Operational & Commercial Issues for Power Plants to be set up in India

The intent of this paper is to familiarize the reader with certain ground realities and special features of operation of electricity grids in India, as also with the tariff structure adopted for large thermal power plants. The discussion herein would be of interest to all those proposing to participate in generating capacity augmentation programme of India, as plant designers, equipment suppliers, plant owners / operators and investors. The issues covered include:

1. Overall power situation in India
2. Must-run vs. load-following for nuclear plants
3. Scheduling and dispatch for nuclear and thermal plants
4. Grid frequency
5. Regulation and frequency response
6. Grid disturbances, islanding and load rejection
7. Voltage fluctuations
8. Availability tariff
9. Renewable energy

Overall Power Situation in India

Reliable operation of the large interconnected grids of North America and Europe is founded on established practices of tight frequency control and all control areas sticking to their respective interchange schedules. The grid frequency normally remains within +/- 0.03 Hz of the rated frequency, and any excursion beyond that is considered alarming. Utilities deviations from their schedules are minimal, and have to be made up in kind the next day. They are therefore not priced. Adequacy of generating capacity enables maintenance of requisite spinning and cold reserves at all times, for overcoming contingencies. In a regime with such discipline, all power plants must generate power according to the schedules decided by the concerned load dispatch centres, and pit-head and nuclear power plants can steadily operate at a substantially constant MW as per their respective schedule.

The situation, on each of the above counts, is very different in India. The peak-hour consumer demand far exceeds the available generating capacity. Capacity shortage is officially stated as around 15%. Load-shedding is a daily routine except in metropolitan cities and State capitals. Rural supplies are regularly rostered commonly and restricted to 8-12 hours a day in most States. State utilities, in their anxiety or compulsion to minimise load-shedding in their area, tend to overdraw power from the larger grid. Interchange schedules go for a toss, and frequency often plunges below the stipulated lower limits. As per a recent report, the frequency was below 49.2 Hz for about 25 % of the time during August 2009. On the other hand, industries and commercial establishments need back-up diesel generators for continued operation when power supply from the grid is cut-off or is curtailed (for a few hours every day), and domestic consumers have to bank on their own battery-backed “inverters” to get the basic amenities of „light and fan round the clock.

Since deviation from drawal schedules of State utilities are inevitable and substantial, and cannot be returned in kind, they are priced. Utilities pay for overdrawal, and get paid for under-drawal at a frequency-linked rate, which goes up as frequency declines and goes down as frequency rises.

With continuing growth of population, rise of general prosperity, and Governments commitment to supply power to all, the electricity demand growth would continue to outpace generating capacity augmentation, and grid frequency regime may not improve for many years to come. The power plants to be set up in India shall therefore have to be engineered to operate in such frequency regime without too adverse an impact on their life and efficiency.

Must-Run vs. Load-Following for Nuclear Plants

As of now, the aggregate generating capacity of nuclear power plants in India is only about 3% of the total installed capacity. Being so small a portion of the total generation, the nuclear plants have been allowed to generate their entire available capability, and no backing down during off-peak hours has been insisted upon by their customers, more so in view of the prevailing situation of overall generation deficit and because of the nuclear stations claiming a special status.

As the percentage of nuclear plant capacity in the total installed capacity increases in future (as is being aimed at), the above aspect would need to be reviewed. It may then not be put under the carpet simply by raising the issues of operational problems, reactor safety and fuel rods life. A much more pragmatic approach would be to bank on the low variable cost of the nuclear power generation, to get these commercial ventures to operate as base-load stations. In turn, this would require implementation of two-part tariff for nuclear plants, with clearly separated energy charge (to cover fuel and other variable costs) and capacity charge (to cover the fixed costs). As long as the energy charge rates of the nuclear plants are less than or of the same order as those of the coal-fired generation at pit-heads, the nuclear plants shall not be required to back down at any time. They would thus be running as must-run, without being categorised in that manner, and thus avoid the technical problems associated with load-following mode of operation, that too without any heart-burning.

The regional and State load dispatch centres (RLDCs and SLDCs) already have a mandate for optimum scheduling and dispatch, and have to ensure economic operation of the regional and State grids respectively. (Please see sections 28(3) and 32(2) of the Electricity Act, 2003 of India.) They would automatically schedule the nuclear plants for base-load operation if their energy charge rates are lower than or of the same order as those of pit-head stations. Further, as long as the above criterion is satisfied, it is not necessary for energy charge rate to reflect the true variable cost of a nuclear plant, which need not even be disclosed except in case of regulator-specified cost-plus tariff.
The fixed cost recovery shall have to be effected through capacity charge, payment of which may be proportional or directly linked to the day-by-day MW capability of the plants. The capacity charge rate could even be specified in Rupees per MW per day, or some similar formulation. Such a tariff mechanism is already an established practice for thermal (fossil fuel-fired) generation in India and the same could easily be replicated for nuclear plants. It would equitably take care of the legitimate interests of the plant owners as well as their customers.
Much debate is taking place in other countries about load-following capability of nuclear plants, particularly where they constitute a large percentage of the total generating capacity. This would not be an issue in India, since nuclear capacity would remain below 20% of the total installed capacity for many decades to come. As long as their variable costs remain well below those of load-centre coal and other fossil-fired stations, nuclear plants would not have to do any load-following, i.e. they would not be required to back down during off-peak hours.
Let me clarify here that by load-following discussed above, I mean variation of generation over the day (from peak-load hours to off-peak) to match the variation in total system load hour-by-hour. Such duty is to be performed by thermal stations having higher fuel costs and by hydro-electric stations. With the foreseen generation mix, it is expected that nuclear and pit-head generating stations would always be scheduled to operate as base-load stations. However, they would still be required to have primary speed control and regulation (to be discussed later) to collectively shoulder the minute-to-minute fluctuations of system load and load-generation mismatch.

Scheduling and Dispatch for Nuclear and Thermal Plants
The nuclear power plants would have large capacities and would generally be contracted to sell power to more than one State. They would therefore, fall within the jurisdiction of Central Electricity Regulatory Commission (CERC), and would have to comply with the Indian Electricity Grid Code (IEGC), which can be accessed under „Regulations on the CERC website (www.cercind.gov.in). Such plants shall be scheduled by the Regional Load Dispatch Centres (RLDCs) according to Chapter – 6 of the IEGC, directly relevant parts of which have been annexed to this paper. A perusal of sections 6.4 and 6.5 is recommended. It would be observed that India has opted for a scheme of decentralized control, in which generating stations are scheduled on day-ahead basis by the load dispatch centres, but are permitted self-dispatch depending on plant and system conditions. An important implication of this is that the plant operators need not be very precise or fussy about declaration of plant availability,and about generating power strictly as per schedule. Also, since deviation from schedule are permitted, it is not necessary to have the schedules revised every time the generation level has to be changed, either an account of plant availability variation or due to system load-generation balance changes.

Grid frequency
Frequency is the most crucial parameter in the operation of an A.C. system. The rated frequency in India is 50.0 Hz. While the frequency should ideally be close to the rated frequency all the time, it has been a serious problem in India. There was a time it varied from below 48.0 Hz to above 52.0 Hz, even beyond its legally permissible limit of +/- 3%, i.e. from 48.5 Hz to 51.5 Hz as per Indian Electricity Rules, 1956. After introduction of Availability tariff in 2002-03, the frequency has remained in 49.0 - 50.5 Hz band for most of the time. Further attempts are on since April 2009 to narrow down the band to 49.2 – 50.3 Hz, but as mentioned earlier, the frequency remained below 49.2 Hz for about 25 % of the time in August 2009. Two typical frequency plots of these days are enclosed.
There are many reasons for such frequency regime, which would be considered unacceptable elsewhere. Suffice it to say here that India is unlikely to attain a reasonable frequency stability (of the order of +/- 0.1 Hz) even in the next decade, and grid frequency would continue to vary and fluctuate. The nuclear and other power plants set up in India would have to withstand such frequency variations and fluctuations, and therefore need to be engineered for trouble-free operation in such frequency regime. Specifically, the steam turbines must be capable of sustained operation in 49.0 – 50.5 Hz range, as is stipulated in IEC: 45.
It has been mentioned earlier that the nuclear and pit-head stations would be scheduled as base-load stations and would be exempted from load-following duty, but would have to provide primary frequency response and regulation. What is basically meant by this is that if a generating unit is set to generate x1 MW, and frequency is constant at f1 Hz (f1 need not be equal to 50.0), it would be generating x1 MW, irrespective of whether f1 is higher than 50.0 or lower. When frequency changes from f1 to f2 Hz, and f2 is higher (lower) than f1, the generation would decrease (increase) from x1 to x2 MW without any intentional time delay, through free-governor mode of operation (FGMO). However, the generating unit would not be required to continue generating x2 MW, but may return to x1 MW over the next few minutes ramping up (down) at one percent per minute or slower, even if the frequency stays at f2 Hz.
To explain further, the objective of regulation and frequency response in India would be only to minimize the frequency fluctuations through FGMO, but not to bring the frequency necessarily back to 50.0 Hz. Operation in the above fashion may require some reconfiguration of turbine speed-load control logic and a thermal buffer in the steam cycle to accommodate mismatch between reactor power/fuel injection and generator MW output of up to 5% for a maximum duration of 5 minutes.

Why is Frequency Response and Regulation Necessary?
Frequency fluctuations are caused by load-generation imbalances in the system, and keep happening because consumer load keeps changing. Frequency fluctuations can be minimised if generation is changed in the appropriate direction without any time delay, which is possible only through free-governor mode of operation. The present frequency regime in India is indicative of the generating units not providing this primary regulation and frequency response through FGMO, due to which frequency fluctuates minute-to-minute much more than what it would if the generating units actually operated or free-governor mode. For example, a 1% change in system load (500 MW in a 50000 MW system) would cause a frequency change of 0.3 – 0.4 Hz if no generating unit was on FGMO, and of only 0.02 Hz if all generating units operated on free-governor mode.
Nuclear power plants are particularly susceptible to frequency fluctuations. As frequency changes, the speed of the coolant pumps changes proportionately, and the coolant flow and consequently the temperature differential across the reactor also vary. The above temperature differential is a primary signal for reactor power control, and its variation gives a command for change of reactor power even when the reactor has been operating at the optimum level. This is turn causes unnecessary fluctuations of reactor power and undesirable wear of fuel rods, etc. Nuclear power plants in India have been affected over the years by the grid frequency fluctuations, but have still refused to consider operation on free-governor mode, the only measure which can minimise frequency fluctuations. They have been able to get away from participation in this collective responsibility on account of

1. nuclear capacity being a very small percentage of the total generating capacity,
2. other generating stations also refusing to participate in frequency control, and
3. the nuclear stations claiming a holy cow status. It is foreseen that all this would change in the coming years, and nuclear stations would also be required to provide primary frequency response and regulation as was outlined earlier.

Grid disturbances, Islanding and Load-rejection
There was a time when regional grids in India had very frequent grid disturbances, both minor and major. The nuclear and other plants then in operation had to bear the brunt of islanding and load-rejection. Even tripping of generating units and poisoning out were not uncommon. The situation has considerably improved since implementation of Availability Tariff in 2002-03. India has not suffered a grid collapse or a major grid disturbance in the last seven years, though the risk of these still persists. It can now be said that the normal safeguards and provisions to withstand islanding and load-rejection adopted for nuclear power plants in other countries should suffice in India as well. H.P – L.P. bypass to dump the steam to condenser would generally be necessary for this purpose, along with capability to go on house-load and safe shut down in the event of a total disconnection from the grid or a complete grid collapse.
As for power plants of other types, they should be engineered for early restart once the station auxiliary supply has been restored from the grid. Thermal and renewable power plants generally need not have a self-restart or black-start capability.

Voltage Fluctuations
While frequency is a system-wide parameter, and has one value throughout the grid on minute-to-minute basis, voltage differs from location to location. It is a local parameter depending on system and load configuration, and is required to be tackled locally through reactive power control. The grid voltage profile was a serious problem in India till 2002, but has since been effectively controlled through,

1. Timely augmentation of EHV transmission system, i.e. laying of additional transmission lines,
2. Installation of shunt reactors and series capacitors, and
3. Installation of shunt capacitors in sub-transmission and distribution system.

The last item has largely been prompted by a scheme of pricing of reactive energy drawl by State utilities from the regional grids, details of which can be seen under section 6.6. of the Indian Electricity Grid Code (IEGC), relevant extracts of which are enclosed.
The voltage profile on EHV grid has now improved to the extent that the large generating stations, which are generally away from load centres, are not required to supply reactive power for meeting the reactive component of consumer load. They have to generate or absorb reactive power mainly to maintain the voltage at the local EHV bus at the required levels, as per instructions of the regional load dispatch centres. (Para 6 of section 6.6 of IEGC may be seen in this connection).
It can reasonably be expected that, provided the necessary coordination with Central Electricity Authority and Power Grid Corporation of India takes place sufficiently in advance, the requisite transmission system for the future nuclear and other power plants would be getting established in a planned and timely manner, and the plants would not face any special voltage profile problem. The standard and proven generator designs and excitation systems should therefore suffice. However, it may be desirable / necessary to provide on-load tap changers (OLTC) on generator transformers in order to maintain the generator terminal voltage at the optimum level under different operating conditions and requirements of reactive power generation / absorption.
Reactive power injection or absorption by generating stations under long-term capacity contracts and covered by Availability tariff is not separately paid for as per the present philosophy in India. It is expected that the same approach would be adopted for the nuclear and other power plants of the future when contracted long-term for

their capacity. However, for power plants not covered by long-term capacity contracts (e.g. renewable and merchant plants), reactive power injection/absorption may be priced according to the scheme described in section 6.6 of the IEGC.

Availability Tariff

The Availability Tariff successfully adopted in India since 2002-03 for the fossil fuel-fired central generating stations is described in Annexure-2, a perusal of which is recommended. The nuclear power plants presently operating in India and owned by Central Government have still not opted for its adoption due to certain apprehensions, which really are not well-founded. There is no valid reason why Availability tariff concept should not be extended to the nuclear plants, to the benefit of all parties. Introduction of larger nuclear plants with single-part tariff (as presently practiced) is liable to lead to operational and commercial problem in grid operations, as was perpetually the case with Central thermal stations up to 2002. It would be advisable, particularly for private investors, to insist on adoption of Availability tariff for dispute-free scheduling and operation of their generating stations, whether their tariff is determined on cost-plus basis or through competitive bidding. For the guidance of those concerned / interested, relevant extracts of the CERC notification dated 19th January 2009 on terms and conditions of tariff for the April 2009 – March 2014 period are attached as Annexure – 3. Please note that while Availability tariff itself has only two parts, i.e. capacity charge and energy charge, its Indian version has a very important attachment, termed Unscheduled Interchange (UI) charge. This last component is for pricing of all deviations from schedules, both inadvertent and deliberate. As explained in Annexure-2, the UI charge is at an energy rate linked to grid frequency. The rate goes up as frequency falls below 50.0 Hz (in a deficit situation), and goes down as frequency goes above 50.0 Hz (in a surplus situation). The UI rate is many things rolled together: pool price, incremental cost (system lambda), marginal price, balancing market price. UI is a multi-purpose tool which enables many things in India, a discussion on which would require a separate session.

Renewable Energy

Power plants generating energy from renewable sources (mini-hydro, wind and solar) have very different characteristics, and require a totally different treatment. Their special features, relevant in the present context, are as follows:

- Their level of generation is decided by nature, and cannot be controlled or regulated as per consumer load pattern.
- While their generation may have a daily and seasonable pattern, any prediction of their hour-to-hour generation on the next day always has a degree of uncertainty. Therefore in case a renewable energy plant is schedule day-ahead (for the next day) based on statistical general generation pattern, weather prediction etc. for the next day, it is liable to have large deviations from the given schedule.

These features being inherent need to be accommodated for fulfilling stated goal of maximizing the electricity generation from renewable energy sources. Still because of these features, (actually drawbacks compared to other types of generation) the utilities have a hesitation in absorbing (and paying for) the renewable generation, while Government and regulatory authorities want the utilities to absorb more and more renewable energy, leading to a conflict.

The first issue is the pricing of renewable energy, and there are two distinct ways to go about it. One is that utilities be required to pay a rate to the generator which covers the latters cost, and the price differential between the renewable energy and conventional energy is covered either by Government subsidy or by uplift in consumer tariff. In this approach, rate fixation is very subjective on many counts, and regulators may find it difficult to specify a rate which reasonably covers the generation cost and does not impose an unreasonable burden on the Government, utilities or the consumer.

The other way of pricing renewable energy is to pay for it at the system marginal price. This, as compared to the first approach has many advantages, and it is very easily possible to adopt it in India, through the established mechanism of unscheduled interchange (UI) mentioned earlier. In this scheme, the entire injection of renewable energy could be treated as UI, and paid for at the prevailing UI rate. Alternatively, the scheduled injection could be paid for at a regulator specified or contracted rate, and the deviation from schedule treated as UI.

The other issue pertains to scheduling. In Western countries, scheduling of renewable energy, or rather the inevitable deviations from schedule pose two major problems in grid operation, One is that of commercial treatment of the deviations, which cannot be neutralised in kind. This is not a problem in India at all. All deviations can be easily accounted as UI in an objective and dispute-free manner. The other problem is that REs deviation from schedule (or variability of injection) give rise to load-generation imbalance in the control area in which they are embedded, and cause fluctuations of control areas net interchange. In countries having substantial wind generation, this constitutes a serious problem, causing power flow variations throughout the inter-connection, as also frequency fluctuations. Since India already has a full-fledged mechanism for handling deviations from interchange schedules and also allows frequency to fluctuate, the above is just not a problem in India. It is therefore rather unfortunate that under the influence of Western philosophies and practices, measures are being proposed to curb or neutralize the inevitable deviations of renewable energy injection. One can only hope that unnecessary costs and complications would not be created.

Another beauty of UI mechanism, not fully appreciated, is that it works back-to-back. For example, if the injection of a generating station into its host control area is 10MW short of schedule, and the control area consequently

overdraws 10MW from the larger grid, whatever UI charges the control area has to pay to the larger grid, it recovers the same from the defaulting generating station.

Annexure 1

Extracts from the “Indian Electricity Grid Code”
(Issued by CERC on 14th March 2006, updated up to July 2009)

CHAPTER I - GENERAL
1.6 Free Governor Action

- All thermal and hydro (except those with zero pondage) generating units: with effect from the date to be separately notified by the Commission.
- Any exemption from the above may be granted only by CERC for which the concerned constituent/ agency shall file a petition in advance.
- The Gas turbine/Combined Cycle Power Plants and Nuclear Power Stations shall be exempted from Sections 4.8 (c), 4.8 (d), 5.2 (e), 5.2 (f), 5.2 (g) and 5.2 (h) till the Commission reviews the situation.

1.7 Charge/Payment for Reactive Energy Exchanges

The rate for charge/payment of reactive energy exchanges (according to the scheme specified in section 6.6 shall be 5.0 paise/kVArh w.e.f 01.04.2006, and shall be scalated at 0.25 paise/kVArh per year thereafter, unless otherwise revised by the CERC.

CHAPTER - 4 - CONNECTION CONDITIONS
4.8 Generating Units and Power Stations

- A Generating Unit shall be capable of continuously supplying its normal rated active/reactive output within the system frequency and voltage variation range indicated at section 4.6 above, subject to the design imitations specified by the manufacturer.
- A generating unit shall be provided with an AVR, protective and safety devices, as set out in connection agreements.
- Each Generating Unit shall be fitted with a turbine speed governor having an overall droop characteristic within the range of 3% to 6% which shall always be in service.
- Each Generating Unit shall be capable of instantaneously increasing output by 5% when the frequency falls limited to 105% MCR. Ramping back to the previous MW level (in case the increased output level cannot be sustained) shall not be faster than 1% per minute.

CHAPTER-5 - OPERATING CODE FOR REGIONAL GRIDS
5.1 Operating Policy

- The primary objective of integrated operation of the Regional grids is to enhance the overall operational economy and reliability of the entire electric power network spread over the geographical area of the interconnected States. Participant utilities shall cooperate with each other and adopt Good Utility Practice at all times for satisfactory and beneficial operation of the Regional grid.
- Overall operation of the Regional grid shall be supervised from the Regional Load Despatch Centre (RLDC). The roles of RLDC and RPC shall be in accordance with the provisions made in Chapter-2 of the IEGC.
- All Regional constituents shall comply with this Operating Code, for deriving maximum benefits from the integrated operation and for equitable sharing of obligations.
- A set of detailed internal operating procedures for each regional grid shall be developed and maintained by the respective RLDC in consultation with the regional constituents and shall be consistent with IEGC to enable compliance with the requirement of this IEGC.
- The control rooms of the RLDC, all SLDCs, power plants, substation of 132 kV and above, and any other control centres of all regional constituents shall be manned round the clock by qualified and adequately trained personnel.

5.2 System Security Aspects

- All Regional constituents shall endeavor to operate their respective power systems and power stations in synchronism with each other at all times, such that the entire system within a Region operates as one synchronized system.
- No part of the grid shall be deliberately isolated from the rest of the Regional grid, except (i) under an emergency, and conditions in which such isolation would prevent a total grid collapse and/or would enable early restoration of power supply, (ii) when serious damage to a costly equipment is imminent and such isolation would prevent it, (iii) when such isolation is specifically instructed by RLDC. Complete synchronization of grid shall be restored as soon as the conditions again permit it. The restoration process shall be supervised by RLDC, as per operating procedures separately formulated.
- No important element of the Regional grid shall be deliberately opened or removed from service at any time, except when specifically instructed by RLDC or with specific and prior clearance of RLDC. The list of such important grid elements on which the above stipulations apply shall be prepared by the RLDC in consultation with the constituents, and be available at RLDC/SLDCs. In case of opening/removal of any important element of the grid under an emergency situation, the same shall be communicated to RLDC at the earliest possible time after the event.
- Any tripping, whether manual or automatic, of any of the above elements of Regional grid shall be precisely intimated by the concerned State LDC/agency to RLDC as soon as possible, say within ten minutes of the event. The reason (to the extent determined) and the likely time of restoration shall also be intimated. All reasonable attempts shall be made for the elements restoration as soon as possible.
- All generating units, which are synchronized with the grid, irrespective of their ownership, type and size, shall have their governors in normal operation at all times . If any generating unit of over fifty (50) MW size (10 MW for North-Eastern Region) is required to be operated without its governor in normal operation, the RLDC shall be immediately advised about the reason and duration of such operation. All governors shall have a drop of between 3% and 6%.
- Facilities available with/in load limiters, Automatic Turbine Run-up System (ATRS), Turbine supervisory control, coordinated control system, etc., shall not be used to suppress the normal governor action in any manner. No dead bands and/or time delays shall be deliberately introduced.
- All Generating Units, operating at or up to 100% of their Maximum Continuous Rating (MCR) shall normally be capable of (and shall not in any way be prevented from) instantaneously picking up five per cent (5%) extra load when frequency falls due to a system contingency. The generating units operating at above 100% of their MCR shall be capable of (and shall not be prevented from) going at least up to 105% of their MCR when frequency falls suddenly. After an increase in generation as above, a generating unit may ramp back to the original level at a rate of about one percent (1%) per minute, in case continued operation at the increased level is not sustainable. Any generating unit of over fifty (50) MW size (10 MW for NER) not complying with the above requirements, shall be kept in operation (synchronized with the Regional grid) only after obtaining the permission of RLDC. However, a constituent can make up the corresponding short fall in spinning reserve by maintaining an extra spinning reserve on the other generating units of the constituent.
- The recommended rate for changing the governor setting, i.e., supplementary control for increasing or decreasing the output (generation level) for all generating units, irrespective of their type and size, would be one (1.0) per cent per minute or as per manufacturers limits. However, if frequency falls below 49.5 Hz, all partly loaded generating units shall pick up additional load at a faster rate, according to their capability.
- Except under an emergency, or to prevent an imminent damage to a costly equipment, no constituent shall suddenly reduce his generating unit output by more than one hundred (100) MW (20 MW in case of North-Eastern region) without prior intimation to and consent of the RLDC, particularly when frequency is falling or is below 49.2 Hz. Similarly, no constituent shall cause a sudden increase in its load by more than one hundred (100 MW) (20 MW in case of North-Eastern region) without prior intimation to and consent of the RLDC.
- All generating units shall normally have their automatic voltage regulators (AVRs) in operation, with appropriate settings. In particular, if a generating unit of over fifty (50) MW (10 MW in case of North-Eastern region) size is required to be operated without its AVR in service, the RLDC shall be immediately intimated about the reason and duration, and its permission obtained. Power System Stabilizers (PSS) in AVRs of generating units (wherever provided), shall be got properly tuned by the respective generating unit owner as per a plan prepared for the purpose by the CTU from time to time. CTU will be allowed to carry out checking of PSS and further tuning it, wherever considered necessary.
- Provision of protections and relay settings shall be coordinated periodically throughout the Regional grid, as per a plan to be separately finalized by the Protection Committee of the RPC.
- All Regional constituents shall make all possible efforts to ensure that the grid frequency always remains within the 49.2 - 50.3 Hz band, the frequency range within which steam turbines conforming to the IEC specifications can safely operate continuously.
- All Regional constituents shall provide automatic under-frequency and df/dt load shedding in their respective systems, to arrest frequency decline that could result in a collapse/disintegration of the grid, as per the plan separately finalized by the concerned RPC forum, and shall ensure its effective application to prevent cascade tripping of generating units in case of any contingency. All

Regional constituents shall ensure that the above under-frequency and df/dt load shedding/islanding schemes are always functional. However, in case of extreme contingencies, these relays may be temporarily kept out of service with prior consent of RLDC. RLDC shall inform RPC Secretariat about instances when the desired load relief is not obtained through these relays in real time operation. RPC Secretariat shall carry out periodic inspection of the under frequency relays and maintain proper records of the inspection.

- All regional constituents shall also facilitate identification, installation and commissioning of System Protection Schemes (including inter-tripping and run-back) in the power system to protect against situations such as voltage collapse and cascading. Such schemes would be finalized by the concerned RPC forum, and shall be kept in service. RLDC shall be promptly informed in case any of these are taken out of service.
- Procedures shall be developed to recover from partial/total collapse of the grid and periodically updated in accordance with the requirements given under section 5.8. These procedures shall be followed by all the Regional constituents to ensure consistent, reliable and quick restoration.
- Each Regional constituent shall provide adequate and reliable communication facility internally and with other constituents/RLDC to ensure exchange of data/information necessary to maintain reliability and security of the grid. Wherever possible, redundancy and alternate path shall be maintained for communication along important routes, e.g., SLDC to RLDC.
- The Regional constituents shall send information/data including disturbance recorder/sequential event recorder output etc., to RLDC for purpose of analysis of any grid disturbance/event. No Regional constituent shall block any data/information required by the RLDC for maintaining reliability and security of the grid and for analysis of an event.
- All regional constituents shall make all possible efforts to ensure that the grid voltage always remains within the following operating range.

Voltage - (KV rms)

Nominal	Maximum	Minimum
400	420	360
220	245	200
132	145	120

CHAPTER-6 - SCHEDULING AND DISPATCH CODE
6.4 Demarcation of responsibilities

1. RLDCs shall coordinate the scheduling of generating stations owned by Central Government organizations (excluding stations where full share is allocated to host state),Ultra-Mega power projects and other generating stations of 1000 MW or larger size in which, States, other than the host State have permanent shares of 50% or more. Generating stations not meeting the above criteria regarding plant size and share of other States shall be scheduled by the SLDC of the State in which they are located. However, there may be exceptions for reasons of operational expediency, subject to approval of CERC.
2. In case of a generating station, contracting to supply power only to the State in which it is located, the scheduling, metering and energy accounting shall be carried out by the respective State Load Despatch Centre.
3. The State Load Despatch Centre which is responsible for coordinating the scheduling of a generating station shall also be responsible for:
    - real-time monitoring of the stations operation,
    - checking that there is no gaming in its availability declaration,
    - revision of availability declaration and injection schedule,
    - switching instructions,
    - metering and energy accounting,
    - issuance of UI accounts,
    - collections/disbursement of UI payments,
    - outage planning, etc.
4. The Regional grids shall be operated as loose power pools (with decentralized scheduling and dispatch), in which the States shall have full operational autonomy, and SLDCs shall have the total responsibility for (i) scheduling/dispatching their own generation (including generation of their embedded licensees), (ii) regulating the demand of their customers, (iii) scheduling their drawal from the ISGS

(within their share in the respective plants expected capability), (iv) arranging any bilateral interchanges, and (v) regulating their net drawal from the regional grid as per following guidelines.

5. The system of each regional entity shall be treated and operated as a notional control area. The algebraic summation of scheduled drawal from ISGS, long term, medium term and open access shall provide the drawal schedule of each regional entity, and this shall be determined in advance on daily basis. While the regional entities would generally be expected to regulate their generation and/or consumers load so as to maintain their actual drawal from the regional grid close to the above schedule, a tight control is not mandated. The regional entities may, at their discretion, deviate from the drawal schedule, within the limit specified by the CERC as long as such deviations do not cause system parameters to deteriorate beyond permissible limits and/or do not lead to unacceptable line loading.
6. The above flexibility has been proposed in view of the fact that all States do not have all requisite facilities for minute-to-minute on-line regulation of the actual net drawal from the regional grid. Deviations from net drawal schedule are however, to be appropriately priced through the Unscheduled Interchange (UI) mechanism.
7. Provided that the States, through their SLDCs, shall always endeavour to restrict their net drawal from the grid to within their respective drawal schedules, whenever the system frequency is below 49.5 Hz. When the frequency falls below 49.2 Hz, requisite load shedding shall be carried out in the concerned State(s) to curtail the over-drawal.
8. The SLDCs/STUs shall regularly carry out the necessary exercises regarding short-term demand estimation for their respective States, to enable them to plan in advance as to how they would meet their consumers load without overdrawing from the grid.
9. The ISGS shall be responsible for power generation generally according to the daily schedules advised to them by the RLDC on the basis of the requisitions received from the SLDCs, and for proper operation and maintenance of their generating stations, such that these stations achieve the best possible long-term availability and economy.
10. While the ISGS would normally be expected to generate power according to the daily schedules advised to them, it would not be mandatory to follow the schedules tightly. In line with the flexibility allowed to the States, the ISGS may also deviate from the given schedules depending on the plant and system conditions. In particular, they would be allowed/encouraged to generate beyond the given schedule under deficit conditions. Deviations from the ex-power plant generation schedules shall, however, be appropriately priced through the UI mechanism.
11. Provided that when the frequency is higher than 50.3 Hz, the actual net injection shall not exceed the scheduled dispatch for that time block. Also, while the frequency is above 50.3 Hz, the ISGS may (at their discretion) back down without waiting for an advice from RLDC to restrict the frequency rise. When the frequency falls below 49.5 Hz, the generation at all ISGS (except those on peaking duty) shall be maximized, at least upto the level which can be sustained, without waiting for an advice from RLDC.
12. However, notwithstanding the above, the RLDC may direct the SLDCs/ISGS/other regional entities to increase/decrease their drawal/generation in case of contingencies e.g. overloading of lines/transformers, abnormal voltages, threat to system security. Such directions shall immediately be acted upon. In case the situation does not call for very urgent action, and RLDC has some time for analysis, it shall be checked whether the situation has arisen due to deviations from schedules, or due to any power flows pursuant to short-term open access. These shall be got terminated first, in the above sequence, before an action, which would affect the scheduled supplies from ISGS to the long term customers is initiated.
13. For all outages of generation and transmission system, which may have an effect on the regional grid, all constituents shall cooperate with each other and coordinate their actions through Operational Coordination Committee (OCC) for outages foreseen sufficiently in advance and through RLDC (in all other cases), as per procedures finalized separately by OCC. In particular, outages requiring restriction of ISGS generation and/or restriction of ISGS share which a beneficiary can receive (and which may have a commercial implication) shall be planned carefully to achieve the best optimization.
14. The regional constituents shall enter into separate joint/bilateral agreement(s) to identify the States shares in ISGS projects (based on the allocations by the Govt. of India, where applicable), scheduled drawal pattern, tariffs, payment terms etc. All such agreements shall be filed with the concerned RLDC(s) and /RPC, Secretariat, for being considered in scheduling and regional energy accounting. Any bilateral agreements between constituents for scheduled interchanges on long-term/short-term basis shall also specify the interchange schedule, which shall be duly filed in advance with the RLDC.
15. All constituents and other regional entities should abide by the concept of frequency-linked load dispatch and pricing of deviations from schedule, i.e., unscheduled interchanges. All generating units of the constituents, their licensees and generating companies and other regional entities should normally be operated according to the standing frequency linked load dispatch guidelines issued by the RLDC, to the extent possible, unless otherwise advised by the RLDC/SLDC.
16. The ISGS shall make an advance declaration of ex-power plant MW and MWh capabilities foreseen for the next day, i.e., from 0000 hrs to 2400 hrs. During fuel shortage condition, in case of thermal stations, they may specify minimum MW, maximum MW, MWh capability and declaration of fuel shortage. The generating stations shall also declare the possible ramping up / ramping down in a block. In case of a gas turbine generating station or a combined cycle generating station, the generating station shall

declare the capacity for units and modules on APM gas, RLNG and liquid fuel separately, and these shall be scheduled separately.

17. While making or revising its declaration of capability, the ISGS shall ensure that the declared capability during peak hours is not less than that during other hours. However, exception to this rule shall be allowed in case of tripping/re-synchronisation of units as a result of forced outage of units.
18. It shall be incumbent upon the ISGS to declare the plant capabilities faithfully, i.e., according to their best assessment. In case, it is suspected that they have deliberately over/under declared the plant capability contemplating to deviate from the schedules given on the basis of their capability declarations (and thus make money either as undue capacity charge or as the charge for deviations from schedule), the RLDC may ask the ISGS to explain the situation with necessary backup data.
19. The CTU shall install special energy meters on all inter connections between the regional constituents, other regional entities and other identified points for recording of actual net MWh interchanges and MVArh drawals. The installation, operation and maintenance of special energy meters shall be in accordance with Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006. All concerned entities (in whose premises the special energy meters are installed) shall fully cooperate with the CTU/RLDC and extend the necessary assistance by taking weekly meter readings and transmitting them to the RLDC by Tuesday noon.
20. The RLDC shall be responsible for computation of actual net injection / drawal of concerned regional entities, 15 minute-wise, based on the above meter readings. The above data along with the processed data of meters shall be forwarded by the RLDC to the RPC secretariat on a weekly basis by each Thursday noon for the seven day period ending on the previous Sunday midnight, to enable the latter to prepare and issue the Unscheduled inter-change (UI) account All computations carried out by RLDC shall be open to all regional entities for checking/verifications for a period of 15 days. In case any mistake/omission is detected, the RLDC shall forthwith make a complete check and rectify the same.
21. The ISGS shall be required to demonstrate the declared capability of its generating station as and when asked by the Regional Load Despatch Centre of the region in which the ISGS is situated. In the event of the ISGS failing to demonstrate the declared capability, the capacity charges due to the generator shall be reduced as a measure of penalty.
22. The quantum of penalty for the first mis-declaration for any duration/block in a day shall be the charges corresponding to two days fixed charges. For the second mis-declaration the penalty shall be equivalent to fixed charges for four days and for subsequent misdeclarations, the penalty shall be multiplied in the geometrical progression.
23. The operating log books of the generating station shall be available for review by the Regional Power Committee. These books shall keep record of machine operation and maintenance.
24. Any generation from the generating stations other than hydro generating stations up to 105% of the declared capacity in any time block of 15 minutes and averaging up to 101% of the average declared capacity over a day shall not be construed as gaming, and the generator shall be entitled to UI charges for such excess generation above the scheduled generation (SG).
25. For any generation from the generating stations other than hydro generating stations beyond the prescribed limits, the Regional Load Despatch Centre shall investigate so as to ensure that there is no gaming, Generating stations shall be entitled to recover the Unscheduled Interchange charges only if the investigation establishes that there is no gaming. If gaming is found by the Regional Load Despatch Centre, the corresponding Unscheduled Interchange charges payable to the generating station on account of such extra generation shall be reduced to zero and the amount shall be adjusted in UI pool account of the beneficiaries in the ratio of their capacity share in the generating station.
26. Hydro generating stations are expected to respond to grid frequency changes and inflow fluctuations. The hydro generating stations shall be free to deviate from the given schedule without indulging in gaming and causing grid constraint and a compensation for difference between the actual net energy supply by the hydro generating station and the scheduled energy (ex-bus) over day shall be made by the concerned Regional Load Despatch Centre in the day ahead schedule for the 4th day (day plus 3). If gaming is found by the Regional Load Despatch Centre, the corresponding Unscheduled Interchange charges payable to the generating station on account of such extra generation shall be reduced to zero and the amount shall be adjusted in UI pool account of the beneficiaries in the ratio of their capacity share in the generating station.
27. RLDC shall periodically review the actual deviation from the dispatch and net drawal schedules being issued, to check whether any of the constituents and other regional entities are indulging in unfair gaming or collusion. In case any such practice is detected, the matter shall be reported to the Member Secretary, RPC for further investigation/action.
28. NLDC shall be responsible for scheduling and despatch of electricity over inter-regional links in accordance with grid standards specified by the Authority and grid code specified by Central Commission in coordination with Regional Load Despatch Centers. NLDC shall be responsible for coordination with Regional Load Despatch Centers for the energy accounting of interregional exchange of power. NLDC shall be responsible for coordination for trans-national exchange of power.
29. NLDC shall develop a procedure for scheduling of inter-regional power exchanges, calculation of available transfer capability and power exchanges of the country with other countries including aspects such as, scheduling and coordination for inter-regional exchanges, allocations across the regional boundaries, scheduling and HVDC setting responsibility, etc.

30. In case the State in which an ISGS is located has a predominant share in that ISGS, the concerned parties may mutually agree (for operational convenience) to assign the responsibility of scheduling of the ISGS to the State's LDC. The role of the concerned RLDC, in such a case, shall be limited to consideration of the schedule for inter-State exchange of power on account of this ISGS while determining the net drawal schedules of the respective states.

6.5 Scheduling and Dispatch procedure (to be read with provisions of Open Access Regulations 2008)

1. All inter-State generating stations (ISGS), in whose output more than one State has an allocated/contracted share, shall be duly listed. The station capacities and allocated/contracted shares of different beneficiaries shall also be listed out.
2. Each State shall be entitled to a MW dispatch up to (foreseen ex-power plant MW capability for the day) x (States share in the stations capacity) for all such stations. In case of hydro-electric stations, there would also be a limit on daily MWh dispatch equal to (MWh generation capacity for the day) (States share in the stations capacity.
3. By 9 AM every day, the ISGS shall advise the concerned RLDC, the station-wise ex-power plant MW and MWh capabilities foreseen for the next day, i.e., from 0000 hrs to 2400 hrs of the following day.
4. The above information of the foreseen capabilities of the ISGS and the corresponding MW and MWh entitlements of each State, shall be compiled by the RLDC every day for the next day, and advised to all beneficiaries by 10 AM. The SLDCs shall review it vis-à-vis their foreseen load pattern and their own generating capability including bilateral exchanges, if any, and advise the RLDC by 3 PM their drawal schedule for each of the ISGS in which they have shares, long-term bilateral interchanges, approved short-term bilateral interchanges and composite request for day-ahead open access and scheduling of bilateral interchanges.
5. Scheduling of collective transaction:
    - NLDC shall indicate to Power Exchange(s), the list of interfaces/ control areas/regional transmission systems on which unconstrained flows are required to be advised by the Power Exchanges(s) to the NLDC. Power Exchange(s) shall furnish the interchange on various interfaces/control areas/regional transmission systems as intimated by NLDC. Power Exchange(s) shall also furnish the information of total drawal and injection in each of the regions. Based on the information furnished by the Power Exchanges, NLDC shall check for congestion. In case of congestion, NLDC shall inform the Exchanges about the period of congestion and the available limit for scheduling of collective transaction on respective interface/control area/transmission systems during the period of congestion for Scheduling of Collective Transaction through the respective Power Exchange. The limit for scheduling of collective transaction for respective Power Exchange shall be worked out in accordance with CERC directives. Based on the application for scheduling of Collective Transaction submitted by the Power Exchange(s), NLDC shall send the details (Scheduling Request of Collective Transaction) to different RLDCs for final checking and incorporating them in their schedules. After getting confirmation from RLDCs, NLDC shall convey the acceptance of scheduling of collective transaction to Power Exchange(s). RLDCs shall schedule the Collective Transaction at the respective periphery of the Regional Entities.
    - The individual transactions for State Utilities/intra-State Entities shall be scheduled by the respective SLDCs. Power Exchange(s) shall send the detailed break up of each point of injection and each point of drawal within the State to respective SLDCs after receipt of acceptance from NLDC. Power Exchange(s) shall ensure necessary coordination with SLDCs for scheduling of the transactions.
    - Timeline for above activities will be as per Procedure for Scheduling of Collective Transaction issued by the CTU or Government Company or authority or corporation operating the RLDCs and NLDC.
6. The SLDCs may also give standing instructions to the RLDC such that the RLDC itself may decide the best drawal schedules for the States.
7. By 6 PM each day, the RLDC shall convey:
    - The ex-power plant "dispatch schedule" to each of the ISGS, in MW for different hours, for the next day. The summation of the ex-power plant drawal schedules advised by all beneficiaries shall constitute the ex-power plant station-wise dispatch schedule.
    - The "net drawal schedule" to each regional entity, in MW for different time block, for the next day. The summation of the station-wise ex-power plant drawal schedules from all ISGS and drawal from regional grid consequent to other long term, medium term and open access transactions , after deducting the transmission losses (estimated), shall constitute the regional entity-wise drawal schedule.
8. The hydro electric generation stations are expected to respond to grid frequency changes and inflow fluctuations. They would, therefore, be free to deviate from the given schedule as long as they do not indulge in gaming and do not cause a grid constraint. As a result, the actual net energy supply by a hydro generating station over a day shall differ from schedule energy (ex-bus) for that day. A

compensation shall then be made by the concerned load dispatch centre in the day ahead schedule for the 4th day (day plus 3).

9. The declaration of the generating capability by ISGS should also include limitation on generation during specific time periods, if any, on account of restriction(s) on water use due to irrigation, drinking water, industrial, environmental considerations etc.
10. The concerned Load Despatch Centre shall periodically check that the generating station is declaring the capacity and energy sincerely, and is not manipulating the declaration with the intent of making undue money through UI.
11. Since variation of generation in run-of-river power stations shall lead to spillage, these shall be treated as must run stations.
12. Run-of-river power station with pondage and storage type power stations are designed to operate during peak hours to meet system peak demand. Maximum capacity of the station declared for the day shall be equal to the installed capacity including overload capability, if any, minus auxiliary consumption, corrected for the reservoir level. The Regional Load Despatch Centers shall ensure that generation schedules of such type of stations are prepared and the stations dispatched for optimum utilization of available hydro energy except in the event of specific system requirements/constraints.
13. The schedule finalized by the concerned load dispatch centre for hydro generating station, shall normally be such that the scheduled energy for a day equals the total energy (ex-bus) expected to be available on that day, as declared by the generating station, based on foreseen/planned water availability/release. It is also expected that the total net energy actually supplied by the generating station on that day would equal the declared total energy, in order that the water release requirement is met. While the 15- minute wise, deviations from schedule would be accounted for as Unscheduled Interchange (UI), the net energy deviation for the whole day, if any, shall be additionally accounted for as shown in the illustration.

    Illustration - Suppose the foreseen/expected total energy (ex-bus) for Day-1 is E1, the scheduled energy is S1, and actual net energy (metered) is A1, all in exbus MWh. Suppose the expected energy availability for Day 4, as declared by the generator, is E4. Then, the schedule for day 4 shall be drawn up such that the scheduled energy for Day 4, shall be S4=E4+(A1-E1), Similarly, S5= E5+(A2-E2), S6=E6+(A3-E3), S7=E7+(A4-E4), and so on."

14. While finalizing the above daily dispatch schedules for the ISGS, RLDC shall ensure that the same are operationally reasonable, particularly in terms of ramping-up/ramping-down rates and the ratio between minimum and maximum generation levels. A ramping rate of upto 200 MW per hour should generally be acceptable for an ISGS and for a regional constituent (50 MW in NER), except for hydro-electric generating stations which may be able to ramp up/ramp down at a faster rate.
15. The SLDCs/ISGS shall inform any allowable modifications/changes to be made in drawal schedule/foreseen capabilities, if any, to RLDC by 10 PM or preferably earlier.
16. While finalizing the drawal and dispatch schedules as above, the RLDC shall also check that the resulting power flows do not give rise to any transmission constraints. In case any impermissible constraints are foreseen, the RLDC shall moderate the schedules to the required extent, under intimation to the concerned constituents. Any changes in the scheduled quantum of power which are too fast or involve unacceptably large steps, may be converted into suitable ramps by the RLDC.
17. Notwithstanding anything contained in Regulation 6.5(20), in case of forced outage of a unit, the RLDC shall revise the schedules on the basis of revised declared capability. The revised declared capability and the revised schedules shall become effective from the 4th time block, counting the time block in which the revision is advised by the ISGS to be the first one.
18. In the event of bottleneck in evacuation of power due to any constraint, outage, failure or limitation in the transmission system, associated switchyard and substations owned by the Central Transmission Utility or any other transmission licensee involved in inter-state transmission (as certified by the RLDC) necessitating reduction in generation, the RLDC shall revise the schedules which shall become effective from the 4th time block, counting the time block in which the bottleneck in evacuation of power has taken place to be the first one. Also, during the first, second and third time blocks of such an event, the scheduled generation of the ISGS shall be deemed to have been revised to be equal to actual generation, and the scheduled drawals of the beneficiaries shall be deemed to have been revised to be equal to their actual drawals.
19. In case of any grid disturbance, scheduled generation of all the ISGS and scheduled drawal of all the beneficiaries shall be deemed to have been revised to be equal to their actual generation/drawal for all the time blocks affected by the grid disturbance. Certification of grid disturbance and its duration shall be done by the RLDC.
20. Revision of declared capability by the ISGS(s) (except hydro stations) and requisition by beneficiary(ies) for the remaining period of the day shall also be permitted with advance notice. Revised schedules/declared capability in such cases shall become effective from the 6th time block, counting the time block in which the request for revision has been received in the RLDC to be the first one. Provided that RLDC may allow only one revision, in case of Run of the River (ROR) and pondage based hydro

generating stations, if there is large variation of expected energy (MWh) for the day compared to previous declaration.

21. If, at any point of time, the RLDC observes that there is need for revision of the schedules in the interest of better system operation, it may do so on its own, and in such cases, the revised schedules shall become effective from the 4th time block, counting the time block in which the revised schedule is issued by the RLDC to be the first one.
22. To discourage frivolous revisions, an RLDC may, at its sole discretion, refuse to accept schedule/capability changes of less than two (2) percent of previous schedule/capability.
23. The Regional Load Despatch Centre shall also formulate the procedure for meeting contingencies both in the long run and in the short run (Daily scheduling).
24. Generation schedules and drawal schedules issued/revised by the Regional Load Despatch Centre shall become effective from designated time block irrespective of communication success.
25. For any revision of scheduled generation, including post facto deemed revision, there shall be a corresponding revision of scheduled drawals of the beneficiaries.
26. A procedure for recording the communication regarding changes to schedules duly taking into account the time factor shall be evolved by the Central Transmission Utility.
27. After the operating day is over at 2400 hours, the schedule finally implemented during the day (taking into account all before-the-fact changes in dispatch schedule of generating stations and drawal schedule of the States) shall be issued by RLDC. These schedules shall be the datum for commercial accounting. The average ex-bus capability for each ISGS shall also be worked out based on all before-the-fact advice to RLDC.
28. Collective Transaction through Power Exchange(s) would normally be curtailed subsequent to the Short Term Bilateral Transaction(s).

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