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Voltage Profile Improvement by Reactive Power Injection using Fuzzy Inference System

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ABSTRACT— *With the increasing load, power systems are becoming indefensible to voltage instability. Voltage instability is a major concern for the secure and reliable operation of the power system. Voltage instability causes a progressive and uncontrollable decline in voltage. The main factor causing instability of the system is the inability of the power system to meet the demand of reactive power. Deficiency of reactive power support causes the bus voltage deviation from the allowed limits at the buses. The main focus is to raise the overall voltage of the system to avoid voltage instability. One of the methods to achieve this is by reactive power support. In this paper a fuzzy inference system based approach is used for determining the amount of reactive power to be injected at more sensitive buses in a network. Depending on the severity of the contingency, voltage sensitivity and the voltage of the buses during contingency, the amount of reactive power to be injected is decided. Sensitivity assessment is done to find out the lines which are most sensitive to instability. This approach is tested on IEEE 24 bus system.*

Keywords — contingency assessment, voltage sensitivity, performance indices, FIS.

1, INTRODUCTION

Voltage Stability is the ability of a power system to maintain bus voltage within acceptable limit under normal operating condition and after being subjected to a disturbance or change in system conditions like change in power demand [1].Voltage instability occurs due to operation at the edge of the limit and deficiency of reactive power in the system. A power system is reliable and stable if it withstands the outages which, leads to cascading events [2-4]. One of the main reasons for cascading effect is contingencies. Contingency is the loss or failure of one or more components of the system [5]. To enhance power system stability, reliability and security, contingency analysis and contingency ranking of the power system is done. The ranking of contingencies according to their order of severity is known as contingency ranking [6, 7]. Contingency ranking gives the information about the severity of contingency and weak lines present in the network so that they can be pre-defined and hence required corrective measures known in advance in case of that contingency can be taken [8, 9]. Sensitivity analysis gives useful information about weakest parts of the power system with respect to voltage instability. A system is voltage stable if V-Q sensitivity is positive for every bus and voltage unstable if V-Q sensitivity is negative for at least one bus [1, 10]. Sensitivity analysis is also applied to the assessment of voltage contingency ranking [10, 11]. A Fuzzy Set theory based algorithm is used to identify the weak buses in the proposed method [12-14].

2, CONTINGENCY RANKING AND VOLTAGE SENSITIVITY ANALYSIS

Contingency ranking is the process of listing the possible contingencies of system on the basis of their severity [15, 16]. Contingency in a system may be severe or critical [6].There are various existing methods used for contingency ranking [17]. Here, contingency ranking based on Performance Index (PI) is used [22]. Voltage sensitivity is taken from Jacobian matrix in power flow analysis [18].

$$\begin{pmatrix}\Delta P\\ \Delta Q\end{pmatrix} = \begin{pmatrix}J_{P\theta} & J_{PV}\\ J_{Q\theta} & J_{QV}\end{pmatrix}\begin{pmatrix}\Delta\theta\\ \Delta V\end{pmatrix}$$

Where,

Δ P = Incremental change in bus real power

Δ Q = Incremental change in bus reactive power

Δ θ = Incremental change in bus voltage angle

ΔV = Incremental change in bus voltage magnitude

$$\Delta V = J_R^{-1}\Delta Q$$
$$J_R = J_{QV} - J_{Q\theta} \times J_{P\theta}^{-1} \times J_{PV}$$

Where,

J_R= Reduced Jacobian Matrix

ΔV/ Δ Q = voltage sensitivity

- V-Q sensitivity is given by $\Delta V/\Delta Q$ which represents the slope of Q-V curve at a given point.
- If $\Delta V/\Delta Q$ is positive the system is Voltage stable.
- If $\Delta V/\Delta Q$ is negative or zero, the system is voltage unstable.[11]

3 PROPOSED SYSTEM

In this paper a method is proposed for determining the amount of reactive power to be injected at sensitive buses only in order to improve the voltage profile of the overall system by minimum reactive power support. It takes into account the voltage of buses, voltage sensitivity, performance index based contingency ranking and reactive power flow at that bus. FIS is used to determine the amount of reactive power support to be provided at the different buses [19].

3.1 Proposed Fuzzy Inference System (FIS)

In the proposed FIS, three inputs has been taken as shown in figure1PI based rank of the contingency, voltage of bus during contingency and voltage sensitivity at that bus. The output of the fuzzy inference system is the reactive power support factor [20].

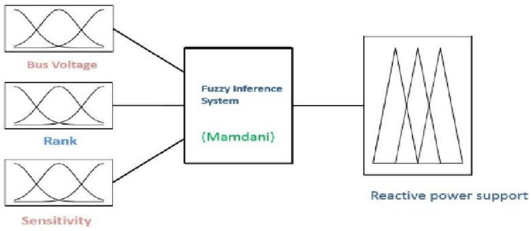

Figure.1 Fuzzy Inference system

IEEE 24 BUS is taken for the simulation of proposed method [21]. The amount of reactive power injection is based on the proposed method. 12th bus is considered as the slack bus.There is 42 outages. Here outage of line 6-10 is considered; figure 2 shows the output surface obtained from the developed FIS. From the figure 2, we see that as voltage increases or contingency severity decreases the output of FIS decreases. The output has highest magnitude for the lowest voltage and for the high credibility of contingency rank, as they will need more reactive power support for maintaining the voltage level within acceptable limits.

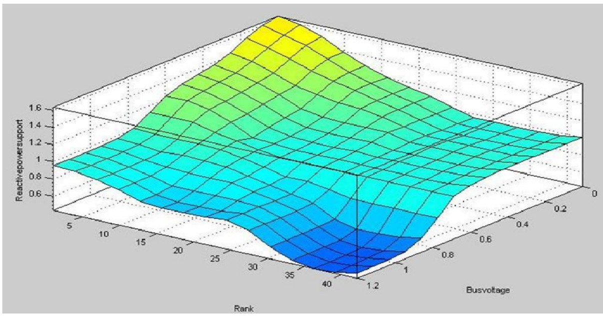

Figure.2 Surface view

Bus No.	V	V1	RPS	R1	R2	V2	V3	R3	R4	V4	V5
1	1	0.98	1.07	6.783	7.25781	1	1	55.191	59.05437	1.01	1.01
2	1	0.97	1.09	18.941	20.64569	1	1	1.304	1.42136	1	1
3	0.9374	0.9292	1.14	37	42.18	0.9385	0.9398	37	42.18	0.9418	0.9479
4	0.9583	0.9414	1.12	15	16.8	0.9609	0.9625	15	16.8	0.962	0.9647
5	0.9691	0.9559	1.1	14	15.4	0.9788	0.9815	14	15.4	0.9856	0.9888
6	0.9539	0.7617	1.32	28	36.96	0.9094	0.9047	28	36.96	0.9094	0.9047
7	1	1	1.03	36.429	37.52187	1.01	1.03	40.251	41.45853	1.02	1.04
8	0.9542	0.9518	1.1	35	38.5	0.9768	0.9919	35	38.5	0.9839	0.9997
9	0.9567	0.9517	1.1	36	39.6	0.9616	0.9645	36	39.6	0.9636	0.9684
10	0.964	0.9578	1.09	40	43.6	0.9692	0.9726	40	43.6	0.9725	0.977
11	0.961	0.9589	1.1	0	0	0.9635	0.9648	0	0	0.9647	0.9689
12	1	1	1.08	221.432	239.1465	1	1	232.047	250.6107	1	1
13	1	1	1.03	47.951	49.38953	1	1	51.56	53.1068	1	1

Bus No.	V	V1	RPS	R1	R2	V2	V3	R3	R4	V4	V5
14	0.9485	0.9477	1.11	39	43.29	0.95	0.9506	39	43.29	0.9505	0.9581
15	0.97	0.97	1.07	24.408	26.11656	0.97	0.97	34.856	37.29592	0.97	0.98
16	0.97	0.97	1.07	10.661	11.40727	0.97	0.97	11.241	12.02787	0.97	0.98
17	0.9894	0.9894	1.04	0	0	0.9911	0.9911	0	0	0.9911	0.9952
18	1	1	1.03	65.489	67.45367	1	1	65.228	67.18484	1	1
19	0.9674	0.9674	1.08	37	39.96	0.9674	0.9674	37	39.96	0.9674	0.9748
20	0.9838	0.9837	1.05	26	27.3	0.9837	0.9837	26	27.3	0.9837	0.9863
21	1	1	1.03	22.347	23.01741	1	1	22.597	23.27491	1	1.01
22	1	1	1.03	44.044	45.36532	1.02	1.02	44.088	45.41064	1.02	1.03
23	1	1	1.03	12.981	13.37043	1	1	11.994	12.35382	1	1
24	0.943	0.9382	1.14	0	0	0.9419	0.9419	0	0	0.9432	0.952

Table.1 Voltages during outage of line 6-10

V = Voltage under normal condition (p.u.)
V1= Voltage during contingency (p.u.)
RPS = Reactive power support factor
R1 = Reactive power flow under normal conditions (Mvar)
R2 = Reactive power injected (Reactive power support factor * Reactive Power flow under normal conditions) (Mvar)
R3 = Reactive power flow during contingency (Mvar)
V2 = Voltage after reactive power injection (Reactive power support factor *Reactive Power flow under normal conditions) p.u.)
V3 = Voltage when reactive power injected is 1.25 times reactive power flow under normal conditions (p.u.)
R4 = Reactive power injected (Reactive power support factor * reactive power flow during contingency) (Mvar)
V4 = Voltage after reactive power injection (Reactive power support factor * reactive power flow during contingency) (p.u.)
V5= Voltage when reactive power injected is 1.25 times reactive power flow during contingency (p.u.)

From table 1, we see that during contingency voltage at buses has dropped to a lower value. After reactive power support the voltages had risen. Figure 4 and 5 shows the voltage profile of the test system**.**

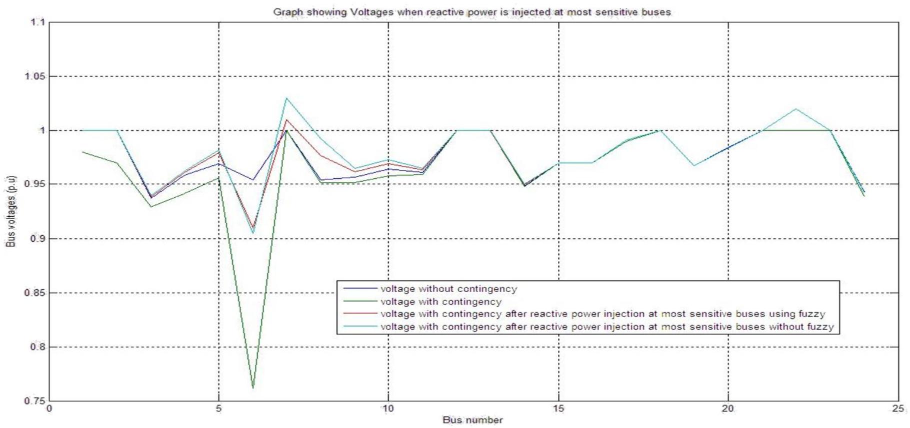

Figure.3 Voltage profile for PI Based contingency ranking 1, reactive power flow under normal conditions is considered.

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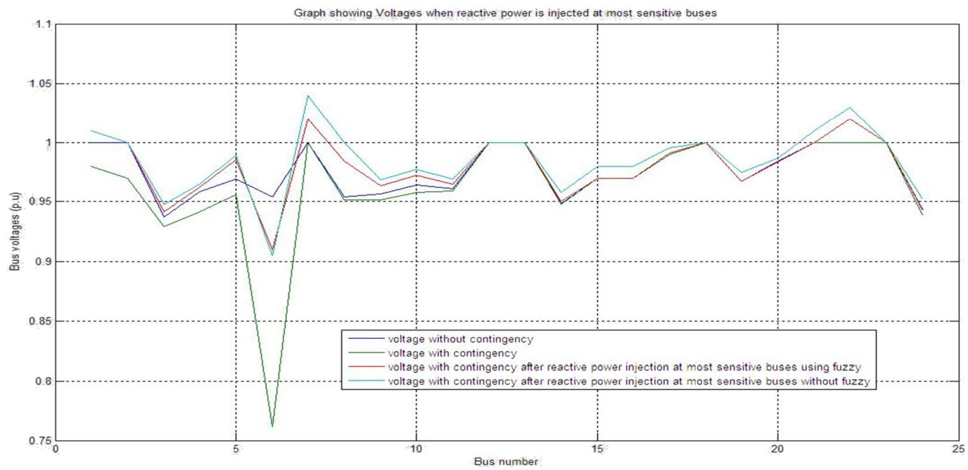

Figure.4 Voltage profile for PI Based contingency ranking 1, reactive power flow during contingency is considered.

IV. CONCULSION

Voltage profile is improved after reactive power support injected at sensitive buses only as seen from the figure3 and figure4. Voltage rises to a higher value when reactive power injected is 1.25 times the reactive power flow at buses under normal conditions and with contingency than the reactive power injected with the FIS system under normal conditions and with contingency. So reactive power support given through the FIS system is more optimized than 1.25 times reactive power flow at the bus. Also as we inject reactive power to sensitive buses only, we need less amount of reactive power as compared to injection of reactive power at all buses, and hence it is also an economical approach.

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