Module 6 : Preventive, Emergency and Restorative Control

Lecture 30 : A Blackout !

Objectives

In this lecture you will learn the following

- Definition of blackouts and their occurences.
- A detailed description of the January 2001 Collapse of Northern Regional Grid of India

When can a blackout occur ?

In the previous lecture we saw how a system can go from an alert state to an emergency state because of equipment limit violations or instability. The first line of defence against these undesirable transients is to carry out static and dynamic security analysis (using computer simulations) in order to check the system behaviour under different contingency situations (if they were to occur). Preventive Control actions ensure that any such contingency (if it occurs) does not lead to equipment limit violation or instability.

Emergency control actions come into play if an actual disturbance takes place and is evolving into an equipment limit violation or instability, or both. These actions try to prevent an emergency situation from deteriorating into a near-complete loss of generation and load (a **blackout** !).

Inspite of security analysis and preventive actions (done during actual operation), and emergency control actions (usually pre-designed offline), blackouts do occur. It should be understood that because of the large number and diversity of equipment in a power system, *every disturbance and contingency scenario cannot be anticipated* . Moreover there may be mal-operation of protective equipment and relays.

Therefore, blackouts have occured from time to time in the world. In this lecture we describe a real life event - the January 2001 blackout of the northern regional grid of India.

The January 2001 collapse of the Northern Regional Grid of India

North India enters new millennium shivering in the dark (Indian Express, Wednesday, January 3, 2001)
NEW DELHI, JANUARY 2: Virtually the entire northern India, from Jammu and Kashmir to Uttar Pradesh, faced its worst ever blackout in the last five years as seven states went without power for nearly sixteen hours since around four in the morning on Tuesday.....

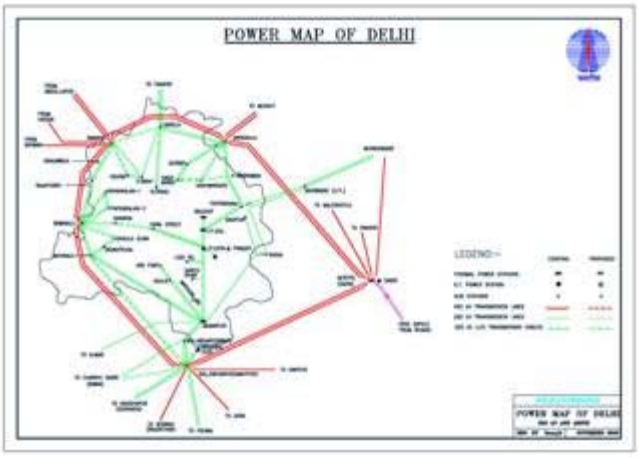
Overview of the Northern Regional Grid (adapted from the REPORT OF THE COMMITTEE ON GRID DISTURBANCE IN NORTHERN REGION ON 2ND JANUARY, 2001 authored by V.V.R.K.Rao & R.N.Srivastava - http://powermin.nic.in/reports/report_disturbance_northern_rg.htm, and the text of the submission by Power Grid Corporation of India Ltd (PGCIL) before the Central Electricity Regulatory Commission on 15-1-2001)

Northern Regional Grid is the 2nd largest inter-connected network (synchronous grid) in the country. As on 1st January, 2001 Northern Regional Power System had an Installed capacity of 27042 MW comprising of 8311 MW Hydro (31%), 17597 MW thermal (including GT and Diesel plants) (65%), and 1130 MW Nuclear (4.0%) and balance 4 MW wind. The share of state sector (16190 MW) and central sector (10852 MW) in the total capacity was 60% and 40%. The Region has a hydro-thermal mix of 31:69.During the period up to December, 2000, the Northern Region had been facing peak shortage of 10% and energy shortage of about 6%. Against a requirement of 98 billion units of energy, the actual met had been about 92 billion units. The peak demand met was of the order of 19860 MW against a restricted peak demand of 21740 MW. The shortages vary from month to month.

The Northern Regional Power System has major thermal power stations located at the coal based pit heads at Singrauli, Rihand, Obra and Anpara. The Region has major hydro electric power stations located in the Himalayan belt, such as Bhakra, Dehar, Pong, Chamera, Baira-Siul and Salal, Uri and the hydro power stations in the Yamuna region of UP. A number of thermal power Stations are also located near the load centres, such as

Tanda, Unchahar, Panki, Dadri, Parichha, Harduaganj, Badarpur, Indraprastha, Rajghat, Panipat, Ropar, Bhatinda, Suratgarh and Kota and also the Rajasthan and Narora Atomic Power Stations. Also the Region includes Gas Turbine Power Stations at Auraiya, Anta, Dadri, Indraprastha and Srinagar.

The large coal pit head thermal power stations are located in the extreme South-Eastern part of the Regional grid. Therefore, there is a large flow of power from the South-Eastern part to the Central and Western parts of the grid round the year. During winter months when the flows dwindle to their annual minimum value, many of hydro stations are shut down during night off peak hours. To handle the bulk transmission of power, a point-to-point high voltage direct current link, viz. ± 500 kV HVDC Rihand-Dadri bipole with a capacity of 1500 MW has been established which operates in parallel with an extensive 400 kV A.C. transmission system and the underlying 220 kV network. There also exists a high voltage 500 MW capacity back-to-back DC link between Singrauli in Northern Region and Vindhyachal in the Western Region over which power exchanges are carried out between the two regions. A 2x140 MVAR SVC (Static Var Compensator) is also provided at 400 kV substation at Kanpur which helps in improving the stability of the system. For a grid diagram of the system, view the same below (courtesy NRLDC website : www.nrldc.org).



(the above maps can also be viewed from this site : http://nrldc.org/nrldc/powermaps.asp)

(Click on the Maps to enlarge)

Situation prior to the collapse - An alert scenario

The following major links connect the large generation stations (total capacity > 6 GW) in the south-eastern part of the grid to the load centres in Western UP and Delhi.

a) **Rihand Dadri (±500 kV, 1500 MW) HVDC link. Power is transmitted on 2 wires which are ± 500 kV with respect to the ground (this is commonly known as a bipole configuration).**
b) **400 kV (AC) Singrauli- Kanpur-Ballabhgarh-Dadri**
c) **400 kV (AC) Singrauli-Lucknow-Moradabad-Muradnagar-Dadri**
d) **400 kV (AC) Singrauli-Vindhyachal-Kanpur-Agra-Ballabhgarh**
e) **400 kV (AC) Obra-Panki-Muradnagar**
f) **400 kV (AC) Anpara-Unnao-Agra-Muradnagar**

What we show here is only a "reconstruction" of what probably happened on that fateful night, based on manual observations and recorded measurements. Since all measurements and observations are not necessarily synchronised with a common clock, some amount of correlating or "pieceing together" of evidence is required. However some uncertainty is expected in the final sequence. A rigourous approach would involve simulation (numerically evaluating the response) of the entire sequence on a computer and correlating the same with the observed data. However, this is not shown here.

Time (Hrs.)	Event
1st Jan, 2001	1st Jan, 2001
23:21, 23:33 and 23:41	Transient faults on the operating pole-1 of HVDC Rihand-Dadri (POWERGRID) line. The line continued in operation with successful auto-re-starts.
23:49	Singrauli and Rihand Stations were asked to back down from 1840 MW to 1620 MW and from 910 MW to 810 MW respectively.
2nd Jan,2001	2nd Jan,2001
00:02	Transient faults on the operating pole-1 of HVDC Rihand-Dadri line. The line continued in operation with successful auto-re-starts.
00:17	Pole-1 of HVDC bi-pole was put on reduced voltage mode of operation thereby reducing power flow on this line from 750 MW to 500 MW.
01:05	400 kV Obra-Panki S/C (UPPCL) line tripped on fault and remained under breakdown.
01:07	Frequency goes above 51.0 Hz, NRLDC asked Singrauli and Rihand Stations to back down from 1620 MW to 1540 MW and from 810 MW to 730 MW respectively.
02:45 02:47 03:26 03:41 04:31	400 kV Agra – Ballabhgarh line tripped on Y-phase earth fault and auto reclosed.
03:11	400 kV Panki – Muradnagar developed fault. Circuit Breaker at Panki end did not operate resulting in back-up protection operation of Main bus A. 400 kV Panki – Kanpur II and ICT -II (inter-connecting transformer) at Panki connected to this bus also tripped.
03:12	400 kV Unnao – Agra line also tripped on fault.
03:18	System frequency rose to 51.2 Hz.

Situation prior to the collapse - Alert to Emergency

03:31	220 kV Narora Atomic Power Plant – Muradabad tripped on fault.
03:35	220 kV Panki – Fatehpur tripped on fault.
03:33 03:54	400 kV Agra – Kanpur line also tripped on B-phase earth fault and auto reclosed.
03:50	Load dispatcher asked Singrauli Generators to further backdown from 1480 to 1320 MW.

At 04:38 hrs, 220 kV Panki-Fatehpur line tripped on fault.

With all these outages, the system could not be kept in synchronism and the following lines tripped (as a consequence of relay response to an out of step situation) and the system separated naturally into 2 subsystems.

04:38 400 kV Lucknow – Moradabad, 400 kV Kanpur – Agra, 400 kV Kanpur – Ballabhgarh, East – West separation of Northern Grid took place.

The separation of the system into 2 islands need not have led to a complete blackout.

Since one island had excess generation, quick tripping of a few generators or govenor action could have stabilised frequency. In the under-generated island, under-frequency load shedding would have stabilised the frequency. However neither of these emergency measures were in place. Therefore,

04:40	Frequency of western part dipped and sub-system collapsed.
04:40 – 04:44	Frequency of eastern part shot up to more than 52.5 Hz. All running machines in eastern part tripped on over frequency and sub-system collapsed

Practically, whole of North India was plunged into darkness. A few generators survived by separating themselves from the rest of the grid and kept running supplying only their "house load".

Some of the major causes of the blackout can be summarised as follows:

a) Long duration of equipment (converter transformer) outage in the HVDC link

b) Heavy pollution and fog causing insulation flashovers.

c) Inadequate preventive control

d) Inadequate emergency control

After the blackout, it took almost 16 hours to fully recover and reconnect the grid. What are the issues in the restoration of the grid ?

We shall study restoration issues in the next lecture. In the meanwhile, can you carry out a survey of the recent blackouts which have taken place in the world ?

Recap

In this lecture you have learnt the following

- The various factors that contribute to a blackout.

- The sequence of events that led to the 2001 blackout in North India.

Congratulations, you have finished Lecture 30. To view the next lecture select it from the left hand side menu of the page.