AN OPERATIONAL APPROACH OF SUPPLEMENTATION OF REACTIVE POWER NEEDS OF POWER UTILITIES.

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Abstract: Reactive power plays a vital role in maintenance of the grid stability. It is essential for transfer of the real power from source to load centers through the transmission and distribution system ultimately to reach the consumer. The issue of adequate supplementation of the reactive power needs, draws the attention of many practicing engineers and academicians, by finding a suitable and tractable solutions. Though they are many studies available still the power systems failures are happening on account of voltage instability due to inadequacy of supplementation of reactive power needs of power system. Voltage stability is concerned with the ability of a power system to maintain acceptable voltages at all buses in the system under normal conditions and after being subjected to a disturbance. A system enters a state of voltage instability when a disturbance such as an increase in load demand or a change in system conditions causes a progressive and uncontrollable decline in voltage in this paper it is focused on the issue to be considered for survival of power system in the event of critical disturbance. Here the investigation is carried out for diagnosing the low voltage buses to be supplemented with the reactive power support, so that all the buses in the system can have voltage incidence within the operable limits even at the incidence of occurrence of severe disturbance, so that the power system failure can be mitigated due to voltage collapse.

IndexTerms **– Power System, Reactive Power, Voltage stability, Critical disturbance, Constraints, Compensation.**

INTRODUCTION

Modern power systems in the new scenario of deregulation and restructuring, is experiencing the high degree of crusts and troughs, what so ever be the reasons like large expansion of grids, penetration of large generators without associated transmission system in place, weak inter-links, hidden failures in protection system, tendency to go far maximum utilization of the transmission network up to its maximum capabilities etc. The stability power system depends on the operating conditions, i.e. when the effective control actions are not applied or not enough, to the power system operating in emergency state, the system attains in extremes state, where in, the system may undergo cascading outages leading to blackouts. The major incidents of blackouts were experienced by many nations.

In order to maintain the power system security the active and reactive power balance constraints must not be violated. These types of constraints are called equality constraints. On the other hand there is another type called inequality constraints. The Inequality constraints include voltages, power angles, frequencies and thermal limits etc. During the system operation the operating conditions of the system can be classified as five states. Normal, Alert, Emergency, In extremes and Restorative. The system need to be protected when it tries to move from emergency to in extremis state due to voltage constraints violation.

To prevent such happenings of voltage collapse it is needed to identify the buses which are prone to very low voltages during disturbance .The required reactive power support is provided at the respective buses, so that all the buses will have voltages within the required margins.

Objective:

Though the state power utilities transmission system is designed considering the planning studies to meet the required demand taking care of equality and in equality constraints most of them could not survive in real time power system operation during critical disturbances. This aspect emphasized the need of relooking into the additional system requirements.

This paper is initiated to analyze and supplement the essential reactive power requirement to improve the voltage profiles at the instance of critical disturbance.

The strategic approach adapted:

The power system is modeled with the proposed demand by using CYMEFLOW module of the CYME international software.

The power solution is utilized, to determine the low voltage incident buses in the proposed system, violating the required margins under the scenario of disturbance.

The requirement of reactive power compensation is made by injecting the MVAR into the respective buses for improving the voltage profiles, without any voltage abnormality, so that it could survive even under the incidence of critical disturbance leading to voltage collapse.

In this study the power system is modeled representing the transmission lines generators and loads Modeling of the power system of the state utility .This is the most fundamental step involved in designing of the scheme, as the further analysis and development depends mainly on the outcome results based on this frame work, which will represent the real power system snap shot. Hence considering these aspects into consideration collecting the actual field data, the system is modeled with the existing transmission lines of 400kV,220kV and 132 kV voltages, power transformers of 315 MVA at rated voltages of 400/220kV,250 MVA power transformers at rated voltages of 400/220kV,200MVA power transformers at rated voltages of 400/220kV in 400kV network. The Power transformers of 160MVA at rated voltages of 220/132,100 MVA power transformers at rated voltages of 220/132, in 220kV network are considered in modeling of the transmission system. The existing of thermal, hydro and gas generators are considered in modeling the generators with their with rated MVA capacities, rated voltage and permissible ‘Q’ limits. The distributed loads incident on 132 kV substations are considered for load modeling with constant loads ‘P’ and ‘Q’. This is the total integrated system modeling for performing the required studies

Performing the load flow studies to represent the base case of the real time system, for maximum demand conditions .This step requires the preparation of the input quantities of the real power injections at the various generators and the load demand fed from each of the substations in real time system to meet the peak demand of the system of the state utility

The main task is, obtaining the power flows in the modeled system for the real time operation conditions meeting the maximum demand of the system. For this the base load studies are obtained by using the CYMFLOW software adopting the fast decoupled method.

INVESTIGATION OF THE POST disturbance scenario FOR ITS SURVIVAL

The region which is prone for collapse after disturbance is as shown in fig(1) ,is to be ascertained for its survival. Till date it is observed that, at the time critical disturbances leading to total power system black out due to the various reasons,of which the major issue i.e., considered will be the asynchronous oscillation arising and the power imbalances between the generation and demand in the system. In this context apart from this conventional finding outs of, the requirements, an additional attention is also made to go for investigation of the major phenomena of voltage limits violations.

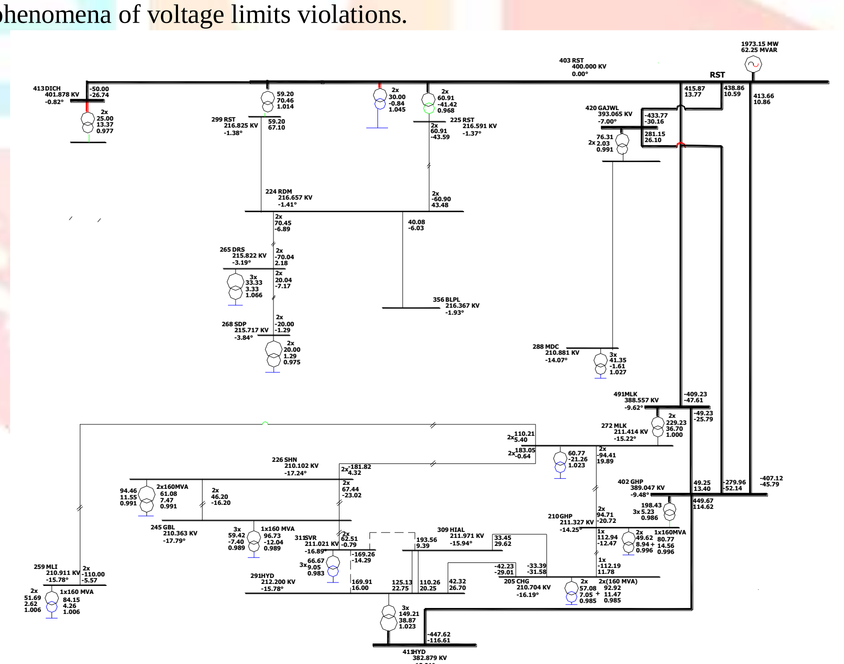

Fig. 1. Power Flow Diagram of Designed Island

Considerable focus is made on the realisation of the study state system limits, with respect to voltage collapse phenomena, for the survival of the system. When the situation demands, the voltage recovery in the critical region, the suitable reactive compensation technique is adopted which is physically carried out, for the reducing the system vulnerability to voltage collapse.

Factors affecting the voltage stability:

The devices that contributes for the voltage stability are like generator over excitation on load tap changers and compensation devices etc., the synchronous generator are the primary devices for voltage and reactive power control in power systems in the voltage stability studies the active and reactive power capability of generator is need to consider accurately achieving the best results. The limits of generator active and reactive powers are commonly referred as P-Q diagram. The P-Q diagram of the generator under consideration in this island scheme is shown below.

The active power limits are due to the design of turbine and boiler. Active power limits are constant and the reactive power limits are complicated which have a circular shape and voltage dependent. Normally the reactive power limits are described as constant limits in the load flow program as Q_{min} and Q_{max}. The dependence of generator reactive power limits is an important aspect in voltage stability studies. The limitation of the reactive power has three different causes. Stator Current Limits, Over Excitation Limits & Under Excitation Limits. When the excitation current is limited to maximum value, the terinal voltage is the maximum excitation voltage less the voltage drop in synchronous reactance. The power sytem has become weaker becaue the constant voltage has moved more remote from the loads

The stator current limit should be taken into account because the limit decreases when the voltage decreases. The stator current is more restictive than exictation current limit with terminal voltage of 1.0 and 0.9 pu when generator output is higher that 0.8 and 0.35pu respectively due to the voltage depedance the reactive capability increase when the terminal voltage decrease and generator ouput is less the previous values of output power. The stator current limiter is used to limit the reactive power output to avoid stator overloading. Generator reactive capability form the system point of view is generally much less than the indicated by manfacutures reative capability curves due to constraints imposed by power plant acceleries and power system itself. The acceleries system like pump fans etc., may stop due to under voltage which may cause triping of the power plant.

RESULTS AND DISCUSSIONS.

The study involves the identification of the nodes in the system where there are low voltages occurring as shown in fig(2).

From the power flow study results tabulated in table (I) the following buses were found with voltages incident out side the specified margins.

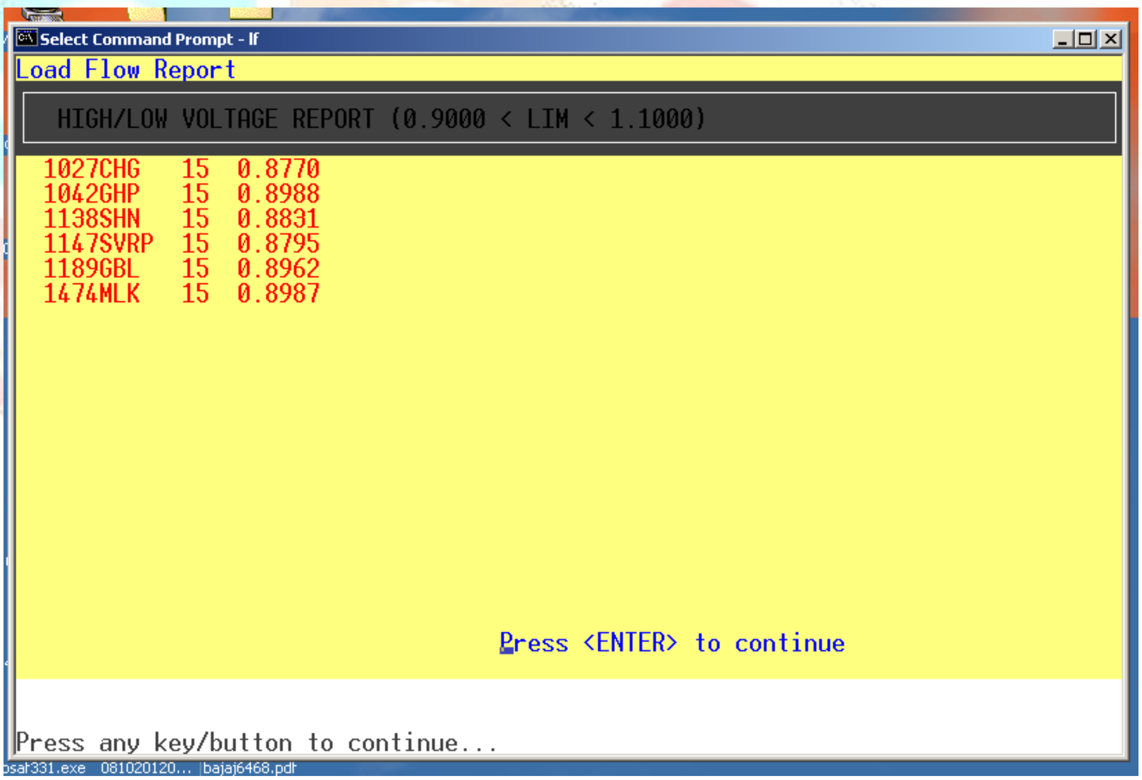

Fig. 2. Abnormal Voltage report from the load flow studies ,violating the required voltage margins

Table 1 Voltages incident at various bus locations in the critical region after the disturbance

BUS number	**Voltage Magnitude in kv**	**Voltage angle**
402	374.408	-9.7
403	400.000	0.0
411	365.903	-12.4

413	401.878	-0.8
420	382.391	-7.1
491	374.074	-9.8
205	199.124	-17.0
210	200.827	-14.9
224	216.657	-1.4
225	216.591	-1.4
226	198.226	-18.2
241	214.884	-1.4
245	198.340	-18.8
259	199.400	-16.6
265	215.822	-3.2
268	215.717	-3.8
272	200.168	-15.9
288	200.447	-14.5
291	200.986	-16.6
299	216.825	-1.4
302	216.672	-1.4
309	200.683	-16.7
311	199.376	-17.8
316	207.151	-9.0
356	216.367	-1.9
1027	115.766	-21.1
1042	118.640	-18.4
1078	137.683	-5.2
1089	119.383	-20.2
1127	139.596	-1.4
1131	138.100	-1.1
1136	126.101	-5.0
1138	116.564	-22.3
1147	116.094	-22.5
1168	126.322	-2.4
1189	118.293	-23.0
1370	122.891	-17.4
1474	118.634	-20.3

Table 2 Voltages incident at various bus locations with the reactive compensation

Bus number	**Voltage Magnitude in kv**	**Voltage angle**
402	382.572	-9.6
403	400.000	0.0
411	375.871	-12.2
413	401.878	-0.8
420	388.678	-7.0
491	382.428	-9.7
205	206.392	-16.5
210	207.283	-14.5
224	216.657	-1.4
225	216.591	-1.4
226	205.687	-17.6
241	214.884	-1.4
245	205.855	-18.2
259	206.709	-16.1
265	215.822	-3.2
268	215.717	-3.8

272	207.274	-15.5
288	207.891	-14.3
291	207.907	-16.1
299	216.825	-1.4
302	216.672	-1.4
309	207.662	-16.2
311	206.602	-17.2
316	211.602	-8.9
356	216.367	-1.9
1027	121.066	-20.3
1042	122.724	-17.7
107	137.683	-5.2
1089	124.401	-19.5
1127	139.596	-1.4
1131	138.100	-1.1
1136	126.101	-5.0
1138	121.336	-21.4
1147	120.734	-21.6
1168	126.322	-2.4
1189	123.150	-22.0
1370	128.300	-16.9
1474	130.217	-19.3

From the above results it is found that the voltages at some of the buses are found to be very low due to the reactive power deficiency.

Here the required remadial action is to be taken for maintaining the voltage stability in the post disturbance state. The suitable reactive compensation is done by adding the reactive power source at the respective load centers by installing the capacitor banks.

With the addition of these capacitor banks at various bus nodes experiencing the low voltages, again the power flow studies simulations are carried out. With this modifications the voltages incident at various bus are here with tabulated in the table (II)

Table 3 Ritive study of thee voltages incident at low voltages buses after the formation of island with and without compensation

Name of the Critical Buses	Voltages in the newly formed island without without compensation		Voltages in the newly formed with with compensation	
	PU	KV	PU	KV
1027	0.8770	115.766	0.917	121.066
1042	0.8988	118.640	0.930	122.724
1138	0.8831	116.564	0.919	121.336
1147	0.8795	118.634	0.915	120.734
1189	0.8962	116.094	0.933	123.150
1474	0.8987	118.293	0.986	130.217

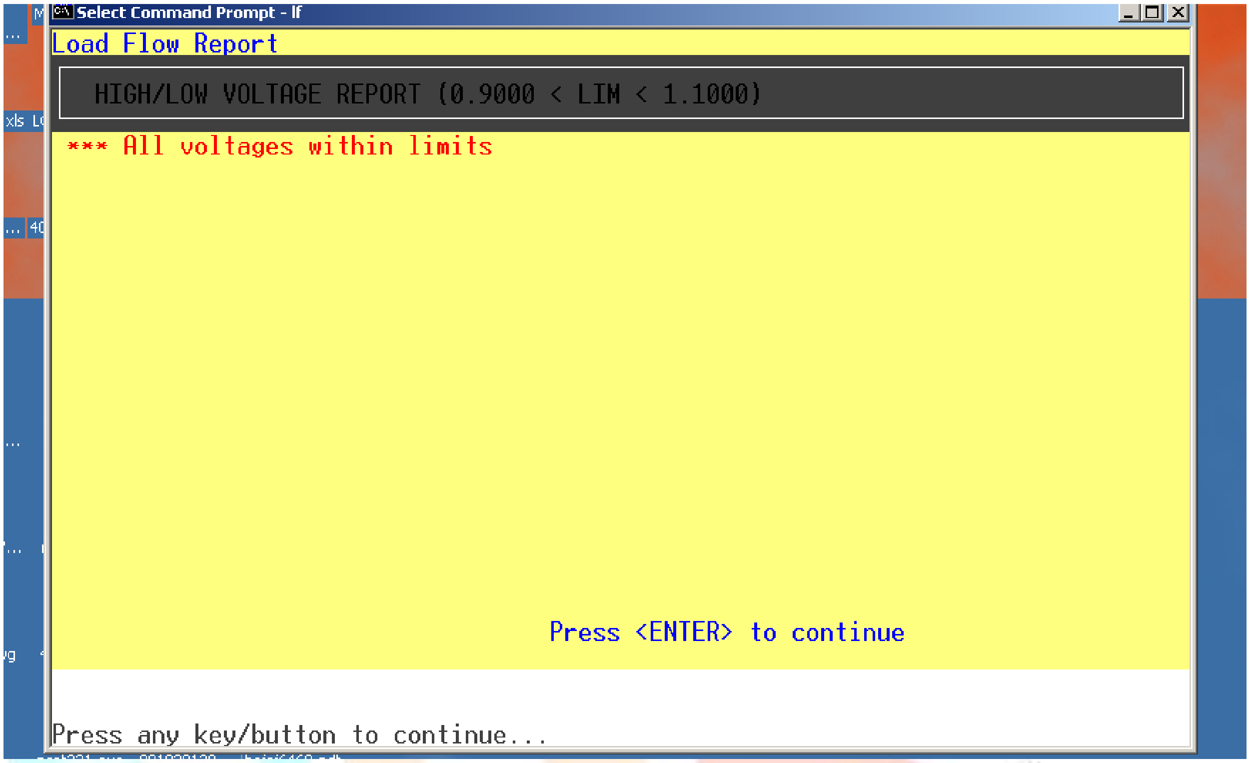

Fig. 3. Voltage report from the load flow studies after carrying out the reactive compensation

With this capacitive compensation it is found that the low voltages which were incident at some of the highly loaded buses were found improved as shown in the table (III) and the voltages are observed with in the required margins, even after the disturance, as per the load flow report shown in fig (5).

CONCLUSION

The power system of respective state utilities, though were designed for feeding the proposed loads by considering the maximum demand conditions, fulfilling the equality and in equality constraints, at the time of occurrence certain critical failures, it was observed that the system tends to collapse on account of, the insufficient supplementation of the reactive power in a particular region of the system. Hence from the operational considerations, it needs to be investigated for additional VARS supplementation, so that the system would be well equipped to meet the requirements even in case of critical failures also. Thus, the concern of the state utilities, to prevent the power system failure, due to voltage collapse Though the suggested operational approach, of supplementation of reactive power needs, is based study state considerations of real power systems operation, with the shunt capacitive compensation, when the real power system in this country gains the operational experience on STATVARS and SATACOMS it needs to focus on their applications in real time dynamic system operation conditions.

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