STRATEGIES FOR OPERATIONAL PLANNING OF POWER DEFICIENT SYSTEMS – CASE STUDY OF WESTERN GRID OF INDIA

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Abstract

Most of the developing countries like India are experiencing rapid growth in demand as compared to availability and consequent power deficits.[1][2] Hence, the operational planning involves managing the shortfalls through increase in availability by garnering all other resources available and by planning of load shedding on long term basis (one year) and fine tuning every quarterly and on a month-ahead horizon. Further, the management of shortfalls has to be precisely planned in day-ahead basis as pre-dispatch activity. The day ahead planning comprises of planning short term open access transactions and planning of unscheduled load shedding. The management of deficit has to be further handled through balancing markets on the day of operation to account for demand forecasting errors, forced and partial outages of generating units etc. This operational planning exercise is very exhaustive and has to be planned meticulously in power deficient systems as the twin objectives of safe and secure grid operation and supplying adequate power to consumers often clash with each other. A case study for Western region of India is discussed with vivid description of all operational planning activities from one year horizon to the day of operation where about 7000 MW of power shortage has to be managed. The various managerial policies and criterion adopted for planning the demand control measures would be useful to other developing countries also.

I. INTRODUCTION

In Western region, the operational planning starts one year ahead in the month of June for the period July to June next year. The demand control measures planned include scheduled load shedding for each of the power utilities in the region and this is prepared by Western Regional Load Dispatch Center (WRLDC)[3]. The States also plan for short term open access transactions which are on the first come first serve basis in a month ahead horizon. Actions are also planned for increasing availability from resources like captive power plants (non utility sector). The day ahead planning includes demand forecasting by the States, scheduling of power from Central sector power plants, as well as entering into new open access transactions on day ahead/same day basis. The supply demand balance is achieved through scheduled load shedding with correction applied through planning unscheduled load shedding. The unscheduled load shedding accounts for fluctuations in availability due to forced outages, transmission outages, fuel related problems or demand fluctuations due to weather related factors and other important events. The scheduling exercise was done under the framework of availability based tariff. On the day of operation due to errors in demand forecast, forced outage of units, some of the States may require balancing power. The pricing of this balancing power is done through Unscheduled Interchange (UI) mechanism of availability based tariff (ABT). The UI mechanism also helps in pricing of deviations in case of open access bilateral transactions. A brief description of ABT is also included in the paper. In case

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system frequency goes below 49 Hz, the commercial mechanism normally ceases to operate and WRLDC impose emergency measures through which the States are directed to implement distress load shedding by opening pre-identified EHV feeders. Further, in case of contingencies and disturbances, Automatic Under Frequency Load Shedding (AUFLS) relays operate to save the system from collapse. A precise and elaborate methodology is required to identify / segregate feeders under various demand control mechanisms and defense mechanism.

Some of the states not carrying out proper operational planning exercise would not be able to plan their load generation balance (matching) resulting in inadequate scheduled / unscheduled load shedding. Such states overdraw from the grid causing security problem in operation. Consequently, they may also have to pay huge amount of UI charges to the UI pool account which puts financial burden on these states. The Central Electricity Regulatory Commission (CERC) emphasizes on the proper operational planning exercise to avoid such problems. Even though competition exists on the supply side, the tariff to the end consumers is fixed by the regulatory commissions and only minor variations are allowed by the Commissions. This puts emphasis on proper operational planning by the States to see that the cost of supplies and the revenues realized through fixed tariff to consumers are matched. The paper describes the details of various measures adopted by Western region.

II. OVERVIEW OF WESTERN REGIONAL GRID

(A) Power Supply Arrangements and Position

Western region comprise the state systems of Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh, Goa & Union Territories of Dadra & Nagar Haveli and Daman & Diu. The power supply in the states of Western region is managed by State Electricity Boards/Departments. These are originally vertically integrated utilities owning generation, transmission and distribution. Presently, the restructuring and reforms have taken place all over the region and these vertically integrated utilities have now been split into several utilities managing generation, transmission and distribution separately. Western region is also having some private utilities managing power supply in some licensed areas within the State. The region is also having power stations owned by Central sector utilities like National Thermal Power Corporation (NTPC) & Nuclear Power Corporation (NPC). All the states in the region are having allocations at the power stations owned by Central sector utilities. The region is also having some jointly owned power stations. The power from the NTPC stations is scheduled to the states on a daily basis based on the scheduling procedure given in Indian Electricity Grid Code (IEGC) and these stations are covered under ABT mechanism. The State grids are operated by State Load Dispatch Centers (SLDC) which are the apex bodies in the States while the regional grid is operated by WRLDC which is apex body for grid operation at the regional level. A strong backbone transmission network owned by Power Grid Corporation of India Ltd (PGCIL)[4], the Central Transmission Utility interconnects the State grids and helps in evacuation of the power from Central sector power stations to the state grids. The transmission network of PGCIL also interconnects Western region with other regions through synchronous / asynchronous interconnection. At present, Western regional grid is interconnected synchronously with Eastern and North Eastern regions while Northern and Southern regions are connected to Western region asynchronously through HVDC back to back links. The regional interconnections enable economy exchanges, short term bilateral transactions and long term bilateral transactions among the regional grids. The regional inter-connections have schedules based on the above transactions and deviations occur in case of synchronous interconnection or the Regional Load Dispatch Centers (RLDC) change the set points of HVDC back to back links in case of asynchronous interconnection to facilitate transfer of unscheduled exchanges. Such deviations are priced based on UI mechanism of ABT. A brief of scheduling procedure and ABT mechanism is described in the ensuing paragraphs.

Western region is having effective capacity of 34909 MW (including wind and diesel) as against peak demand of 33140 MW. Anticipated power supply position for the summer months of April/May is given in Tables-1 (a) & 1(b).

Table-1(a)
Anticipated peak demand position in April/May 2006 (MW)

Constituent	Effective capacity	Peak Demand Met			Demand	Shortage
		Own Gen.	Drawl from ISGS & bilateral	Total		
MSEB	13654	9100	2500	11600	16000	4400
GEB	8101	5100	1850	6940	9250	2300
MPSEB	4761	3000	1400	4400	5500	1100
CSEB	1371					
GOA	48	30	260	290	290	-
Central Sector	6974					
Western Region	34909	18530	6360	24890	33140	8250

Table-1(b)
Anticipated Energy Position (MUs/ day)

Constituent	Energy requirement	Energy availability	Shortage
MSEB	340	265	75
GEB	195	170	25
MPSEB	110	85	25
CSEB	49	40	6
GOA	5.6	5.6	0
W.R	700	566	134

The availability from all sources of the region works out to 24890 MW leaving a deficit of 8250 MW. This deficit is managed through scheduled load shedding of around 7000 MW. The day ahead load generation balance is achieved through planning of unscheduled load shedding. In case of contingencies on the day of operation, the adverse load generation balance is managed through distress load shedding. Table-2 gives the frequency profile for the month of April 2006.

Table-2

Frequency range	% time
< 49 Hz	34.88
49-50.5 Hz	65.11
> 50.5 Hz	0.01

About 35% of the time, system frequency is below 49 Hz and minimum frequency even touched 48.23 Hz. About 132 times frequency touched 48.5 Hz necessitating operation of under frequency relays at stage-I.

The actual power supply position with various performance indicators is given in Table – 3(a) and 3(b)

Table-3(a)
Actual Power supply position Apr'06

State	Demand Req.in MW	Availability MW	Shortage (%)	Energy Req.in MUs/day	Availability In MUs/day	Shortage (%)
GEB	9381	7898	15.81	180	163	9.67
MPSEB	5782	4209	27.21	45	40	22.78
CSEB	2267	1927	15.00	109	84	11.41
MSEB	16397	12498	23.78	347	267	23.09
Goa	367	367	0	7.32	7.07	3.45
D&D	182	182	0	3.69	3.56	3.40
DNH	326	326	0	7.42	7.20	3.03
WR	32383	25809	20.30	700	572	18.31

Table-3(b)

	GEB	MPSEB	CSEB	MSEB	GOA	Central Sector	W.R.
Installed Capacity (in MW)	8386	4770	1412	13641	48	6974	35231
Capacity under outage (in MW)							
Planned	274-349	0-0	0-0	620-830		0-210	274-559
Forced	0-339	0-0	0-0	0-420		0-1040	120-1644
Total (in MW)	274-688	0-0	0-0	620-1250		0-1250	394-2202
Import/Export From other regions (MUs)	927.39	1027.45	266.03	2094.68			4770.18
Daily Max.L/S (MW)	253-1100	0-1636	0-208	0-4291			369-6671

(B) A Brief on Scheduling Mechanism[5]

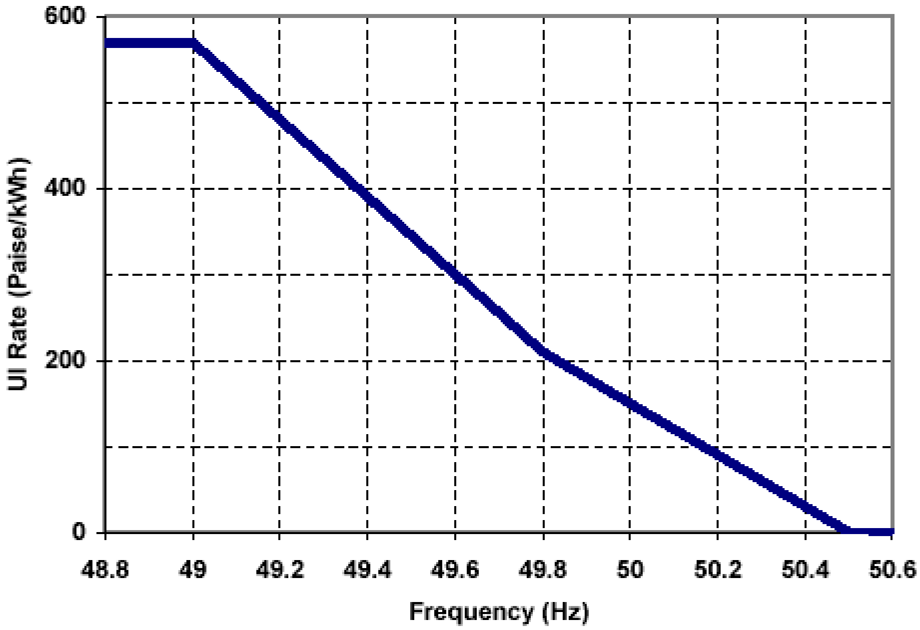
The states within the region have several shared power stations which include Central sector power stations covered under ABT mechanism. These stations are having allocations to all the states or some of the states within the region and are termed as Inter

State Generating Stations (ISGS) which are scheduled by the RLDCs. Under the scheduling mechanism, each ISGS has to declare their foreseen capability for the following day by 9 A.M. RLDC computes state-wise entitlements (based on allocations made by the Central Government) which are sent to SLDCs by 10 A.M. The states in turn furnish their station-wise requisitions against entitlements to RLDC by 3 P.M for each of the stations. The states arrive at these requisitions based on their forecasted demand, availability from own stations/IPPs, bilateral open access transactions entered into by them. The requisitions are made as per merit order. By 5 P.M each day, RLDC shall issue a schedule for all the ISGS stations (dispatch schedule) and to the states (drawl schedule) based on the requisitions of the states and operational feasibility based on network constraints. At this time, any un-requisitioned power at ISGS stations or surpluses/deficits available with the states would become known so that the pool members within the region and outside the region can enter into day ahead bilateral transactions which are supposed to be finalized by 10 P.M. Accordingly, the pool members would furnish revised requisitions to RLDC and the final schedule for the following day is issued by RLDC by 11 P.M. Based on the un-foreseen events or economic reasons, the states or the generating stations can revise their schedules. At times, schedules are also required to be revised due to transmission constraints. The scheduling mechanism forms the core of operational planning on a day ahead horizon. This exercise would also help in fine tuning the requirement of unscheduled load shedding.

(C) Brief on ABT Mechanism[6]

Severe deficit in the region leads to low frequency operation with overdrawls by one or more states on certain parts of the day and in surplus conditions high frequency problem coupled with under-drawl by one or more states are causing operation in a wide frequency range and also there is continued security threat. The ABT mechanism was introduced in the country with Western region being the first to introduce the mechanism from 1st July 2002. The mechanism is specially designed to suit the requirement of deficient power systems[7] and streamline the operation of regional grids. The scheduling mechanism requires all the state utilities to follow the schedule issued by the RLDC and all the ISGS to follow the generation schedule issued to them. Any of the pool members helping the grid by under drawing in a deficit situation would be compensated while those pool members overdrawing have to pay for deviations from schedules at high prices. The pricing of deviations from schedules are linked to system frequency. The mechanism enables separation of fixed and variable charges of generating stations thereby helping in merit order scheduling based on variable charges. The fixed charges are linked to availability rather than plant load factor. The third part of ABT is related to pricing deviation from schedules at frequency linked prices. The UI price curve is shown in Fig.1

Fig.1



The UI price curve has two slopes. The UI price at 50.5 Hz is zero and increased up-to 49.8 Hz (210 paise/ut) linearly with a slope of 6 paise from 0.02 Hz. The price of UI thereafter linearly increases at the rate of 9 paise per 0.02 Hz till 49 Hz. At 49 Hz and below the price of Ui power is 570 paise/unit. The UI mechanism of ABT helps in exchange of balancing power by the pool members. The generators or states are allowed to inject power into the pool or draw fro the pool at UI prices within a frequency band of 49-50.5 Hz. The UI mechanism also helps in pricing of deviation in case of open access bilateral transactions. If system frequency goes below 49 Hz, WRLDC would impose emergency measures by directing the states to implement distress load shedding by opening of pre-identified EHV feeders.

III. OPERATIONAL PLANNING

(A) Operational planning on yearly horizon

For the purpose of operational planning on annual basis, the year considered begins in July of the current year and extends till June next year. This period was selected due to the considerable impact of monsoon on hydro availability as well as its significant impact on demand. By the beginning of July each year, the progress of monsoon would be known and accordingly the forecast of overflow of hydro reservoirs can be done with a better approximation. First the hydro generation is allocated on monthly basis for the whole year from each hydro power station. The next exercise would be forecasting the demand for one year ahead. Due to significant rainfall, the agricultural demand (pump sets) would be absent during July to September. One criteria used is projecting the demand from only growth rates based on the previous years. The demand that can be met is also restricted to be total power available from all sources. In the monsoon months due to reduction of demand, most of the thermal sets would be taken out for annual overhaul. Generating unit outage planning is done month-wise and coordinated among various States and Central Sector utilities such that generation availability would not lead to significant load curtailment. For optimizing the outage planning, Loss of Load Probability (LOLP) criterion is used to optimize the load shedding. The forced outage and operational outage rates are determined from the past data. The transmission outage planning is also coordinated with generator outage planning and a coordinated outage plan for both generation and transmission is developed.

The monthly generation availability from thermal stations is computed based on the planned outages as indicated in the outage plan, assumed forced outage rate (13.5%) or based on past data and assumed partial outage rates (or 5%) based on auxiliary problems, fuel related problems etc. The availability from gas stations is also linked to fuel linkages and fuel supply constraints. The above exercise would give monthly availability from all sources within the region. The availability would be increased or decreased based on the forecasted bilateral transactions from other regions based on assessment. The month-wise forecasted demand and availability would indicate the surpluses/deficits in various months utility/state-wise.

(B) Operational Planning On Quarterly Basis

The operational planning exercise carried out for one year horizon is modified/revised on a quarterly basis based on the more current information. The first quarter July to September signify the monsoon season in which the demand is on the lower side due to absence of agricultural demand and is characterized by high hydro availability with some overflowing reservoirs at the end of the quarter. Since inflows are coming into the hydro reservoirs, the hydro generation is used to the full extent possible whereas many thermal generating stations are taken out for annual overhaul. During this quarter, the coal based generation face some constraints such as wet coal problem, flame failures, etc.

The quarter October to December is having high demand in the grid due to the onset of Rabi season when agricultural demand is predominant with many pump sets operating. This quarter also being the festival season, commercial and residential demands are also on the higher side. The success of monsoon in the earlier quarter determines the hydro availability for this quarter. Most of the thermal generation sets would be brought back from planned outages and all efforts would be made to minimize thermal outages.

The quarter January-March will have high demand similar to that of previous quarter due to continuation of agricultural activities. The industrial demand would also be at its peak as this is the last quarter of the financial year and production is maximized before the budget.

The last quarter April-June is having high residential and commercial loads due to summer conditions. The hydro reservoirs would be depleted and generation from run of the river hydro plants would be minimal. The forced outages from thermal generation are on the higher side due to high ambient temperature with many thermal units tripping on tube leakages. Sine it is difficult to carry out load shedding during this hot summer season, all efforts would be made to maximize generation availability.

Thus the outage planning, tieing up of open access transactions are closely linked to the planning on the quarterly horizon. The expected conditions of availability as well as demand in each quarters could be more precisely projected in the last month of the previous quarter. The western region being power deficient system, load shedding of the order of 7000 MW is carried out in almost 9 months of the year. Since the demand is exhibiting seasonal variations, the scheduled load shedding is planned on a quarterly basis and fine tuned every month in the monthly operating committee meetings. Based on the monthly shortfalls, the scheduled load shedding is planned as 80% of the shortfall forecasted in the quarterly review of the operational planning exercise. Margin of 20% is required considering the forecasting errors in demand, fluctuations in availability on daily basis, weather effects, availability of power assistance from other regions on day to day basis.

(C) Operational Planning On Monthly Horizon

The power supply position of the previous month and projections for the next two months are discussed in the monthly operating committee meeting by all the States and Central utilities to draw up coordinated actions plans. WRLDC prepares hourly scheduled load shedding for the next month based on the anticipated availability and demand. The changes in outage planning are also discussed in these meetings.

(D) Operational Planning On Day Ahead Basis

The commercial mechanism - ABT adopted in the country requires a thorough and precise operational planning on day ahead basis and this exercise is left to the individual States. Each State forecast their demand for the following day based on the past data. The EMS functions have a module for short term load forecasting based on load profile using historical data for same day/same week of previous years and another module based on weather forecasts. The forecast from each state is conveyed to WRLDC which compiles the data and prepares regional demand forecast applying diversity factors. The states also forecast availability from each of the power plants based on the latest information of plant availability, O&M, fuel linkages/constraints, partial outages (aux. problems) etc. The Central Sector stations forecast their availability and declare the same to RLDC for the purpose of scheduling exercise. The Central sector/jointly owned stations under ABT have to follow the detailed scheduling procedure given in Indian Electricity Grid Code (IEGC). Based on the declarations from Central Sector power plants, RLDC computes the entitlements of states and communicate the same to the States. The States have to make requisitions against these entitlements based on merit order. Plant-wise requisitions from the states are compiled to draw up schedule for each Central Sector plant and further tested for operational feasibility against transmission constraints after which the final schedules are drawn up. The day ahead operational planning exercise helps the states with large deficits to opt for un-requisitioned power sold out in some of the Central sector plants within or outside the region. The States can also decide upon open access transactions based on surplus/deficit scenario coming out of the day ahead planning exercise. To facilitate the operational planning exercise in vogue, the short term open access approvals are also structured to fit into the operational planning exercise. The short term open access transactions are structured/approved under the following categories:

- Approved for a period of 3 months maximum (bunching) which suits the requirement of quarterly planning.
- Transactions approved after the above quarterly approvals for a period not exceeding a month on first come first serve basis which fit into monthly planning exercise.
- Day ahead and same day transactions which fit into day ahead planning.

(E) Day ahead balancing

In case of deficient power states in the region, day ahead power balance can not be obtained without planning for load shedding. Out of the total deficits for the following day, scheduled load shedding takes care of a major portion of the deficits and the scheduled load shedding is planned and frozen atleast a month in advance and announced to public. The balance part of the deficit is taken care of through planning of unscheduled load shedding. The planning for unscheduled load shedding is an important activity in the day ahead planning exercise and unscheduled load shedding is nothing but a correction applied on scheduled load shedding. Unscheduled load shedding accounts for fluctuations in availability due to forced outages, transmission outages, fuel related problems, demand fluctuations due to weather related factors and other important events. The day ahead planning comprise the most important exercise of power balancing on a day ahead basis. The exercise involves day ahead demand forecast, forecast of availability, finalisation of schedules from Central Sector power stations and short term bilateral transactions already tied up in advance. In addition to these, trading of un-requisitioned power and bilateral transactions on day ahead basis also take place. The unscheduled load shedding for the following day is also finalized.

(F) Same Day Operational Planning

The scheduling exercise on day ahead basis was carried out under the framework of Availability Based Tariff and day ahead schedules are frozen at 2300 hours of the day for the following day. On the day of operation, due to errors in demand forecast, forced outage of units at Central Sector plants/ state plants, some of the States or central sector plants, sellers/buyers of short term open access transactions may revise their schedules – one and half hour ahead for planned deviations and one hour ahead for unforeseen problems. However, the deviations from schedules may require purchase of balancing power from the regional power pool. The pricing of balancing power is done through UI mechanism of ABT. The UI mechanism also helps in pricing of deviations in case of open access bilateral transactions.

IV. LOAD CURTAILMENT PLANNING

(A) Scheduled Load Shedding

Scheduled load shedding is announced usually a month ahead and wide publicity is given to the consumers. Computation of scheduled load shedding state-wise is done by WRLDC on an hourly basis and issued one month in advance and further staggering on intra-hour basis done by the States. The same is discussed in the monthly operating committee meetings and finalized. The scheduled load shedding takes care of around

80% of the projected shortfall of the states. The scheduled load shedding once announced is not changed based on the system conditions (frequency in real time) and is executed from the sub-stations exactly as per the pre-determined time intervals. This poses a problem in grid operation as scheduled load shedding is carried out despite high frequency conditions on a given day due to high availability or reduced demand. Further, scheduled load shedding is carried out in a sudden manner at the appointed time and is often not staggered by the state utilities. The suddenness give rise to sudden shoot up of frequency to very high level and can not be contained as turbine governors are not put into operation. Further, after about 15 minutes, scheduled load shedding done at other locations in the state is restored which again leads to a frequency dip. The sudden load shedding also gives rise to high voltages leading to tripping of some 400kV line on over voltage protection. Considering these aspects, the scheduled load shedding is staggered to the possible extent. The scheduled load shedding is implemented in the following ways:-

- Statutory cut on the maximum demand of high tension and low tension industries
- Statutory cut on the consumption of high tension and low tension industries.
- The rural feeders are made into groups and each group is shed for 8-12 hours in a day with number of groups shed at any point of time.
- Load shedding in urban areas for 1½ -3 hours in a day during morning and evening peak hours.
- Single phasing, a technique through which the agricultural loads and residential / commercial loads in the rural areas are separated and only 3-phase loads are subjected to shut down.
- Staggering of holidays through which power supply to a particular area is totally cut for about 12 hours.
- Recess staggering through which the lunch break and shift timings are staggered

The effect of some of the above measures for the month of April '06 can be seen from Tables 4(a) & 4(b).

Table-4(a)
Scheduled Load shedding

S.No	Scheduled L/S	Quantum(MW)
1	Power cut on HT/LT industries	159
2	Weekly off/Holidays staggering	300
3	Staggering of power supply	450
4	Effect of single phasing	1400

Table-4(b)
Power supply to Agriculture Sector (Average Hours per day)

	GEB	MPSEB	CSEB	MSEB
3-ph supply	6 hrs 30 mins	12hrs	21hrs	17hrs
1-ph supply	10 hrs	6 hrs	-	12 hrs
No supply	7 hrs 30 mins	6 hrs	3 hrs	7 hrs *****

***** Without single phasing facility.

(B) Unscheduled Load Shedding

Unscheduled load shedding is planned by the states on a day ahead basis after they carry out the load generation balancing exercise for the following day. The unscheduled load shedding is effected through different set of feeders other than those selected for scheduled load shedding. Since unscheduled load shedding is not announced before hand to the public, such load shedding gets maximum public resentment.

While scheduled load shedding is done on hourly basis, unscheduled load shedding is done only when the frequency dips below 49 Hz. Delayed actions in the implementation of scheduled load shedding cause dangerous frequency dips. As soon as any generating units trips when the frequency is below 49 Hz, unscheduled load shedding has to be implemented by the concerned States.

(C) Distress Load Shedding

In case of sudden loss of generation leading to frequency going below 49 Hz, distress load shedding is carried out to bring up the frequency above 49 Hz. Normally, the overdrawing states are directed by RLDC to effect the distress load shedding. However, when the frequency goes below 48.8 Hz or when RLDC declares system emergency, all the States are directed to carry out distress load shedding and the quantum of this load shedding is based on the stiffness of each state grid. The distress load shedding is carried out through identification of 66kV/132kV/220kV radial feeders which are opened by a emergency call from the load dispatch center. The distress load shedding prevents a major security threat in the event of frequency going down below 49 Hz and ensures operation between 49-50.5 Hz where ABT signals provide incentives/dis-incentives for the pool members. The distress load shedding also acts as a backup to the non-performing AUFLS Stage-I.

(D) Automatic Under Frequency Load Shedding (AUFLS)

This is basically defense mechanism against disturbances and include both discrete relays and trend relays (df/dt). The discrete relays are set at 3 stages 48.5 Hz, 48.2 Hz and 48.0 Hz with the quantum of load connected being 960 MW, 960 MW and 1280 MW. The trend relays are set in stages with settings of 49.2 Hz, 0.4 Hz/second and 49.0 Hz, 0.2 Hz/second giving a load relief of 2867 MW and 1911 MW. One of the constraint being faced is frequency touching 48.5 Hz on some occasions when the power deficit in the region is very high. Some of the states have a tendency to bypass these relays especially those at 48.5 Hz (stage-1) which is leading to a major security threat. It has also been found that some of the feeders to which under frequency relays are connected are included under scheduled or unscheduled load shedding and when the need arises, the requisite amount of load shedding is not forthcoming through AUFLS. These issues are continuously addressed by WRLDC and Western Regional Power Committee (WRPC) Secretariat also is required to inspect the healthiness of AUFLS by making surprise visits/checks to the sub-stations.

V. IMPLEMENTATION ASPECTS

(A) PLC based load shedding scheme

At some locations, programmable logic controller (PLC) based load shedding is implemented. This would help in allocating different feeders to different load shedding schemes viz., scheduled, unscheduled, AUFLS and also based on priority.

(B) Rotational Load Shedding Scheme

At sub-stations, roastering is done so that the same feeders are not subjected to load shedding again and again. In case of AUFLS, more feeders are used to get the relief. In case of tripping of a feeder on under frequency twice, such feeder can be bypassed from tripping again during the day.

(C) Rural Load Shedding

For the purpose of implementing scheduled load shedding, load shedding in rural areas is considered to a large extent and mostly includes agricultural pump sets. The rural loads are made into several groups and number of these groups are selected under scheduled load shedding for a part of the day usually ranging from 6-12 hours. When the groups under scheduled load shedding are restored with power supply, another set of groups would be taken under scheduled load shedding. Since the residential loads (single phase) and agricultural loads (3-phase) in rural areas are not segregated in number of states, scheduled load shedding in rural areas affect residential loads also especially on those groups selected for load shedding during evening peak hours viz., 1800-2200 hours. In order to avoid shedding of rural residential loads during night hours, a technique called 'single phasing' is implemented in some of the States partially. Single phasing enables segregation of single phase residential loads and 3-phase agricultural loads so that load shedding can be selective. One advantage of agricultural loads is that they can be shifted to any part of the day considering the availability of power. These loads even-though generate less revenue to the SEBs, flexibility of shifting these loads helps in flattening of the load curve to a large extent and indirectly help in reducing investment for meeting the peak demand.

(D) Voluntary Schemes

The States in Western region have also introduced voluntary schemes inducing consumers not to use particular type of loads (agricultural loads) during certain periods of the day. The scheme introduced in Maharashtra "Akshyay Prakash Yojana" in rural areas allows people in a village not to use agricultural loads on a voluntary basis during evening peak hours and the Electricity Board in turn ensures un-interrupted power supply to residential areas during night hours. Gujarat has also introduced a similar scheme called "Jyoti Gram Yojana". The above schemes are working satisfactorily and more and more villages are brought under these schemes.

(E) Urban Load Shedding

Load shedding is implemented in urban areas also due to severe power deficits and usually implemented through power cuts of 1½ hours to 3 hours in the morning and evening peak hours.

VI. CONCLUSIONS

1. This paper describes operational strategies for power deficient systems over various time horizons – one year to same day, in detail. The defence mechanism for maintaining system security are also described.
2. Operational planning is vital tool for proper assessment of power purchases to be made by the States, planning of scheduled load shedding and other load curtailment measures.
3. The day ahead operational planning is the most important exercise for grid operation. A state utility may inject UI or draw UI based on errors in the planning exercise. At times, the UI burden may be very high and regulatory commissions may impose restrictions on the purchase of UI.
4. The scheduled and unscheduled load shedding takes place every hour with some loads shed and some other loads restored leading to wide frequency fluctuations, over voltages and some times low frequency oscillations. At present, Power System Stabilizers (PSS) were tuned on number of generators and the problem of low frequency oscillations was overcome. However, trippings of lines on over voltage is a major problem. Further, system operators have to switch on reactors just before load shedding and immediately remove these reactors as new set of loads are restored. Staggering of load shedding over a wide area is a major and involved exercise. Replacement of existing over voltage relays with numerical relays has to be done due to difficulties in setting of drop off to pick up ratio.
5. It is also required to select feeders for UF & df/dt relays in widely dispersed manner as operation of these relays is sensitive to location of the disturbance.
6. IEGC was introduced in the year 2000 which has stipulations on outage planning. This has led to annual outage planning for both generators and transmission lines to be carried out for the financial year April to March[8]. This has changed the yearly operational planning horizon from July-June period to April-March period even though the philosophy is unchanged.

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