Mvar Management On Load Bus For Meeting Voltage Stability Margin Using Contingency Analysis Method

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Abstract— **This paper presents Mvar management load bus for meeting voltage stability margin using contingency method. The study involves the development of algorithm to manage the VAR value at the load bus to identify the collapse point. Therefore power system researchers striving around the clock solely to propose the initiative steps in order to ensure in alleviating those sort of problem systematically. In this study, contingency due to line outage is implemented technique in prolonging the voltage capability due to load increment. The technique has been tested using IEEE 14 Reliable Test System (RTS) in demonstrating its capability.**

Keywords: **Blackout, contingency, capability, electrical, density, power.**

I. INTRODUCTION

Educating the user to inculcate of optimizing the usage of existing resources especially the electrical power is mostly encourage because of many reasons and in addition, the outcome of the electrical power usage saving scheme is to channel the total revenue losses that could be saved via the suitable activities. Moreover, the saving scheme is inadequate to keep the system reliable to operate. A unique model so called as linear programming model is proposed to reschedule the amount of load generated by generators. The aim of this method is to monitor the security of each bus load voltage and eventually the voltage is not exceeding the permissible limits and stable [1]-[3]. Frankly, in maintaining the system stable at all time is a tough challenge since the trend of the demand is fluctuating daily. The SYSCAN (System Collapse Analysis) is applicable to ensure the system security margin within its tolerance value and also this technique provide an indicator to inform whether the system is operating under stress [4]-[6]. As operating at the large system, the stress condition from the system become the key in order to take an initial precaution whilst a serious system collapse could be prevented before some abnormal situation in the network occurred. The abnormal condition is usually depending on constrains such as voltage and line power limit. Hence these factors have been becoming the benchmark for the power operator to conform the system without stirring any inappropriate actions. Since then, several techniques are proposed to see the system vulnerability from any corner. Furthermore, an expectation due to contingency based on dynamic security indices has spawned to the better power security assessment which is not offering in available static package. Since then, the real system analysis could be evaluated thoroughly. In other words, an application on dynamic system analysis (DSA) is used for more complex accurate estimation on system operation. In fact, the accurate evaluation on this dynamic involving entire generators rotor angles or simply known as centre of inertia (COI). This COI exhibits the significant of the stability achievement with respect to both kinetic and potential transient energy distribution [7]. Instead of dynamic indices analysis, the fuzzy intelligence approach has shown its versatility in solving power system security issue. Using this technique, the degree of severity within the power system parameter namely bus voltages and line loses are ranked due to various loading condition, hence it can be fuzzified based on contingency severity cases [8]-[11]. Nonetheless, the fuzzy only applicable for medium system and to overcome the deficiency, one method so called as look-ahead is proposed involving the large system for instance 1690 bus. Under this technique, the load prediction namely MW and MVAR have been carried out in order to observe the voltage variation. Consequently, a preparation of contingency action can be made [12]. Incidentally, this method requires both real-time data and predictive data before any forecasting strategy can show it superiorities. Despite, the available predictive only encapsulating the transmission line system. The radial system analysis for contingency in bulk power system is proposed. Research on this kind of system is exploited using radial basis function networks (RBFNs) which is incorporating with non-linear mapping capabilities [13]-[14]. From the mapping, estimation regarding to bus voltage and angle based on power mismatch can be determined. The power mismatch is considered acceptable if the error is small and reasonable. Anyhow, the costs effective operating scheme is important since the stability can be affecting the smoothest of the system operation. This paper proposed a systematical contingency analysis in mitigating the voltage collapse due to load increment to the load bus. The technique consist of the combination of lines searching which is only the problematic lines are considered. From the proposed method, the most severe bus which is identified earlier can be improved so that the system still can be operated although the system is operated under stress.

II. CONTINGENCY SCHEME IN POWER SYSTEM

Contingency scheme is a technique for solving a line or generator form the system. This is called as contingency due to line outage or generator outage. If a component is outaged or removed, this is termed as (N-1). On the other hand, more than one component can be removed from the system, which is termed as (N-M).

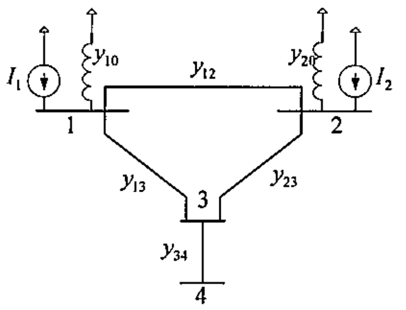

Figure 1. The Four bus system

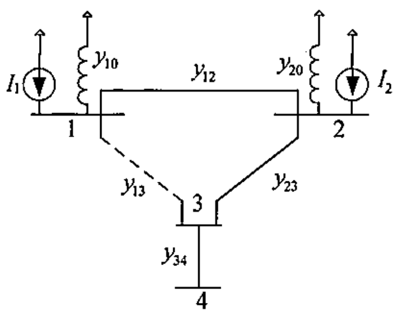

Figure 2. One line is disconnected

Figure 1 shows a simple 4 bus system which can be used to demonstrate single line outage contingency. If the line connecting bus 3 is removed, the power flow in the system will be affected. This effect is illustrated in Figure 2. The derivation of this system can be done by first applying the Kirchhoff 's Current Law (KCL) for each node, which can be explained by equation (1)-(4) [15].

$$I_1 = y_{10}V_1 + y_{12}(V_1 - V_2) + y_{13}(V_1 - V_3) \quad (1)$$

$$I_2 = y_{20}V_2 + y_{12}(V_2 - V_1) + y_{23}(V_2 - V_3) \quad (2)$$

$$0 = y_{23}(V_3 - V_2) + y_{13}(V_3 - V_1) + y_{34}(V_3 - V_4) \quad (3)$$

$$0 = y_{34}(V_4 - V_3) \quad (4)$$

Simplify equation (1)-(4), yields,

$$I_1 = (y_{10} + y_{12} + y_{13})V_1 - y_{12}V_2 - y_{13}V_3) \quad (5)$$

$$I_2 = -y_{12}V + (y_{20} + y_{12} + y_{23})V_{21} - y_{23}V_3 \quad (6)$$

$$0 = -y_{13}V_1 - y_{23}V_2 + (y_{13} + y_{23} + y_{34})V_3 - y_{34}V_4 \quad (7)$$

Equation (5) and (7) can be reduced to be :-

$$I_1 = (y_{10} + y_{12})V_1 - y_{12}V_2) \quad (8)$$

$$0 = y_{23}V_2 + (y_{23} + y_{34})V_3 - y_{34}V_4 \quad (9)$$

The admittances of each line for the system are given in equation (10)-(17)

$$Y_{11} = y_{10} + y_{12} + y_{13} \quad (10)$$

$$Y_{22} = y_{20} + y_{12} + y_{23} \quad (11)$$

$$Y_{33} = y_{13} + y_{23} + y_{34} \quad (12)$$

$$Y_{44} = y_{34} \quad (13)$$

$$Y_{12} = y_{21} = -y_{12} \quad (14)$$

$$Y_{13} = y_{31} = -y_{13} \quad (15)$$

$$Y_{23} = y_{32} = -y_{23} \quad (16)$$

$$Y_{34} = y_{43} = -y_{34} \quad (17)$$

However, if one of the lines is disconnected i.e line y_{13}, hence the flow in the line is zero, the line can be also be assumed to be removed. Rearranging equation (10), (12) and (15) yields

$$Y'_{11} = y_{10} + y_{12} \quad (18)$$

$$Y'_{33} = y_{23} + y_{34} \quad (19)$$

The reduced equations can be rewritten as in equation (21)-(24)

$$I_1 = Y'_{11}V_1 + Y_{12}V_2 \quad (21)$$

$$I_2 = Y_{21}V_1 + Y_{22}V_2 + Y_{23}V_3 \quad (22)$$

$$0 = Y_{23}V_2 + Y'_{33}V_3 + Y_{34}V_4 \quad (23)$$

$$0 = Y_{44}V_3 + Y_{44}V_4 \quad (24)$$

In general, equations (21)-(24) can be simply substituted into matrix form, hence

$$\begin{bmatrix} I_1 \\ I_2 \\ . \\ . \\ I_i \\ . \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & \cdots & & Y_{1n} \\ Y_{21} & Y_{22} & \cdots & & Y_{2n} \\ . & . & . & . & . \\ Y_{i1} & Y_{i2} & \cdots & & Y_{in} \\ . & . & . & . & . \\ & & \cdots & & \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ . \\ . \\ V_i \\ . \end{bmatrix} \quad (25)$$

Where

$Y_{11}, Y_{12}, \ldots Y_{1n}$ representing admittances in the transmission line.

$I_1, I_2, I_3 \ldots\ldots I_i$ representing current source in the transmission line.

$V_1, V_2, V_3 \ldots\ldots V_i$ representing voltage source in the transmission line.

Hence, the bus voltage at bus n, can be obtained

$$\frac{I_n}{Y_n} = V_n$$

Where

I_n = Current at line n

Y_n = Admittance at line n

I.SELECTION OF THE LINE.

The systematic solution finding strategy has been carried out in order to alleviate the instability bus voltage. Therefore to demonstrate the problem, an IEEE test system is used in this paper.

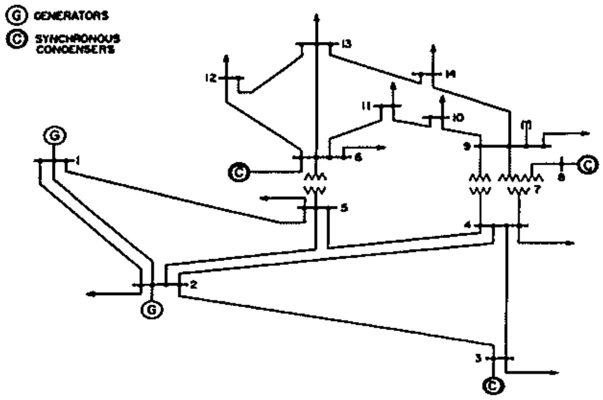

Figure 3: A typical 14 IEEE BUS RTS

Hence this study the IEEE 14 Bus RTS was taken as the test specimen. The single one diagram for the system is depicted in Figure 3. In general, this system equipped with 5 generators including slack bus and 9 load buses meanwhile there are 20 lines connecting from sending bus i and receiving bus j. In determining the critical load buses , the criteria are specified according to the voltage stability of each load bus. The standard limit in accessing bus stability is at 0.95 until 1.05 p.u..

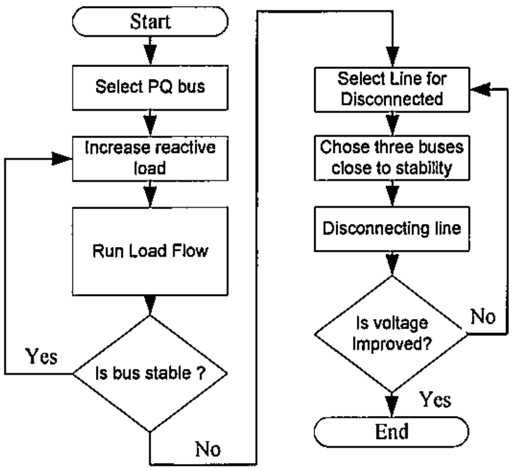

Figure 4. Flowchart for contingency analysis

In order to understand the technique of this experiment, the overall process of this method is summarized in the flow chart illustrated in Figure 4. From the flow chart, the process is continued until the improvements of the voltages are encountered.

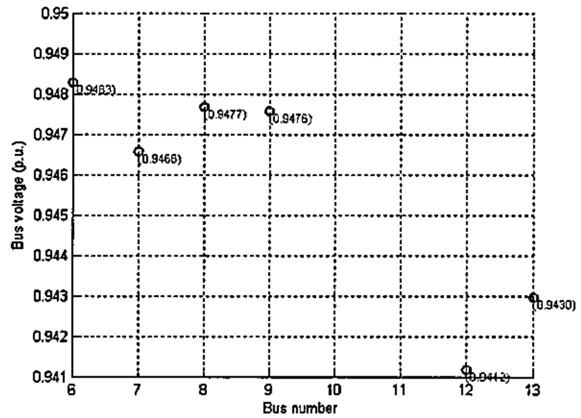

Figure 5: Selection of instability bus

Figure 5 illustrates the voltage for certain load buses namely load bus 6, bus 7, bus 8, bus 9, bus 12 and bus 13. However, only the top three of the load bus which is producing the highest voltage value is selected. Therefore, from the figure, the highest three are bus 6, bus 8 and bus 9. These buses have been chosen as the test specimen because, each of voltage namely bus 6, bus 8 and bus 9 generating the nearest to the stability point if compared to other three buses namely bus 7, bus 12 and bus 13. The buses begins to be unstable when each load are reaching 41 MVAR, 51 MVAR and 41 MVAR where the voltages are 0.9483 p.u, 0.9477 p.u and 0.9476 p.u respectively. Frankly speaking, in choosing the suitable outages line for contingency analysis, the line which is not connecting with generators and bus 6, bus 8 and bus 9 are chosen.

Table I: List of involve lines for bus 6, bus 8 and bus 9

Bus 6		Bus 8		Bus 9	
7	9	6	7	6	8
9	10	6	9	6	7
9	14	7	9	10	11
10	11	9	10	12	13
12	13	9	14	13	14
13	14	10	11		
		12	13		
		13	14		

Table I tabulates the suitable prospective lines need to be disconnected bus 6, bus 8 and bus 9. For instance at bus 6, the line connecting bus 7 to bus 9, bus 9 to bus 10, bus 9 to bus 14, bus 10 to bus 11, bus 12 and bus 13, bus 13 to bus 14 finally bus 7 and bus 9 are buses which not connecting with bus 6 and generators buses. The objective is to avoid the interruption the generator from supplying their power. Same elaboration applies for bus 8 and bus 9. Noticed that, the shaded rows in Table I indicates the not available buses.

II. RESULT AND DISCUSSIONS

In this section, the results of the proposed technique are shown in Table II, Table III and Table IV. In Table II, after transmission line connecting bus 7 and bus 9 has been disconnected, the improvement of voltage Vm(6) is from 0.9482 p.u. to 0.9509 p.u. Similarly to bus 8 and 9 where the voltage for Vm(8) and Vm(9) achieved when line connecting bus 9 and 14 and line connecting bus 6 and bus 7 is removed.

Table II: Result after line outage for bus 6

i	*j*	Q at bus 6 (MVAR)	Vm(6) After (p.u)	Vm(6) Before (p.u)
7	9	41	0.9509	0.9482
9	10	41	0.9480	
9	14	41	0.9487	
10	11	41	0.9433	
12	13	41	0.9481	
13	14	41	0.9450	

Table III: Result after line outage for bus 8

i	*j*	Q at bus 8 (MVAR)	Vm(8) After (p.u)	Vm(8) Before (p.u)
6	7	51	0.9396	0.9476
6	9	51	0.9445	
7	9	51	0.9471	
9	10	51	0.9472	
9	14	51	0.9481	
10	11	51	0.9440	
12	13	51	0.9476	

Table IV: Result after line outage for bus 9

i	*j*	Q at bus 9 (MVAR)	Vm(9) After (p.u)	Vm(9) Before (p.u)
6	8	41	0.9416	0.9476
6	7	41	0.9480	
10	11	41	0.9212	
12	13	41	0.9469	
13	14	41	0.9275	

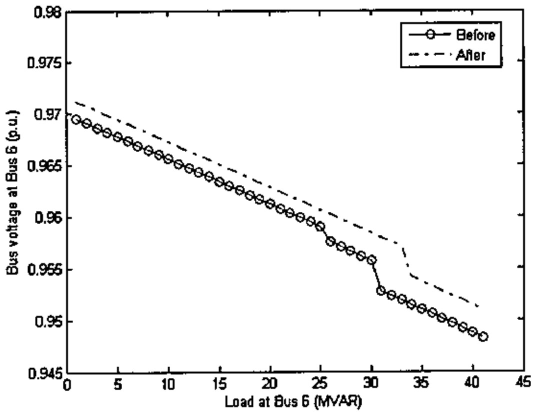

Figure 6: Voltage improvement at bus 6

The voltage profile for the voltage improvement for bus 6, bus 8 and bus 9 are illustrated in Figure 6, Figure 7 and Figure 8. From all the figures, the improvement are obtained after the line outage have been carried out as being mentioned previously.

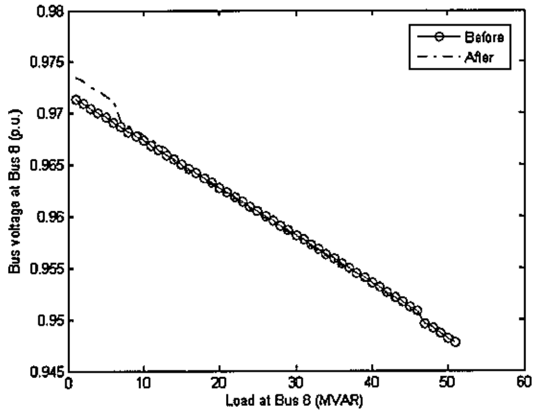

Figure 7: Voltage improvement at bus 8

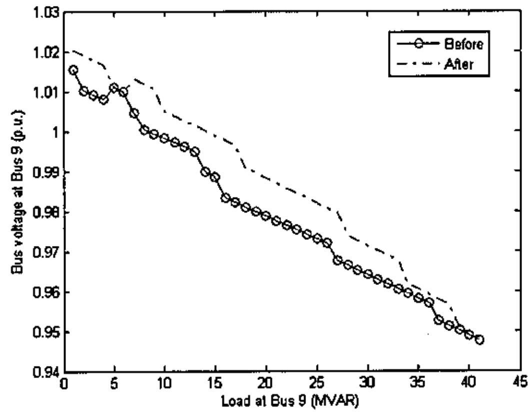

Figure 8: Voltage improvement at bus 9

III. CONCLUSION

This paper presents the technique of contingency analysis for managing VAR in maintaining voltage stability limit via contingency analysis. The system is starting to collapse once the loads are increased close to their maximum capability. From the conducted experiment, the results show that, improvement can be achieved when one of the line is removed, so that the initial voltage collapse due to load increment can be sustained. Further modification and improvement of the proposed technique in catering the complex and largest system.

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