A STUDY OF POWER SYSTEM SECURITY AND CONTINGENCY ANALYSIS

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ABSTRACT
An important factor in the operation of a power system is the desire to maintain system security. System security involves practices suitably designed to keep the system operating when the components fail. An operationally "secure" power system is the one with low probability of system blackout or equipment damage. A secured system is one which has the ability to undergo a set of disturbances without getting into an emergency condition. In other word a normal operating condition of a power system is considered to be secured if there is neither any occurrence of over loading of any neither equipment nor transient instability due to a set of credible contingency. The secured condition satisfies not only the loading and operating constraints but a third set of constraints known as the security constraints. In the modern days the power system is becoming wide and complex. Contingency Analysis (CA) is critical in power system analysis. This work reviews the techniques for contingency analysis based on line flow analysis. Contingency analysis is performed considering the line and generator outage contingencies, in order to identify the effect of an increase in loading to critical line and generator outages.

Keywords- Contingency, Contingency analysis, Security, Security assessment, System monitoring.

I. INTRODUCTION

Power system security may be looked upon as the probability of the system's operating point remaining within acceptable ranges, given the probabilities of changes in the system (contingencies) and its environment. DyLiacco first pointed out in 1967 that a power system may be identified to be operating in a number of states. The three states are defined as follows:

A. *Preventive state*: The preventive state is actually the normal state. The term 'preventive' was used to stress the 'Security' aspect of the normal operation. Normal operating condition usually means that all the apparatus are running within their prescribed limits, and all the system variables are within acceptable ranges. The system should also continue to operate 'normally' even in the case of credible contingencies. The operator should 'foresee' such contingencies (disturbances) and take preventive control actions (as economically as possible) such that the system integrity and quality of power supply is maintained.
B. *Emergency state*: The power system enters an emergency state when some of the components operating limits are violated; some of the states wander outside the acceptable ranges, or when the system frequency starts to decrease. The control objective in the emergency state is to relieve system stress by appropriate actions.
C. *Restorative state*: Restorative state is the condition when some parts (or whole)of the system has lost power. The control objective in this state is to steer the system to a normal state again by taking appropriate actions.

An important part of security study therefore, moves around the power system's ability to withstand the effects of contingencies. A particular system state is said to be secure only with reference to one or more specific contingency cases and a gives set of quantities monitored for violation. Most power systems are operated in such a way that any single contingency will not leave other components heavily overloaded. So that cascading failure are avoided. Contingency analysis is the study of the outage of elements such as transmission lines, transformers and generators, and investigation of the resulting effects on line power flows and bus voltages of the remaining system. Contingencies referring to disturbances such as transmission element outages or generator outages may cause sudden and large changes in both the configuration and the state of the system. Contingencies may result in severe violations of the operating constraints. Consequently, planning for contingencies forms an important aspect of secure operation. System security can be said to comprise of three major functions that are carried out in energy control center:

A. *System monitoring*
B. *Contingency analysis*
C. *Corrective action analysis.*

System monitoring supplies the power system operations or dispatches with pertinent up-to-date information on the conditions of the power system on real time basis as load and generation change. Telemetry systems measure, monitor and transit the data, voltages, currents, current flows and the status of circuit breakers and switches in every substation in a transmission network.

The second major security function is contingency analysis. Modern operation computers have contingency analysis programs stored in them. These foresee possible system troubles (outages) before they occur. They study outage events and alert the operators to any potential overloads or serious voltage violations.

The third major security function, corrective action analysis, permits the operators to change the operation of the power system if a contingency analysis program predicts a serious problem in the event of the occurrence of a certain outage. Thus this provides preventive and post-contingency control .A simple example of corrective action is the shifting of generation from one station to another. This may result in change in power flows and causing a change in loading on overloaded lines.

II. POWER SYSTEM STATIC SECURITY LEVELS

In the diagram given below arrowed lines represent involuntary transitions between levels 1 to 5 due to contingencies. The removal of violations from level 4 normally requires corrective rescheduling or remedial action bringing the system to level 3, from where it can return to either level 1 or 2 by preventive rescheduling depending upon the desired operational security objectives. Levels 1 and 2 represent normal power system operation. Level 1 has the ideal security but is too conservative and costly. Level 2 is more economical, but depends on post contingency corrective rescheduling to alleviate violations without loss of load, within a specified period of time.

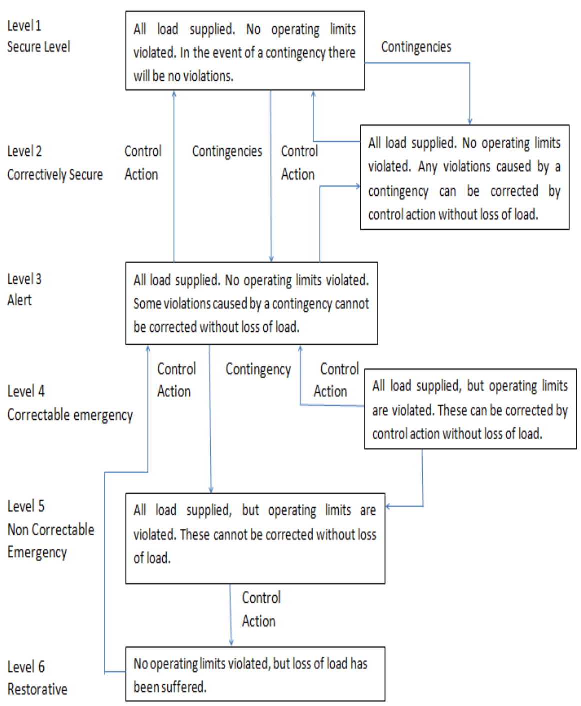

Fig. 1 Power system static security levels

III. SECURITY ANALYSIS

System security can be broken down into two major functions that are carried out in an operations control center.

A. Security assessment

B. Security control

The former gives the security level of the system operating state. The later determines the appropriate security constrained scheduling required to optimally attaining the target security level.

The static security level of a power system is characterized by the presence or otherwise of emergency operating conditions (limit violations) in its actual (pre-contingency) or potential (post-contingency) operating states. System security assessment is the process by which any such violations are detected.

System assessment involves two functions:

A. System monitoring

B. Contingency analysis

System monitoring provides the operator of the power system with pertinent up-to-date information on the current conditions of the power system. In its simplest form, this just detects violations in the actual system operating state. Contingency analysis is much more demanding and normally performed in three distinct states .i.e. contingency definition, selection and evaluation. Contingency definition gives the list of contingencies to be processed whose probability of occurrence is high. This list, which is usually large, is in terms of network changes i.e. branch and/or under injection outages.

The second major security function, security control, allows operating personnel to change the power system operation in the event that a contingency analysis program predicts a serious problem, should a certain outage occur.

IV. MODELING FOR CONTINGENCY ANALYSIS AND SELECTION

An unpredictable condition in the power system is known as contingency. The impact of the occurrence of contingencies should be evaluated. This process, usually called contingency analysis, aims at detecting post-contingency operational limits violations. Power systems are operated so that overloads do not occur either in real-time or under any statistically likely contingency. The contingency analysis is required to operate the power system in such a way that power is delivered reliably. Within the constraints placed on the system operation by reliability considerations, the system will be operated most economically. Primary purpose of maintaining power system security is to keep power system operation under stable condition, such that the Single line failure does not lead to cascade tripping and overall blackout. This is often called maintaining system "security" Simulator is equipped with tools for analyzing contingencies in an automatic fashion Contingencies can consist of several actions or elements. Simple example: -outage of a single transmission line. Complex: - outage of a several lines, a number of generators, and the closure of a normally open.The power system limits of most interest in contingency analysis are those on line flows and bus voltage, since these are soft limits, limited-accuracy models and solutions are justified.

The utility has to specify whether it wants to monitor post-contingency "steady-state" conditions immediately after the outage (system inertial response) or after the automatic controls. (Governor, AGC, ED) have responded. There are two main approaches Contingency Selection.

A. *Direct Methods*: These involve screening and direct ranking of contingency cases. They monitor the appropriate post-contingent quantities (flows, voltages). The severity measure in often a performance index.

B. *Indirect Methods:* These give the values of the contingency case severity indices for ranking .without calculating the monitored contingent quantities directly.

Simulation of line outage is more complex than a generator outage. Since line outage results in a change in system configurations. Any piece of equipment in the system can fail either due to internal causes or due to external causes such as lightning strikes, objects hitting the transmission towers or human errors in setting relays. As a consequence of above disturbances, single failure lead to cascaded tripping and overall blackout. Two major types of failure events

A. *Transmission line outages.*

B. *Generation unit failures.*

Transmission line failures causes changes in the line flows and voltages on the transmission equipment remain connected in the system therefore the analysis of transmission line failures requires methods to predict these line flows and voltages. So as to be sure they are within their limits. Generation failure can also cause line flows and voltages to change in the transmission system with the addition of dynamic problems involving system.

The present case discussed above is demonstrated considering the five bus system. Pre and post contingency data is given as follows for comparison.

S No	Bus No.	Voltage Magnitude	Power generated / load
1	1 Slack Bus	1.06 ∠ 0°	---
2	2 PV Bus	1.0474 ∠ -2.8°	40+j30
3	3 PQ Bus	1.02422 ∠ -5.0°	45+j15
4	4 PQ Bus	1.02866 ∠ -5.3°	40+j5
5	5 PQ Bus	1.0179 ∠ -6.2°	60+j10

Table 1. Pre Contingency Bus voltage Data

S No	Line No.	Flow of power (P + jQ)
1	1-2	88.9 – j8.6
2	1-3	40.7+j1.2
3	2-1	-87.5+j6.2
4	2-3	24.7+j3.6
5	2-4	27.9+j3.0
6	2-5	54.8+j7.3
7	3-1	-39.5 – j3.0
8	3-2	-24.3 – j6.8
9	3-4	18.9 – j5.2
10	4-2	-27.5 – j5.9
11	4-3	-18.8+j3.2
12	4-5	6.3 – j2.3
13	5-2	-53.7 – j7.2
14	5-4	-6.3 – j2.8

Table 2. Pre Contingency power flow

Case 1: When line from bus no 2-4 was open.

S No	Bus No.	Voltage Magnitude	Power generated / load
1	1 Slack Bus	1.06 ∠ 0°	---
2	2 PV Bus	1.0468 ∠ -2.6°	40+j30
3	3 PQ Bus	1.0107 ∠ -5.9°	45+j15
4	4 PQ Bus	1.0068 ∠ -6.6°	40+j5
5	5 PQ Bus	1.0114 ∠ -6.4°	60+j10

Table 3. Post Contingency Bus voltage Data

S No	Line No.	Flow of power (P + jQ)
1	1-2	81.8 – j5.5
2	1-3	48.6+j5.2
3	2-1	-80.6+j2.5
4	2-3	37.5+j7.3
5	2-4	---
6	2-5	63.1+j10.2
7	3-1	-46.7 – j5.3
8	3-2	-36.7 – j9.1
9	3-4	38.5 – j0.6
10	4-2	---
11	4-3	-38.4 – j1.1
12	4-5	-1.6 – j1.1
13	5-2	-61.6 – j8.9
14	5-4	-61.6 – j8.9

Table 4. Post Contingency power flow

Case 2: When generator outage at bus no 2 has taken.

S No	Bus No.	Voltage Magnitude	Power generated / load
1	1 Slack Bus	1.06 ∠0°	---
2	2 PQ Bus	1.0245 ∠-3.7°	20+j10
3	3 PQ Bus	1.0061 ∠-5.7°	45+j15
4	4 PQ Bus	1.0043 ∠-6.1°	40+j5
5	5 PQ Bus	0.9956 ∠-7.1°	60+j10

Table 5. Post Contingency Bus voltage Data

S No	Line No.	Flow of power (P + jQ)
1	1-2	123.8+j21.7

2	1-3	47.6+j7.3
3	2-1	-120.9 – j19.7
4	2-3	21.8+j1.5
5	2-4	25.6+j1.4
6	2-5	-53.6+j6.8
7	3-1	-45.9 – j7.6
8	3-2	-21.5-j4.8
9	3-4	22.4 – j2.6
10	4-2	-25.2 – j4.4
11	4-3	-22.3 – j0.7
12	4-5	7.5-j1.3
13	5-2	-52.5 – j6.5
14	5-4	-7.5 – j3.5

Table 6. Post Contingency power flow

V. CONCLUSION

The Contingency analysis is performed for the given 5 bus system and it is noticed that in Case 1, when the line from bus 2 to bus 4 were to open, the flow on the line 2-3 has increased to 37.5 MW and that most of the other line flows has also changed. It may also be noted that bus voltage magnitudes also get affected, particularly at bus 4; change is almost 2% less. In case 2, due generator outage result in change in line flows and bus voltages. All the generation lost from bus 2 is picked up on the generator at bus 1. In case there have been more there have been more than 2 generators in the system, say at bus no 3 also. It was possible that the loss of generation on bus 2is made up by an increase in generation at buses 1 and 3. The difference in line flows and bus voltages would show how the lost generation is shared by the remaining units. Again it is important to know which line or unit outages will render line flows or voltages to cross the limits. To find the effects of outages contingency analysis techniques are employed.

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