such as transient stability, dynamic stability and voltage stability. The voltage instability is a kind of the system instability phenomenon is actually starts from one bus or a few buses and it will extended to entire power system. The effect of the instability in the power system is that, it might caused the stress over the conductors and as the result the insulator failed to act eventually blackout occurred. The major problems for the TNB is that, they do not know the security condition very accurate. When the unexpected things happen, the TNB has insufficient information to keep the system secure. If the outages occurred within the power system, it will establish the instability, if the appropriate load shedding had been taken, the large area blackout could be prevented[1]. For instance, in the year 2003, southern Peninsular Malaysia the

electricity blackout crisis affected the southern part of Peninsular Malaysia, including Kuala Lumpur, Selangor, Negeri Sembilan, Melacca and Johore due to the power failure.The Northeastern blackout in August 2003, the First Energy system operator did not know that they would run their system vulnerable due to the next contingency [11].The five States (Including Kuala Lumpur) had been affected for 5 hours from 10.00 am. The most terrible power outage in Malaysia was in 1992, all the peninsular Malaysia turned into darkness when the switchgear in Paka Terengganu was malfunctioned and consequently it puts so much stress on the grid system, therefore it is create the instability situation on the system and finally trips all the generator stations within the grid accordingly.

There are several methods that can be used to analyze the system security in the power system and one of the method is that by using the Performance Index(PI). This method was first proposed to evaluate the line loading and voltage performance, however to analyze the static security information for different elements, the PI method is can not be used [1].

In this paper, the method of Vulnerability Index (VI) and Margin Index (MI) are used to give more accurate information regarding to the whole system performance including from the generator level, the vulnerable indices for the real power output, reactive power output and generation loss and margin indices for real and reactive power output will be considered.

To perform the Vulnerability Index(VI) and the Margin Index(MI), the test specimen can be used instead of the real bus system. The available test system are 24-Bus IEEE RTS [11]. These test specimens are used in order to validate the system and also to get the results which is to understand the problems and also the behavior and action taken if those methods are applied to the real bus system.

II. THE APPROCH

The techniques of using the Vulnerability Index (VI) and Margin Index (MI) are the others way to evaluate the vulnerability and Margin of the individual element and for entire bus system.

Vulnerability Index and Margin indices for the generator can be valuated based on the following equations :-

$$= \frac{}{}\left(\frac{}{}\right) \quad (1)$$

(1)

$$= \frac{}{}\left(\frac{}{}\right) \quad (2)$$

$$= \quad (3)$$

$$= \sum \; + \; + \quad (4)$$

$$= 1 - \frac{}{} \quad (5)$$

$$= 1 - \frac{}{} \quad (6)$$

Where,

=VI of individual generator real power output
= VI of individual generator reactive power output
=VI individual generator loss

, = MI of individual generator real power output

, = MI of individual generator reactive power output

, = Weight of individual generator real power output

, = Weight of individual generator reactive power output

_ , = Weight of individual generator loss influence

, = Individual generator real, reactive power output

, = Maximum real power output of generator

, = Maximum reactive power output of generator

=1 when generator is off, 0 when generator is on

N= 1 in general

Vulnerability Index and Margin indices for the bus can be valuated based on the following equations :-

$$, = \frac{\quad ,}{} \left(\frac{}{\Delta \quad ,}\right) \qquad (7)$$

$$, = \frac{}{\quad ,} \left(\quad , \right) \qquad (8)$$

$$, = \quad , \qquad (9)$$

$$= \sum \left(\quad , + \quad , + \quad , \right) \qquad (10)$$

$$, = 1 - \frac{}{\Delta \quad ,} \qquad (11)$$

$$, = 1 - \quad , \qquad (12)$$

Where,

, =VI of individual bus voltage magnitude

, = VI of individual generator reactive power output

_ =VI of individual load bus load loss

_ = Total VI of all buses

, = MI of individual bus voltage magnitude positive if bus voltage within limit, zero or negative if it at or out of limit.

, = MI of individual load bus loadability

, = Weight of individual bus voltage power influence

, = MI weight of individual bus loadability

_ , = Weight of individual bus load loss influence

, = Bus loadability

= Bus voltage magnitude

=Schedule bus voltage magnitude

Δ , =Voltage variant limit

=Load loss ratio, 0~1, 0: no loss; 1: completely loss

N= 1 in general

The generators and buses were tested to determine the vulnerability and Margin indices. In IEEE 24 RTS. The values of all weights chosen in this calculation is 1 because to simplify the analysis, and value for the voltage variant limit is set to be 0.075 p.u

In this study, the value of the loadability is determined by using the program called **Automatic Voltage Stability Analysis** or AVSA computation technique[15]. The number of load bus and the bus value is fixed, the program will then running until it diverges. The maximum value is assigned as the loadability. Different bus will give different of loadability value, therefore all the loadability bus values will be taken and used into the vulnerability and margin index analysis.

III. RESULTS AND DISCUSSION

In this paper, the 24-Bus IEEE RTS system is being used to determine the vulnerability and security margin index. The power flow program is run to obtain the numerical result such as loads, voltages, bus output. Figure 1 illustrates the single line diagram for 24-Bus IEEE RTS.

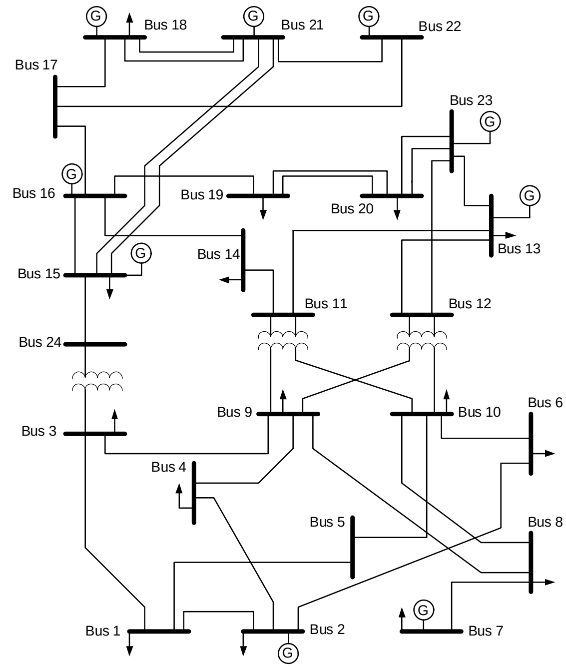

Figure1 IEEE 24 bus RTS single line diagram

For the load vulnerability assessment, the AVSA is initially run to obtain the maximum of loadability. IEEE 24 RTS is consist 1 Slack Bus,13 load buses and 10 generator buses. The procedure to obtain the results are shown as flow chart below

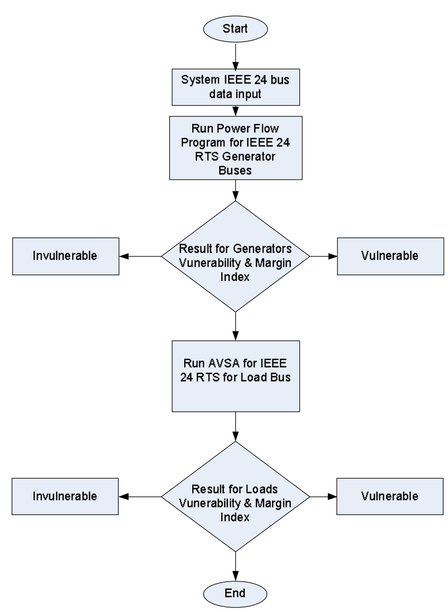

Figure 2 Vulnerability assessment flow chart

Table 1 shown the results obtained after the vulnerability and Margin index program for generator is executed.

Table 1

Gen	VIpg	VIqg	VIg	MIpg	MIqg
2	**0.1263**	**0.0299**	**0.7474**	**0.9403**	**1.00**
7	**0.0553**	**0.0353**	**0.8895**	**0.9232**	**1.00**
13	**0.1287**	**0.0343**	**0.7426**	**0.9314**	**1.00**
14	**0.2377**	**0.1346**	**0.5245**	**0.7309**	**1.00**
15	**0.1495**	**0.0435**	**0.7011**	**0.9131**	**1.00**
16	**0.1581**	**0.0624**	**0.6837**	**0.8752**	**1.00**
18	**0.0324**	**0.0032**	**0.9353**	**0.9936**	**1.00**
21	**0.0322**	**0.0022**	**0.9356**	**0.9956**	**1.00**
22	**0.0264**	**0.0191**	**0.9473**	**0.9617**	**1.00**
23	**0.0282**	**0.0192**	**0.9437**	**0.9617**	**1.00**

Table 2 below shown the total VI of all generators.The numerical results of these VI are calculated based the equation (4).

Table 2

TOTAL VI OF ALL GENERATORS	
BUS 2	**0.9036**
BUS 7	**0.9800**
BUS 13	**0.9056**
BUS 14	**0.8968**
BUS 15	**0.8939**
BUS 16	**0.9042**
BUS 18	**0.9708**
BUS 21	**0.9700**
BUS 22	**0.9927**
BUS 23	**0.9910**

The program is running to obtain the numerical results. The values of the selected bus are recorded.

Table 3 and 4 below shown the results of the Vulnerability and Margin index for the loads bus after the program is executed.

Table 3

BUS	VIv	VIloab	VIldloss	MIv	MIloadab
3	**0.362**	**2.16**	**1**	**1.8514**	**-1.08**
4	**0.0053**	**2.53**	**1**	**1.1033**	**-1.25**
5	**0.0828**	**4.5**	**1**	**0.5929**	**-2**
6	**0.278**	**3.92**	**1**	**0.2538**	**-1.8**
8	**0.0028**	**4.5**	**1**	**1.0749**	**-2**
9	**0.141**	**6.48**	**1**	**1.5310**	**-2.6**
10	**0.049**	**10.8**	**1**	**0.6865**	**-3.65**
11	**0.061**	**17.7**	**1**	**1.3484**	**-4.95**
12	**0.0173**	**10.6**	**1**	**1.1859**	**-3.6**
17	**0.0459**	**10.6**	**1**	**1.303**	**-3.6**
19	**0.165**	**15.1**	**1**	**1.5744**	**-4.5**
20	**0.192**	**102**	**1**	**1.619**	**-13.3**
24	**0.768**	**8.2**	**1**	**2.239**	**-3.05**

Table 4

TOTAL VI OF ALL BUSES	
BUS 3	**3.53**
BUS 4	**3.54**
BUS 5	**5.58**
BUS 6	**5.2**
BUS 8	**5.5**
BUS 9	**7.62**
BUS 10	**11.9**
BUS 11	**18.8**
BUS 12	**11.6**
BUS 17	**11.6**
BUS 19	**16.3**
BUS 20	**103**
BUS 24	**9.97**

In this study, the selected buses will be picked up and to be the value will be compared. For instance , the load bus no 3, 19 and 20 will be chosen. The bus values of each bus is set to be 205, 550 and 1400 Mvar. Since in the power flow program is utilized in the per unit system, the bus value will be divided with the base value i.e 100.

Table 5

VI load index	
BUS 3	**7.99**
BUS 19	**18.9**
BUS 20	**102**

Table 6

VI load index	
BUS 3	**8.21**
BUS 19	**18.9**
BUS 20	**107**

The bus values at the load at 3, 19 and 20 are determined. At bus 3, the bus value is set to be 205 Mvar, this values is chosen because form the analysis using the Fast Voltage Stability Index (FVSI) [14], the maximum load that can be injected to the bus 3 is 205 Mvar. For this reason, that value is used in this analysis in order to get the Vulnerability and Margin Index. The similar procedure to the bus 19 and bus 20. The bus values injected 550 and 1400 Mvar respectively.The result is shown in table 5

The result obtained in table 5 is compared to the values in the table 6. To run the vulnerability and Margin Index program, the maximum load of each loads is determined. The AVSA program is used to analyzed the maximum valued of each bus. The value is set and run until the program is diverges. The maximum load values is the value just before the AVSA program is diverges.The values form table 5 and 6 are compared and observed. The values are significant closed form one to another.

IV. CONCLUSION

The vulnerability and Margin index is a kind of method to determine the maximum loadability of the system before its collapse. The experiment is tested using the IEEE 24 RTS.

The value generated form this program can be used to understand and predict the vulnerability of the bus in the system. The benefit of the analysis is that the preventive and emergency steps can be taken to minimized the outages to the system.

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