REPORT OF THE COMMITTEE
ON
FREE GOVERNOR MODE OPERATION OF GENERATING UNITS

OCTOBER 2015

ACKNOWLEDGEMENT

This report has been finalized with the support of Committee Members. The Committee is thankful to all of them and places on record the contribution made by each one of them. We would like to make a special mention of Sh. S R Narasimhan of POSOCO, Shri S.C.Shrivastva, Joint Chief(Engg.), Shri Devendra Saluja, Deputy Chief (Engg.) and Shri. Virendra Singh Rana, Assistant Chief (Engg.) of CERC for their active involvement and painstaking efforts in helping the Committee in finalizing its recommendations.

CONTENT

CENTRAL ELECTRICITY REGULATORY COMMISSION
NEW DELHI

BACK GROUND: FGMO/RGMO IN GENERATING UNITS

1.0 The Free Governor Mode Operation was made mandatory for providing primary response to tackle frequency excursions right from first issue of IEGC in 1999. However, even after introduction of FGMO provisions, the desired primary response was not becoming available.

2.0 In 2004, in Petition No. 66/2003 filed by SRLDC against NTPC Ramagundam, in which many other generating entities were also made party, CERC vide interim order dated 21.05.2004, referred the matter to a CEA Technical Committee for examining the technical difficulties in the implementation of FGMO. CEA vide its report dated 08.11.2004 recommended control logics for units fitted with EHG governors and for LMZ machines CEA suggested FGMO by adopting scheme as implemented by MSEB at Nasik.

3.0 Commission, revised IEGC which was notified to be effective from 01.04.2006 and essentially modified the requirement of holding the increased / decreased generation level by Governor Action for 5 minutes and allowed the return of the machine to the original load at a slow rate of 1% per minute. However, Section 1.6 of IEGC stipulated that the Free Governor Action will be applicable from the date to be separately notified by the CERC.

4.0 CERC, after considering the following concerns of the generators revised IEGC during 2010, evolved a concept of RGMO to tackle these difficulties:

a) Generators apprehended that if they put their units on FGMO and other Generators remain out of the same by locking their governors, few units under FGMO will come under stress as they will have to share more system load.

b) The natural free governor action tends to reduce the generation when the frequency improves. The same was not desired during the circumstances when the frequency was well below the healthy system frequency of 50Hz.

c) There would be control valve hunting even for small variation of frequency

5.0 The Regulation 5.2 (f) of CERC (Indian Electricity Grid Code) Regulations 2010 as amended, provides as under:

Quote

5.2 System Security Aspects

…..

(f) All thermal generating units of 200 MW and above and all hydro units of 10 MW and above, which are synchronized with the grid, irrespective of their ownership, shall have their governors in operation at all times in accordance with the following provisions:

Governor Action

i) Following Thermal and hydro (except those with upto three hours pondage) generating units shall be operated under restricted governor mode of operation with effect from the date given below:

a) Thermal generating units of 200 MW and above,

1) Software based Electro Hydraulic Governor (EHG) system : 01.08.2010

2) Hardware based EHG system 01.08.2010

b) Hydro units of 10 MW and above 01.08.2010

ii) The restricted governor mode of operation shall essentially have the following features:

a) There should not be any reduction in generation in case of improvement in grid frequency below 50.05 Hz. (for example if grid frequency changes from 49.9 to 49.95 Hz., then there shall not be any reduction in generation). For any fall in grid frequency, generation from the unit should increase by 5% limited to 105 % of the MCR of the unit subject to machine capability.

b) Ripple filter of +/- 0.03 Hz. shall be provided so that small changes in frequency are ignored for load correction, in order to prevent governor hunting.

c) If any of these generating units is required to be operated without its governor in operation as specified above, the RLDC shall be immediately advised about the reason and duration of such operation. All governors shall have a droop setting of between 3% and 6%.

d) After stabilisation of frequency around 50 Hz, the CERC may review the above provision regarding the restricted governor mode of operation and free governor mode of operation may be introduced.

iii) All other generating units including the pondage upto 3 hours, Gas turbine/Combined Cycle Power Plants, wind and solar generators and Nuclear Power Stations shall be exempted from Sections 5.2 (f) ,5.2 (g), 5.2 (h) and ,5.2(i) till the Commission reviews the situation.

6.0 Initially, LMZ machines were left out of the prescribed RGMO. However, considering the facts that certain generators were facing difficulties in implementing RGMO and overall desired primary response was not coming, Commission by way of an amendment notified the following proviso to Regulation 5.2 (f) of IEGC Regulations,2010:

"Provided that if a generating unit cannot be operated under restricted governor mode operation, then it shall be operated in free governor mode operation with manual intervention to operate in the manner required under restricted governor mode operation. *"*

7.0 Statement of Reasons (SOR) on Amendment to IEGC, in 2012 reads as follows:

> *"3.4* ***We feel that if the generator is unable to carry out the RGMO in its units, then it should provide grid support through FGMO. It is clarified that the provision is made in view of the difficulties faced by certain generating companies to modify the machines to make them capable of operating in RGMO automatically****. The proposed revision intends to allow the generators to operate the units in FGMO with manual intervention till the machine is modified for RGMO operation. We are of the view that the proposed amendment should be retained. We are also conscious of the fact that ultimately machines have to be operated in FGMO for which the progressive narrowing down of frequency band will help."*

8.0 Subsequent to the above amendment, NTPC and certain other utilities have filed petitions with CERC for exemption of some of their LMZ units and other units not fitted with EHG from FGMO with manual intervention.

Constitution of the Committee

9.0 In view of the difficulties expressed by the generators, CERC vide office order dated 24.09.2014 (Copy enclosed as Annexure-I) constituted a Committee under the Chairmanship of Sh.A.Velayutham, Ex-Member, MERC. The terms of the reference of the Committee were as follows:

- **i.** To look into the problems of the generating units in implementing FGMO with manual intervention.
- **ii.** To suggest measures for implementation of FGMO with suitable modification/amendments in certain Regulations/IEGC.
- **iii.** Any other recommendation to facilitate FGMO/RGMO operation.

10.0 The composition of the Committee constituted vide order dated 24.09.2014 (Copy enclosed as Annexure-II) was as follows:

1. Shri A. Velayutham (Ex-Member, MERC) - Chairman
2. Shri Chandan Roy (Ex-Director, NTPC) - Member
3. Shri L. D. Papne (Director, CEA) -Member
4. Shri S. Satyanarayan (SE,WRPC) - Member
5. Shri S.K Soonee, (CEO,POSOCO) - Member
6. Shri S.Sathiyanarayan GM (Operations),NLC}- Member
7. Shri V.M.Yadunandanan {AGM(CE)EDN}-Member
8. Shri P.P.Francis {GM(OS),NTPC}-Member
9. Shri Neeraj Kaul (Director (Steam), Alstom) - Member
10. Shri A.K.Saxena {Chief (Engg.), CERC}- Convener

11.0 During the deliberations of the first meeting Committee on the suggestion of POSOCO decided to incorporate the following State Generating Companies (one from each region) to co-opt as Members of the Committee:

i. Rajasthan Rajya Vidyut Utpadan Nigam Ltd. (RRVUNL), from Northern Region

ii. Maharashtra State Power Generation Company Ltd. (MAHAGENCO) from Western Region

iii. West Bengal Power Development Corporation Ltd. (WBPDCL) from Eastern Region

iv. Tamilnadu Generation and Distribution Corporation Ltd. TANGEDCO from Southern Region

v. Assam Power Generation Corporation Ltd. (APGCL) from North- East Region

12.0 Subsequently, the above mentioned organizations nominated their representatives. Accordingly, following nominated members were co-opted for the further deliberations:

1. Shri G. Sharda {SE(C&I), RRVUNL}- Member
2. Shri A.K.Bohara {EE(Turbine),RRVUNL} -Member
3. Shri E.S.Moze (SE, MAHAGENCO)- Member
4. Shri S.S.Sen {Director(O&M),WBPDCL} -Member
5. Shri R. Pugazhendi {Executive Engineer(C&I),TANGEDCO}- Member
6. Shri Mukud Das {DGM(Design),APGCL}- Member

Deliberations of the Committee

13.0 Committee held 3 meetings at CERC; first meeting was held on 03.11.2014, second meeting was held on 21.11.2014 and the third meeting was held on 16.03.2015**.**

14.0 Minutes of first and second meeting along with various documents/hard copies of presentations submitted/ made by members are enclosed as **Annexure-III and Annexure-IV.**

15.0 During the meetings of the Committee detailed deliberations were held. Members contributed their views during the meetings as well as in writing. Though different opinions were expressed by grid operator, generators and manufacturers during the discussions, it was generally agreed by all that ensuring healthy grid operation is a priority. Concern of some of the Generators in regard to limitations of their units based on basic design/control strategy was noted by the Committee.

Issues for Deliberations

16.0 The Committee deliberated on following issues :

- **i.** Necessity of Primary response by way of Governor Action and introduction of secondary and tertiary Control
- **ii.** Whether to continue with RGMO or switch over to FGMO
- **iii.** Whether to treat LMZ units separately and grant them exemption from governor operation
- **iv.** Reasons for poor response from existing units fitted with EHG governors and the remedial measures required, if any
- **v.** Widening the scope of Governor Mode operation

17.0 Necessity of Primary response by way of Governor Action and introduction of secondary and tertiary Control.

17.1 Power systems require ancillary services to maintain security of the grid and support their primary function of delivering energy to customers. Ancillary services are principally real-power generator control capacity services while system operation is governed by the behavior of generating units and load in various time frames and it aims to maintain the required instantaneous and continuous balance between aggregate generation and load. System frequency is indicator of balance between generation and load. It can be observed everywhere on the power system and provides an immediate indication of the imbalance between generation and load. Frequency drops from its reference value (nominal value 50 Hz) when load exceeds generation and rises when generation exceeds load. Large frequency deviations affect health of equipment and have the potential to cause collapse of power system. Therefore, frequency is needed to be tightly controlled through the collaborative efforts of generators, System operator namely RLDCs/SLDCs and Discoms. Three levels of Frequency Control Services are generally used to maintain the balance between generation and load i.e. Primary Frequency Control, Secondary Frequency Control, Tertiary Frequency Control. Three levels differ as per their time of response to a fluctuation and the methodology adopted to realize the fundamental operating philosophy of maintaining reliability and overall economy.

Primary Control

17.2 Continuous load changes/outage of a large generator, result in mismatch of generation and load leading to variation in frequency of interconnected power system. Keeping governors free to operate would enable smooth control of frequency fluctuations beyond the dead band of Governors, as well as act as security against grid disturbances. Time frame for primary governor control action is of the order of a few seconds i.e. 5-30 seconds and should last for at least 3-4 minutes to enable secondary control to take over which will allow the primary reserves to be restored. For primary control to work properly, most of the generation has to be under governor control so that adequate primary reserve is available at all times. Primary control tend to arrest the fall in frequency.

Secondary Control

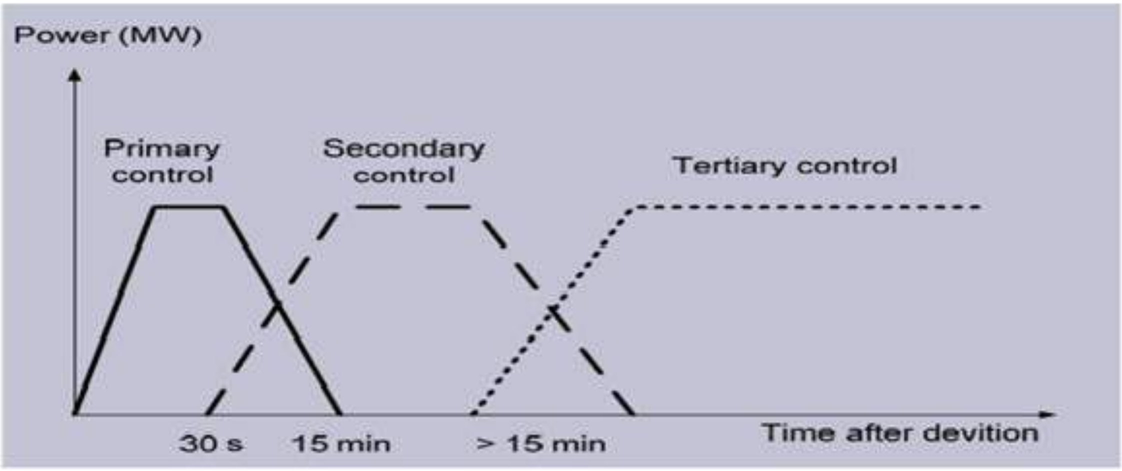
17.3 If the load generation imbalance caused by an outage of large generator or load results in sudden variation in frequency of interconnected power system, primary response through governor action described above would help arrest the fall in frequency. However, the frequency has to be brought back to 50 Hz through corrective action taken by the Control Area in which the generation or load is affected. Supplementary corrective action or secondary control has to be taken to bring frequency back to 50 Hz. Time line of secondary control action is 15/30 minutes for large events. For large interconnection system, the secondary control is achieved through Automatic Generation Control (AGC). AGC is used to help continuously balance the power system, maintain a constant frequency and eliminate area control error. Generators that provide regulations reserve increase or decrease output to meet the constantly changing load, thereby maintaining balance between load and generation on the system and acceptable frequency levels. They do so by responding to the automatic generation control signals from a system operator.

However, the secondary control through AGC has not yet been introduced in India. In view of the fact that primary control has been made mandatory in India, it is high time that a roadmap for introduction of secondary control in India needs to be drawn at the earliest. This would require identified generating units to receive the control signal from the AGC software being run at the control centre through appropriate communication & control infrastructure. Secondary control also requires that each Area Control Centre (SLDC) must have the AGC software as well as the ability to send the control signal.

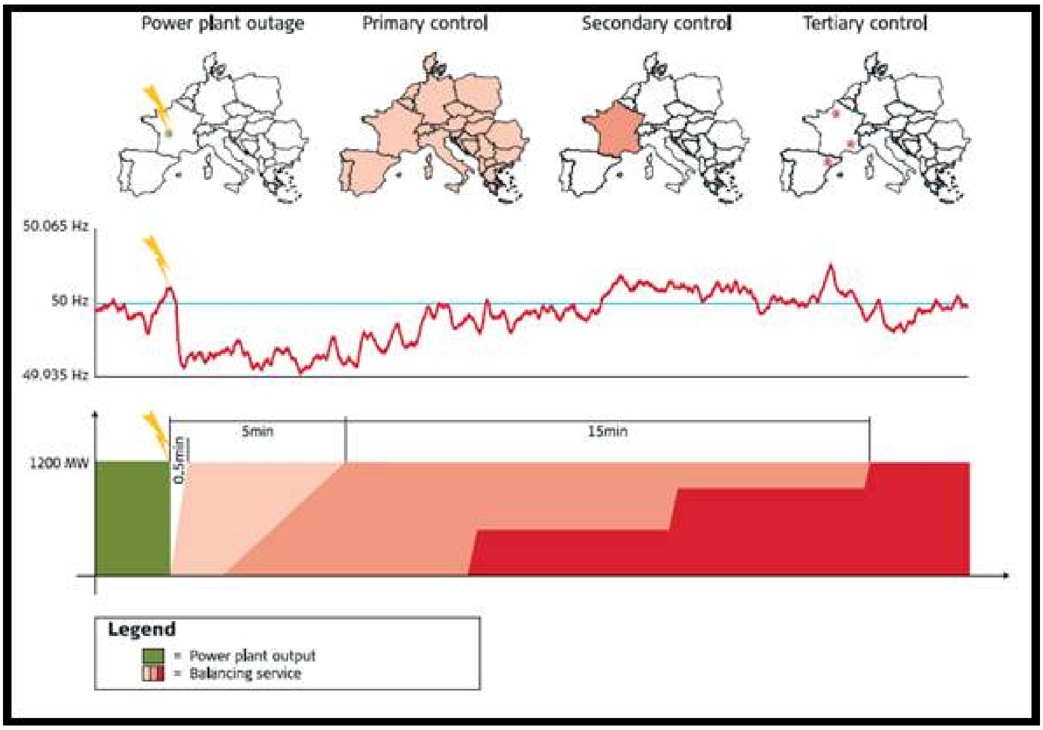
Tertiary Control

17.4 Loss of large generator (or load) may cause a large enough system excursion that cannot be handled by secondary control reserves alone. The above secondary control reserves also need to be restored through tertiary reserves. Tertiary reserve provides significant insurance against wide spread outages. Tertiary reserve had been a luxury in our system that was perennially short of generation. Since generation reserve situation is getting better, it is proposed to use such surplus reserve by procuring and compensating tertiary reserve to start with.

17.5 World over the primary control (governor control) is used for frequency stabilization after a large disturbance which operates in seconds (proportional control), the Secondary control restores the primary reserves & frequency to 50 Hz and operates in minutes (Integral control) and the tertiary control restores secondary reserves and operates in tens of minutes. All the three types of controls are essential part of any power system for its smooth operation and from system balancing aspect. Theses controls complement each other.



17.6 In this regard, the frequency restoration process by the combined action of primary, secondary and tertiary control in case of power plant outgae in France is shown as below:



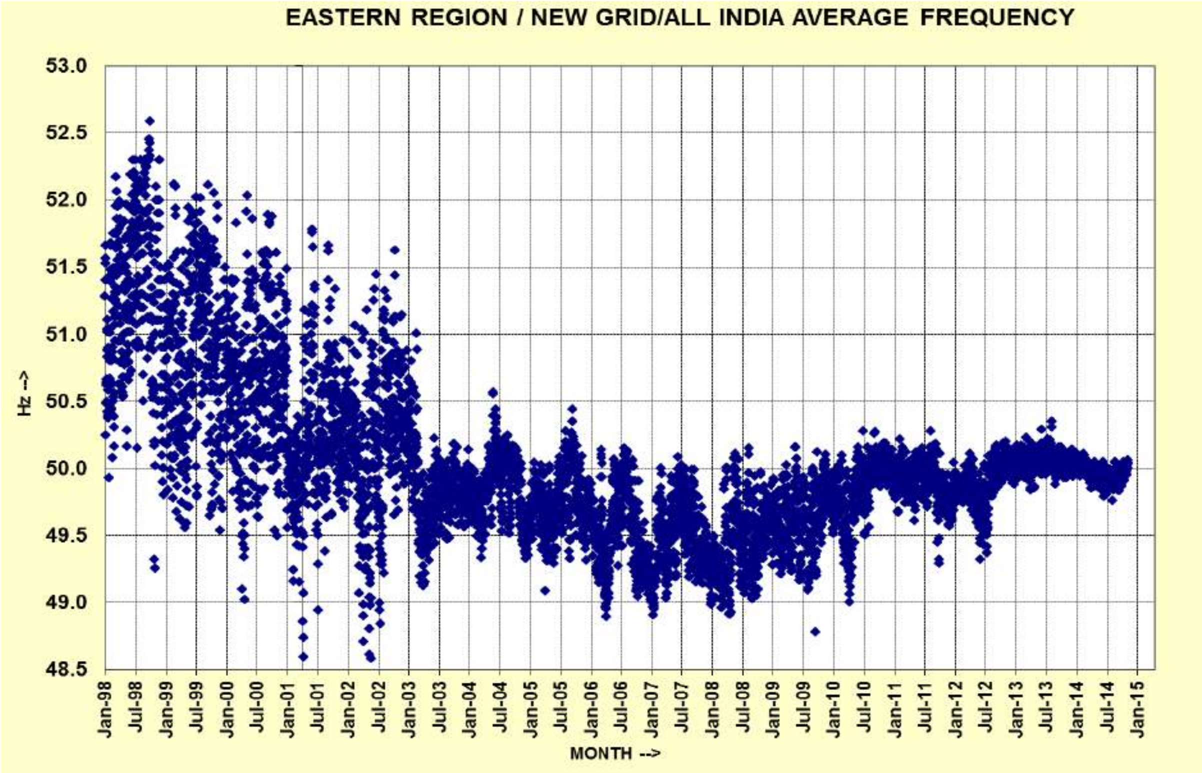
17.7 Each control area's contribution to the frequency support is provided by the natural response of its generators and loads to frequency variations. Frequency response typically comprises of two components:

a. **Load Damping**: There is reduction in power consumption by the rotating loads that slow down in response to a decline in frequency. The load response to a change in frequency can vary depending upon the type of load. The thyristor based loads (Silicon load) do not contribute to frequency response and their incidence is increasing day by day. Load response occurs directly or with minimum lag as the frequency changes.

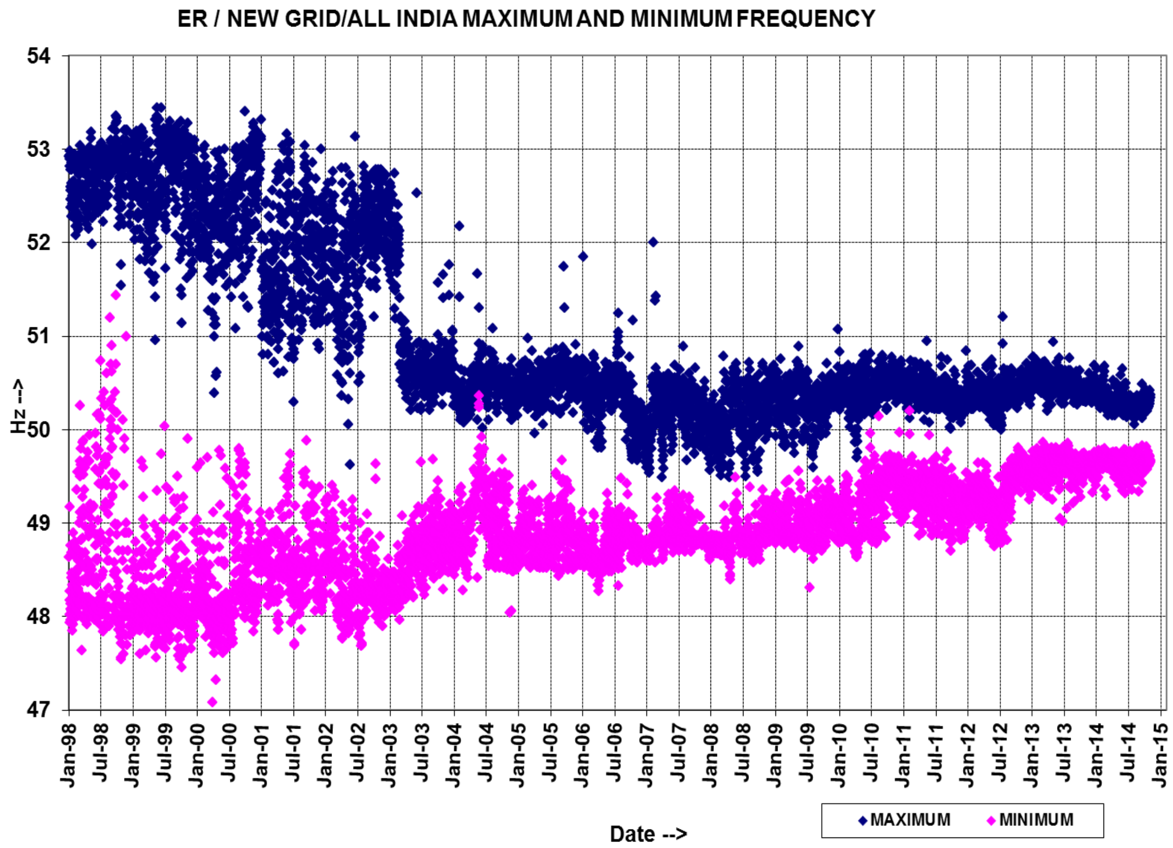
b. **Generator Response**: A change in output of a generating unit due to its governor action. Governor response from properly tuned units commences in 5-30 seconds and takes about a minute to deliver. It is responsible for bottoming of frequency and its partial recovery after bottoming up.

17.8 It is re-iterated here that for desired primary response to be available at all times, the importance of secondary control being simultaneously in place cannot be denied. The primary response has already been made mandatory by the Commission and in spite of absence of secondary reserves some primary response in varying degree is available. As such, it is highly desirable that urgent steps are taken for introducing the secondary control at the earliest to make primary response more effective. However, in the mean time, the primary control through RGMO/FGMO with manual intervention may continue for dealing with large frequency variations through collective efforts of the generators.

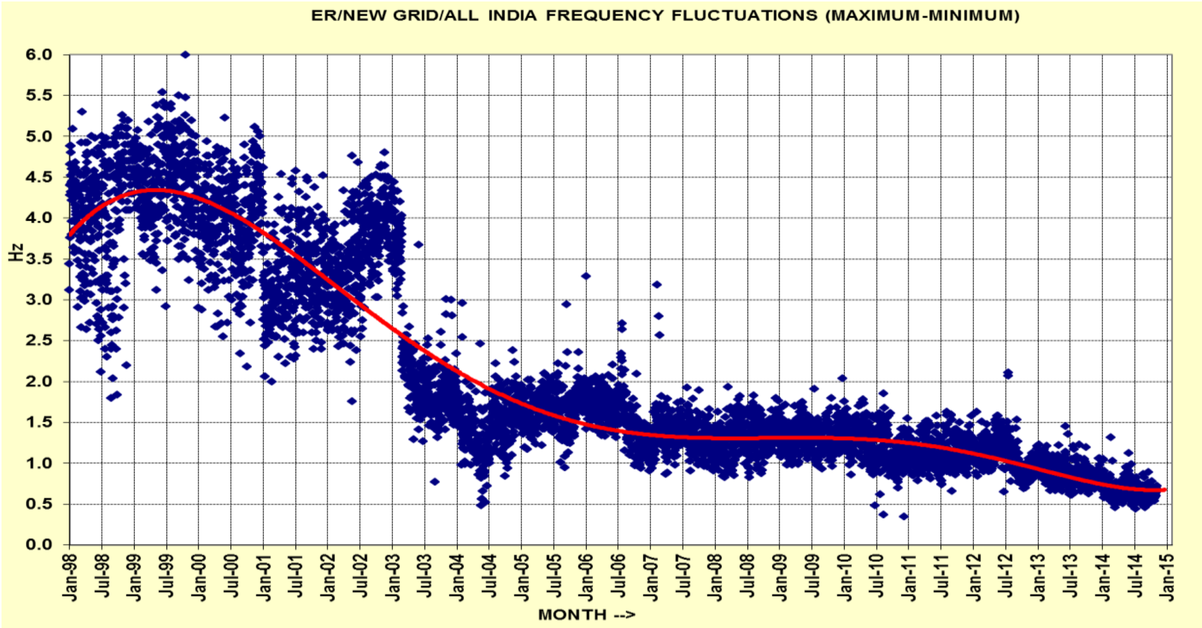
17.9 The average frequency profile in the country as reported by POSOCO is as follows:



17.10 The maximum and minimum frequency profile in the country is as follows:



17.11 The maximum and minimum frequency fluctuation band has come down drastically as follows:



17.12 It may be seen that the average frequency profile is remaining close to 50 Hz most of the time after narrowing of frequency band to 49.90 to 50.05 Hz with effect from 17.02.2014. However, maximum & minimum frequency still goes beyond the operating range of 49.9 Hz to 50.05 Hz specified in IEGC and frequency spikes are also witnessed.

17.13 Further, there has been substantial generation capacity addition in the XI plan & in the XII plan and the peak shortage has come down to around 3.5%. There are situations when there is surplus power during certain parts of the day. There is a lot of generation capacity which remains un-requisitioned and substantial capacity remains stranded due to fuel shortages.

17.14 As such, for desired primary response to be available at all times, Committee feels that it is high time that the secondary and tertiary controls may be resorted to through introduction of Automatic Generation Control (AGC), Ancillary Services and Demand Response.

18.0 Whether to continue with RGMO or switch over to FGMO

18.1 In the past Indian Grid was operating with a poor frequency profile, Generators were asked to implement governor control with substantial frequency variation. Unscheduled Interchange (UI) measures introduced to bring operational discipline, thereby reducing the frequency variation, though helped to improve the frequency profile, discouraged generators to enable the governor. After achieving improvement in frequency profile, RGMO was insisted.

18.2 The RGMO was introduced by the Commission to take care of the main concern of the generators that if some of the generators put their units on governor control and others do not put their units on governor control, their units on FGMO would be unduly stressed and would have to share more load. Commission had, therefore, provided that each unit would not be required to share load of more than 5%.

18.3 Representatives of CEA and POSOCO are of the view that time has come to do away with this stipulation and the units may be asked to operate on FGMO in view of the stabilized frequency profile and narrow range in which grid frequency remains.

18.4 Further, CERC has recently brought out draft "Ancillary Services Operation Regulations (ASOR), 2015 through operation of un-requisitioned surplus power of ISGSs. Once implemented, Ancillary Support Services may help improve the frequency profile further.

18.5 The primary response of the generating stations is much less than the desired for various reasons as deliberated in para 20 of this report. As such, overall primary response in the grid is not adequate.

18.6 Committee is, therefore, of the opinion that it would not be advisable to do away with RGMO stipulations at present till the time secondary and tertiary controls are in place. If FGMO is introduced at this stage i.e without introducing secondary and tertiary controls, units may be required to increase the loading by more than 5%. Further, the restriction imposed by RGMO that there shall not be any unloading in case of frequency improvement below 50.05 Hz will get removed if FGMO is resorted to and will act contrary to the requirement of frequency improvement.

18.7 As such, Commission may review switching over to FGMO after a period of one year

19.0 Whether to treat LMZ units separately and grant them exemption from governor operation

19.1 The following problems have been reported by the generators with regard to RGMO/FGMO with manual intervention in LMZ units:

- The reduction in load due to governor action cannot be limited to any desired quantum, unlike the electronic governors. If the frequency increases by 1Hz, the machine will unload by 50% (4% governor droop).
- These machines do not have HP/LP steam bypass system which can operate in parallel to the turbine steam flow. Therefore, such large changes cannot be accommodated and the unit may trip due to water/steam side disturbance.
- These units cannot be provided with any slow automatic return logic. Any correction will have to be made manually by the operator. The frequency changes in our power system still being there, the operator will have to continuously modify the set point of the control system, to continuously change its speed reference. This would remain a challenge for the operator, who has to manage several other equipments / systems also, at the same time.

- Continuous and unrestricted modulation of control valves will result in large fluctuations in Main and Reheat steam parameters adversely affecting the health of the machine.

- In short, if these machines are put on FGMO with manual intervention, there will be frequent and large quantum load fluctuations due to governor action. The resultant process disturbances will also be frequent, large and beyond the capability of the relevant control system to manage. Such a situation will lead to frequent outages on process violation.

19.2 It may be appreciated that the Commission through an order dated 21.5.2004 in Petition No 66/2003 had referred the matter to CEA for examining the technical difficulties in the implementation of FGMO**.** CEA had constituted a Technical Committee under the chairmanship of Member (Thermal) CEA. Committee after considering the problems posed by the generators including NTPC recommended adoption of scheme as implemented by MSEB at Nasik for the LMZ machines. NTPC during the deliberations with CEA stated that they are also adopting a similar scheme in their LMZ units but this was resulting in frequent manual interventions because the units are required to be brought back to scheduled generation as the boiler control loops are not in auto. NTPC, however, agreed that manual interventions have been reduced after ABT due to reduction in frequency excursions before CEA Committee.

19.3 With regard to the contention of the generators about uncontrolled unloading in the event of frequency increase, it may be appreciated that the RGMO stipulation as provided in the IEGC does not require unloading of the unit in case of improvement in frequency below 50.05 Hz which is being achieved with FGMO with manual intervention by utilities like TANGEDCO. The unit unloading comes into play only after frequency increases beyond 50.05 Hz.

19.4 In this regard, it has been reported by POSOCO that average frequency profile of All India Grid remains within the band of 49.90-50.05 Hz for most of the time, however, minimum and maximum frequency on daily basis still reaches to 49.70 to 50.30 Hz, which needs to be reduced to the operating frequency band as specified in IEGC.

19.5 As such, considering the fact that system frequency seldom goes beyond 50.30 Hz i.e increase of 0.25 Hz above 50.05Hz, the units would require to unload by only 10% considering 5% droop. Accordingly, Committee feels that unloading by 10% would not cause any process disturbances beyond the capability of the machine. Further, for the incidence of frequency decrease, units are required to increase generation by only 5% as primary response along with ramping back @ one percent per minute as per stipulations of IEGC.

19.6 These stipulations of RGMO may be handled by manual intervention in case of mechanical governors. TANGEDCO has already brought out that their LMZ units are operating under FGMO with Manual Intervention (MI) and providing the desired response.

19.7 In the light of above, the Committee feels that the concerns shown by the generators are not well founded.

19.8 Further, OEMs such as Siemens, Alstom, GE and BHEL, by way of their presentations have brought out that retrofit solutions are available in which LMZ units can be fitted with EHG and thereby these may meet the IEGC stipulations with regard to the RGMO. However, such retrofit may have to be aligned with the Renovation and Modernization of the units having completed useful life; otherwise requires additional capital expenditure before the expiry of useful life. These expenditures would have to be serviced through tariff for which they would require approval of the Appropriate Commission.

19.9 In this regard, it may be appreciated that RGMO operation is one of the consideration with regard to expenditure on retrofitting and has to be decided with due care by the generators. It is up to the generator whether to go for retrofit or continue with FGMO with manual intervention but adequate response has to be ensured at all times. As such, Committee feels that there is no need for granting any exemption to LMZ units from operation under RGMO/FGMO with manual intervention.

20.0 Reasons for poor response from existing units fitted with EHG governors and the remedial measures required, if any

20.1 The Committee has been informed that existing units even fitted with EHG are not giving adequate response. The various reasons for not giving adequate response are as follows:

- Non triggering mechanism due to higher ripple factor more than 0.03 Hz kept in the control.
- Different load limiters and different tuning parameters in the control algorithm of units,
- RGMO switched off condition
- In the existing RGMO application program, after the primary response to full level (5%), a halt time for 3 to 10 minutes has been introduced by the OEMs for recovery of large time constant equipment namely Boiler
- Operation of generating units above their Installed Capacity without keeping margins for primary response
- Non remunerative Deviation charges discouraging generator to provide response
- Absence of secondary and tertiary control in Indian grid due to which thermal reserve once released in providing the primary response does not get recouped. As such, unit may not or may show partial primary response during subsequent frequency fall event.

20.2 The Committee feels that the first three reasons for the inadequate response may be dealt though seeking strict compliance by way of appropriate regulatory measures such as imposing penalty for non compliance.

20.3 M/s Solvina has shown that the primary response of a generating unit could be measured by giving impulse separately for frequency deviation. In this regard, Committee recommends that periodic checkups to ensure desired RGMO/FGMO response should be made mandatory and should be conducted at regular intervals, through independent third parties selected by POSOCO/SLDCs. The cost of such tests may be recovered by the RLDCs/SLDCs as part of RLDC/SLDC Fee and Charges.

20.4 As regards, halt time of 3-10 minutes induced for providing subsequent primary (governor) response, the same would depend on the thermal reserves depending upon unit size and its replenishing through boiler support. Thus, this is not entirely within the control of the generator.

20.5 It has also been observed that units operate at capacity higher than the Installed Capacity and as a result units are unable to give desired response of 5% over and above the Installed capacity.

20.6 In this regard, Committee feels that Grid operation with adequate regulation reserves is very important. This could be taken care of if the unit is not scheduled by RLDC/SLDC beyond ex-bus generation corresponding to 100% of the Installed Capacity. However, this would require necessary amendment in the IEGC.

20.7 Further, units, even at part loads, resort to operation with its Valves Wide Open (VWO). This does not leave any scope for providing primary response during frequency decrease. As such, Committee feels that units should not be allowed to operate under VWO condition. Necessary amendments in IEGC may be made to this effect by CERC. The commercial angle behind non-willingness of generators to provide primary response is non remunerative deviation charges as the grid frequency is remaining close to 50 Hz. As a result, generator is unable to recover even its energy charges. The generators tend to avoid this by introducing larger ripple factors. For example, units whose variable charges are more than 261.36 paise/kWh (DSM charges corresponding to 49.97 Hz) would like to adjust their ripple factors till a frequency after which they start earning more than their variable charges e.g a unit whose variable charges are say 450 paise/kWh would not like to increase generation till frequency touches 49.87 Hz where the Charges for Deviation become around 469.76 paisa/kWh. Further, the cap rate of 303.04 Paise/kWh fixed for coal and lignite based units stops them for providing any kind of primary response. As such, units whose variable charges are more than 303.04 Paise/kWh would not like to increase the generation by primary response as they will be at commercial loss.

20.8 In view of the above, Committee suggests that CERC may review DSM so that units provide primary response.

21.0 Whether to widen the scope of Governor mode operation by including gas/liquid fuel based combined cycle units, Captive Thermal Power Plants, nuclear power plants & Renewable Energy based units and whether to relax small gas turbines and small hydro stations of old vintage.

21.1 Committee also deliberated on the feasibility of bringing Gas/liquid fuel based units/stations under FGMO/RGMO operation, which were earlier exempted from RGMO/FGMO due to wide fluctuation in frequency.

21.2 M/s Solvina, based on its test at Bawana Gas Station, has indicated in its report that gas stations are capable of providing sustainable primary response. Further, it has been gathered that gas/liquid based combined cycle stations i.e SUGEN and DGEN of M/s Torrent Power Limited are providing primary response to frequency excursions.

21.3 As such, Committee is of the opinion that CERC by way of amendments in IEGC Regulations shall include Gas/liquid fuel based units/stations under FGMO/RGMO operation. However, in case of gas/Liquid fuel based units also, adequate margins while scheduling shall be kept by RLDC/SLDC in due consideration of prevailing ambient conditions of temperature and pressure viz a viz site ambient conditions on which installed capacity of these units have been specified.

21.4 Further, units of 200 MW and above of thermal captive power plants, which are connected to the grid, shall also be explicitly brought under the relevant regulation of primary response. The FRC of such captive power plants may be monitored by concerned SLDC/RLDC/POSOCO and reported to CERC.

21.5 Committee also considered bringing Nuclear units under the FGMO/RGMO regulation as the frequency has stabilized within a narrow band and as such variation of generation according to governor droop may be handled by these units without much process disturbances. However, considering the sensitivities associated with nuclear power plants, the inclusion of Nuclear Units may be considered through discussions with various stakeholders.

21.6 Further, in view of the increasing penetration of the Renewable Energy based power plants, it is suggested that the discussions on feasibility of frequency response from renewable sources of energy may be initiated. CEA, Technical Standards for Connectivity to the Grid, also warrant these units to control active power injection in accordance with a set point which shall be capable of being revised based on the directions of the appropriate load dispatch centre.

21.7 Regarding relaxation of RGMO/FGMO stipulations, it has been brought out by CERC that during the recent past, a number of old vintage small capacity hydro stations/units have sought exemption from the RGMO/FGMO stating that it is becoming increasingly difficult to arrange for the spare parts for the governing system and the governors are not operating. Committee is of the view that in consideration of small contribution these units make to the overall FRC and considering their maintenance and operational problems, the current limit of 10 MW for hydro stations for providing primary response through FGMO/RGMO may be increased to 25 MW.

21.8 Any reference to frequency control is incomplete without HVDC systems which also generally have a frequency control feature. For instance, NERC policies stipulate as follows in this regard:

> "*Turbine governors and HVDC controls, where applicable, should respond to system frequency deviation unless there is a temporary operating problem*"

Accordingly, Committee is of the view that available HVDC system may also be asked to provide frequency response.

Committee's Recommendations

1. It is highly desirable that urgent steps are taken for introducing the secondary control at the earliest to make primary response more effective. However, in the mean time, the primary control through RGMO/FGMO with manual intervention may continue for dealing with large frequency variations through collective efforts of the generators.

2. The secondary and tertiary control may be introduced through opertionalising Automatic Generation Control (AGC), Ancillary support Services and Demand Response.

3. It would not be advisable to do away with RGMO stipulations at present till the time secondary and tertiary controls are in place. The Commission may review switching over to FGMO after a period of one year

4. Committee feels that there is no need for granting any exemption for the LMZ units from operation under RGMO/FGMO with manual intervention. The generator may decide on their own whether to go for retrofit for adopting RGMO features or continue with FGMO with manual intervention.

5. The inadequate primary response may be dealt through seeking strict compliance by way of regulatory measures such as imposing penalty for non compliance. In this regard Committee recommends that periodic checkups to ensure desired RGMO/FGMO response be made mandatory and should be conducted at regular intervals, through independent third parties selected by POSOCO/SLDCs. The cost of such tests may be recovered by the RLDCs/SLDCs as part of RLDC/SLDC Fee and Charges.

6. The unit may not be scheduled by RLDC/SLDC beyond ex-bus generation corresponding to 100% of the Installed Capacity. Further, units should not be allowed to operate with their valves wide open. However, these stipulations would require necessary amendment in the IEGC. In case of

gas/Liquid fuel based units also, adequate margins while scheduling should be kept by RLDCs/SLDCs in due consideration of prevailing ambient conditions of temperature and pressure viz. a viz. site ambient conditions on which installed capacity of these units have been specified.

7. CERC may review Deviation Settlement Mechanism (DSM) so that units are incentivized to provide primary response.

8. Gas/Liquid fuel based stations, which are currently exempted from RGMO/FGMO stipulations, shall be included in the list of eligible units capable of providing primary response and may be mandated accordingly by way of amendment to IEGC.

9. Units of 200 MW and above of thermal captive power plants, which are connected to the grid, may also be explicitly brought under the relevant regulation of primary response.

10. For widening the scope of RGMO/FGMO, Commission may initiate discussions with stakeholders for including units of nuclear stations and renewable energy based stations.

11. HVDC systems available in the country may also be asked to provide frequency response.

12. The current lower limit of 10 MW for hydro stations for providing primary response through FGMO/RGMO may be increased to 25 MW.

Annexure-I

CENTRAL ELECTRICITY REGULATORY COMMISSION
3rd & 4th Floor, Chanderlok Buildign 36, Janpath, New Delhi -110001
(Tele No. 23353503/ Fax No. 23753923)

CERC/Engg/Thr/FGMO Committee/2014 Date 24.09.2014

OFFICE ORDER

Subject: Committee on FGMO of Thermal Generating units.

The Regulation 5.2(f) of IEGC specifies that if a generating unit cannot be operated under restricted governor mode operation, then it shall be operated in free governor mode operation with manual intervention to operate in the manner required under restricted governor mode operation.

2. Some of the generating Companies have sought relaxation from the above provision of FGMO in respect of certain units citing various reasons. In the light of this, the Commission has decided to constitute a Committee with following composition to go in to the issues concerning FGMO of the units and make suitable recommendations to the Commission:

1. Shri A. Velayutham, Ex-Member MERC - Chairman
2. Shri Chandan Roy, Ex-Director NTPC - Member
3. Dr. LD Papne, Director, CEA - Member
4. Shri Satyanarayana, SE, WRPC - Member
5. Shri S.K Soonee, CEO POSOCO - Member
6. Representative from NTPC - Member
7. Representative from NLC - Member
8. Representative from BHEL - Member
9. Shri Neeraj Kaul, Alstom India - Member
10. Chief (Engg) CERC - Convener

The Terms of Reference of Committee are given below:

i. To look into the problems of the generating units in implementing FGMO with manual intervention.
ii. To suggest measures for implementation of FGMO with suitable modification/ amendments in certain Regulations/ IEGC.
iii. Any other recommendation to facilitate FGMO/RGMO operation.

4. Committee shall submit its recommendation to the Commission within two months.

24/9/14

(Shubha Sarma)
Secretary

Copy to:

1. Shri A. Velayutham, Ex-Member MERC
2. Shri Chandan Roy, Ex-Director NTPC
3. Dr. LD Papne, Director CEA
4. Shri Satyanarayana, SE WRPC
5. Shri S.K Soonee, CEO POSOCO
6. Shri N.N Mishra, Director (Operation) NTPC with a request to nominate their representative.
7. Chairman, NLC with a request to nominate their representative.
8. CMD, BHEL with a request to nominate their representative.
9. Shri Neeraj Kaul, Alstom India
10. Chief (Engg) CERC

Copy also to:

PS to Chairperson/M (DD)/M (AKS)/ M (ASB)

CENTRAL ELECTRICITY REGULATORY COMMIISSION
3rd & 4th Floor, Chandralok Building, 36, Janpath, New Delhi 110001
Phone: 011-23353503/23752958

CERC/Engg./Thr/FGMO Committee/2014 Date 12.11.2014

Office Order

Sub: Constitution of Committee on FGMO in generating units.

CERC had vide Office Order of even number dated 24.09.2014 constituted a Committee for implementation of FGMO in Generating units. Subsequently it has been decided that representatives from State Generating Companies, one from each region will be part of the Committee as Member.

2. In partial modification to the aforementioned CERC Office Order, representatives of the State Generating Companies as mentioned below will be part of the Committee as Member.

i) Rajasthan Rajya Vidyut Utpadan Nigam Ltd. (RRVUNL), from Northern Region

ii) Maharashtra State Power Generation Company Ltd. (MAHAGENCO) from Western Region

iii) West Bengal Power Development Corporation Ltd. (WBPDCL) from Eastern Region

iv) Tamilnadu Generation and Distribution Corporation Ltd. TANGEDCO from Southern Region

v) Assam Power Generation Corporation Ltd. (APGCL) from North-East Region

3. The other terms of reference of the Committee will remain the same.

12/11/14
(Shubha Sarma)
Secretary

Copy to:

1. CMD,RRVUNL
2. MD,MAHAGENCO
3. CMD,WBPDCL
4. CMD,TANGEDCO
5. MD,APGCL

Copy for information to:

1. Shri A. Velayutham, Ex-Member MERC
2. Shri Chandan Roy, Ex-Director NTPC
3. Dr. LD Papne, Director CEA
4. Shri Satyanarayana, SE WRPC
5. Shri S.K Soonee, CEO POSOCO
6. Shri N.N Mishra, Director (Operation) NTPC
7. Chairman, NLC
8. CMD, BHEL
9. Shri Manoj Kaul, Alstom India
10. Chief (Engg), CERC

Copy also to:

PS to Chairperson/M (DD)/M (AKS)/ M (ASB)

Annexure-III

Minutes of First Meeting of Committee on FGMO of Generating Units, held on 03.11.2014 at CERC, New Delhi

1. The convener of the Committee, Sh. A.K. Saxena, Chief (Engg.), CERC welcomed the Committee members.

2. Joint Chief (Engg.), CERC, Sh. S.C. Shrivastava presented a brief on the background for 'Implementation of FGMO in Generating Units' bringing out the various provisions of IEGC Regulations and Regulators perspective. The difficulties being faced in implementing FGMO/RGMO in LMZ machines, as indicated by Generators in various petitions to the Commission, were also brought to the notice of the Committee. The presentation suggested that in view of the fact that quiet a number of LMZ machines installed in the country are close to their useful life of 25 years, it may be prudent to allow the complete replacement of the mechanical governing system with EHG governing system along with associated control systems on boiler and turbine side as a part of R&M for life extension.

3. Chairman of the Committee Shri. A. Velayutham, Ex-Member, MERC stressed upon the need of implementing Governor Operation for achieving reliable and stable grid operation. He stressed that in view of low load response due to decrease in share of rotating load, generators role in providing primary response during frequency excursions becomes important. He further stressed that system operator will have to play a major role in implementing Governor operation. He requested the Committee members to give their views so that appropriate suitable and implementable solution could be formulated.

4. Shri. Chandan Roy Ex-Director, NTPC stated that the final target should be to implement FGMO in view of the narrowing of the operating frequency band. However, it may not be advisable to revert back to FGMO for units already put under RGMO, because of the investment already made. He stressed that if LMZ machines with mechanical governors constitute a minor portion of the installed capacity, they may be exempted from FGMO stipulations.

5. Deliberating on the model adopted by MSEB at Nasik for implementing FGMO with manual control, Dr.LD Papney, Director, CEA stressed that time for implementing FGMO needs to be considered in view of narrowing of the operating frequency band to 49.90 to 50.05 Hz.

6. Shri. S.K. Soonee, CEO, POSOCO, referring to 31 cases of frequency excursions during recent past, brought out that Frequency response witnessed in the unified grid is of the order of 5000 MW/Hz only where as it should be in the range of 25000MW/Hz. He stressed that desired primary response is not coming from the generators and that the country should be able to absorb generation loss of 4000 MW(largest UMPP) without much of frequency excursion. He also stressed the need for secondary control, spinning reserves, tertiary control in form of Ancillary service and making area control error every 10minutes or so. He suggested that generators should not be allowed to declare availability beyond 100% more so under the prevailing fuel shortage scenario, so that there is enough margin for providing primary response. In this context he also invited attention to provision of 5% spinning reserve as preferred in National Electricity policy.Further, he pointed out that some methodology/testing procedure may have to be worked out to test that provisions of IEGC are being followed or not. The need of testing primary response by inducing frequency, distinct from prevailing frequency of the system, as adopted in Sweden was also emphasized. He stressed that it is the best time for implementing FGMO in view of the narrowing of the operating frequency. Sh. Soonee, then underlined the need of involving State generating Companies in the deliberations /meetings of the Committee as the FGMO implementation is a pan India exercise. The Committee agreed to co-opt one state Generating Company from each region in further deliberations /meetings. Committee decided that representative of a) MAHAGENCO b) RRVVUNL c) WBPDCL d) TANGEDCO and e) APGCL be included as members. The Committee recommended that approval of competent authority of CERC be taken in thid regard.

7. Mr. Neeraj Kaul, representative of M/s ALSTOM mentioned his experience in U.S. of measuring primary response of a unit post frequency response by way of triggering certain frequency in the system. He suggested that certain stations/units may be identified by the Committee for observing the response of the units subsequent to frequency excursion.

8. Shri. P.P.Francis, GM(OS) NTPC gave a detailed presentation bringing out that facts and figures associated with the FGMO implementation. It was stressed that primary or Governor Control can bring constancy of frequency (at a target frequency of say 50Hz) along with secondary control . During the slow changes in load / frequency the Secondary Control will control the frequency within the Governor dead band (0.06% as per IEC) and prevent the Primary Control from "being called". Thus, the Primary Control

remains always active but does not act. When large / sudden changes in frequency occur, the secondary Control (inherently a slow control) becomes ineffective and the Governor dead band is breached and the Governor Control acts to deliver large generation quantum quickly. Being a proportional control, this will not restore frequency to the constant target. As the slow acting Secondary Control restores the frequency to the target, the Governor control margin delivered gets automatically withdrawn and these machines remain active for delivery in the next event. In the absence of Secondary Control, Governor Control responds to the continuously changing frequency and do not have the required control margin when its real service becomes necessary. The Hon'ble Commission has already initiated discussions on introduction of Ancillary Services in India and Secondary Control happens to be one of the important Ancillary Service. He stressed that NTPC has incorporated all features of RGMO as specified in IEGC Regulation 5.2 (f) in all its machines with EHG governors, however, LMZ machines, with mechanical governors directed to be operated in FGMO with MI, are posing operational problems and that is the only reason for seeking exemption from FGMO.

9. Shri. S. Satiyanarayanan, GM, NLC, brought out that NLC has already implemented RGMO/FGMO with MI in all its units. However, response to the tune of 2% as against 5%, is generally observed due to technical limitation associated with lignite fired units. He further brought out that the units cannot be backed down beyond technical minimum in the event of frequency going above 50 Hz.

10. Shri. V.M. Yadunandanan, AGM, BHEL brought out that they have installed EHG governing system in LMZ machine at Obra TPS under R&M and the unit is now capable of providing desired response under RGMO/FGMO.

11. Shri. A. Velayutham, Chairman of the Committee, expressed thanks to and opined that all the members deliberate the issues in their respective organizations. It was also agreed that during the next meeting M/s ALSTOM and M/s Siemens may be requested to give presentation regarding retrofitting of LMZ machines to make them compatible for FGMO/RGMO implementation.

12. Committee decided to hold the next meeting at 2.30p.m.on 21.11.2014

Annexure-IV

Minutes of Second Meeting of Committee on FGMO of Generating Units, held on 21.11.2014 at CERC, New Delhi

1. The **convener of the Committee**, **Shri A.K. Saxena, Chief (Engg.), CERC** welcomed the Committee members.

2. After welcoming the new members from TANGEDCO and WBPDCL, Chairman of the Committee, Shri A. Velayutham requested members to present their views.

3. Shri S.K. Soonee, CEO, POSOCO made a presentation. The highlights of his presentation were as follows-

a) The frequency control would be sustainable if Primary Control (Governor Control), Secondary Control, Tertiary Control and proper imbalance pricing mechanism are pressed into service together. The Imbalance pricing mechanism should ensure that a generator does not get commercially hit for putting its machine on FGMO. The prevailing Deviation Settlement Mechanism (DSM) Regulations and DSM rates are not expected to cause any undue loss to the generator.

b) Whereas Primary Control, which is a proportional control, acts within few seconds of large imbalance, Secondary Control is an integral control and keeps the frequency excursion within narrow range in case of imbalances caused by daily and seasonal load changes. Further, in case of large imbalance to the tune of 1000 MW, subsequent to Governor Control, Secondary Control operates in minutes and restores primary reserves and frequency to 50 Hz. Tertiary Control operates in tens of minutes and restores secondary reserves.

c) The objective of FGMO implementation shall be that the grid should be able to handle large imbalances without pressing UFRs into service.

d) The real time frequency in Europe and U.S remains within the narrow range of 49.96 to 50.04 Hz i.e. +/- 0.04 Hz and 59.96 to 60.04 i.e. +/- 0.04 Hz respectively.

e) The average frequency profile has improved after grid integration. The average frequency of the All India Grid remains within the band of 49.90-50.05 Hz for most of the time. However, real time minimum and maximum frequency on daily basis still reaches to 49.7 to 50.20 Hz, which needs to be reduced to the permissible frequency band. Further, frequency spikes have been observed at hourly boundaries.

f) The FRC of All India Grid is still low i.e. around 5000-6500 MW/Hz and needs to be improved to the level of 20,000 to 25,000 MW/Hz by way of primary control.

g) Load fluctuations need to be addressed by way of better forecasting, automatic generation control and keeping reserves while declaring availability and by bringing Area Control Error (ACE) to zero. In order to facilitate primary response (RGMO/FGMO), schedules be restricted to within 95% of Declared Capability.

h) The DSM be de-linked with frequency as the same is prohibiting generators in providing necessary Governor control.

4. Chairman of the Committee observed that secondary and tertiary control though required for primary control to be sustainable, are not covered under TOR of the Committee. As of now, Committee should focus on primary control and the secondary and tertiary control could be **recommended as way forward**. Chairman, then invited M/s Alstom and M/s Siemens to give their presentation on retrofitting of turbine governor control in LMZ machines so as to make them compatible with the requirements of FGMO/RGMO.

5. The highlights of presentation made by the representative of M/s Alstom are as follows-

a) There are around 67 LMZ machines in India with installed capacity of 13 GW.

b) The old design of the mechanical governing system with heavy components is insensitive. The dead band is around 0.1% as against dead band of 0.06% possible with EHG governors. The LMZ machines are facing operational difficulties due to shortage of spares.

c) With adoption of our solution, governing system can be made compliant to the requirements of IEGC in regard to implementation of RGMO/FGMO.

d) Only 25-30 days are required for installing basic variant into the existing LMZ machine. The total time required would be 8-11 months considering time required for calling tenders, bid evaluation, placement of order and supplies to be made by the selected bidder etc.

e) The option of basic variant is aimed at customers who require minimum adoption to conform to CERC Grid Code Regulations. The existing mechanical controller is replaced by redundant electronic controller, incorporating a digital governor. The electronic controller is connected, via an electro-hydraulic converter, to an actuator of the T.L type. This then operates the HP and IP valves through existing levers. Additional options which can be incorporated while retrofitting the basic variant are-

i. Improved oil filtration by installing an oil filter in the electro-hydraulic converter supply
ii. A relay to reset the turbine protection system prior to start-up

iii. An electronic over speed protection system

f) The standard variant, like basic variant, includes replacement of mechanical controller by redundant electronic controller. However actuation of HP and IP valves in this variant is separated for better operational flexibility. In fact the HP can have an actuator for each of its four control valves. The existing mechanical protection system is replaced by a three channel system, connected to a 2 out of 3 trip unit. This gives a hydraulic link from the protection unit to the control system. An oil filtration unit is included in the supply of the trip unit.

6. The highlights of presentation made by the representative of M/s Siemens are as follows-

a) Siemens is a pioneer in providing customized solution for various STG OEMs in addition to its own fleet of KWU units. Proven state of the art governing system upgrade solution for LMZ STG units including K200-130, K310-150, etc. is available.

b) SPPA R3000 based EHG (Electro Hydraulic Governing) is established solution for up-gradation of the existing mechanical governing system. It ensures improved turbine operation and appropriate response of STG as per National Grid Code RGMO guidelines.

c) There is a possibility of implementing the solution without removal of existing components. In such cases shorter outage time is sufficient and the existing hydro-mechanical governor can be retained.

d) Siemens successfully upgraded old hydro-mechanical system with SPPA R3000 based EHG governing system in 2008 for 2x310 MW LMZ STG units at Aghios Dimitrio, Greece.

e) Further, SIL3 Turbine protection system ensures higher safety and availability for complete power plant.

f) The "Key Highlights" of the Siemens solution are as follows:

i. Conformance to National Grid code RGMO guidelines.
ii. Implementation of Acceleration limiter and other pre emergency functionalities.
iii. Simple implementation of Electro Hydraulic System as against existing complex hydro-mechanical linkage systems.
iv. Possibility-Without removal or retrofit of existing control valves, Governing and oil system.
v. Easy diagnostics of the EHS system and shorter downtime.

7. Shri R.Pugazhendi, Executive Engineer, North Chennai TPS,TANGEDCO, made following observations/ views regarding operation of their units under RGMO regime :

a. The software for RGMO implementation may be fine tuned and improved upon for achieving the ripple factor effect of 0.03 Hz. Though the incidences of RGMO have been reduced substantially to 5-7 in a day but still at times RGMO operation or frequency excursions in the range of 40-50 a day have also been observed. This puts undue strain on turbine. It has also been seen that some time certain stations have not provided RGMO response such as Idduki which is role model in Southern Region for RGMO behavior can also be attributed to tuning of software for ripple effect.

b. In the existing RGMO application program, after the primary response to full level (5%), a halt time for 3 to 10 minutes have been introduced by the OEMs for recovery of large time constant equipment namely Boiler. Then if any needy RGMO incident occurs/arises during this halt period, the machine will not respond leading to in-consistency under RGMO clause.

c. The results of planned RGMO test carried out in one NTPC unit of Dadri STPS Stage II indicated in the presentation of POSOCO show an immediate dip in the generation after the primary response, even though the unit operators were well aware of the planned trial of decrementing the frequency level. This is the general cry of every Generator that this dip in load after RGMO response need not be treated as reverse response by SRPC. TANGEDCO suggested that analysis pattern to study the RGMO response be modified to 5 or 10 seconds basis instead current practice of one minute basis so that the RGMO response of generators felt by the Grid will be appreciated.

d. This RGMO test also showed that the TG was kept at responded level for more than 22 minutes and TANGEDCO expressed that as per IEGC clause 5.2 (h), the generators can ramp back to the original generation level kept before RGMO response at the rate of about 1 % per minute and need not be kept at the responded level in case of non sustainability. TANGEDCO requested the forum that due to slow response of large time constant boiler, the secondary response shall not be posed on to the Generators as like in this RGMO test for 22 minutes.

e. TANGEDCO expressed that visibility of status at TN LDC has been made for North Chennai TPS & Tuticorin TPS.

f. Inconsistency in RGMO performance among the units may be due to different load limiters, different tuning parameters in the control algorithm of units, RGMO switched off condition, non triggering mechanism due to higher ripple factor kept in the control, RGMO controller in halt time mode for recovery of boiler as designed in the RGMO software block, etc..For ensuring consistent RGMO performance, tuning works in NCTPS are still in progress.

g. Out of 64 RGMO machine incidents in the period of October 2013 to January 2014, Mettur TPS comprising of 4 x 210 MW LMZ sets have responded for 34 times under FGMO with Manual Intervention (MI).

h. As future activities, clause on demanding implementation of RGMO as per the available guidelines of Hon'ble CERC at the time of commissioning the new 660 MW projects has been specified in the Technical Specifications for Ennore SEZ Kattupalli 2 x 660 MW units, Udangudi 2 x 660 MW Units & Ennore Thermal Power Station Expansion 1 x 660 MW units. This will continue for the next new projects of TANGEDCO for ensuring commitment of the vendors to carry out RGMO in the turbine control systems.

i. The expected average demand of 6000 MW/Hz as primary response in the grid at the National level and the maximum RGMO response of 5% of generation will be extended to the grid for the fall/raise in frequency level of 0.13 Hz. For this level of 0.13 Hz, the average primary response demand will be 780 MW. By keeping an average demand for every RGMO incident as 1000 MW or lower value based on current generation by SRLDC, Bangalore, the RGMO performance analysis is being prepared. From the primary response demand at National level depending on the quantum of frequency drop/raise for any RGMO incident and the expected share of Southern Region shall be calculated for each RGMO incident to maintain the frequency. The performance of the generating stations shall be analyzed/ graded considering expected share of Southern Region.

8. Chairman of the Committee was informed that two state utilities i.e RRVUNL and MAHAGENCO have not nominated their representatives for the Committee. It was decided that these utilities be requested to send their representatives for the next meeting of the Committee.

9. Representative of NTPC submitted that he would be giving his views separately in writing. His written submissions (copy enclosed as Annexure IV a) may be considered by the Committee in the next meeting.

10. The Chairman of the Committee thanked the participants and observed that there shall be a last concluding meeting of the Committee, the date for which shall be decided in due course of time. It was opined that every member shall firm up their views and after considering the submissions of other participants.

11. Representative of WRPC, who could not attend the meeting, has also submitted his views, which may also be considered in the next meeting. (Copy enclosed as Annexure-IV b.)

Annexure-IV a

November 26, 2014

Sub: **Material submission for consideration of the CERC committee for Implementation of FGMO: P P Francis, GM (OS), NTPC Ltd.** (Member)

With reference to the Terms of Reference (TOR) of the subject committee, a few very pertinent points are brought out in the following paragraphs:

The TOR of the Committee reads as below:

1. To look into the problems of generating units in implementing RGMO/FGMO
2. To suggest measures for implementation of FGMO with suitable modifications / amendments in CERC Regulations / IEGC
3. Any other recommendations to facilitate FGMO operation

Background of the present issue before the CERC:

CERC (Indian Electricity Grid Code) Regulations 2010 as amended by the First Amendment dated 5.3.2012 (Effective from 17.9.2012) included a provision as under, in partial modification of the prescription of restricted governor mode of operation (RGMO):

Quote

> ***"Provided that if a generating unit cannot be operated under restricted governor mode operation, then it shall be operated in free governor mode operation with manual intervention to operate in the manner required under restricted governor mode operation."***

Unquote

(Emphasis supplied)

Generating units equipped with purely mechanical Governors are not amenable to introducing the unconventional requirements stipulated in the above IEGC provisions wrt "restricted governor mode operation (RGMO)". When the RGMO prescription was stipulated, it was clearly understood that it will be applicable to Electric Governors and was so stipulated in the IEGC till the impugned proviso was introduced by the said amendment. The said amendment is directly in contravention of the premises under which the need for RGMO prescription had been introduced. If for a moment it is accepted that the proviso can be implemented, the so called RGMO prescription itself was not required to be introduced in place of the erstwhile existing provision of FGMO at all. By making RGMO applicable to EHG equipped machines, IEGC had very well recognized that the logic of RGMO cannot be implemented on machines with mechanical / hydraulic governors and that these units would remain out of the purview of the requirements of "restricted governor mode operation". By the impugned amendment IEGC contravened its own earlier covenant.

This committee is expected to be looking into ways and means of making these machines amenable to RGMO, purpose, objective and mechanism of achieving the said objective of which is not known to anybody, including the proponents of RGMO! At least it is time for the committee to affirm that RGMO serves a well recognized purpose and provide the means for achieving the same. Even in the case of Electronic Governors, it may be pointed out that the changes made to meet the said RGMO requirements could be retro-introduced by NTPC C&I engineers in our units, with varying degree of difficulty, depending on the technology and scheme of realizing the required changes governor control, in that particular make of machine. The purpose for which this is being done is at least not clear to me.

Expected machine behavior under RGMO as per IEGC:

It will not be out of place for the committee to understand what the RGMO functionality is, in its correct perspective, before setting out to find means of implementing the same. I am taking the liberty of raising this question, as it appeared to me from the deliberations of the two meetings of the committee on 3rd and 21st November, that there is no unanimity of understanding among the committee members itself. This position can be easily established by each one of us individually describing the RGMO functionality as understood by us, in isolation. The representative of TANGEDCO had minced no words when he wanted to know from the OEM the logic scheme implemented in his machines! RGMO logic implemented in each machine is likely to be at variance, as the same is non-standard and has been realized variously.

I am stating below, our understanding of the requirements, as realized in most of the EHG controlled machines of NTPC:

- If frequency < 50.05 Hz, any decrease in frequency will result in increase in generation by Governor Action as per droop (4-5 %)
- If the frequency < 50.05 Hz, any increase in frequency will not result in decrease in generation by Governor Action
- If frequency > 50.05 Hz, any increase in frequency will result in decrease in generation by Governor Action, though there is no explicit stipulation in this regard in the IEGC
- The quantum of generation change by Governor Action will be limited to ±5%
- The increased / decreased generation will be offset by a slow automatic resetting command to ramp back to the original MW set point @ 1% per minute

Note: *The frequency threshold of 50.05 Hz mentioned in the above, was introduced in place of 50.20 Hz in the IEGC stipulation, by the Second Amendment dated 06.01.2014, effective from 17.02.2014*

Historic development of the stipulations on Governor Control in IEGC:

In the last 14 odd years, this prescription has been in existence, in one form or other, in the IEGC and no significant results have been achieved. The stipulation has undergone so many changes, none having been well engineered or thought out. The large number of modifications which the stipulations had to undergo is itself indicative of something wrong with the stipulation itself.

The FGMO stipulation found a place in the IEGC at a time when frequency constancy was not at all a target. Rather, frequency was intended to be a variable and the frequency indexed pricing mechanism of Unscheduled Interchange (UI) was considered a mechanism of trade. When constancy of frequency was not a target at all, there was no perceivable role for anything like “Secondary Control” and FGMO was postulated (without doubt a misconception that it is possible!) as a crude means of dealing with sharp and large frequency excursions. Much change has since happened in the said premises and presently we have been trying to approach the constant nominal frequency of 50.0 Hz at any cost, including denial of service. The author of this note is of the opinion that neither does constancy of frequency necessarily mean 50.0 Hz, nor does it give any right of denial of service to the utility.

The progressive developments are indicated below:

1. The prescription of “Free Governor Mode of Operation (FGMO) appeared in the very first issue of IEGC, drafted and issued by the CTU and approved by CERC, without much background work being done on the subject and with very limited understanding at that time, way back in 1999. The word “Free” in the nomenclature and the letter “F” in the acronym were also an Indian “innovation” not to be found elsewhere in the world! This term, however, refers to pure and simple Governor Control, applied on the Prime Mover input control valves.
2. In 2004, in a petition filed by SRLDC against NTPC Ramagundam, in which many other generating entities were also made party, CERC vide interim order dated 21.05.2004, referred the matter to a CEA Technical Committee for examining the technical difficulties in the implementation of FGMO. Obviously it had been recognized that the then existing FGMO provisions could not have been implemented.
3. The prescription of FGMO in IEGC was examined technically by a committee, constituted by CEA vide its order dated 30.04.2004, (on the basis of oral orders of the CERC). This committee, chaired by the then Member (Thermal), CEA, recommended radical modifications (indicating the grossly erroneous presumptions in the IEGC prescription) to make the FGMO prescription in the IEGC implementable. CEA had submitted the report of the said committee to the CERC in November 2004. The committee chose however, not to go into the merits of the FGMO prescription per se and thus leaving the prescription itself being unexamined on merit.
4. CERC did not accept the CEA report in full and explored alternative control logics to be implemented in the Governor Control mechanism. These changes were incorporated in the revised IEGC which was notified to be effective from 01.04.2006 and essentially modified the requirement of holding the increased / decreased generation level by Governor action for 5 minutes and allowed the return of the machine to the original load at a slow rate of 1% per minute. However, Section 1.6 of IEGC stipulated that the Free Governor Action will be applicable from the date to be separately notified by the CERC. Thus, effectively the prescription on Free Governor Action remained suspended, till the applicable dates were notified by the CERC in the revised IEGC 2010, which once again modified the requirements.
5. The prescription on Governor Action (5.2.f) in IEGC 2010 further underwent another quantum change in its requirements. Based on the informal discussions with several Generators including NTPC, the IEGC 2010 stipulated a new “restricted governor mode of

operation (RGMO)". This new control mode required retrofitting of a modified Governor Control logic and was hence made applicable only to machines equipped with Electro-Hydraulic Control. This revision of the prescription was on the basis of the appreciation of the CERC that erstwhile prescription of FGMO was not workable due to a host of reasons.

6. The IEGC amendment notified on 05.03.2012, which came into effect on 17.09.2012 stipulated that all the applicable machines, which could not be modified as per the 'restricted governor mode of operation (RGMO)', shall be operated on FGMO, with manual supplementary action to satisfy the requirements of 'restricted governor mode of operation'. This stipulation, as already stated, is difficult to comply with. It will be noted that the entire modification to RGMO would have been redundant and unnecessary, if this stipulation were to be workable!
7. The preset petition and this committee itself is a fall out of this re-introduction of the once junked "FGMO".

How Governor Control can be used:

Having discussed the evolution of "RGMO" and the subsequent resurrection of "FGMO" in IEGC, the committee must recognize that the purpose, mechanism and functioning of FGMO / RGMO have never been seriously analyzed nor discussed. This is what I had attempted in my presentation made before the committee on 3rd November meeting. This mode of control was further substantiated in the presentation made by the representative of POSOCO before he committee once again in his presentation on 21st November meeting. However, for reasons best known to the representative of POSOCO, he got the sequence of implementing the frequency control system all wrong, when he insisted that Governor Control can be implemented first to be followed by introduction of Secondary Control later. In my opinion this will amount to putting the horse behind the cart! The crux of the matter is summarized in the following:

- Governor Control (FGMO if you like!) is an integral part and just a small element of the Power System Frequency Control mechanism. It is not a one-stop-solution for frequency control.
- Governor Control can only supplement the limited function of "Frequency Containment" or "Frequency Responsive" in large frequency deviation (large generation load mismatch) events. Governor Control can be used to deliver large quantum of generation proportional to frequency

change, for a short duration (typically 15-30 minutes), by which time, “other” control measures take over and restore the “Governor Control Reserve”.

- This “other” control measure is what is known as “Secondary Control” or “Supplementary Control”, which can be manually delivered in single area systems but would require to be automated (as “AGC”) to meet the dual requirement of frequency and net exchange control.
- Governor Control to be useful in such events would require that the “Governor Control Reserve” is preserved for such events. In other words it is necessary to preserve the Governor Control Reserve by operating the system at constant frequency (within the small dead band of 0.06% of nominal frequency) by “other” control mechanisms. This aspect has not even been noted in our present erroneous prescription of Governor Control (FGMO / RGMO) in IEGC. Once again this “other” control referred to here is nothing but “Secondary Control”.
- Thus it is essential that Secondary Control (an integral control) is perpetually in action to match load and generation in real time, thus keeping the frequency constant within the aforementioned dead band (IEC:45 Part-1) of the Governor. Only then can the Governor Control can remain active and not acting normally so that this control is “called up” to act in sudden large mismatch events. Obviously there is no question of Governor Control being used without “Secondary Control” and constant frequency.
- This is the grave error in our prescription in IEGC when it has been imagined that “Secondary Control is absent by design” and Governor Control in isolation has been mandated to be used for frequency control. This error needs to be corrected up front without which it will not be possible to use Governor Control fruitfully for the so called “system security requirement”, however noble the intent is.
- The right approach to my mind is to introduce “Secondary Control” first. This would make the system operate on constant frequency, for over 90% of the time. The remaining period where frequency deviation exists will be a few instances of up to 30 minutes duration each, corresponding to large events (disturbances). Once this is achieved, two pronged action will be required to correct this. Required quantum of Governor Control reserve can then be worked out and maintained based on the acceptable frequency deviation limits.
- Simultaneously, we have to find solutions to issues of our own creation like Uncontrolled load disconnection, presently happening in our system which will have to be gradually avoided and replaced by controlled sequenced ordered disconnection. No doubt this will need some amount

of automation, the road map for which is already ready by way of another quick-fix solution we have been considering, viz. ADMS.

To sum up, the fact of the matter is that the Governor Control, an inseparable part of a comprehensive frequency control mechanism, cannot be implemented in isolation, without the other supplementary controls.

Quantum of Governor Control Reserve Required:

The quantum of Governor Control Reserve required in the system can be estimated as below, to follow the UCTE principles. If we consider,

- 4,000MW/Hz load governing / damping (D), taken arbitrarily, much lower than the figures indicated in the POSOCO presentation, allowing for some contribution for minor Governor Action
- A 4,000MW generating station outage as the largest credible disturbance, largest generating station outage
- 1.0 Hz as the maximum acceptable dynamic frequency deviation level (49.0 Hz). The corresponding value for UCTE is 0.8 Hz (49.2 Hz)
- 0.4Hz as the minimum acceptable short term frequency deviation (49.6 Hz quasi steady state minimum frequency, the targeted frequency recovery level by Governor Action). The corresponding value for UCTE is 0.2 Hz (49.8 Hz)

The loss of 4,000MW generation will cause a dynamic frequency dip to about 0.8 Hz to 49.2 Hz. Governor action is desired to arrest frequency decline and bring frequency up, to 49.6 Hz. At 49.6 Hz, the system load would be less by 1,600MW (4,000MW/Hz * 0.4Hz) and the generation increase required to be delivered from the Governor Control reserve is 2,400MW (4,000 – 1,600MW). This will amount to having Governor Control Action from 15,000MW worth of Generating capacity at 5% droop, carrying just 2,400MW of Governor Control Reserve. This corresponds to Governor Control rate (1/R) of 6,000MW/Hz. The composite FRC of the system will be 10,000MW/Hz {β = D + 1/R i.e. (4000 + 6000) MW}. The real requirement of Governor Control Reserve will thus be just 2,400MW delivered at a rate of 6,000MW/Hz and not 20,000MW indicated by POSOCO representative in his mention on 3rd November, which approximately corresponds to 0.2 Hz quasi steady state frequency deviation target, a costly luxury. Obviously, let us face the reality; all of us, including POSOCO, has a lot to learn on the subject. Opinion of “three eminent professors” made in some unknown context may not be the last word!

Retrofitting EHG in MHG controlled machines:

Mechanical Hydraulic Governor (MHG) controlled machines are not amenable to the introduction of control logic modifications as is possible with Electrical Hydraulic Governor (EHG), in the electric logic circuits. Hence these machines cannot be made to operate as per RGMO requirements. It goes without saying that if EHG control is retrofitted, these machines can also be operated on RGMO.

MHG is a technology which has more than 150 years of industry authentication. In my +34 years experience I have not heard of many failures of MHG. Its performance wrt control suitability has also not been under any question. The mention of higher insensitivity (dead band) of 0.10% in place of deliberately introduced insensitivity (dead band) of 0.06% (as per IEC: 45, Part-1) is of no consequence at all. The mentions made by the vendors of the other advantages of retrofit, like faster response, accurate droop etc. were just sales talk and must be ignored. The advantage of Electrical Governor is essentially reduced initial cost and simplicity.

In fact, even today, KWU/BHEL machines equipped with EHG, do have a full function Hydraulic Governor as back up, which is continuously in service following the EHG set point. It is not uncommon that these machines come on Hydraulic mode on failure of EHG for a host of reasons. Without this back up, the machines would have had to trip, which is the case with machines having no such back up (e.g. Ramagundam (3x200MW), Rihand Stage-1 (2x500MW), Talcher Kaniha Stage-1 (2x500MW) etc.).

The barest minimum retrofit to achieve RGMO in these machines will amount to the introduction of Electrical Speed Sensing (by mounting a toothed wheel on the shaft at a suitable location) and using multiple speed pickups in at least a 2 out of 3 configuration, processing the speed (proportional to the pulse rate) signals into a voltage or current signal, build up the proportional control to modulate valve position servomotor using an Electro Hydraulic Transducer (EHT).

This bare minimum retrofit was proposed to be offered by M/s Siemens in the presentation made before the committee on 21st November. This would leave the original control oil system, valve actuator servomotor, rocker arms, valve mechanical linkages etc. unchanged. Thus the modification only retrofits the control logic realization to electrical.

M/s Alstom proposed slightly more extensive multiple retrofit options, but for the purpose of RGMO the option would be the one similar to what was proposed by Siemens.

No doubt these options are available and may be if scouted for some more vendors would offer similar options. The pertinent question is whether there is a well established need for the retrofit? This is the primary question the committee has to find answer for. To answer this primary question we must examine the following pertinent questions:

1. ***What is expected to be achieved by RGMO?***
2. ***Has RGMO shown the desired results in the machines on which it has been implemented?***
3. ***What are the reasons why the desired response is not forthcoming from those RGMO machines, as reported by POSOCO in their presentation?***
4. ***Is the non-availability of reserve capacity on these machines the only reason for non-realization?***
5. ***After all these expensive retrofits, is RGMO the one-stop-solution we desire?***
6. ***Why nothing called RGMO exist anywhere else in the world? Are we smarter than them all?***
7. ***If the answer for question (6) above is 'we want FGMO, but we settled for RGMO as a compromise solution', are these MHG controlled machines capable of FGMO?***
8. ***If it is capable of FGMO why the expensive retrofit, to realize some mode of operation, the desired result of which is yet to be recognized?***

In my firm opinion and belief, we must get off the current ego trip and must seriously apply our minds on the central subject of frequency control, ways and means of achieving the same as the world does. It will be highly inappropriate for this committee to recommend such expensive retrofits (to my estimates it will cost about Rs 15 Cr per machine) unless there are compelling reasons for the same. On the basis of such an error by this committee, if CERC mandates the same the said error will be further compounded.

The Committee's Terms of Reference:

There appears to be the view of some of the members, that the present committee must restrict itself to the TOR given to it and must refrain from looking at the issue more logically. I beg to disagree, with all humility.

If a group of Electrical Engineers are given a TOR for recommending methods of applying a voltage across a conductor of resistance 'R', such that, the current flowing (V/R) is not proportional to the voltage applied, the group must invariably report that the requirement cannot be met, which has been well established by ohm's law. I am of the opinion that this committee is in a similar situation and making unconvinced and half baked recommendations will be a crime towards the power system engineers' fraternity and to the nation as a whole. We have been suffering from our failure to find and adopt technically correct solutions for the past 14 odd years and it is incumbent on this committee to call a spade a spade, at least at this late opportunity.

My views on the TOR have been fully included in the foregoing paragraphs. However, for the sake of completeness, my views on each of the three TOR items are indicated below:

1. To look into the problems of generating units in implementing RGMO / FGMO:

   The basic problem arises from the need for almost continuous modulation of output in either direction prompted by the unpredictable frequency. The machines are never under stable situation of full throttle margin in the process, being perpetually in a mode of action or recovery. No process changes to support like change in boiler firing can be taken since the requirement is not certain by the time the response of the boiler firing change is realized, which takes about 4 - 6 minutes. Having once acted no mechanism exists in FGMO to return the machine to the original level and recoup.

   In RGMO also, if attempted without boiler firing change the pressure deviation forces to reset the output change quickly. RGMO response will not be available on machines operating in the overload regime. Above all, RGMO response serves no useful purpose to my mind.

2. To suggest measures for implementation of FGMO with suitable modifications / amendments in CERC Regulations / IEGC

   CERC regulations need to be amended to introduce "Secondary Control" urgently, which is a pre-requisite to successful constant frequency operation, which will enable Governor Control. Without this FGMO or RGMO will not serve any purpose. Introduction of Secondary Control involves working out an efficient arrangement for the same. The committee can recommend appointment of an international consultant for the purpose, as nobody in India has clear understanding or any experience of constant frequency control.

3. Any other recommendations to facilitate FGMO operation

   The committee must categorically recommend immediate suspension of RGMO/FGMO prescriptions in IEGC which is fundamentally flawed. It should recommend that the process of implementing Constant Frequency Control to be initiated without further delay. It must be clearly stated that something which is technically not workable could not have worked in the past 14 years and will not work in future also. The only solution is to adopt frequency control the way the world is doing. The entire process had been explained in my presentation made on 3rd November meeting of the committee and in support I had also submitted a soft copy of the UCTE/ENTSOE operation handbook.

Concluding remarks:

In case this committee chooses to discuss the way forward I do have clear road map in mind, which can be presented to the committee in our next meeting. If we fail in this noble effort we will only be prolonging the trauma of the generators, System Operators and above all CERC on the implementation of the purposeless, un-implementable compromise solution of RGMO/FGMO, which in the first place was prescribed in complete error.

(P P Francis)

Views of Mr. S. Satyanarayan, SE,WRPC

1) With respect to implementation of RGMO/FGMO, there are generators who seek exception from implementing due to various reasons. Not all the reasons can be satisfactorily assessed, in a short time. In order to simplify the above, the Committee may like to recommend that "Generators seeking exception from this clause shall have to approach the manufacturers with respect to implementing the RGMO/FGMO and submit a plan as suggested by the manufacturer, by when the machine can become RGMO/FGMO compliant. Such exceptions with above details may then be put up to Commission for approval".
2) A little long term: An indirect way to make the generators toe in line with governor requirements is to clarify that DSM schedules are for frequency assumed at 50 Hz. Thereafter any schedule of generator shall be post facto corrected with respect to a RGMO MW- freq table. Suppose the schedule was 100 MW. During the block the freq was down and so required a higher MW as per RGMO table at say 105 MW. Then deviations shall be treated as if the schedule was 105 by applying a post facto correction. This would motivate the generators to implement the governor guidelines as there would be a financial implication (I also suggest that any change in billing schemes by way of regulation, should have a trial period of say 2-6 months at least to see impact under various power system conditions. In this trial period old billing shall be in effect. New billing shall be studied by the Commission to see whether the law implements the spirit and then only make it firm, to avoid other legal hassles from past experience.)
3) Proper addressing of Governor related Issues: There is a need to revisit the issue of how the Indian grid has tackled the Governor problem. To give support without frequently changing load set point, for LMZ Turbine machines, Maharshtra had enabled Turbine-Follow method. This method achieved the above. However for KWU related machines, with electronic governor the exact equivalent of above control scheme was not possible. It may be noted that in developed grids, there is a principle of AGC by which deviations are corrected at 5 mins- 15 min intervals. If a region loses generation, it gets support from other generators by way of governors action. But the deficit agency is expected to correct such deviations in 5 mins intervals. After that this reserve support is NOT available. In other words, the reserve energy from Governors is a short time emergency support. If utilities still bring in more load,(as in our system), then governor reserves are consumed and nothing is left. Theoretically AGC is possible at 50 Hz as reference frequency. Earlier UI mechanisms in some sense did not full throttle allow the governor action(as it permitted deviations in frequency). With DSM, deviations of frequency beyond a point is not permitted. As such the standard governor action can come back and is meaningful if implemented with AGC. Maybe using supplementary control mechanism like Ancillary support, the Governor's responsibilities can be defined. In short there is a need to study the FGMO problem once again in light of the new DSM regulations. Being a separate work, this may be taken up later. Committee may like to discuss.

Annexure-V

TASK FORCE ON IMPLEMENTATION OF FGMO IN GENERATING UNITS FIRST MEETING (03-11-2014)

Terms of Reference of the Task Force on FGMO

- To look into the problems of the generating units in implementing FGMO with manual invention.
- To suggest measures for implementation of FGMO with suitable modification/ amendments in certain Regulations/IEGC.
- Any other recommendation to the Commission within two months.

Stable, Reliable and Secure Grid

- Operating Grid Frequency band as per IEGC– 49.9 Hz to 50.05 Hz
  - Mismatches between supply and demand in real time
  - Give rise to fluctuations in frequency

Requires

- Primary Response from generators: FGMO/RGMO
- Secondary Response : Absent by Design
- Tertiary Response
  - Availability Based Tariff (ABT)-UI
  - Use of Un-Requisitioned Surplus
  - Peaking Stations
  - Hydro Stations/ Pumped Storage Plants

Regulator's Perspective

•Grid Security Concerns

•FGMO as tool for controlling frequency variations

•Collective action on the part of Generators- Sharing of load variation due to frequency excursion

Historical Background

The Commission in its order dated 30.10.1999 in Petition No.1/1999 on draft IEGC submitted by CTU observed as follows:

"***We are convinced that provision for free governor action in generating units is desirable for overall grid control.***"

System Security Aspect – Section 5.2 (f) of IEGC

All thermal generating units of 200 MW and above and All hydro units of 10 MW and above synchronized with the grid and Irrespective of their ownership

- –To have governors in operation at all times
- – Specified units Under Restricted Governor Mode of Operation

Specified Units under for RGMO

a) Thermal generating units of 200 MW and above,

Software based EHG System : 01.08.2010

Hardware based EHG System: 01.08.2010

b) Hydro units of 10 MW and above 01.08.2010

Features of RGMO

- Any fall in grid frequency, generation from the unit should increase
  - by 5% limited to 105 % of the MCR
  - subject to machine capability.

  Ripple filter of +/- 0.03 Hz.
  - small changes in frequency are ignored
  - to prevent governor hunting.
- No reduction in generation in case of improvement in grid frequency below 50.2 Hz.
  - for example, if grid frequency changes from 49.3 to 49.4 Hz, then there shall not be any reduction in generation
- To have a droop setting of between 3% and 6%.

Exemption from FGMO/RGMO

All other generating units other than thermal generating units of 200 MW and above and Hydro units of 10 MW above exempted from Sections 5.2 (f) ,5.2 (g), 5.2 (h) and ,5.2(i) and includes

- The Hydro stations with pondage upto 3 hours
- Gas turbine/Combined Cycle Power Plants,
- Wind and solar generators and
- Nuclear Power Stations

Exemption from RGMO

Provided that if a generating unit cannot be operated under restricted governor mode operation, then it shall be operated in free governor mode operation with manual intervention to operate in the manner required under restricted governor mode operation.

Statement of Reasons (SOR) on Amendment to IEGC, in 2012

"3.4 We feel that if the generator is unable to carry out the RGMO in its units, then it should provide grid support through FGMO. It is clarified that the provision is made in view of the difficulties faced by certain generating companies to modify the machines to make them capable of operating in RGMO automatically. The proposed revision intends to allow the generators to operate the units in FGMO with manual intervention till the machine is modified for RGMO operation. We are of the view that the proposed amendment should be retained. We are also conscious of the fact that ultimately machines have to be operated in FGMO for which the progressive narrowing down of frequency band will help."

Generators Concerns about FGMO

- FGMO should be implemented in all stations simultaneously
- Frequent variation in grid frequency may have adverse effect on the life of units
- Hunting of control valve
- When grid frequency is below 50 Hz then any reduction in load due to improvement in grid frequency would unduly penalize them with UI

EXEMPTIONS SAUGHT BY NTPC

- NTPC have filed petition with CERC for exemption from FGMO for their LMZ machines equipped with purely mechanical governor as shown below:

Sl. No.	Name of the Unit	No. Of Units	Capacity (MW)	Stage
1	Badarpur	2	210	II
2	Singrauli	5	200	I
3	Vindhyachal	6	210	I
4	Kahalgaon	4	210	I
5	Ramagundam*	3	200	I

* Ramagundam is equiped with Electrical Governors.

REASONS AS CITED BY NTPC

- "Restricted Governor Mode Operation" **can be met only with Electro Hydraulic Governor.**

- Recognizing the fact, Hon'ble Commission permitted such units to remain out of the purview of RGMO.

- In the case of **Ramagundam** the retrofit is not possible as the electronics are of very early **vintage** and are **not amenable to retrofit.**

DIFFICULTIES IN CASE OF MECHANICAL GOVERNORS AS PER NTPC

- The reduction in load due to governor action cannot be limited to any desired quantum.
- No HP/LP steam bypass system and the unit may trip out due to water/steam side disturbance.
- **Manual Operation** –The frequency changes in our power system being perpetual in nature, it is not physically / practically possible for the operator to continuously modify the set point of the control system.
- If these machines are put on FGMO with manual intervention, there will be frequent and large quantum load fluctuations due to governor action. The resultant process disturbances will also be frequent, large and beyond the capability of the relevant control system to manage.

Difficulties in case of Ramagundam Stage-I AS PER NTPC

- These machines are of generic GE design and are equipped with Electrical Governors supplied by M/s Ansaldo, Italy. Stable load on the machines is achieved by the supplementary Steam Pressure Control.

- If the Steam Pressure Control were to be not available, the machine would be operating on FGMO and will suffer from all the difficulties described above in the context of mechanically governed machines. Such an operation is not possible unless the grid frequency is controlled constant.

- The electronics involved are of very old vintage and impossible to modify the control logic.

- It will be possible to make appropriate modifications to meet the requirements of restricted governor mode of operation, once the major R&M work on these machines are implemented.

- In the light of the difficulties and constraints, NTPC has sought relaxation under Part 7 Regulation 4 of the Indian Electricity Grid Code (IEGC) for above machines from compliance of the stipulation regarding operation in FGMO with manual intervention, made applicable vide amendment effective from 17.09.2012.

- It is to bring out that during 2003-04, certain generators including NTPC, OHPC, NLC, NEEPCO and Hasedo Theramal Power Station filed petitions in CERC for exemption of some of their units from participating in FGMO. During the course of hearing, Commission directed the petitioners to bring out their difficulties to the notice of CEA, which in turn was required to submit a detailed report in the matter.

RECOMMENDATION OF COMMITTEE OF CEA WITH REGARD TO LMZ MACHINES

(CERC order dated 20.08.2009 in Petition No. 66/2003)

- *Adoption of the scheme introduced by MSEB at Nasik, where the reserve steam in the boiler was used for increased generation for about 4-5 minutes.*
- *Committee recommended a time period of three months for implementation of the scheme adopted at Nasik station of MSEB.*
- *The Committee also recommended further improvement of putting the boiler controls in auto mode through adoption of the same scheme as recommended for the KWU machines.*

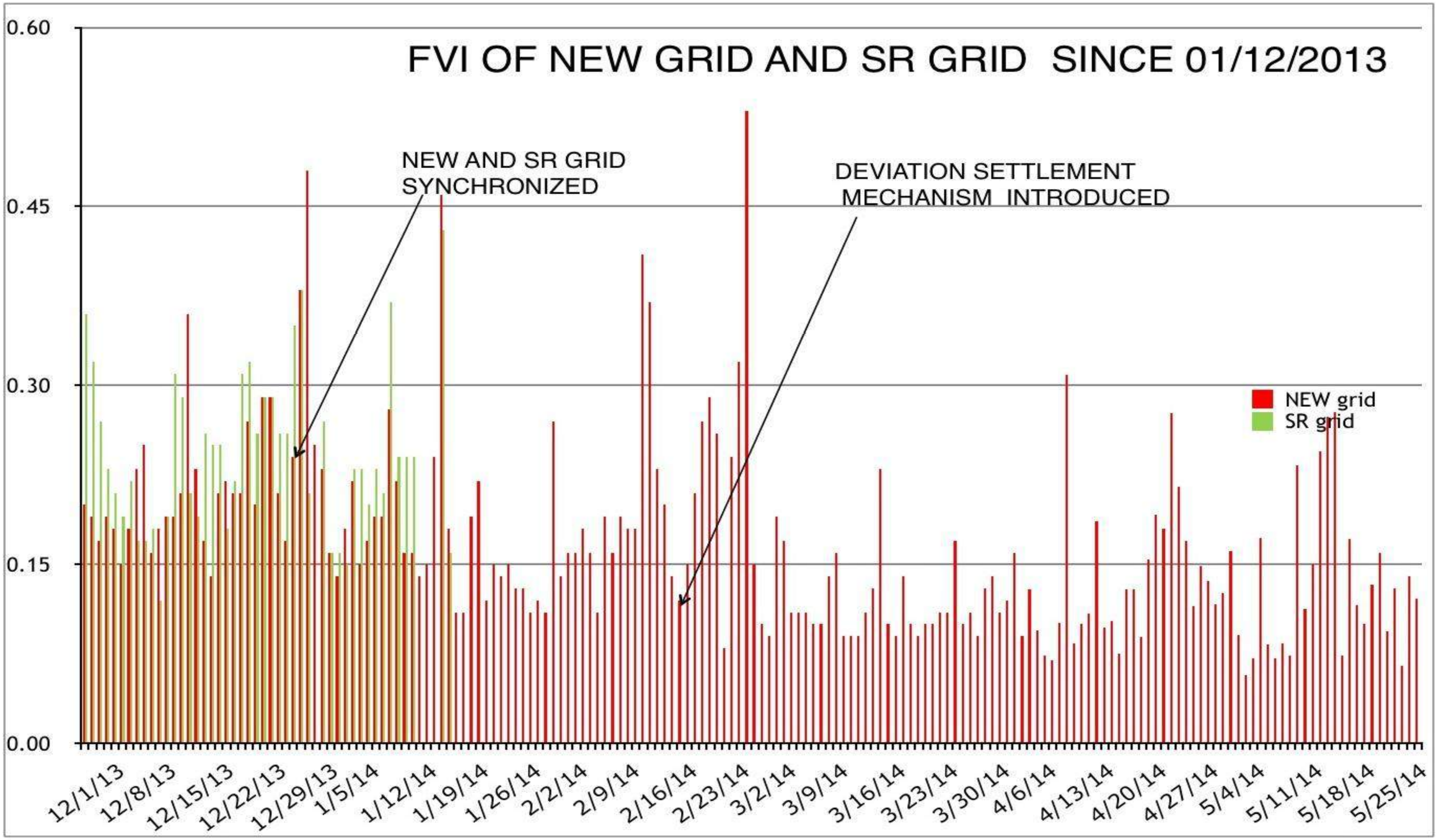
Commission's view

(CERC order dated 20.08.2009 in Petition No. 66/2003)

- Absence of any concrete proposal by BHEL or any other OEM for up-gradation of the control system ,
- Commission recommended for adoption of FGMO with manual intervention as adopted by MSEB at Nasik for LMZ turbines.
- In view of the fact that LMZ machines installed in the country are very old and have completed their useful life, it may be prudent to allow the **complete replacement** of the mechanical governing system with EHG governing system along with associated control systems on boiler and turbine side & the expenditure so incurred may be allowed by the Commission under **R&M expenditure**.

POSOCO'S VIEWS ON NTPC REQUEST

- Operation Grid Frequency band narrowed down to 49.9 Hz to 50.05 Hz
- Grid Frequency remaining close to 50 Hz
- Large frequency exceptions not expected in integrated grid



FVI OF NEW GRID AND SR GRID SINCE 01/12/2013
NEW AND SR GRID SYNCHRONIZED
DEVIATION SETTLEMENT MECHANISM INTRODUCED
NEW grid
SR grid
0.60
0.45
0.30
0.15
0.00
12/1/13
12/8/13
12/15/13
12/22/13
12/29/13
1/5/14
1/12/14
1/19/14
1/26/14
2/2/14
2/9/14
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3/30/14
4/6/14
4/13/14
4/20/14
4/27/14
5/4/14
5/11/14
5/18/14
5/25/14

Recent Development

- M/s ALSTOM Projects India Limited, have developed a scheme by which the LMZ machines can be made compliant to the grid regulations of CERC. The scheme involves replacement of mechanical controller with a redundant electronic controller, incorporating a digital governor M/s ALSTOM, have reportedly carried out 40 such upgrades worldwide in LMZ turbines.

- M/s Siemens has also developed a scheme by which the mechanical governing system of LMZ turbine may be modified, without complete replacement.

- **If desired**, ALSTOM Projects India Limited/ Siemens can be requested to make a presentation before the Committee.

Other Issues

- Reverting back to FGMO on stabilization of frequency as per regulation 5.2 (f) (ii) (d).

- FGMO operation in old Hydro Units with mechanical governors.

- Extent of generation increase required against particular level of frequency decrease. Current stipulation being 5% for any fall in grid frequency (not quantified in regulation 5.2(f)(ii)(a).

GRID CODE

Quote

5.2 System Security Aspects

.....

(f) All thermal generating units of 200 MW and above and all hydro units of 10 MW and above, which are synchronized with the grid, irrespective of their ownership, shall have their governors in operation at all times in accordance with the following provisions:

Governor Action

i) Following Thermal and hydro (except those with upto three hours pondage) generating units shall be operated under restricted governor mode of operation with effect from the date given below:

a) Thermal generating units of 200 MW and above,

1) Software based Electro Hydraulic Governor (EHG) system : 01.08.2010

2) Hardware based EHG system 01.08.2010

b) Hydro units of 10 MW and above 01.08.2010

c) If any of these generating units is required to be operated without its governor in operation as specified above, the RLDC shall be immediately advised about the reason and duration of such operation. All governors shall have a droop setting of between 3% and 6%.

GRID CODE

d) After stablisation of frequency around 50 Hz, the CERC may review the above provision regarding the restricted governor mode of operation and free governor mode of operation may be introduced.

ii) The restricted governor mode of operation shall essentially have the following features:

a) There should not be any reduction in generation in case of improvement in grid frequency below 50.05 Hz. (for example if grid frequency changes from 49.9 to 49.95 Hz., then there shall not be any reduction in generation). For any fall in grid frequency, generation from the unit should increase by 5% limited to 105 % of the MCR of the unit subject to machine capability.

b) Ripple filter of +/- 0.03 Hz. shall be provided so that small changes in frequency are ignored for load correction, in order to prevent governor hunting.

iii) All other generating units including the pondage upto 3 hours Gas turbine/Combined Cycle Power Plants, wind and solar generators and Nuclear Power Stations shall be exempted from Sections 5.2 (f) ,5.2 (g), 5.2 (h) and ,5.2(i) till the Commission reviews the situation.

Provided that if a generating unit cannot be operated under restricted governor mode operation, then it shall be operated in free governor mode operation with manual intervention to operate in the manner required under restricted governor mode operation.

Annexure-VI

Frequency Control in the Indian context

POSOCO

21st Nov 2014

Outline

- Generally Accepted principles
- Frequency profile
- Load forecasts and ensuring adequacy
- Reserves requirement and fulfillment
- Decentralized secondary control
- Issues to be resolved

Generally accepted principles

- Primary control (governor control)for frequency stabilization after a large disturbance…………………operates in seconds (proportional control)

- Secondary control for restoring primary reserves and frequency to 50 Hz………….operates in minutes (Integral control)

- Tertiary control to restore secondary reserves…………operates in tens of minutes

- Imbalance pricing mechanism essential for proper accounting and settlement on 15-minute time block basis. (there shall not be any commercial loss to a generator for putting machines on FGMO otherwise it does not become sustainable)

Frequency Control Services in action

Swissgrid: Overview of Ancillary Services

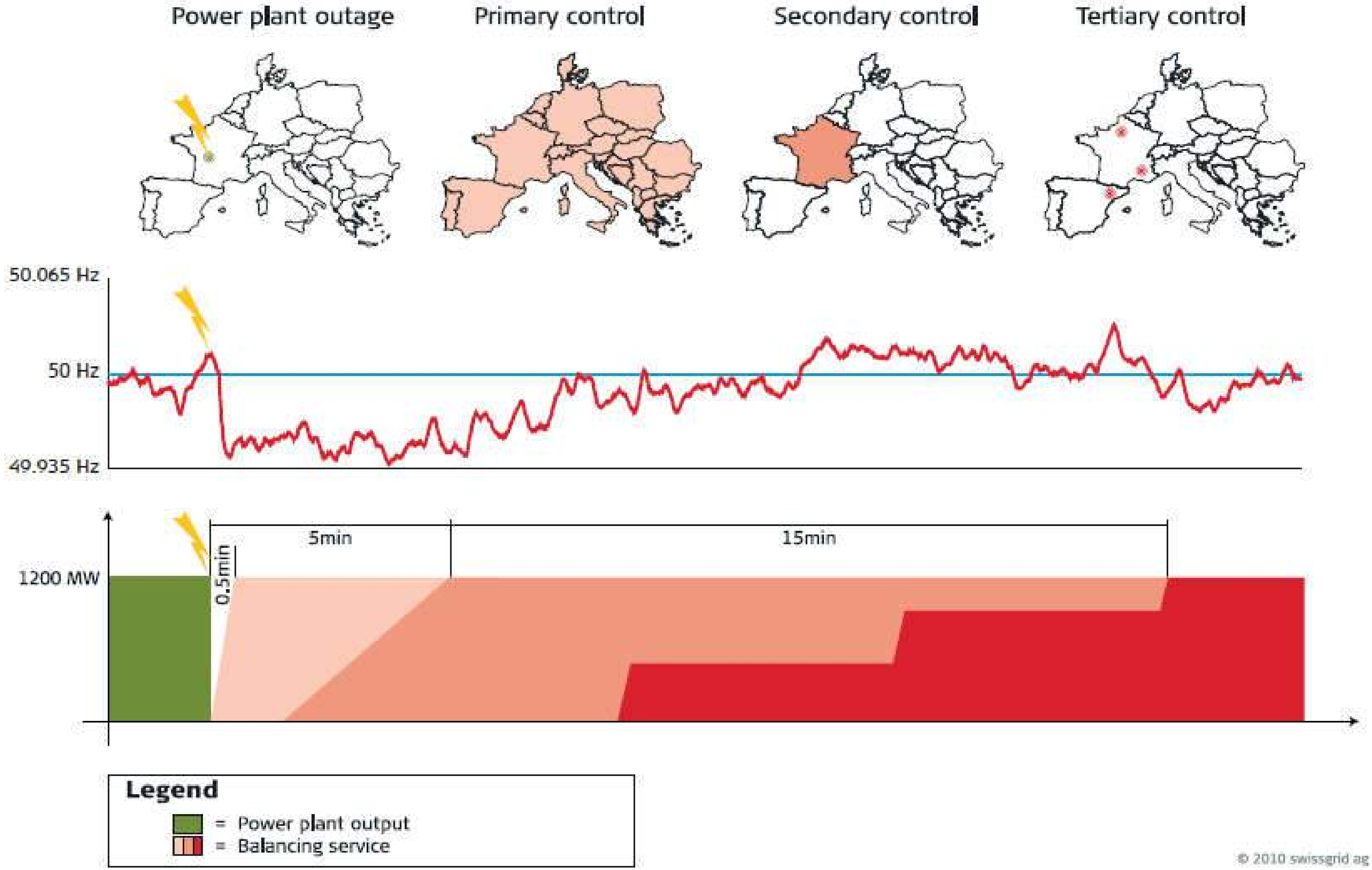


Figure 1: Example of a power plant outage in France

Frequency Control Services

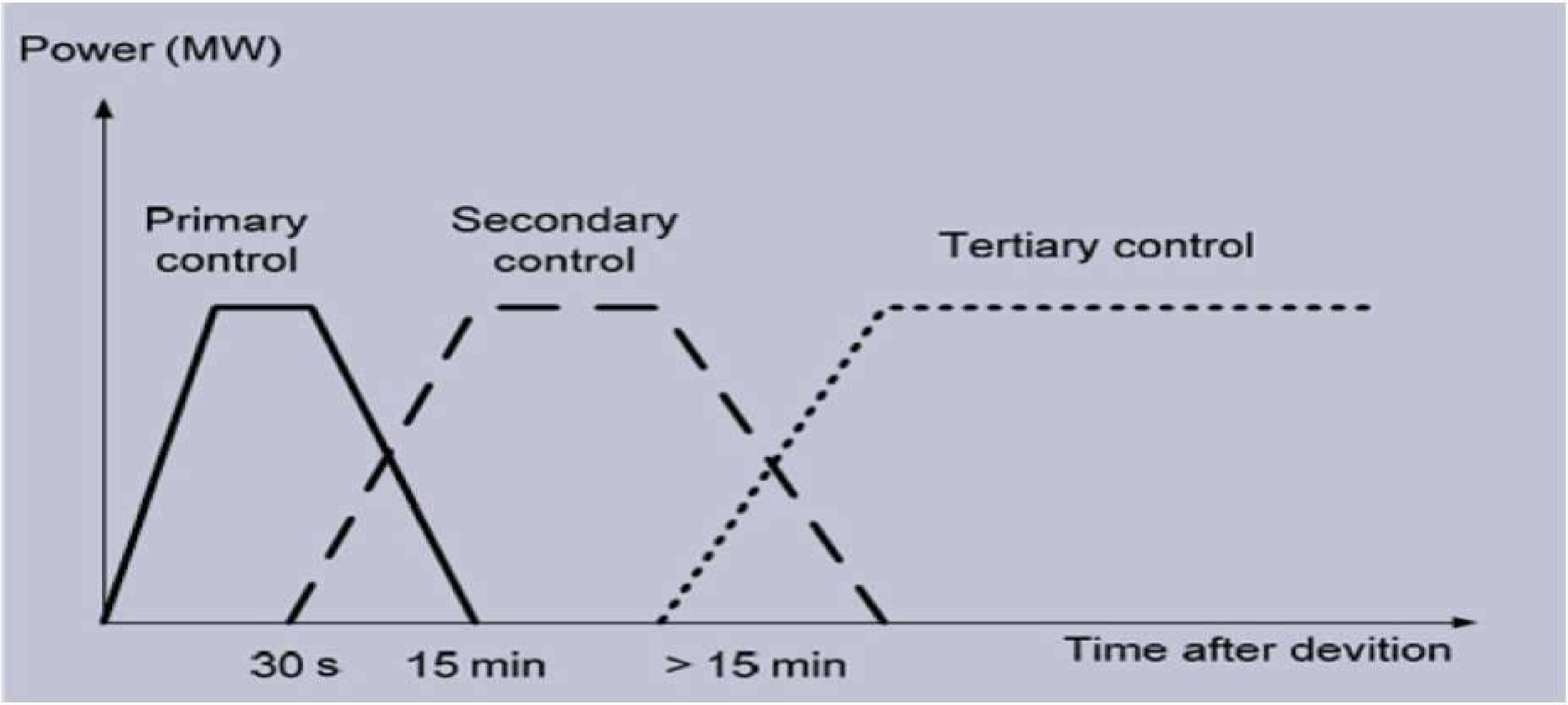


Figure 5: UCTE's classification of frequency reserves

- Primary Control: activated within seconds through speed governor action on turbines
- Secondary Control: activated within minutes through Automatic Generation Control (AGC) signals from Load Despatch Centres to power plants
- Tertiary control: activated in tens of minutes through pressing of reserves

Frequency profile of Continental Europe

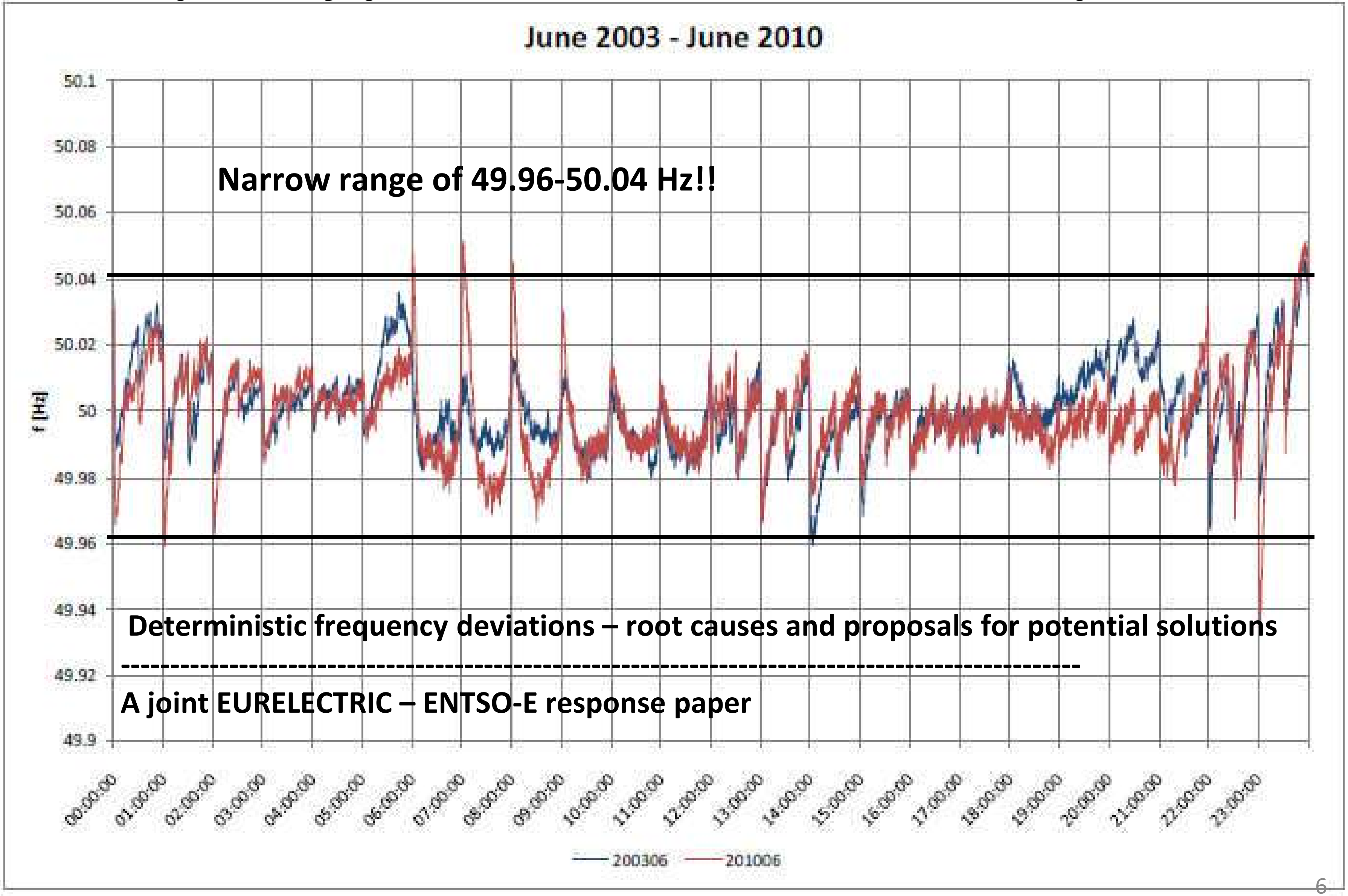
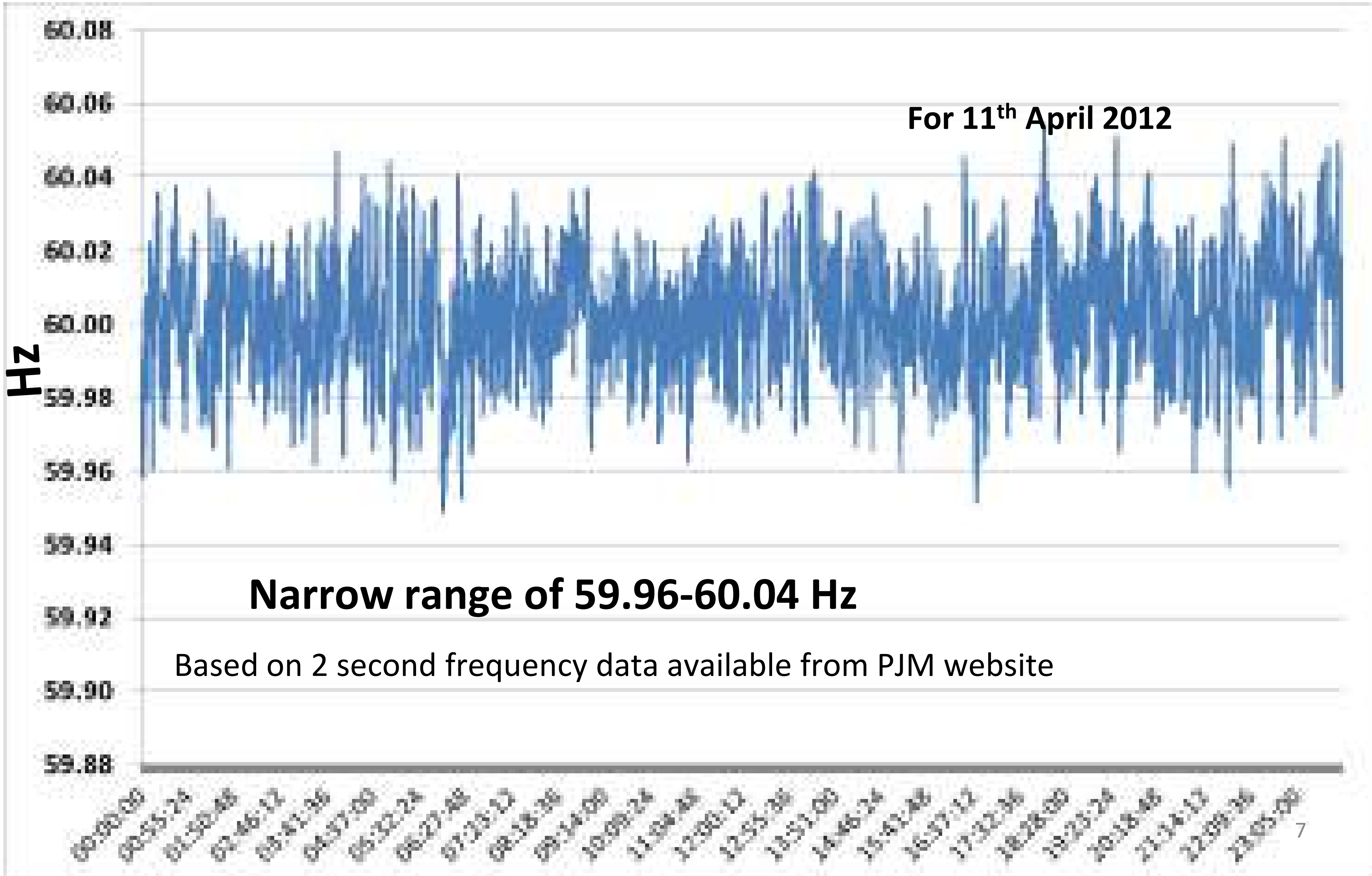
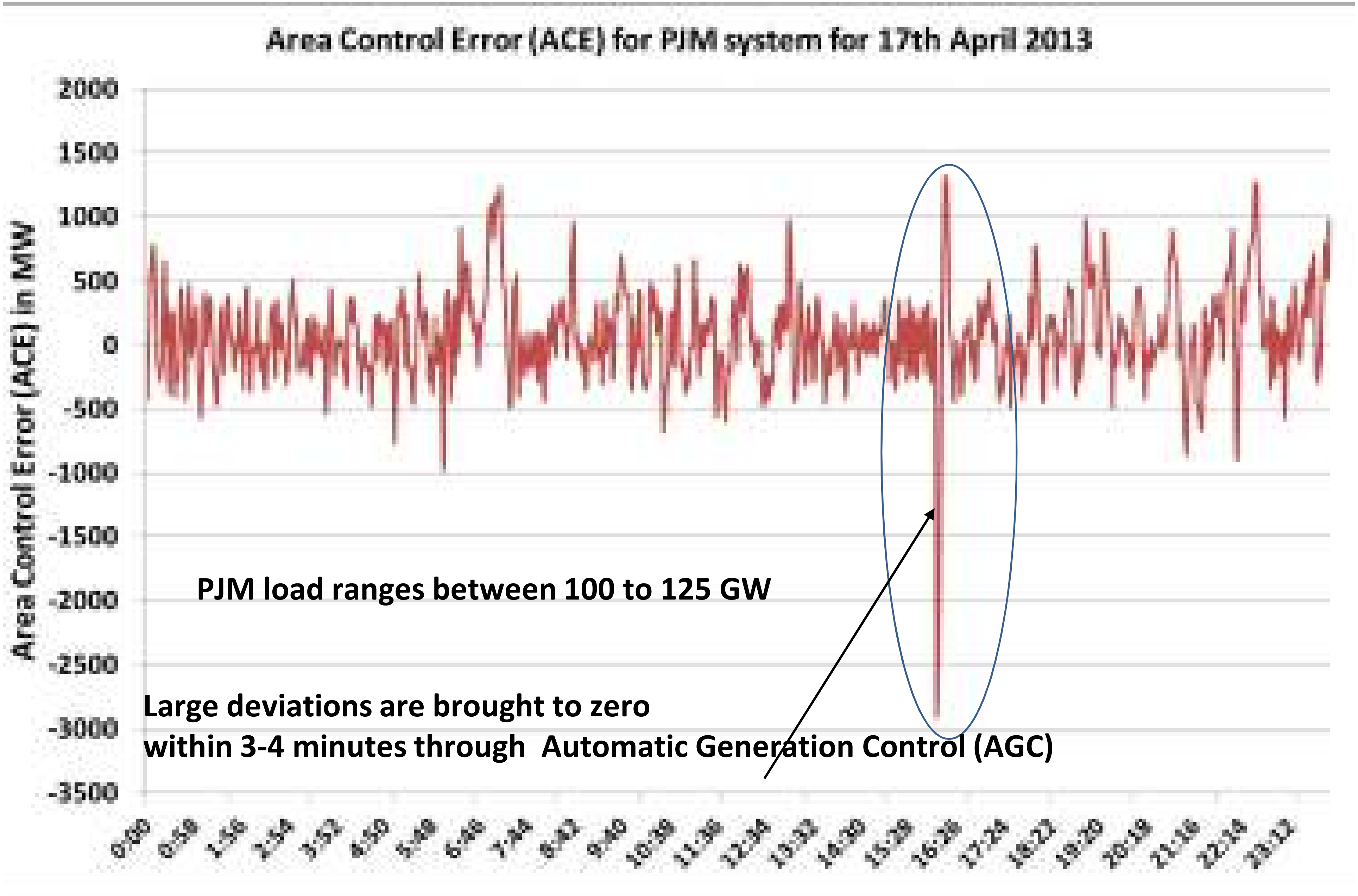


Fig. 3.1: Average frequency values in Continental Europe, June 2003 and June 2010, Source: Swissgrid

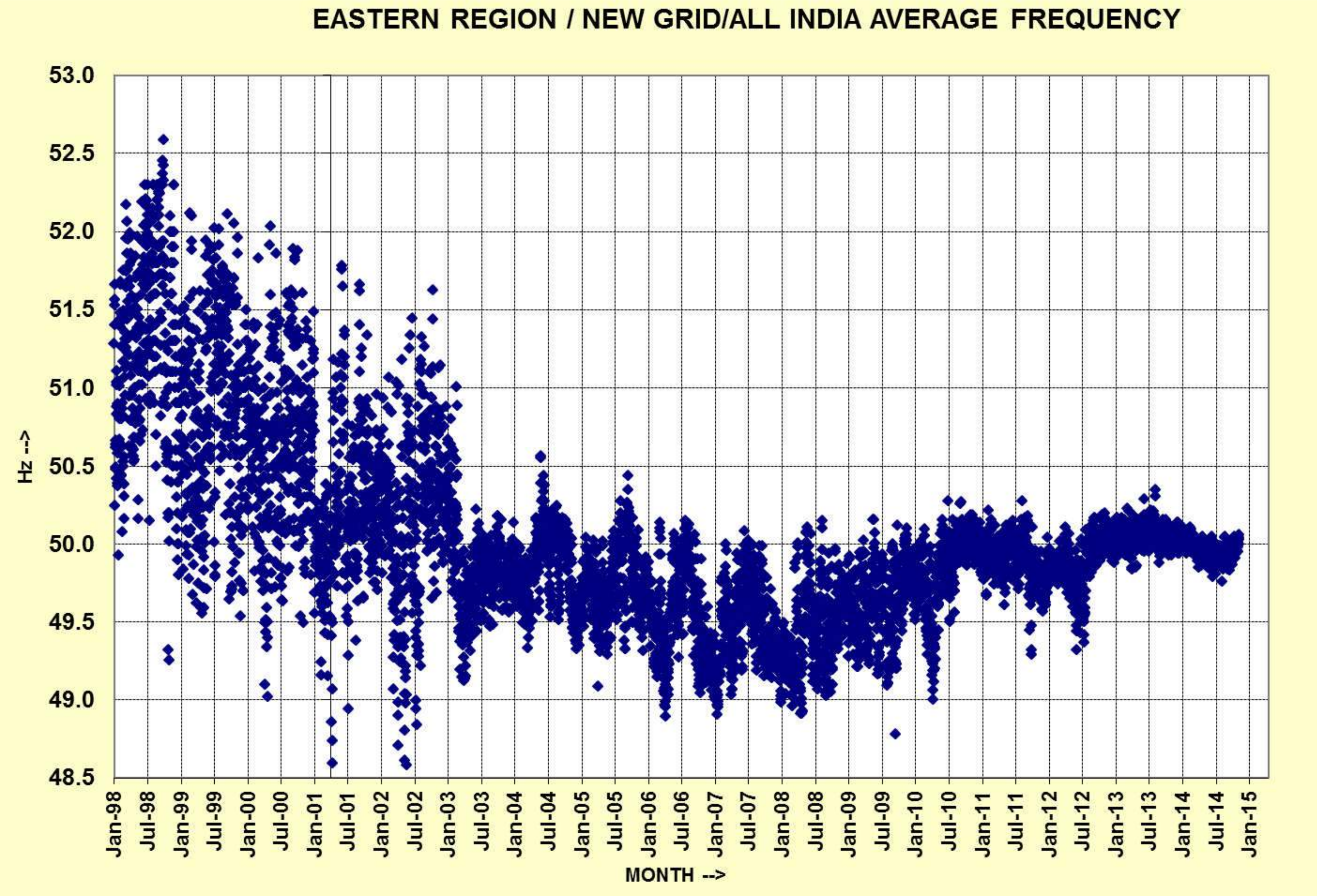
Typical frequency profile for Eastern Interconnection, US



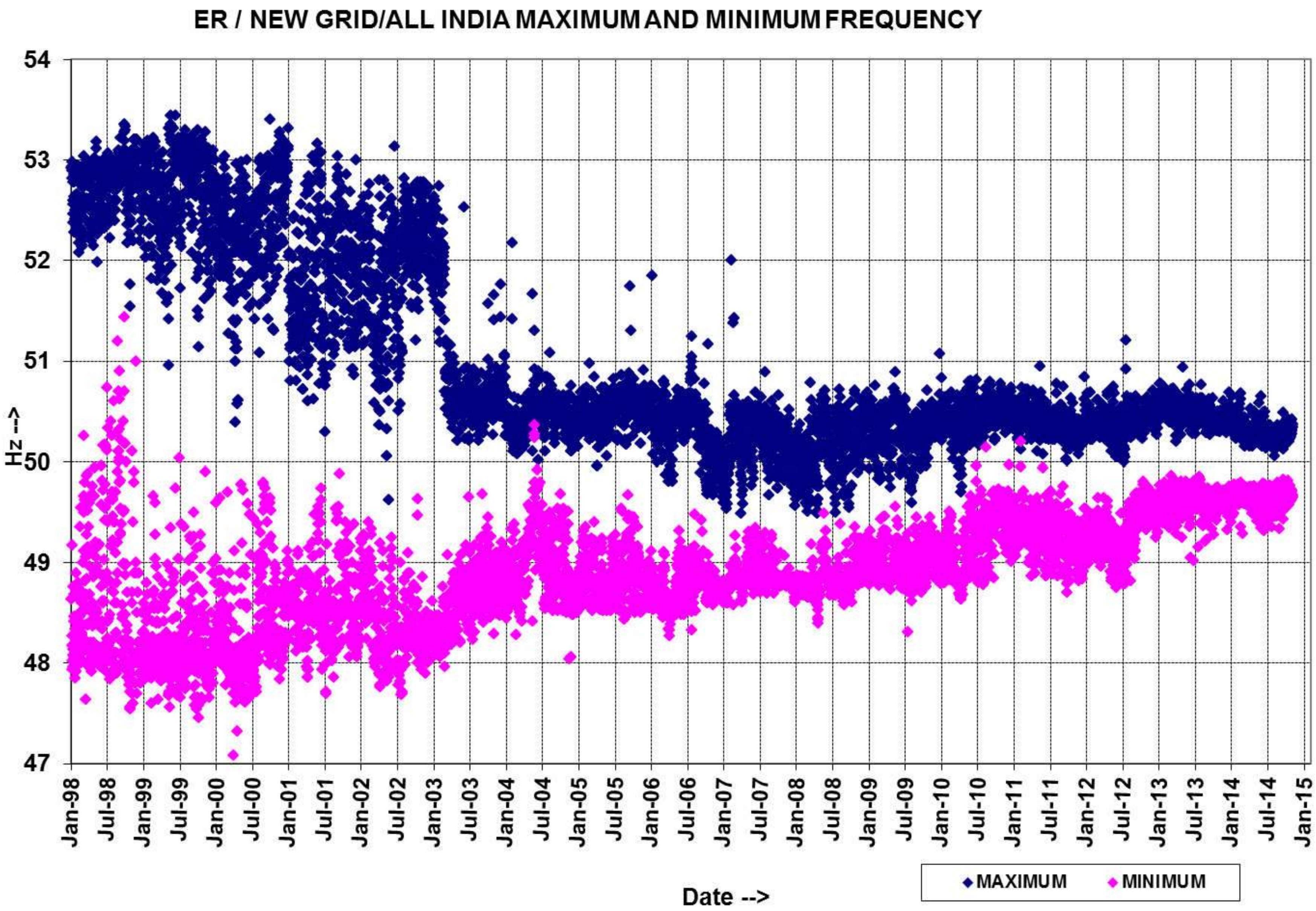


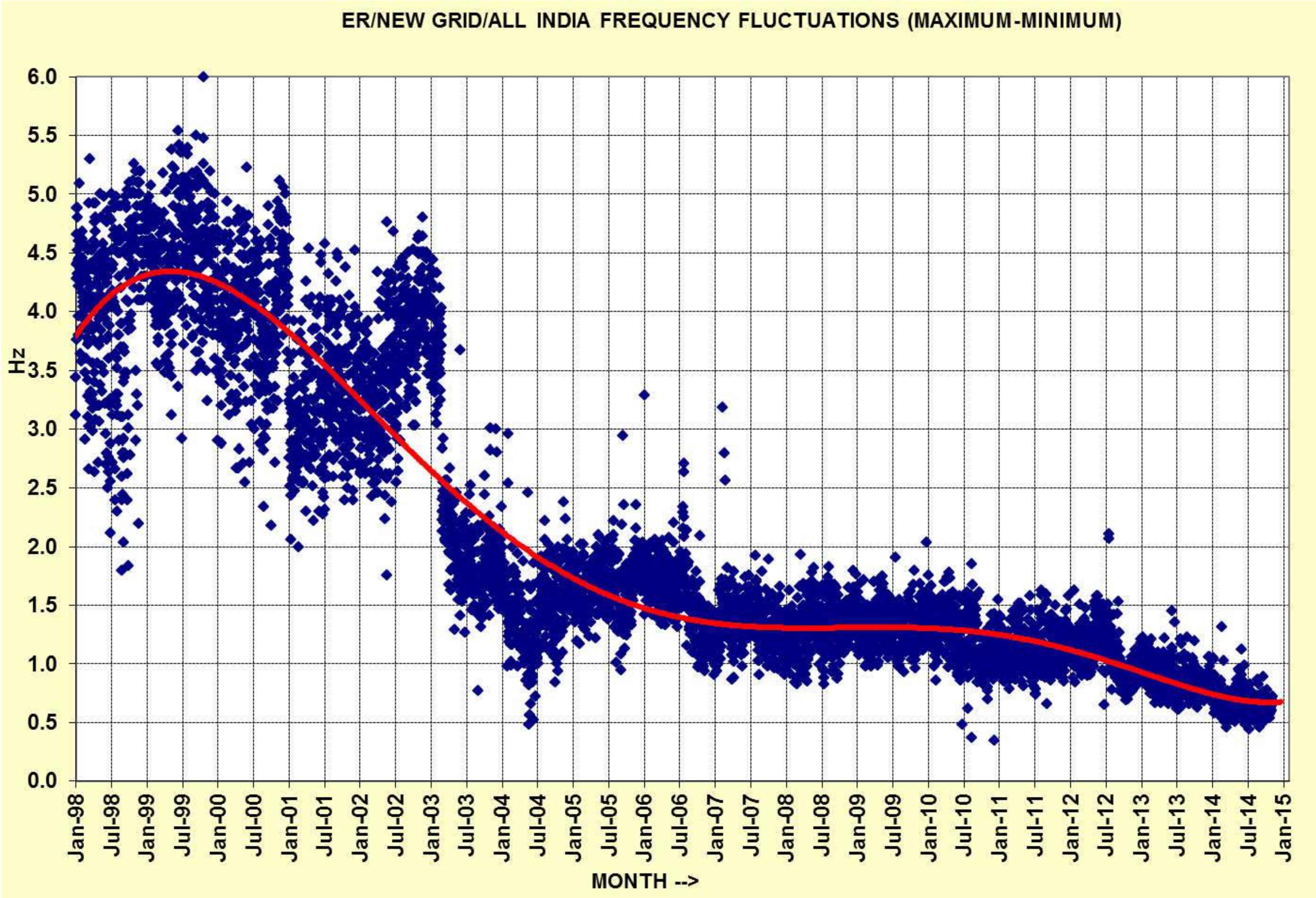
Source: PJM website; derived from 1 minute ACE data available

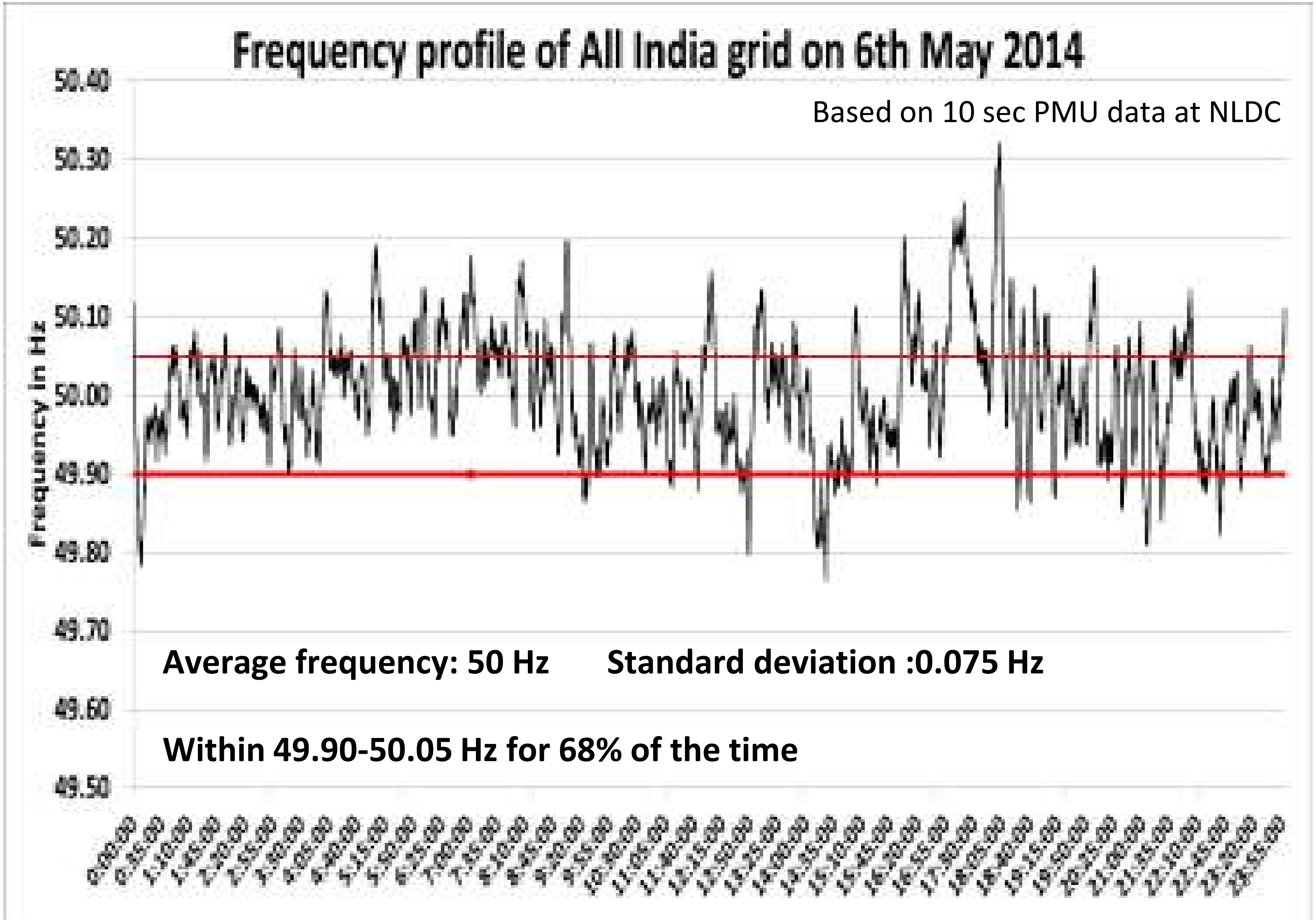
FREQUENCY PROFILE SO FAR



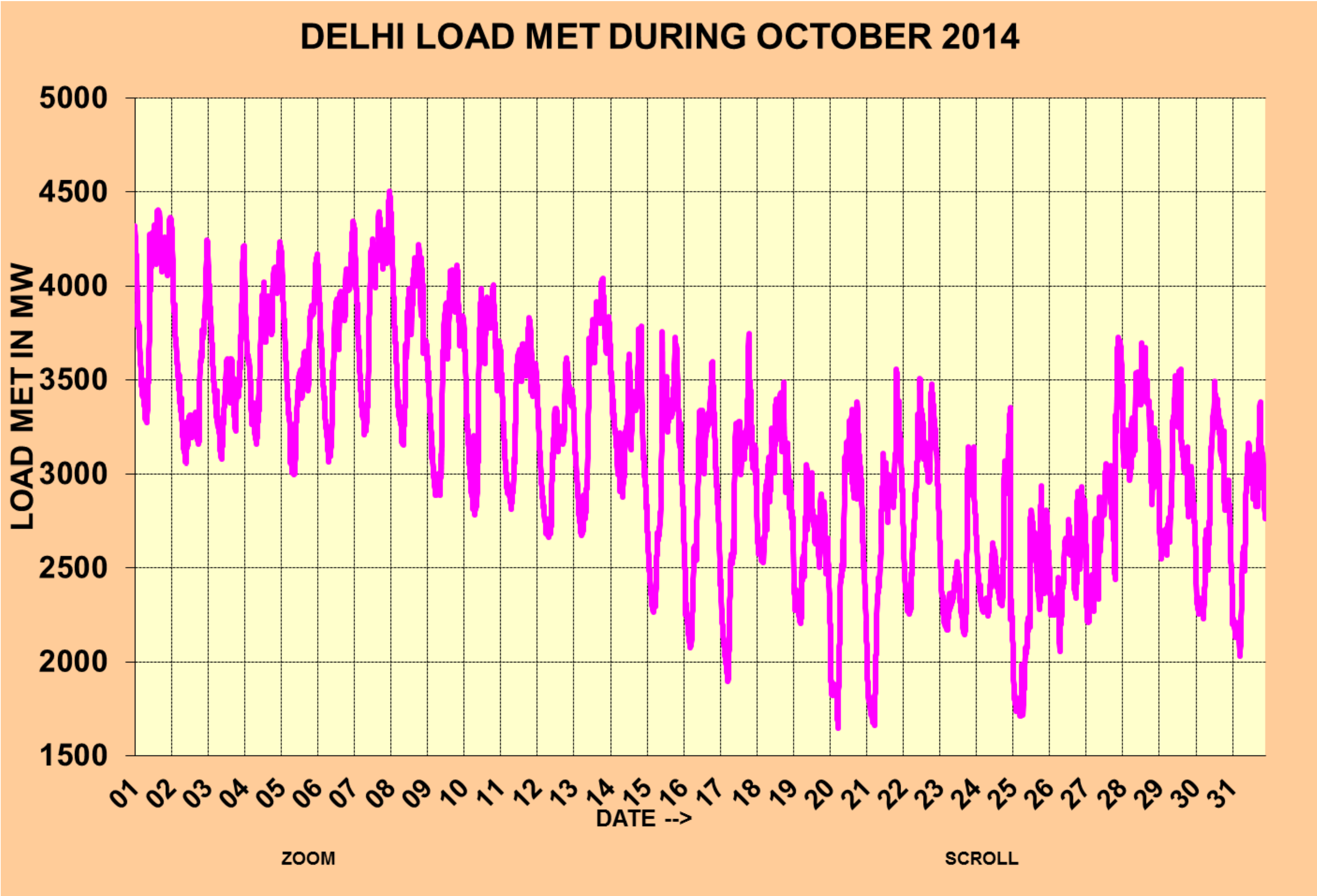
EASTERN REGION / NEW GRID/ALL INDIA AVERAGE FREQUENCY
53.0
52.5
52.0
51.5
51.0
50.5
50.0
49.5
49.0
48.5
Hz -->
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Jul-04
Jan-05
Jul-05
Jan-06
Jul-06
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13
Jul-13
Jan-14
Jul-14
Jan-15
MONTH -->

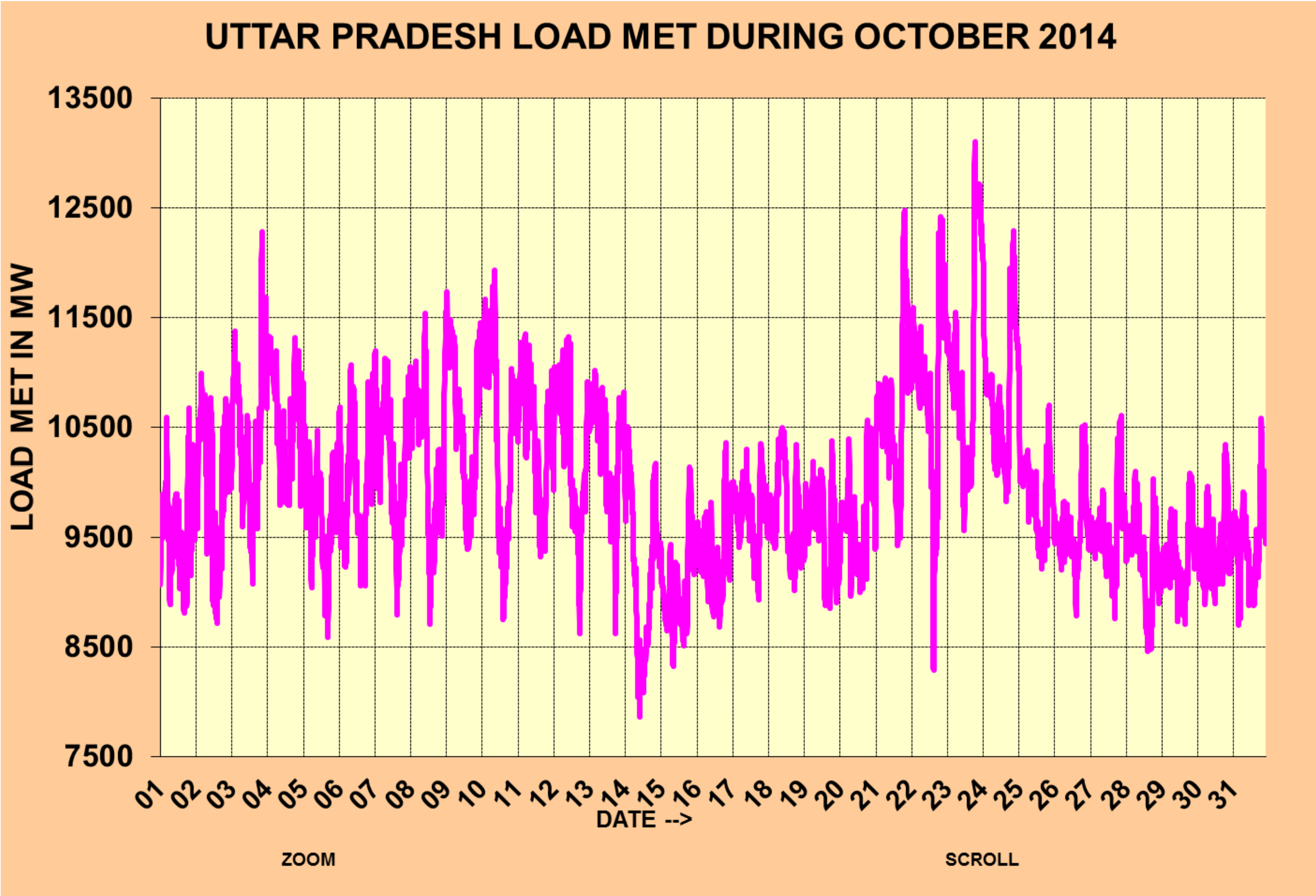

ER / NEW GRID/ALL INDIA MAXIMUM AND MINIMUM FREQUENCY
54
53
52
51
50
49
48
47
Hz -->
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Jul-04
Jan-05
Jul-05
Jan-06
Jul-06
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13
Jul-13
Jan-14
Jul-14
Jan-15
Date -->
MAXIMUM
MINIMUM

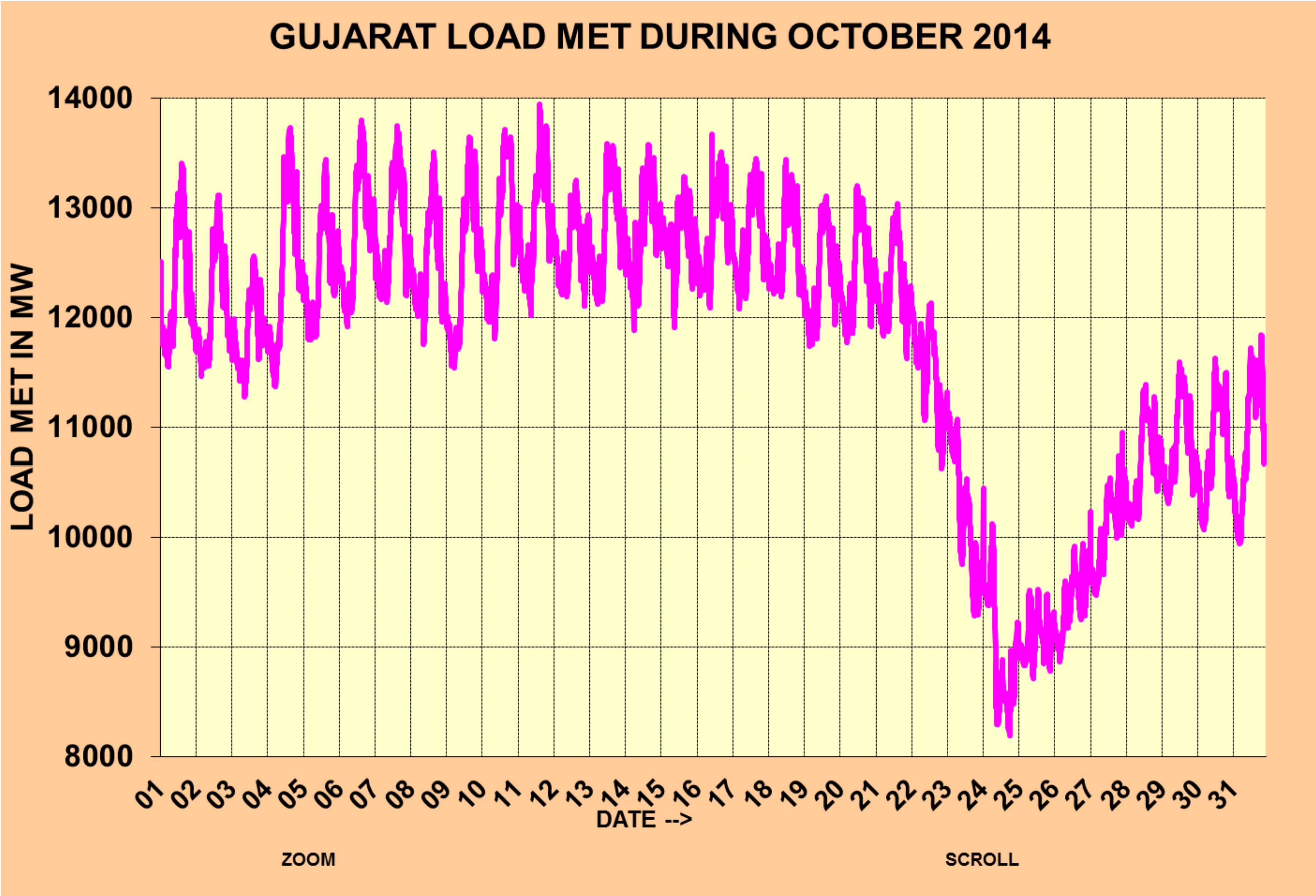

ER/NEW GRID/ALL INDIA FREQUENCY FLUCTUATIONS (MAXIMUM-MINIMUM)
Hz
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Jul-04
Jan-05
Jul-05
Jan-06
Jul-06
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13
Jul-13
Jan-14
Jul-14
Jan-15
MONTH -->

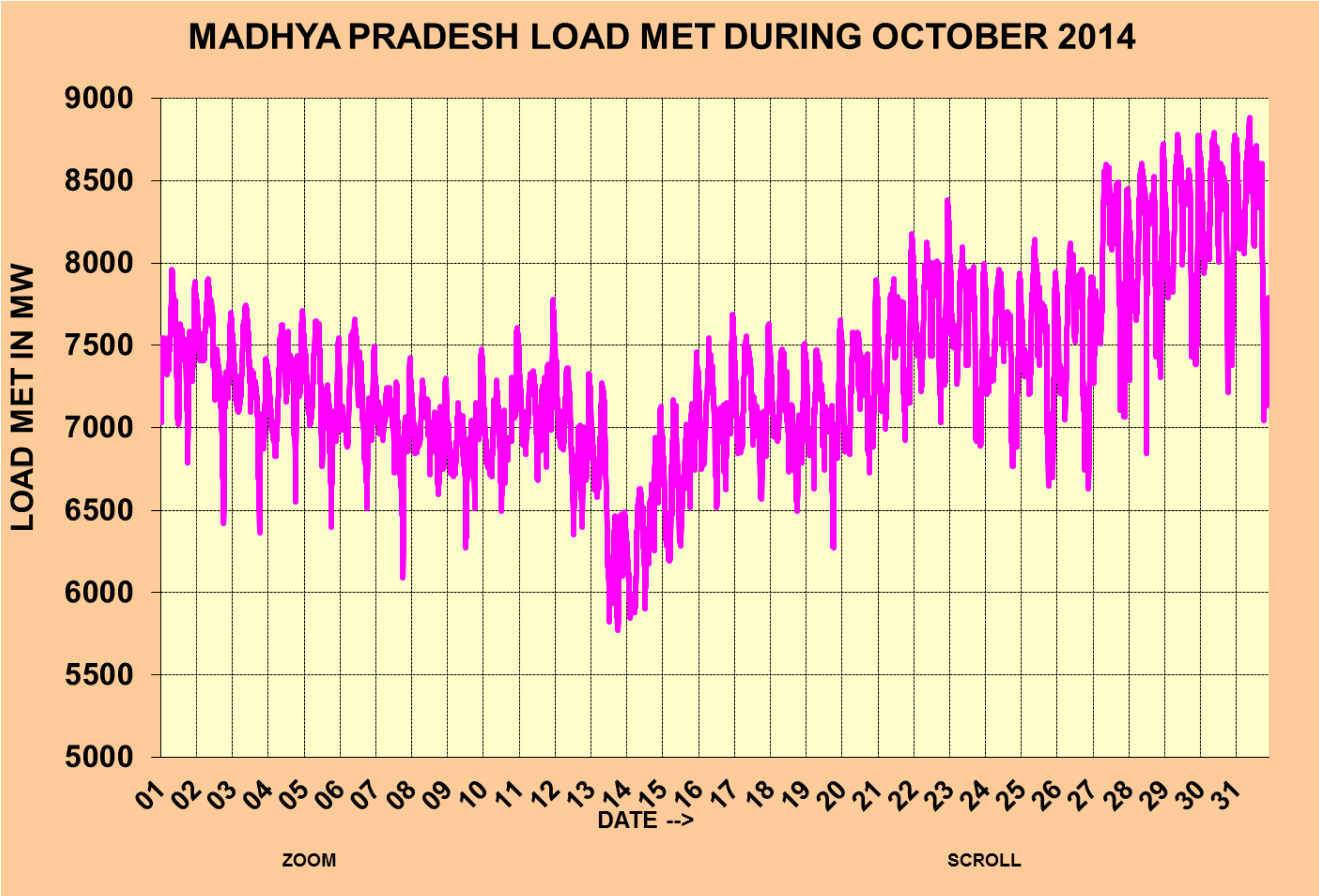

Frequency profile of All India grid on 6th May 2014
Based on 10 sec PMU data at NLDC
Frequency in Hz
50.40
50.30
50.20
50.10
50.00
49.90
49.80
49.70
49.60
49.50
Average frequency: 50 Hz
Standard deviation :0.075 Hz
Within 49.90-50.05 Hz for 68% of the time

LOAD FORECAST AND ADEQUACY

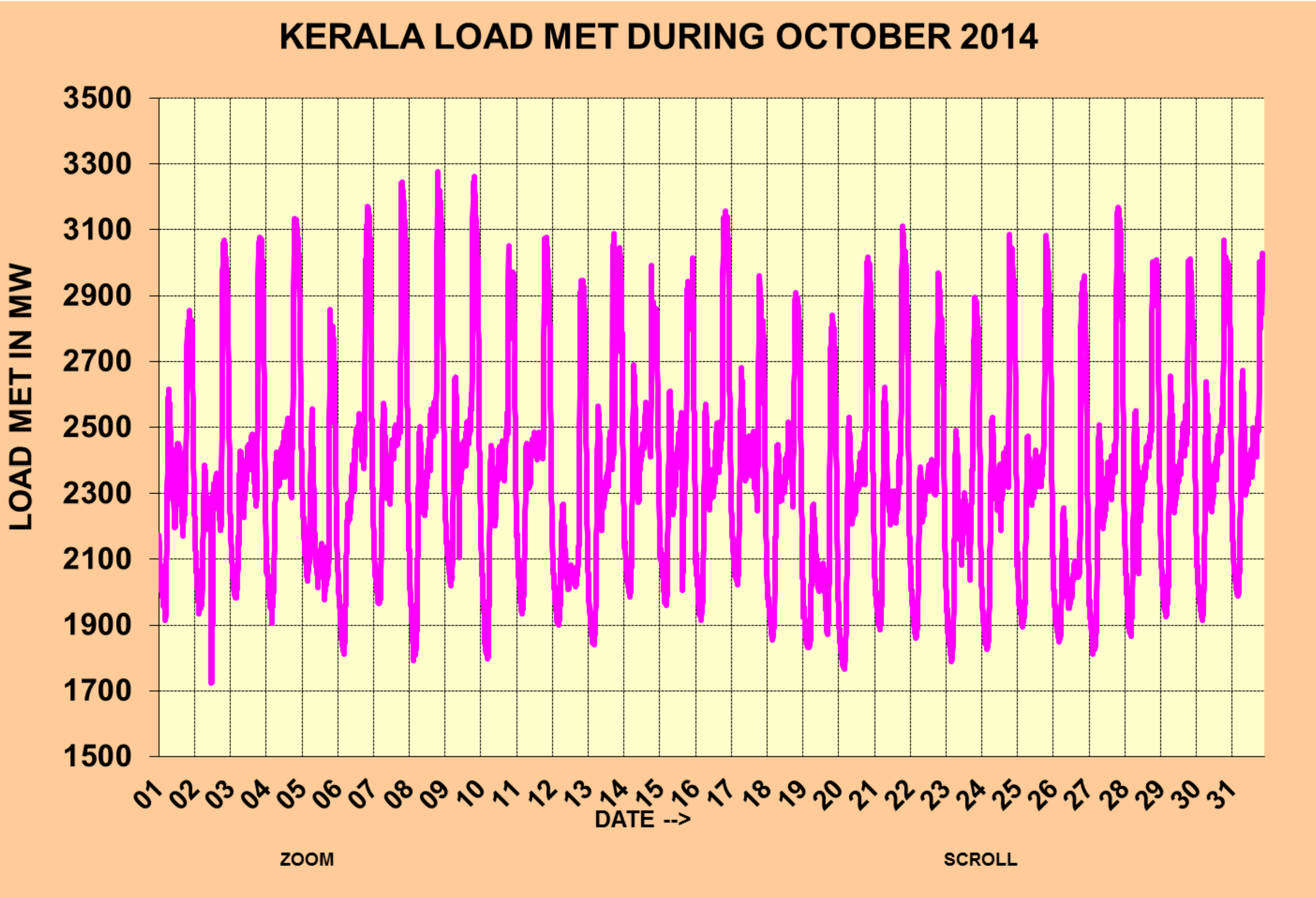

DELHI LOAD MET DURING OCTOBER 2014
5000
4500
4000
3500
3000
2500
2000
1500
LOAD MET IN MW
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
ZOOM
SCROLL

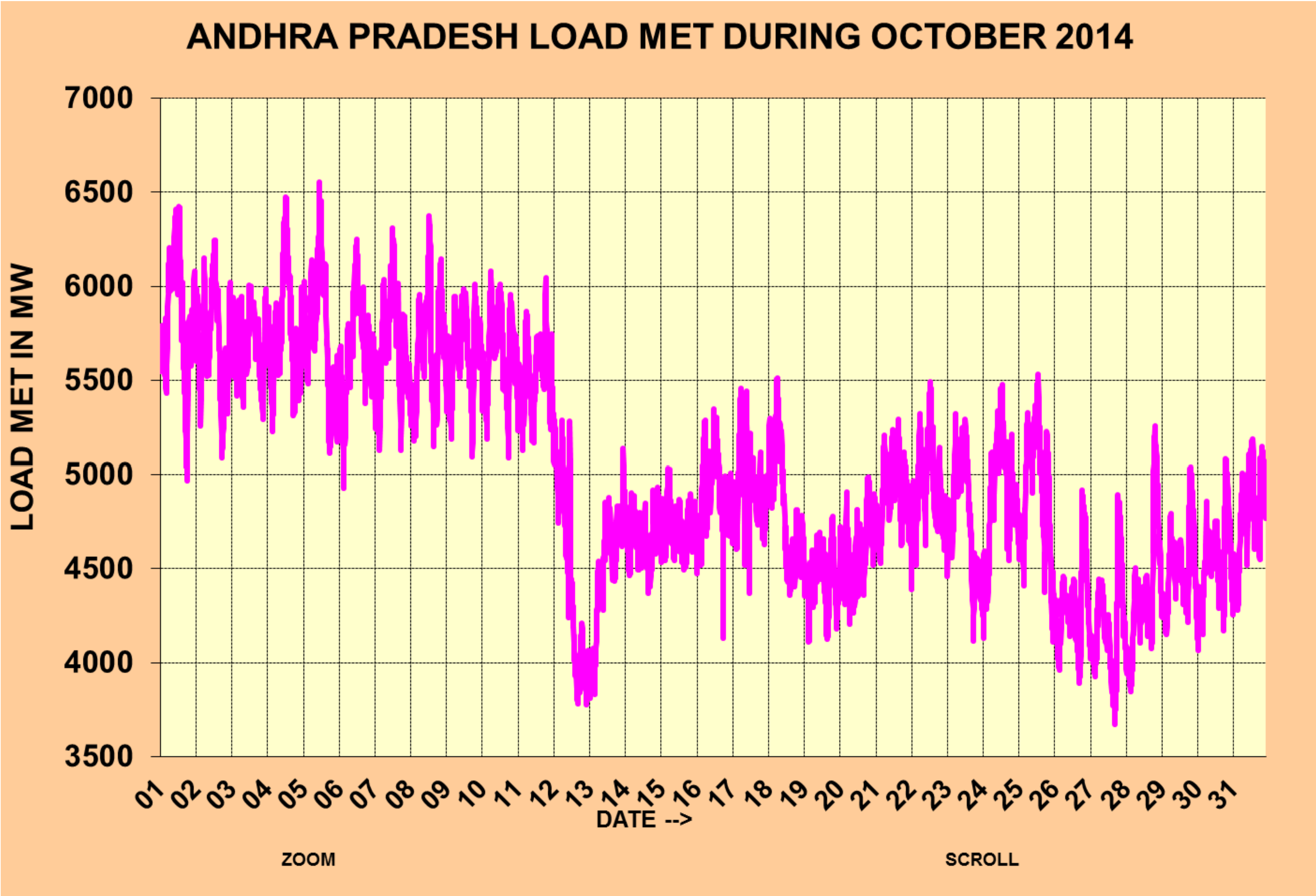

UTTAR PRADESH LOAD MET DURING OCTOBER 2014
LOAD MET IN MW
13500
12500
11500
10500
9500
8500
7500
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
ZOOM
SCROLL

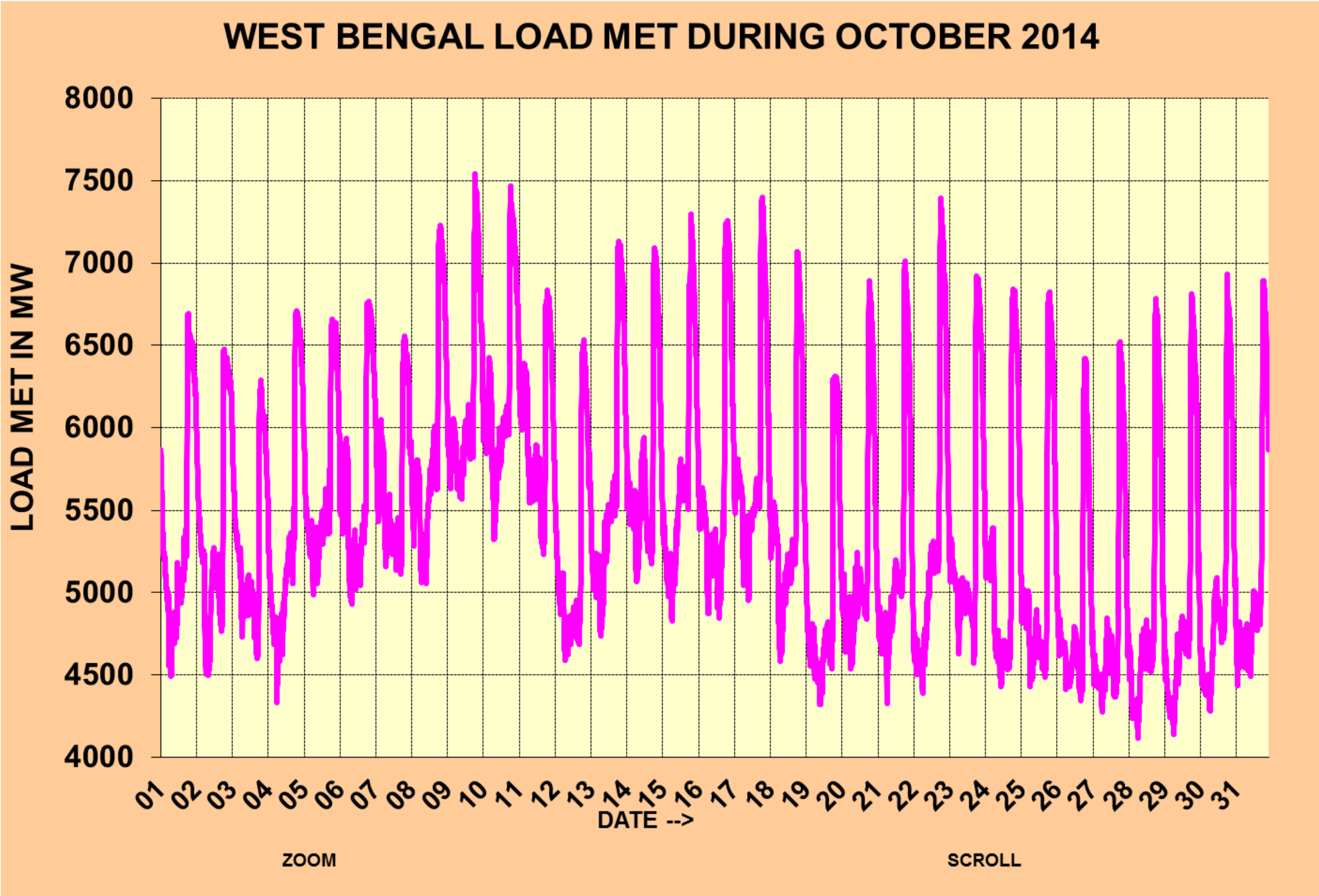

GUJARAT LOAD MET DURING OCTOBER 2014
14000
13000
12000
11000
10000
9000
8000
LOAD MET IN MW
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
ZOOM
SCROLL

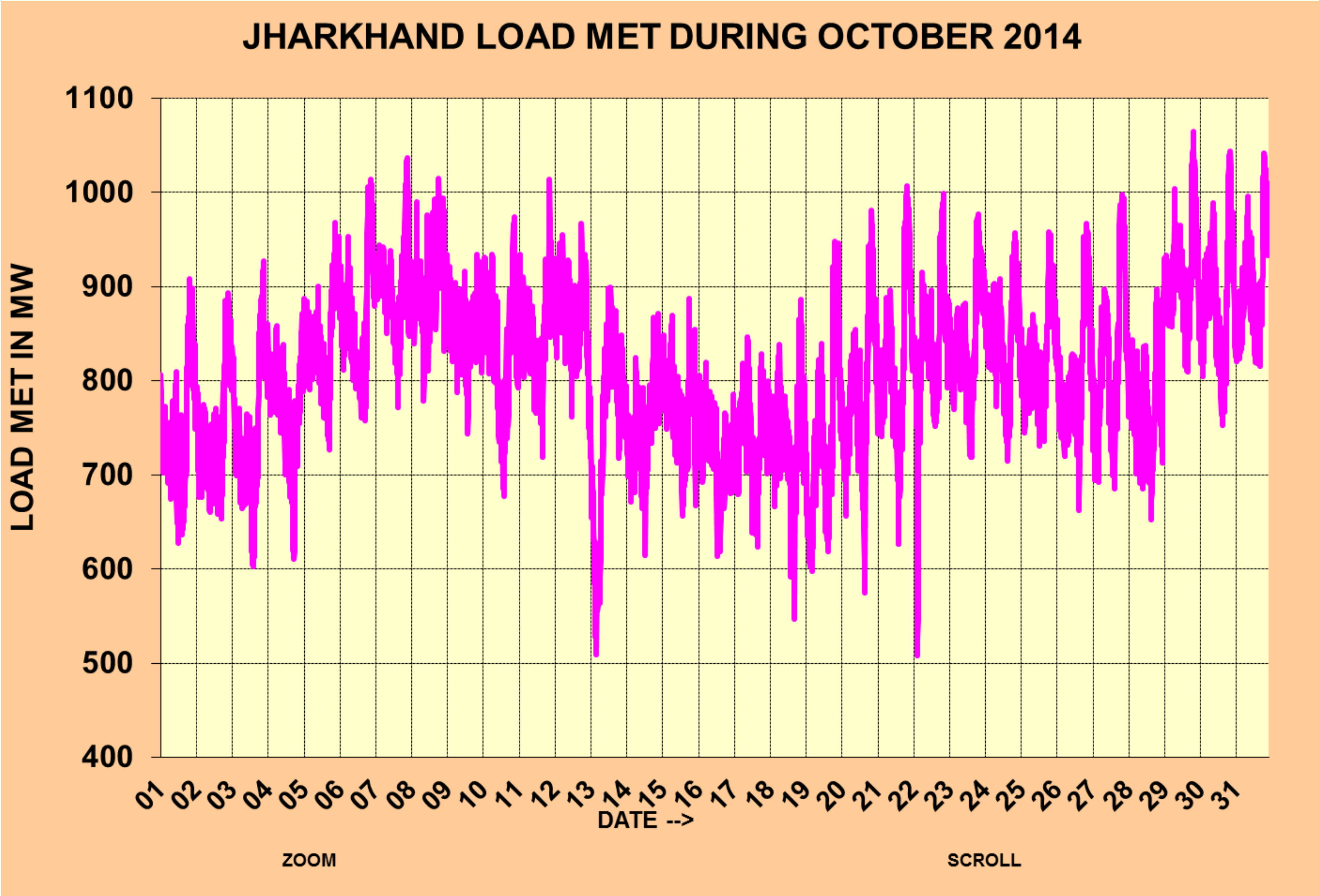


MADHYA PRADESH LOAD MET DURING OCTOBER 2014
LOAD MET IN MW
9000
8500
8000
7500
7000
6500
6000
5500
5000
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
ZOOM
SCROLL

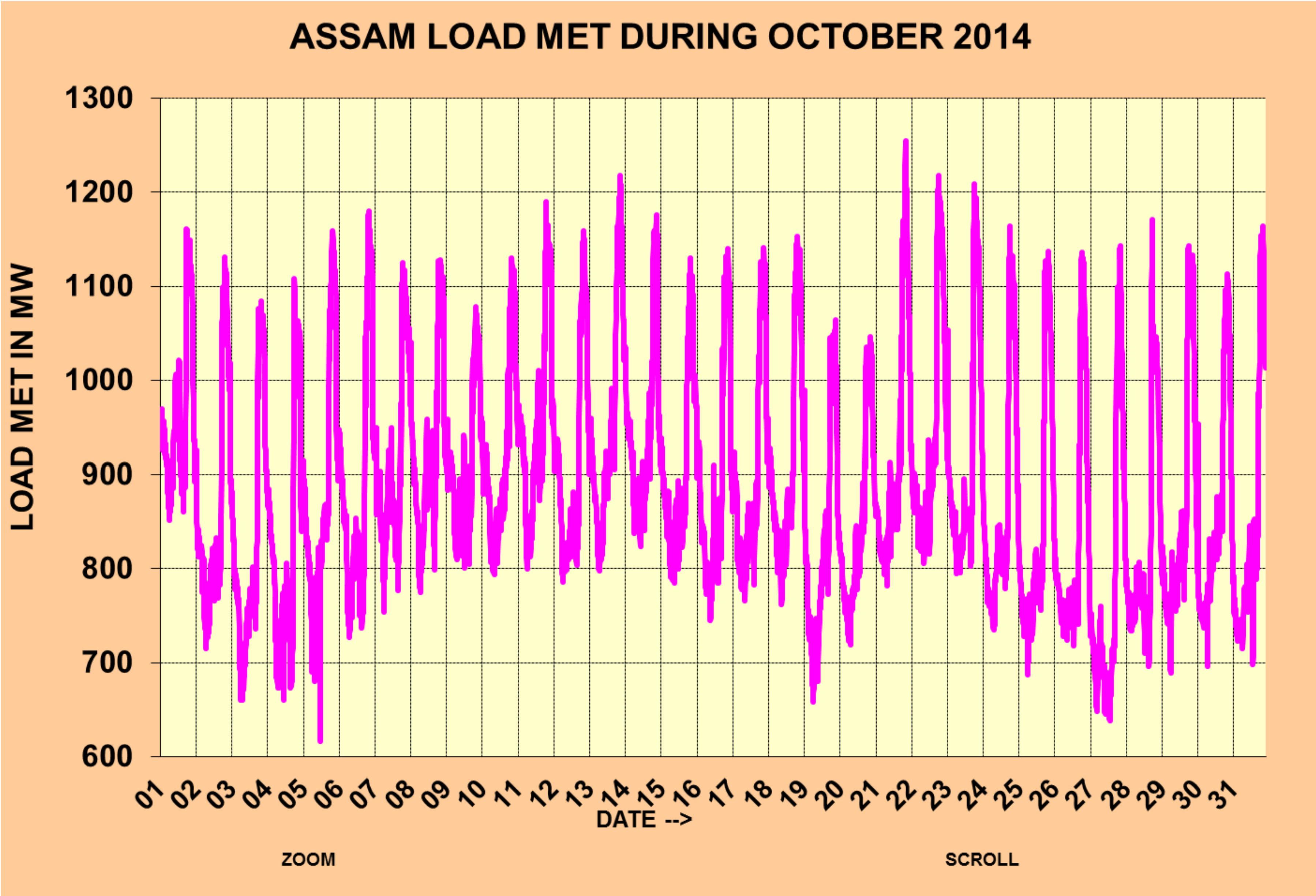

KERALA LOAD MET DURING OCTOBER 2014
LOAD MET IN MW
3500
3300
3100
2900
2700
2500
2300
2100
1900
1700
1500
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
ZOOM
SCROLL


ANDHRA PRADESH LOAD MET DURING OCTOBER 2014
LOAD MET IN MW
7000
6500
6000
5500
5000
4500
4000
3500
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
DATE -->
ZOOM
SCROLL

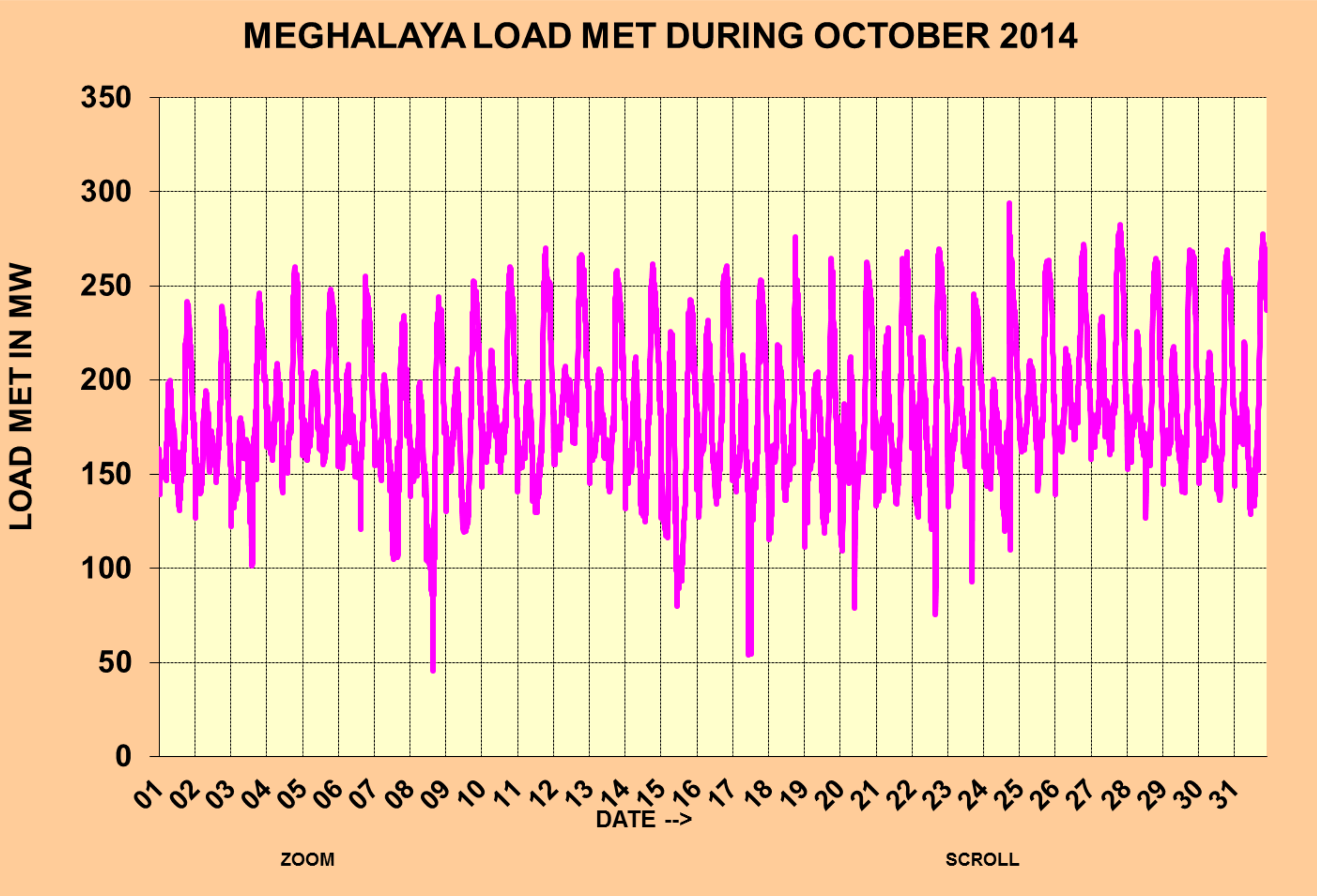

WEST BENGAL LOAD MET DURING OCTOBER 2014
8000
7500
7000
6500
6000
5500
5000
4500
4000
LOAD MET IN MW
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
DATE -->
ZOOM
SCROLL



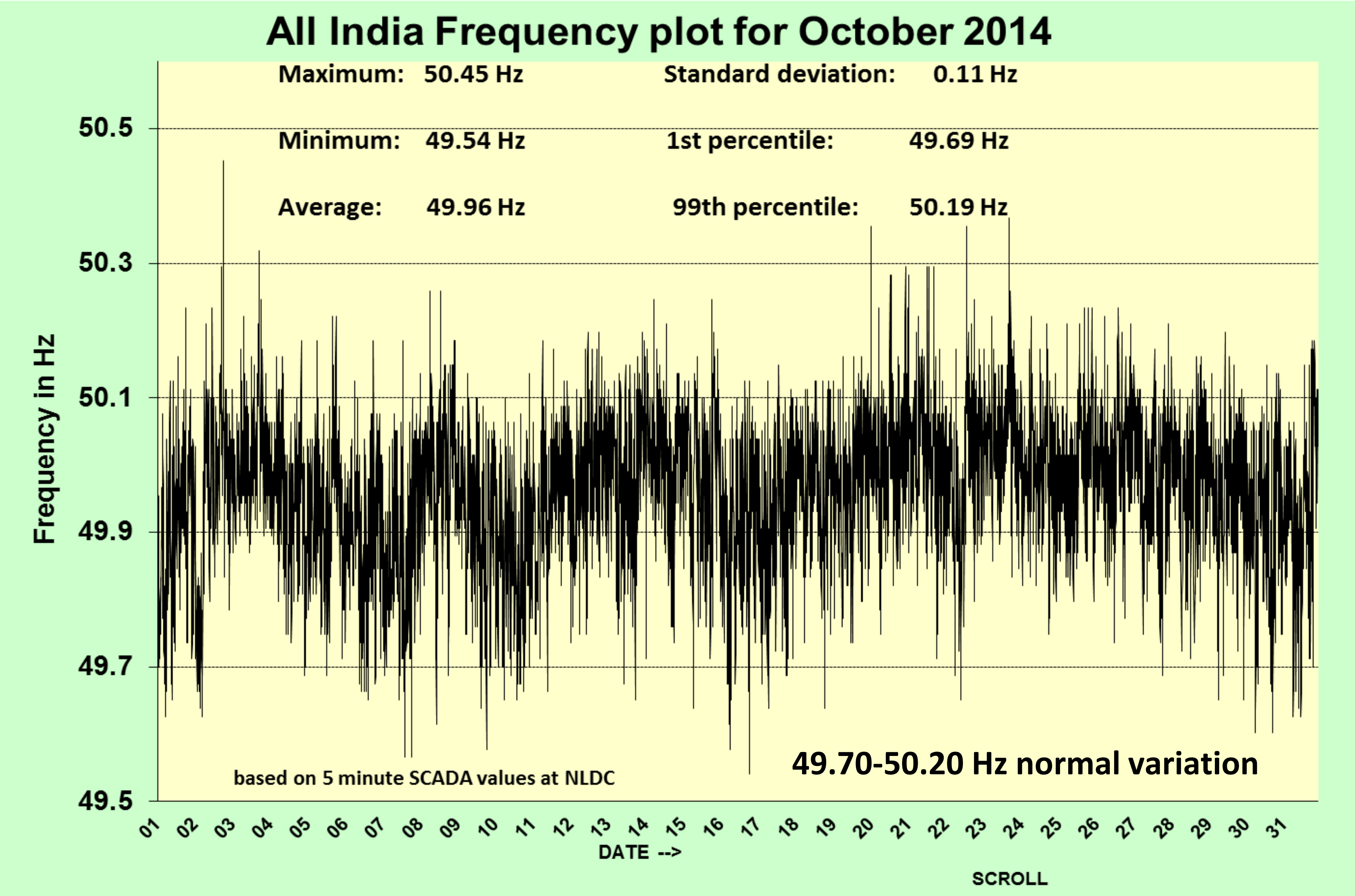
JHARKHAND LOAD MET DURING OCTOBER 2014
LOAD MET IN MW
1100
1000
900
800
700
600
500
400
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
ZOOM
SCROLL



ASSAM LOAD MET DURING OCTOBER 2014
LOAD MET IN MW
1300
1200
1100
1000
900
800
700
600
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
ZOOM
SCROLL


MEGHALAYA LOAD MET DURING OCTOBER 2014
LOAD MET IN MW
350
300
250
200
150
100
50
0
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
DATE -->
ZOOM
SCROLL

RESERVES REQUIREMENT AND FULFILLMENT


All India Frequency plot for October 2014
Maximum: 50.45 Hz
Standard deviation: 0.11 Hz
Minimum: 49.54 Hz
1st percentile: 49.69 Hz
Average: 49.96 Hz
99th percentile: 50.19 Hz
Frequency in Hz
50.5
50.3
50.1
49.9
49.7
49.5
based on 5 minute SCADA values at NLDC
49.70-50.20 Hz normal variation
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
SCROLL

Frequency Response Characteristics (FRC)

S. No.	Date	Event	Frequency Change (Hz)	MW change	FRC (MW/Hz)
1	04-05-14 (1448 hrs.)	Kawai (2 x 660 MW) tripping	-0.12	920	7666
2	17-05-14 (2132 hrs)	400/220kV ICTs of Muradnagar tripped	0.12	810	6750
3	19-05-14 (1022 hrs.)	CGPL unit # 2 of 830 MW tripped	-0.13	736	5662
4	28-08-14 (1113 hrs.)	Farakka power Station tripped.	-0.19	1040	5474
5	20-05-14 (2057 hrs.)	Tiroda station tripping	-0.34	1848	5435

Reserves for frequency control

- 49.70-50.20 Hz normal variation in frequency on daily basis
- 5500-6000 MW/Hz Frequency Response Characteristic (FRC)
- If frequency to remain within 50 Hz+/- 0.03 Hz, the load changes should be within (0.03 x 5500 MW) or approx. 165 MW.
- At least 0.30 Hz x 5500 MW/Hz= 1650 MW of reserves required
- Both upward and downward regulation required
- Security Criteria to be honored while kicking in reserves
- Primary → Secondary → Tertiary reserves

CANDIDATES FOR RESERVES

National Electricity Policy

- Section 2.0: Availability of Power - Demand to be fully met by 2012. Energy and peaking shortages to be overcome and adequate spinning reserve to be available.
- 5.2.3 In order to fully meet both energy and peak demand by 2012, there is a need to create adequate reserve capacity margin. In addition to enhancing the overall availability of installed capacity to 85%, a spinning reserve of at least 5%, at national level, would need to be created to ensure grid security and quality and reliability of power supply.

6000-7000 MW of spinning reserve on an All India basis!

Central Sector Generating Stations

		Installed Capacity (MW)	2013-14		Difference (%) (1-2)	Additional MW
			Availability (%) (1)	PLF (%) (2)		
NR	ANTA GPS	419	98.34	53.50	44.84	188
	AURAIYA GPS	663	98.12	30.84	67.28	446
	DADRI GPS	830	97.47	46.77	50.70	421
	DADRI NCTPS-I & II	1820	101.44	82.80	18.64	339
	APCPL Jhajjar	1500	97.16	41.46	55.70	836
	RIHAND STPS	3000	92.16	83.80	8.36	251
	UNCHAHAR TPS	1050	99.36	86.03	13.33	140
	TOTAL					2620
ER	Farakka STPS	2100	91.16	72.18	18.98	399
	Kahalgaon STPS	2340	90.98	71.11	19.87	465
	TOTAL					864

Central Sector Generating Stations

		Installed Capacity (MW)	2013-14		Difference (%) (1-2)	Additional MW
			Availability (%) (1)	PLF (%) (2)		
WR	KSTPS	2600	94.67	90.68	3.99	104
	VSTPS	4260	94.72	86.93	7.79	332
	KAWAS	656	91.39	24.16	67.23	441
	GANDHAR	657	92.48	22.97	69.51	457
	SIPAT-II	2980	91.27	73.43	17.84	532
	Mundra UMPP	4000	80.34	68.29	12.05	482
	Mauda	1000	49.85	16.81	33.04	330
	RGPPL	2220	60.56	7.75	52.81	1172
	TOTAL					3850
SR	NTPC,RAMAGUNDAM	2600	91.04	86.70	4.34	113
	NTPC, SIMHADRI-II	1000	85.89	75.56	10.33	103
	TOTAL					216
All India Total (Central Sector)						7551

State Sector Generating Stations

		Installed Capacity (MW)	2013-14		Difference (%) (1-2)	Additional MW
			Availability** (%) (1)	PLF (%) (2)		
NR	Faridabad CCPP	432	90	45.81	44.19	191
	Badarpur TPS	705	90	67.14	22.86	161
	Pragati CCGT-III	1500	90	5.99	84.01	1260
	Rajiv Gandhi TPS	1200	90	41.69	48.31	580
	Panipat TPS	1360	90	43.63	46.37	631
	Mahatma Gandhi TPS	1320	90	53.68	36.32	479
	Ropar TPS	1260	90	72.53	17.47	220
	Kota TPS	1240	90	87.01	2.99	37
	Suratgarh TPS	1500	90	71.61	18.39	276
	Kawai TPS	1320	90	58.27	31.73	419
	Anpara	1630	90	80.24	9.76	159
	Obra	1278	90	35.33	54.67	699
	Paricha	1140	90	65.31	24.69	281
	Anpara-C	1200	90	65.81	24.19	290
	** assumed		TOTAL (NR)			5683

State Sector Generating Stations

		Installed Capacity (MW)	2013-14		Difference (%) (1-2)	Additional MW
			Availability** (%) (1)	PLF (%) (2)		
WR	Ukai	1350	90	45.96	44.04	595
	Wanakbori	1470	90	38.98	51.02	750
	APL Mundra	4620	90	73.57	16.43	759
	Sanjay Gandhi TPS	1340	90	67.75	22.25	298
	Satpura TPS	1455	90	44.51	45.49	662
	Essar Mahan	600	90	16.78	73.22	439
	Bhusawal TPS	1420	90	53.26	36.74	522
	Chandrapur TPS	2340	90	53.67	36.33	850
	Tirora	2640	90	62.62	27.38	723
	** assumed @90%		TOTAL (WR)			5598

State Sector Generating Stations

		Installed Capacity (MW)	2013-14		Difference (%) (1-2)	Additional MW
			Availability** (%) (1)	PLF (%) (2)		
SR	Rayalseema TPS	1050	90	76.72	13.28	139
	Bellary TPS	1000	90	68.83	21.17	212
	Raichur TPS	1720	90	65.04	24.96	429
	Udupi TPS	1200	90	64.75	25.25	303
	Mettur TPS	1440	90	76.44	13.56	195
	North Chennai TPS	1830	90	74.33	15.67	287
	** assumed @90%		TOTAL (SR)			1565

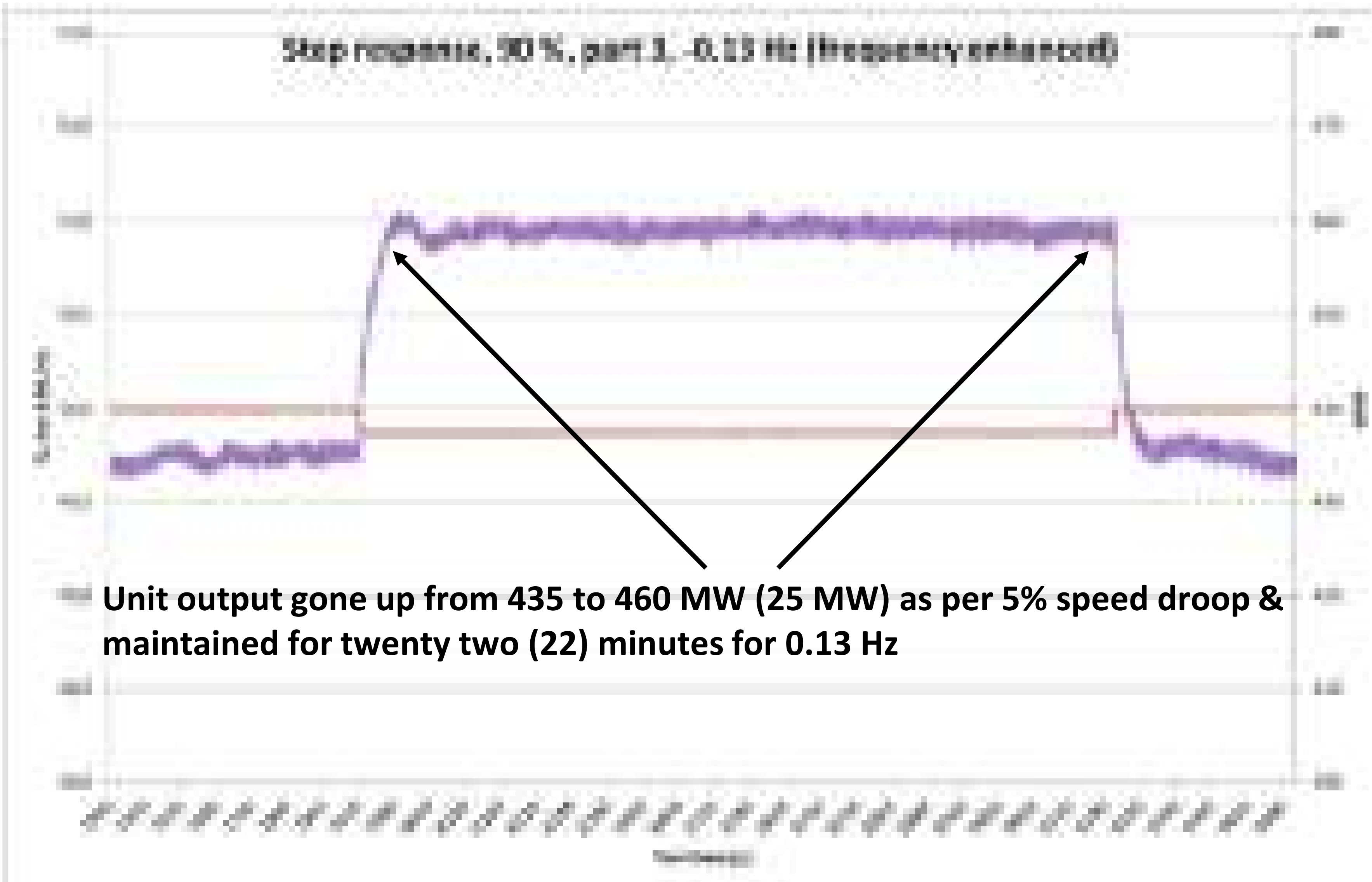
State Sector Generating Stations

		Installed Capacity (MW)	2013-14		Difference (%) (1-2)	Additional MW
			Availability** (%) (1)	PLF (%) (2)		
ER	Chandrapura	890	90	61.62	28.38	253
	Durgapur Steel TPS	1000	90	50	40	400
	Mejia TPS	2340	90	64.25	25.75	603
	Patratu TPS	770	90	10.84	79.16	610
	Maithon RB TPP	1050	90	68.8	21.2	223
	GMR Energy (Kamalanga)	1050	90	26.09	63.91	671
	Sterlite	2400	90	39.73	50.27	1206
	Kolaghat	1260	90	57.07	32.93	415
	Santaldih	980	90	31.88	58.12	570
	** assumed @90%		TOTAL (ER)			4949
All India Total (State Sector)						17796

Number of units installed in India

Primary response testing at Dadri NTPC 490 MW unit on 17th Nov 2014

CERC order dated 31st Dec 2012 in petition no 191/2011



Primary response testing at Dadri NTPC 490 MW unit on 18th Nov 2014

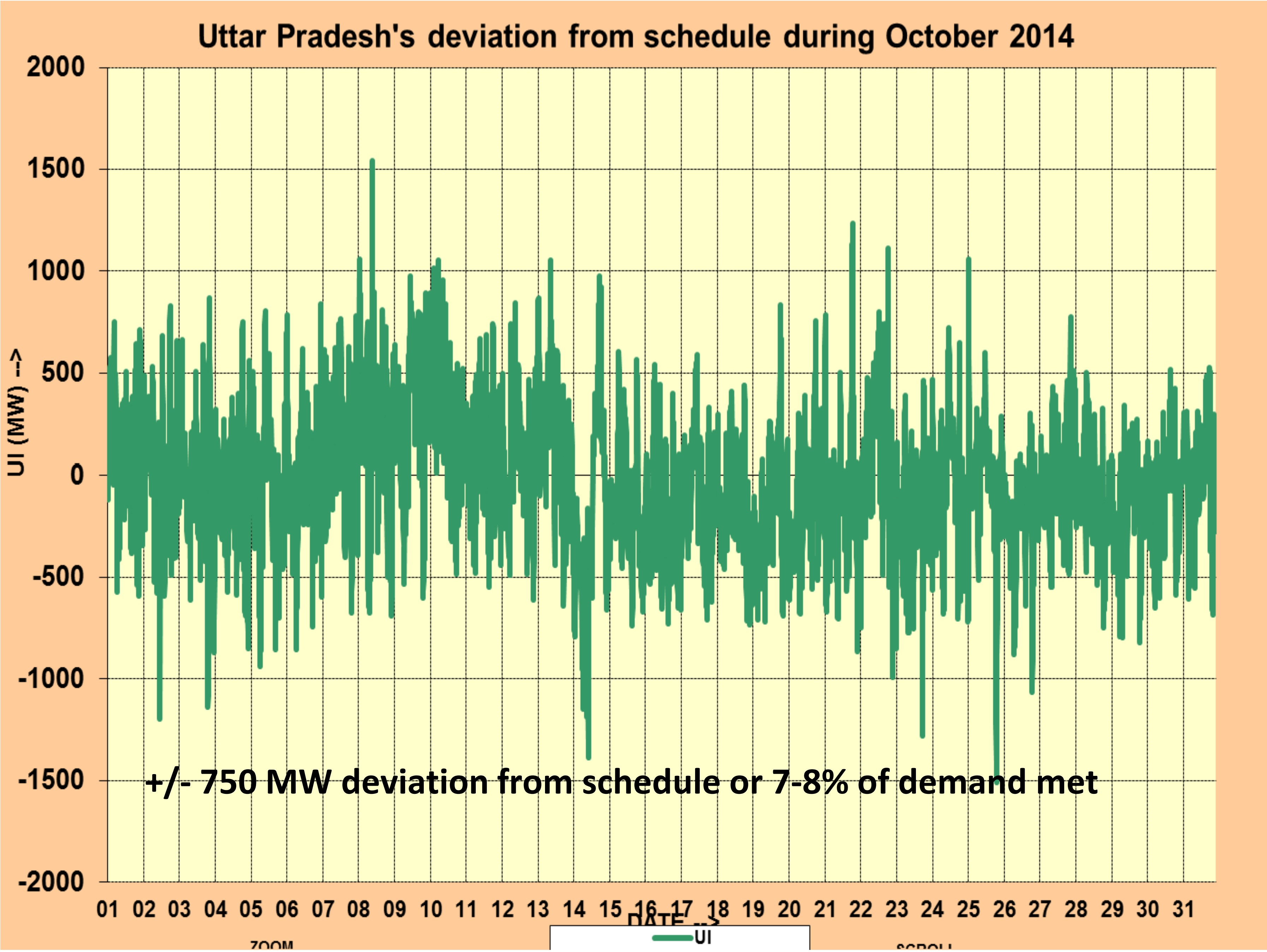
CERC order dated 31st Dec 2012 in petition no 191/2011

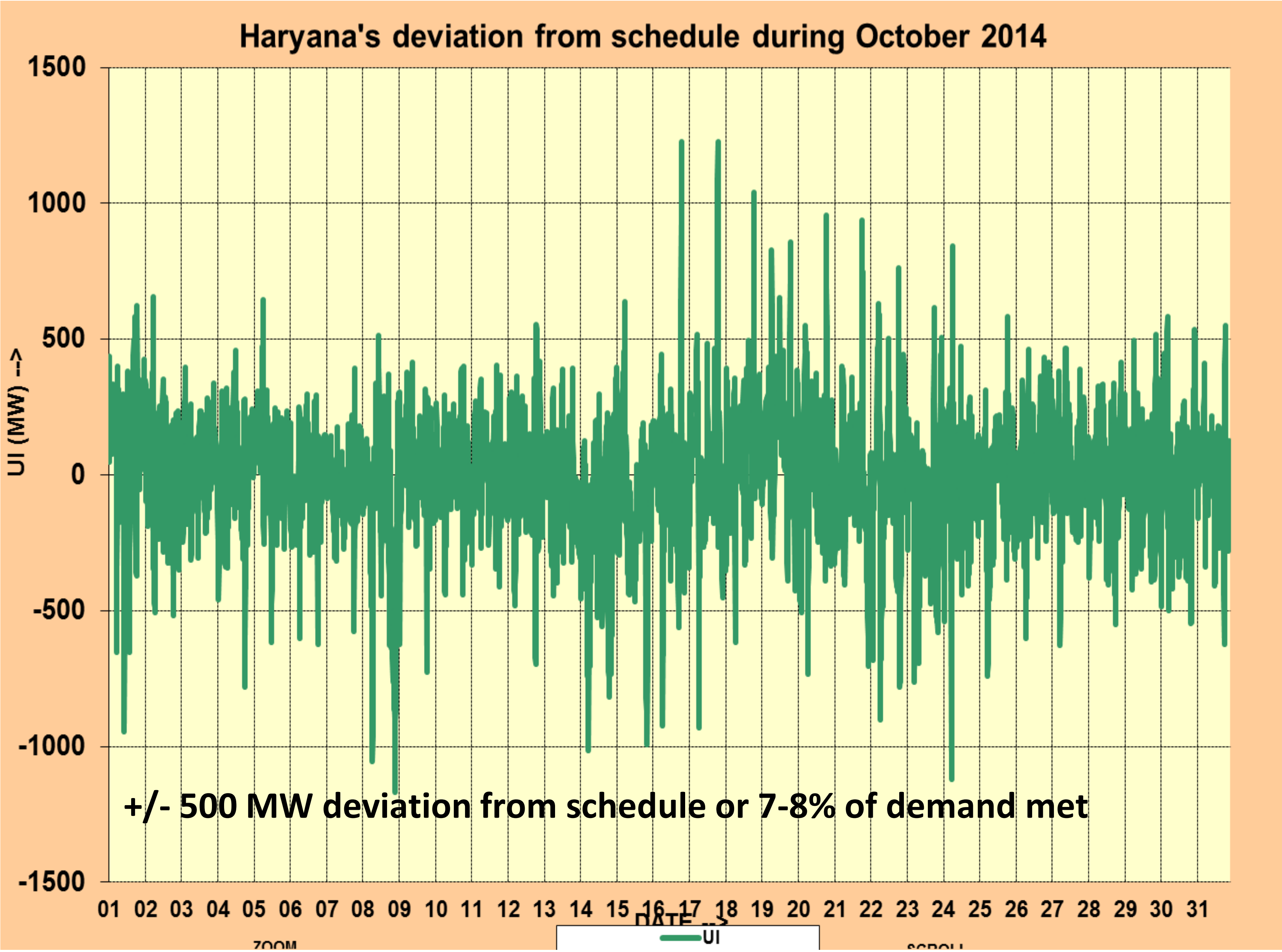
Primary response

- General droop setting is 5% (40% capacity/Hz)
- If 50 GW capacity is on primary response
  - 20,000 MW/Hz would be available ideally
  - 15,000 MW/Hz assuming 75% response
- 4500-5000 MW/Hz response from loads
- Total FRC ~ 20,000 MW/Hz
- For 1500 MW load change, freq. change ~ 0.075 Hz
- Unit output would change by 3% (40%/Hz x 0.075 Hz)
- Load changes random and in both directions
- Manual intervention may be unnecessary

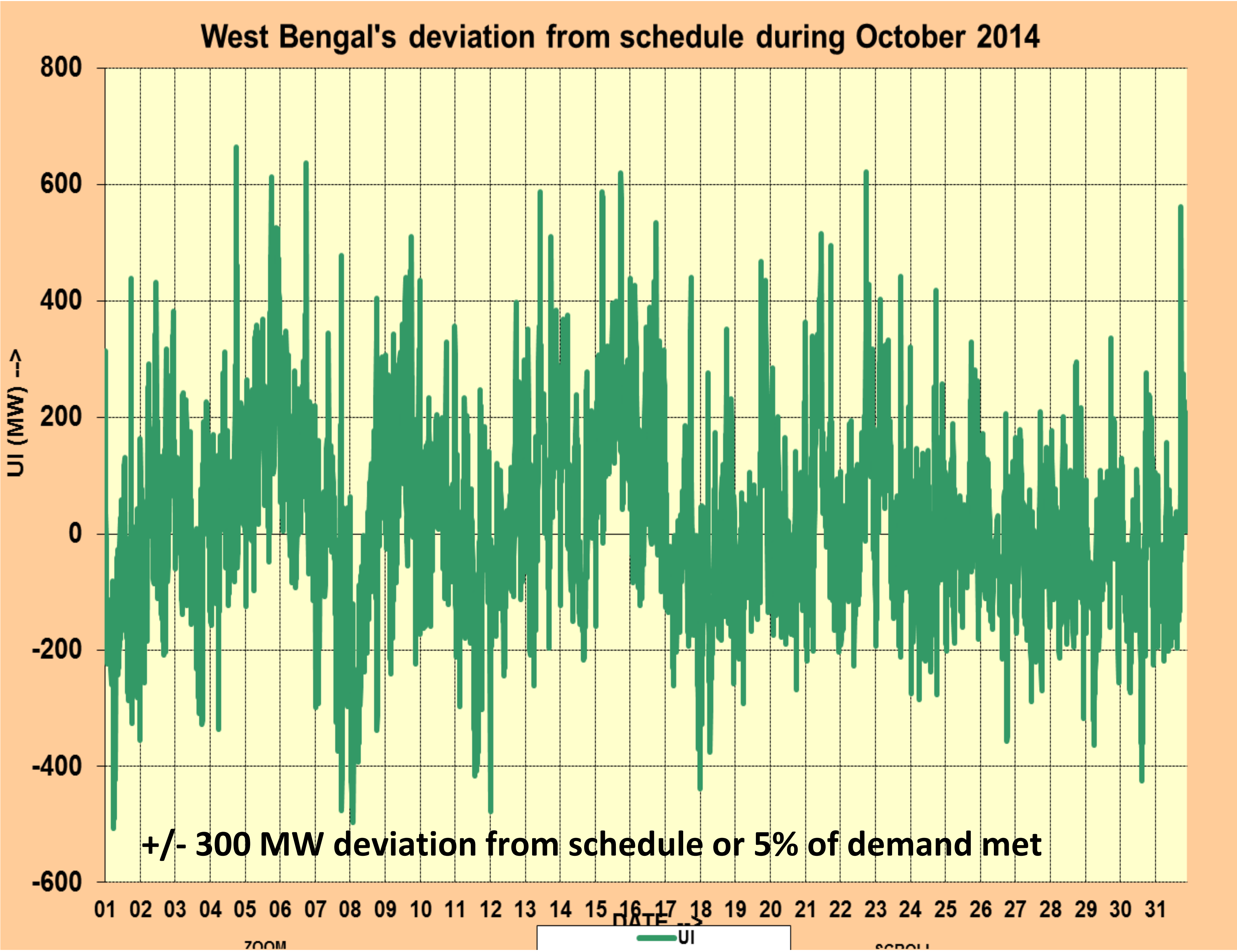
Need to give a genuine trial !!

DECENTRALIZED SECONDARY CONTROL

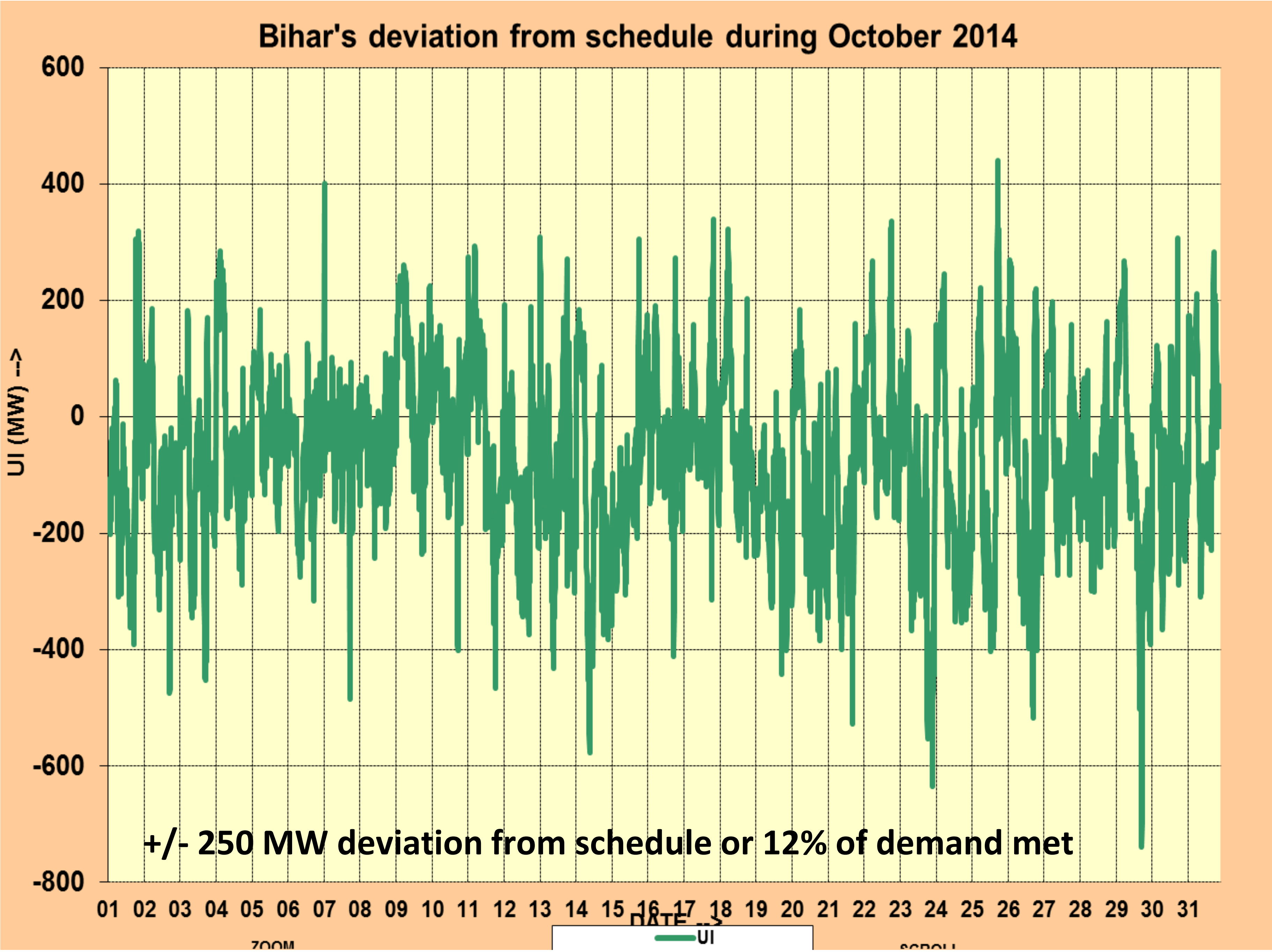

Uttar Pradesh's deviation from schedule during October 2014
UI (MW) -->
2000
1500
1000
500
0
-500
-1000
-1500
-2000
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
UI
+/- 750 MW deviation from schedule or 7-8% of demand met



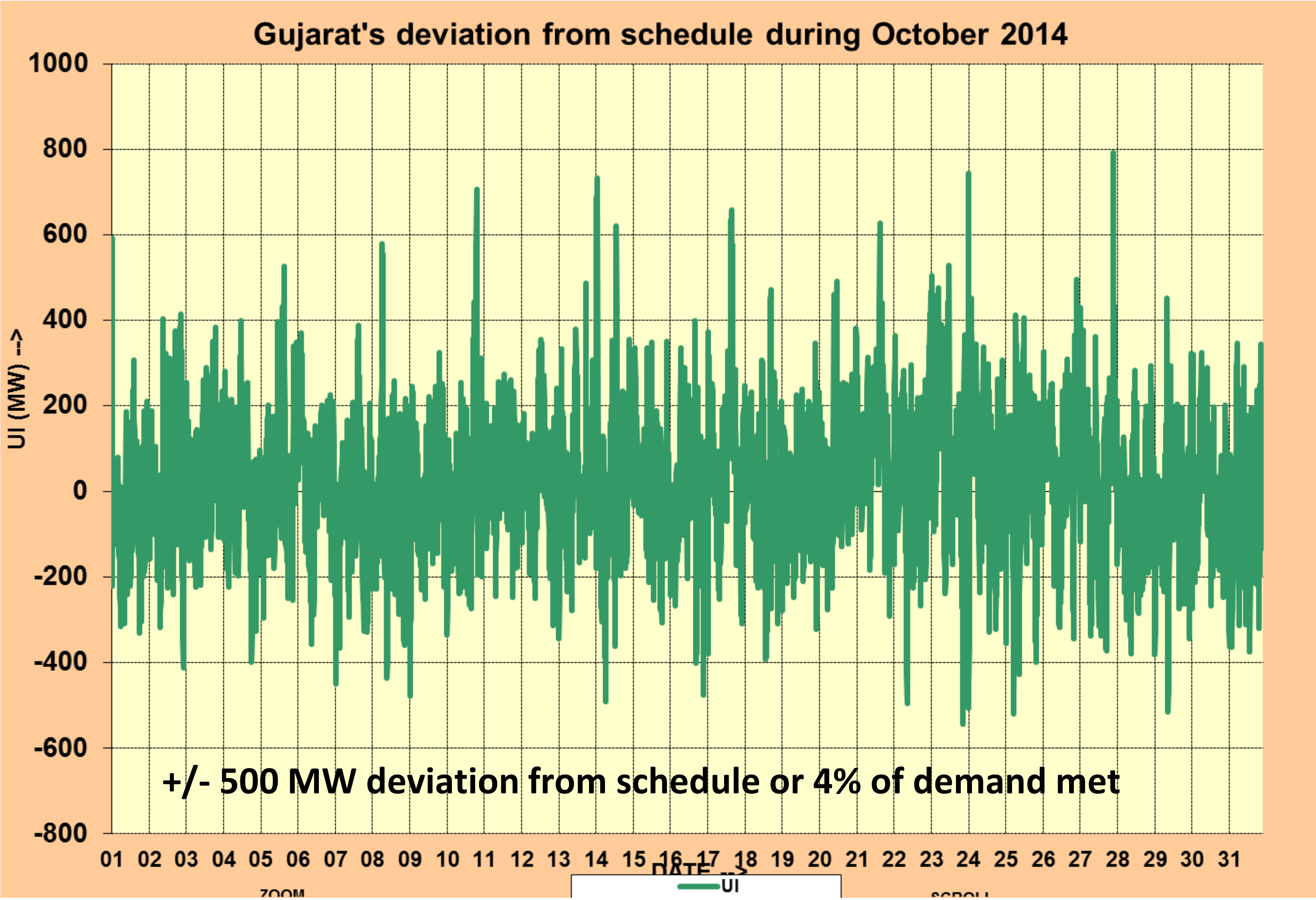
Haryana's deviation from schedule during October 2014
UI (MW) -->
1500
1000
500
0
-500
-1000
-1500
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
UI
+/- 500 MW deviation from schedule or 7-8% of demand met

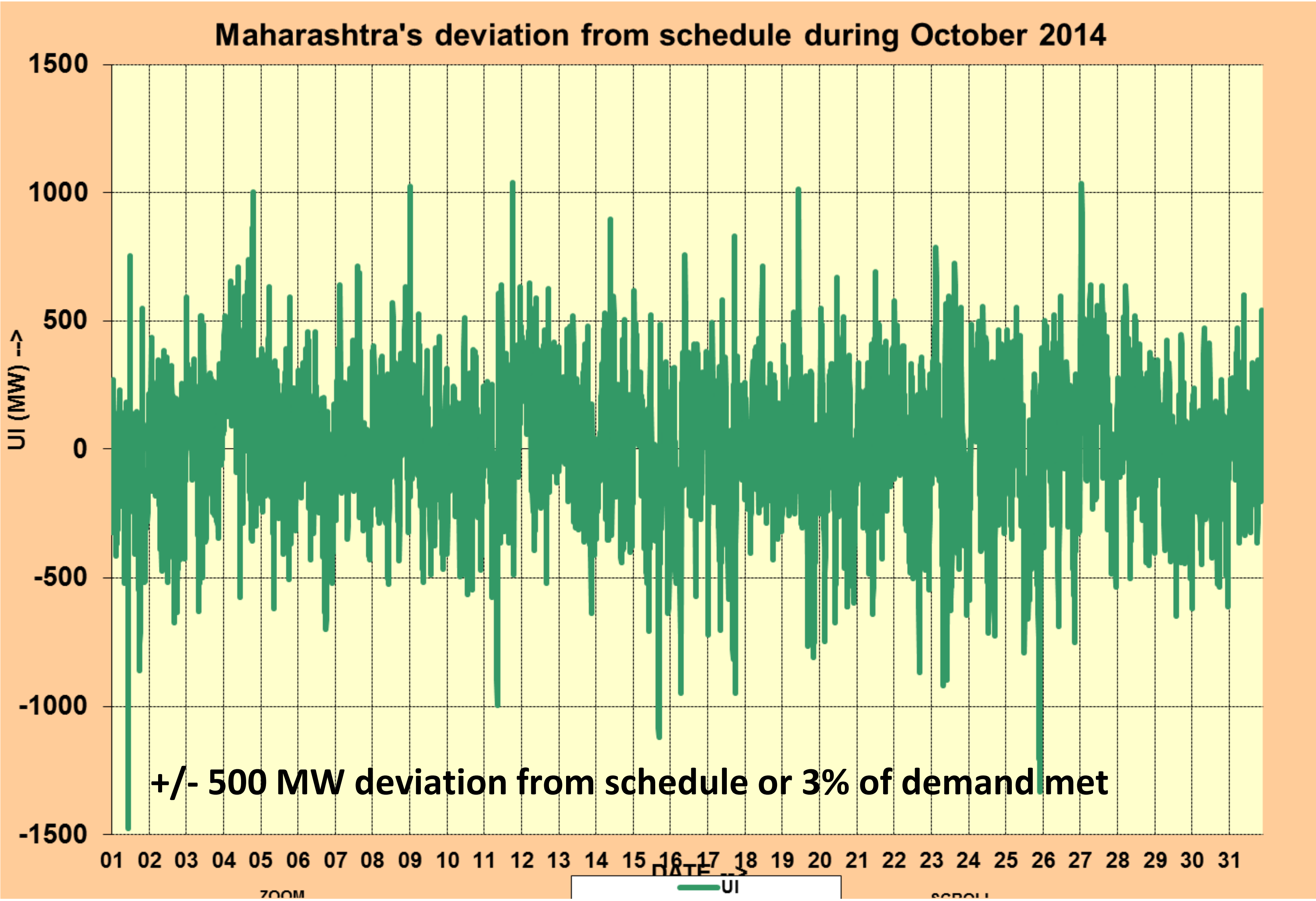


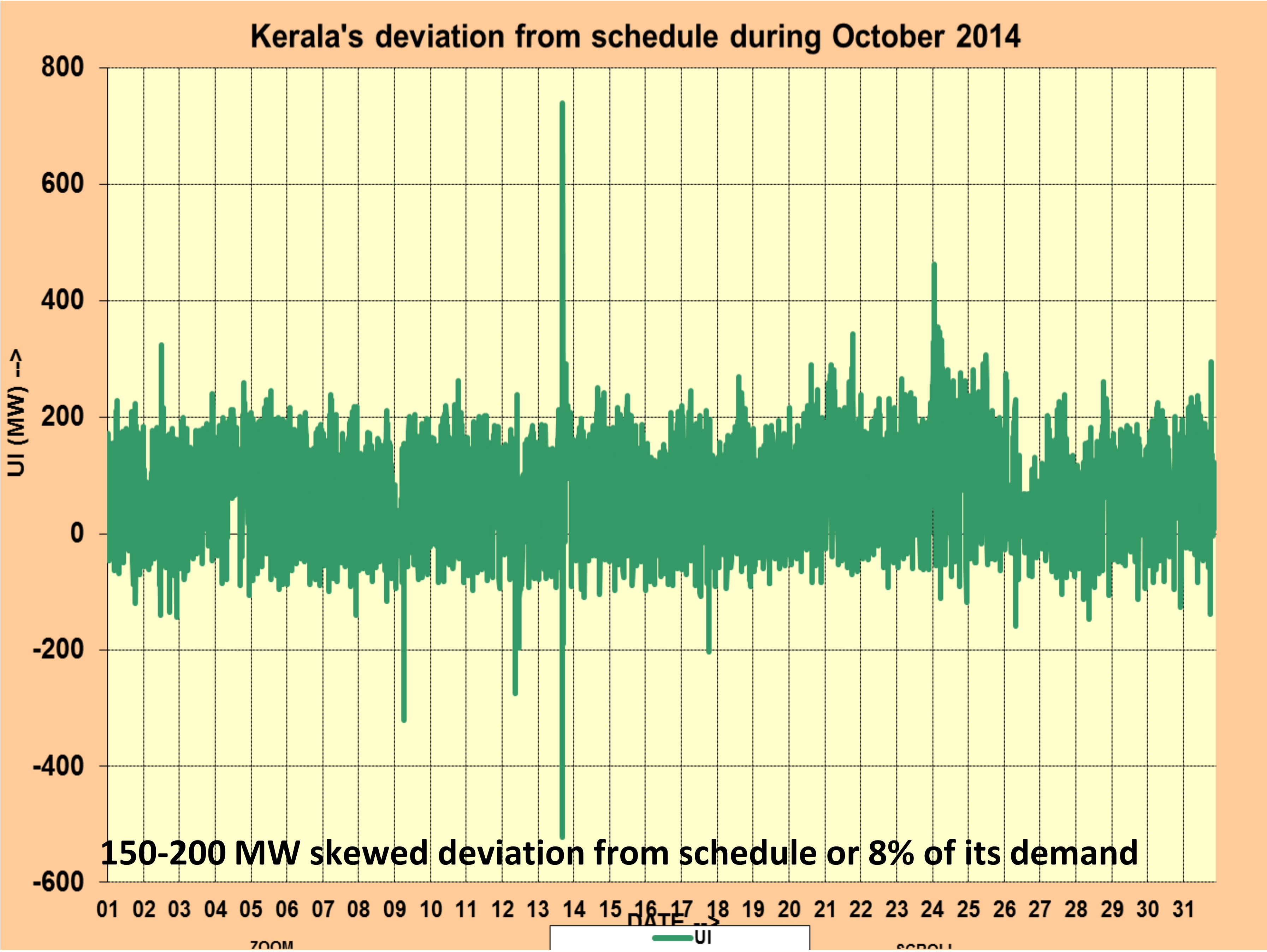
West Bengal's deviation from schedule during October 2014
800
600
400
200
0
-200
-400
-600
UI (MW) -->
+/- 300 MW deviation from schedule or 5% of demand met
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
UI



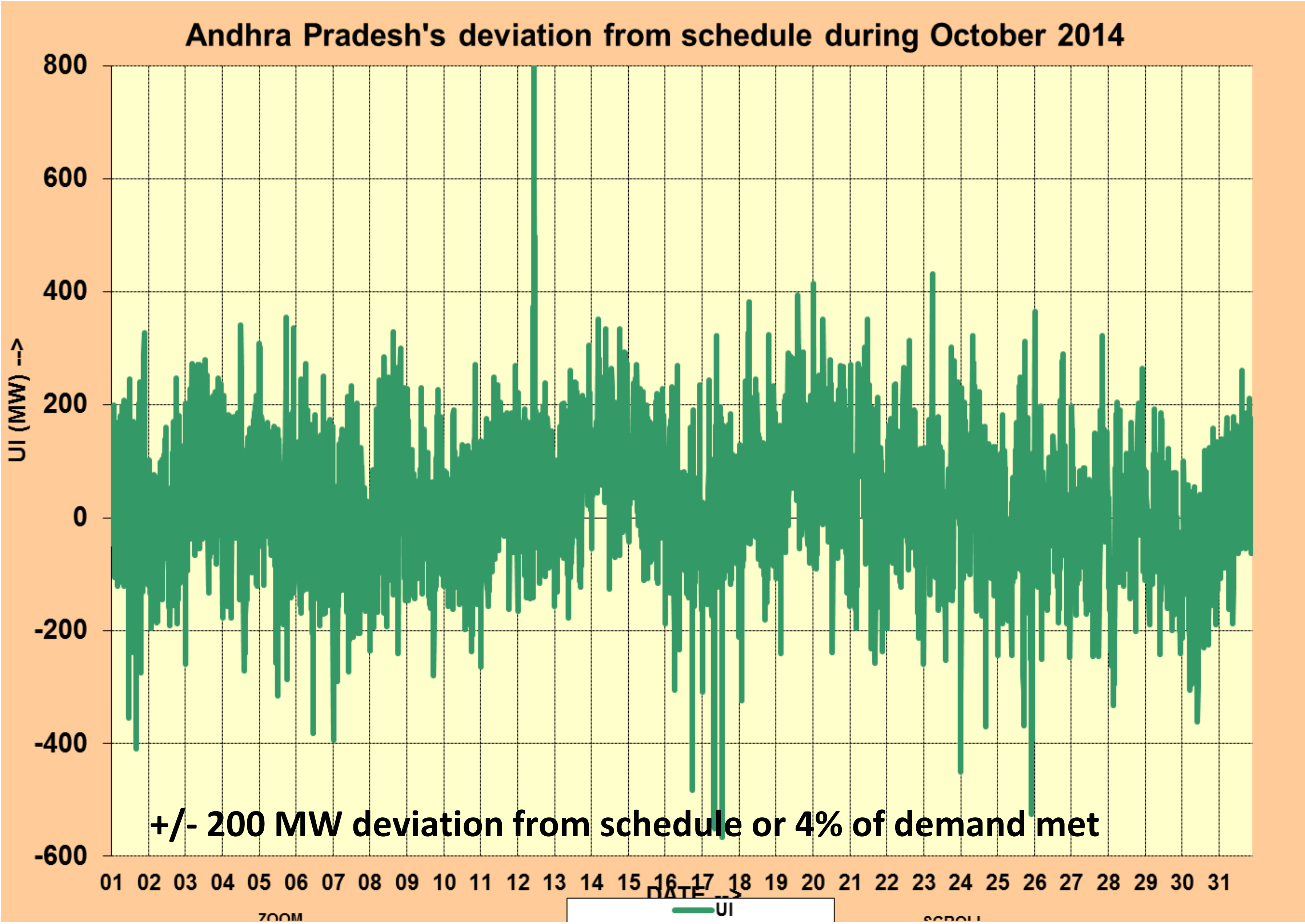
Bihar's deviation from schedule during October 2014
600
400
200
0
-200
-400
-600
-800
UI (MW) -->
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
UI
+/- 250 MW deviation from schedule or 12% of demand met

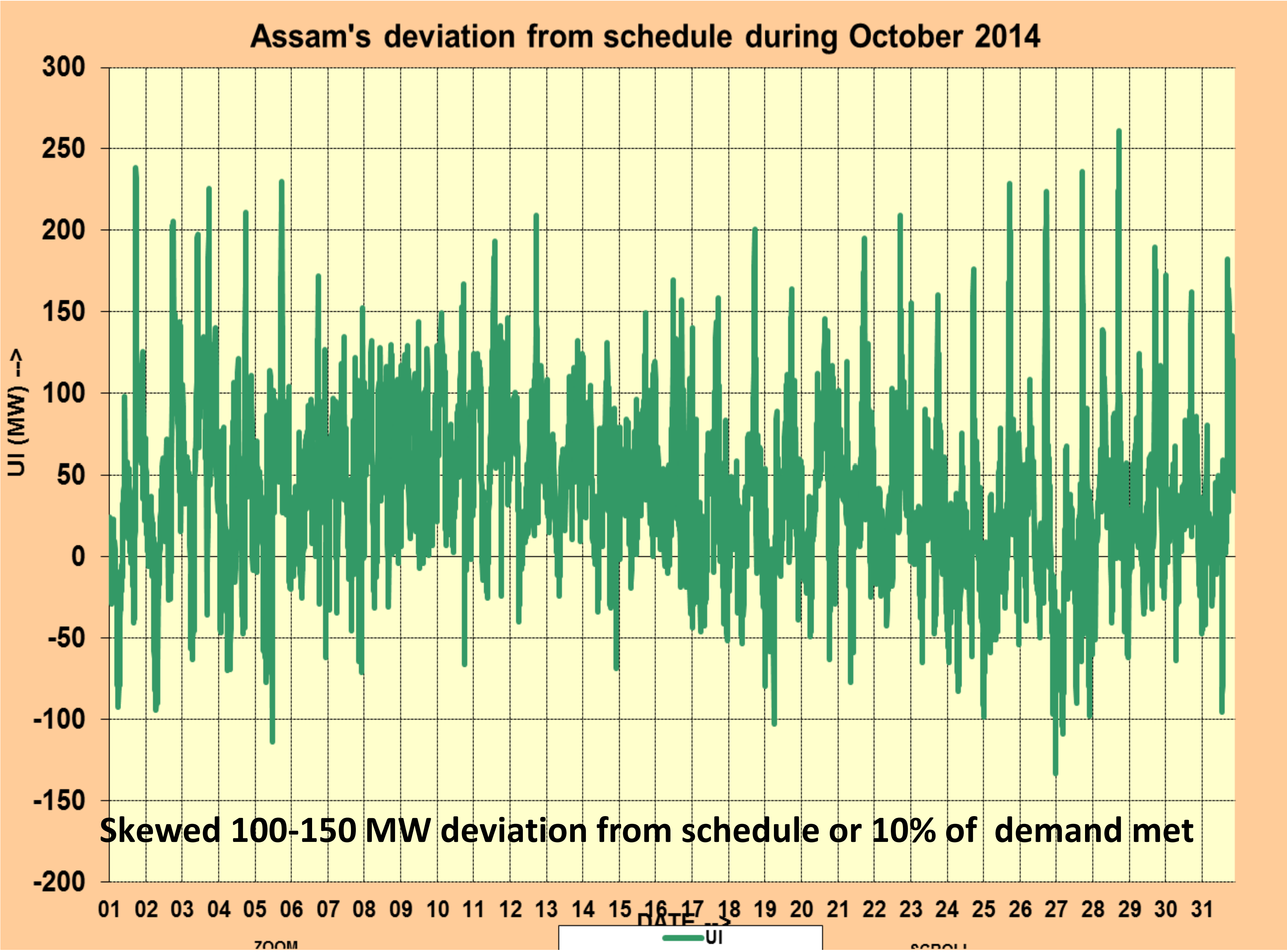

Gujarat's deviation from schedule during October 2014
1000
800
600
400
200
0
-200
-400
-600
-800
UI (MW) -->
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
UI
+/- 500 MW deviation from schedule or 4% of demand met


Maharashtra's deviation from schedule during October 2014
1500
1000
500
0
-500
-1000
-1500
UI (MW) -->
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
UI
+/- 500 MW deviation from schedule or 3% of demand met

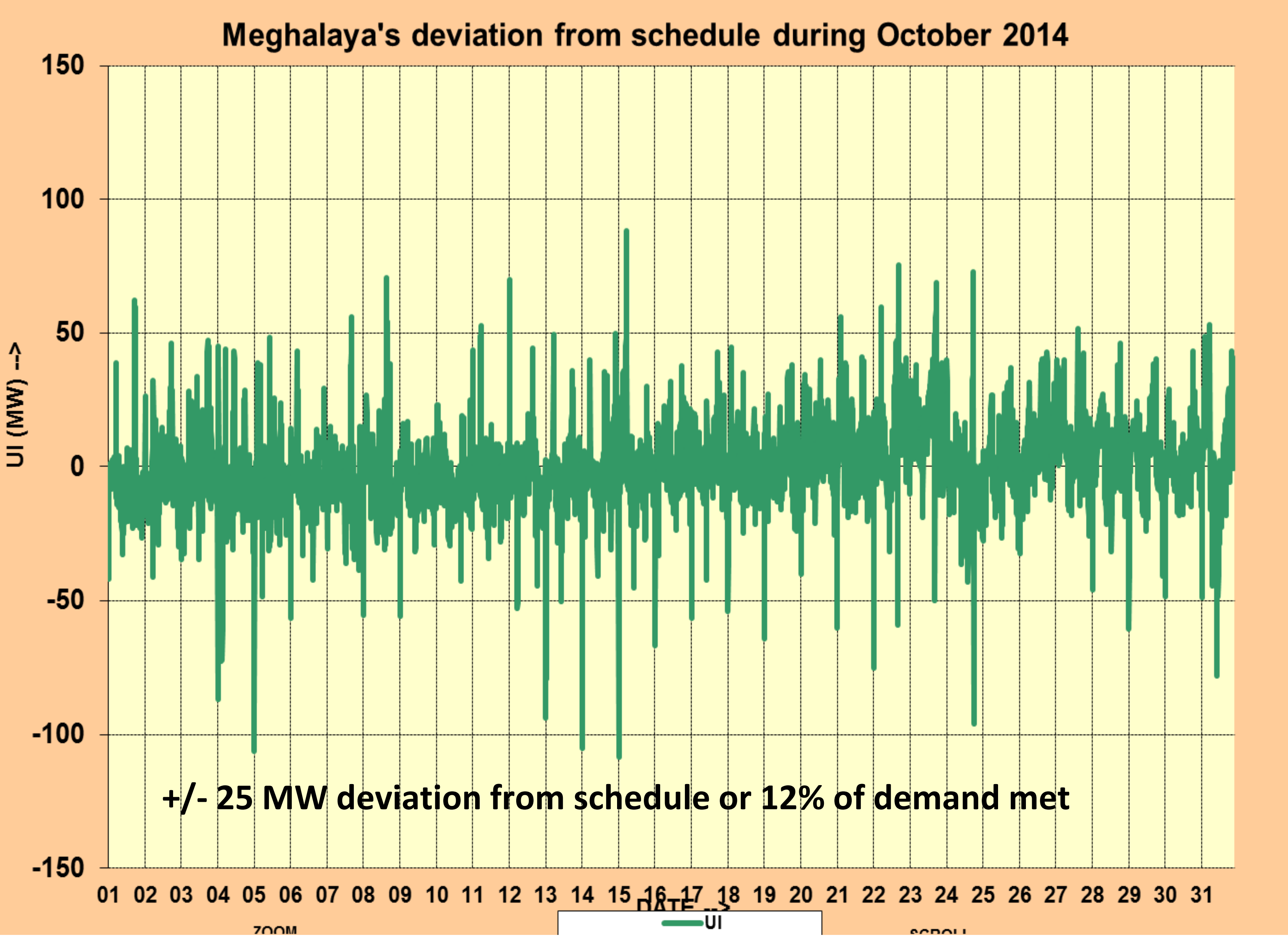


Kerala's deviation from schedule during October 2014
800
600
400
200
0
-200
-400
-600
UI (MW) -->
150-200 MW skewed deviation from schedule or 8% of its demand
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
UI


Andhra Pradesh's deviation from schedule during October 2014
UI (MW) -->
800
600
400
200
0
-200
-400
-600
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
UI
+/- 200 MW deviation from schedule or 4% of demand met



Assam's deviation from schedule during October 2014
300
250
200
150
100
50
0
-50
-100
-150
-200
UI (MW) -->
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
UI
Skewed 100-150 MW deviation from schedule or 10% of demand met



Meghalaya's deviation from schedule during October 2014
150
100
50
0
-50
-100
-150
UI (MW) -->
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DATE -->
UI
+/- 25 MW deviation from schedule or 12% of demand met

Decentralized Secondary Control

- Nearly thirty five (35) state control areas
- Reserves required to take care of forecast errors and uncertainty in generation availability
- Both up and down regulation required.
- Control areas having negligible internal generation
- Renewable generation impact on reserve reqt.
- Quality of telemetered data

System Protection Schemes (SPS)

- SPS a last resort and used for large contingencies non-envisaged at planning horizon.
- Grid Security Expert System (GSES) proposed in the past involving multiple SPS
  - Order dated 20th Feb 2014 in Petition 265/MP/2012
- More controls required rather than SPS
- Primary & secondary control need immediate implementation

Extract from recommendations of external experts

In the first stage, it is recommended that all large generating plants (say, 200 MW and above) should be on Free Governor Mode of Operation (FGMO). Generating units in these plants must have working governors with a standard droop set by [illegible]. For primary control to work properly most of the generation has to be under governor control and adequate primary reserve has to be available at all hours.

The implementation of secondary control requires that all generating units (above the required size) are under primary governor control. So AGC has to be in the second stage that should be implemented as soon as enough governors and primary control is operational. Of course, in the first stage when the governors are being installed and tested they should also be made ready to receive the control signals from the AGC to the governors. Secondary control also requires that each area control center have the AGC software as well as the ability to send the control signals.

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Issues to be resolved

- Definition and Criteria for reserves
- Schedules to be within 95% of Declared Capability
- Primary response to be always available
- Decentralized secondary control/AGC
- Qualifying Requirements for generating stations
- Incorporating secondary control in schedules
- Telemetered data & state estimation for AGC algorithm
- Payments for regulation services
- Tertiary Control, Ancillary Services, hourly market, intra-hourly market, imbalance pricing

References

- ‘Understanding Automatic Generation Control’, A report of the AGC Task Force of the IEEE PES/PSE/System Control subcommittee’, August 1992
- EPRI Power System Dynamics tutorial, July 2009
- ENTSOE Operation Handbook
- Indian Electricity Grid Code, Central Electricity Regulatory Commission
- CERC (Deviation Settlement) Regulations, 2014

THANK YOU

Annexure-VII

Frequency & Net Interchange Control in Multi Utility Power Pools

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Introduction:

- Indian Power Systems, Operating with a very ***loose control of frequency***
- The ***need for constant frequency***, largely unappreciated
  - The desirability and need of constant frequency only in rhetoric; ***lacks conviction***
  - Workable, Frequency ***Control strategy*** not well understood
- Frequency ***Constancy***, does not necessarily mean at ***Nominal*** Frequency
- Constant Frequency Control strategy & the necessary ***control mechanism is entirely missing***!

Control Needs in Multi Utility Power Systems

- Frequency Control
  - Frequency (f) depends on Real Power (P) balance
  - **‘P’** balance needed only **globally**
- ‘Inter Area’ Power Exchange Control
  - Requires Control Area wise ‘P’ balance
- Voltage Control
  - Voltage (V) depends on Reactive Power (Q)
  - **‘Q’ balance required at each node**
- Economy of Despatch (Merit Order)

The first named two controls discussed

What is Frequency?

- In ac systems, current direction / voltage polarity reversal is periodic and continuous
- Follows a sinusoidal pattern,

$$V\ (I) = V_{max}\ (I_{max}).\ \mathrm{Sin} 2\pi f t,$$

In this expression,

f is the frequency and

$2\pi f = \omega$, the angular velocity of phasor

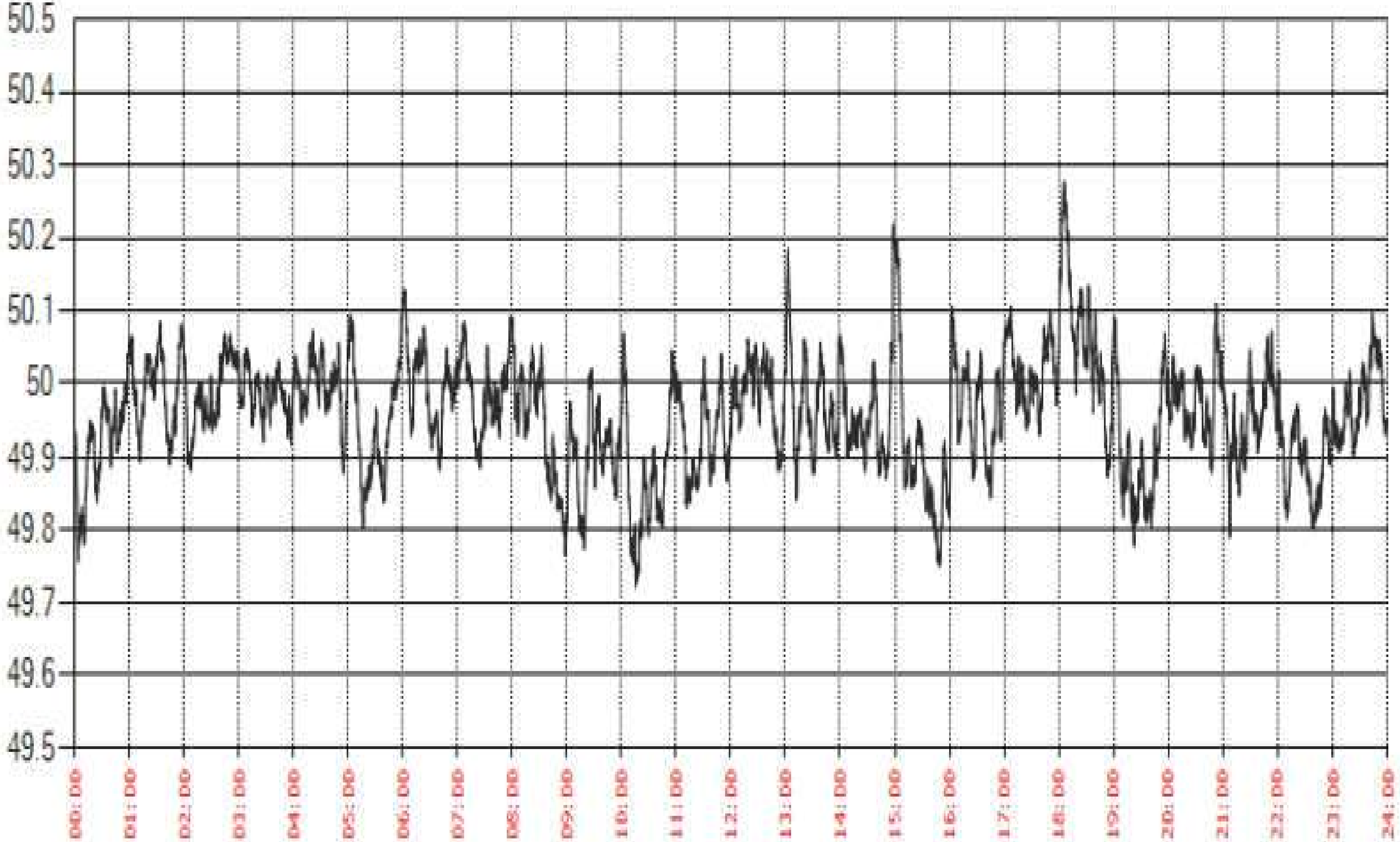
- Frequency is thus,

Half the number of times, direction / polarity reversal takes place in one second

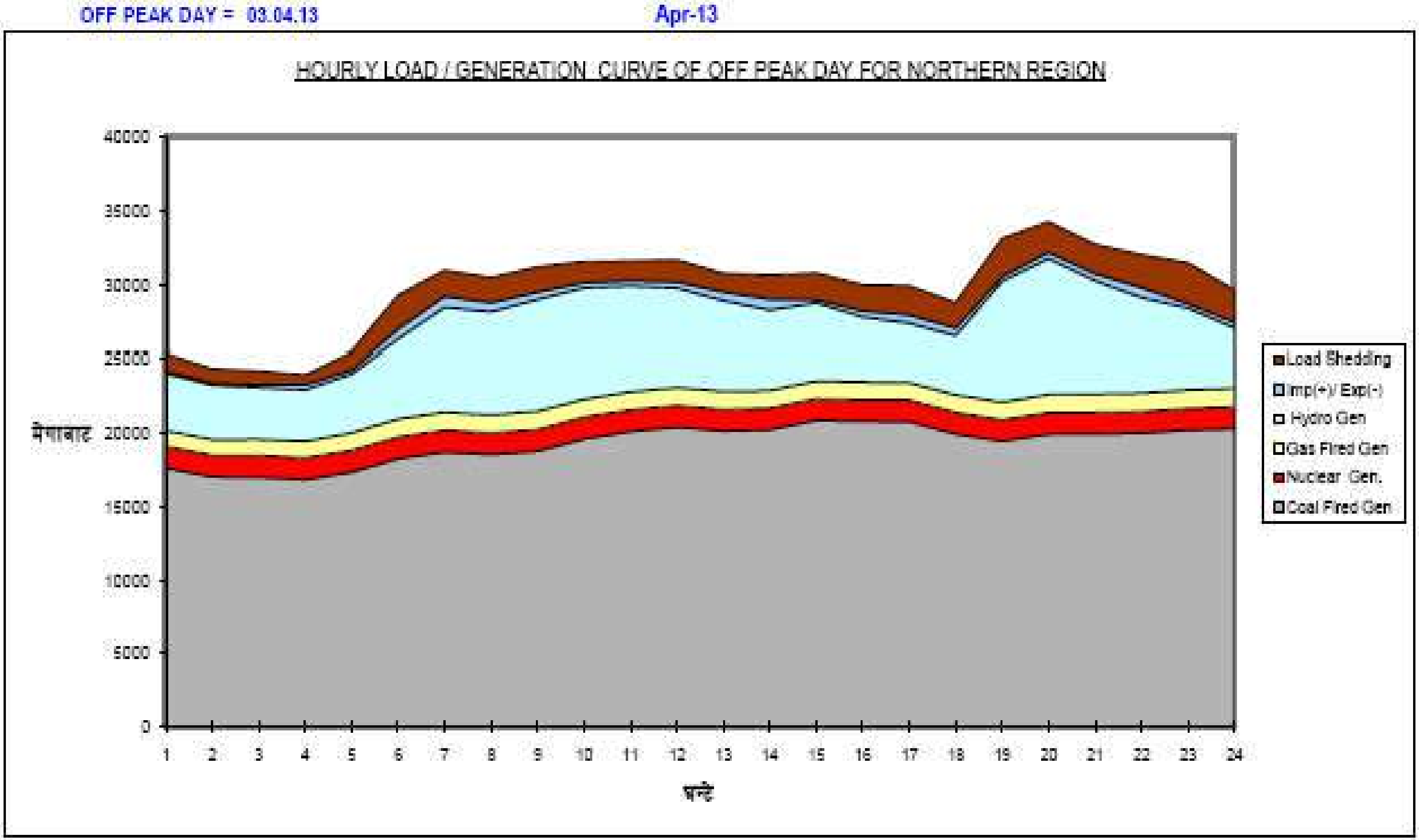
Choice of ac System Frequency

- Power producing/utilizing machines smaller and cheaper at higher speed/frequency
  - Aircrafts' power supply is at hence chosen at 400Hz
- Higher frequency reduces "flicker"
  - A problem with incandescent lamps in ac systems
  - 25Hz initially chosen, increased eventually to 50/60Hz
  - Sivasamudram / Kolar (India) also used 25Hz
- Higher frequency means poorer voltage regulation.
  - Lower frequency preferred in Railway traction; 50Hz itself used in India
  - Utility owned, extraction steam driven, 25/16Hz Aux. Generators used in most countries

Frequency Plot for a typical day in April 2014

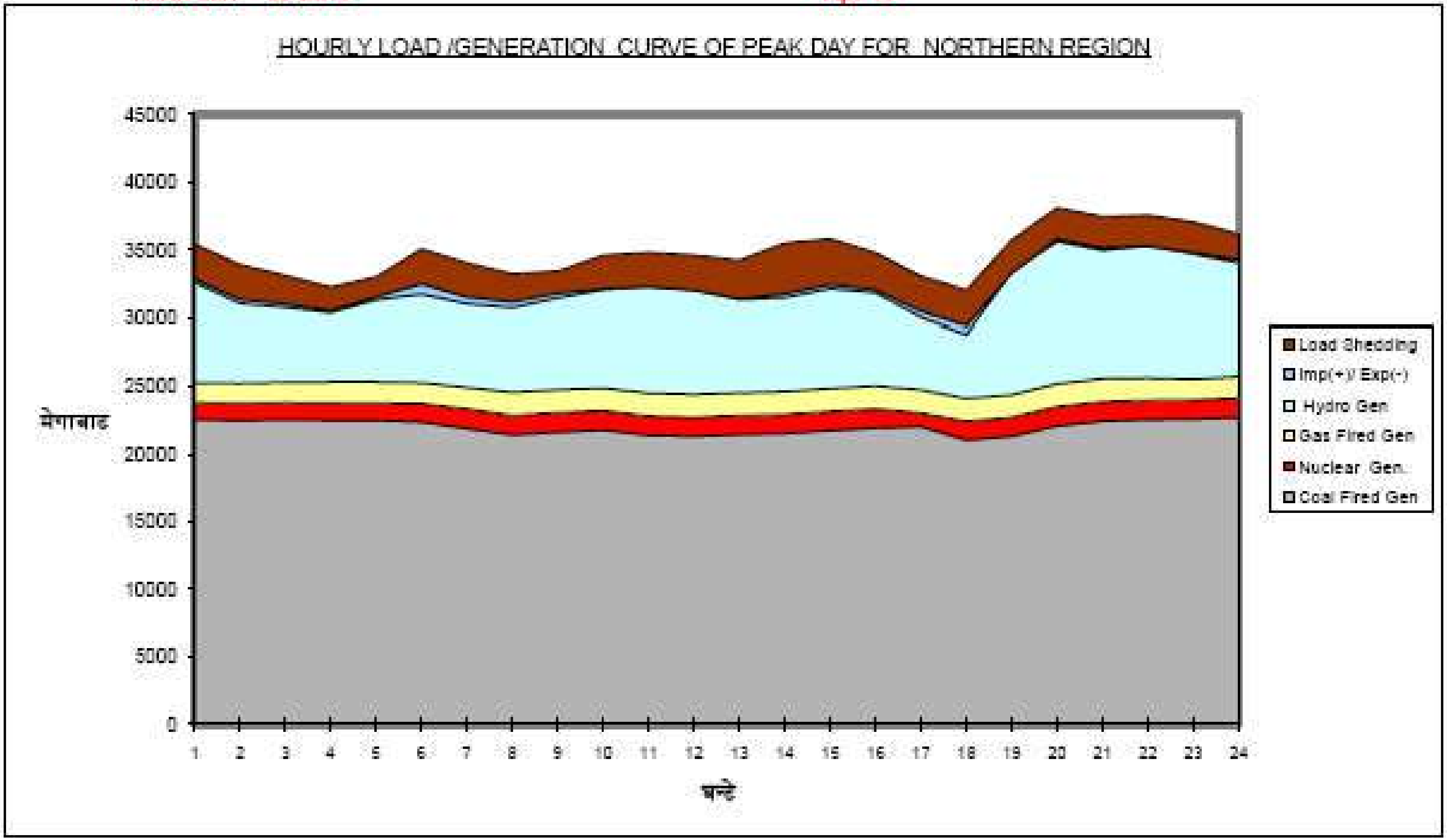


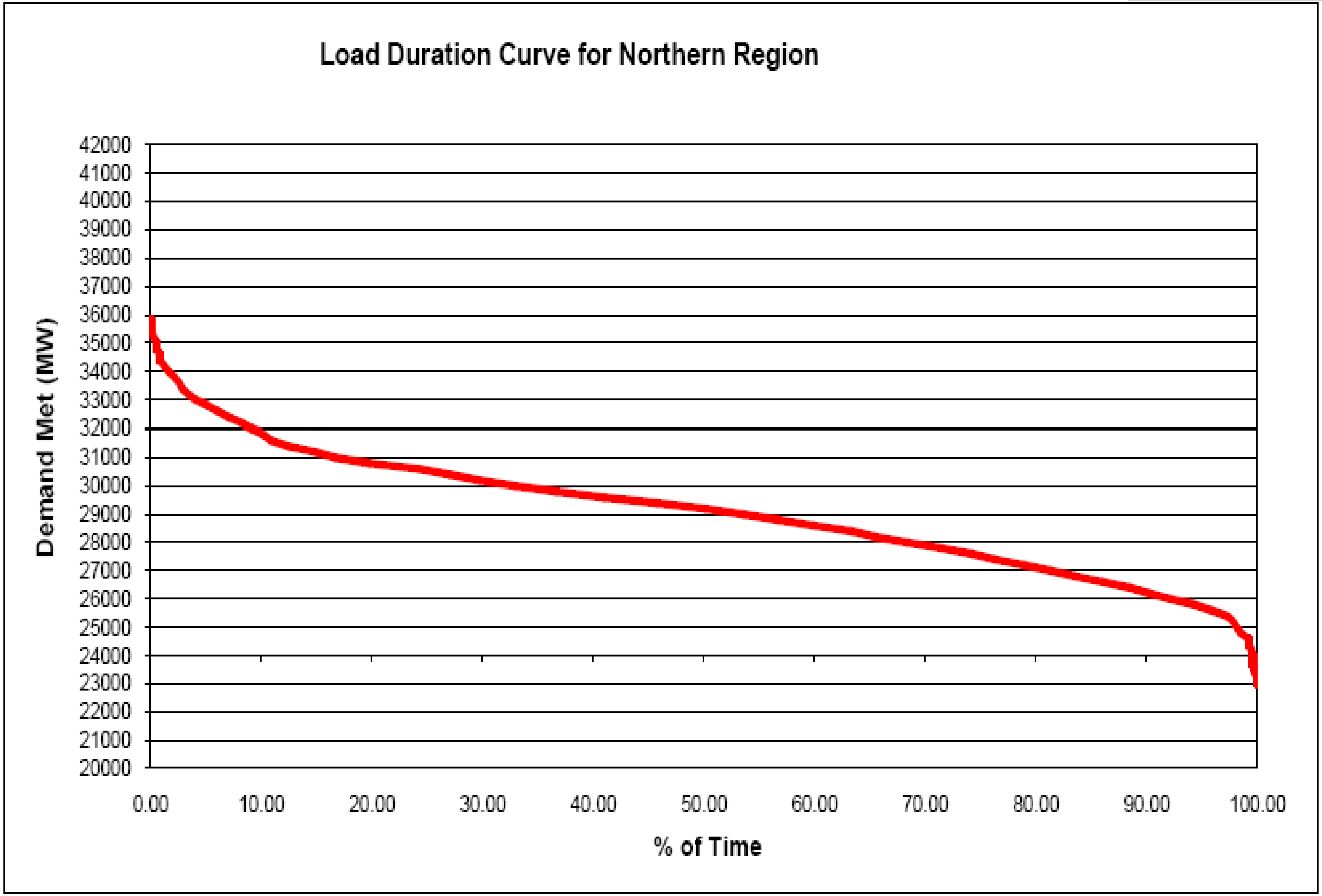
Typical Hourly Demand Curve NR: Low Demand Day



Typical Hourly Demand Curve NR: High Demand Day

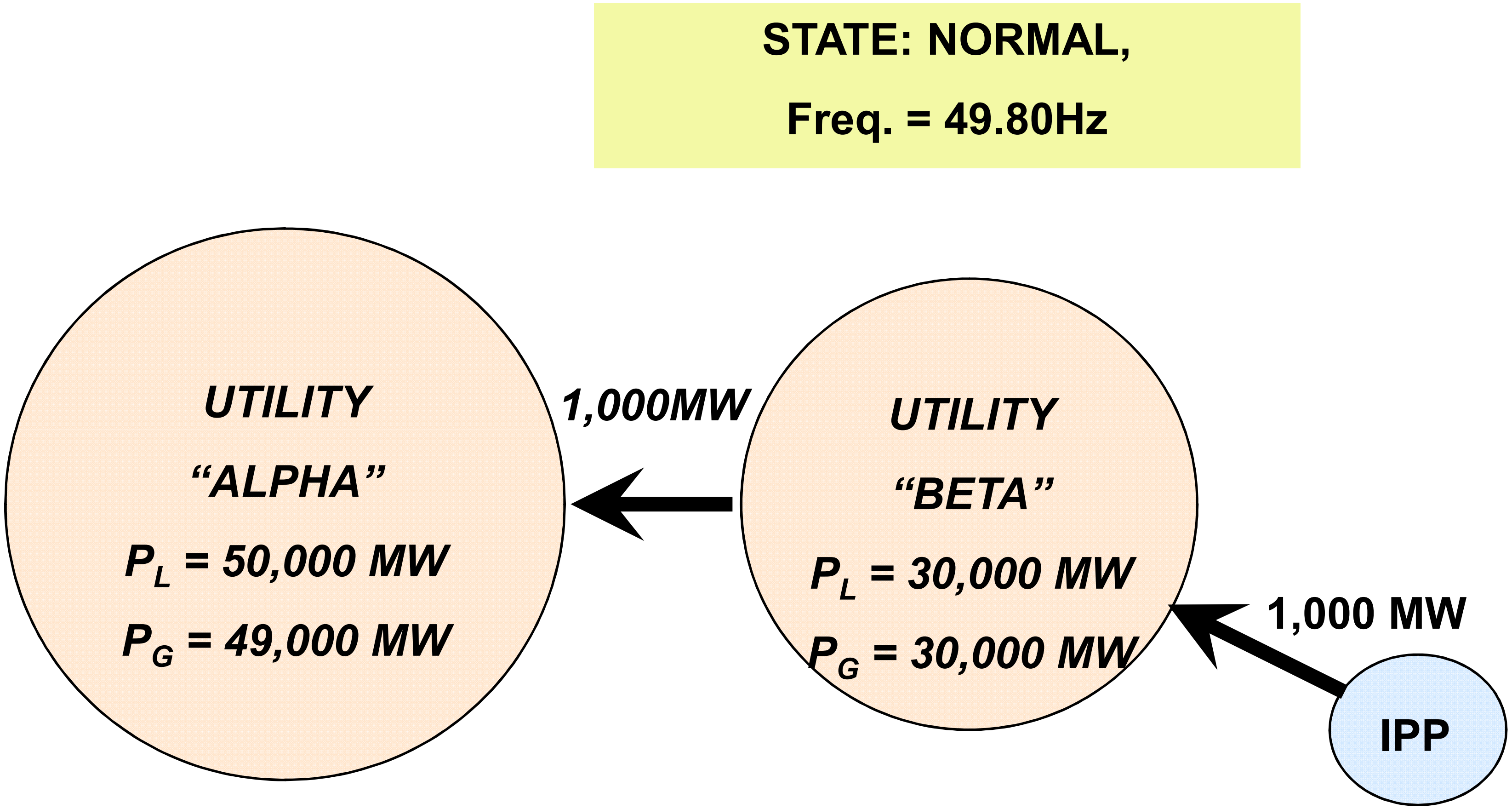
PEAK DAY = 28.04.13 Apr-13





Load Duration Curve for Northern Region
42000
41000
40000
39000
38000
37000
36000
35000
34000
33000
32000
31000
30000
29000
28000
27000
26000
25000
24000
23000
22000
21000
20000
Demand Met (MW)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
% of Time

Why Constant Frequency?

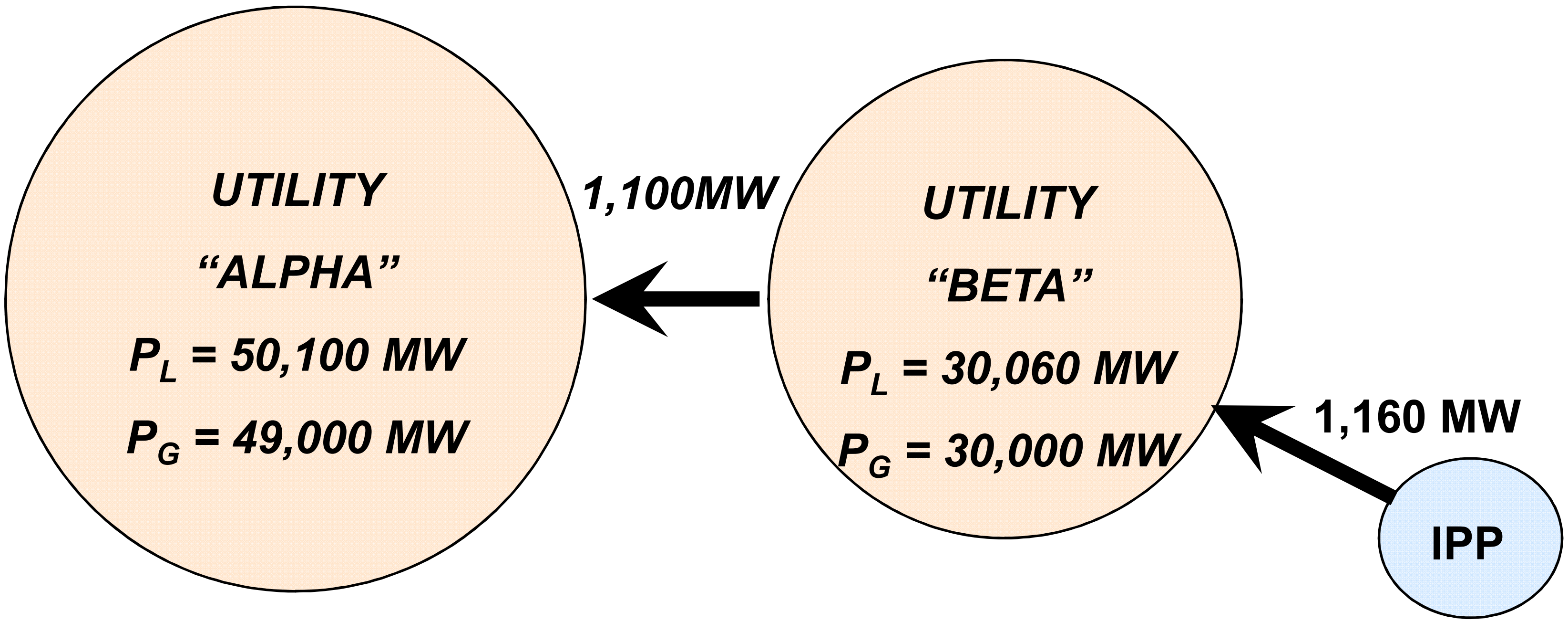


SAMPLE TWO UTILITY POWER POOL (WITH ONE IPP)

Why Constant Frequency?

STATE: NORMAL,

Freq. = 49.85Hz



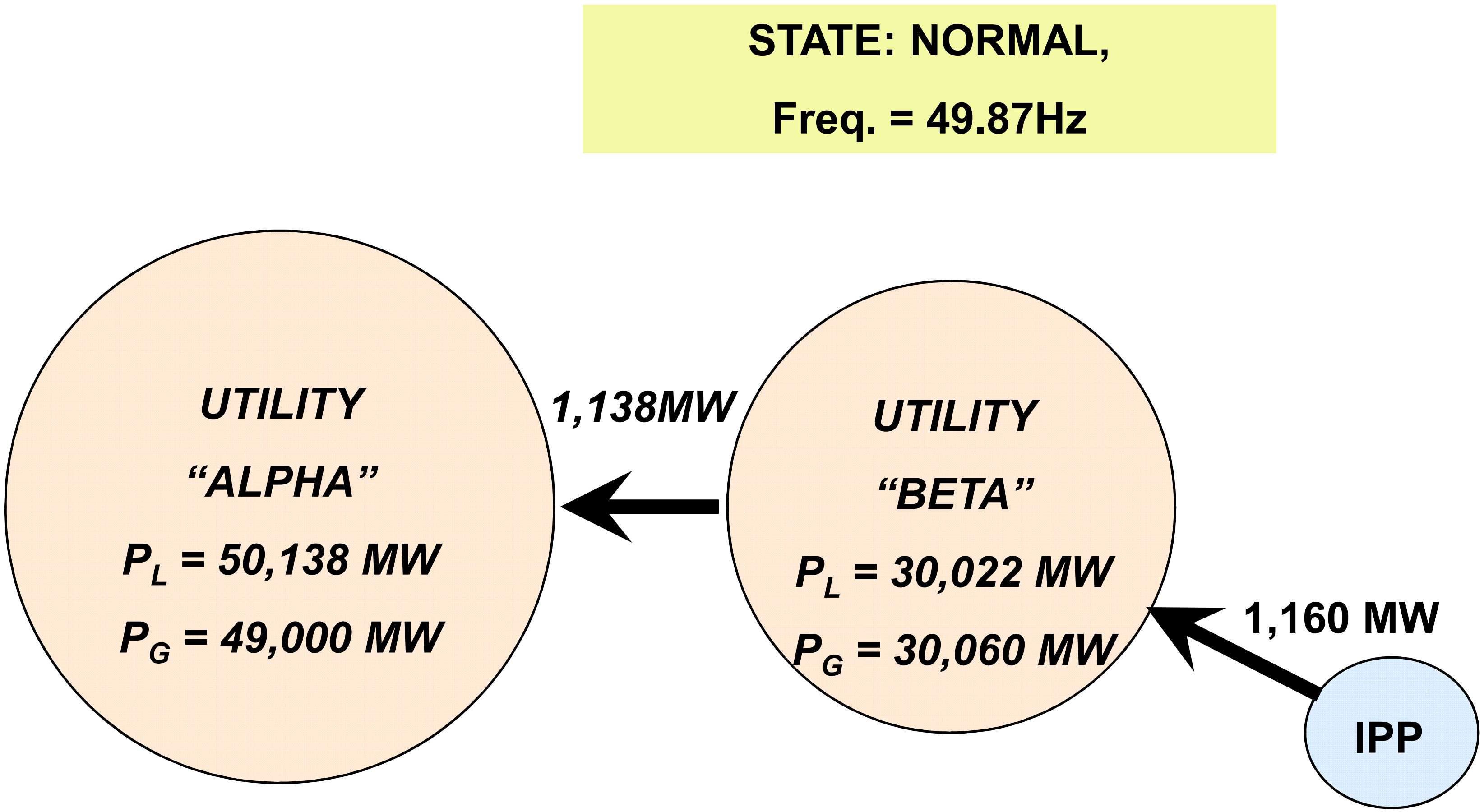
SAMPLE TWO UTILITY POWER POOL (WITH ONE IPP)

(IPP increases generation by 160MW: UI Created!)

Why Constant Frequency?

- Both Alpha and Beta suddenly find themselves over-drawing 100MW and 60MW respectively;
- With no significant benefit
  - The frequency increases marginally from 49.80Hz to 49.85Hz
  - From one acceptable operating frequency to another acceptable operating frequency!
- Assuming the incremental cost of generation of IPP as Rs 1/kWh and the UI rate as Rs 3.93/kWh
  - Alpha and Beta end up paying to the IPP Rs 393,000/- and Rs 235,800/- respectively, in each hour,
  - The IPP pockets Rs 468,800/- each hour! In one day the IPP pockets Rs 11,251,000/-
- Does the utility have any option to avoid this loss?

Why Constant Frequency?



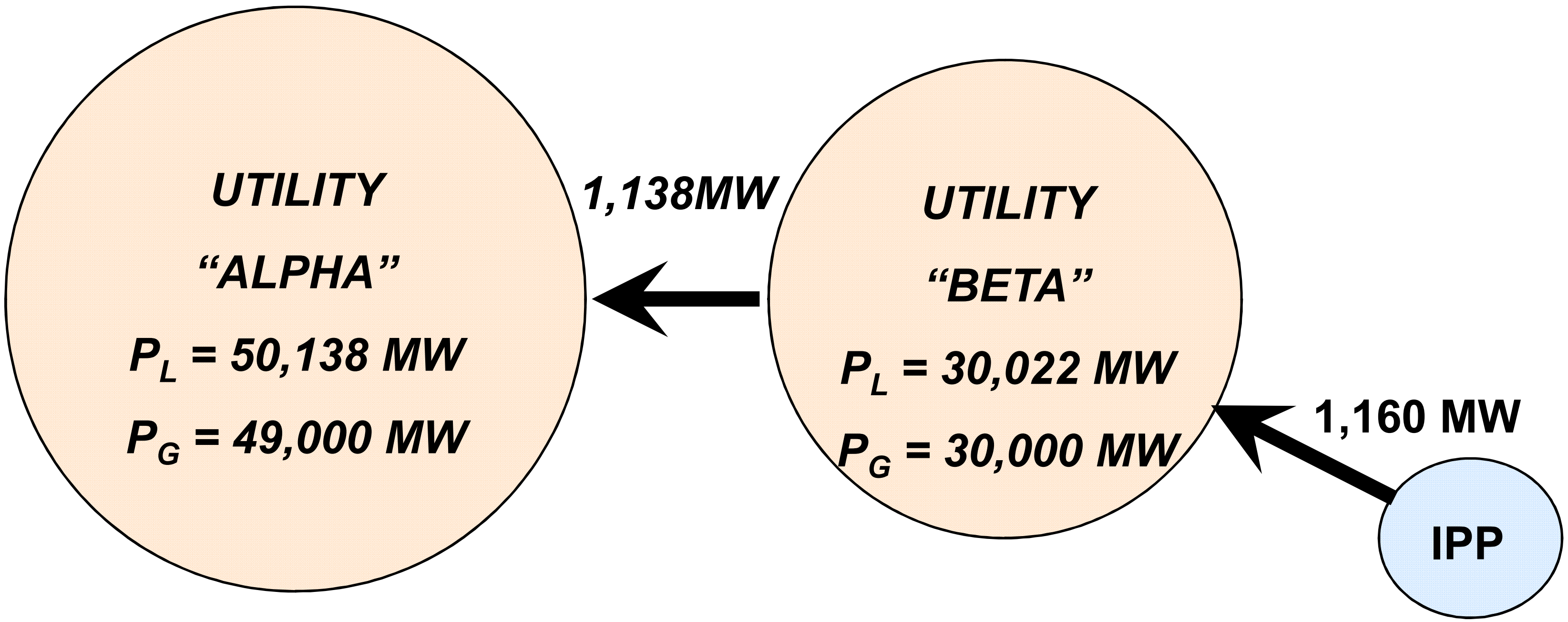
SAMPLE TWO UTILITY POWER POOL (WITH ONE IPP)

(Beta increases generation by 60MW to offset UI!)

Why Constant Frequency?

STATE: NORMAL,

Freq. = 49.87Hz



SAMPLE TWO UTILITY POWER POOL (WITH ONE IPP)

(Beta reduces load by disconnecting 60MW to offset UI!)

Why did Beta's efforts fail?

- If Beta increases generation, to offset its over drawal, the quantum required will be far in excess of 60MW
  - Generation increase by 60MW; Frequency rise by 0.01875Hz
  - Beta's drawal reduces by 38MW, (still 22MW > schedule!)
  - Alpha draws more (138MW): Did nothing at all!
- Else, needs to shed load, far in excess of 60MW!
  - If Beta sheds 60MW load, frequency rises by 0.01875Hz
  - Beta's drawal reduces by 38MW, (still 22MW > schedule)
  - Alpha draws more (138MW), Did nothing at all!

Constancy of frequency prevents this anomaly!

Constancy does not necessarily mean nominal frequency of 50Hz!

Power System Dynamics (Natural): Kinetic Energy exchange

- Consider a new load being connected to the system
  - Immediately gets served, by natural readjustments
  - At the instant of connection, *load* exceeds *generation*
  - The new load serviced from the Kinetic Energy of the system,
  - The frequency of the Power System falls, losing Kinetic Energy
- Reverse happens when generation is added
  - Excess power gets absorbed by natural readjustment
  - At the instant of generation addition, *generation exceeds load*
  - Surplus energy gets stored as Kinetic Energy in the rotating system
  - The frequency of the system increases, gaining Kinetic Energy
- If other corrective dynamics were to be absent, the change in frequency would have been perpetual!

Power System Dynamics (Natural):

Energy Release by Loads

- Power consumption of every load device, has a definite relationship, to the supply frequency
  - Power consumption of some loads are immune to frequency, e.g. incandescent lamps, resistance heaters, VFD etc.
  - Power consumption in motive loads, depends on speed (frequency), to varying degrees; drive speed varies
- Power consumption in an agricultural pump set varies, in the cubic relation to frequency
  - The above relationship can be appreciated as follows

Power System Dynamics (Natural):

Energy Release by Agricultural Pump

- Consider an Induction motor driven, centrifugal pump, with uncontrolled discharge

Output Power of the pump ***'P'= k x H x Q,***

Where,

$$H = k_1 \times N^2 \quad \& \quad Q = k_2 \times N$$

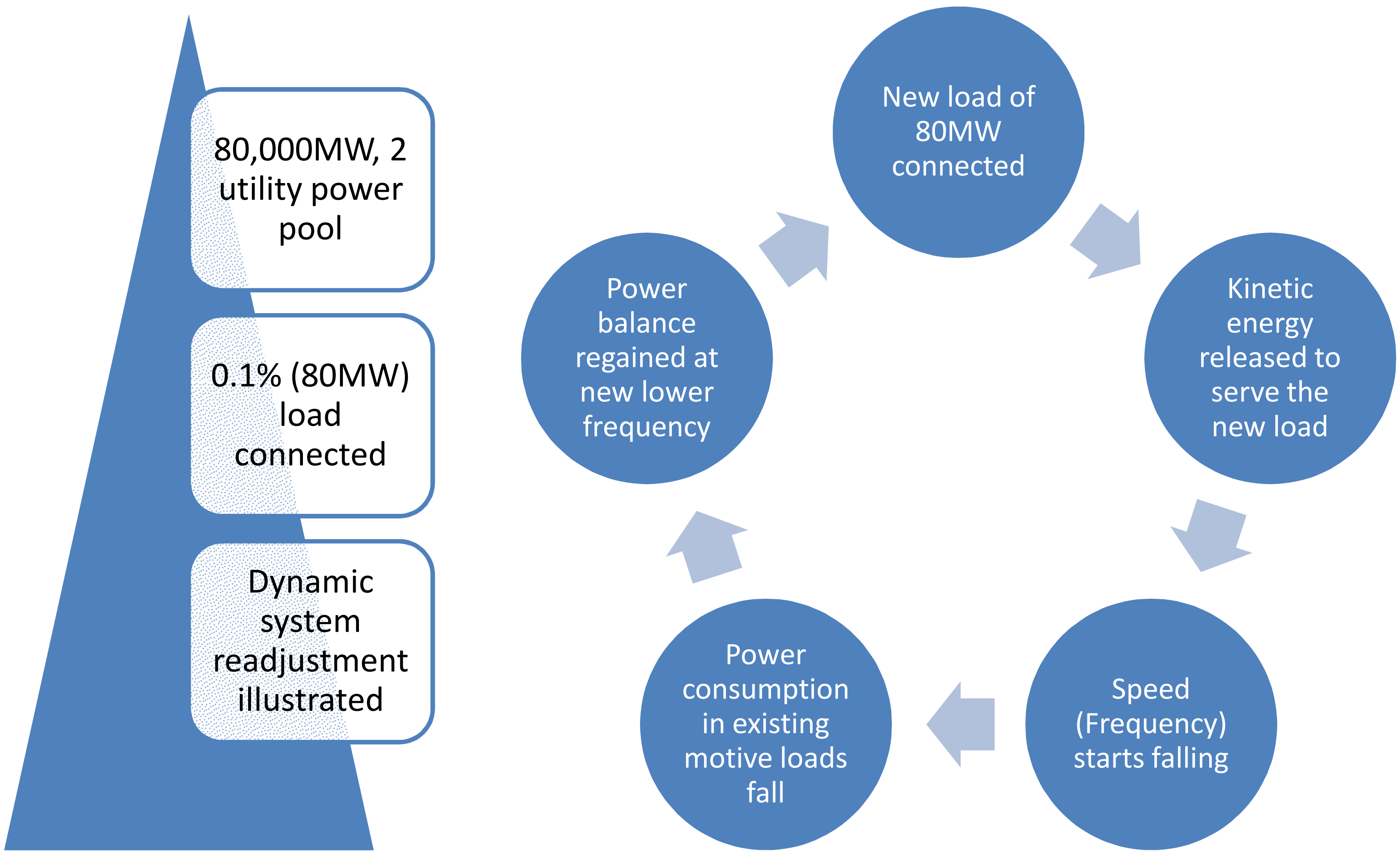
Hence,

$$P = kk_1k_2 \times N^3$$

- Pump power varies as the 3rd power of speed or frequency

$$P = k' \times f^3$$

Load / Frequency Dynamics (Natural)



Load Governing/Damping (Natural)

- Kinetic Energy exchange is a transient phenomenon,
  - Limited only to the small period of changing frequency
- In steady state, the new load is entirely serviced from the power released by the pre-existing system loads
  - Subject to generation remaining unchanged
- This dynamics is “Load Governing” / “Load Damping”
  - Parameter ***“D”*** (for ***Damping***) in lit., having units of ***MW/Hz***
- System Demand change with Frequency, empirically,

$$1\%\ \Delta f \quad \approx \quad 1 - 2\%\ \Delta P_L$$

1.0Hz *Frequency* change causes **2 – 4% *Load Power*** change

Frequency Control: Some Essential Facts

- ***Change*** in *load or generation* ***causes frequency to change***
- Constant Frequency can be realized by perpetually matching Load and generation, ***at the desired frequency***
  - Best scheduling practice cannot eliminate mismatches completely
- ***Load is random*** and hence ***not controllable***;
  - Perpetually changing due to the random behavior of consumers
- Meeting demand ***is obligation*** of the utility , not an ***option***!
  - Disconnecting customers amounts to failure of service
- ***Load / Generation balance*** (at the "target frequency") possible, only ***by real time generation correction (Load following duty of Generators)***
  - Energy balance will otherwise occur naturally; Frequency will vary!
- ***Frequency constancy*** is the reliable indicator of energy balance
  - ***A Control System has to simply correct any frequency change!***

Generation/Load Mismatch

- Generation and load are both changing all the time
- Small load / generation mismatch events on a/c of consumer's random action
  - Mismatch occurs in small quantum and at slow rate
  - Well engineered "Generation Scheduling Process" can only minimize this mismatch; cannot eliminate the same
  - The correction of the consequent slow frequency drift would require corresponding slow corrective change in generation
- Large mismatches are caused by disturbances like loss of a large generator, interconnector, load bus etc
  - Results in sharp and large frequency change
  - Need quick and large quantum, correction in generation/load
- Good 'Frequency Control System' must address both needs!

Frequency Control Tools (Applied):

Governor Control

Governor Control: A Proportional Control

- Exists on all generators; Changes output
- Negative linear proportion of frequency
- Non-restorative in nature

Governor Droop: % Δf which causes 100% ΔP_G

- Aka "Speed Regulation"
- Governor Droop of all machines in the system need not be same/identical

Governor Response time varies with the type of prime mover

- Response time independent of "Droop"
- Sustainability depends on process /prime mover

Frequency Control Tools (Applied): Secondary Control

Secondary Control: An Integral Control	• Applied on selected generators, carrying the control margin(***Spinning Reserve***) • Deliver/withdraw generation on control command
Delivered by the LDC Operator / AGC (aka ALFC)	• Changes Governor Setting: increase / decrease output, till "Δf" error vanish • Corrects slow frequency drift, to prevent "calling up" of Governor Control
Perpetually acting to keep frequency within Governor dead band	• Can be LDC Operator delivered for "Single Area" Systems • AGC essential for "Multi Area Systems": Complexity of control!

Frequency Control Tools (Applied):
Tertiary Control & Emergency

- Tertiary (Non-spinning/Cold Reserve) Control
  - Back up to Secondary Control, to be ‘called in’ when the Secondary Control margin is nearing exhaustion
  - Provided by ‘ready to start’ generating units (Cold Reserve)
    - Quick starting units (GTG, DG, Hydro etc) suitable
  - Alternatively, DSM[1] can provide the service
- Emergency Load Disconnection
  - Can be used if adequate ‘Primary Control Margins’ are not maintained
  - Economical alternative, if loads are interruptible

1. Demand Side Management, a mechanism of voluntarily withdrawing demand by customers, by an arrangement with the utility

Secondary Control

- The slow frequency changes best addressed, by modulating a few generating units carrying reserve for this purpose, by an appropriate Control System
- Known as 'Supplementary', 'Restorative' or 'Secondary' Control; Last one used in Europe (UCTE[1]/ENTSOE[2])
  - Controlled from the LDC, by operator or AGC/ALFC issued command (state of art)
  - Every Generating Unit has provision for accepting remote "raise" / "lower" pulse commands for this purpose
- Maintains frequency constant, within the Governor Dead Band (0.06% as per IEC), under normal operation

1. **U**nion for the **C**oordination of **T**ransmission of **E**lectricity
2. **E**uropean **N**etwork of **T**ransmission **S**ystem **O**perators for **E**lectricity

Many Secondary Control Functions

- Spinning reserve delivery; Concept of spinning reserve has no meaning without Secondary Control
- Facilitates smooth absorption of Renewable Energy injection
- Control tie line flows: The struggle with Sholapur – Raichur would not have occurred
- Enables Governor Control
- Ensures financial equity for the pool partners
- Allows economy of dispatch and ……………

Secondary Control

- Secondary Control maintains 'Inter Area Exchange' the scheduled level, in multi area systems
- In large mismatch events sudden & large quantum change of generation required
  - *Secondary Control is* useless; inherently slow
  - *Primary Control* serves in such events for a short duration
  - Secondary Control returns frequency to the target, after such a disturbance (large change)
  - Restores the *Primary Control Reserve* delivered
- *Primary Control* margins, thus preserved for the large mismatch events and restored quickly once delivered

Secondary Control
Delivery Mechanism

- Single Area Systems can work with manual delivery of *Secondary Control*
  - Delivered by the LDC ‘Frequency Control Desk Operator’: Control target is only frequency
  - Single Area Systems (England, S. Africa) use manual delivery,
- Multi Area Power Pools need automated Secondary Control
  - Manual control difficult in Multi Area Power Pools: Multiplicity of targets, i.e. frequency and net exchange
  - Automatic Generation Control (AGC), aka Automatic Load Frequency Control (ALFC)
  - Multi Area Power Pools (USA, Contl. Europe) use AGC

Primary (Governor) Control

- Governor Control Changes Generated Power (***ΔP_G***), in the negative linear proportion of frequency (Speed) error (***Δf***)
- Control characteristic, expressed mathematically,

$$\Delta P_G = P_G - P_R = -1/R \times \Delta f$$

Or,

$$P_G = P_R - (f - f_n) \times 1/R^*$$

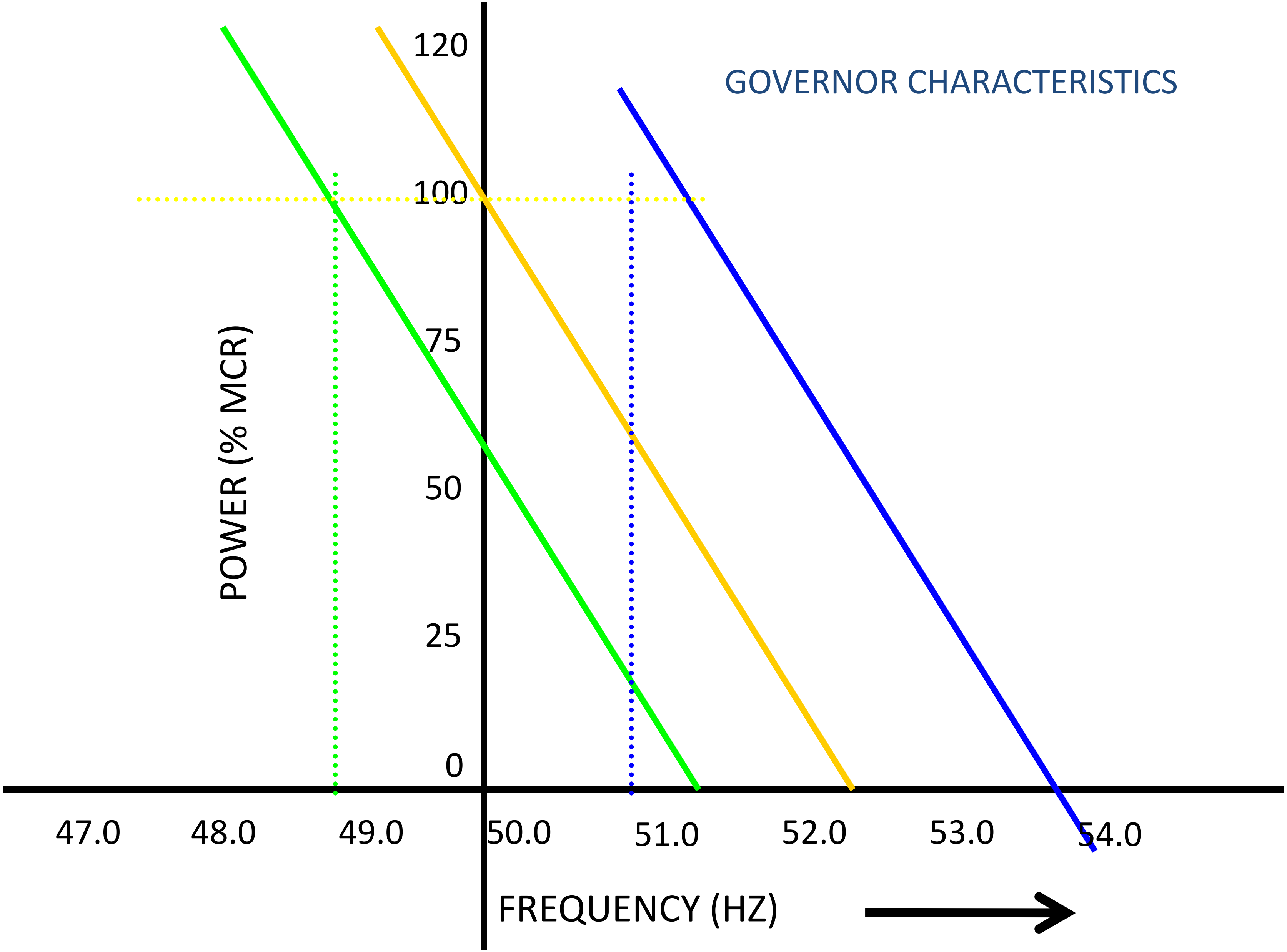
- This is the equation of a straight line of the form

"y =mx + c", *where 'm' is negative*

- The characteristic can be shifted by either changing P_R or f_n (slope remaining fixed)

* R has units of Hz/MW, commonly expressed as "Droop"

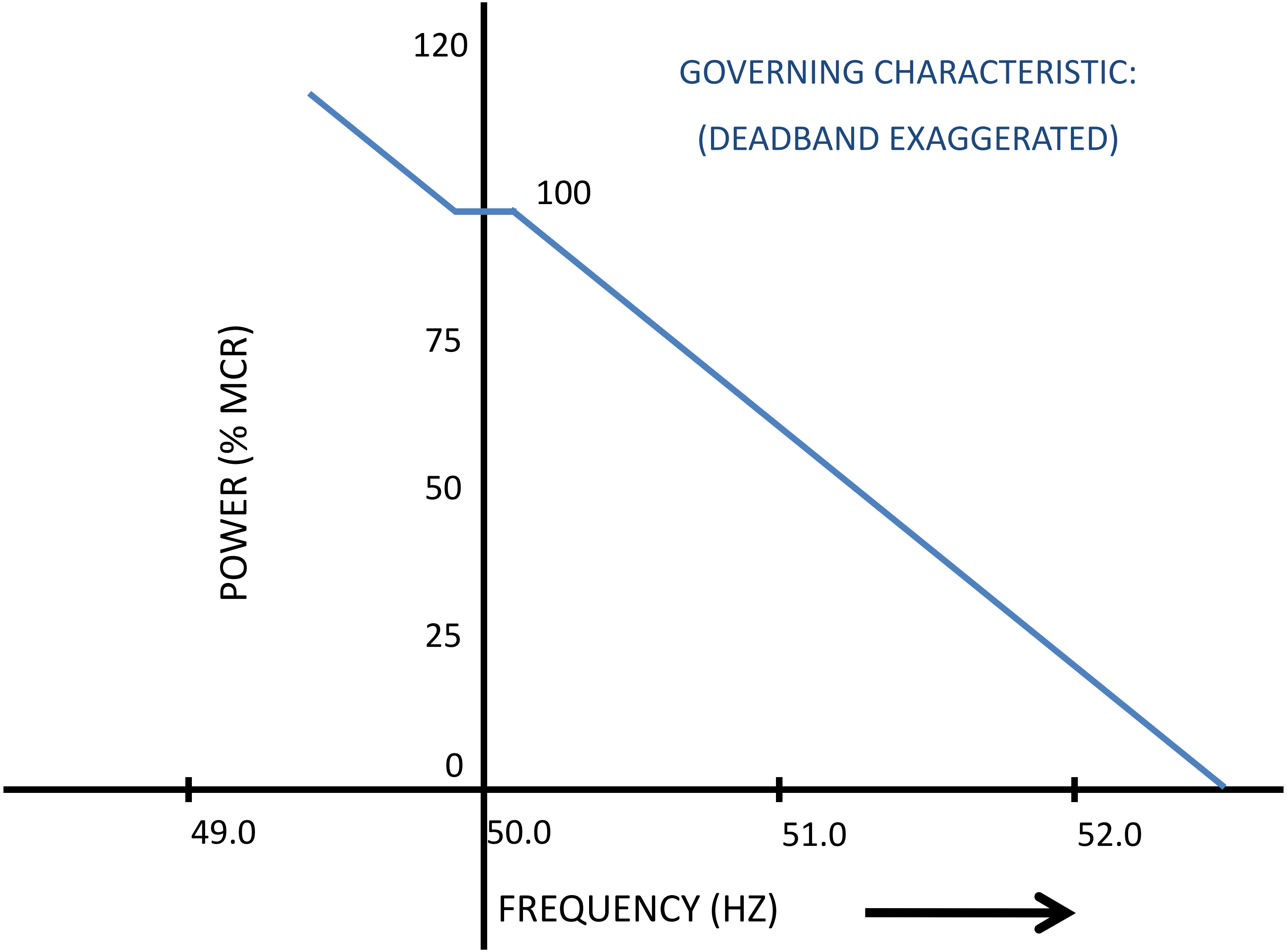
$$\text{Droop (\%)} = R \times 100 \times P_n / f_n$$


GOVERNOR CHARACTERISTICS
120
100
75
50
25
0
POWER (% MCR)
47.0
48.0
49.0
50.0
51.0
52.0
53.0
54.0
FREQUENCY (HZ)

Governor Dead Band

- Small speed change for which Governor is not responsive
- Inherent in Mechanical Governors (backlash)
- Intentional and settable in Electric Governors
- IEC-45, Part-1 prescribes the following for Steam Turbines

Governor Type	Mechanical			Electro Hydraulic		
Turbine MCR (MW)	**< 20**	**20-150**	**> 150**	**< 20**	**20-150**	**> 150**
Overall droop (%)	**3 – 6**					
Dead Band, % of rated speed	**0.40**	**0.20**	**0.10**	**0.15**	**0.10**	**0.06**


GOVERNING CHARACTERISTIC:
(DEADBAND EXAGGERATED)
120
100
75
50
25
0
POWER (% MCR)
49.0
50.0
51.0
52.0
FREQUENCY (HZ)

Primary Control Delivery

- Steam Turbine Plants: Initial delivery fast (steam valves), but back end process correction (boiler) slow
  - Needs other actions to sustain delivery
- CCGT Plants: Control action on fuel valves, combustion introduces small delay
  - Easily sustained
  - Bottom Cycle Steam turbine normally non-responsive
- Hydro Plants: Slow response,
  - Governor Control not applied on ROR units
  - Typically Large Inertia Control valves; slow operation (Pelton fastest/Kaplan slowest) :
  - Valve opening reduces the output initially, till the penstock flow re-adjusts
  - Once delivered, can be sustained indefinitely

Composite Frequency Response

- Composite Frequency Response Characteristic (FRC)

  $\boldsymbol{\beta} =$ $\boldsymbol{D + 1/R}$, Where, $\boldsymbol{\beta}$ is the FRC

- In our sample system,

  $\boldsymbol{D}$ = 4% of 80,000MW/Hz (Load Governing)

  $\boldsymbol{1/R}$ = 40% of 80,000MW/Hz (Primary Control, at 5% droop)

  $\boldsymbol{\beta}$ = (3,200 + 32,000) = 35,200 MW/Hz

- Steady state frequency change, for an 800MW unit tripping:

  $\boldsymbol{\Delta f}$ = (800MW/35,200MW/Hz) = 0.02273Hz

  $\boldsymbol{\Delta P_G}$ $\boldsymbol{= \Delta f \times (-)1/R}$

  = (-) 0.02273Hz x (-) 32000MW/Hz = **727.4MW**

- *Secondary Control* must deliver entire 800MW, to return to target frequency

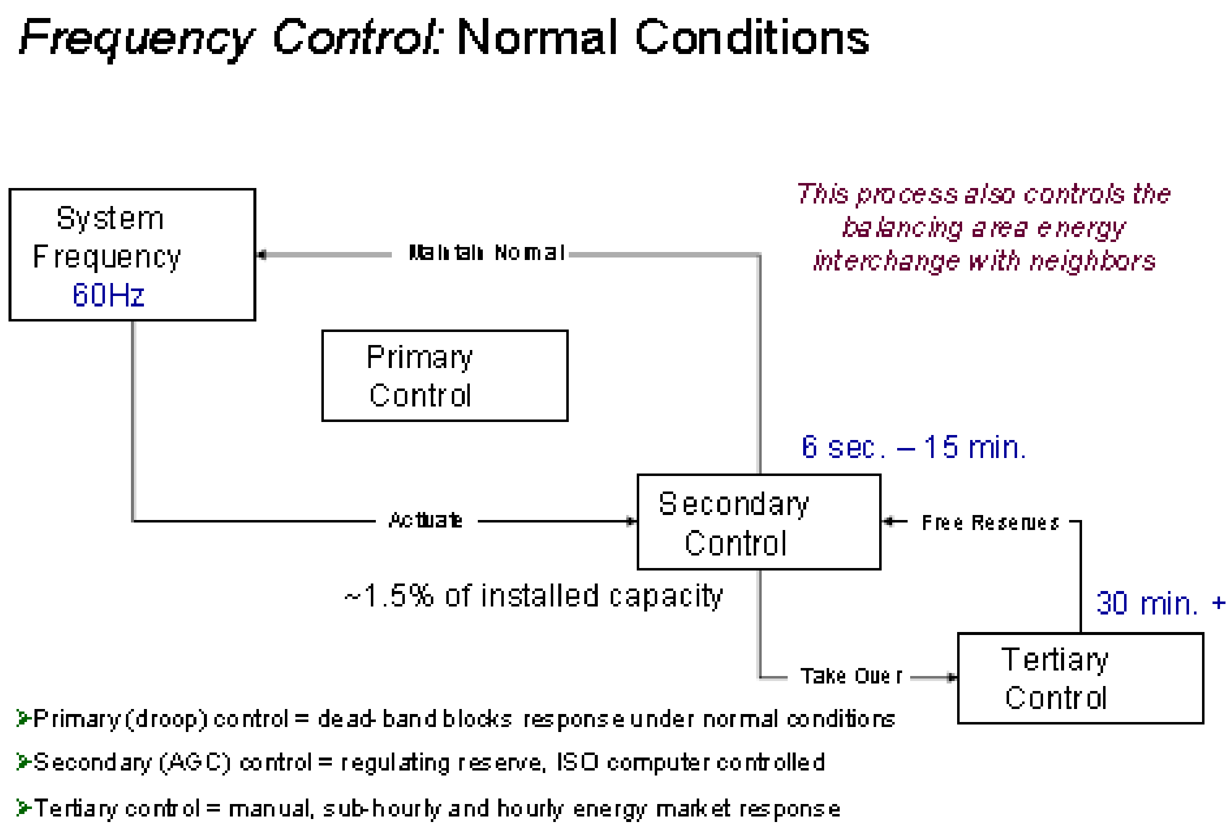


Figure 3 Frequency control is accomplished centrally under normal conditions

Reproduced from:

Brendan Kirby, "Ancillary services: Technical and Commercial Insights", www.science.smith.edu

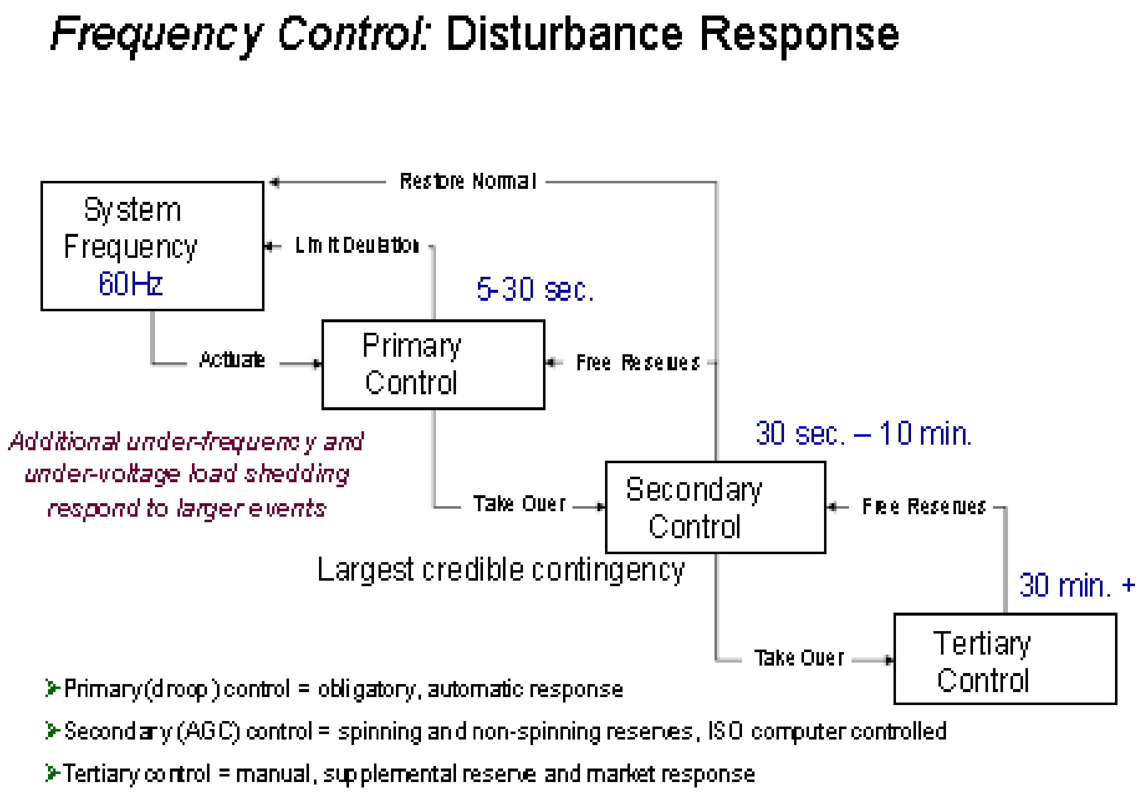
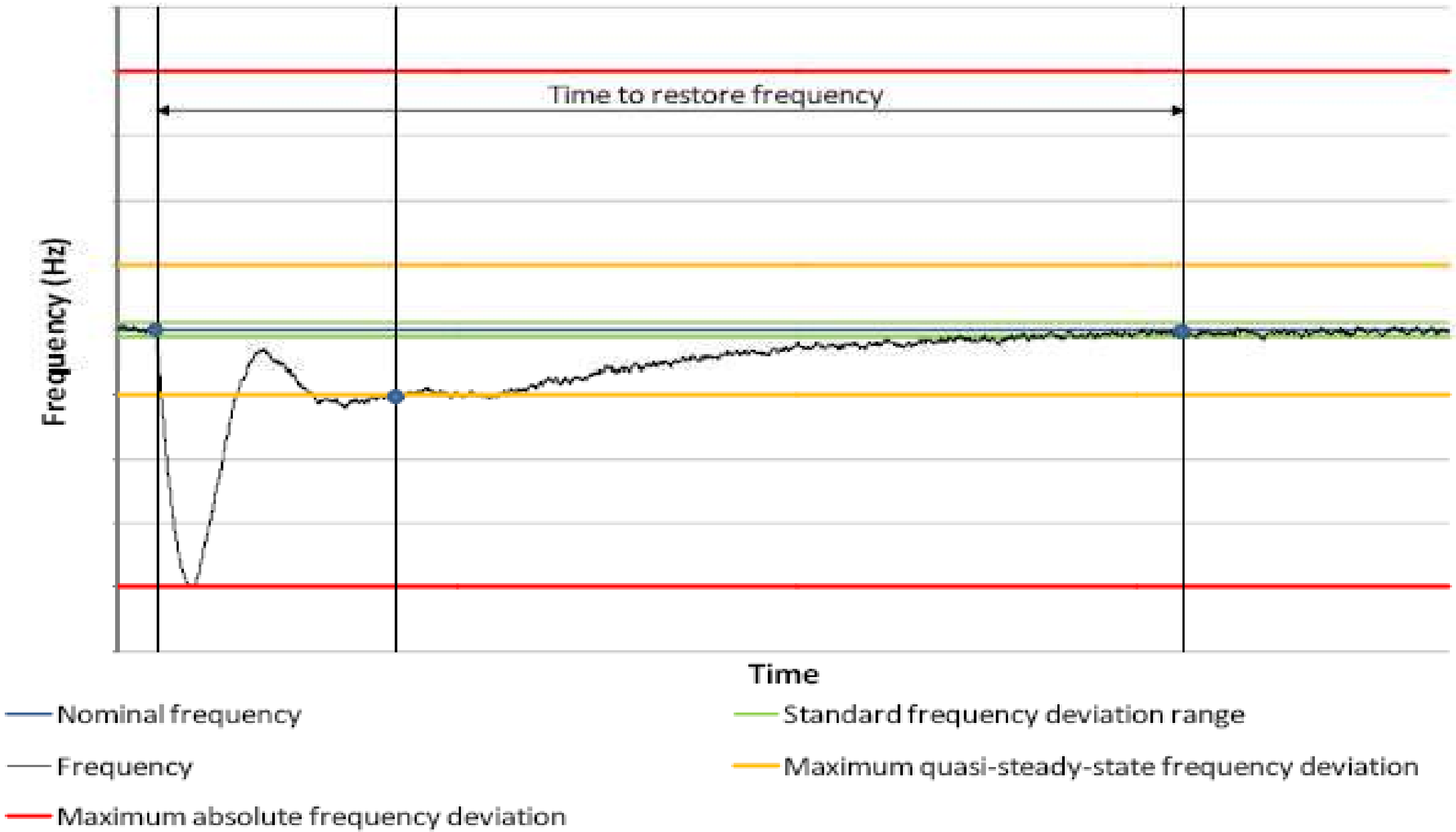


Figure 4 Generator governors provide immediate response to restore system frequency under contingency conditions.

Reproduced from:

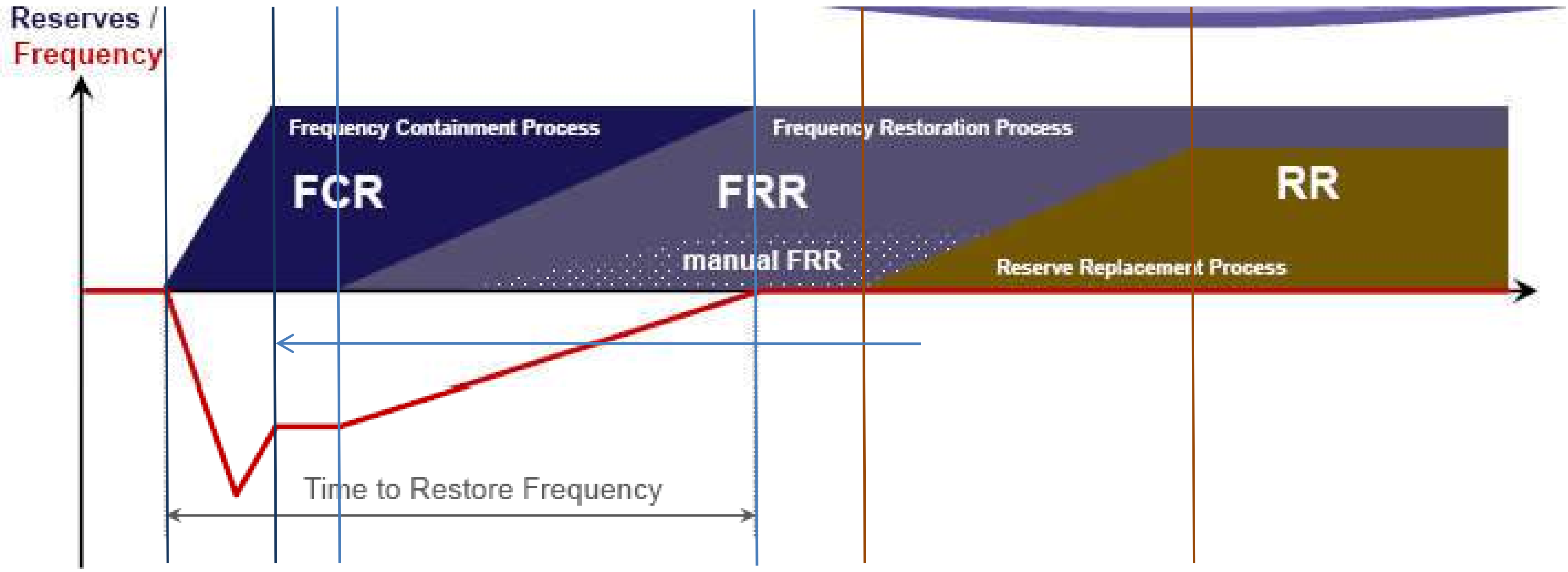
Brendan Kirby, “Ancillary services: Technical and Commercial Insights”, www.science.smith.edu

Frequency Restoration Following a Disturbance: Typical*



* Reproduced from ENTSOE sources

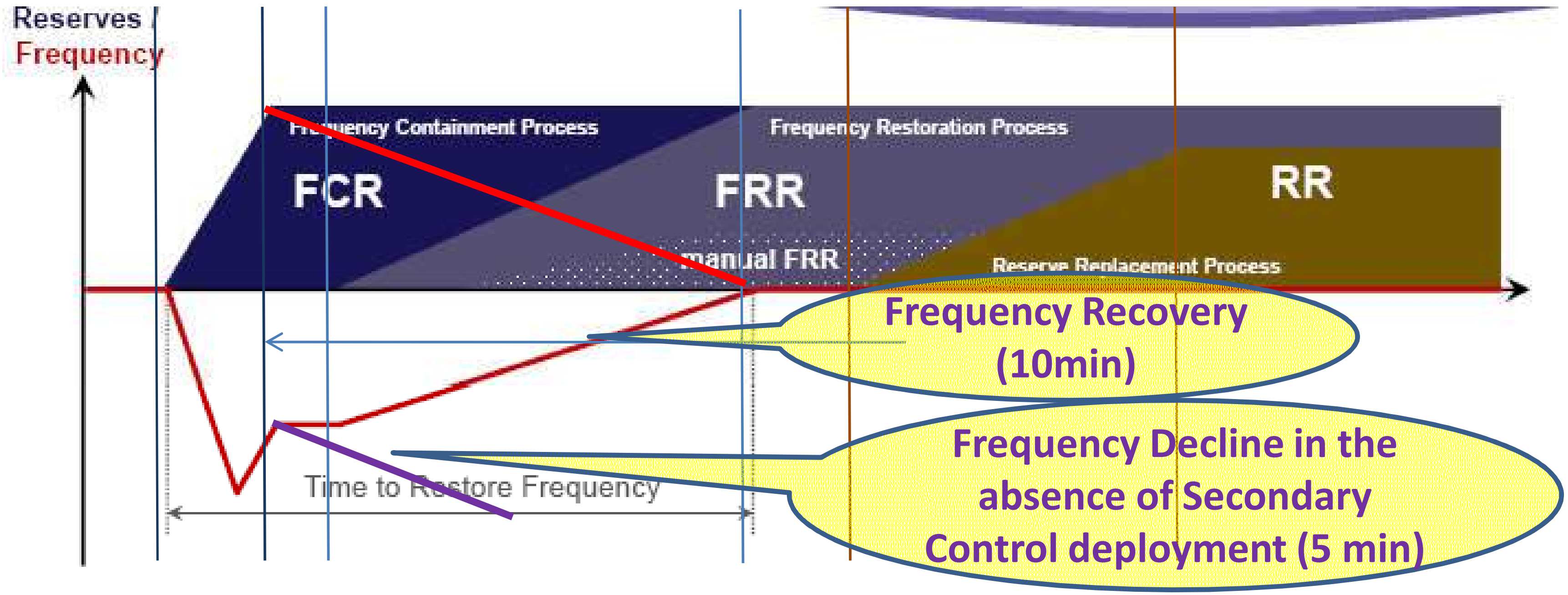
Frequency Restoration Following a Disturbance: Typical*



- Frequency Containment Process → Stabilization
- Frequency Restoration Process → Regulate to Set-Point Value
- Reserve Replacement Process → Restore FRR

* Reproduced from ENTSOE sources

Frequency Restoration Following a Disturbance: Typical*



- Frequency Containment Process → Stabilization
- Frequency Restoration Process → Regulate to Set-Point Value
- Reserve Replacement Process → Restore FRR

**** Secondary Control absent; FCR withdrawn in 5 minutes! Frequency declines***

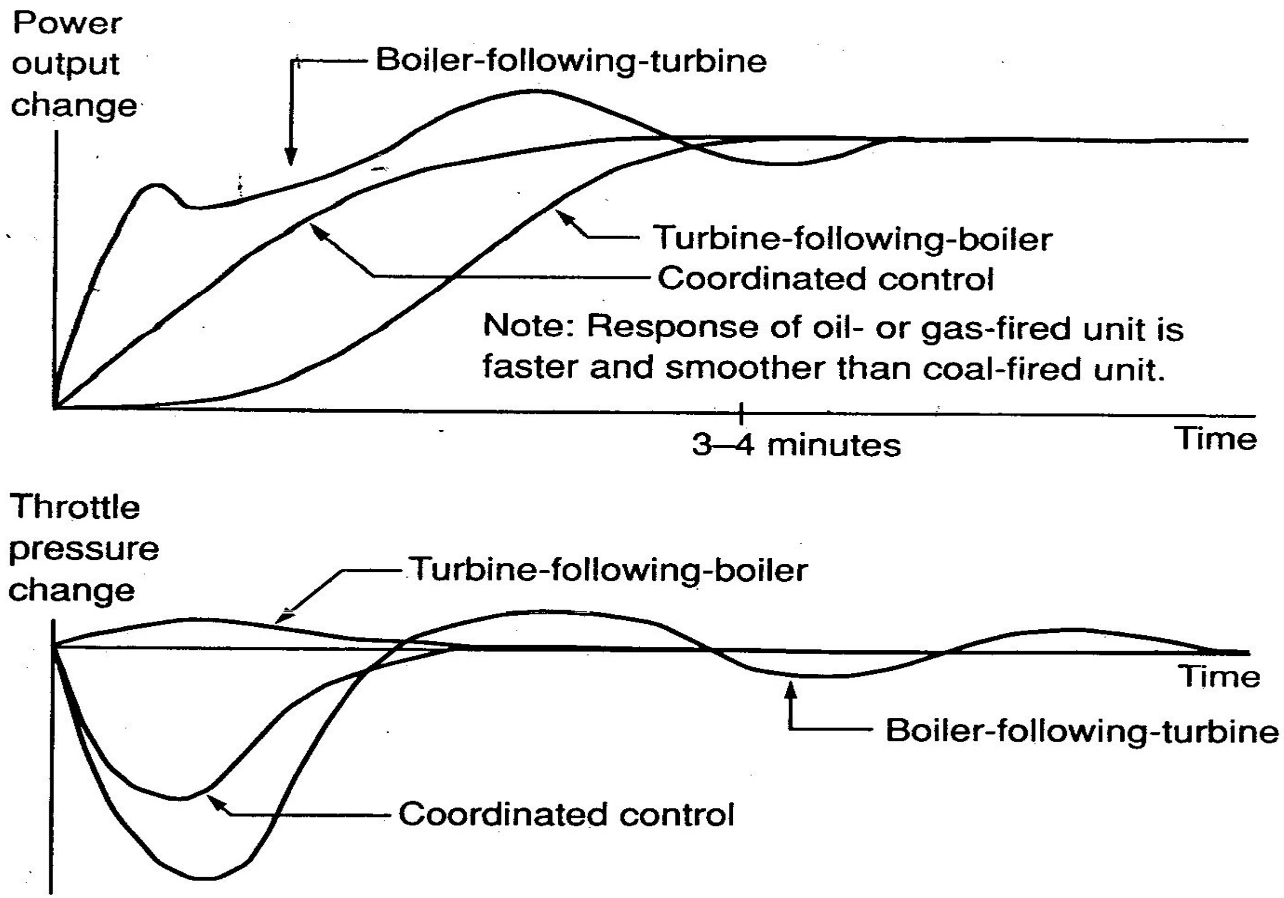
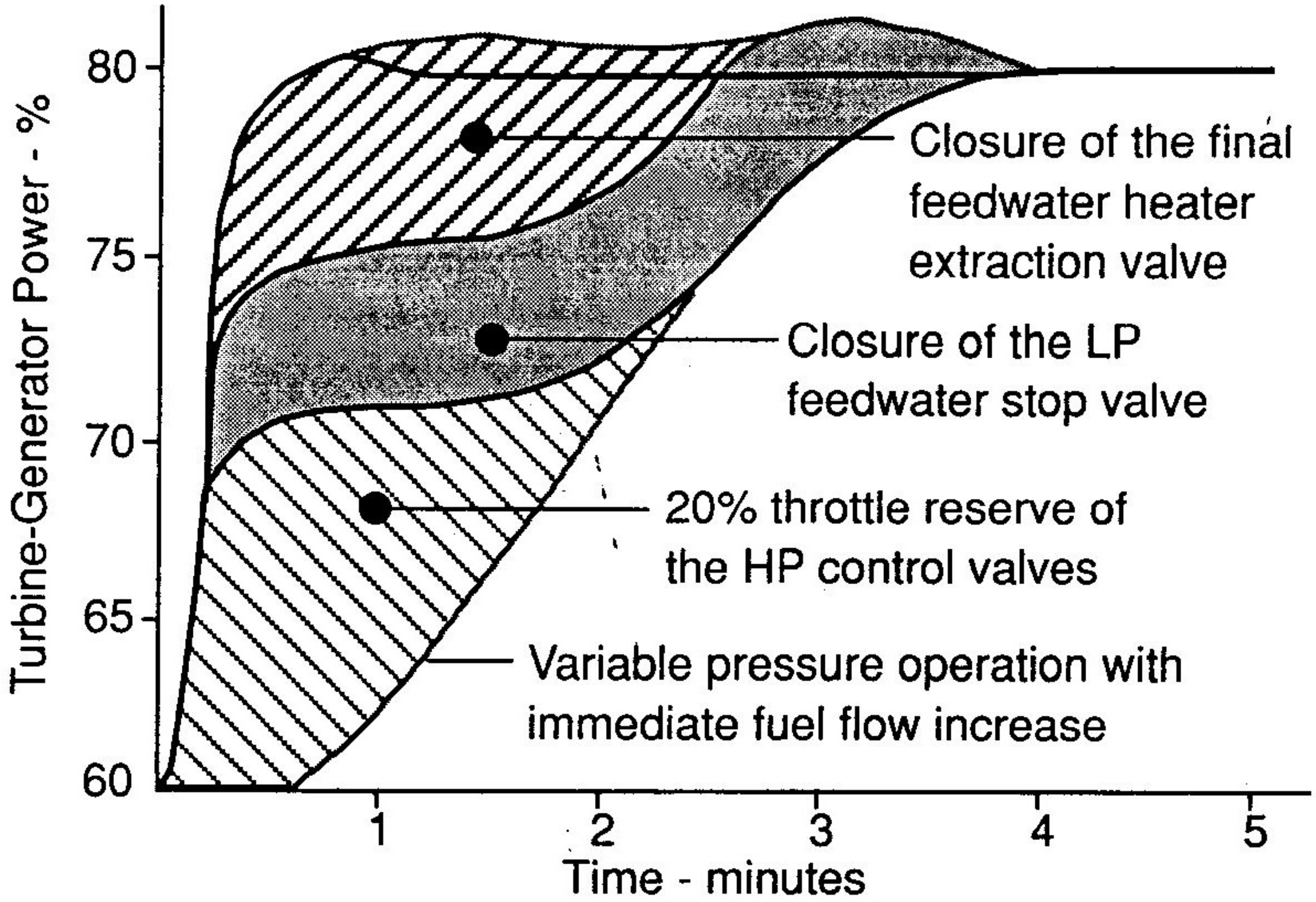


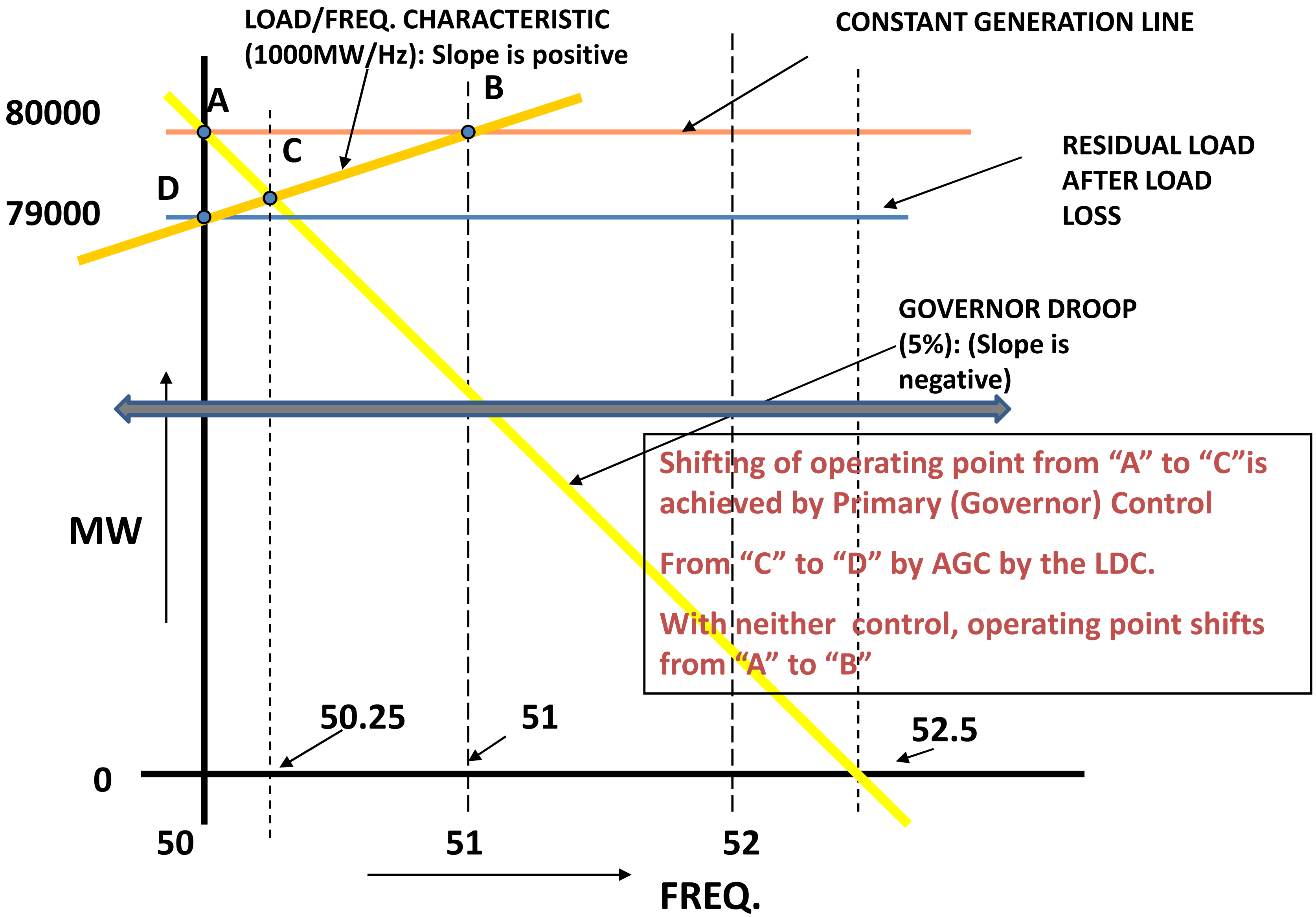
Fig. 5-13. Response for three types of boiler-turbine controls [30].

Reproduced from Carlson W Taylor:
"Power System Voltage Stability"

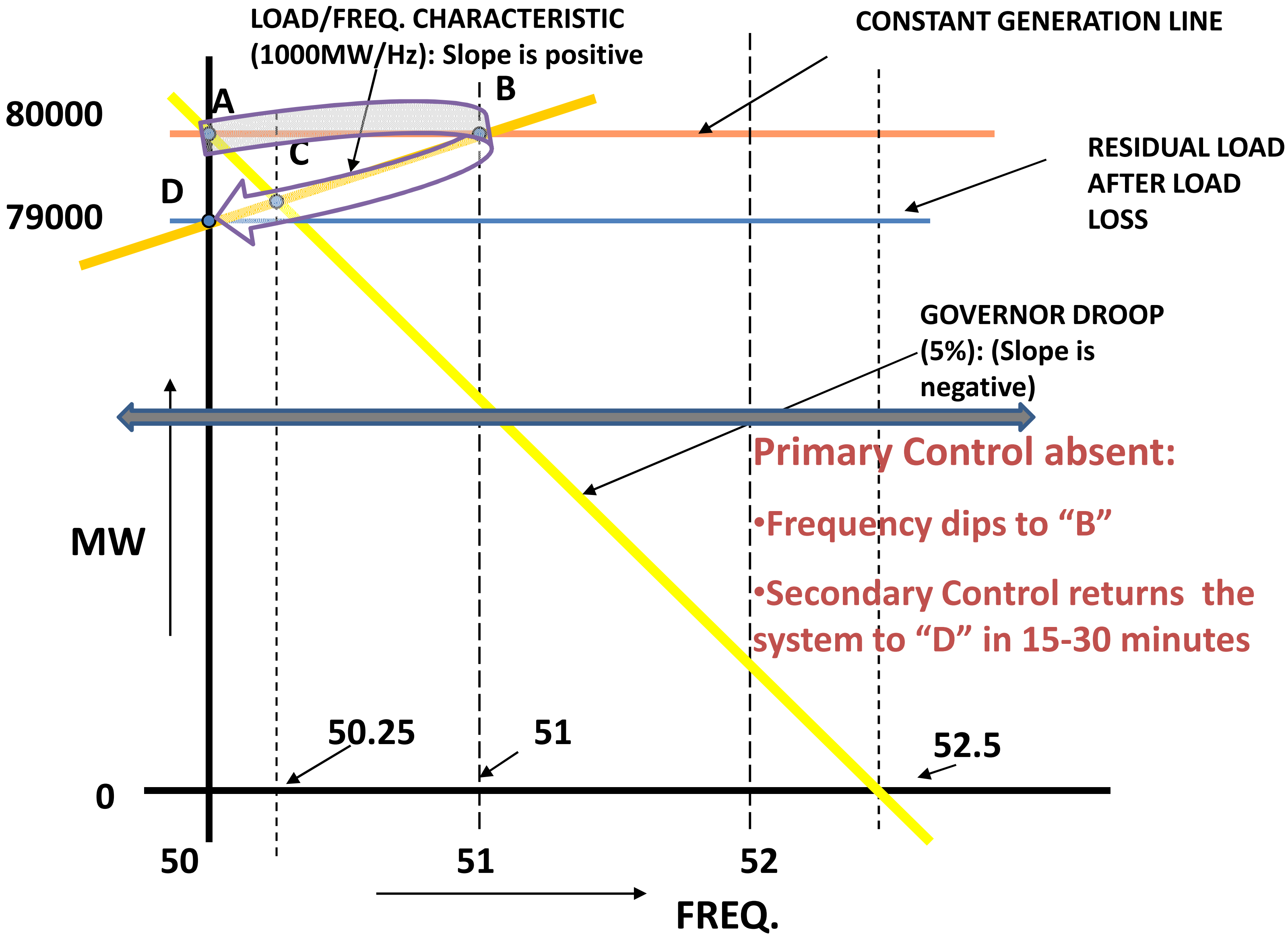


Reproduced from Carlson W Taylor:
Power System Voltage Stability

Frequency Control During Disturbance



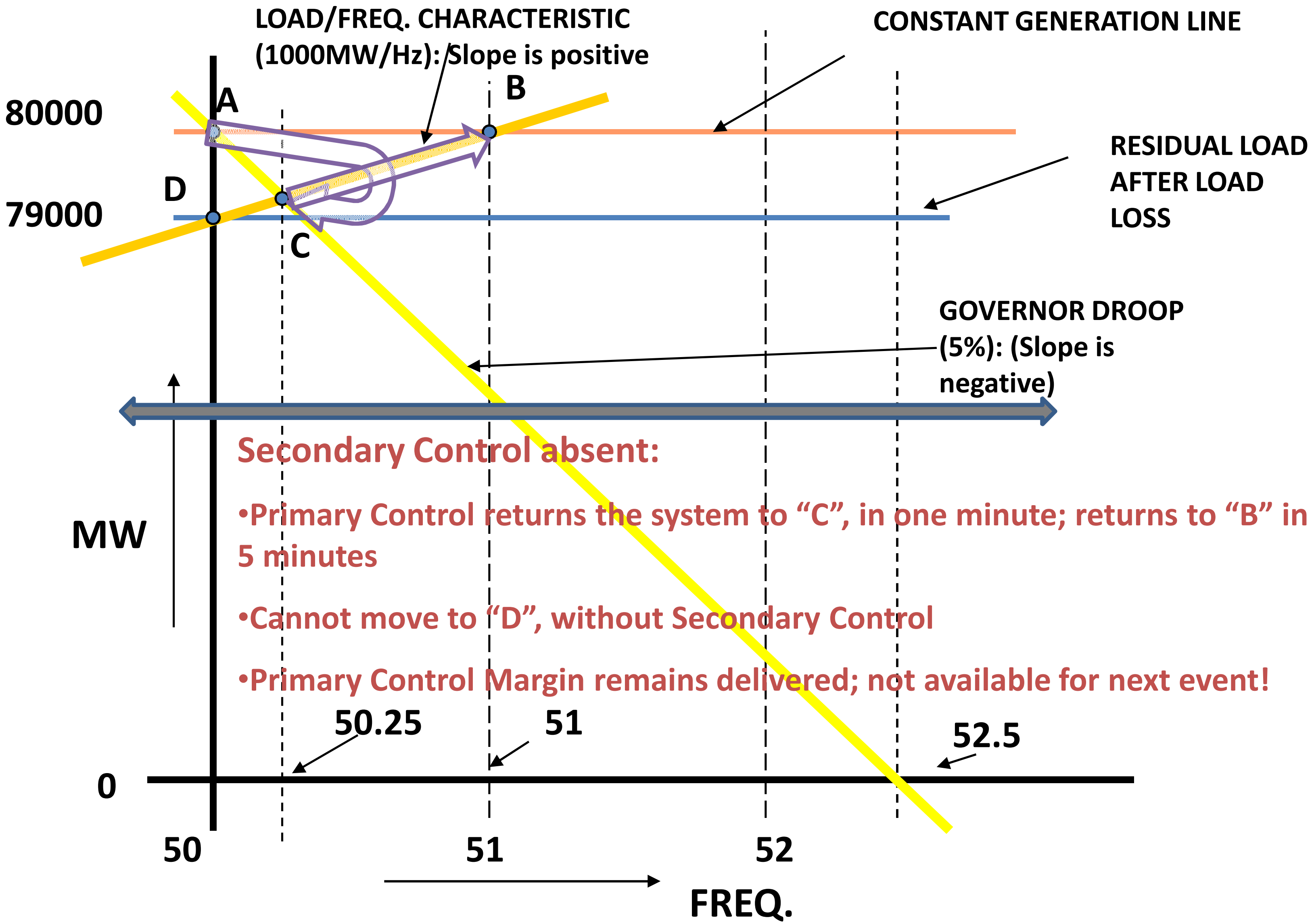
Frequency Control During Disturbance



Primary Control absent:

- Frequency dips to "B"
- Secondary Control returns the system to "D" in 15-30 minutes

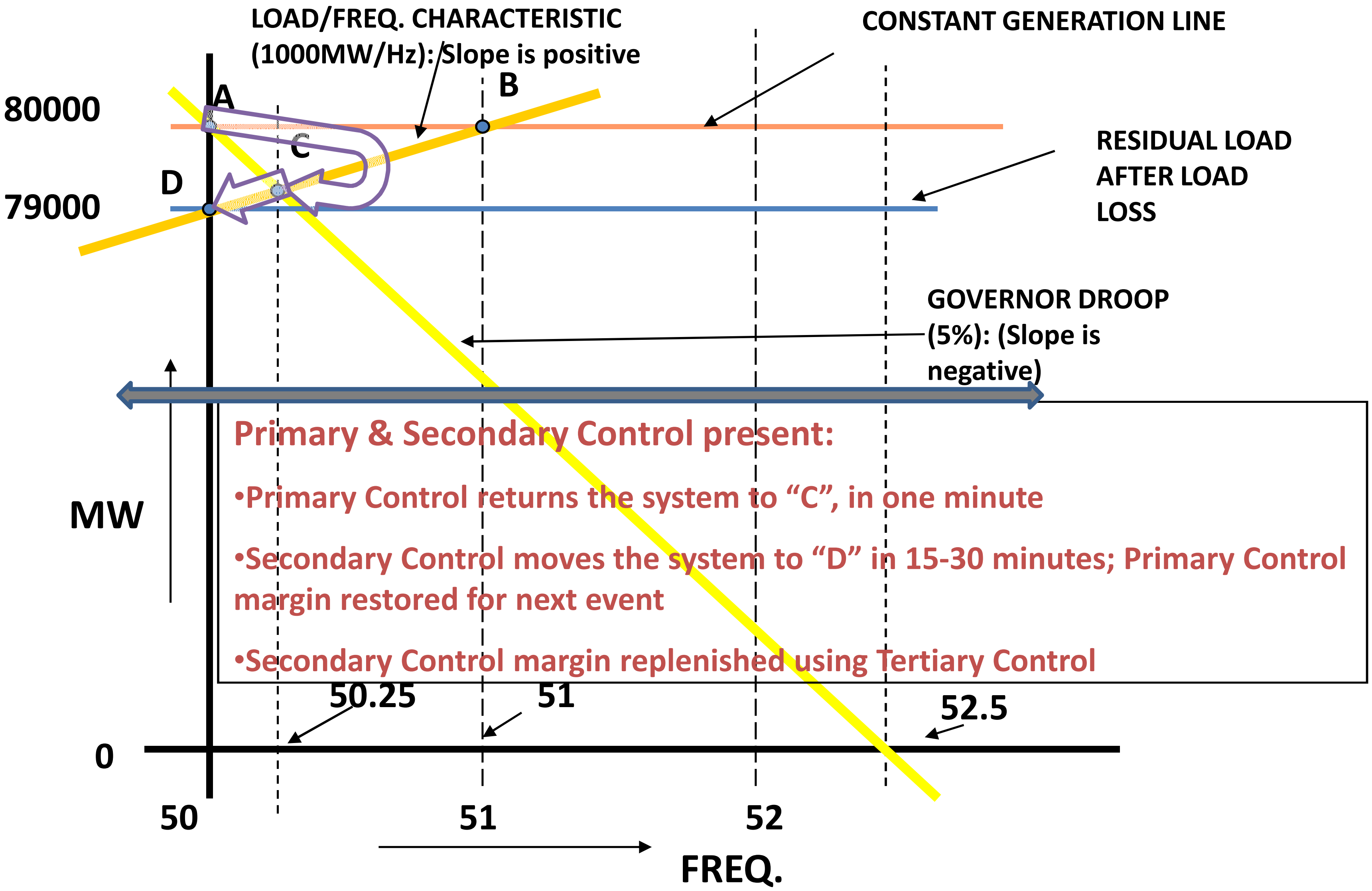
Frequency Control During Disturbance



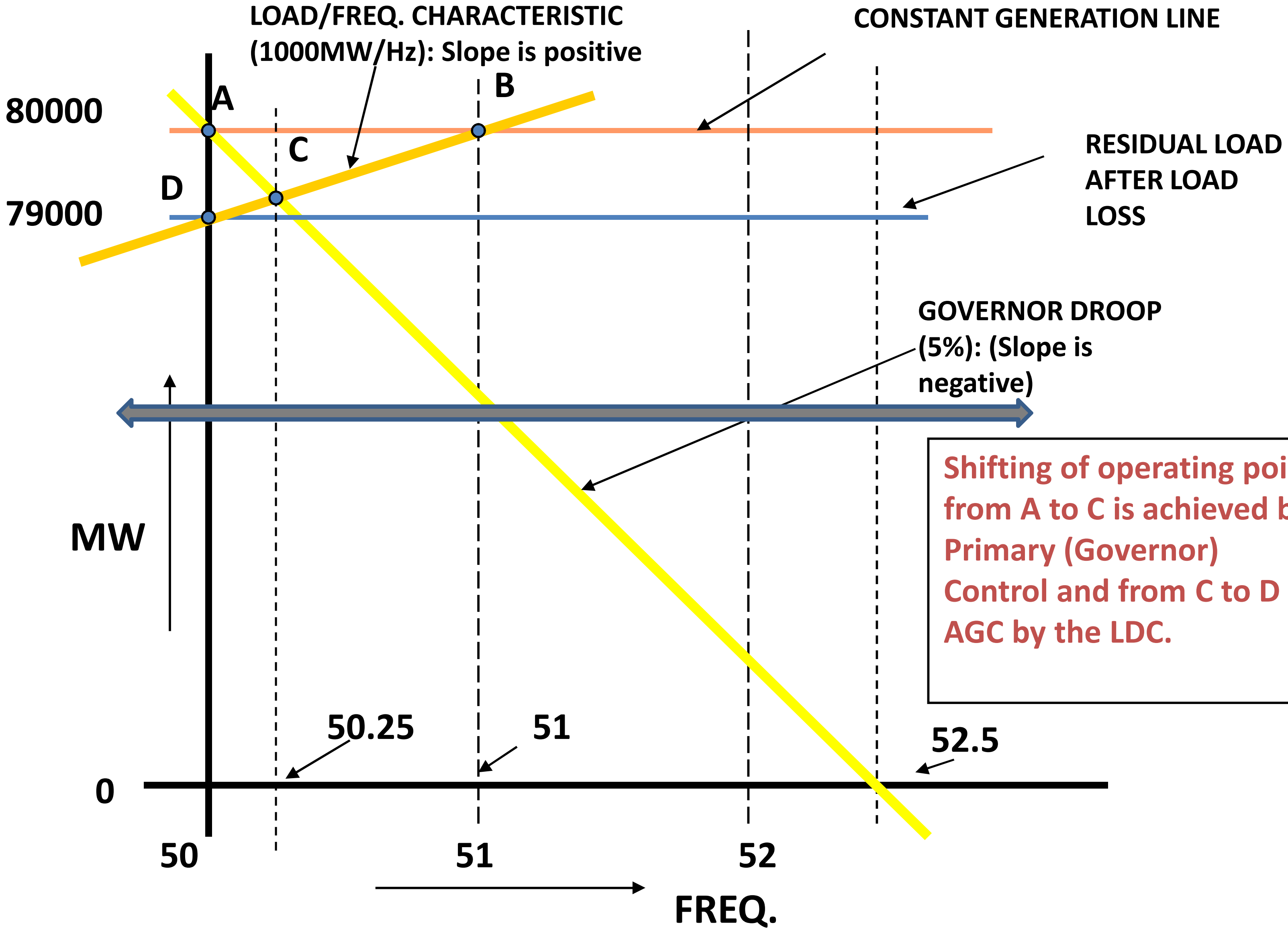
Secondary Control absent:

- Primary Control returns the system to "C", in one minute; returns to "B" in 5 minutes
- Cannot move to "D", without Secondary Control
- Primary Control Margin remains delivered; not available for next event!

Frequency Control During Disturbance

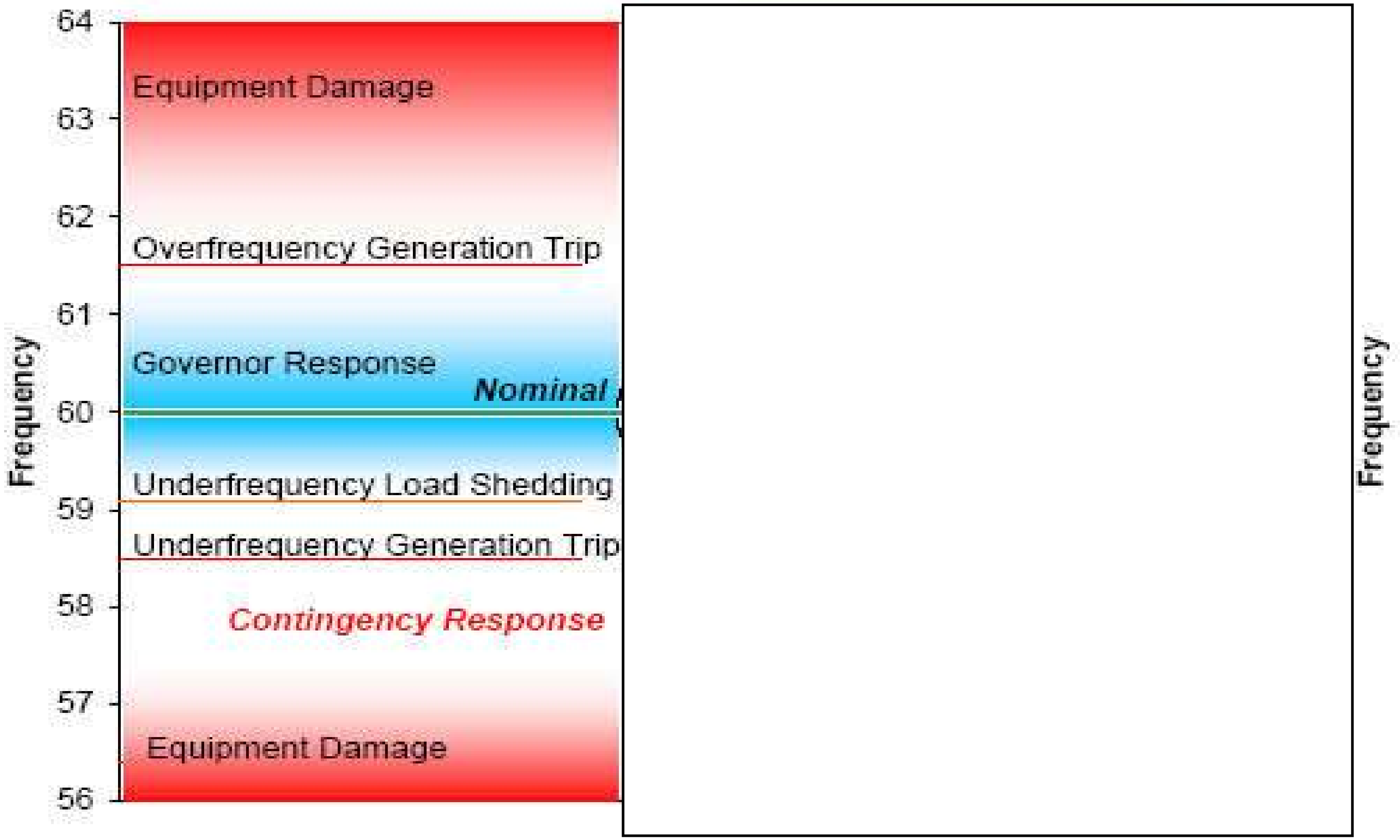


Frequency Control During Disturbance



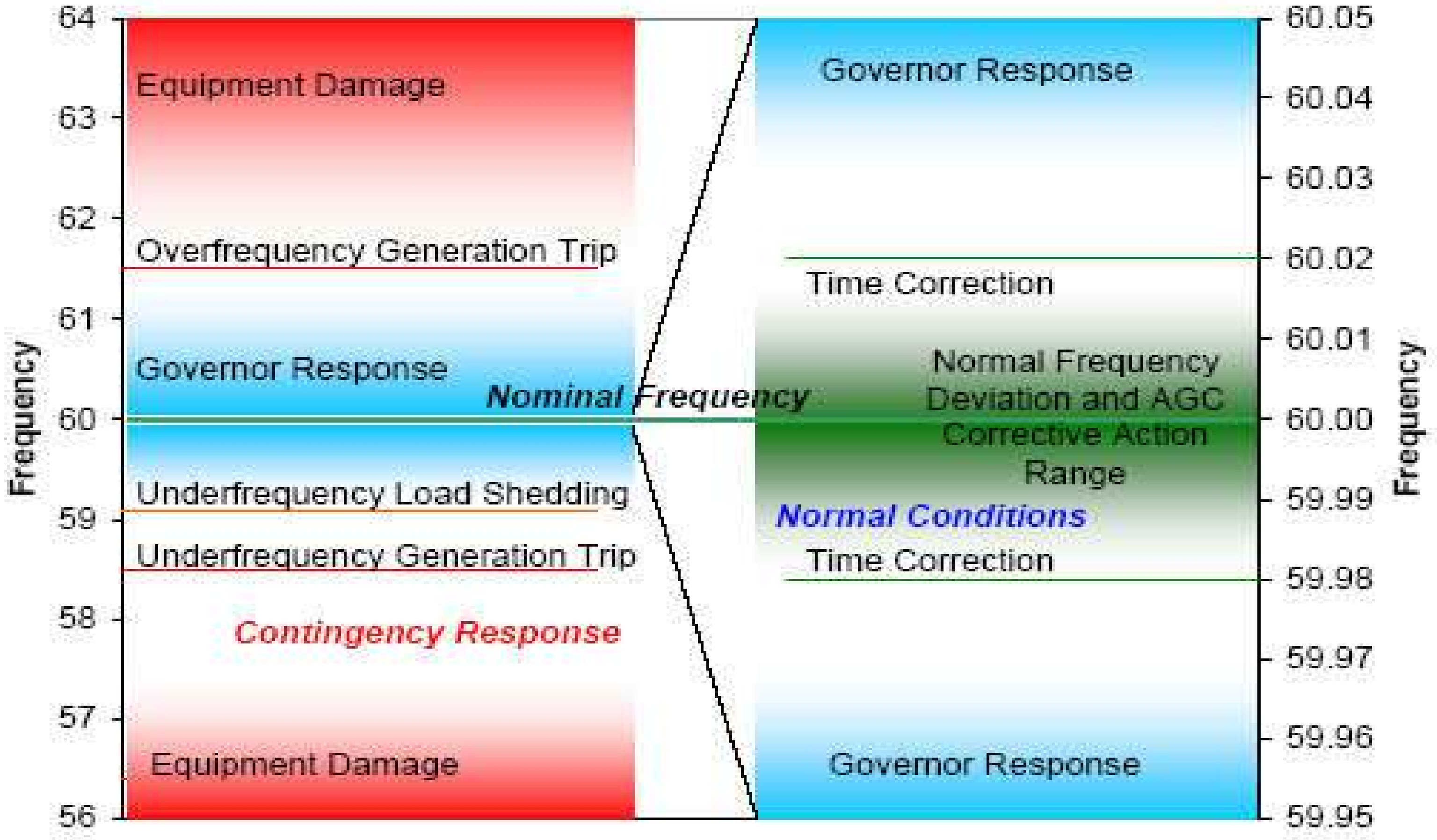
Shifting of operating point from A to C is achieved by Primary (Governor) Control and from C to D by AGC by the LDC.

Ideal Frequency Control Strategy



Reproduced from the report datelined December 2002
"**Frequency Control Concerns In The North American Electric Power System**"
by **CERTS** on behalf of the California Energy Commission

Ideal Frequency Control Strategy



Reproduced from the report datelined December 2002
"**Frequency Control Concerns In The North American Electric Power System**"
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References

1. UCTE Operation Handbook, June 2004 available for free download at www.entsoe.eu
2. Brendan Kirby, “Ancillary services: Technical and Commercial Insights”, www.science.smith.edu
3. Olle Ingemar Elgerd, “Electric Energy Systems Theory: An Introduction”, Tata McGraw-Hill Education, 1983
4. Prabha Kundur, “Power System Stability and Control”, Tata McGraw-Hill, 2006
5. Allen J. Wood / Bruce F. Wollenberg, “Power Generation Operation and Control”, Wiley, 2006

Thank You!

Unknown is Ocean

Annexure-VIII

North Chennai Thermal Power Station

Known is Drop

TANGEDCO

Southern Region

TANGEDCO & The constituents of Southern Region sincerely thank

Hon'ble CERC,
The Respected Chairman, Committee on FGMO,
All the Respected Members,
The Respected Convener

For having given the oppurtunity in the process of for fine tuning the FGMO/RGMO performance of our Generating units to serve to our Country

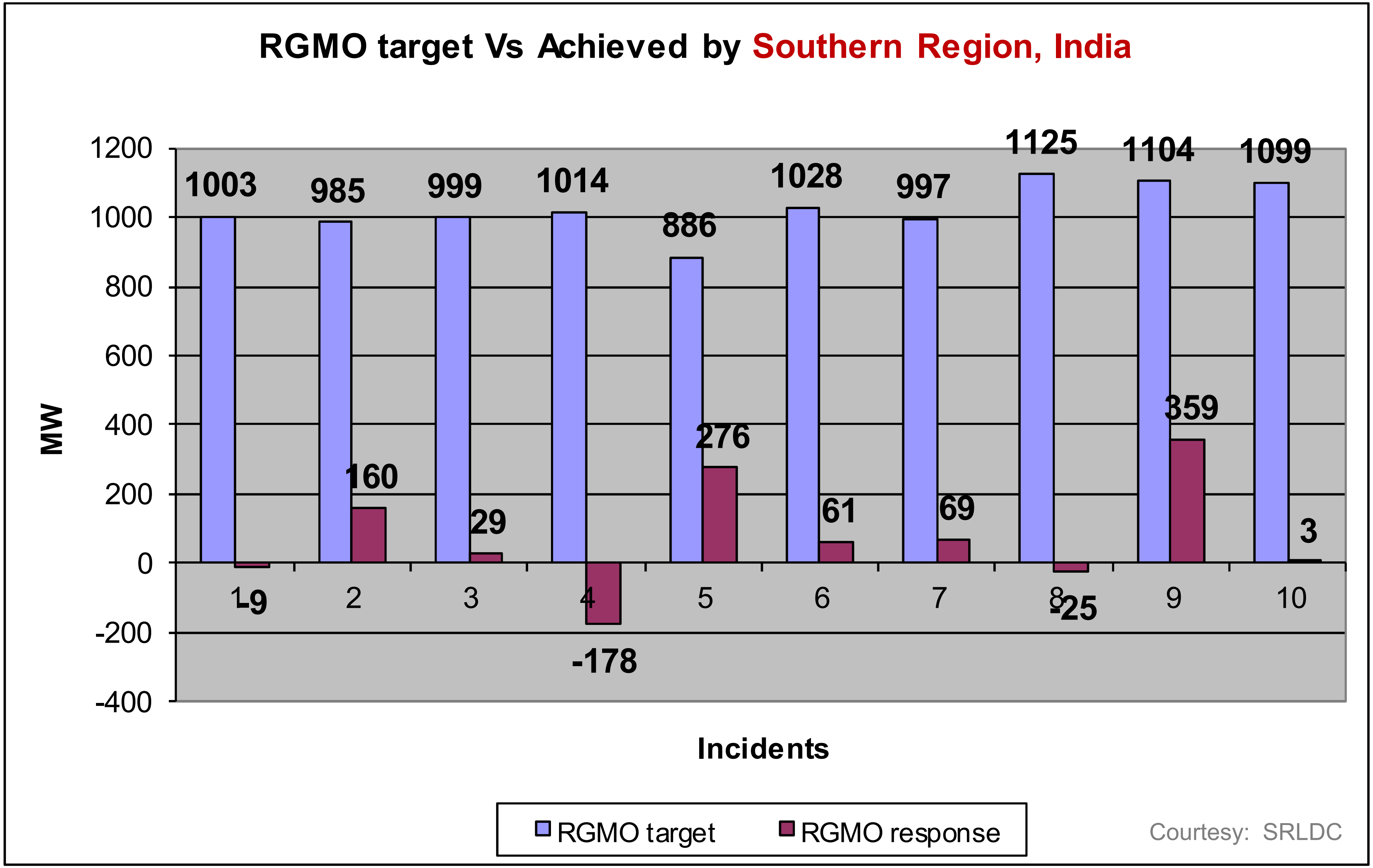
The TOR of the Committee reads as below:

(i) To look into the problems of generating units in implementing RGMO/FGMO

(ii) To suggest measures for implementation of FGMO with suitable modifications / amendments in CERC Regulations / IEGC

(iii) Any other recommendations to facilitate FGMO operation

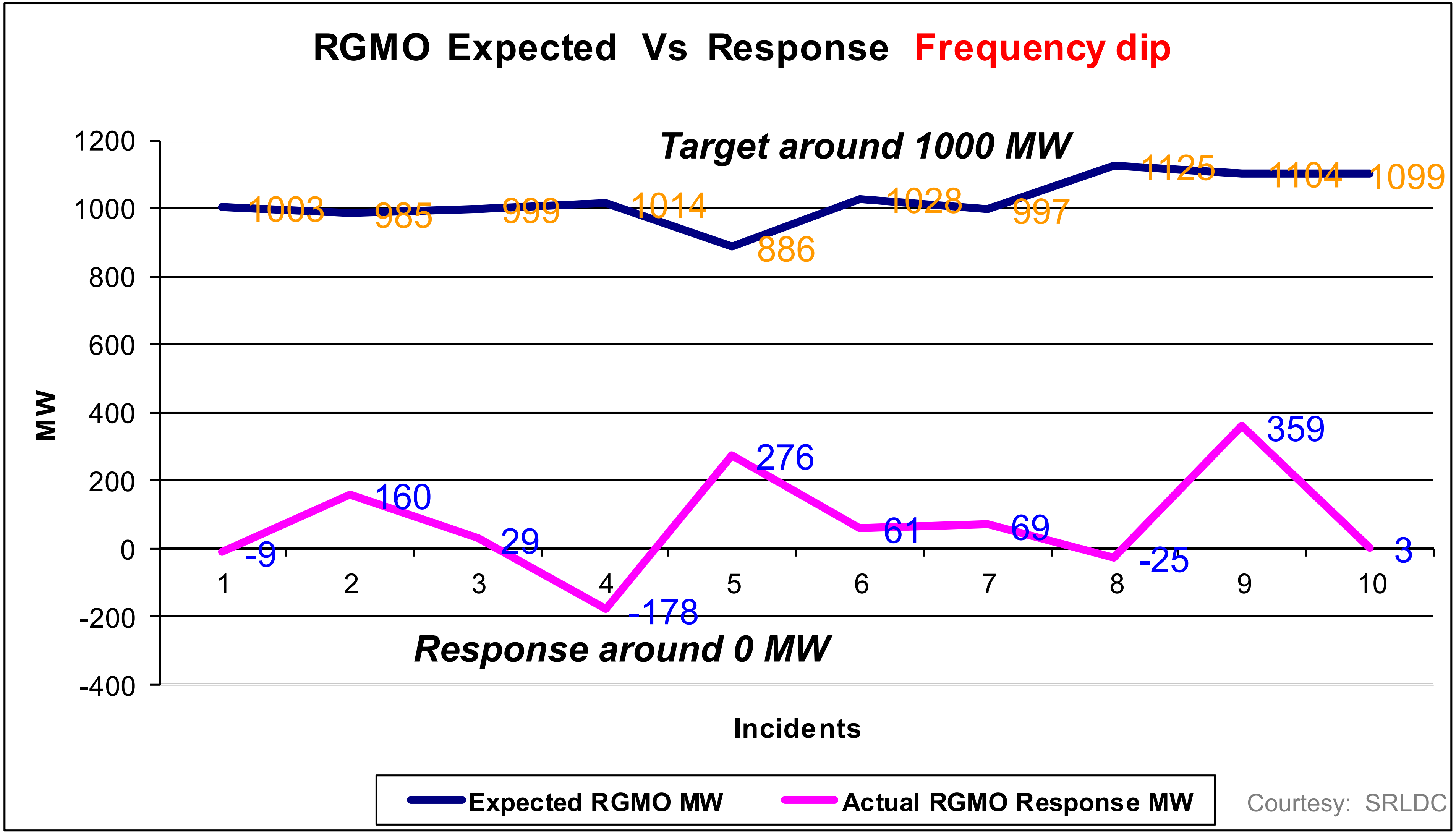
Date	MCR of Machines on Bar	Calculated RGMO 5% of MCR	RGMO Expected by SRPC 5% MCR	Actual RGMO response
Frequency dip incidents				
2-Sep-13	20069	1003.45	1003	-9
3-Sep-13	19709	985.45	985	160
5-Sep-13	19977	998.85	999	29
7-Sep-13	20272	1013.6	1014	**-178**
10-Sep-13	17719	885.95	886	276
12-Sep-13	20553	1027.65	1028	61
13-Sep-13	19935	996.75	997	69
19-Sep-13	22495	1124.75	1125	**-25**
21-Sep-13	22070	1103.5	1104	359
25-Sep-13	21977	1098.85	1099	3
Frequency raise incidents :				Courtesy: SRLDC
1-Sep-13	20223	-1011.15	-1011	**146**
6-Sep-13	19555	-977.75	-978	**21**
10-Sep-13	17719	-885.95	-602	-62
13-Sep-13	19208	-960.4	-959	-128
14-Sep-13	19716	-985.8	-984	-36
16-Sep-13	22529	-1126.45	-1125	-221
19-Sep-13	20097	-1004.85	-1003	-222



On 02 Mar 2015 incident, SR response was 159 * MW as against the thermal target of 744 MW

NCTPS, TANGEDCO

Southern Region, India



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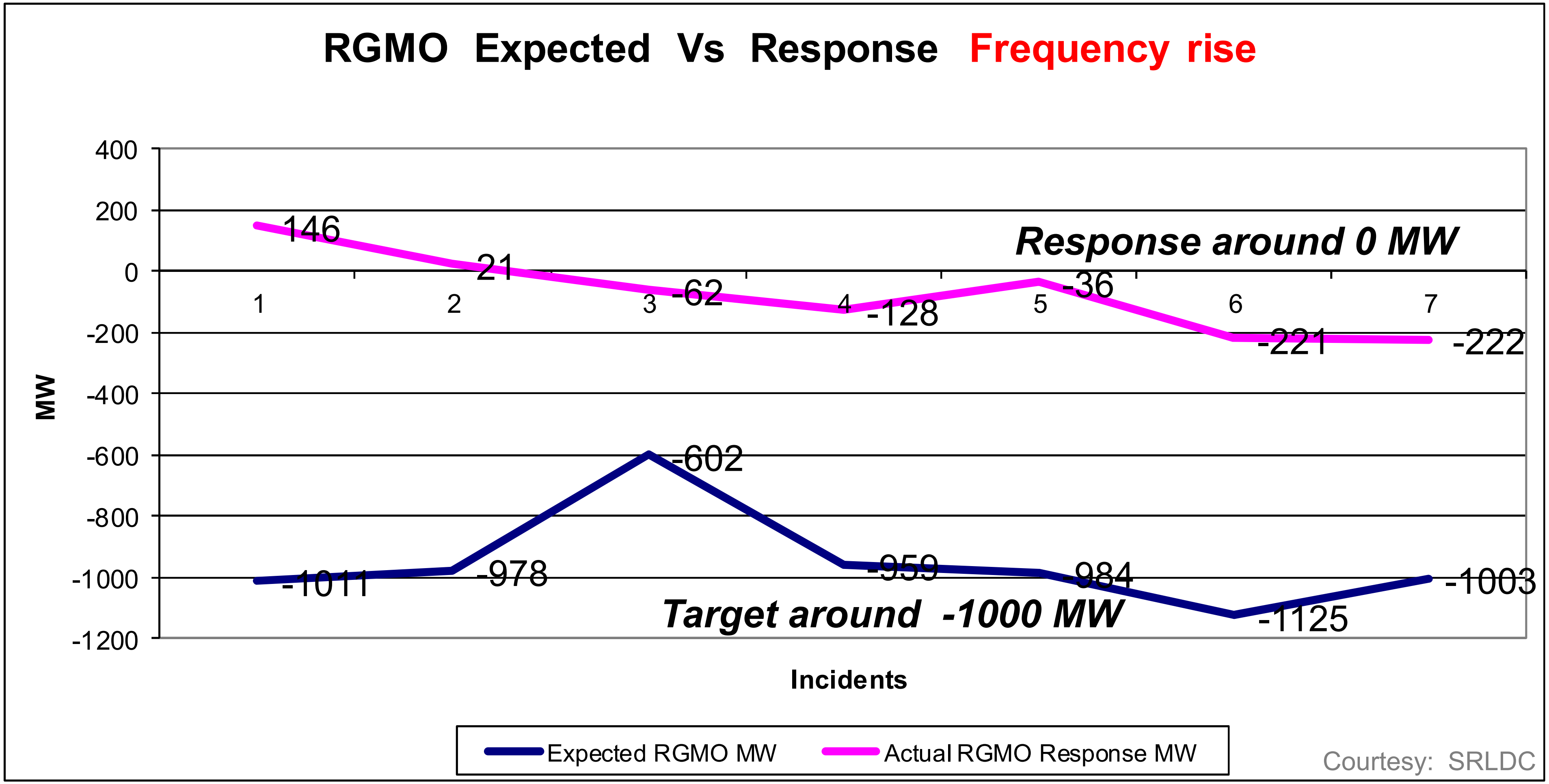


System demands that

for narrowing down the gap between the target & response

RGMO Performance or MW output

Consistency among Units of a station for a single RGMO incident

Consistency of station for several RGMO incidents

Sustainability for 2 – 3 minutes

Sustainability for 2 – 3 minutes by all the Units is the ultimate target and the result by RGMO will have to be analysed by the Power System Engineers. ???

KWU turbines EHG System - RGMO

Date of incident : 02 Mar 2015 49.98 Hz to 49.78 Hz

Performance of NTECL, Tamilnadu, SR JV of NTPC & TNEB						
Unit #	MCR of Machines on Bar	5% of MCR	Current generation	RGMO Expected 5% current generation	**Actual RGMO response**	% achievement
I	500	25	339	16.95	**16**	**94.4**
II	500	25	356	17.80	**16**	**89.89**
III	500	S/D	--	--	--	--
			Station	34.75	32	92.08%

Courtesy: SRLDC

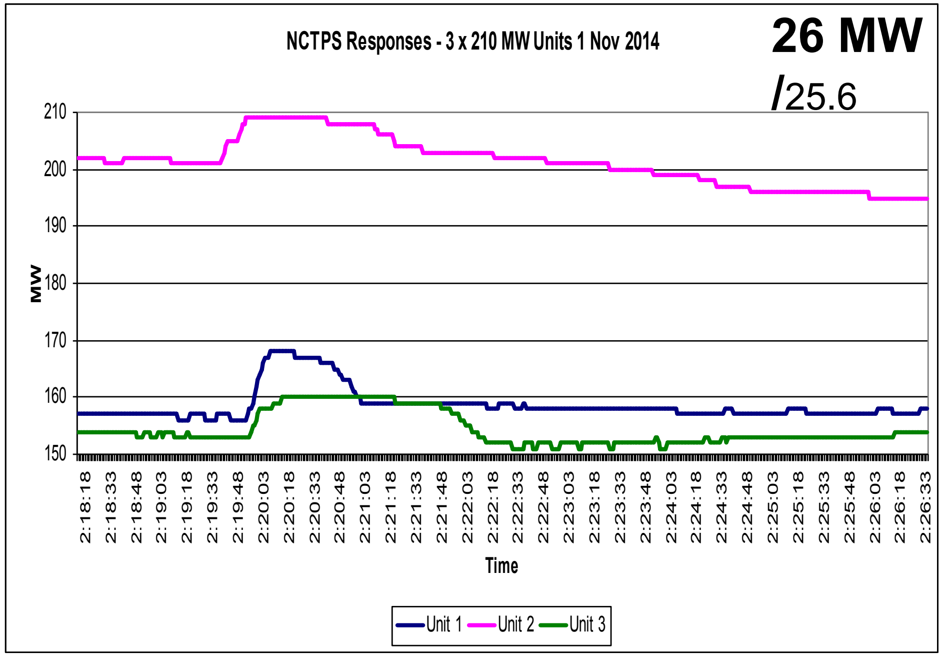
NCTPS, TANGEDCO

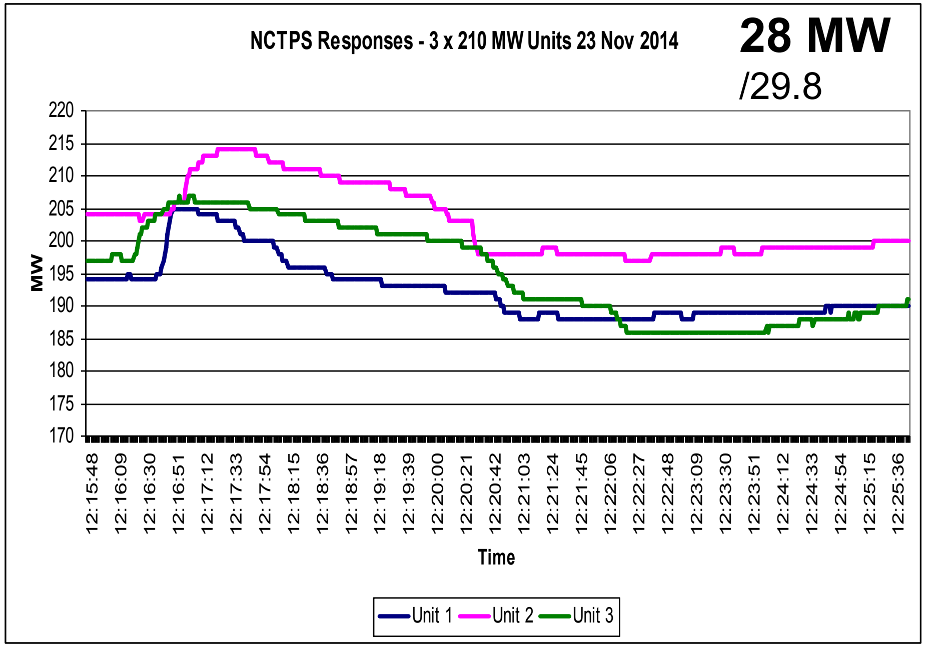
RGMO response of North Chennai Thermal PS 3 x 210 MW Units TNAGEDCO, SR

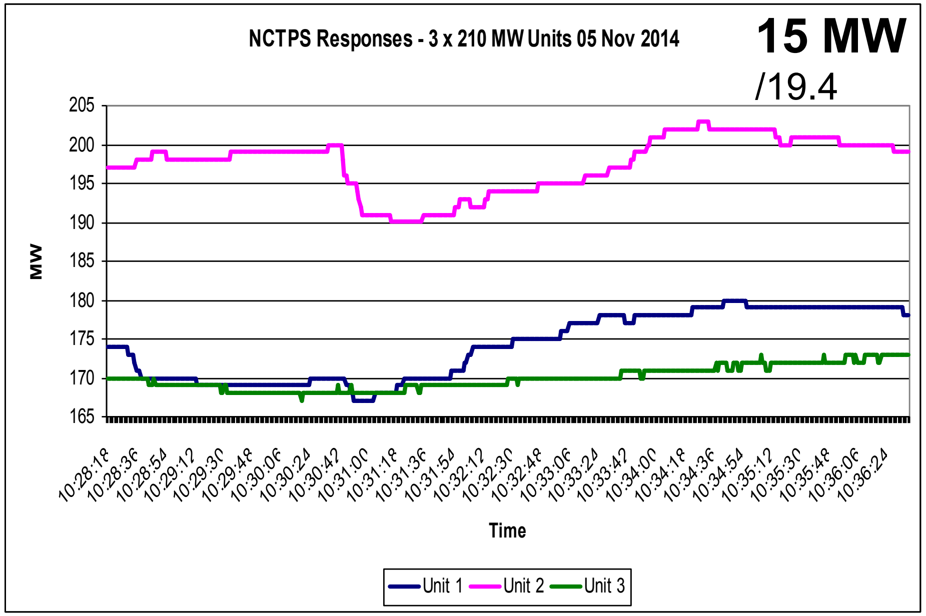
Sl. No	Name of Thermal Station	Unit No.	MW Capa-city	Generation at the instant	Governor Mode	From (MW)	To (MW)	Pickup (MW)	Remarks if any
Incident 1 : 01.11.2014 02:20 to 02:21 Hrs 50.00 Hz to 49.88 Hz									
1	North Chennai Thermal Power Station	I	210	157	RGMO	157	168	**11**	**26 MW** raise has been pumped into the grid with 5.06% increase at the instant generation level.
2		II	210	201	RGMO	201	209	**8**	
3		III	210	153	RGMO	153	160	**7**	
Incident 2 : 05.11.2014 10:31 to 10:32 Hrs 50.05 Hz to 50.14 Hz									
1	North Chennai Thermal Power Station	I	210	170	RGMO	170	167	**3**	**15 MW** fall with 2.78% decrease at the instant generation level has been performed.
2		II	210	200	RGMO	200	190	**10**	
3		III	210	169	RGMO	169	167	**2**	
Incident 3 : 23.11.2014 12:16 to 12:17 Hrs 49.94 Hz to 49.78 Hz									
1	North Chennai Thermal Power Station	I	210	194	RGMO	194	205	**11**	**28 MW** raise has been pumped into the grid with 4.71% increase at the instant generation level.
2		II	210	204	RGMO	204	211	**7**	
3		III	210	197	RGMO	197	207	**10**	

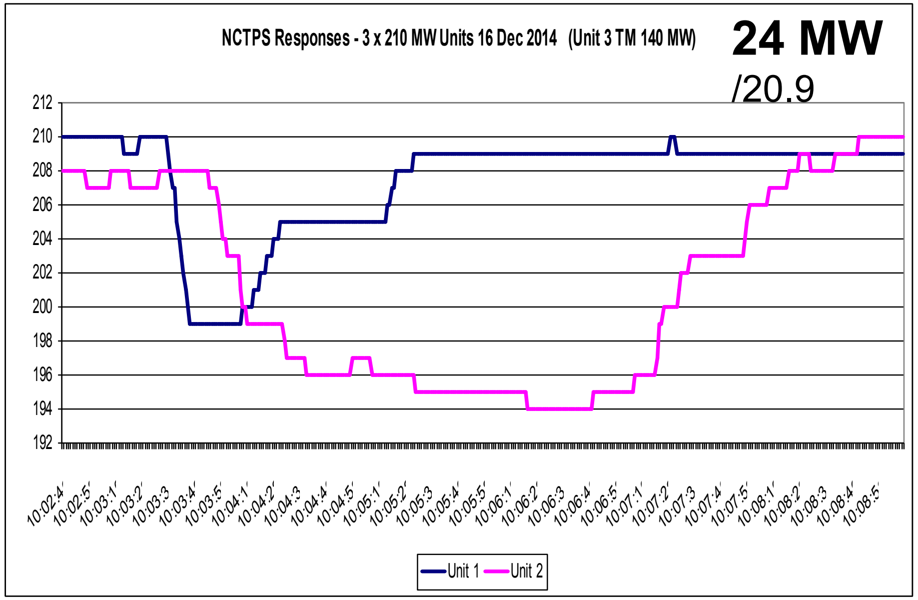
Sl. No	Name of Thermal Station	Unit No.	MW Capa-city	Generation at the instant	Gover nor Mode	From (MW)	To (MW)	Pickup (MW)	Remarks if any
Incident 4 : 16.12.2014 10:03 to 10:04 Hrs 50.00 Hz to 50.10 Hz									
1	North Chennai Thermal Power Station	I	210	210	RGMO	210	199	**11**	**24 MW fall** with 4.26% decrease at the instant generation level has been performed.
2		II	210	208	RGMO	208	195	**13**	
3		III	210	145	RGMO	145	145	**0**	
Incident 5 : 14.01.2015 19:21 to 19:22 Hrs 50.05 Hz to 49.88 Hz									
1	North Chennai Thermal Power Station	I	210	S/D	RGMO	--	--	**--**	**10 MW** raise has been pumped into the grid with 2.72% increase at the instant generation level. Unit 2 - Frequency dip for RGMO not captured due to elevated f measurement. Unit 3 Inspite of process requirement for fall in MW from 198 to 194 MW just before RGMO instance, RGMO lifted this unit level to 204 MW (5.15%)
2		II	210	173	RGMO	173	173	**0**	
3		III	210	194	RGMO	194	204	**10**	
Incident 6 : 02.03.2015 06:49 to 06:50 Hrs 50.03 Hz to 49.77 Hz									
1	North Chennai Thermal Power Station	I	210	213	RGMO	213	214	**1**	**17 MW** raise has been pumped into the grid with 2.68% increase at the instant generation level. Unit 1 – Due to reduced Pressure and load limiter. The operators instructed to keep the load limiter considering RGMO demand.
2		II	210	213	RGMO	213	220	**7**	
3		III	210	209	RGMO	209	218	**9**	

Expected from 3 x 210 MW Units = 31.5 MW at full load









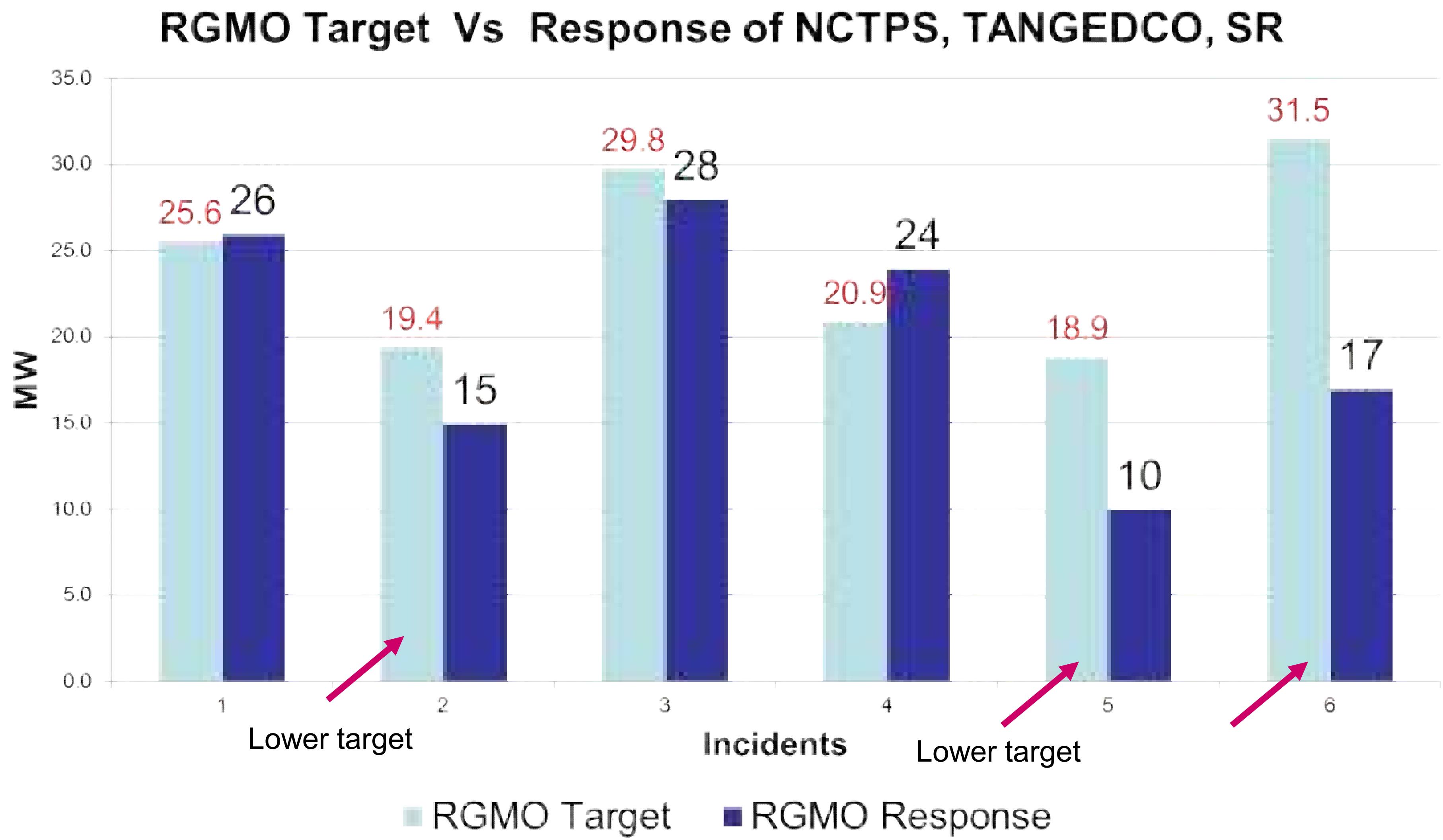
NCTPS, TANGEDCO

KWU turbines EHG System - RGMO

Performance of North Chennai Thermal Power Station, TANGEDCO, SR							
Date	MCR of Machines on Bar	5% of MCR	Current generation	RGMO Expected 5% current generation	Actual RGMO response	% achievement	Remarks
01.11.2014	630	31.5	511	25.6	26	**101.76**	
05.11.2014	630	31.5	539	19.4	15	77.30	Fall of frequency is 0.09 Hz only and target corrected.
23.11.2014	630	31.5	595	29.8	28	94.12	
16.12.2014	630	31.5	418	20.9	24	**114.83**	
14.01.2015	630	31.5	377	18.9	10	53.05	Elevated f measurement & corrected.
02.03.2015	630	31.5	635	31.5	17	53.97	Load limiter problem and operators were advised

These three errors also have been corrected   Average   82.51%   NCTPS, TANGEDCO

From Nov 2014 to Mar 2015



Not capturing at higher frequency
Elevated f measurement
Load limiter

NCTPS, TANGEDCO

KWU turbines EHG System - RGMO

Date of incident : 02 Mar 2015

Performance of Simhadri Thermal Power Station, TANGEDCO, SR						
Unit #	MCR of Machines on Bar	5% of MCR	Current generation	RGMO Expected 5% current generation	Actual RGMO response	% achievement
I	500	25	428	21.4	18.1	**84.6**
II	500	25	401	20.1	13.3	**66.3**
III	500	25	501	25.1	7.7	**30.7**
IV	500	25	496	24.8	5.2	**21.0**
			Station	70	44.3	62.3%

NTECL 32 MW NCTPS 17 MW out of TANGEDCO's 38 MW

Total this three stations 93 MW for 159 * MW

Courtesy: SRLDC

NCTPS, TANGEDCO

LMZ turbines FGMO with MI

Performance of Mettur Thermal Power Station, TANGEDCO, SR						
Date	MCR of Machines on Bar	5% of MCR	Current generation	RGMO Expected 5% current generation	Actual RGMO response	% achievement
16.12.2014	840	42	824	41.2	18	**43.69**
14.01.2015	630	31.5	607	30.35	13	42.84
02.03.2015	840	42	804	40.2	23	**57.14**

Manual intervention – dictates consistency

Alarming for the occurrence of RGMO incident based on ripple factor is given to activate unit operators for the manual intervention

System demands that

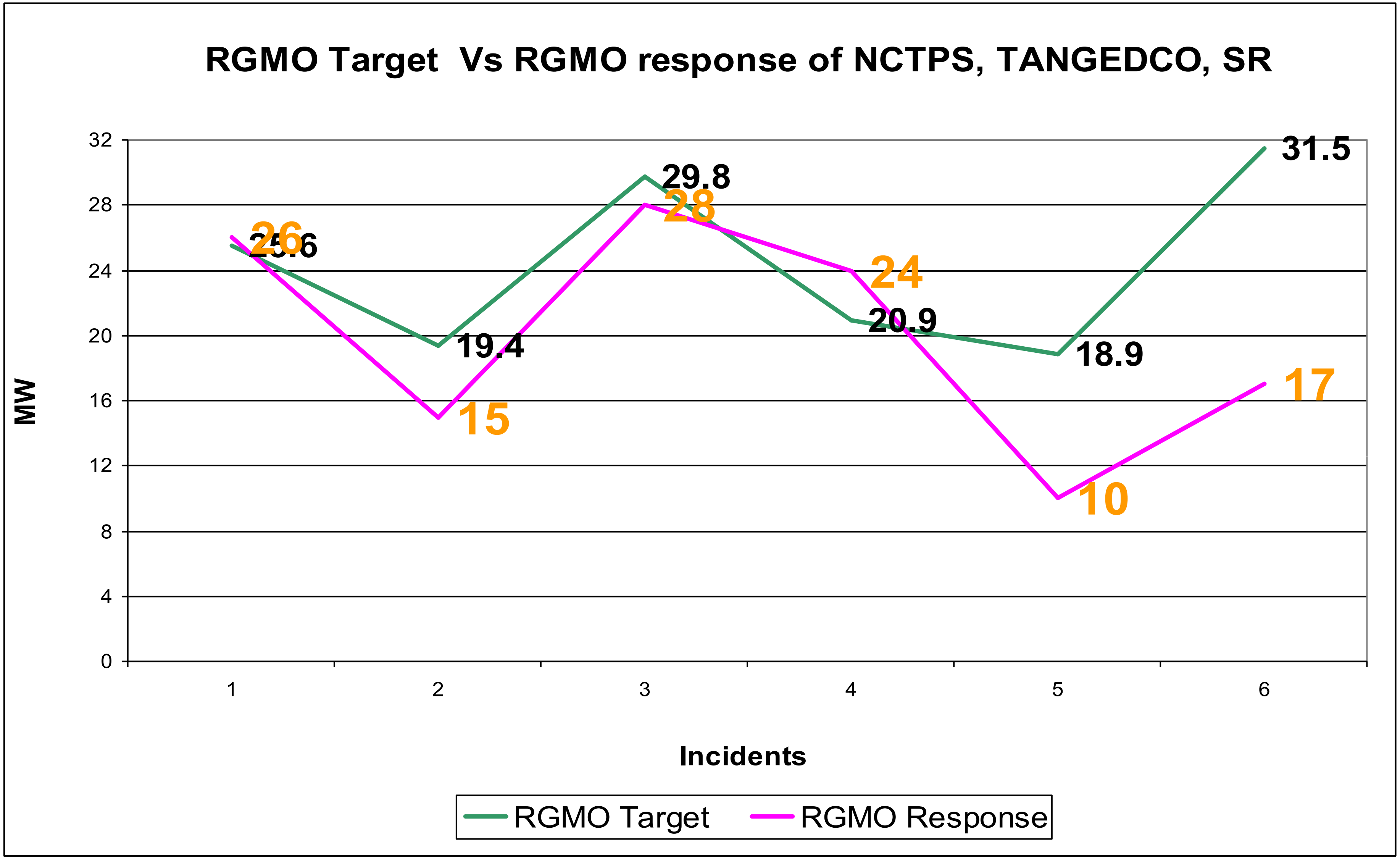
RGMO Performance or MW output

Consistency among Units of a station for a single RGMO incident

Consistency of station for several RGMO incidents

Sustainability for 2 – 3 minutes & again consistency

Sustainability for 2 – 3 minutes by all the Units is the ultimate target and the result by RGMO will have to be analysed by the power system Engineers. ???

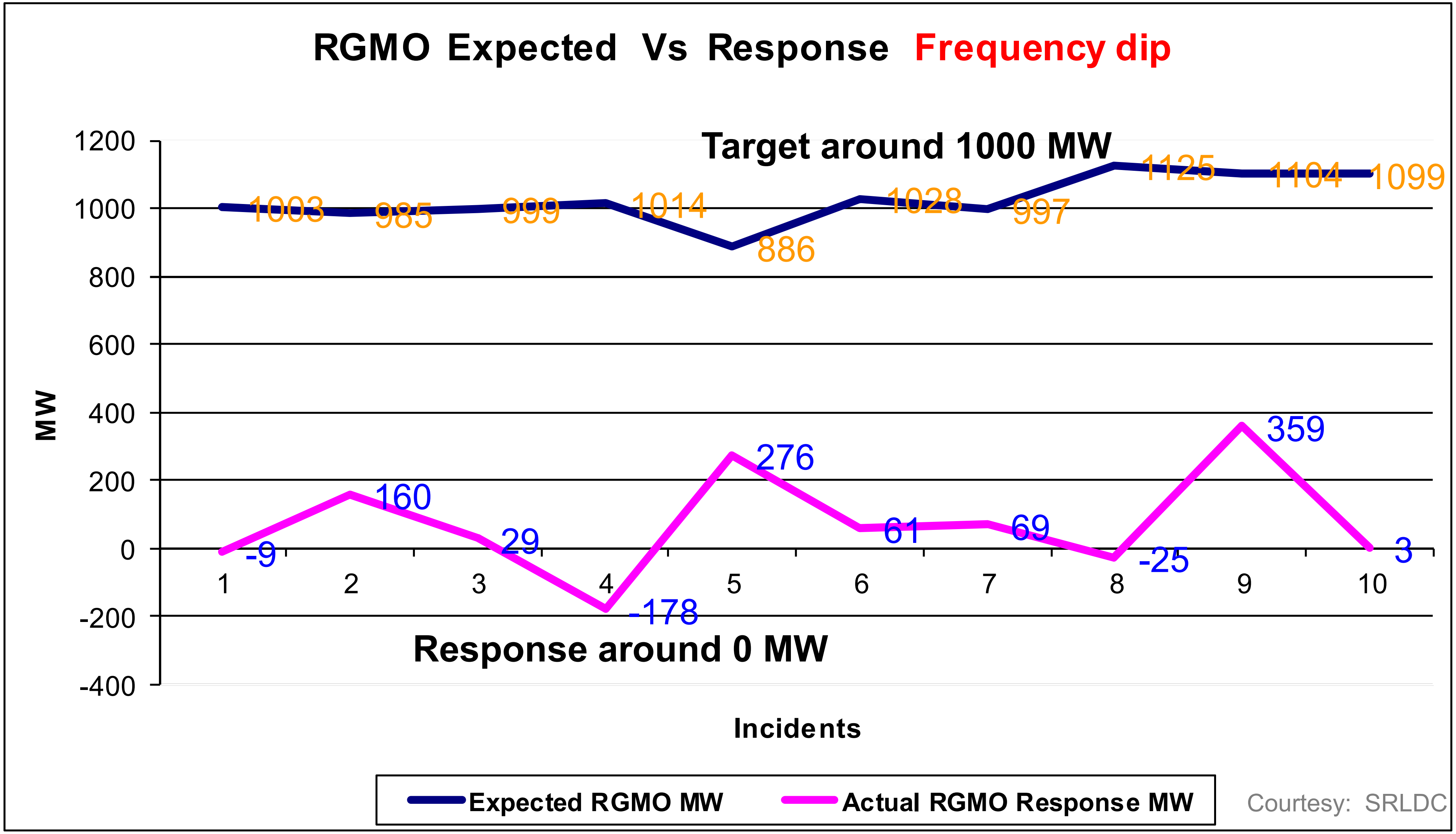


For Sixth incident, SR response was 159*MW (21.37%) as against the target of 744MW

NCTPS share of 17 MW & TANGEDCO achieved 38 MW

NCTPS, TANGEDCO

Southern Region, India



On 02 Mar 2015 incident, SR response was 159 * MW as against the target of 744 MW

66 Thermal units on Bar for the 02 Mar 2015 incident
as reported by SRLDC

Southern Region

We lag, the reason is

Multiple Controllers
Multiple OEMs
Multiple Generating units
Multiple Sizes/capacities
Multiple Outputs
Multiple Process activities
Multiple Unit operators
Multiple Process parameters for

Unique Goal of RGMO
with desired MW on our grid

NCTPS, TANGEDCO

From the submission of
Er.P.P.Francis, GM (OS), NTPC Ltd.,

JV

Page 2 of 12 :

When the RGMO prescription was stipulated, it was clearly understood that it will be applicable to Electric Governors

Page 2 of 12 :

At least it is time for the committee to affirm that RGMO serves a well recognized purpose and provide the means for achieving the same.

Page 2 & 3 of 12 :

there is **no unanimity of understanding among the committee members** itself.

Page 3 of 12 :

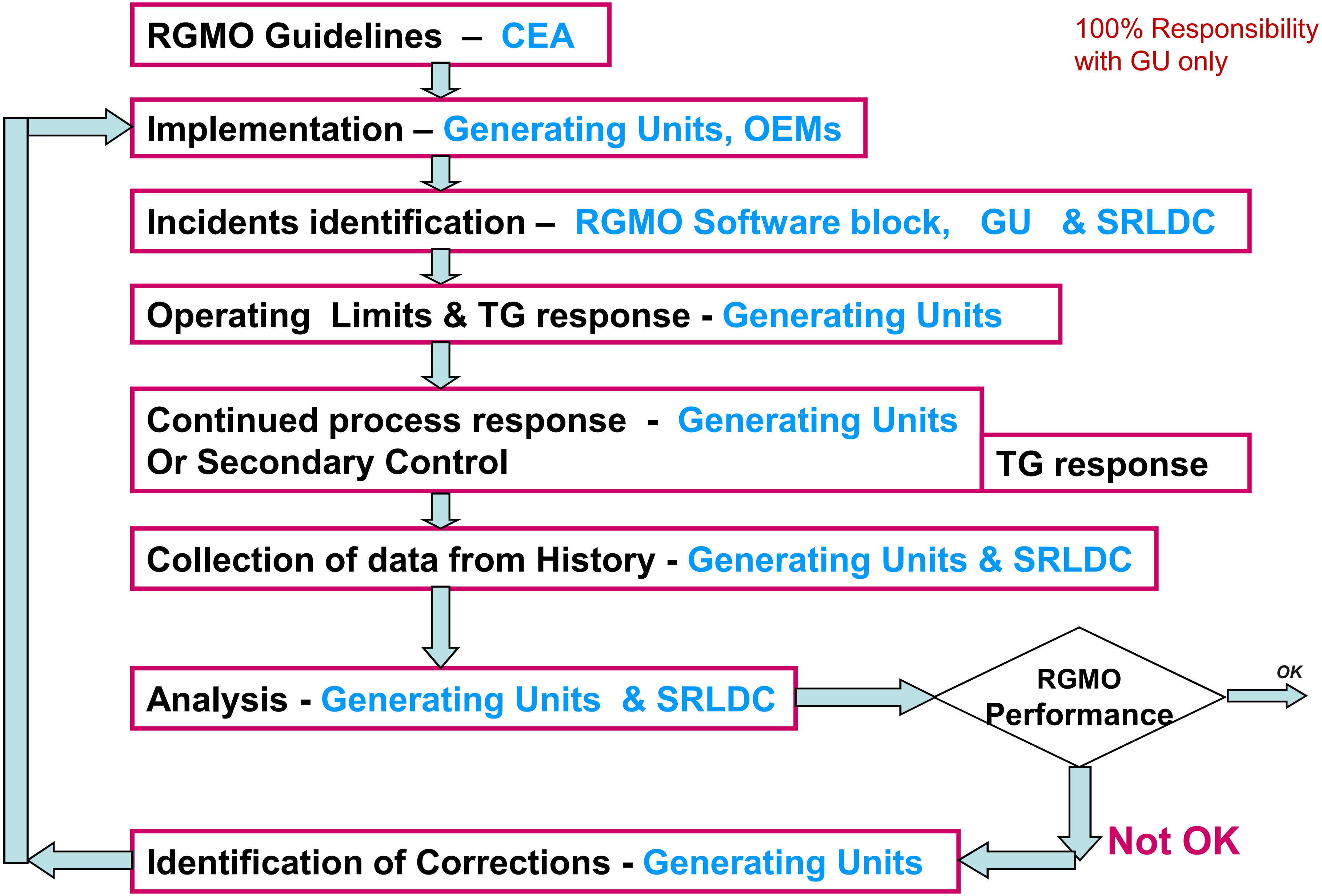
RGMO logic implemented in each machine is likely to be at variance, as the same is **non-standard** and has been realized variously.

From the submission of
Er.P.P.Francis, GM (OS), NTPC Ltd.,

Page 6 of 12 :
the committee must recognize that the purpose, mechanism and functioning of FGMO / RGMO have **never been seriously analyzed nor discussed**.

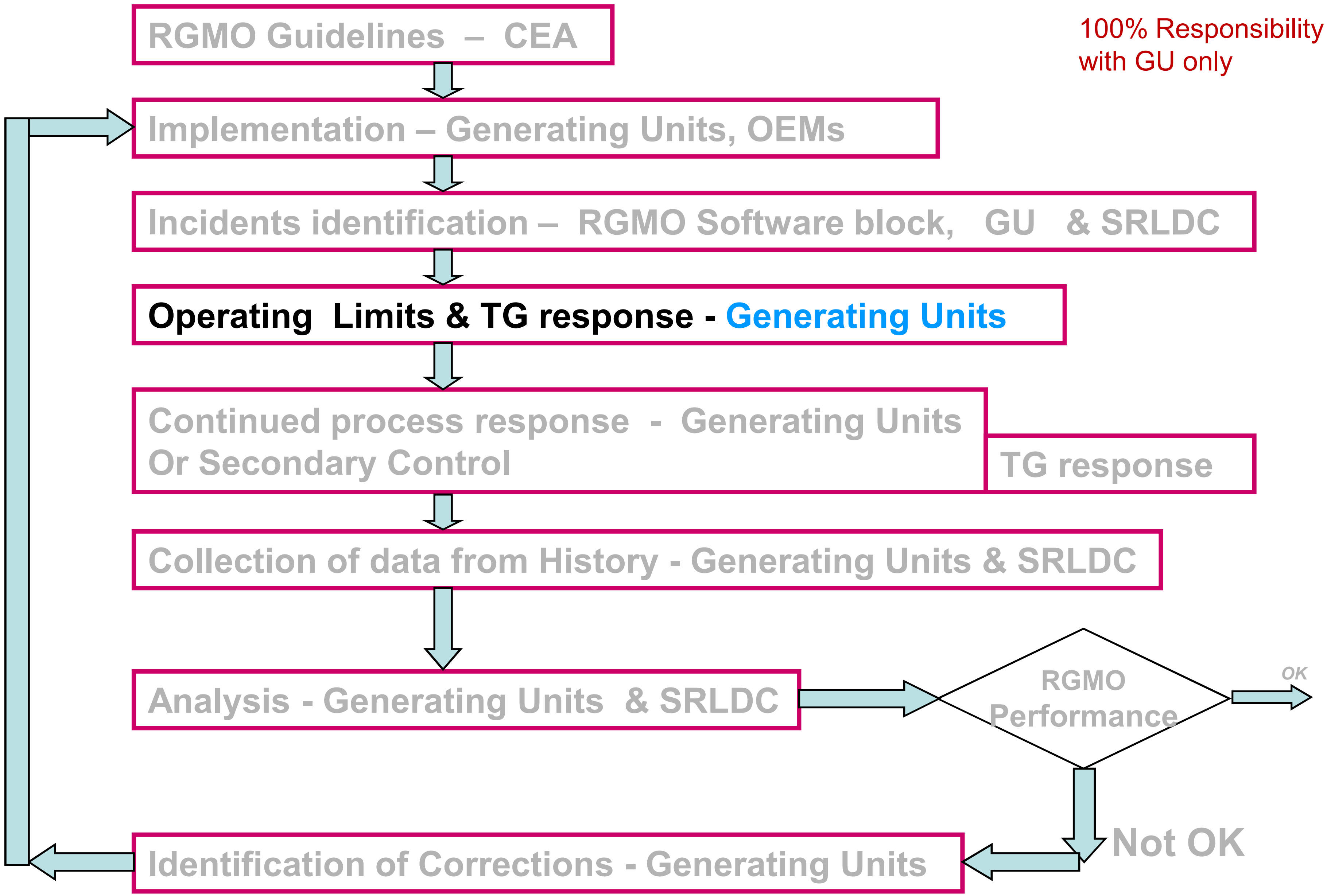
Page 11 of 12 :
We have been suffering from our failure to find and adopt technically correct solutions for the **past 14 odd years** and it is incumbent on this committee to call a spade a spade, at least at this late opportunity.

Page 11 of 12 :
It must be clearly stated that something which is technically **not workable could not have worked in the past 14 years** and will not work in future also. The only solution is to adopt frequency control the way the world is doing.



10% error in each activity, successful rate will be $(0.9)^7 = 0.4783$

20% error in each activity, successful rate will be $(0.8)^7 = 0.2097$



10% error in each activity, successful rate will be $(0.9)^7 = 0.4783$

20% error in each activity, successful rate will be $(0.8)^7 = 0.2097$

Operating Limits & TG response - Generating Units

Date of incident : 02 Mar 2015

Unit 7 of ABCDEF station

Time	Final Load Reference	RFGMO Correction	Actual Load	Actual Frequency
06:49:43	357.87	0	343.58	49.97
06:49:44	357.87	0	343.83	49.97
06:49:45	357.87	0	343.39	49.97
06:49:46	357.87	0	343.00	49.97
06:49:47	357.87	0	343.03	49.97
06:49:48	357.87	0	343.55	49.97
06:49:49	357.87	0	348.22	49.96
06:49:50	357.87	0	347.78	49.91
06:49:51	357.87	0	344.43	49.87
06:49:52	367.69	9.826	344.02	49.86
06:49:53	373.06	15.1964	345.56	49.86
06:49:54	376.98	19.1101	346.02	49.83
06:49:55	380.36	22.4964	344.27	49.81
06:49:56	382.84	25	343.61	49.80
06:49:57	382.87	25	343.94	49.80
06:49:58	382.87	25	344.60	49.79
06:49:59	382.87	25	344.18	49.79
06:50:00	382.87	25	343.63	49.78
06:50:01	382.87	25	343.88	49.77
06:50:02	382.87	25	344.10	49.77
06:50:03	382.89	25	344.07	49.77
06:50:04	382.87	25	343.17	49.77
06:50:05	382.89	25	343.33	49.77
06:50:06	382.86	25	343.83	49.77
06:50:07	382.88	25	343.50	49.77
06:50:08	382.88	25	343.39	49.77
06:50:09	382.88	25	343.19	49.77
06:50:10	382.88	25	343.52	49.77
06:50:11	382.88	25	343.03	49.77
06:50:12	382.88	25	343.88	49.78
06:50:13	382.91	25	343.69	49.78
06:50:14	382.88	25	344.16	49.78
06:50:15	382.88	25	343.80	49.78
06:50:16	382.88	25	344.27	49.78
06:50:17	382.88	25	343.44	49.78
06:50:18	382.85	25	343.33	49.78
06:50:19	382.85	25	343.55	49.78
06:50:20	382.85	25	343.08	49.78
06:50:21	382.85	25	343.52	49.78
06:50:22	382.85	25	343.96	49.78
06:50:23	382.83	25	343.91	49.78
06:50:24	382.83	25	343.11	49.78
06:50:25	382.81	25	343.77	49.78
06:50:26	382.77	25	343.66	49.78
06:50:27	382.77	25	343.55	49.78
06:50:28	382.77	25	343.22	49.78
06:50:29	382.77	25	343.72	49.78
06:50:30	382.77	25	344.02	49.77

RGMO block operated
But no change in actual MW ???

Courtesy: RGMO web group, SR

NCTPS, TANGEDCO

Date of incident : 02 Mar 2015

Units 5 & 6 of ABCDEF station

Time	Frequency	UNIT-5		UNIT-6	
		LOAD	FGMO Correction	LOAD	FGMO Correction
06:50:00	49.97	214.34	0.00	214.45	0.00
06:50:01	49.96	213.71	0.00	213.99	0.00
06:50:02	49.96	213.96	0.00	213.95	0.00
06:50:03	49.96	213.99	0.00	214.37	0.00
06:50:04	49.95	214.02	0.00	214.37	0.00
06:50:05	49.93	215.89	0.00	216.61	0.00
06:50:06	49.86	215.48	0.00	215.52	0.00
06:50:07	49.85	213.84	0.00	214.17	0.19
06:50:08	49.83	213.80	0.00	213.99	2.11
06:50:09	49.81	214.00	1.37	214.42	3.02
06:50:10	49.81	214.26	2.13	214.00	3.02
06:50:11	49.79	214.45	3.11	214.00	4.02
06:50:12	49.79	214.00	4.20	213.88	5.23
06:50:13	49.77	213.51	5.29	214.10	6.34
06:50:14	49.76	213.79	6.14	214.46	7.97
06:50:15	49.78	214.02	7.14	214.51	8.54
06:50:16	49.78	213.83	7.89	214.58	8.54
06:50:17	49.76	214.07	8.47	214.58	8.97
06:50:18	49.75	214.22	8.97	214.93	9.31
06:50:19	49.76	214.70	9.28	215.00	9.58
06:50:20	49.76	214.96	9.55	214.65	9.78
06:50:21	49.76	215.01	9.76	215.27	10.07
06:50:22	49.77	215.17	9.92	215.40	10.16
06:50:23	49.77	215.52	10.05	215.06	10.24
06:50:24	49.77	215.83	10.15	215.30	10.29
06:50:25	49.77	215.76	10.23	215.30	10.34
06:50:26	49.77	215.90	10.29	215.61	10.40
06:50:27	49.78	216.12	10.33	215.38	10.40
06:50:28	49.78	216.49	10.37	215.98	10.40
06:50:29	49.78	216.27	10.40	215.89	10.44
06:50:30	49.78	216.00	10.35	215.64	10.44

Operating Limits & TG response – Generating Units

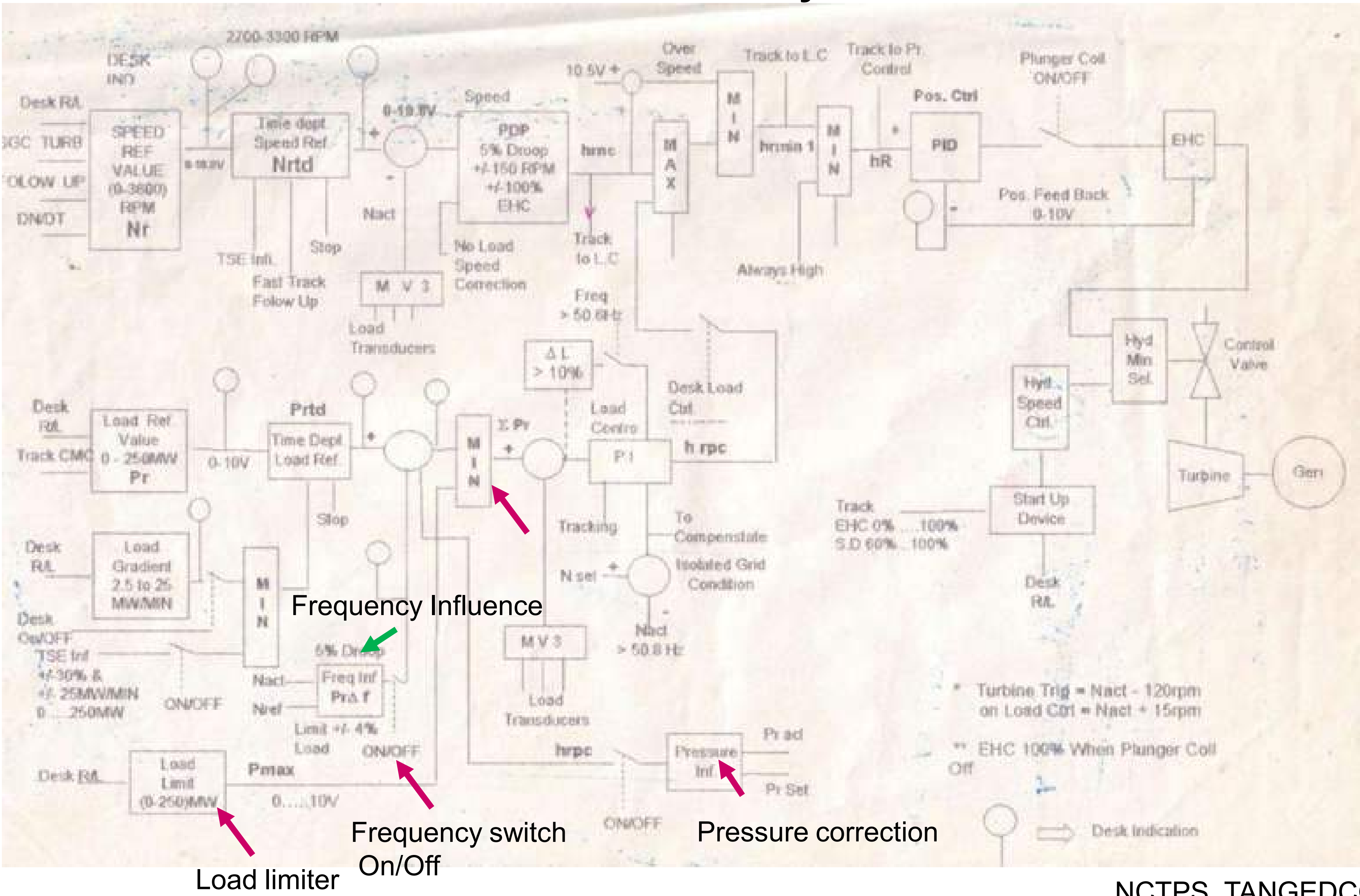
Courtesy: RGMO web group, SR

RGMO block operated

But no change in actual MW ???

NCTPS, TANGEDCO

Turbine Control System



NCTPS, TANGEDCO

Operating Limits & TG response - Generating Units

IEGC 5.2 (g)

(g) 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 and no dead bands and/or time delays shall be deliberately introduced except as specified in para 5.2(f) above.

Frequency switch On/Off

Visibility of RGMO status of Generating units in State LDC room via SCADA

Operating Limits & TG response - Generating Units

Date of incident : 02 Mar 2015

Unit **3** of ABCDEF station

Time	RFGMO Correction	Actual Load	Actual Frequency
49:48.0	0	215.3105	49.9724
49:48.2	0	215.3105	49.9724
49:48.4	0	215.3105	49.9724
49:48.6	0	215.3105	49.9724
49:48.8	0	216.2341	49.9621
49:49.0	0	216.2341	49.9621
49:49.2	0	216.2341	49.9621
49:49.4	0	216.2341	49.9621
49:49.6	0	216.2341	49.9621
49:49.8	0	216.6395	49.9077
49:50.0	0	216.6395	49.9077
49:50.2	0	216.6395	49.9077
49:50.4	0	216.6395	49.9077
49:50.6	0	215.4571	49.8578
49:50.8	0	215.4571	49.8578
49:51.0	0	215.4571	49.8578
49:51.2	0	215.4571	49.8578
49:51.4	0	215.4571	49.8578
49:51.6	0	215.4571	49.8578
49:51.8	5.4414	214.1394	49.8509
49:52.0	5.4414	214.1394	49.8509
49:52.2	5.4414	214.1394	49.8509
49:52.4	5.4414	214.1394	49.8509
49:52.6	7.8997	214.9839	49.8489
49:52.8	7.8997	214.9839	49.8489
49:53.0	7.8997	214.9839	49.8489
49:53.2	7.8997	214.9839	49.8489
49:53.4	7.8997	214.9839	49.8489
49:53.6	7.8997	214.9839	49.8489
49:53.8	8.7842	215.4006	49.823
49:54.0	8.7842	215.4006	49.823
49:54.2	8.7842	215.4006	49.823
49:54.4	8.7842	215.4006	49.823
49:54.6	10.5	214.6574	49.7985
49:54.8	10.5	214.6574	49.7985
49:55.0	10.5	214.6574	49.7985
49:55.2	10.5	214.6574	49.7985
49:55.4	10.5	214.6574	49.7985
49:55.6	10.5	214.4096	49.7916
49:55.8	10.5	214.4096	49.7916
49:56.0	10.5	214.4096	49.7916
49:56.2	10.5	214.4096	49.7916
49:56.4	10.5	214.4096	49.7916
49:56.6	10.5	214.4096	49.7916

Courtesy: RGMO web group, SR

Unit **4** of ABCDEF station

Time	RFGMO Correction	Actual Load	Actual Frequency
49:43.6	4.6109	215.5611	49.9748
49:43.8	4.6109	215.5611	49.9748
49:44.0	4.6109	215.5611	49.9748
49:44.2	4.6696	215.4924	49.9748
49:44.4	4.6696	215.4924	49.9748
49:44.6	4.6696	215.4924	49.9748
49:44.8	4.6696	215.4924	49.9748
49:45.0	4.6696	215.4924	49.9748
49:45.2	4.8867	215.149	49.9748
49:45.4	4.8867	215.149	49.9748
49:45.6	4.8867	215.149	49.9748
49:45.8	4.8867	215.149	49.9748
49:46.0	4.8867	215.149	49.9748
49:46.2	5.0501	215.0117	49.9748
49:46.4	5.0501	215.0117	49.9748
49:46.6	5.0501	215.0117	49.9748
49:46.8	5.0501	215.0117	49.9748
49:47.0	5.0501	215.0117	49.9748
49:47.2	5.0501	215.0117	49.9748
49:47.4	4.8361	215.7671	49.9748
49:47.6	4.8361	215.7671	49.9748
49:47.8	4.8361	215.7671	49.9748
49:48.0	4.8361	215.7671	49.9748
49:48.2	4.9212	216.6827	49.9748
49:48.4	4.9212	216.6827	49.9748
49:48.6	4.9212	216.6827	49.9748
49:48.8	4.9212	216.6827	49.9748
49:49.0	4.9212	216.6827	49.9748
49:49.2	5.0593	217.1291	49.9748
49:49.4	5.0593	217.1291	49.9748
49:49.6	5.0593	217.1291	49.9748
49:49.8	5.0593	217.1291	49.9748
49:50.0	5.0593	217.1291	49.9748
49:50.2	6.7485	215.8931	49.9352
49:50.4	6.7485	215.8931	49.9352
49:50.6	6.7485	215.8931	49.9352
49:50.8	6.7485	215.8931	49.9352
49:51.0	6.7485	215.8931	49.9352
49:51.2	6.7485	215.8931	49.9352
49:51.4	10.5	214.9087	49.8878
49:51.6	10.5	214.9087	49.8878
49:51.8	10.5	214.9087	49.8878
49:52.0	10.5	214.9087	49.8878
49:52.2	10.5	215.4924	49.8878
49:52.4	10.5	215.4924	49.8878
49:52.6	10.5	215.4924	49.8878
49:52.8	10.5	215.4924	49.8878
49:53.0	10.5	215.4924	49.8878

Halt time of 3 Mins

RGMO block operated

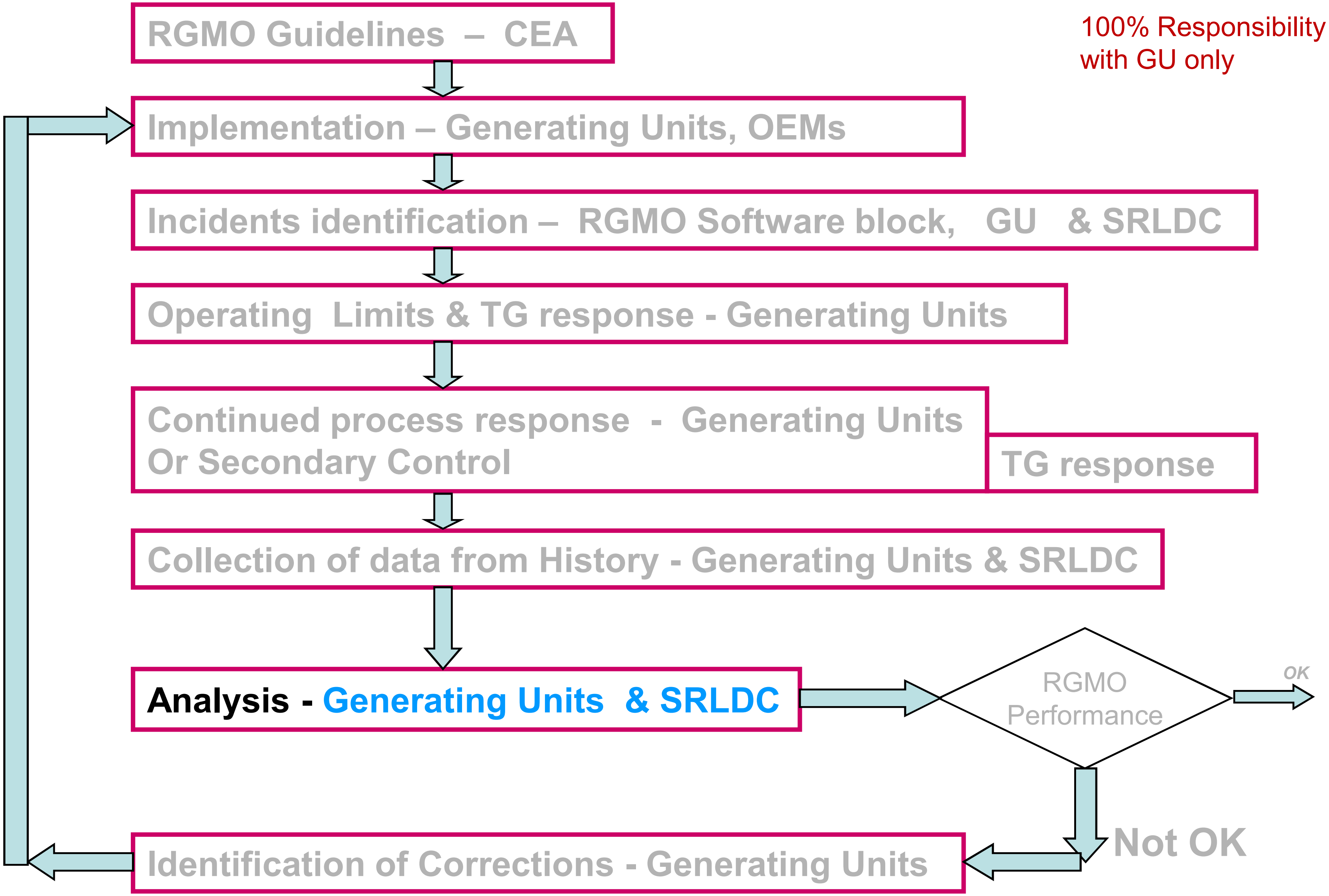
But no change in actual MW

Five Units 55 MW

Response NIL

NCTPS, TANGEDCO

100% Responsibility
with GU only



10% error in each activity, successful rate will be $(0.9)^7$ = 0.4783

20% error in each activity, successful rate will be $(0.8)^7$ = 0.2097

NCTPS, TANGEDCO

Analysis - Generating Units & SRLDC

Unit #/Station	MCR of Machines on Bar	5% of MCR	Current generation	RGMO Expected 5% of current generation	Actual RGMO response
1/wxyz	500	25	405	20.25	xx
2/wxyz	500	25	432	21.6	yy
3/wxyz	500	25	468	23.4	zz
1/abcde	210	10.5	201	10.05	aa
2/abcde	210	10.5	185	9.25	bb
	Total	96		84.55	

Analysis - Generating Units & SRLDC

23rd June 2014

SOUTHERN REGIONAL POWER COMMITTEE
BANGALORE

MINUTES OF THE SPECIAL MEETING ON RGMO /MVAR HELD AT SRPC BANGALORE ON 23rd JUNE 2014

Shri S.R. Bhat, Member Secretary I/c, SRPC welcomed the participants to the Special Meeting. He especially welcomed Shri S.C. Shrivastava, Joint Chief (Engg.), CERC who had kindly agreed to participate in the Meeting. He informed that this was the 5th Meeting (earlier Meetings had been held on 29.06.2014, 25.07.2013, 30.09.2013 & 29.01.2014) in this regard.

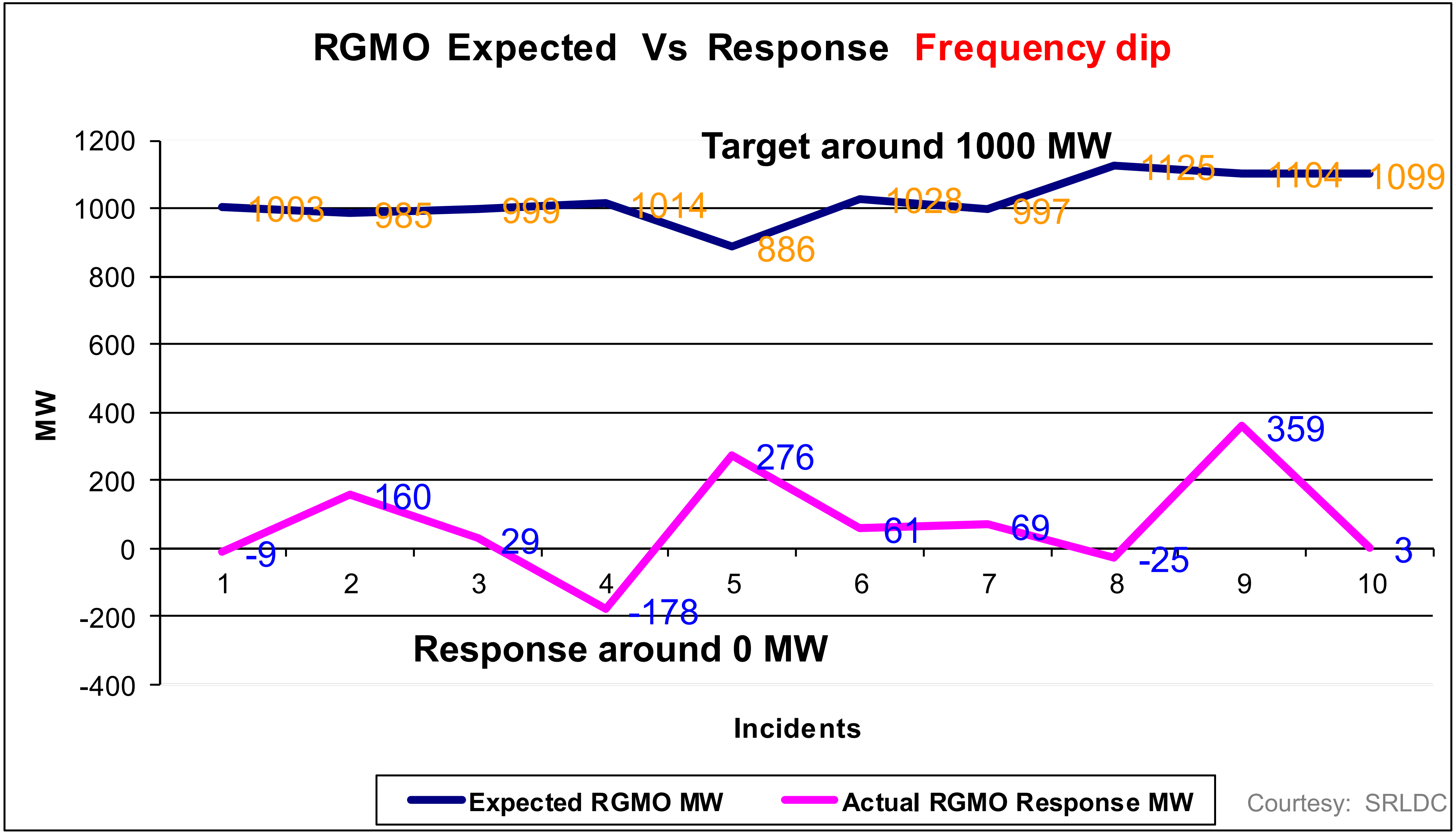
- In response to taking out RGMO at technical minimum, it was stated that issues relating to technical minimum were being studied/deliberated in the Commission. Taking out of RGMO, during technical minimum conditions was not advisable since grid security would get compromised.

- Generators were expected to give response of 5% of the current generation subject to 105% of MCR and analysis would be carried out accordingly for new instances.

On 02 Mar 2015 incident, SR response was 159 * MW as against the target of 744 MW

Now it is not 1000 MW. Thanks to Shri.Shrivastavaji

Southern Region, India



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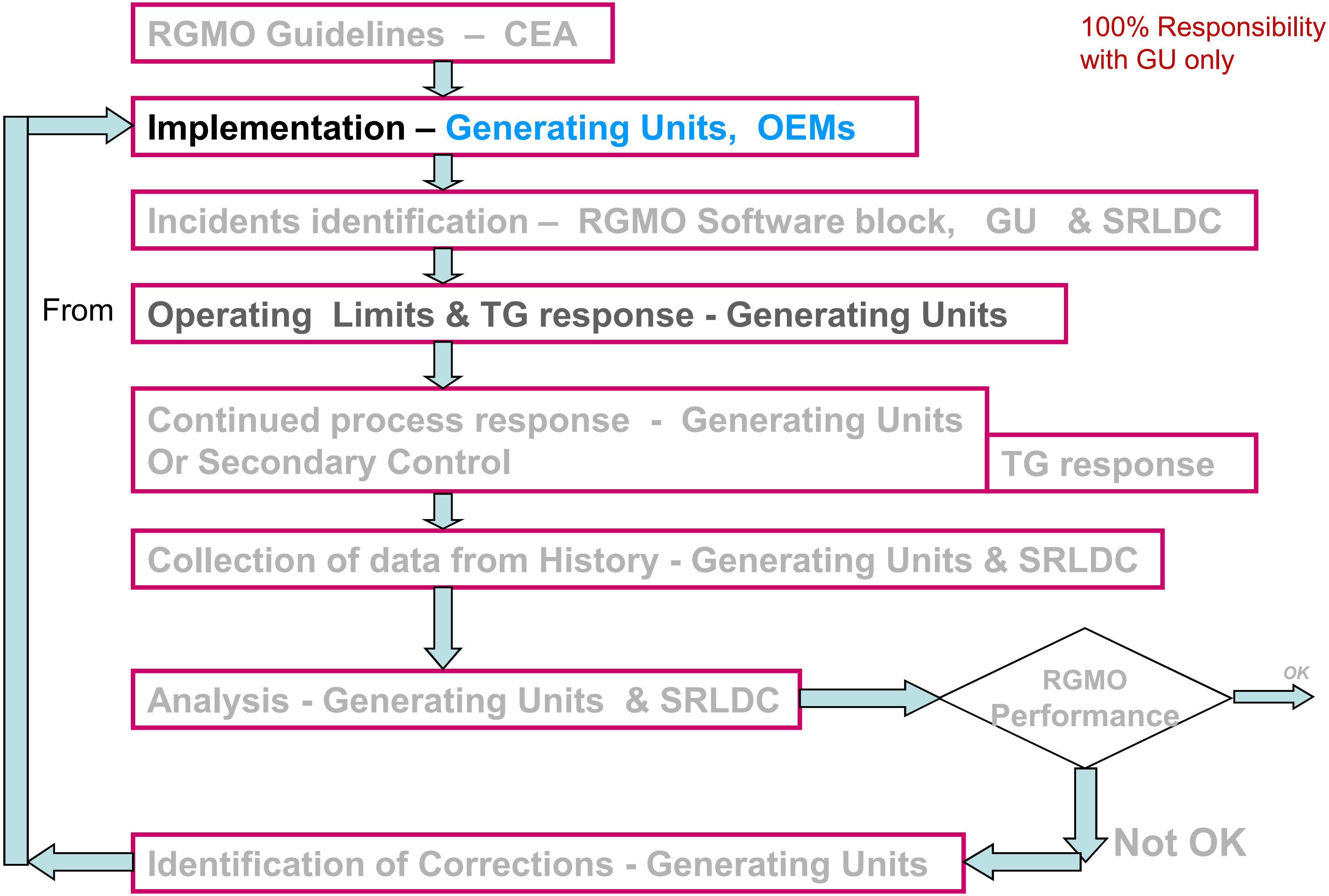
100% Responsibility
with GU only



10% error in each activity, successful rate will be $(0.9)^7 = 0.4783$

20% error in each activity, successful rate will be $(0.8)^7 = 0.2097$

Implementation – Generating Units, OEMs

+344*0,05 = 17.2 MW

Unit 7 of ABCDEF station

Date of incident : 02 Mar 2015

Time	Final Load Reference	RFGMO Correction	Actual Load	Actual Frequency
06:49:43	357.87	0	343.58	49.97
06:49:44	357.87	0	343.83	49.97
06:49:45	357.87	0	343.39	49.97
06:49:46	357.87	0	343.00	49.97
06:49:47	357.87	0	343.03	49.97
06:49:48	357.87	0	343.55	49.97
06:49:49	357.87	0	348.22	49.96
06:49:50	357.87	0	347.78	49.91
06:49:51	357.87	0	344.43	49.87
06:49:52	367.69	9.826	344.02	49.86
06:49:53	373.06	15.1964	345.56	49.86
06:49:54	376.98	19.1101	346.02	49.83
06:49:55	380.36	22.4964	344.27	49.81
06:49:56	382.84	25	343.61	49.80
06:49:57	382.87	25	343.94	49.80
06:49:58	382.87	25	344.60	49.79
06:49:59	382.87	25	344.18	49.79
06:50:00	382.87	25	343.63	49.78
06:50:01	382.87	25	343.88	49.77
06:50:02	382.87	25	344.10	49.77
06:50:03	382.89	25	344.07	49.77
06:50:04	382.87	25	343.17	49.77
06:50:05	382.89	25	343.33	49.77
06:50:06	382.86	25	343.83	49.77
06:50:07	382.88	25	343.50	49.77
06:50:08	382.88	25	343.39	49.77
06:50:09	382.88	25	343.19	49.77
06:50:10	382.88	25	343.52	49.77
06:50:11	382.88	25	343.03	49.77
06:50:12	382.88	25	343.88	49.78
06:50:13	382.91	25	343.69	49.78
06:50:14	382.88	25	344.16	49.78
06:50:15	382.88	25	343.80	49.78
06:50:16	382.88	25	344.27	49.78
06:50:17	382.88	25	343.44	49.78
06:50:18	382.85	25	343.33	49.78
06:50:19	382.85	25	343.55	49.78
06:50:20	382.85	25	343.08	49.78
06:50:21	382.85	25	343.52	49.78
06:50:22	382.85	25	343.96	49.78
06:50:23	382.83	25	343.91	49.78
06:50:24	382.83	25	343.11	49.78
06:50:25	382.81	25	343.77	49.78
06:50:26	382.77	25	343.66	49.78
06:50:27	382.77	25	343.55	49.78
06:50:28	382.77	25	343.22	49.78
06:50:29	382.77	25	343.72	49.78
06:50:30	382.77	25	344.02	49.77

This shall be 17 MW

It is not 25 MW

Courtesy: RGMO web group, SR

NCTPS, TANGEDCO

aRTPP data from EXCEL file.

From the submission of
Er.P.P.Francis, GM (OS), NTPC Ltd.,

Page 3 of 12 :

NTPC's understanding of the requirements, as realized in most of the EHG controlled machines of NTPC:

If frequency < 50.05 Hz, any decrease in frequency will result in increase in generation by Governor Action as per droop (4-5 %)

If the frequency < 50.05 Hz, any increase in frequency will not result in decrease in generation by Governor Action

If frequency > 50.05 Hz, any increase in frequency will result in decrease in generation by Governor Action, though there is no explicit stipulation in this regard in the IEGC

Implementation – Generating Units, OEMs

The quantum of generation change by Governor Action will be limited to ±5%

The increased / decreased generation will be offset by a slow automatic resetting command to ramp back to the original MW set point @ 1% per minute

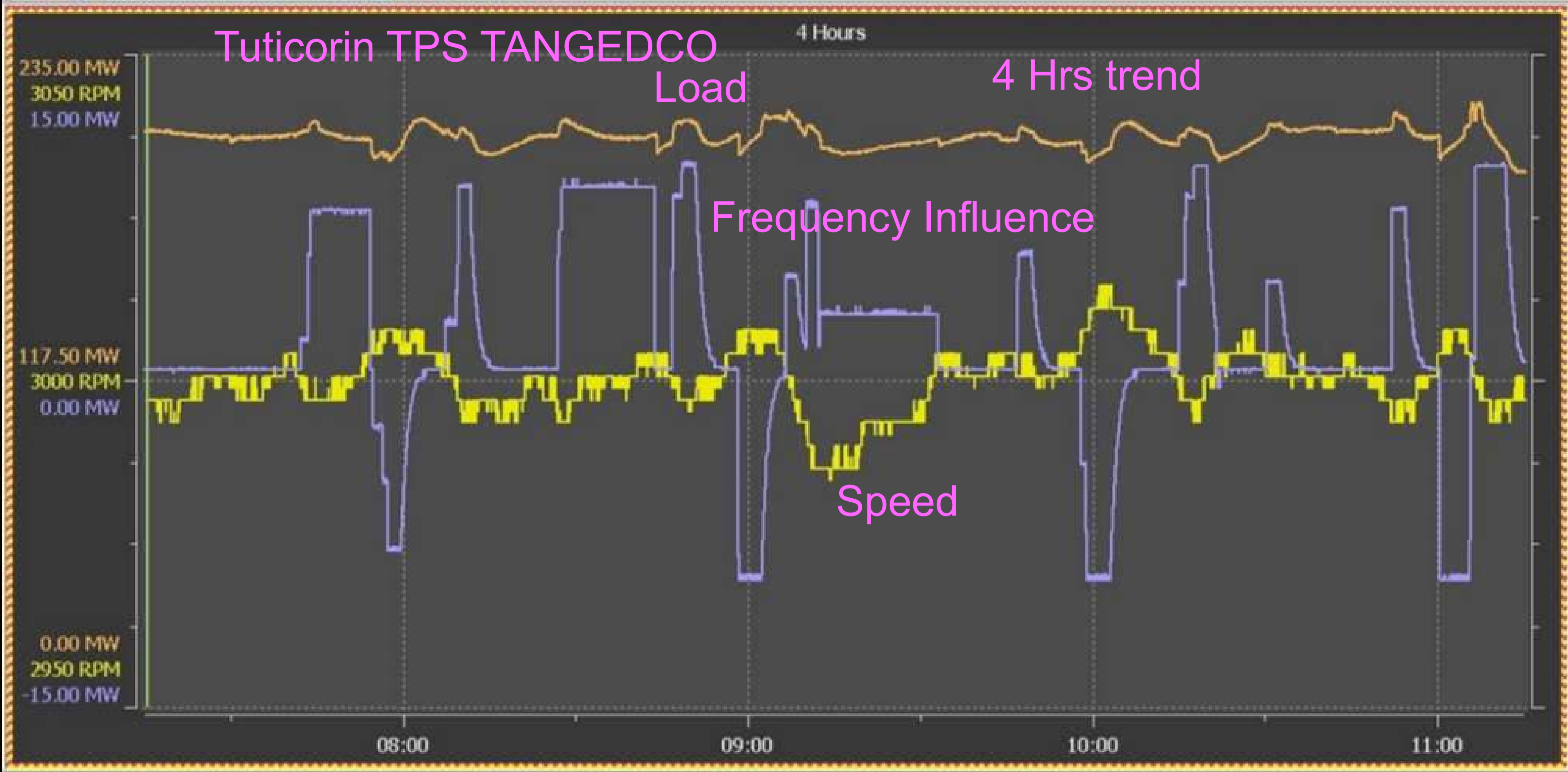
Note: *The frequency threshold of 50.05 Hz mentioned in the above, was introduced in place of 50.20 Hz in the IEGC stipulation, by the Second Amendment dated 06.01.2014, effective from 17.02.2014*

IEGC 5.2 (f)

ii) The restricted governor mode of operation shall essentially have the following features:

b) Ripple filter of +/- 0.03 Hz. shall be provided so that small changes in frequency are ignored for load correction, in order to prevent governor hunting.

Operator Trend Group : Operator Trend-1



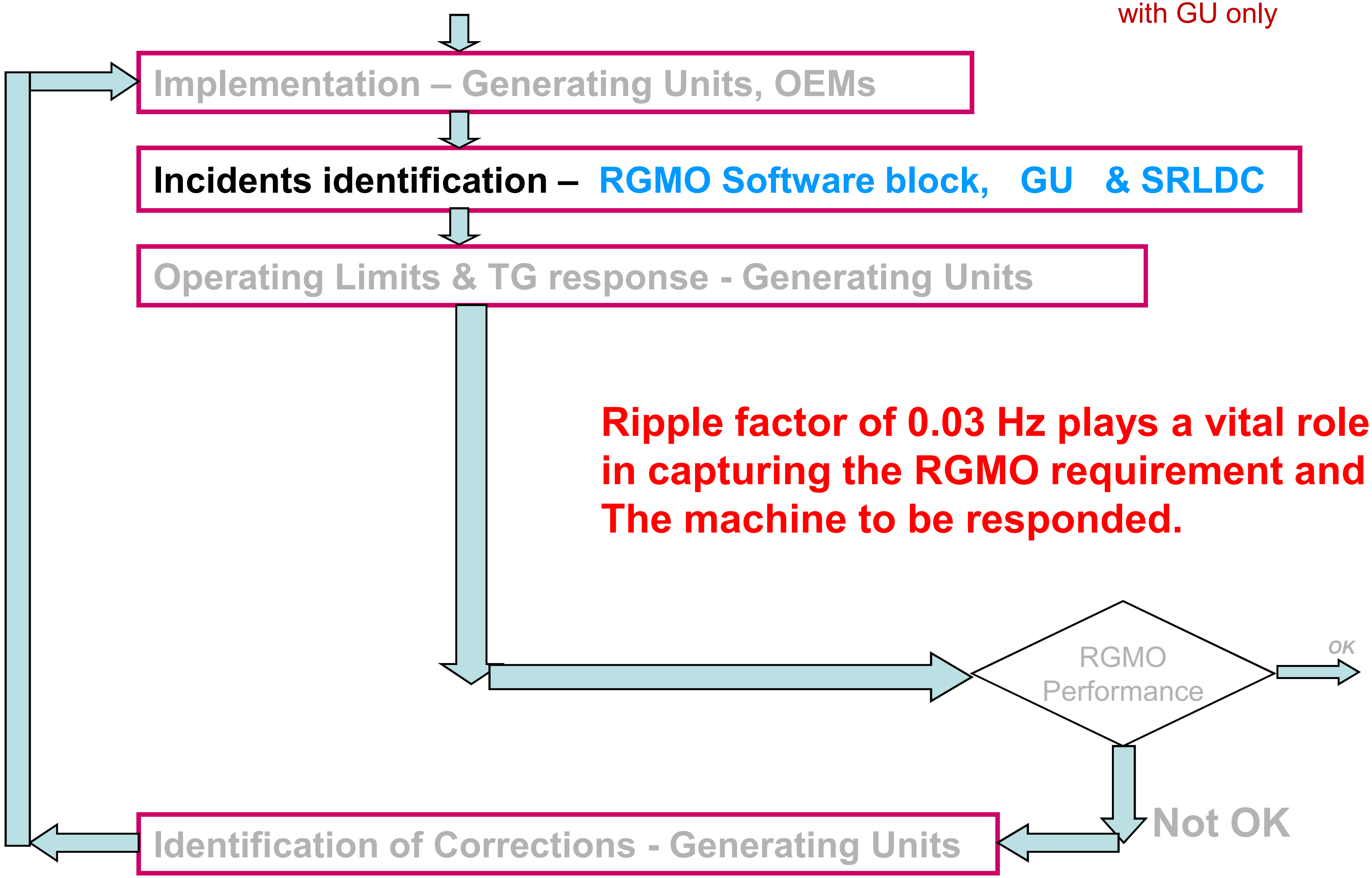
4 Hours | 20-Nov-14 9:15:00 AM

	S	Vi	T	Obje	Object Description	Current Valu	Low Ra	High Ra	Style	Ruler Time	Ruler Value	Mean Val	Min Valu	Max Valu	Treatm	Property	Log Name	Pai	Time
1		☐		04MA	E.H.G. POSITION	84.72 %			Stepp			76.22 %	68.60 %	90.72 %	ExtMom	.Value	SEAMLES	0	00:00:
2		☐		GE01	GRID FREQUENCY	50.01 Hz			Stepp			50.07 Hz	49.83 Hz	50.27 Hz	ExtMom	Value	SEAMLES	0	00:00:
3		☑		04M	LOAD	211.30 MW	0.00	235.0	Stepp	20-Nov-14 7:15:25	207.15 MW	205.29 M	192.38 M	217.90 M	ExtMom	.Value	SEAMLES	0	00:00:
4		☐		04M	SPEED REF	2999 RPM			Stepp			2998 RP	2987 RP	3011 RP	ExtMom	.Value	SEAMLES	0	00:00:
5		☐		04M	FINAL LOAD REF	211.91 MW			Stepp			205.95 M	192.99 M	220.95 M	ExtMom	.Value	SEAMLES	0	00:00:
6		☑		04M	SPEED	2997 RPM	2950	3050	Stepp	20-Nov-14 7:15:25	2997 RPM	3001 RP	2985 RP	3015 RP	ExtMom	.Value	SEAMLES	0	00:00:
7		☐		04M	SPEED REF LIMITED	3001 RPM	0 RP	3603	Stepp			3000 RP	2988 RP	3013 RP	ExtMom	.Value	SEAMLES	0	00:00:
8		☐		04MA	HP CTRL VLV 2 POSN	80.91 %	0.00	110.0	Stepp			64.63 %	49.46 %	92.48 %	ExtMom	.Value	SEAMLES	0	00:00:
9		☐		04LB	MS PRESSURE BEFO	142.77 Kg/Cm	100.0	148.0	Stepp			143.15 K	136.72 K	151.66 K	ExtMom	.Value	SEAMLES	0	00:00:
10		☑		04M	FREQUENCY INFLUE	5.98 MW	-15.00	15.00	Stepp	20-Nov-14 7:15:25	0.49 MW	1.73 MW	-9.16 MW	10.01 M	ExtMom	.Value	SEAMLES	0	00:00:
11		☐														5.43 MW	0.49 MW		
12		☐																	

Start

3:08 PM
20-Nov-14

100% Responsibility
with GU only



10% error in each activity, successful rate will be $(0.9)^7 = 0.4783$

20% error in each activity, successful rate will be $(0.8)^7 = 0.2097$

Incidents identification – RGMO Software block, GU & SRLDC

Analysis - Generating Units & SRLDC

Instances posted by SRLDC for August 2014

Date	Time		Frequency	
	From	To	From	To
8/8/2014	11:31	11:32	49.85	49.74
9/8/2014	6:00	6:01	50.08	50.19
10/8/2014	14:31	14:32	50.06	49.93

Analysis - Generating Units & SRLDC

SOUTHERN REGIONAL POWER COMMITTEE
BANGALORE

MINUTES OF THE SPECIAL MEETING ON RGMO/MVAR HELD AT SRPC BANGALORE ON 27th AUGUST 2014

1. **INTRODUCTION**

A Special Meeting on RGMO performance & MVAR Interchange of SR Generators was held at Bangalore on 27th August 2014.The list of Participants

NCTPS, TANGEDCO made a Presentation wherein it was pointed out that rate of frequency change was less than +/- 0.03 Hz per second and hence RGMO response was not expected during such incidents. BTPS, KPCL also endorsed the views of TANGEDCO and pointed out df/dt was not adequate to warrant RGMO response. However, it was noted that certain units had responded while some others had shown partial response during the above incident though df/dt change was less than the mandated one. It was therefore agreed that analysis for the above incidents would not be considered.

NCTPS, TANGEDCO

Incidents identification – RGMO Software block, GU & SRLDC

Analysis - Generating Units & SRLDC

SOUTHERN REGIONAL POWER COMMITTEE
BANGALORE

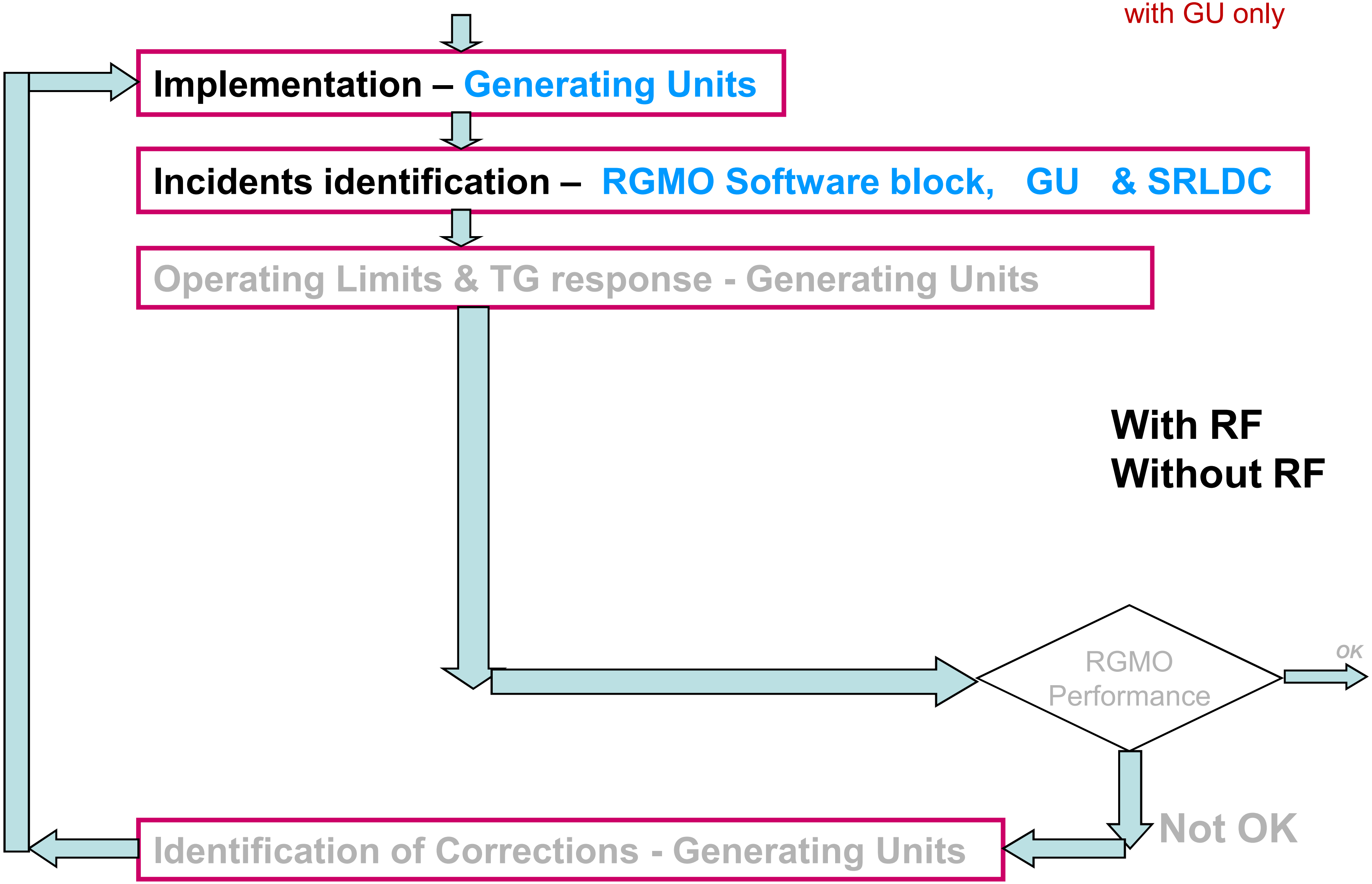
MINUTES OF THE SPECIAL MEETING ON RGMO/MVAR HELD AT SRPC BANGALORE ON 27th AUGUST 2014

Other deliberations in the Meeting:

- SRLDC would also consider PMU input before putting the incidents for analysis. NCTPS would also assist in the process. Incidents would be selected to ensure that adequate df/dt change is visible for RGMO action.

SRLDC started changing the methodology in identifying the RGMO incidents

100% Responsibility
with GU only



With RF
Without RF

10% error in each activity, successful rate will be $(0.9)^7 = 0.4783$

20% error in each activity, successful rate will be $(0.8)^7 = 0.2097$

Implementation – Generating Units

Incidents identification –

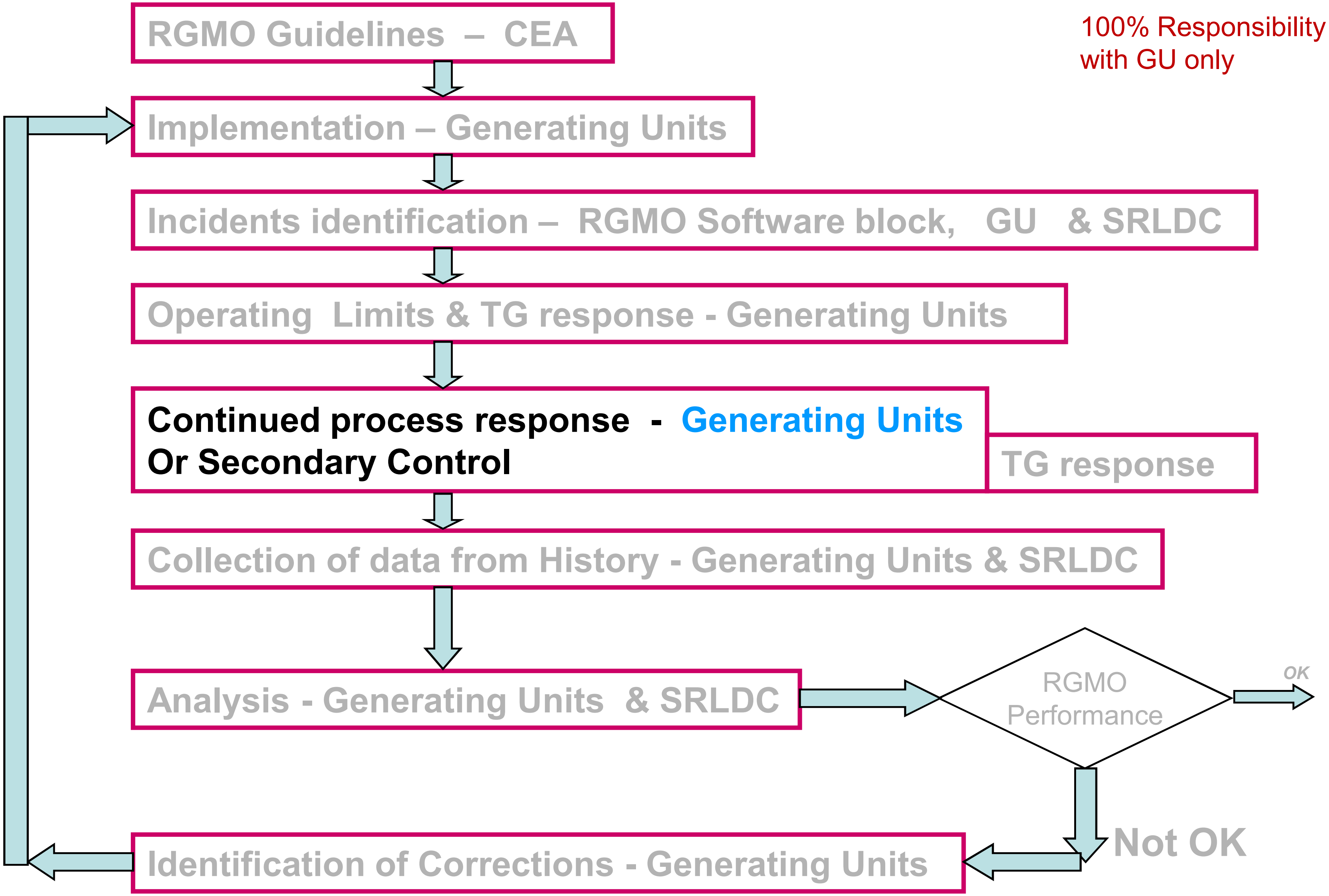
Date of Incident : 02 Mar 2015						RGMO Response				
Time	Grid Freq	Unit-4 Load	Unit-5 Load	Unit-6 Load	Unit-7 Load	Unit-4	Unit-5	Unit-6	Unit-7	Total
6:45:00	50.00	516.5	512.2	515.4	516.7					
6:46:00	50.07	515.0	511.6	515.9	515.6					
6:47:00	50.06	517.1	511.8	515.6	513.5					
6:48:00	50.02	516.7	511.7	517.8	513.4					
6:49:00	49.98	517.2	513.8	518.4	512.9					
6:50:00	49.85	517.0	515.2	521.1	516.4	-0.2	1.5	2.7	3.5	7.5
6:51:00	49.76	516.2	516.0	520.0	515.8	-0.7	0.8	-1.1	-0.6	-1.6
6:52:00	49.74	516.4	515.9	520.9	515.9	0.2	-0.1	0.9	0.1	1.1
6:53:00	49.71	515.2	516.7	520.4	518.1	-1.2	0.8	-0.5	2.2	1.3
6:54:00	49.69	512.5	516.9	519.4	519.5	-2.7	0.2	-1.0	1.4	-2.1
6:55:00	49.68	510.4	516.9	519.3	520.5					
6:56:00	49.68	511.5	516.5	518.9	521.6					
6:57:00	49.70	510.2	517.0	517.9	522.5					
6:58:00	49.72	511.0	516.4	518.0	521.6					
6:59:00	49.77	506.7	516.3	517.6	520.7					
7:00:00	49.82	509.4	516.5	516.9	520.5					
7:01:00	49.87	517.7	515.7	516.3	521.3					

As against 100 MW, only 7.5 MW received.

U4 & U7 w/o RF
Hunting

U5 & U6 with RF
Capturing

100% Responsibility
with GU only



10% error in each activity, successful rate will be $(0.9)^7 = 0.4783$

20% error in each activity, successful rate will be $(0.8)^7 = 0.2097$

NCTPS, TANGEDCO

Continued process response - Generating Units Or Secondary Control

For older machines, the **CMC services are not available** and this facility will be made after renovation and Modernisation of obsolete control systems. **Most of the power plants served for more than twenty years are already in the process of going towards the latest Digital Control System.** Boiler loadings will be varied by CMC for extending the sustainability of RGMO response.

Thermal reserve available in the boiler only shall have to be utilised as RGMO and for sustainability.

In RGMO also, if attempted without boiler firing change the pressure deviation forces to reset the output change quickly. **Sustainability depends on the operator's performance over the process in older plants.**

Honeywell's Digital Control System of 1980's design is working in NCTPS for the last 21 years.

Continued process response - Generating Units Or Secondary Control

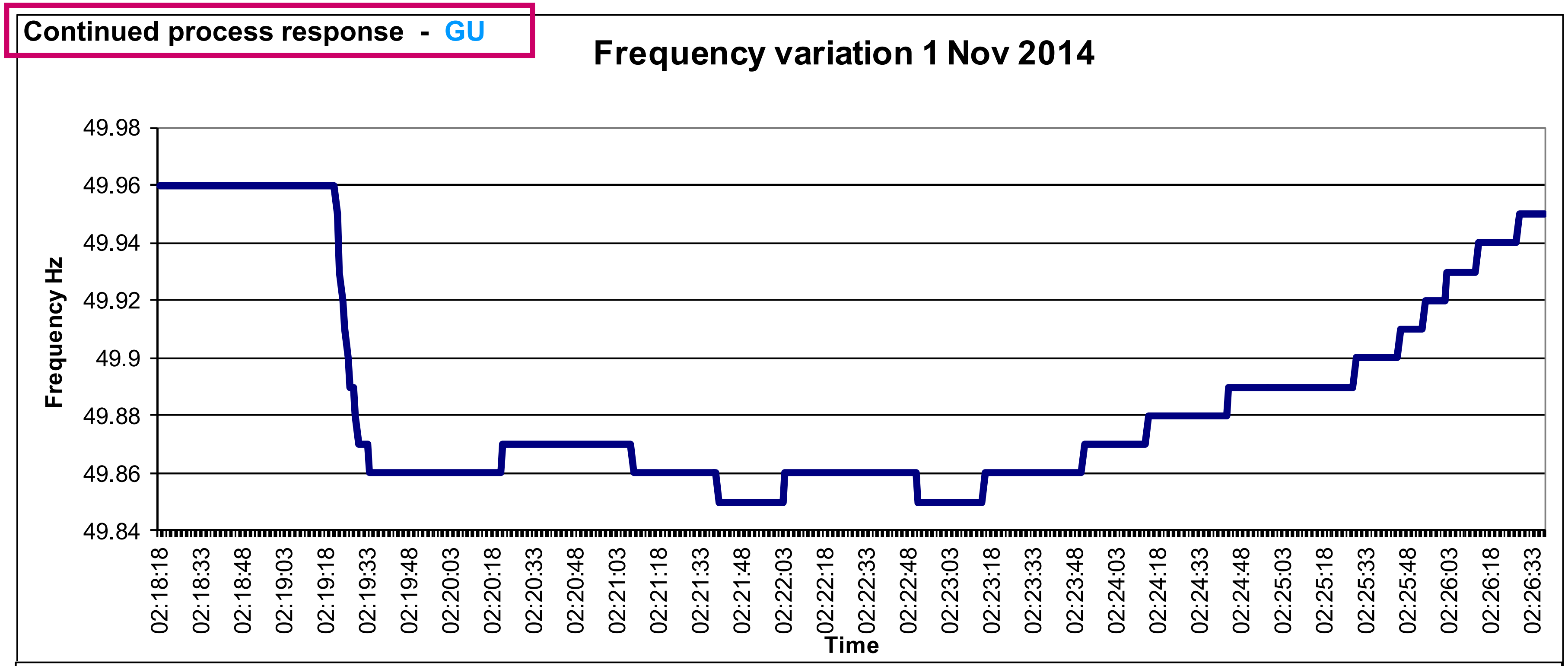
Minute values of Generation

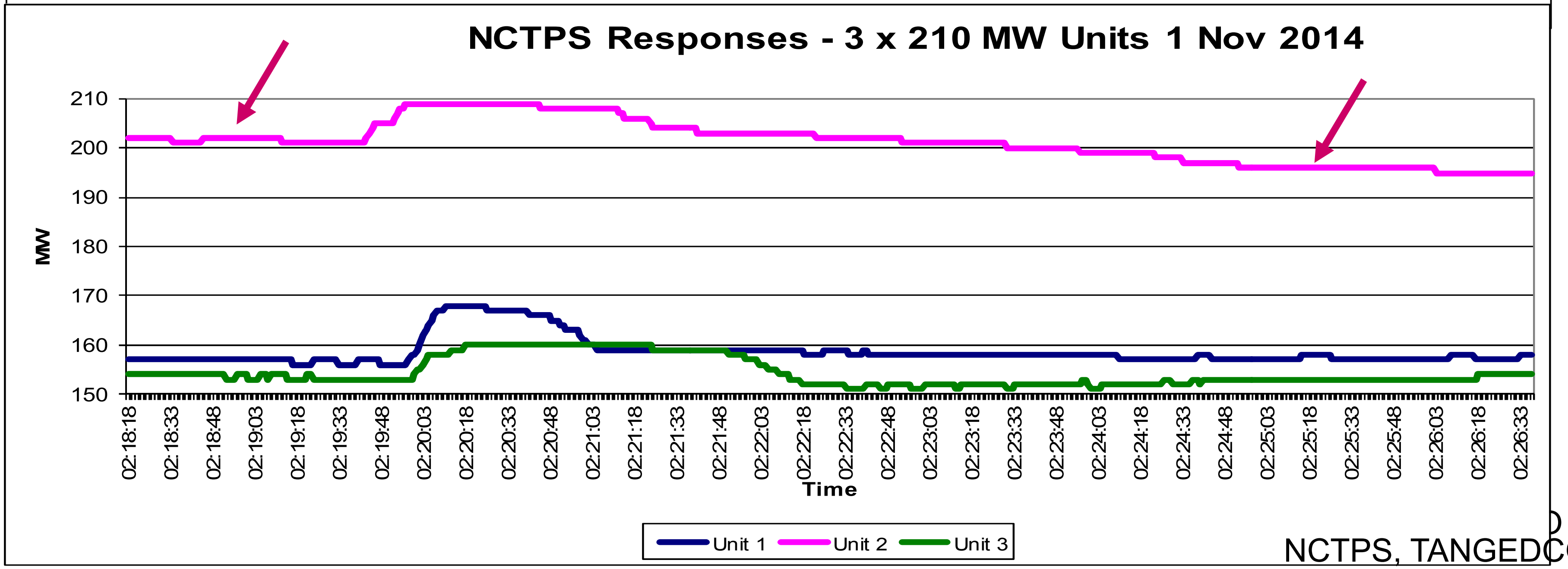
North Chennai Thermal power Station, 3 x 210 MW Units TANGEDCO							
			Generation in MW				
Date	Time	Freuency	Unit 1	Unit 2	Unit 3	Total	Response & %
01-Nov-14	02:15:00	49.9	158	200	155		
01-Nov-14	02:16:00	49.92	157	200	155		
01-Nov-14	02:17:00	49.93	157	201	155		
01-Nov-14	02:18:00	49.95	157	201	154		
01-Nov-14	**02:19:00**	**49.96**	**157**	**201**	**153**	**511**	
01-Nov-14	**02:20:00**	**49.86**	**168**	**209**	**160**	**537**	**26**
01-Nov-14	**02:21:00**	**49.87**	**162**	**208**	**160**		**5.09** %
01-Nov-14	**02:22:00**	**49.85**	**159**	**203**	**157**		
01-Nov-14	**02:23:00**	**49.85**	**158**	**201**	**152**		
01-Nov-14	02:24:00	49.87	**158**	**199**	**152**		

Not restored to original level due to Boiler's large time constant

NCTPS, TANGEDCO

Continued process response - GU

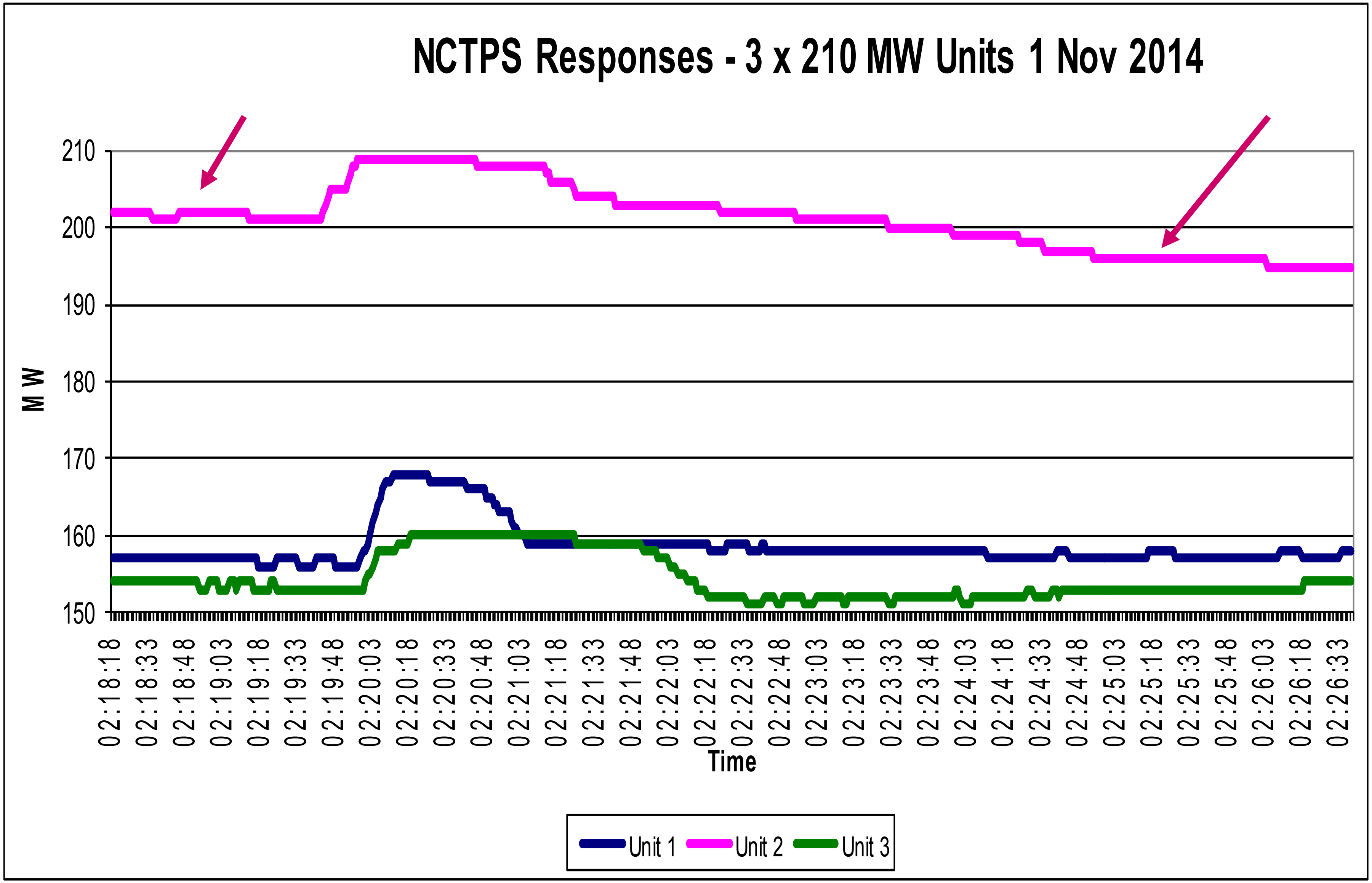




NCTPS, TANGEDCO

Continued process response - GU

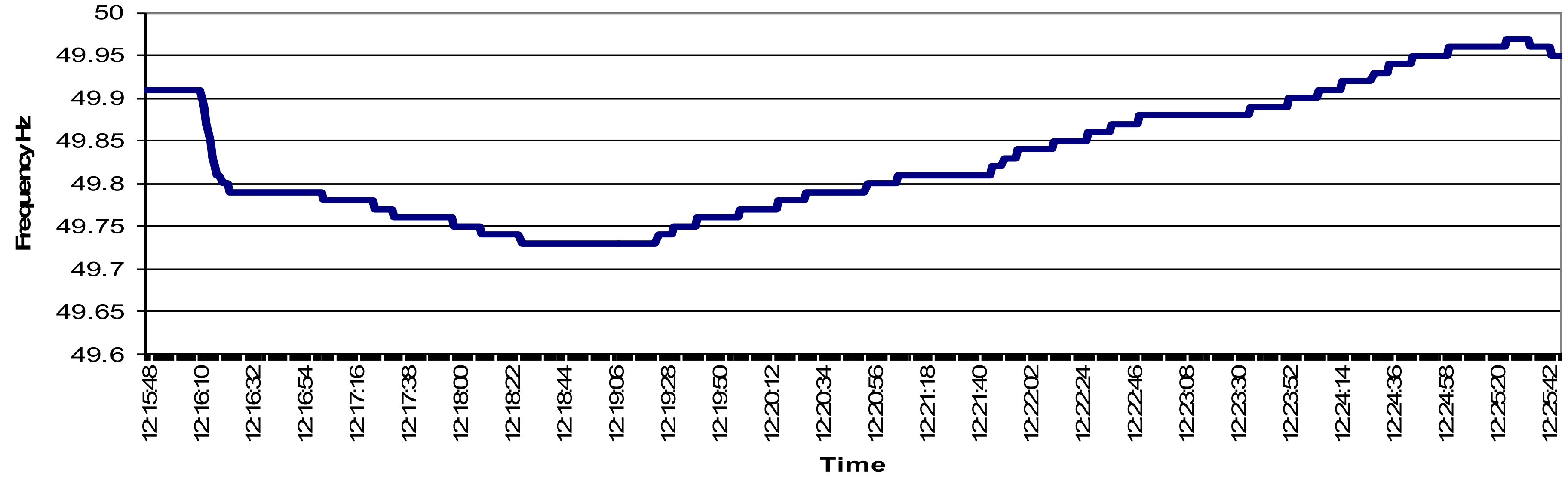
Fall occur at Fourth or fifth minute



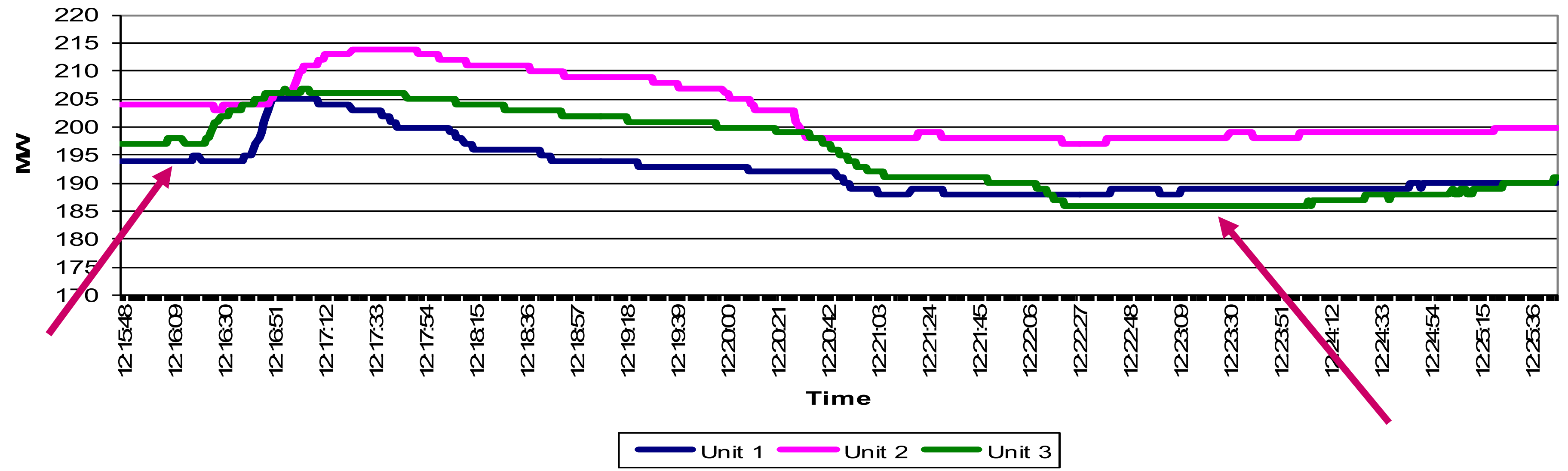
NCTPS, TANGEDCO

Continued process response - GU

Frequency variation 23 Nov 2014

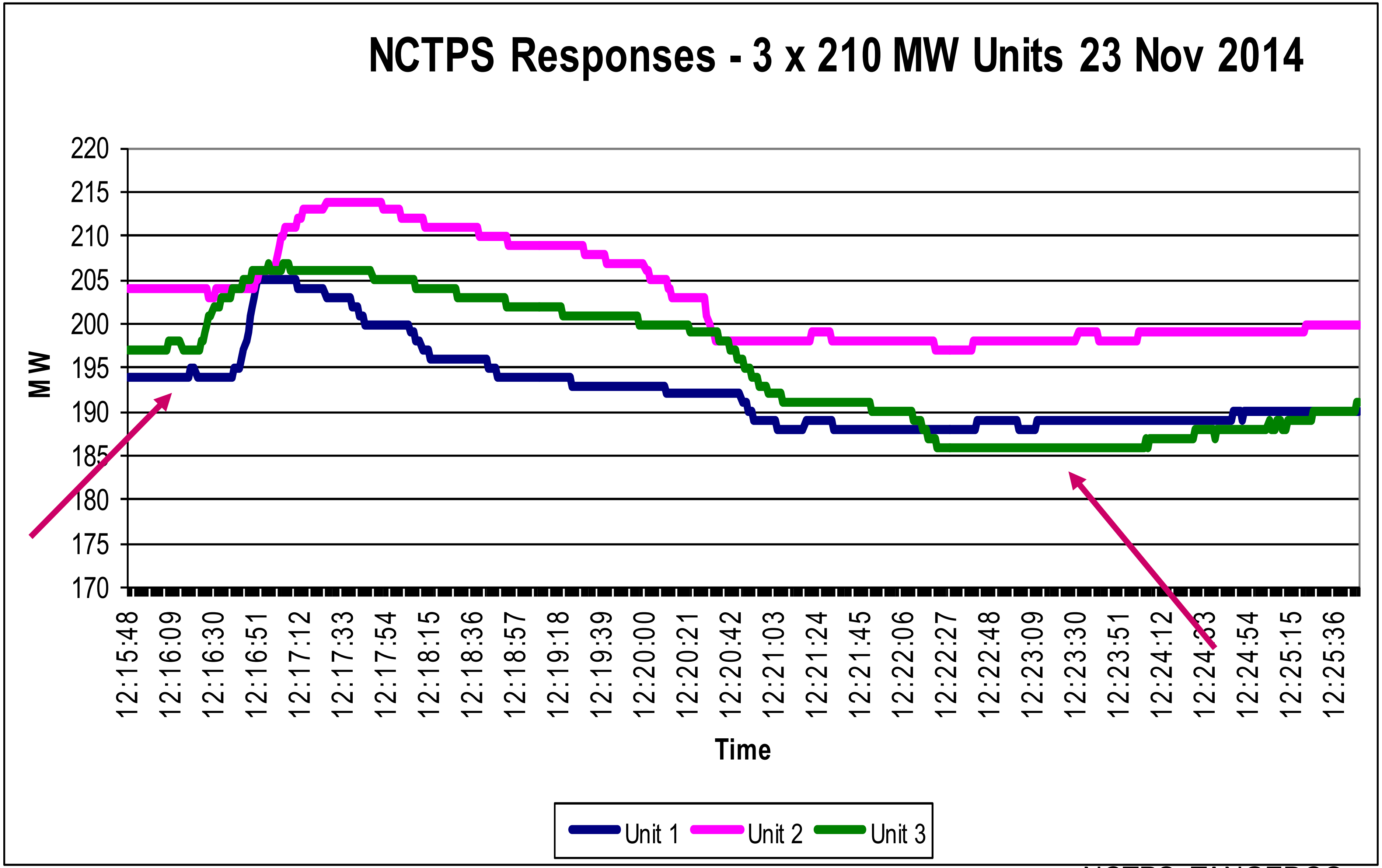


NCTPS Responses - 3 x 210 MW Units 23 Nov 2014



NCTPS, TANGEDCO

Continued process response - GU



NCTPS, TANGEDCO

Continued process response - Generating Units Or Secondary Control

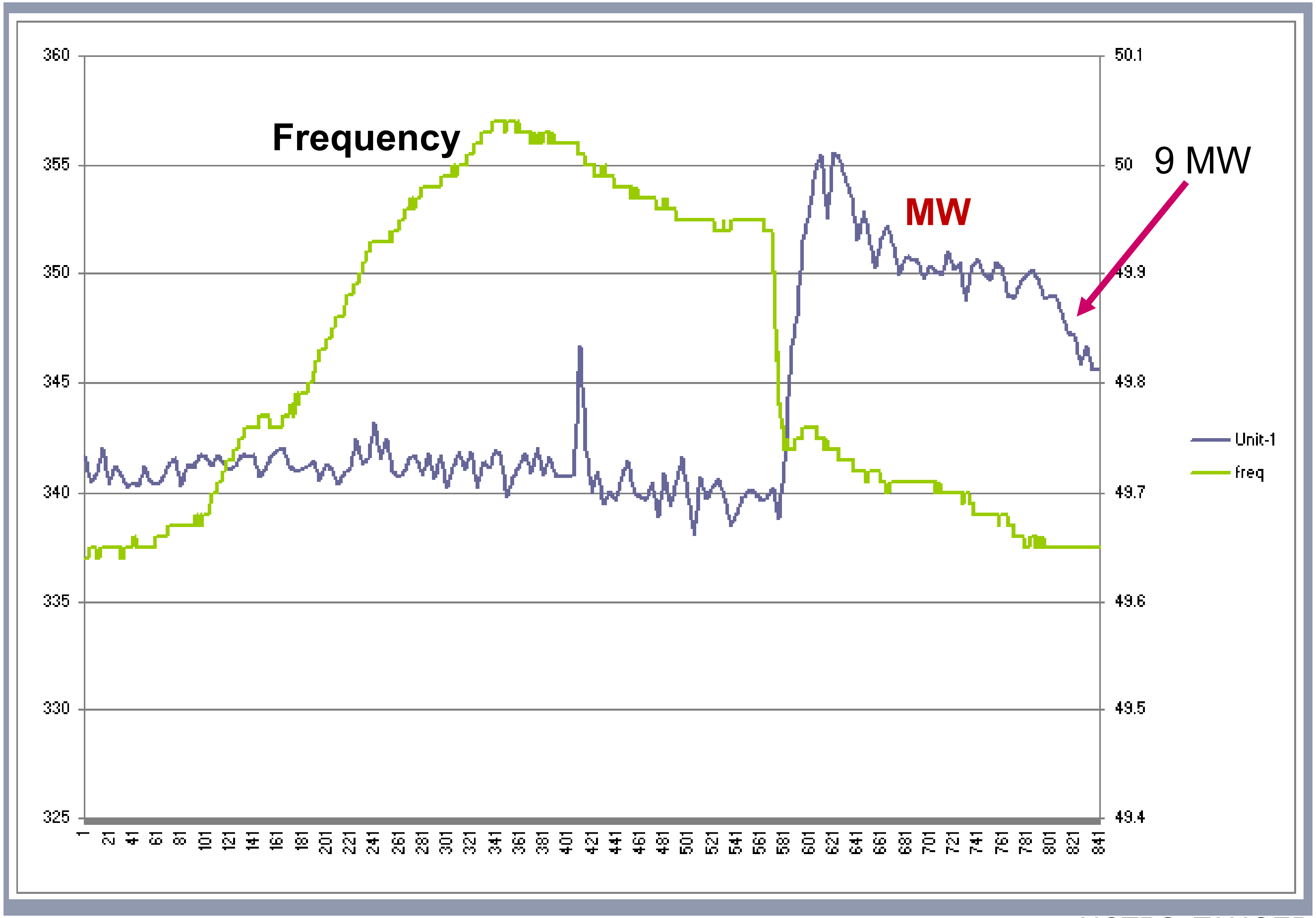
Newly commissioned machines having CMC control, for the same RGMO output, we noticed the sustainability is different which may be due to variation in the process parameters.

Two 500 MW Units of NTECL, Vallur who lead 2nd Mar 2015 incident have been taken as case study.

Continued process response - Generating Units

500 MW Unit 1 of NTECL, Vallur

Date of incident : 02 Mar 2015



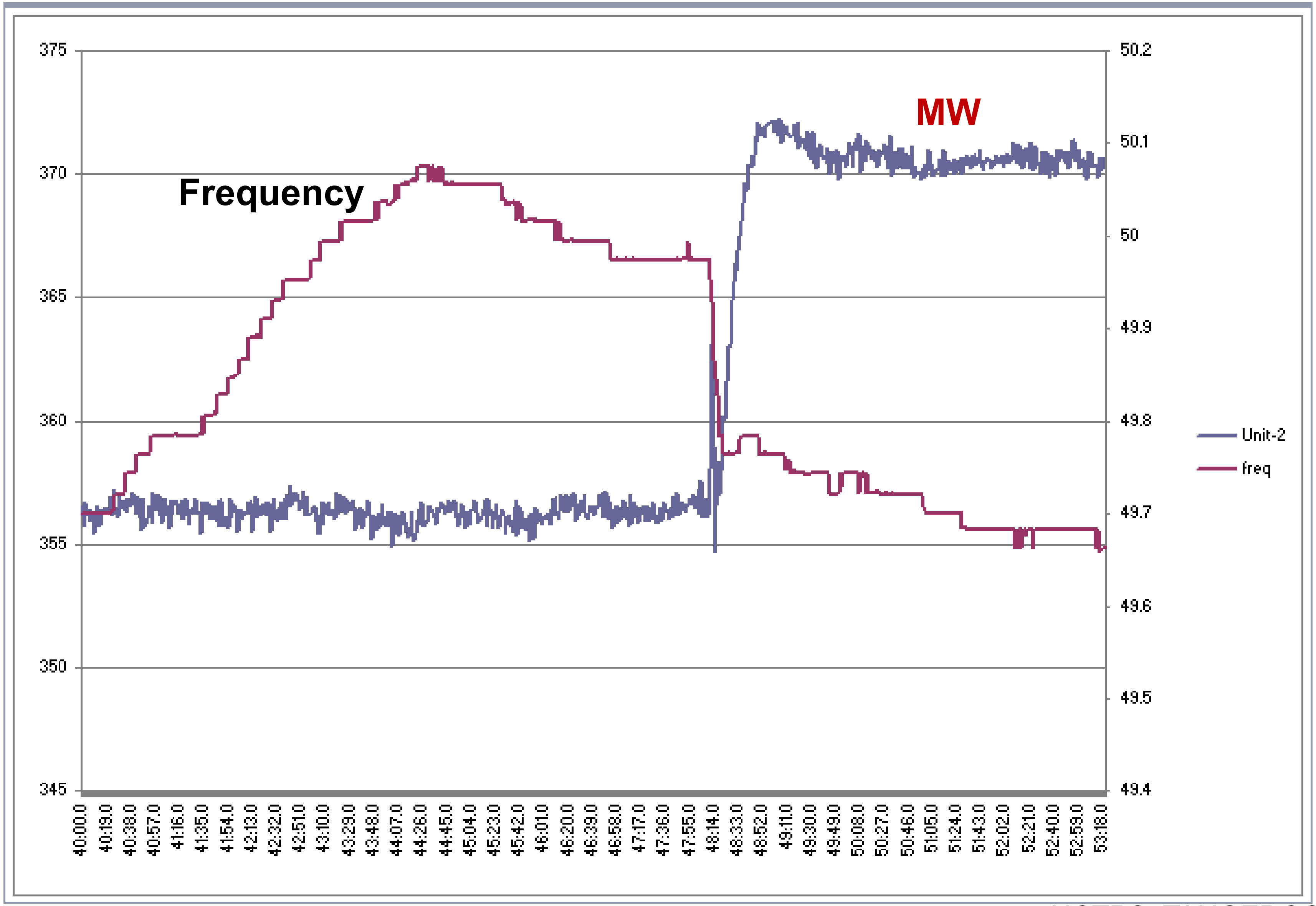
RGMO Response 339 MW to 355 MW 16 MW

NCTPS, TANGEDCO

Continued process response - Generating Units

500 MW Unit 2 of NTECL, Vallur

Date of incident : 02 Mar 2015



RGMO Response 356 MW to 372 MW 16 MW

NCTPS, TANGEDCO

Unit 1 of NTECL, Vallur

Time	Actual MW	Frequency
6:49:25	339.79	49.94
6:49:26	339.88	49.94
6:49:27	339.97	49.94
6:49:28	340.06	49.94
6:49:29	340.14	49.94
6:49:30	340.23	49.9
6:49:31	339.96	49.9
6:49:32	339.68	49.85
6:49:33	339.4	49.82
6:49:34	339.13	49.83
6:49:35	338.85	49.78
6:49:36	339.35	49.78
6:49:37	339.87	49.77
6:49:38	340.38	49.76
6:49:39	340.9	49.76
6:49:40	341.42	49.74
6:49:41	342.39	49.74
6:49:42	343.38	49.75
6:49:43	344.36	49.74
6:49:44	345.35	49.74
6:49:45	346.35	49.74
6:49:46	346.67	49.74

6:50:10	355.5	49.75
6:50:11	354.91	49.75
6:50:12	354.32	49.75
6:50:13	353.73	49.74
6:50:14	353.13	49.75
6:50:15	352.53	49.74
6:50:16	353.12	49.74
6:50:17	353.73	49.74
6:50:18	354.33	49.74
6:50:19	354.93	49.74
6:50:20	355.54	49.74
6:50:21	355.5	49.74
6:50:22	355.46	49.74
6:50:23	355.42	49.74
6:50:24	355.38	49.74
6:50:25	355.34	49.73
6:50:26	355.14	49.73
6:50:27	354.95	49.73
6:50:28	354.75	49.73
6:50:29	354.56	49.73
6:50:30	354.36	49.73
6:50:31	354.2	49.73
6:50:32	354.04	49.73

6:49:47	347	49.74
6:49:48	347.33	49.74
6:49:49	347.66	49.75
6:49:50	347.99	49.75
6:49:51	348.7	49.75
6:49:52	349.42	49.75
6:49:53	350.14	49.75
6:49:54	350.86	49.75
6:49:55	351.58	49.76
6:49:56	351.82	49.76
6:49:57	352.06	49.76
6:49:58	352.3	49.76
6:49:59	352.54	49.76
6:50:00	352.79	49.76
6:50:01	353.17	49.76
6:50:02	353.56	49.76
6:50:03	353.95	49.76
6:50:04	354.34	49.76
6:50:05	354.73	49.76
6:50:06	354.89	49.76
6:50:07	355.04	49.75
6:50:08	355.19	49.75
6:50:09	355.34	49.75

Unit 2 of NTECL, Vallur

Time	Actual MW	Frequency
48:09.0	356.13	49.973
48:10.0	356.21	49.973
48:11.0	356.6	49.973
48:12.0	358.03	49.954
48:13.0	363.03	49.929
48:14.0	359.02	49.866
48:15.0	354.73	49.847
48:16.0	356.57	49.847
48:17.0	358.14	49.827
48:18.0	358.33	49.803
48:19.0	356.98	49.783
48:20.0	358	49.783
48:21.0	359.76	49.783
48:22.0	360.25	49.767
48:23.0	360.09	49.764
48:24.0	361.57	49.767
48:25.0	362.7	49.767
48:26.0	362.97	49.764
48:27.0	363.08	49.764
48:28.0	363.74	49.764
48:29.0	364.84	49.764
48:30.0	365.61	49.767
48:31.0	366.32	49.767
48:32.0	366.08	49.767
48:33.0	366.87	49.767
48:34.0	367.45	49.767
48:35.0	367.48	49.781
48:36.0	368.03	49.783
48:37.0	368.82	49.783
48:38.0	369.18	49.783
48:39.0	369.65	49.783
48:40.0	369.32	49.783
48:41.0	370.36	49.783
48:42.0	370.22	49.783
48:43.0	370.36	49.783
48:44.0	370.75	49.783
48:45.0	370.31	49.783
48:46.0	370.77	49.783
48:47.0	371.51	49.783
48:48.0	371.32	49.783
48:49.0	372.06	49.783
48:50.0	371.6	49.764
48:51.0	371.6	49.767
48:52.0	371.62	49.767
48:53.0	371.84	49.767
48:54.0	371.52	49.767
48:55.0	371.93	49.764
48:56.0	372.01	49.767
48:57.0	372.06	49.764
48:58.0	372.06	49.764
48:59.0	372.09	49.764
49:00.0	372.12	49.764
49:01.0	371.71	49.764
49:02.0	372.09	49.764
49:03.0	372.15	49.764
49:04.0	371.6	49.764
49:05.0	371.82	49.764
49:06.0	372.2	49.764
49:07.0	371.65	49.764
49:08.0	371.3	49.764
49:09.0	372.04	49.764
49:10.0	371.62	49.748
49:11.0	371.93	49.748
49:12.0	371.73	49.748
49:13.0	371.57	49.759
49:14.0	371.49	49.748
49:15.0	371.54	49.745
49:16.0	371.57	49.745

From the submission of
Er.P.P.Francis, GM (OS), NTPC Ltd.,

RGMO response will not be available on machines operating in the overload regime. Above all, RGMO response serves no useful purpose to my mind.
To suggest measures for implementation of FGMO with suitable modifications / amendments in CERC Regulations / IEGC

Full load with Valve wide-open – Commercial advantages

Mill loading maximised – Full/partial generation – Mills under vibration

Calorific value of coal – Partial/full load

Continued process response - Generating Units

Date of incident : 02 Mar 2015

KWU turbines EHG System - RGMO

Performance of Simhadri Thermal Power Station, TANGEDCO, SR						
Unit #	MCR of Machines on Bar	5% of MCR	Current generation	RGMO Expected 5% current generation	Actual RGMO response	% achievement
I	500	25	428	21.4	18.1	**84.6**
II	500	25	401	20.1	13.3	**66.3**
III	500	25	501	25.1	7.7	**30.7**
IV	500	25	496	24.8	5.2	**21.0**

Restricting the **generating units from running with wider open** of control valves for **maximising the RGMO response** to the electrical grid.

Methodology for the machines **running always with 105% generation.** Whether RGMO response will be zero in these machines.???

RGMO & sustainability in these machines-

Incentive **for the machines of RGMO responded at full load and more** which compromised the commercial advantages.

SRPC - Categorization of Performance

Descriptions Used (Expected Response is taken as 5% of Installed Capacity)			
Sl No	Response Code	Description	Explanation
1	R	Responded	Response Greater than 70% of Expected response is achieved
2	PR	Partially Responding	Response 30 to 70 % of Expected response is achieved
3	IR	Insufficient Response	Response less than 30% of Expected response is achieved
4	NR	No Response	No Change in Generation
5	RR	Reverse Response	Generator acts against the RGMO/FGMO feature. i.e when frequency dips , generation also reduces & vice versa

To **sustain the primary response for longer time (3-5 minutes)** and not to fall below the original generation to assist secondary control. This can be utilised in the period of initialisation of secondary control.

Suggested that **Minimum of 3% of MW generation** delivered shall be considered as RGMO responded. **i.e. 60% as against 70%** of expected generation via RGMO. Making as achievable target by individual unit.

On 02 Mar 2015 incident, SR response was 159 MW (21.37%) as against the target of 744 MW.

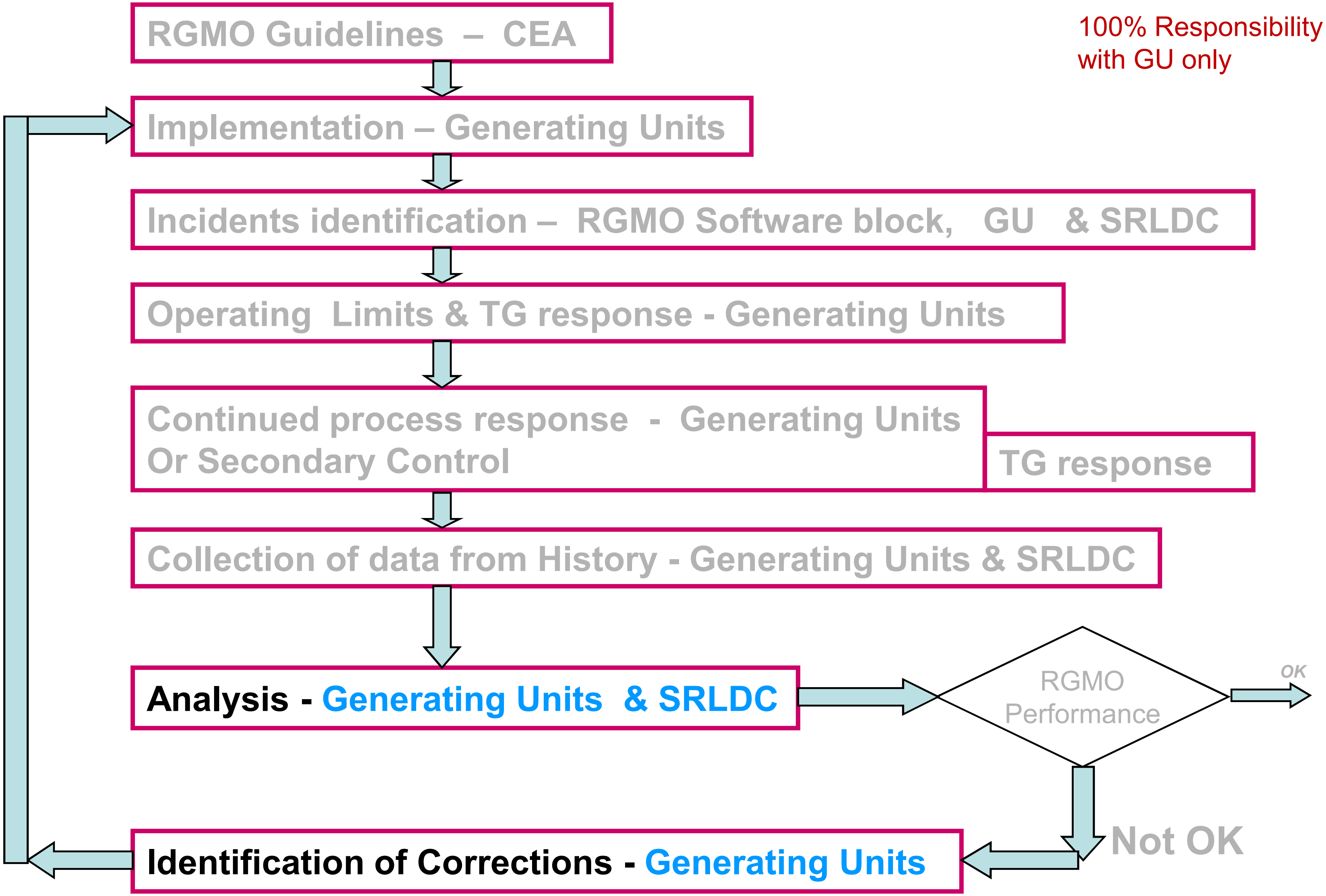
The number of thermal machines on bar is 66 Nos during this incident.

The MW achieved per machines is 2.40 MW as against the target of 11.27 MW per machine.

Improvement in RGMO response from Generating units will be more.

The number of successful units will definitely be more and the performance sustainability with prolonged available thermal reserve in the boiler will also be achieved

100% Responsibility
with GU only



10% error in each activity, successful rate will be $(0.9)^7 = 0.4783$

20% error in each activity, successful rate will be $(0.8)^7 = 0.2097$

From the submission of
Er.P.P.Francis, GM (OS), NTPC Ltd.,

Governor Control (FGMO if you like!) is an integral part and just a small element of the Power System Frequency Control mechanism. It is not a one-stop-solution for frequency control.

Governor Control can only supplement the limited function of "Frequency Containment" or "Frequency Responsive" in large frequency deviation (large generation load mismatch) events.

In general 1 minute data is being studied at State LDC and SRLDC, Bangalore.

Collection of 1 second data from all the generating stations

After getting RGMO performance closer to the our target, For large variation of frequency incidents,

Frequency containment results arriving out of Primary response and the frequency trend patterns for different case studies to be studied with 1 second data. Some examples are given here of course with lesser RGMO performance.

Under max. RGMO performance, this frequency pattern study will be effective for deciding methodologies on secondary control..

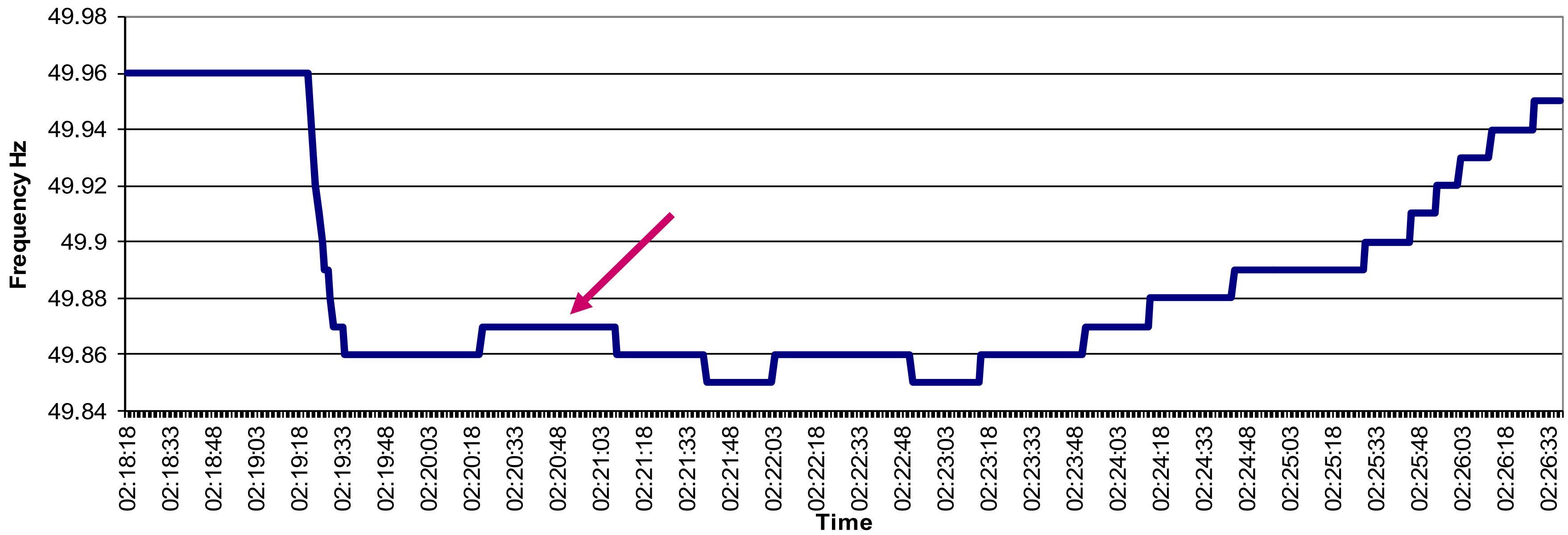
RGMO incident – The quantum of loss / gain of MW in the grid is to be known to the Generating stations. Analysis will be based on this quantum requirement only.

For larger frequency variations, the disturbed grip with intrusion of RGMO generation shall be mathematically modeled and the simulation results shall be arrived at of course with minimum assumptions.

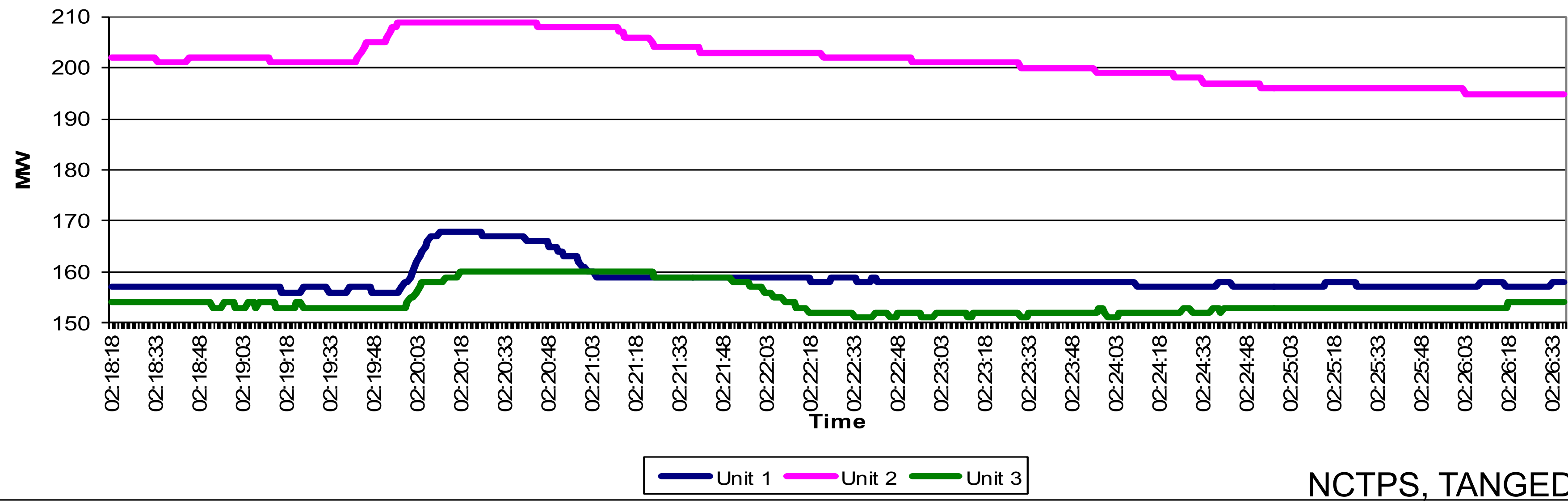
Analysis

Frequency variation 1 Nov 2014

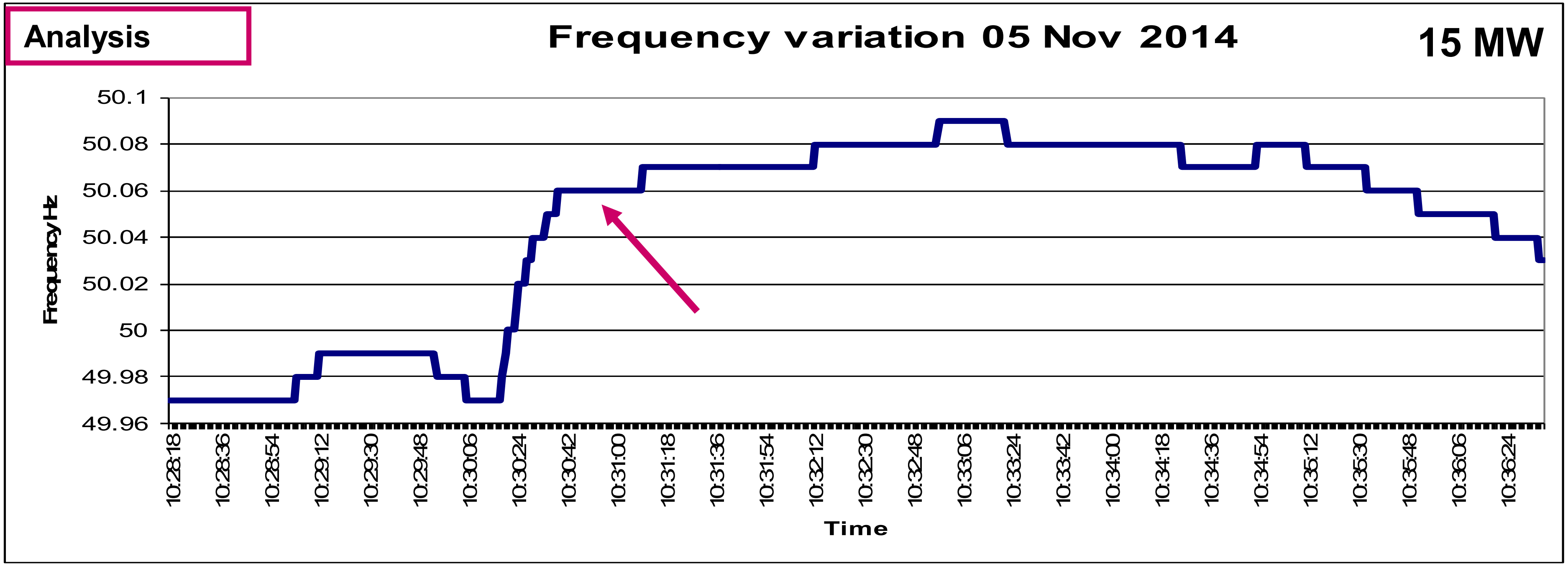
26 MW



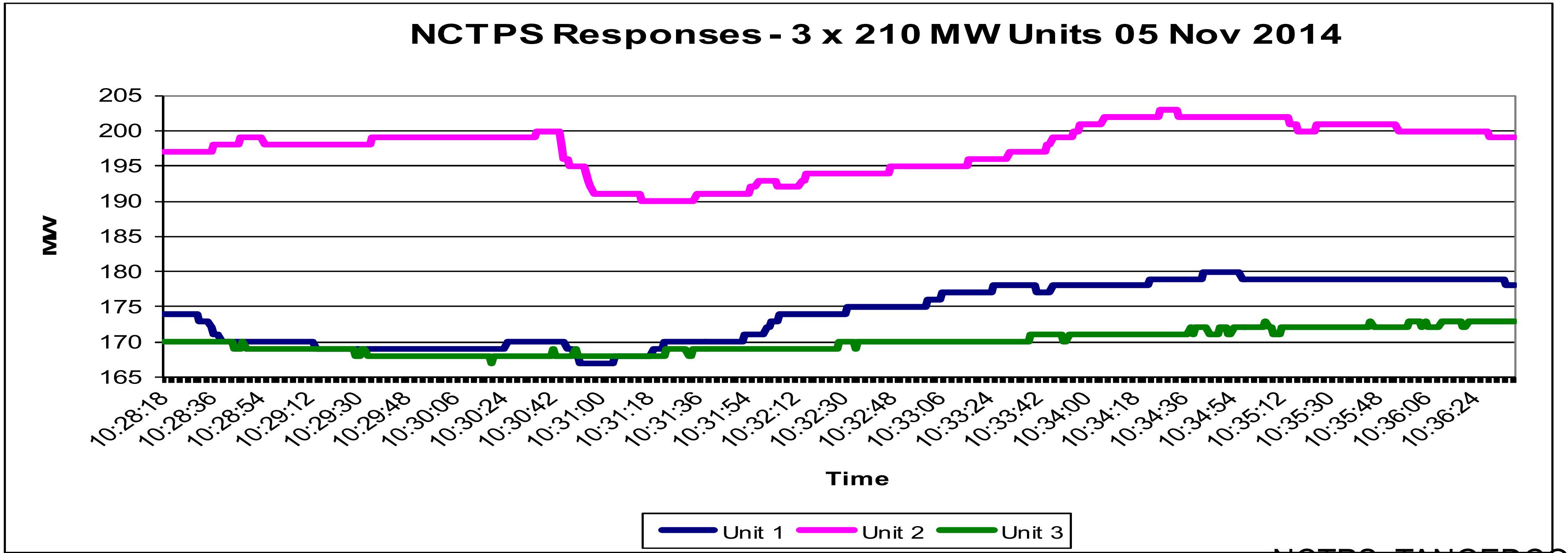
NCTPS Responses - 3 x 210 MW Units 1 Nov 2014



NCTPS, TANGEDCO



Analysis
Frequency variation 05 Nov 2014
15 MW
Frequency Hz
Time

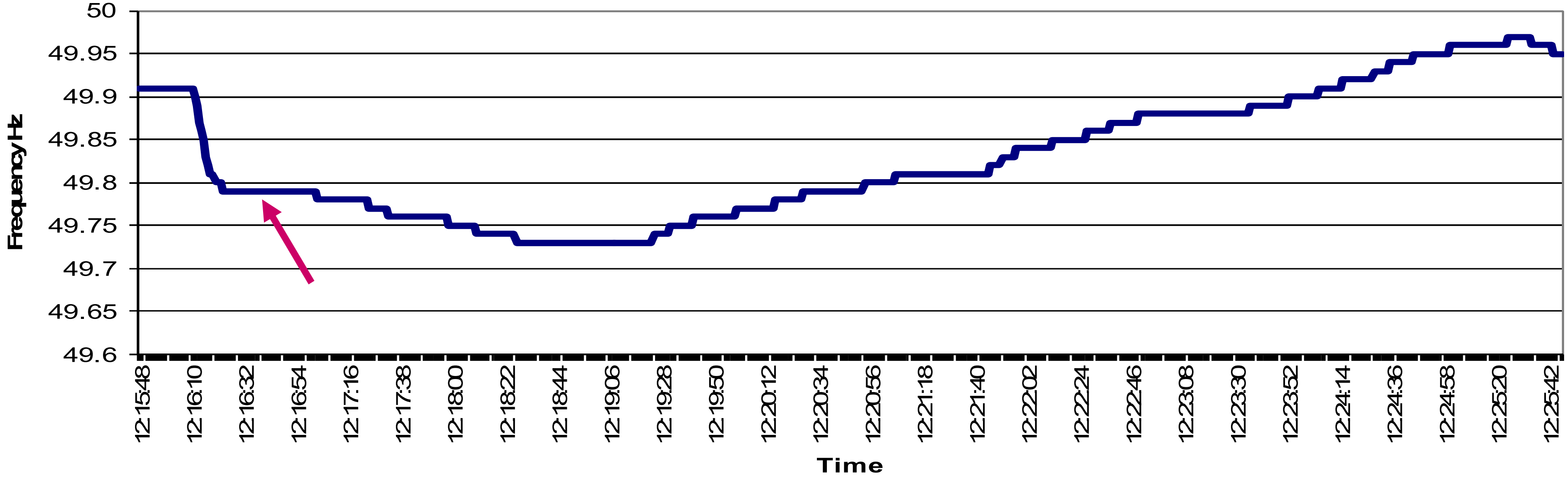


NCTPS Responses - 3 x 210 MW Units 05 Nov 2014
MW
Time
Unit 1
Unit 2
Unit 3

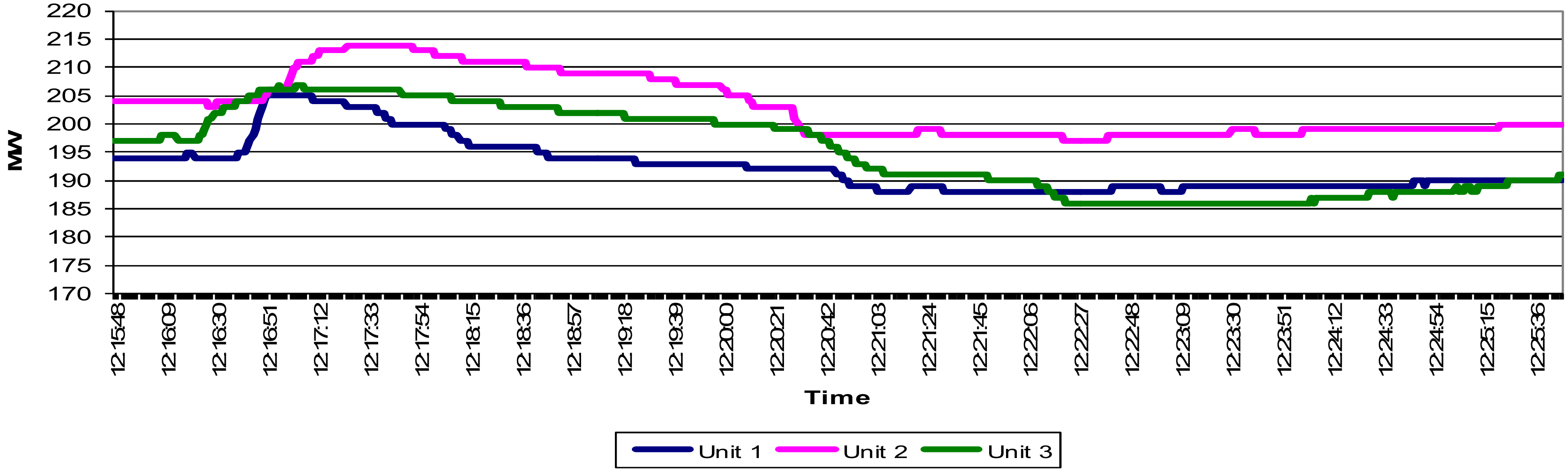
Analysis

Frequency variation 23 Nov 2014

28 MW

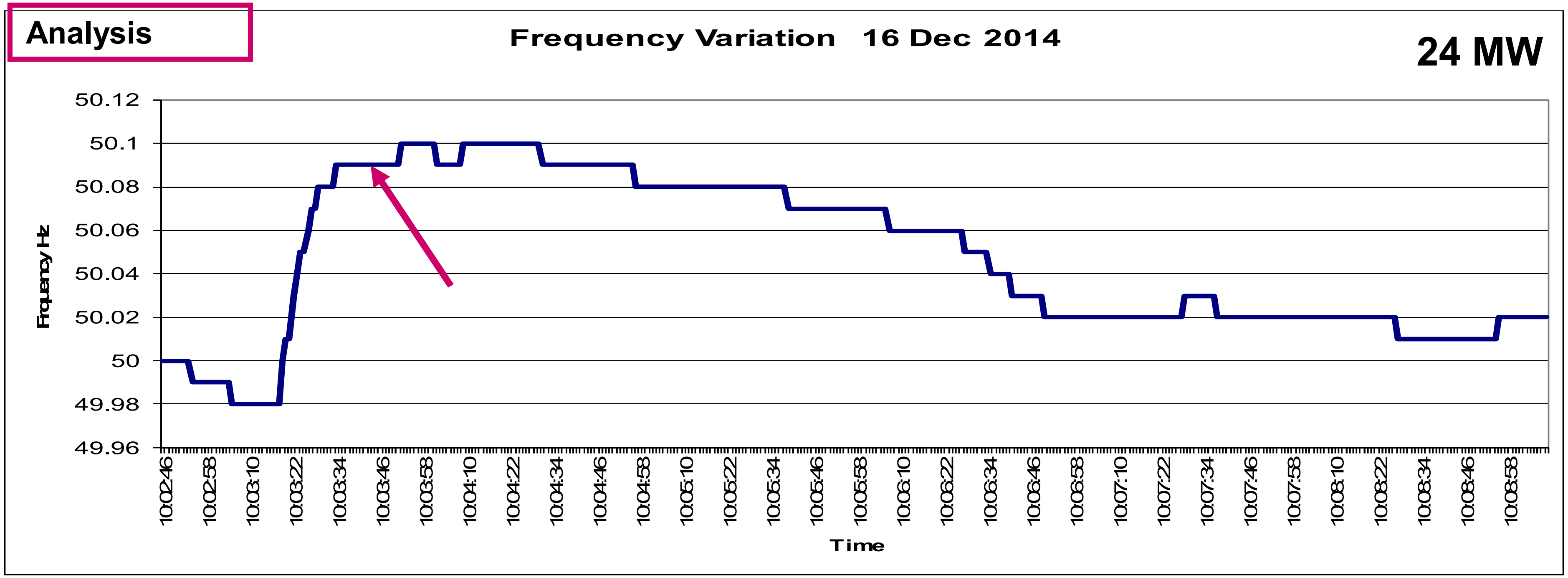


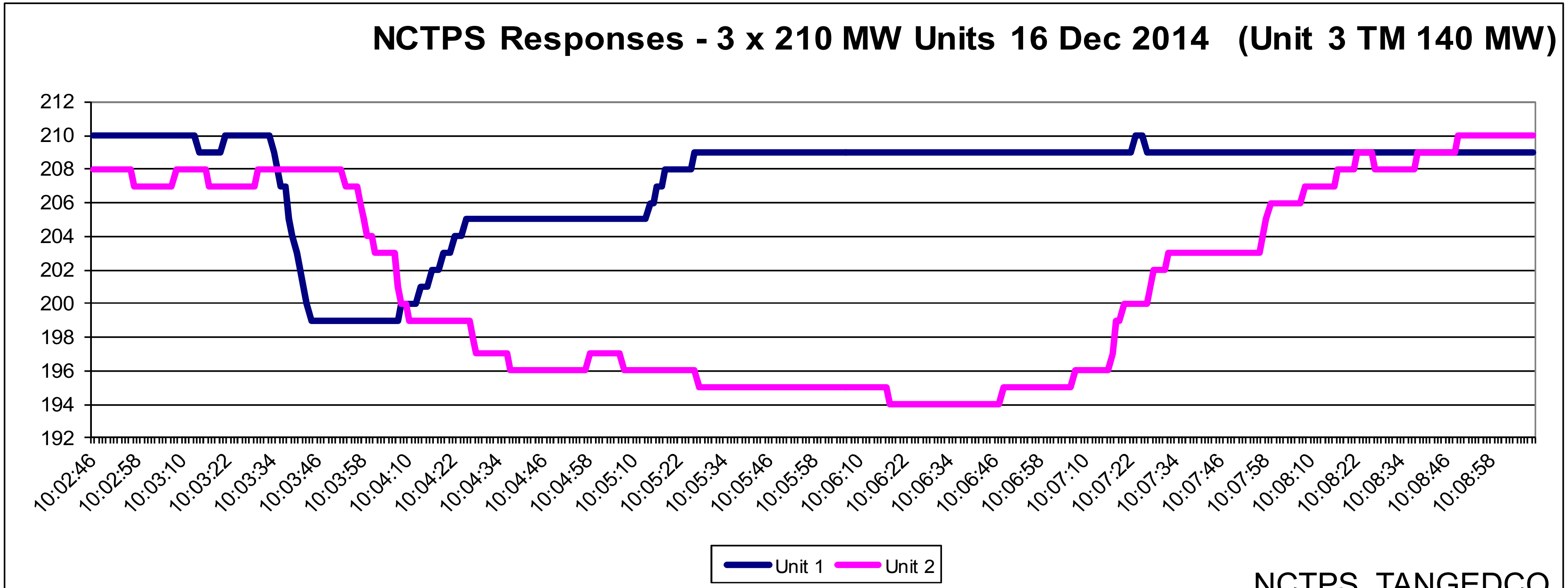
NCTPS Responses - 3 x 210 MW Units 23 Nov 2014



NCTPS, TANGEDCO

Analysis



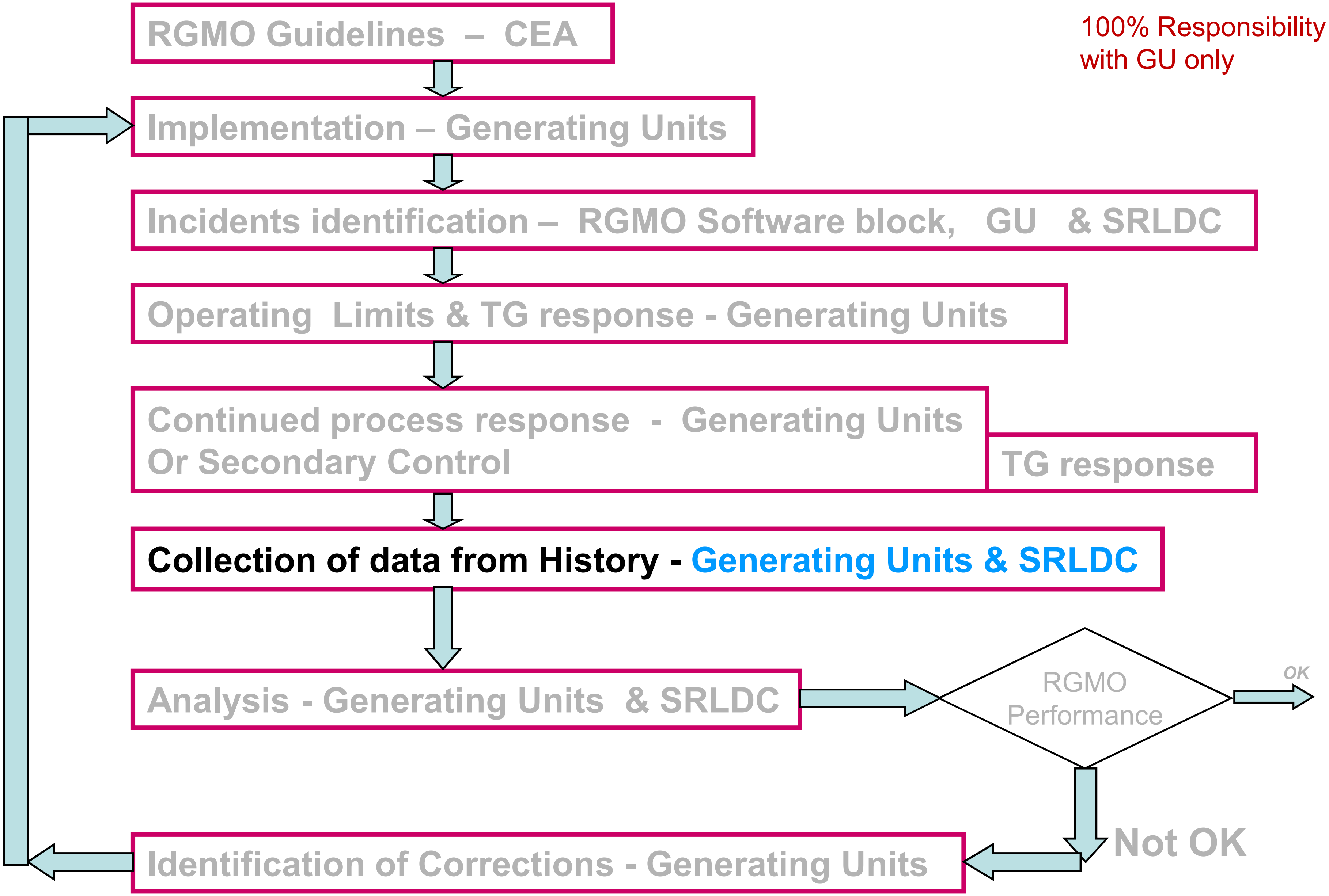


NCTPS, TANGEDCO

RGMO incident – The quantum of loss / gain of MW in the grid is to be known to the Generating stations. Analysis will be based on this quantum requirement only.

To check whether RGMO meeting the actual demand of the grid due to disturbance.

For larger frequency variations, the disturbed grip with intrusion of RGMO generation shall be mathematically modeled and the simulation results shall be arrived at of course with minimum assumptions.



10% error in each activity, successful rate will be $(0.9)^7 = 0.4783$

20% error in each activity, successful rate will be $(0.8)^7 = 0.2097$

NCTPS, TANGEDCO

Collection of data from History - Generating Units & SRLDC

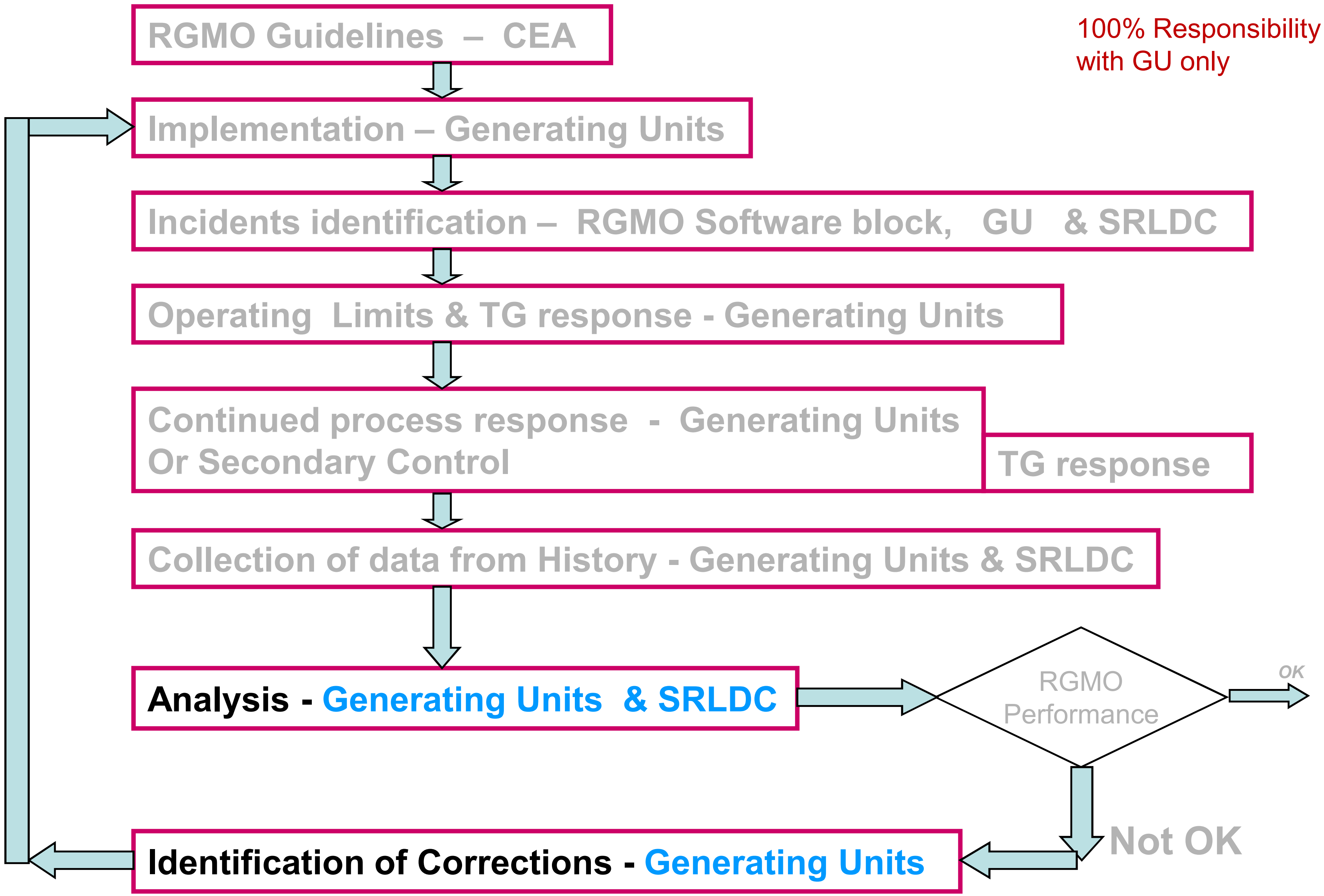
In general 1 minute data is being studied at State LDC and SRLDC, Bangalore.

Collection of 1 second data from all the generating stations

Frequency containment results arriving out of Primary response and **frequency trend patterns for different case studies to be studied with 1 second data**.

Under max. RGMO performance, this frequency pattern study will be effective for deciding methodologies on secondary control.

NCTPS, TANGEDCO



10% error in each activity, successful rate will be $(0.9)^7 = 0.4783$

20% error in each activity, successful rate will be $(0.8)^7 = 0.2097$

Error free Consistent RGMO performance require study on various case studies and process parameters non performing machines.

In order to achieve the expected **average demand of 4000-6000 MW/Hz as primary response in the grid at the National level,**

To study the various RGMO case studies, the patterns of frequency variation for RGMO behaviour, RGMO implementation problems and suggestions/solutions/improvements for reducing the shortfall in RGMO behaviour against our primary response target.

Knowledge transfer on RGMO among the regions is very vital.

Suggest that

We Suggest that

A **National level working/steering/monitoring committee comprising of Hon'ble CERC, CEA, NTPC, NLC, POSOCO, RPCs, Generating Units of all the Regions etc.,** shall be met periodically (quarter yearly) **to study the various RGMO case studies & suggestions/solutions/ improvements for reducing the RGMO shortfall** against our primary response target.

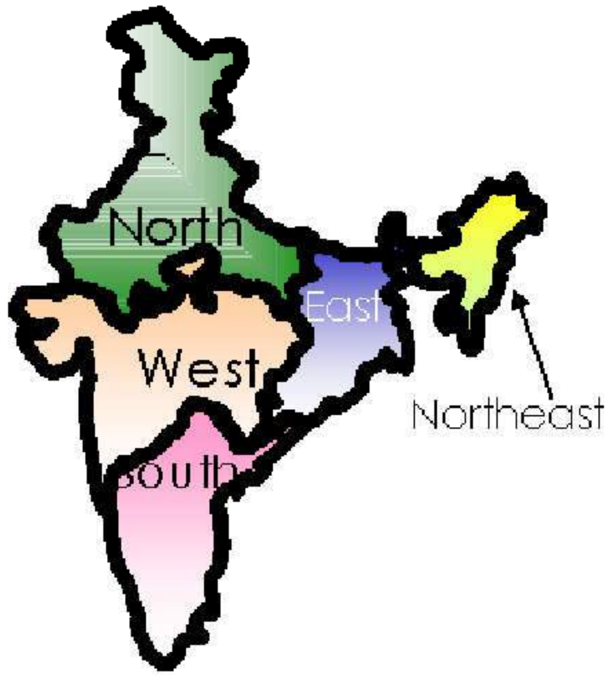
Hon'ble CERC

Regional Power Committee RPC

Regional Load Dispatch Centre RLDC

State Load Dispatch Centre LDC

Generating station **& others**



Five Regional grids in India

From the submission of
Er.P.P.Francis, GM (OS), NTPC Ltd.,

This bare minimum retrofit was proposed to be offered by M/s Siemens in the presentation made before the committee on 21st November. This would leave the original control oil system, valve actuator servomotor, rocker arms, valve mechanical linkages etc. unchanged. Thus the modification only retrofits the control logic realization to electrical.

M/s Alstom proposed slightly more extensive multiple retrofit options, but for the purpose of RGMO the option would be the one similar to what was proposed by Siemens.

From the submission of
Er.P.P.Francis, GM (OS), NTPC Ltd.,

It will be highly inappropriate for this committee to recommend such expensive retrofits (to my estimates it will cost about Rs 15 Cr per machine) unless there are compelling reasons for the same. On the basis of such an error by this committee, if CERC mandates the same the said error will be further compounded.

LMZ turbines FGMO with MI

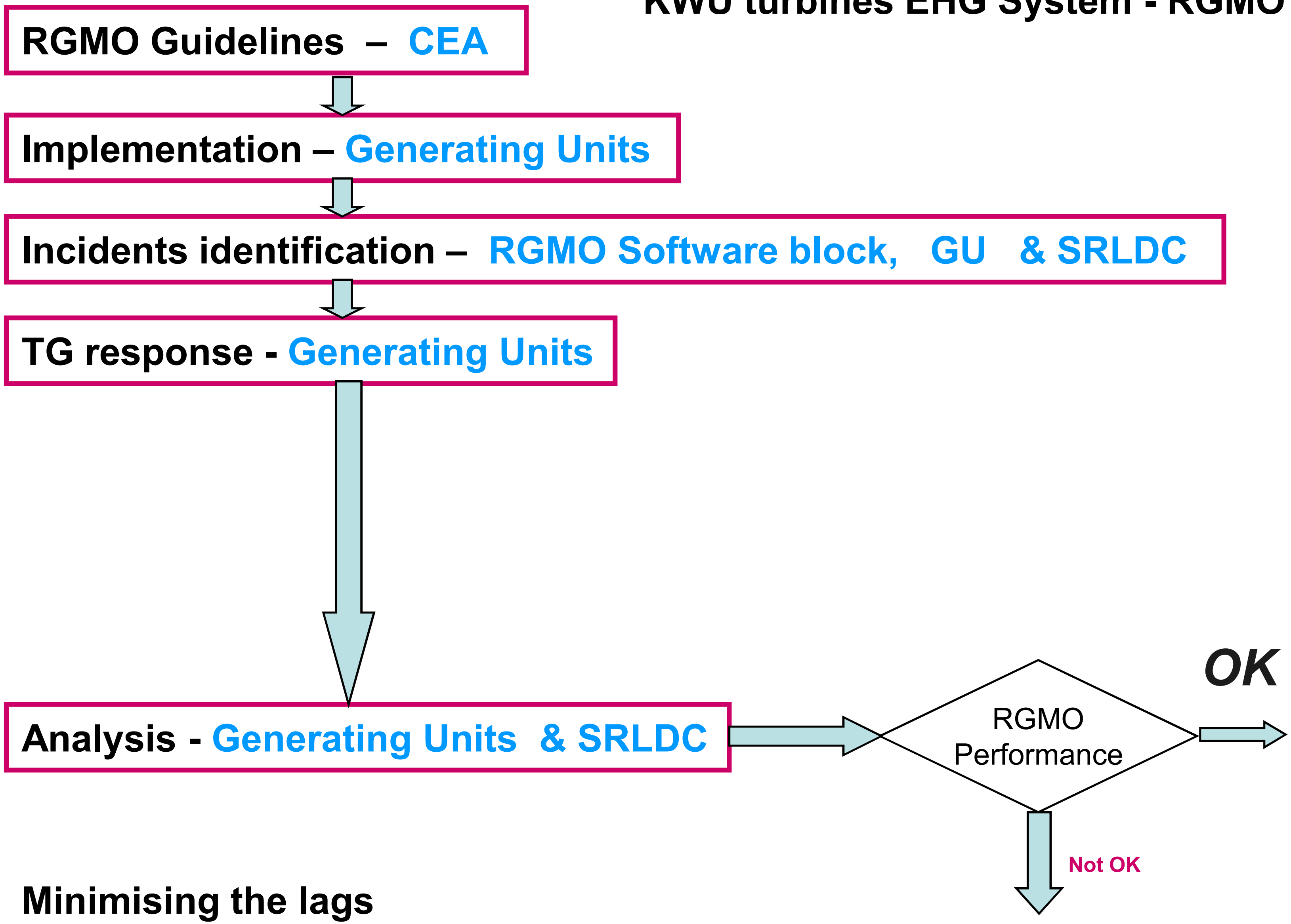
Performance of Mettur Thermal Power Station, TANGEDCO, SR						
Date	MCR of Machines on Bar	5% of MCR	Current generation	RGMO Expected 5% current generation	Actual RGMO response	% achievement
16.12.2014	840	42	824	41.2	18	**43.69**
14.01.2015	630	31.5	607	30.35	13	42.84
02.03.2015	840	42	804	40.2	23	**57.14**

Manual intervention – dictates consistency

Alarming for the occurrence of RGMO incident based on ripple factor given to activate the manual intervention

Similar exercise to be carried out on LMZ MI machines

KWU turbines EHG System - RGMO



Minimising the lags

2% error in each activity, successful rate will be $(0.98)^3$ = 0.9411

67 units of LMZ turbine (Russian Technology) are in operational in **India** which is **second highest figure in the world next to Russia** having 73 Units of LMZ turbines.

Estimated value of conversion - Rs.7 crores per machine
We may obtain the budgetary offer from the companies.

Out of 67 LMZ machines available in India,
About 50% of the machines are for retrofit
considering the years served and present condition of machine,

& If cost reduced to Rs.6 Crores per machine
Total costing would be around Rs.180 Crores
for the primary response only from LMZ turbines.

Suggestions by TANGEDCO, Southern Region

Correcting the problems in implementation of RGMO software block / application program

For continued response of MW, upgradation of older/obsolete Distributed control system for the units. Usage of CMC services in newer control system so as to avail the boiler parameters to the possible level for sustaining the RGMO response.

Operators to be instructed and trained so as to respond over the process disturbances due to change in generation by RGMO and also not to suppress RGMO as per IEGC 5.2.(f)

1 second data of frequency and MW generation of units for a period + & - 3 minutes required to identify the change in frequency pattern due to RGMO response of machines for effecting the secondary control.

Suggestions by TANGEDCO, Southern Region

Operator Simulator training package shall have the RGMO modeling to study the process behaviour of thermal units of any size/capacity.

Visibility of RGMO status of Generating units in State LDC room via SCADA

RGMO incident – The quantum of loss / gain of MW in the grid is to be known to the Generating stations. Analysis will be based on this quantum requirement only.

Suggestions by TANGEDCO, Southern Region

Incentive for the machines of RGMO responded at full load and more which compromised the commercial advantages.

Restricting the generating units running with wider open of control valves – Non delivery of RGMO

RGMO response by the machines having highest PLF run in the wide open mode with 105% generation always. ???

To utilise Thermal reserve available in the boiler – Suggested that Minimum of 3% of MW generation delivered shall be considered as RGMO responded to increase the number of responding machines and To sustain the primary response for longer time (3-5 minutes).

Suggestions by TANGEDCO, Southern Region

Knowledge transfer among the regions are very vital in order to achieve the expected average demand of 6000 MW/Hz as primary response in the grid at the National level,

A National level working/steering/monitoring committee comprising of all the regions, Hon'ble CERC, NTPC, NLC etc., or this committee shall be met periodically/regularly to study the various RGMO case studies and the pattern of RGMO behaviour, RGMO implementation problems, suggestions/solutions/ improvements for reducing the shortfall in RGMO behaviour against our primary response target.

For larger frequency variations, the disturbed grip with intrusion of RGMO generation shall be mathematically modeled and the simulation results shall be arrived at of course with minimum assumptions.

Suggestions by TANGEDCO, Southern Region

Conversion of LMZ turbines control system if required
On studying the frequency pattern of grid during disturbance, based on the complete performance of KWU turbines.

From the submission of Er.P.P.Francis, GM (OS), NTPC Ltd.,

JV

This is the primary question the committee has to find answer for. To answer this primary question we must examine the following pertinent questions:

What is expected to be achieved by RGMO?

Has RGMO shown the desired results in the machines on which it has been implemented?

What are the reasons why the desired response is not forthcoming from those RGMO machines, as reported by POSOCO in their presentation?

Is the non-availability of reserve capacity on these machines the only reason for non-realization?

After all these expensive retrofits, is RGMO the one-stop-solution we desire?
Why nothing called RGMO exist anywhere else in the world? Are we smarter than them all?

If the answer for question (6) above is 'we want FGMO, but we settled for RGMO as a compromise solution', are these MHG controlled machines capable of FGMO?

If it is capable of FGMO why the expensive retrofit, to realize some mode of operation, the desired result of which is yet to be recognized?

Let us aim for

2% error in each RGMO sub activity, successful rate will be $(0.98)^3$ = 0.9411

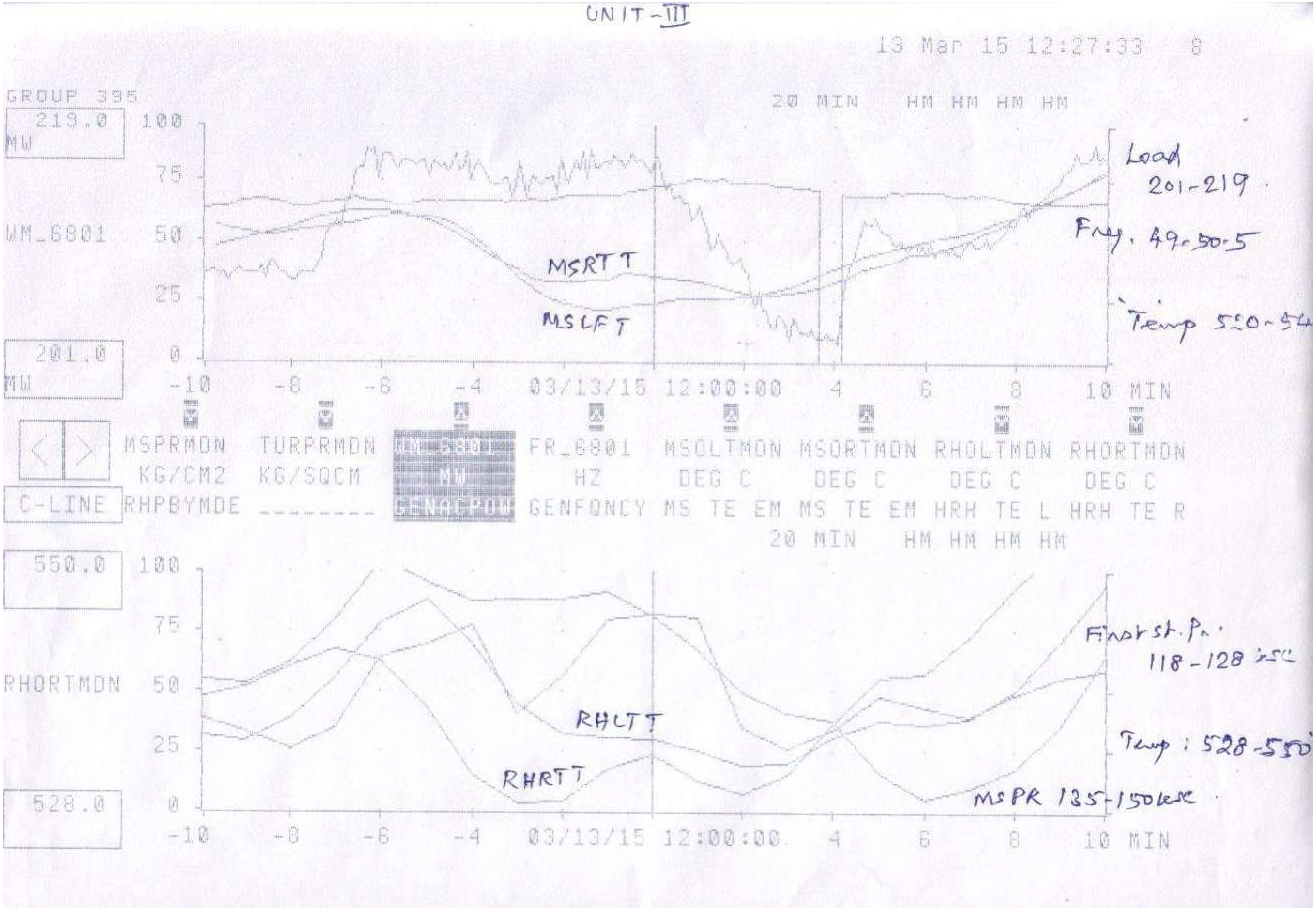
Thanks

For having given the oppurtunity to share our experience and travel in FGMO/RGMO for more than a decade

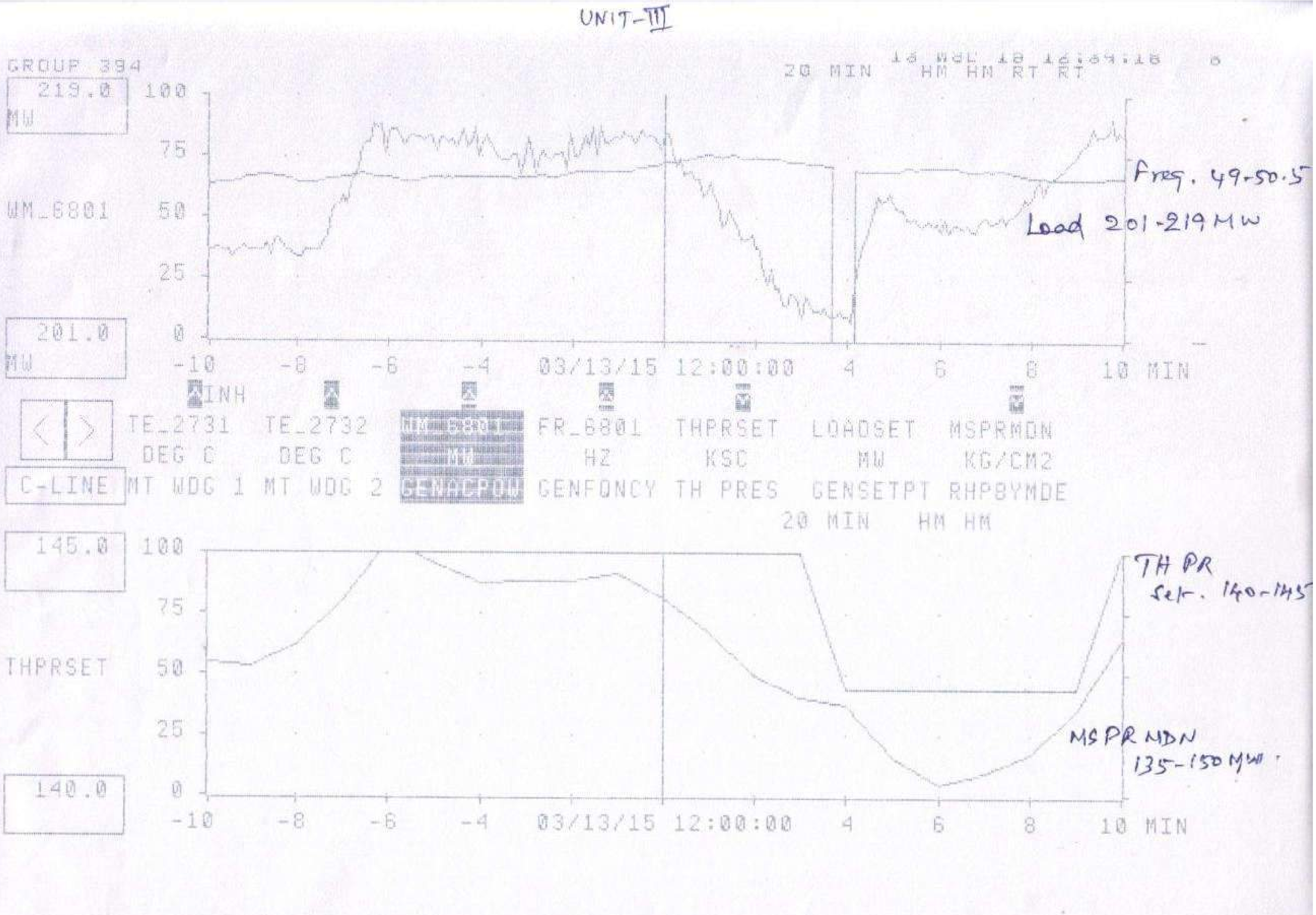
For making GU as Member in the process of fine tuning the FGMO/RGMO performance of our Generating units to serve to our Country

NCTPS, TANGEDCO

European grid
Frequency control????



NCTPS, TANGEDCO



NCTPS, TANGEDCO

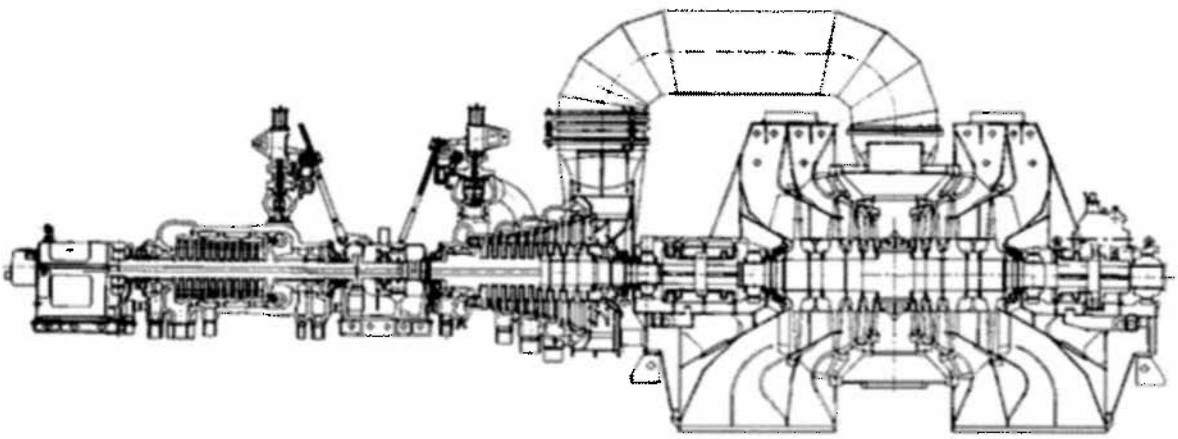
Alstom experience
on the LMZ 200 MW and its derivatives

Fleet with a strong heritage

The first LMZ 200 MW (PVK-200) was commissioned in 1958. An impulse machine designed for base load operation, the design eventually ran to a fleet of some 380 units, produced in 10 sub-types. 67 of these machines were built in India.

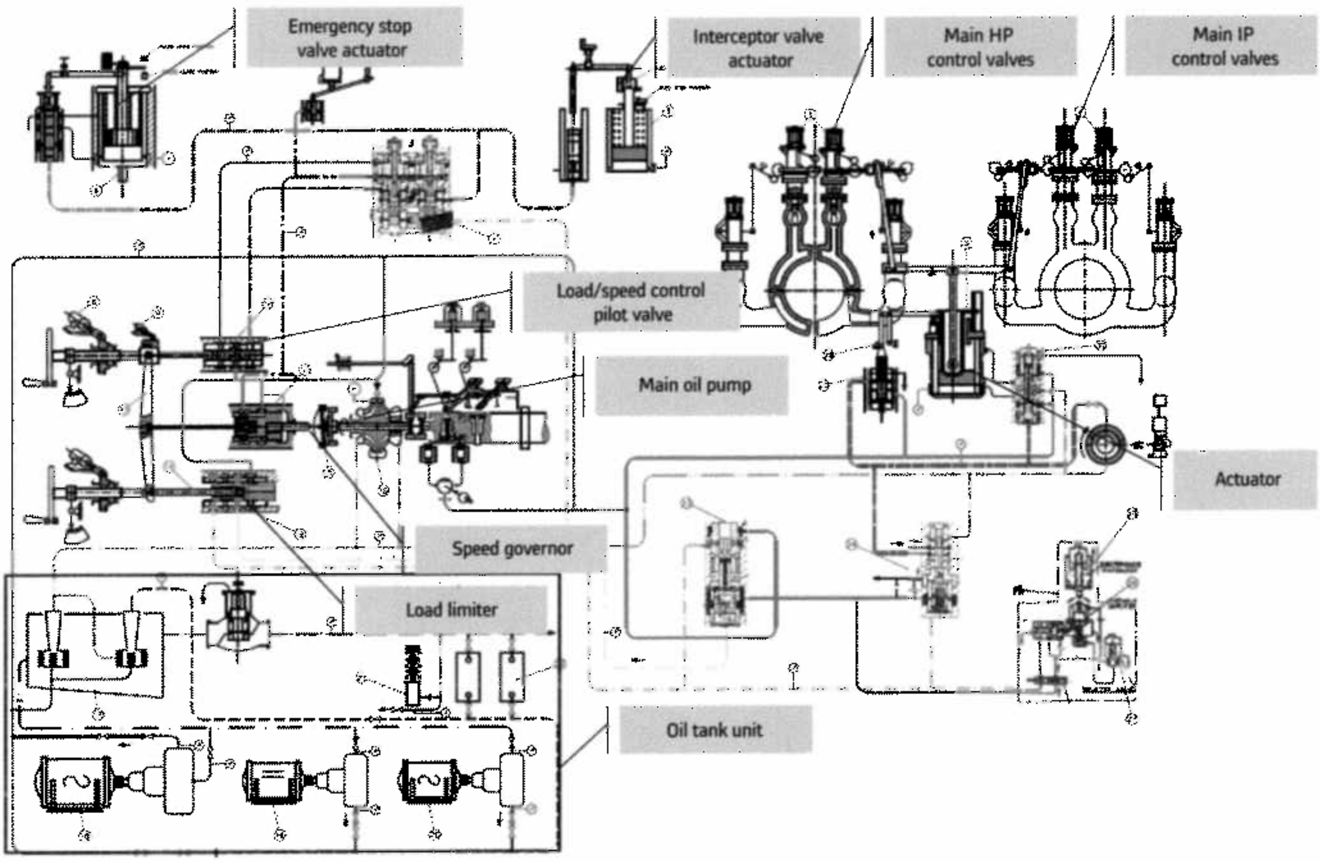
Legacy of Experience and Improvement

Alstom's connection with the LMZ design comes through the Polish company Zamech, which built many LMZ 200 types under licence. From the start, Zamech went about improving the design of the turbine and its associated systems. This process has continued through Zamech's absorption into Alstom, right up to the present day. Thus Alstom is able to offer proven solutions for this machine, backed up both by OEM knowledge and extensive global experience.



Original LMZ Control System

The original control system for the LMZ 200 MW and its derivatives, has the following features:
- An oil pressure of 20 bar
- A single actuator controlling all four HP, and all four IP, control valves.
- Bilateral actuator operation (i.e. using a double-acting piston rather than a return spring).



Typical Issues

Design

- Wear of mechanical components
- High insensitivity (slow to respond with a dead band of around +/-50mHz)
- Difficulty in changing operational modes

Operational

- Shortage of spare parts
- Extensive overhaul work regularly required
- Need for specialised service personnel

Lack of operational flexibility is particularly important in the Indian market, where the Central Electricity Regulation Committee (CERC) is now obliging utilities to incorporate the Restricted Free Governor Operation Mode (RFGOM). This is to ensure centralised grid control when the frequency is rising.

to suit your needs

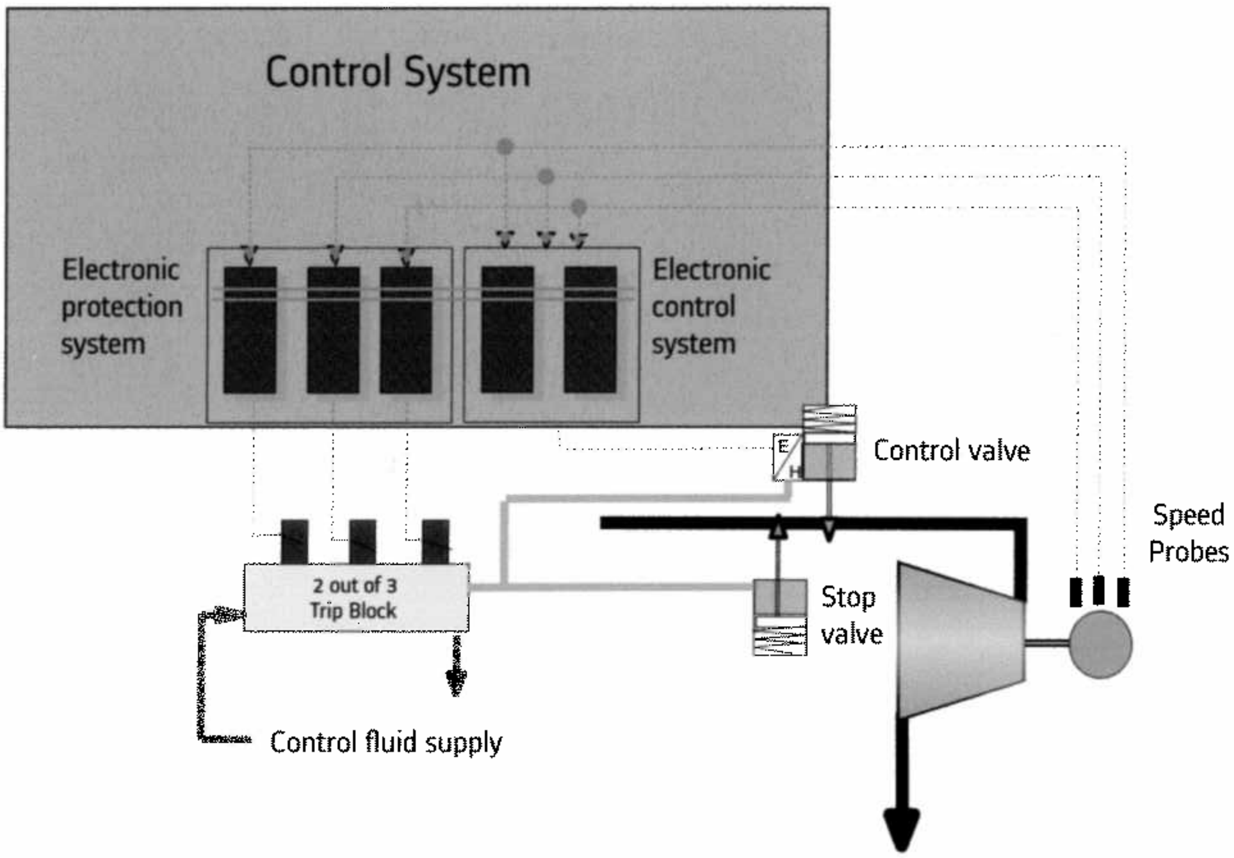
Customisable Alstom Solutions

Being an OEM with a wide range of antecedent companies, Alstom has expertise in all types of control system, from the purely mechanical to the most up-to-date digital layouts.

And with its experience of the Zamech-built machines, Alstom now offers two general design solutions for the LMZ 200 MW. As with most Alstom products, these options can be customised according to specific customer needs. They can also be implemented during a major outage.

Improved flexibility and reliability to meet modern grid requirements

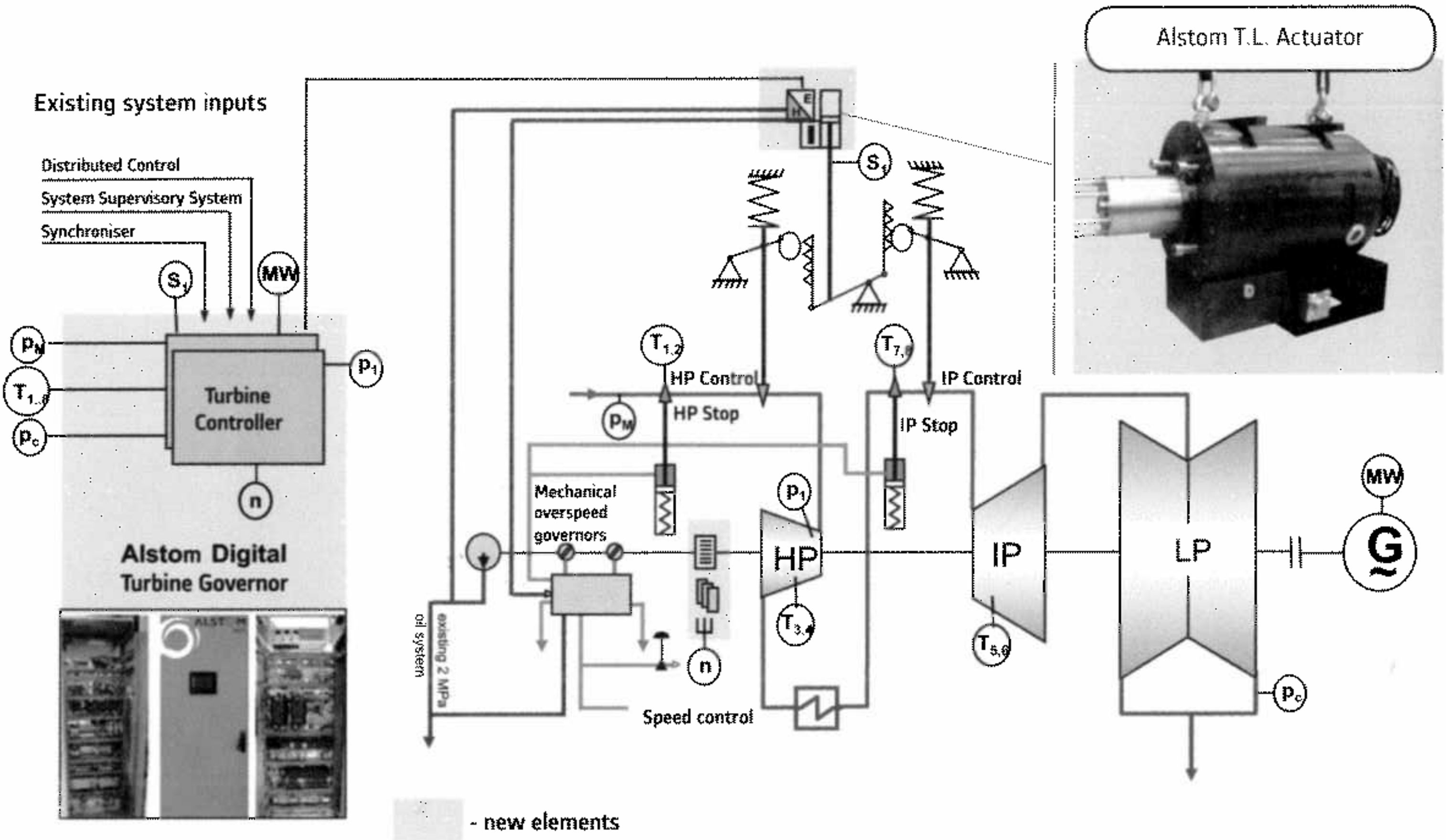
General philosophy of an electro-hydraulic control system



Basic Variant

This option is aimed at customers who only require the minimum adaptation to conform with grid regulations (e.g. CERC). The idea is to replace the mechanical controller with a redundant electronic controller, incorporating a digital governor (Alstom CONTROSTEAM™).

The controller is connected, via an electro-hydraulic converter, to an Alstom actuator of the T.L. type. This then operates the HP and IP by means of the existing levers.



Additional Options

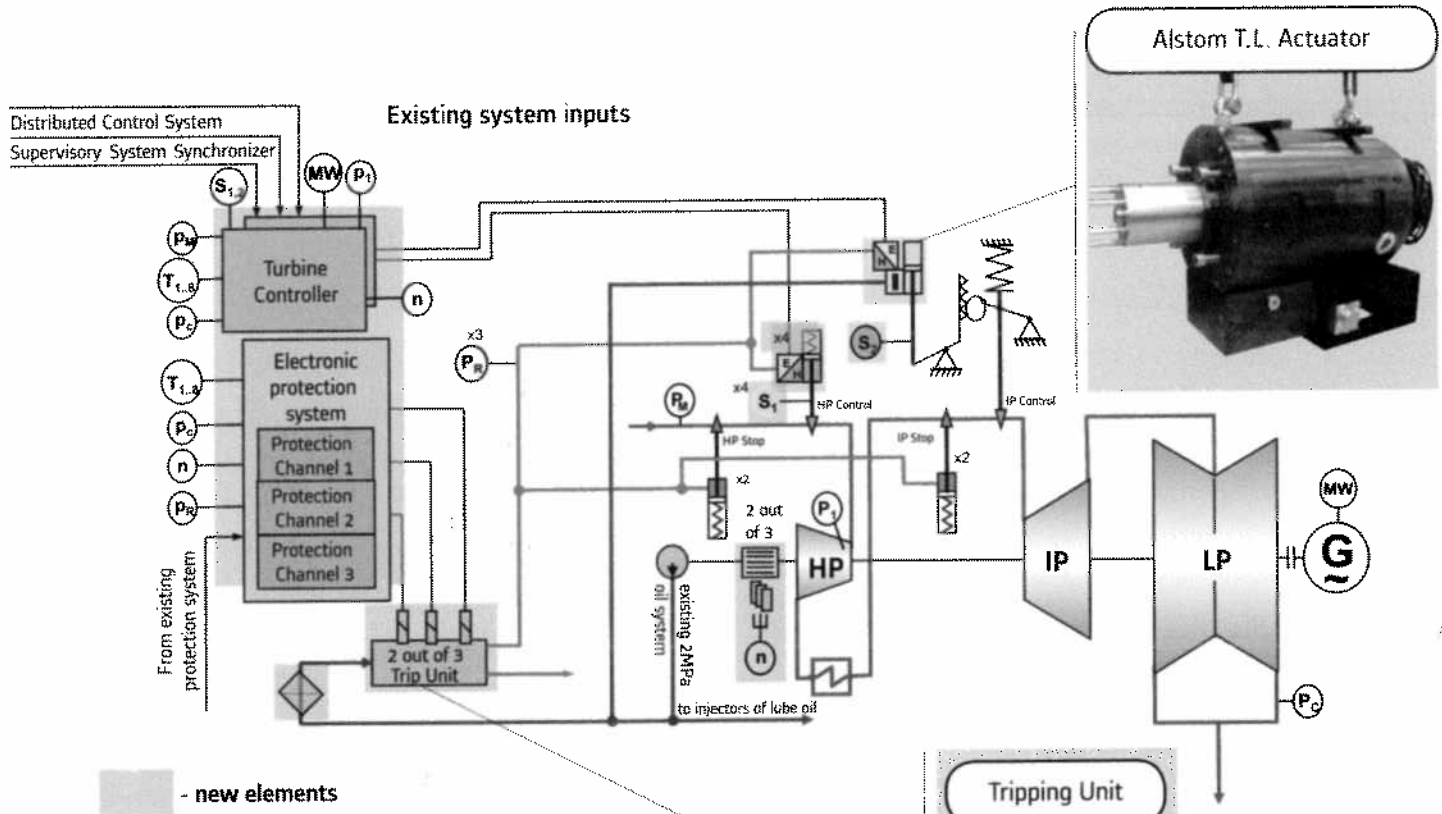
- Improved oil filtration by installing an oil filter in the electro-hydraulic converter supply
- A relay to reset the turbine protection system prior to start-up
- An electronic overspeed protection system

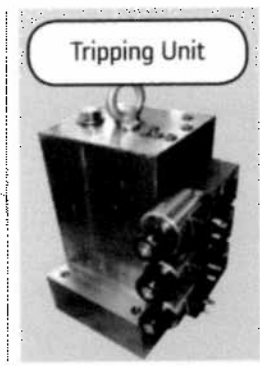
Standard Variant - with more comprehensive functions

This is a more comprehensive option with improved control and protection functions.

As with the Basic variant, the mechanical controller is replaced by a redundant unit, but the actuation of HP and IP valves is now separated for better operational flexibility. In fact the HP can have an actuator for each of its four control valves.

The existing mechanical protection system is replaced by a three channel system, connected to a 2 out of 3 trip unit. This gives a hydraulic link from the protection unit to the control system. An oil filtration unit is included in the supply to the trip unit.





Additional Options

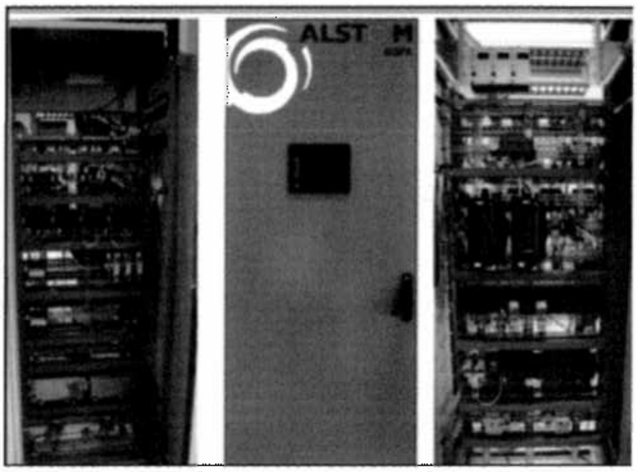
- A 40 bar control oil skid (as is standard for new fossil turbines)
- Improved IP steam control by installing individual actuators for the IP valves

Principal upgrade

Electronic turbine governor

The control equipment is of the most up-to-date Alstom design, consisting of two redundant controllers working in the Master/Slave mode. All control functions are provided for, but there is also the option for manual operation. The governor offers the following features:

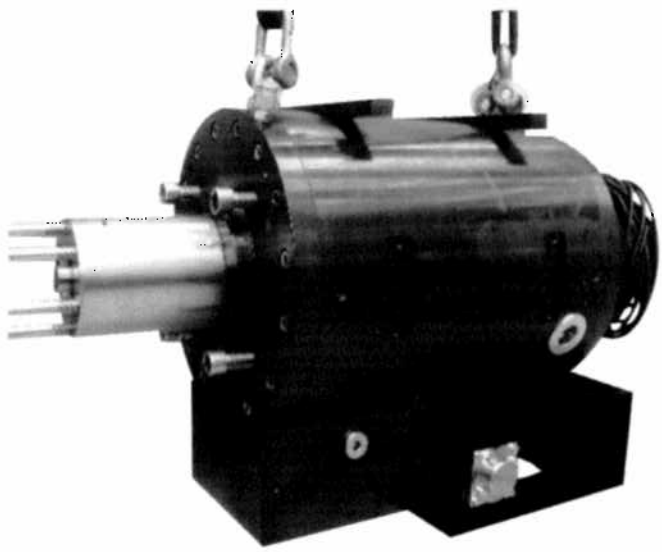
- Automatic calculation of optimum run-up gradients
- Selectable and adjustable frequency filter ('dead band')
- Automatic loading and un-loading functions
- Live steam pressure controller and limiter
- Automatic limiting functions for power plant during disturbances
- Load controller or coordinated load controller for unit control
- HP-exhaust temperature control ('trimming')
- Standardised interfaces for DCS systems



Views of control cabinets

T.L. actuator

This is a standard and fully-proven Alstom design for electro-hydraulic control (EHC), operated by a digital proportional valve with integrated position control. With its tubular housing and the option of a bus interface, the actuator is very adaptable to different applications.

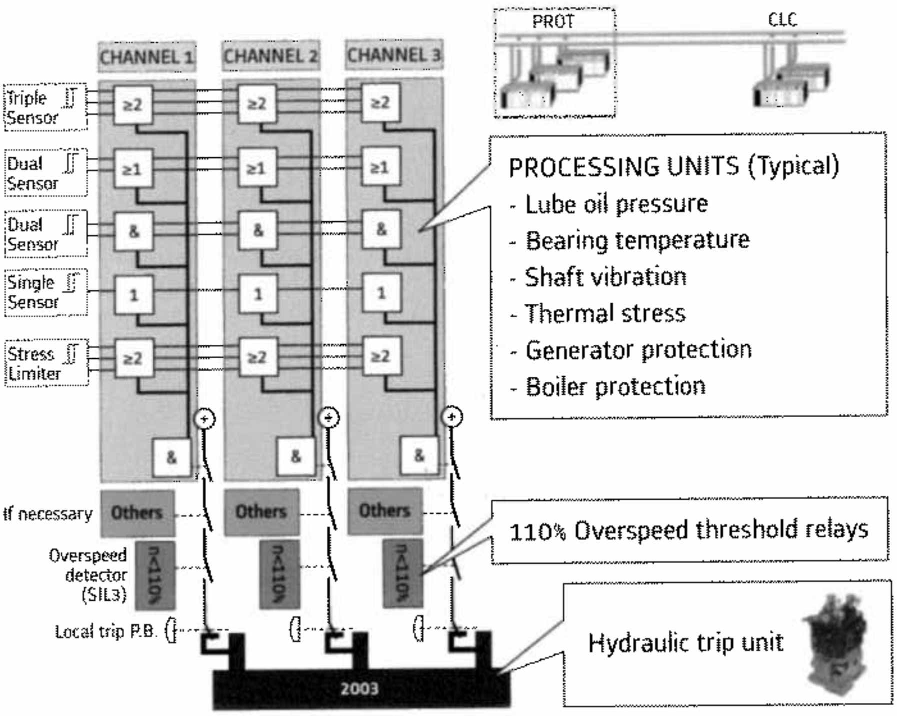


components

Electronic protection system

The electronic turbine protection system consists of three independent channels working on the 2 out of 3 voting principle. The channels communicate with each other and the turbine controller via a high-speed bus link. Analogue speed sensors are preferred to binary ones and up to three can be employed, depending on requirements.

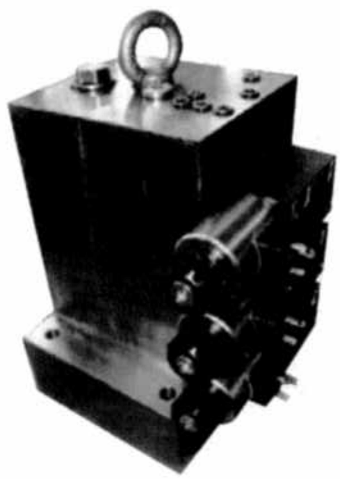
The system allows for full testing during operation. Due to the direct connection to the governor, there are also possibilities for connecting to a wide range of DCS systems, or providing for remote access.



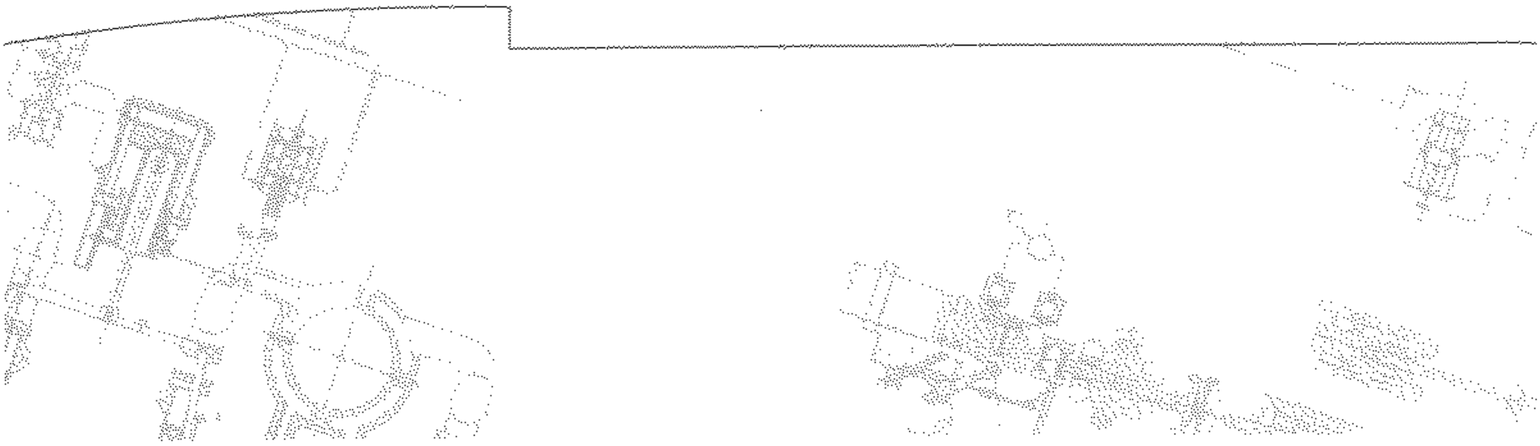
Compact tripping unit

This consists of three solenoids, each connected to a protection channel. Safety oil pressure is established as soon as two of the three solenoids are energised, although, in most cases, all three solenoids will be energised. A turbine trip command will de-energise the solenoids, thereby depressurising the downstream safety oil.

Since two or more channels are required to depressurise the system, each channel can be tested during operation. Solenoid coils can even be replaced with the turbine running.



Your Benefits



Benefits of each Variant	Basic	Standard
Improved reliability	√	√
Flexibility to change the operating logic	√	√
Automatic start-up	√	√
Improved governor reliability through redundancy	√	√
Improved control oil filtration	optional	√
Remote resetting of protection system	optional	√
Improved tripping reliability	optional	√
Reliable electronic ST protection		√
Improved HP valve control		√
Reliable, high pressure control oil system		optional
Improved IP valve control		optional

References

Alstom has experience of more than 200 ST control system upgrades on Alstom and non-Alstom steam turbines worldwide, starting from the mid 1990s. Moreover, there is a plenty of experience in providing control system upgrades for the LMZ 200 MW and similar fleets. To date, more than 40 such systems have been upgraded.

SPPA-R3000

EHC Based solution for LMZ 200/210 MW

Instrumentation, Controls & Electrical

Present Governing System

LMZ Hydro Mechanical Governing System

Sub Groups : LMZ Existing Governing System

LMZ Hydro - Mechanical Governing

Governing Control

- Speed Governor
- Follow Up Pilot Valve
- Speeder Gear
- Speed/Load Control PV
- Summation Pilot Valve
- Intermediate Pilot Valve
- Servomotor Pilot Valve
- CV Servo Motor
- Feedback Pilot valve
- Control Valves (HPT & IPT)

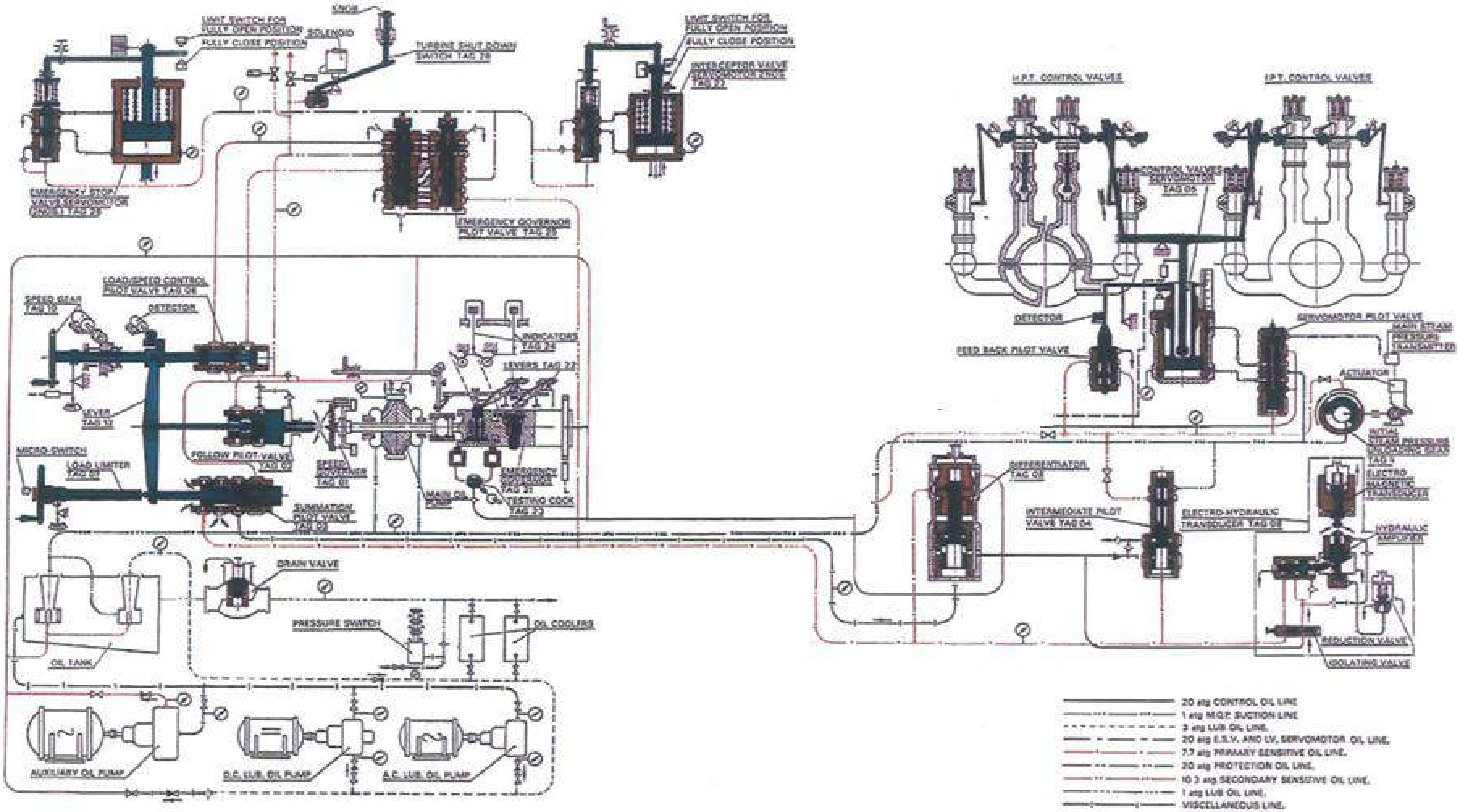
Potection Mechanism

- Emergency Governor (EG)
- EG Testing Lever
- EG Pilot Valves
- ESV Servomotor
- IV Servomotor
- Turbine Shutdown Switch

Pre-Emergency Devices

- ISPUG
- Differentiator
- Load Limiter
- Electro Hydraulic Transducer

Governing Scheme : LMZ 200/210 MW STGs



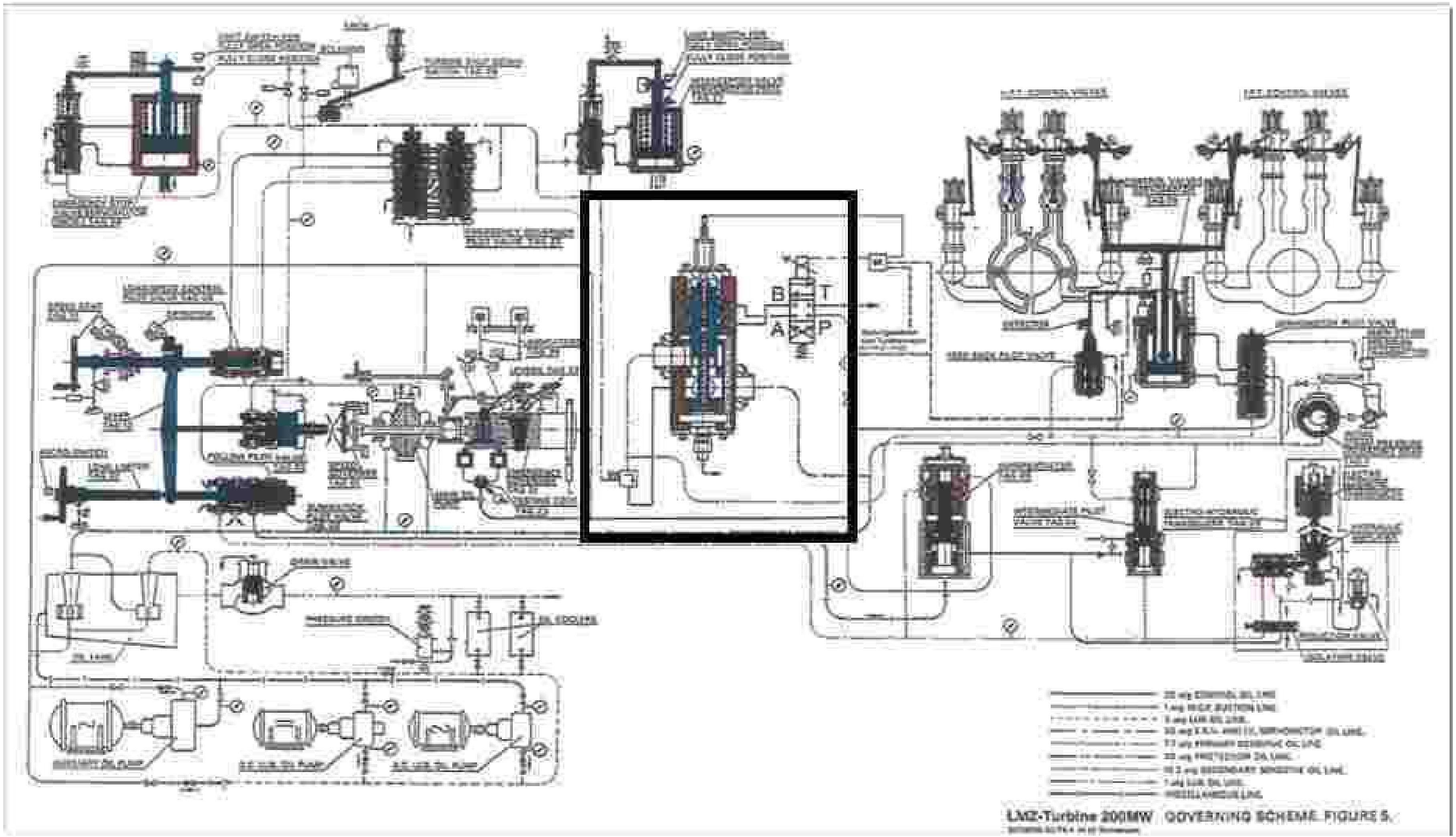
LMZ-Turbine 200MW GOVERNING SCHEME. FIGURE 5.

Our solution

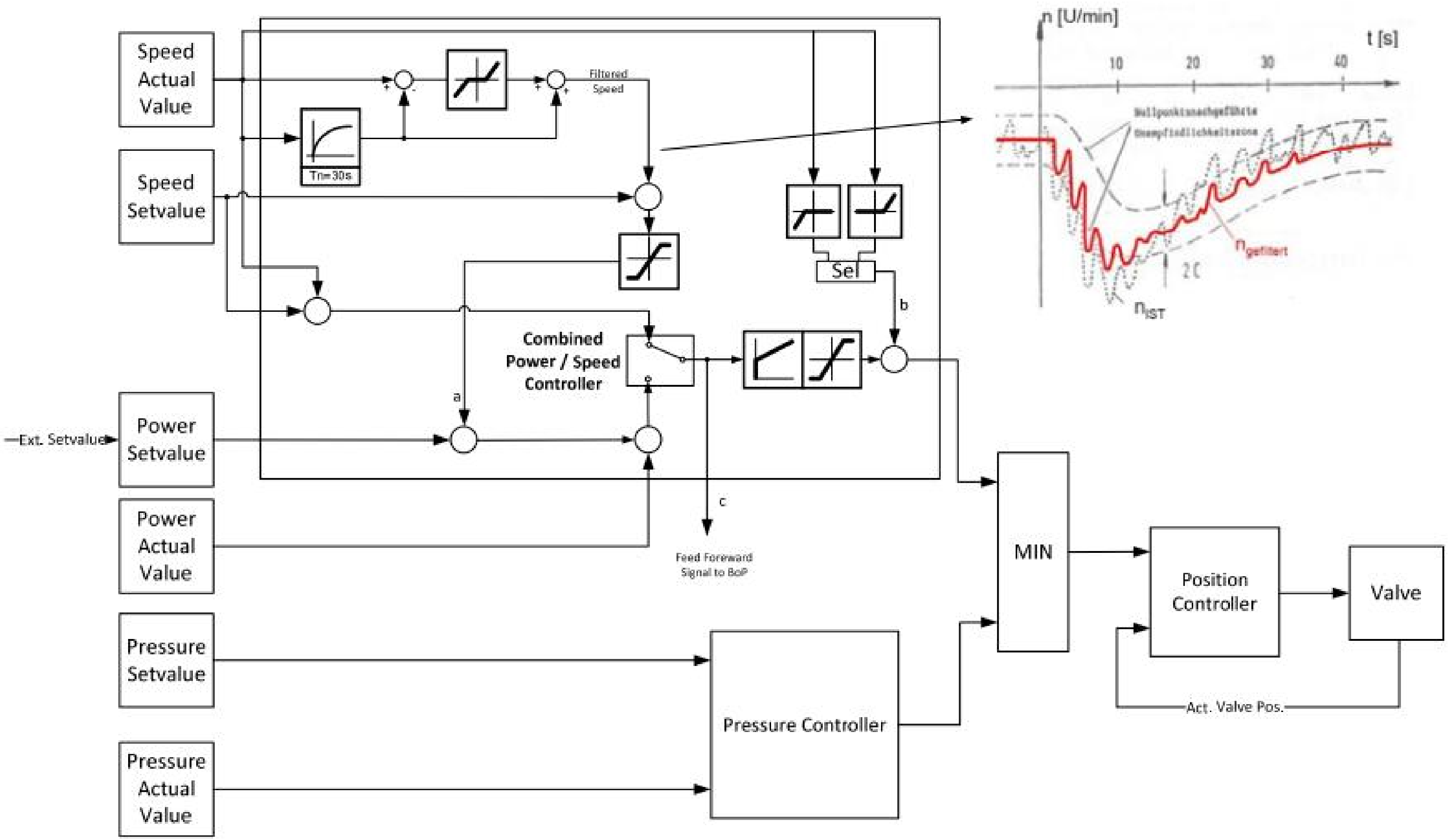
SPPA-R3000 : Turbine Governing system

SIEMENS

Modified Governing Scheme : LMZ 200/210 MW STGs



Modified Governing Scheme : RGMO/FGMO block Diagram



THANK YOU !

SPPA-R3000 : Turbine Governing system

Annexure-XI

Digital Controls for 200/210MW LMZ Steam Turbines

Imagination at work

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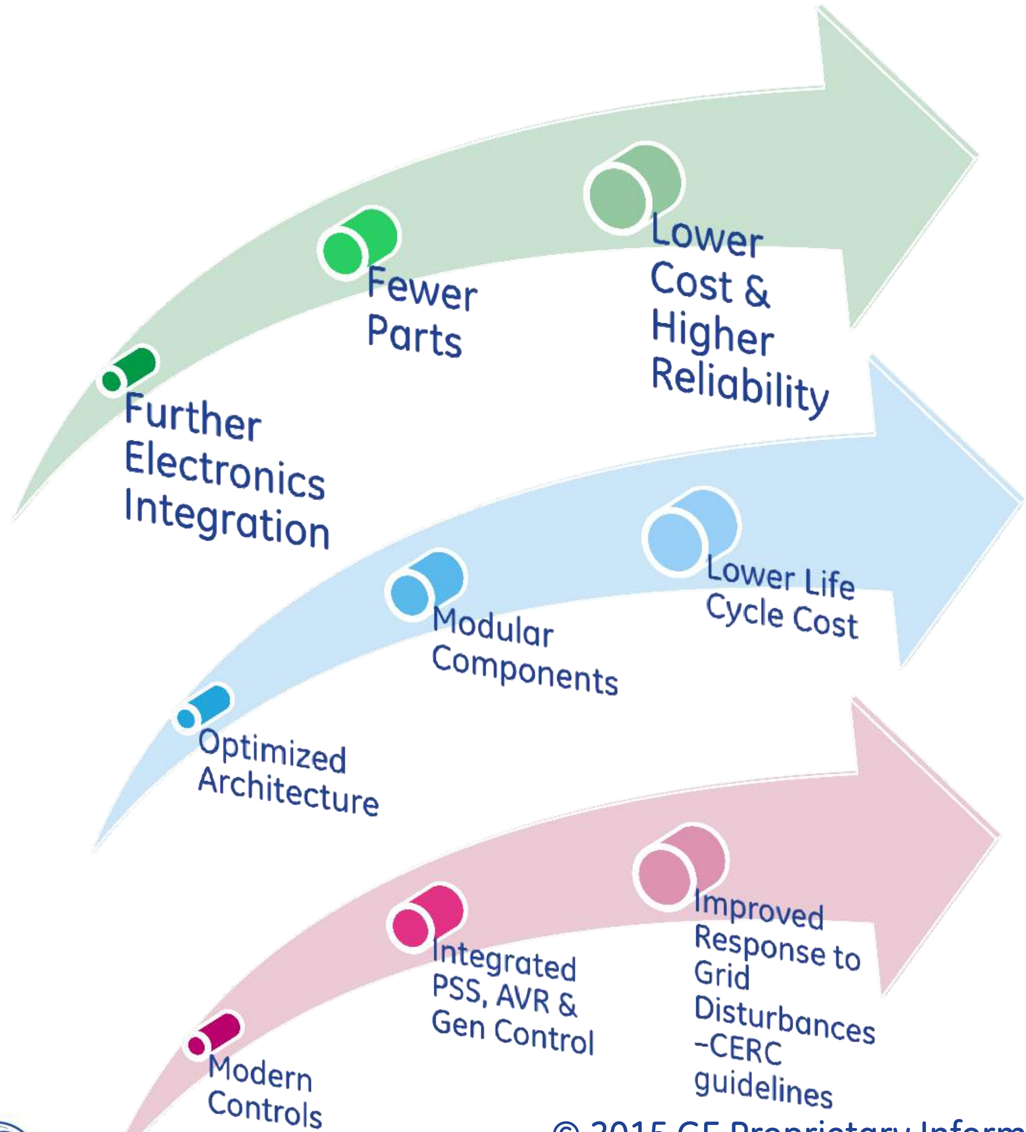
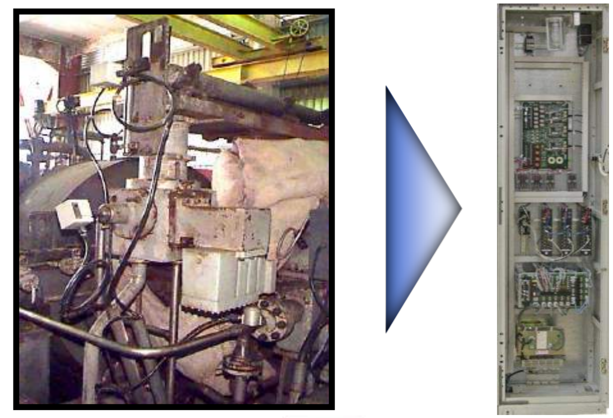
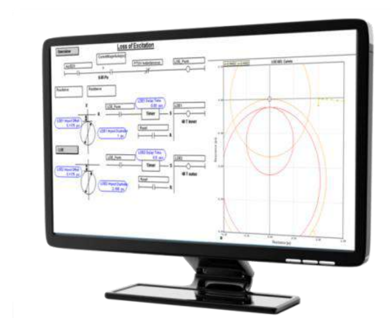
Controls Technology Evolution







OC 6000e Nexus Governor Control System

OC 6000e Nexus Technology Benefits

Increased

Performance – precise control & protection

Flexibility – features & applications

Availability – reliable

Usability – intuitive, powerful tools

Maintainability – serviceable, life cycles support

Customer
Peace of Mind

imagination at work

Experience List…LMZ

#	End User	Model	Manufacturer	Applications			Delivery Date
1	Unit 4 210MW, Shuang Yashan Power Plant	K215-130-1	LMZ	DEH		EH	July, 2001
2	Unit 3 210MW, Shuang Yashan Power Plant	K215-130-1	LMZ	DEH		EH	July, 2002
3	Unit 6, 210MW, Ma Tou Power Plant	K200-130-3	LMZ	DEH	DCS	EH	July, 2000
4	Unit 5, 210MW, Ma Tou Power Plant	K200-130-3	LMZ	DEH	DSC	EH	December, 2002
5	Unit 5, 215MW, Mu Danjiang No.2 Power Plant	K215-130-1	LMZ	DEH		EH	November, 1999
6	Unit 6, 215MW, Mu Danjiang No.2 Power Plant	K215-130-1	LMZ	DEH		EH	March, 2001
7	Unit 1, 125MW, Ji Lin Thermal Power Plant	ЛТ-90/120-130-2	Ural Turbine Power Co.	DEH	DCS	EH	January, 2004
8	Unit 2, 125MW, Ji Lin Thermal Power Plant	ЛТ-90/120-130-2	Ural Turbine Power Co.	DEH	DCS	EH	October, 2003
9	Unit 1, 100MW, Jiao Yuan Power Plant	ЛТ-90/120-130/10-1	Siberia Power Co. Ltd.	DEH	DCS		March, 2001
10	Unit 2, 100MW, Jiao Yuan Power Plant	ЛТ-90/120-130/10-1	Siberia Power Co. Ltd.	DEH	DCS		September, 2001
11	Unit 1, 65MW, Nan Ding Power Plant	ЛТ-65/75-90/13	LMZ	DEH	DCS	EH	September, 2005

LMZ Name Plate*

*As taken at site

Why retrofit governor controls…

Regulatory

CERC guidelines…

- No reduction in MW in case of improvement in frequency below 50.2Hz
- For any fall in grid frequency, MW should increase by 5% limited to 105% of the MCR
- Ripple Filter of +/- 0.03 Hz to be provided to avoid small change in frequency for MW correction …. preventing governor hunting
- 3% to 6% Droop setting required
- CERC to review RGMO once the grid stabilizes at 50Hz…. FGMO to be introduced thereafter

Obsolescence

- Less maintenance due to elimination of moving control parts eg. Cam Shaft, Rack & pinions etc.
- Readily available service for modern electronics versus MHC era
- Readily available spare parts for current electronics versus obsolete mechanical parts
- Better accuracy and resultant control efficiency due to electronic regulation
- Faster dynamic response due to electronic feedback loops
- Array of new functionality added to improve control, protection, and monitoring

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Retrofit solution

EH/Mechanical
➢ **Turbine Governor system** Dismantle mechanical governor related components. Replaced with electronics DEH controller to control speed, load, etc.
➢**Turbine Trip system** Keep mechanical over-speed trip and testing. Add high pressure 2oo4 trip solenoids and 2 over-speed control solenoids.
➢**Oil Supply** Added a standalone 150 bar high pressure fire resistance oil system for governing
➢**Actuators** Dismantle all existing actuators and mechanism used to drive steam valves. Each steam valve equipped with one new high pressure actuator and closing spring house
➢**Inlet steam distribution leverages and cams** Dismantle existing inlet distribution leverages and cams. Inlet steam distribution is controlled by digital curves in new controllers, easy adjustable per turbine conditions

Retrofit of Governor and Trip System

Key Points

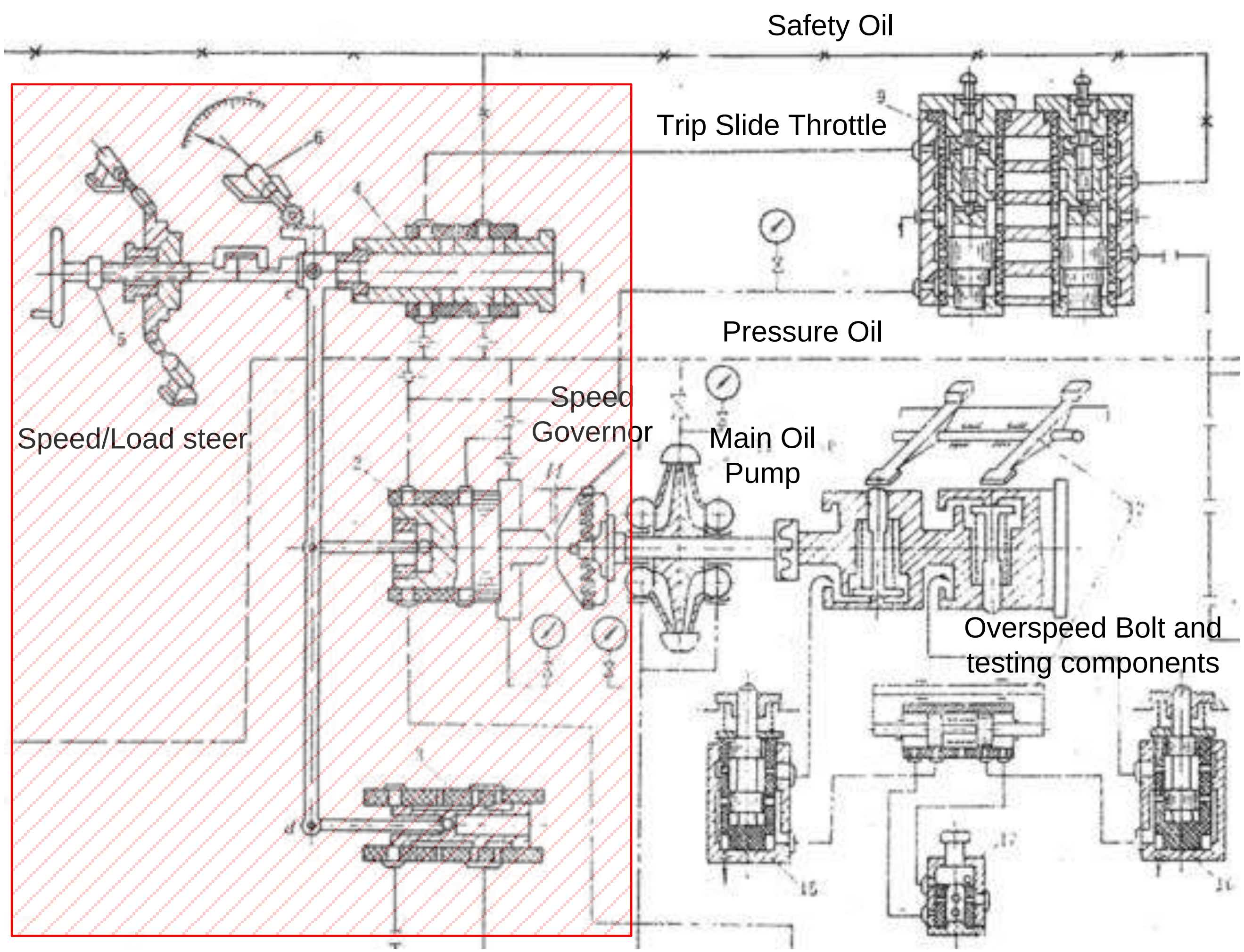
- **Dismantling**

All mechanical governor related components

(marked in red)

- **Keeping**

Turbine oil mechanical over-speed trip and testing system

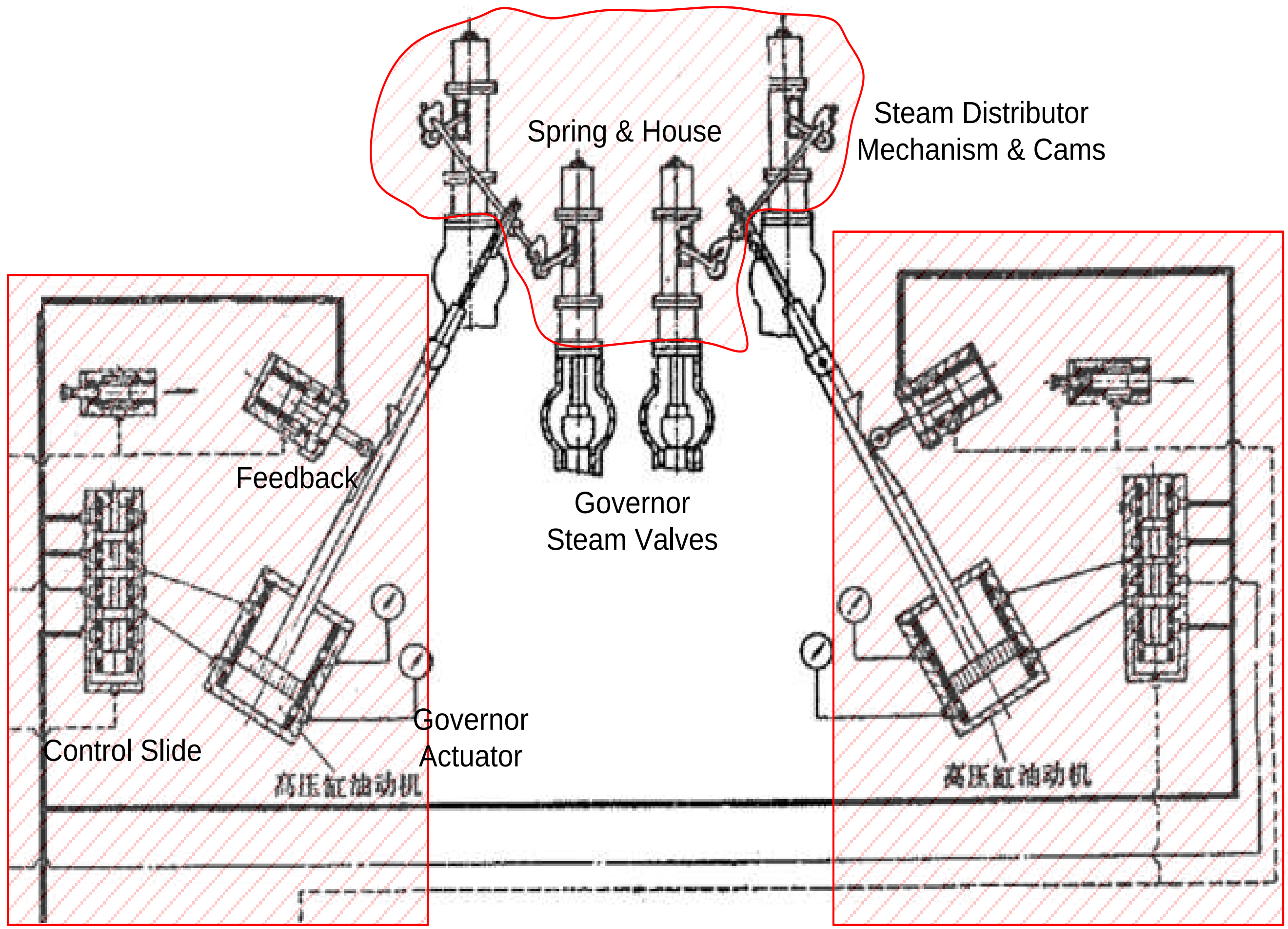


Retrofit of Actuators…Governor valves

Key Points

- **Dismantling**
  Two GV actuators and leverage/cams (Red marked)
- **Replacing**
  Four actuators for four GV (Direct drive)
- **Keeping**

The connection interface of steam valve rods

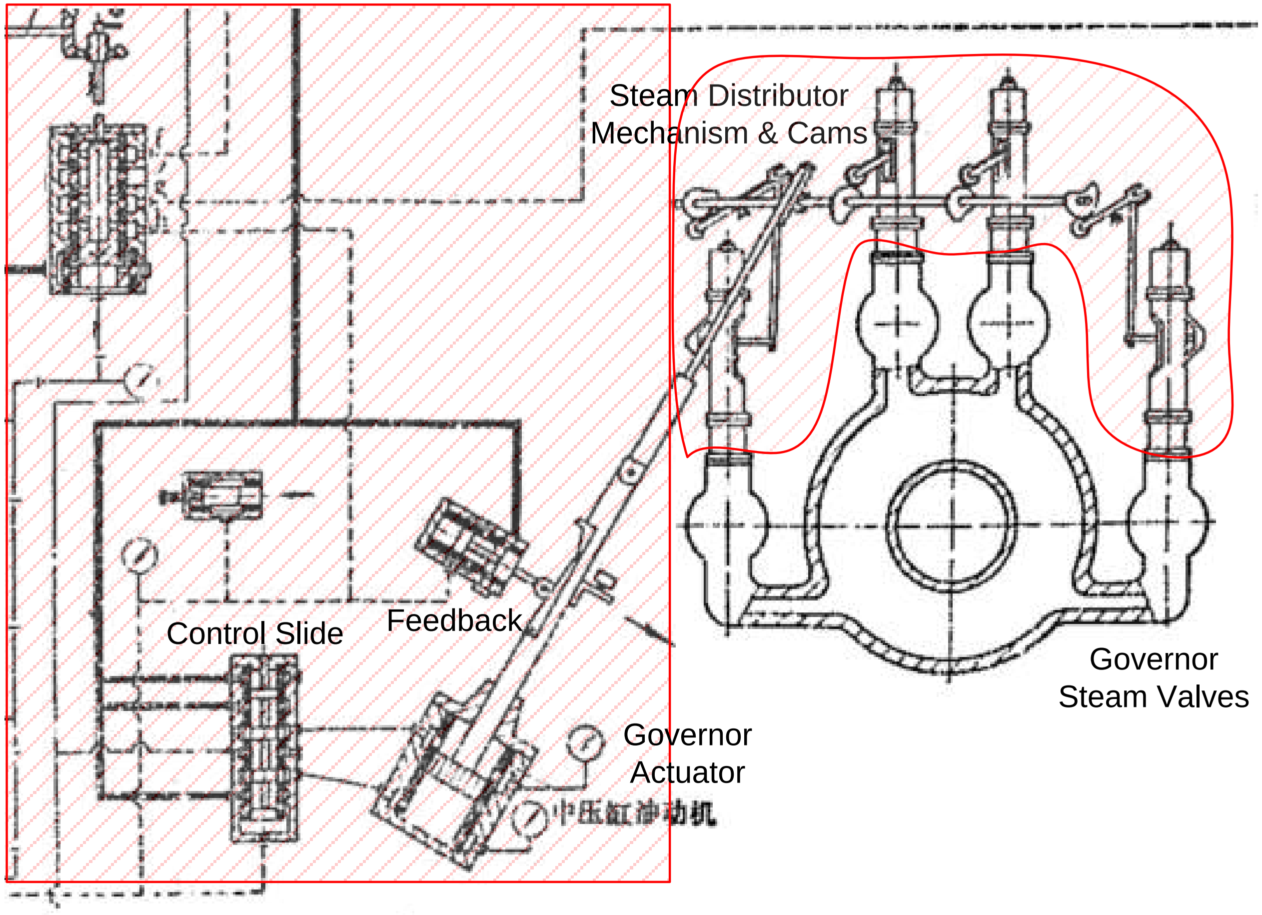


Retrofit of Actuators…Intercept valves

Key Points

- **Dismantling**
  One IV actuator and leverage/cams (Red marked)
- **Replacing**
  Four actuators for four IV (Direct drive)
- **Keeping**

  The connection interface of steam valve rods



Performance comparison… Control System

	Before	After
Speed overshoot at 3000rpm:	30~60 rpm	less than 10 rpm
Speed control Precision (3000rpm):	over +/-20 rpm	+/-1 rpm
Operation/Alarm Data Display:	Limited data	Comprehensive data
Online Testing:	Not available	Support online testing, such as over-speed; trip solenoid ; valve partial or full stroke tests, etc.
Valve management:	- Fixed/large valve overlaps, - Higher heat stress at cold start-up, - Higher throttle loss at partial load conditions	- Valve overlap adjustable, - Lower heat stress at cold start-up, - Lower throttle loss at partial load conditions
System maintainability:	Relatively difficult and time consuming	Much easier

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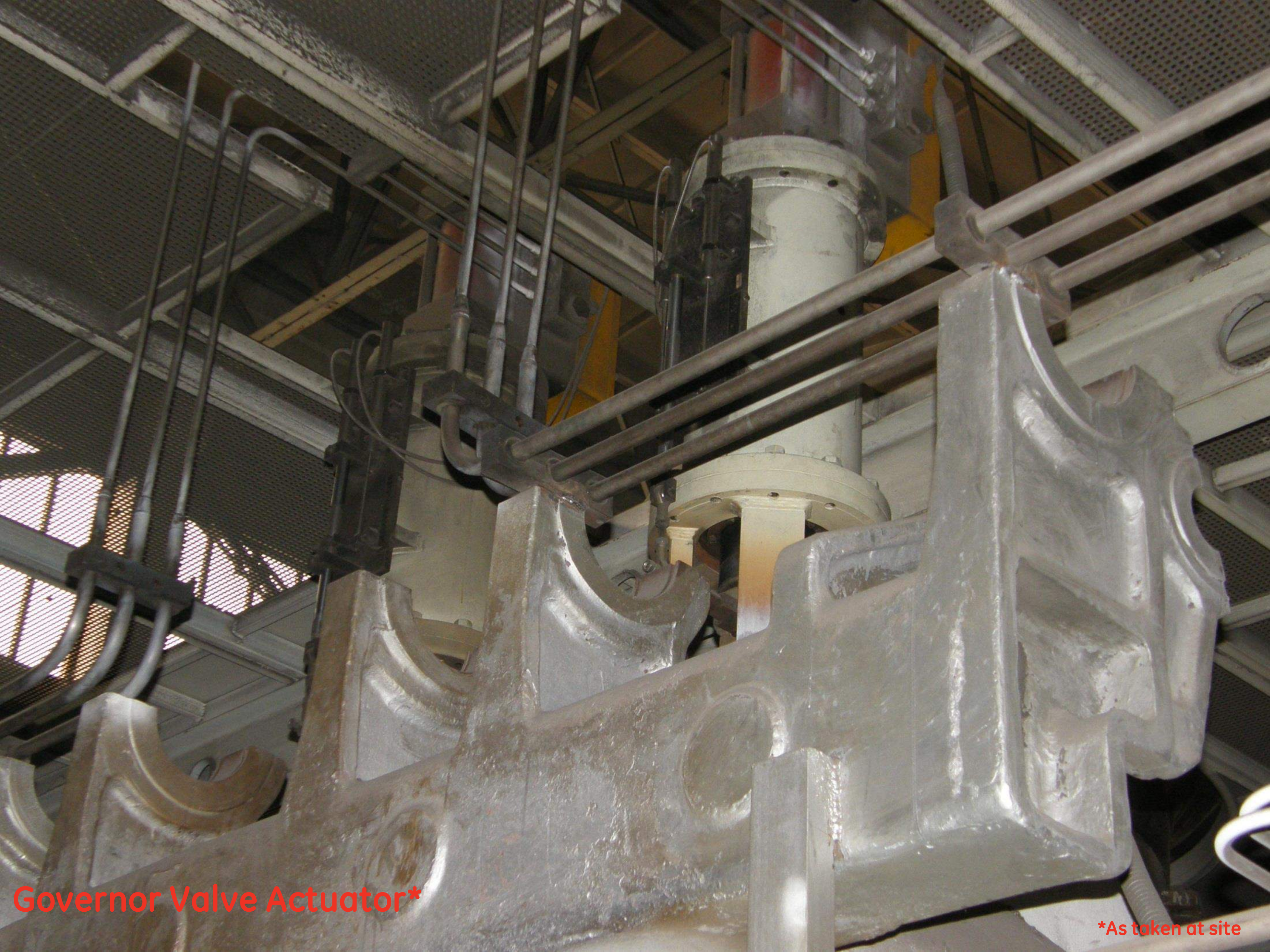
Typical Retrofit Cycle

Begin	Unit shutdown
• 1~3 Days	Turbine cooling
• 4~10 Days	Old instrument dismantling
• 11~25 Days	New control system installation and wiring
• 26~33 Days	New control system recovery and commissioning
• 4~10 Days	Old mechanism system dismantling
• 11~25 Days	EH system retrofit and installation
• 26~33 Days	Oil circulation
• 34~35 Days	Sub-System checking, commissioning
• 36~37 Days	DEH-EH integration testing, system testing and checking
• 37~39 Days	Putting the unit on barring gear

Stop Valve Actuators*

*As taken at site


Governor Actuator*
*As taken at site


Governor Valve Actuator*
*As taken at site

Governor Valves*

*As taken at site

Hydraulic Pressure Unit*

*As taken at site

As taken at site

Turbine Functionality

Base Functionality- Generally the functions of the existing (old) turbine control system are replicated in our new system as a minimum.

Typical Base Functions

- Speed control
- Valve position ctrl
- Extraction pressure
- Back pressure ctrl
- Inlet pressure ctrl
- Valve testing
- Over-speed testing
- Load limit
- Valve position monitoring
- Primary trip

Added Functions after retrofit

- ✓ Bearing temperatures
- ✓ Lube oil interface
- ✓ HPU interface
- ✓ DCS communication
- ✓ Process monitoring
- ✓ Automatic starting
- ✓ Temperature monitoring
- ✓ Auto synchronization
- ✓ Valve management
- ✓ Valve on-line testing

Questions ?

imagination at work

ELECTRO-HYDRAULIC GOVERNING (EHG) SYSTEM SOLUTION FOR 200/210 MW LMZ SETS

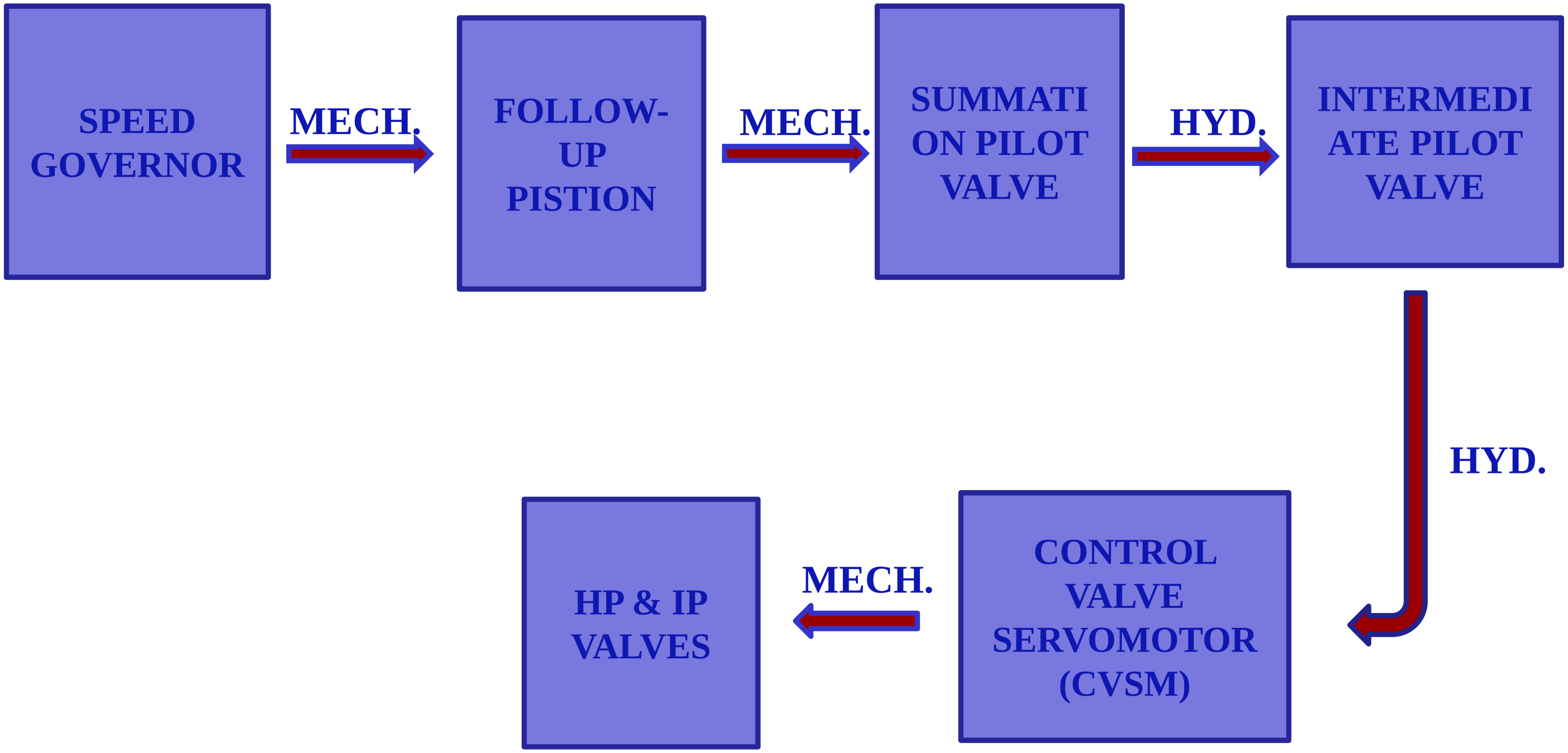
BASIC CONCEPT

- **The mechanical governing system is modified to electro-hydraulic governing system for facilitating the operation of the turbo set in an interconnected grid system.**
- **Both Mechanical and Electro-hydraulic systems are now available and operate independently.**
- **Manual changeover to backup system is possible during operation.**

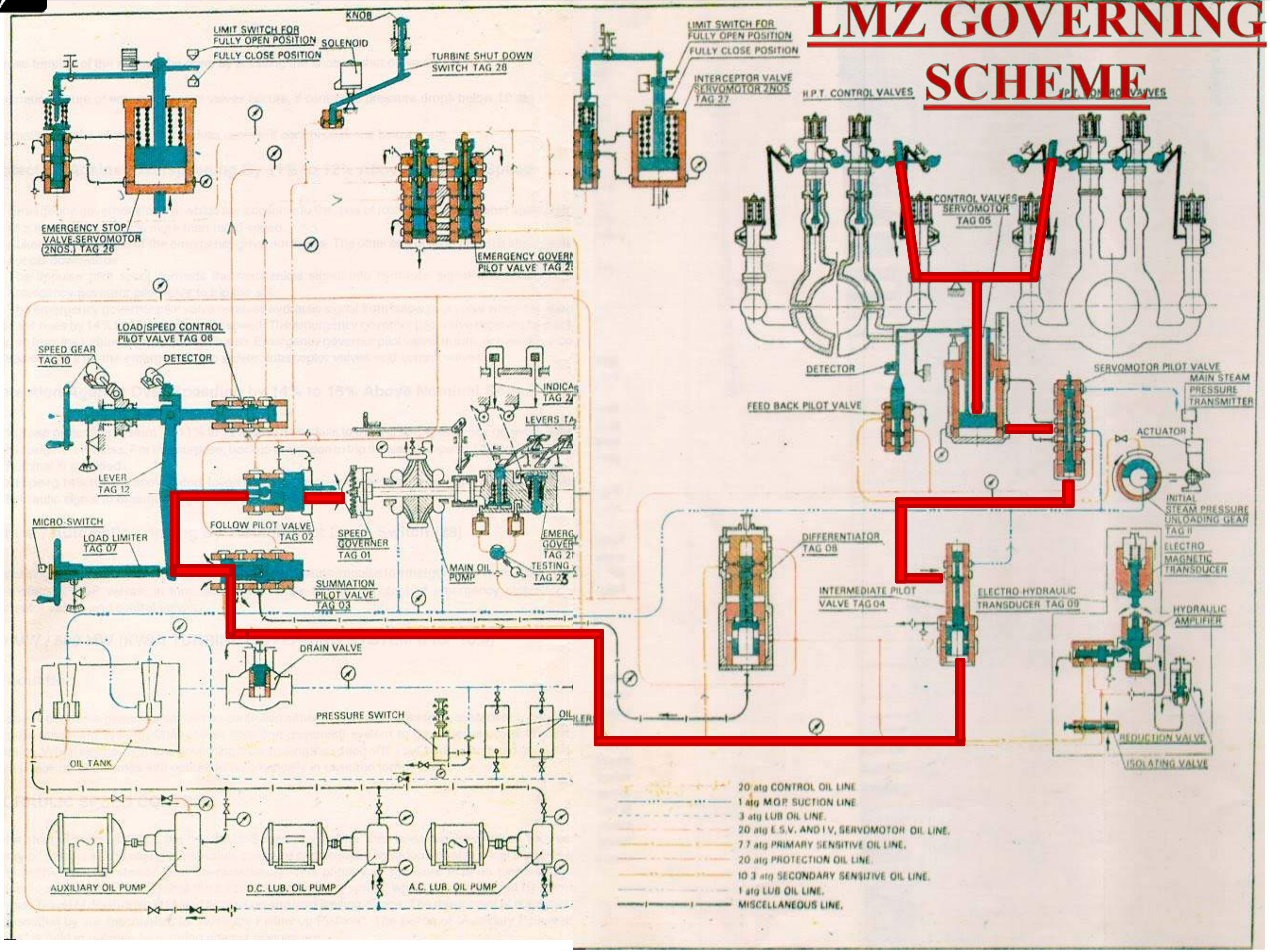
EXISTING DESIGN

Russian design LMZ steam turbines presently installed in the country are equipped with Hydro-mechanical type Governing system.

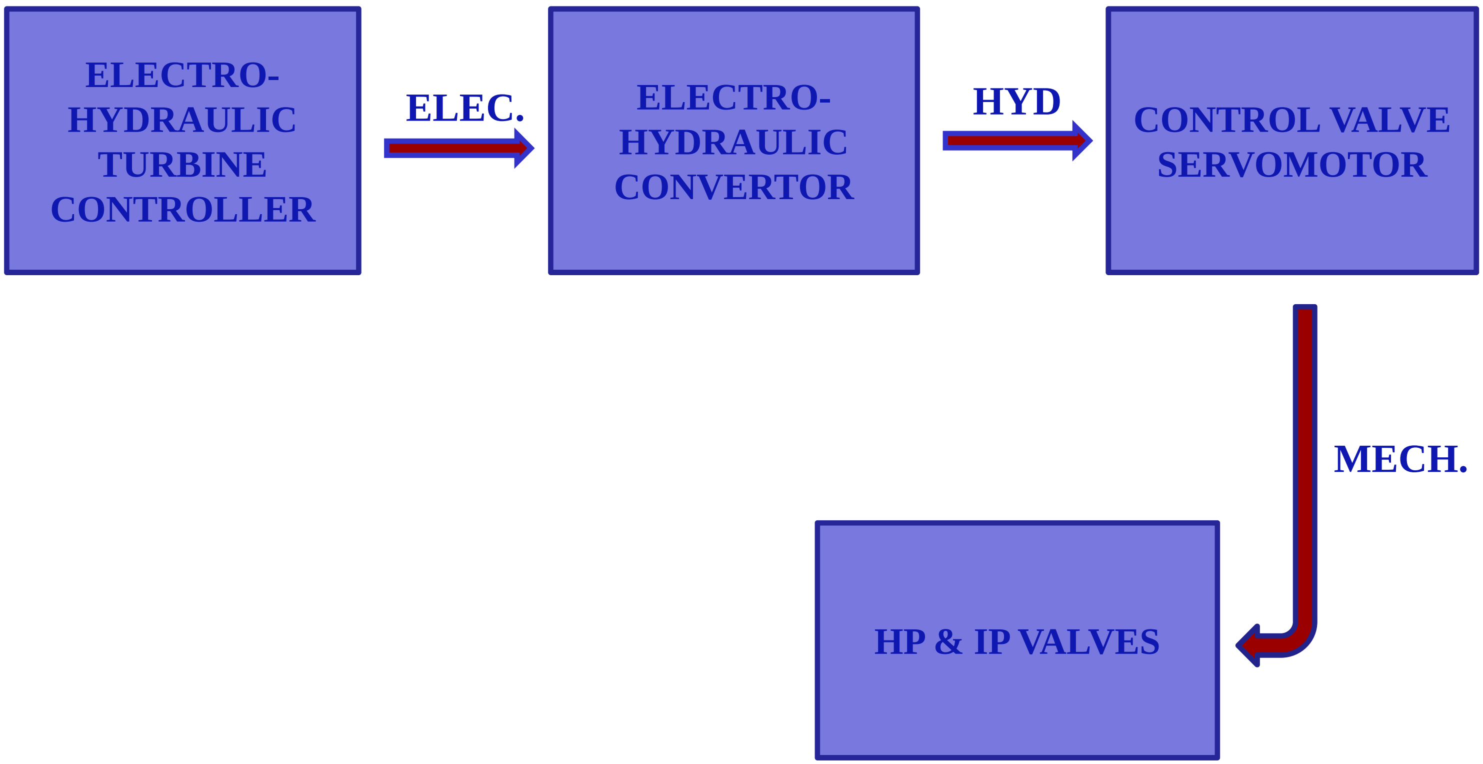
HYDRO-MECHNICAL GOVERNING SYSTEM (EXISTING):



LMZ GOVERNING SCHEME

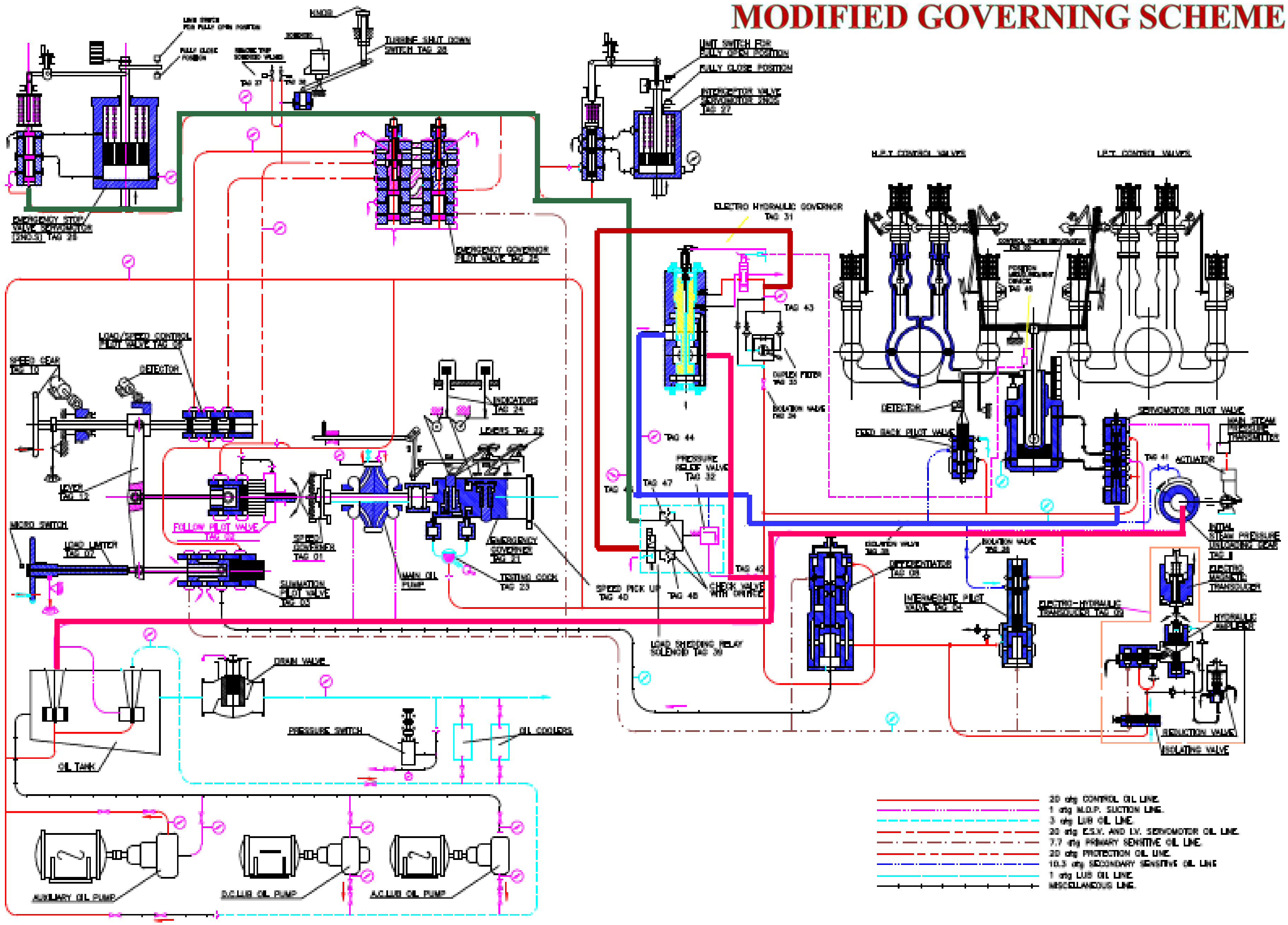


ELECTRO-HYDRAULIC GOVERNING SYSTEM (DEVELOPED)



EHG SYSTEM SOLUTION FOR 200/210 MW LMZ SETS

MODIFIED GOVERNING SCHEME



ADVANTAGES:

- **Faster response and more reliability in operation.**
- **Enhancement in degree of automation in TG set operation.**
- **Technological upgradation of product.**
- **Enhanced customer satisfaction.**
- **Easy implementation of EHG system with minimum changes.**
- **Availability of Back-up system.**
- **RGMO compliant.**

EXPERIENCE

- Turbine Controller is based on proven concept used in BHEL 210/250/500/600 MW sets
- Control element i.e. Proportional Valve is well proven and being used for the same application in 250/500/600MW sets.
- Under execution in Koradi R&M Project and Obra Project.

Thank You!

Annexure-XIII

The West Bengal Power Development Corporation Ltd.

REALIZATION OF RGMO IN UNIT#5 & UNIT#6

Santaldih Thermal Power Station

Turbine Technical Data

- UNIT #5 & UNIT #6 each having capacity of 250 MW.
- **Turbine:** Condensing Tandem Compounded Horizontal Reheat typed **&** KWU designed .
- **Rated Load :** 250 MW.

Turbine Technical Data Contd..

- **Maximum Load** under valve wide open (VWO) condition: 262.5 MW
- **Main Steam Pressure & Temperature** at full load : 147.10 kg/cm2 & 537^0C.
- **Rated speed :** 3000 RPM

Governing System

Equipped with Electro-Hydraulic Governor (Nozzle and Throttle Mode); fully backed-up by a Hydraulic Governor. The integration of electrical and hydraulic system in an excellent combination with following advantages.

- Exact load-frequency droop with high sensitivity.
- Avoids over speeding of turbine during load throw offs.
- Adjustment of droop in fine steps, during on-load operation.

RGMO as realized at STPS,WBPDCL

- Once frequency falls below 50 Hz, any decrease in frequency will result in ramp up in generation by Governor Action as per droop (5 %), limited to 5% of rated capacity i.e. 12.5MW till the frequency reaches value 50.05 Hz.

- If the frequency $<$ 50.05 Hz, any increase in frequency will not result in decrease in generation.

RGMO as realized at STPS,WBPDCL Contd…

- If frequency > 50.05 Hz, any increase in frequency will result in ramp back to the original MW set point.
- The quantum of generation change by Governor Action will be limited to 5%.
- Unit Loading/Unloading Rate for STPS : 1% i.e. 2.5MW/Min.
- Droop: 5% i.e. 10.02 MW/0.1Hz

  1.67 MW/rpm

RGMO In Service For UNIT#5 & 6

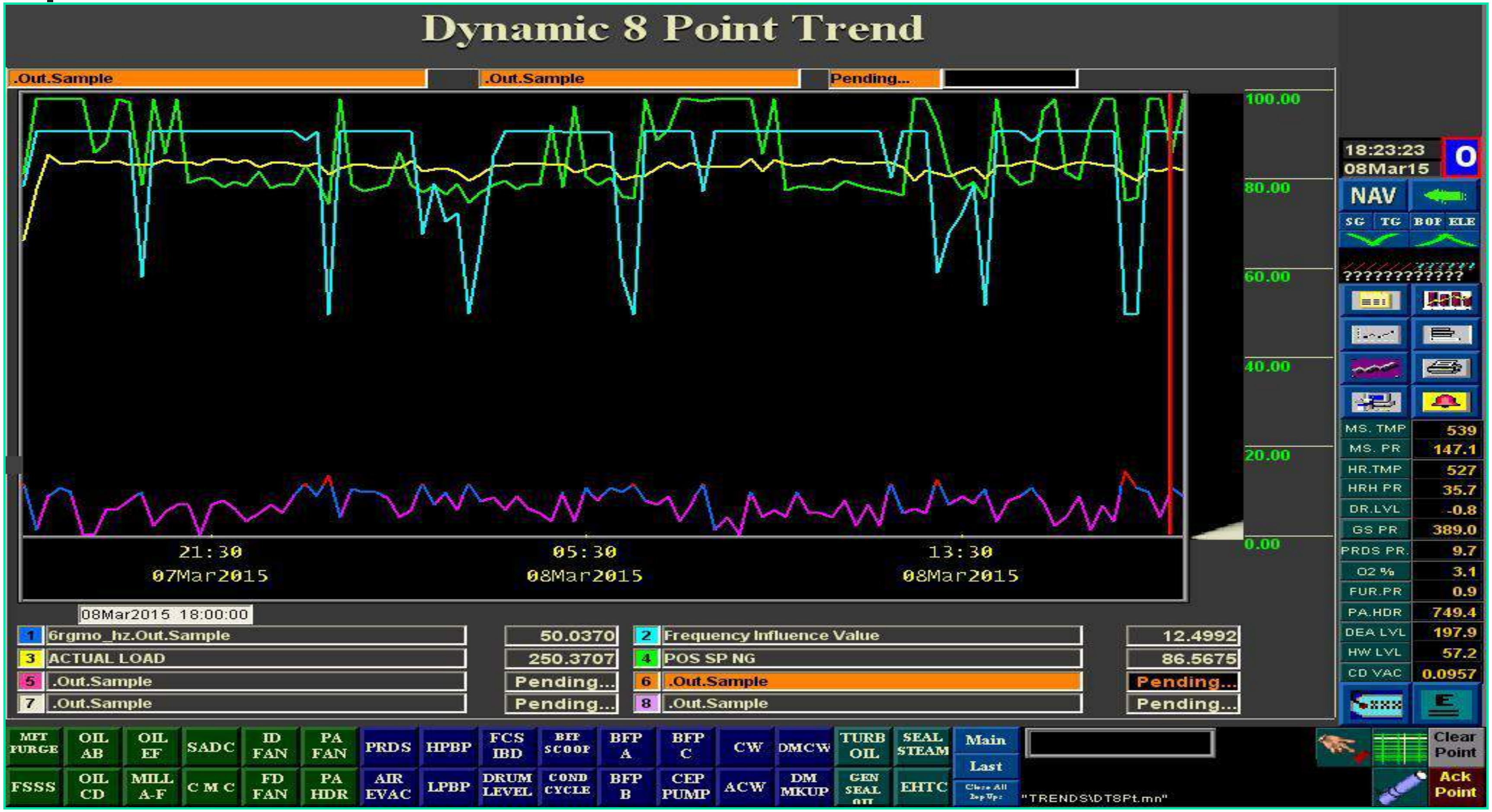
- RGMO put into service in **Unit#5** at 10:45 Hrs on 26th Feb'15 & running continuously.

- RGMO put into service in **Unit#6** from 9:30 Hrs on 10th Dec'14 & running continuously.

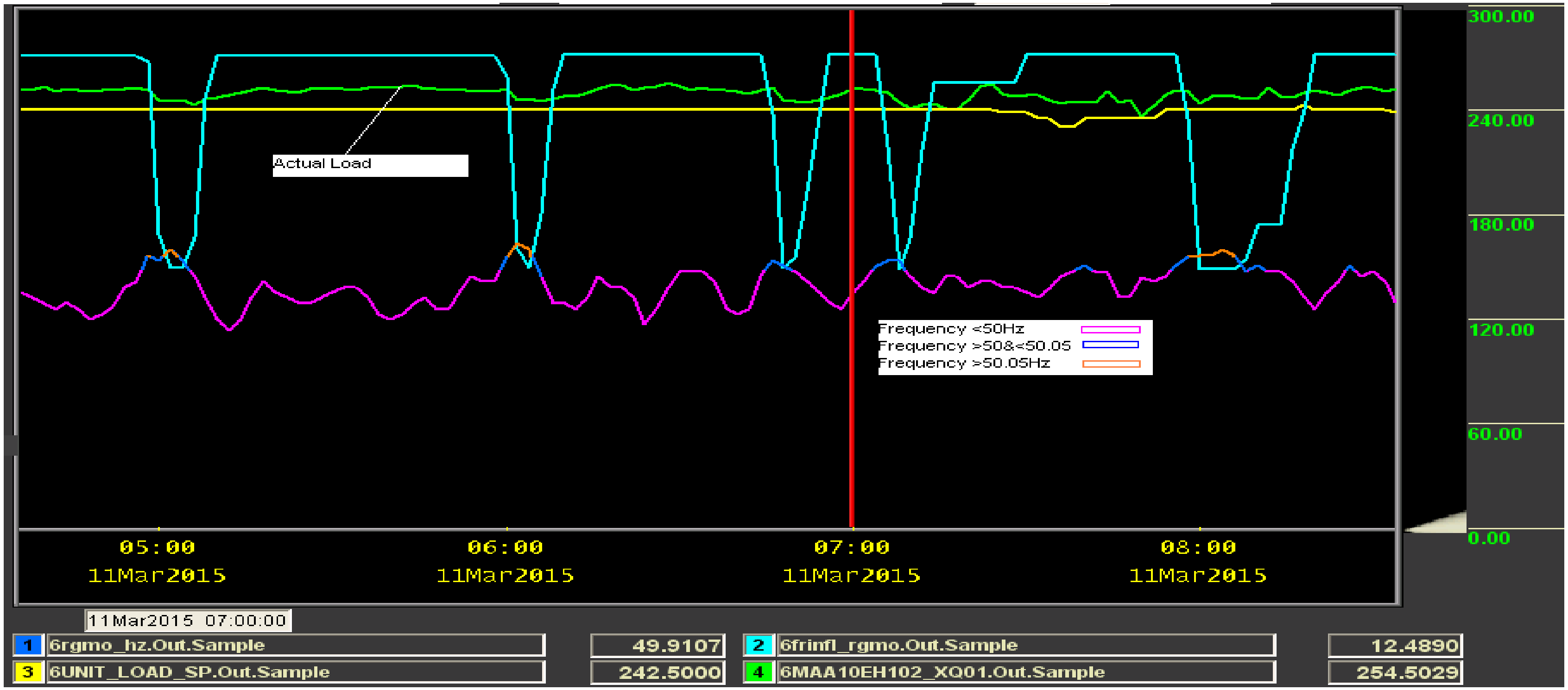
Instance of RGMO In UNIT#6

Date	Time (HH::MM)	Occurrence of Frequency influence on RGMO
11th Dec'14	00:00 to 24:00	23
10th Feb'14	00:00 to 24:00	15
15th Feb'14	00:00 to 24:00	18
03th March'14	00:00 to 24:00	19
06th March'14	00:00 to 24:00	17

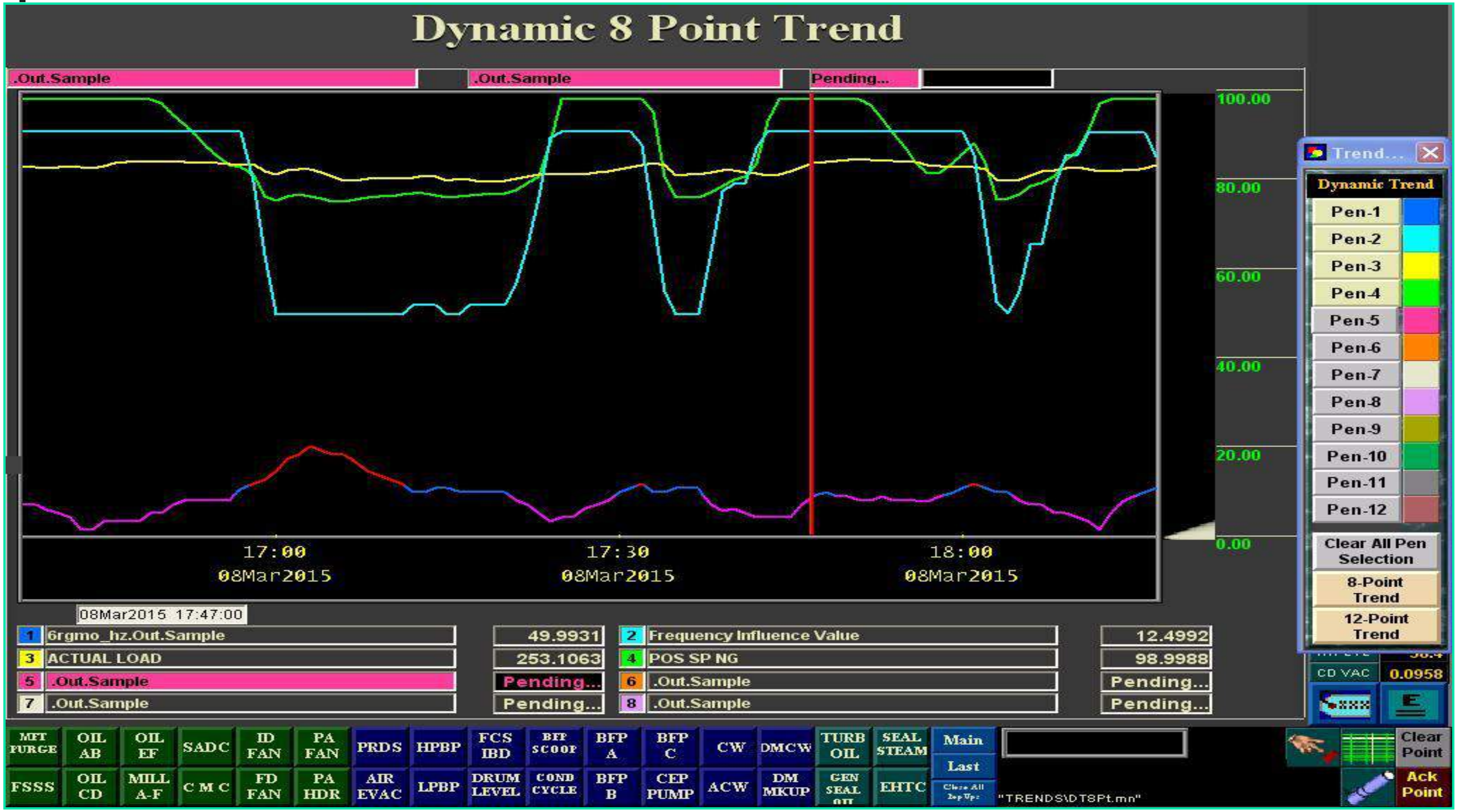
RGMO Influence Trend In UNIT#6



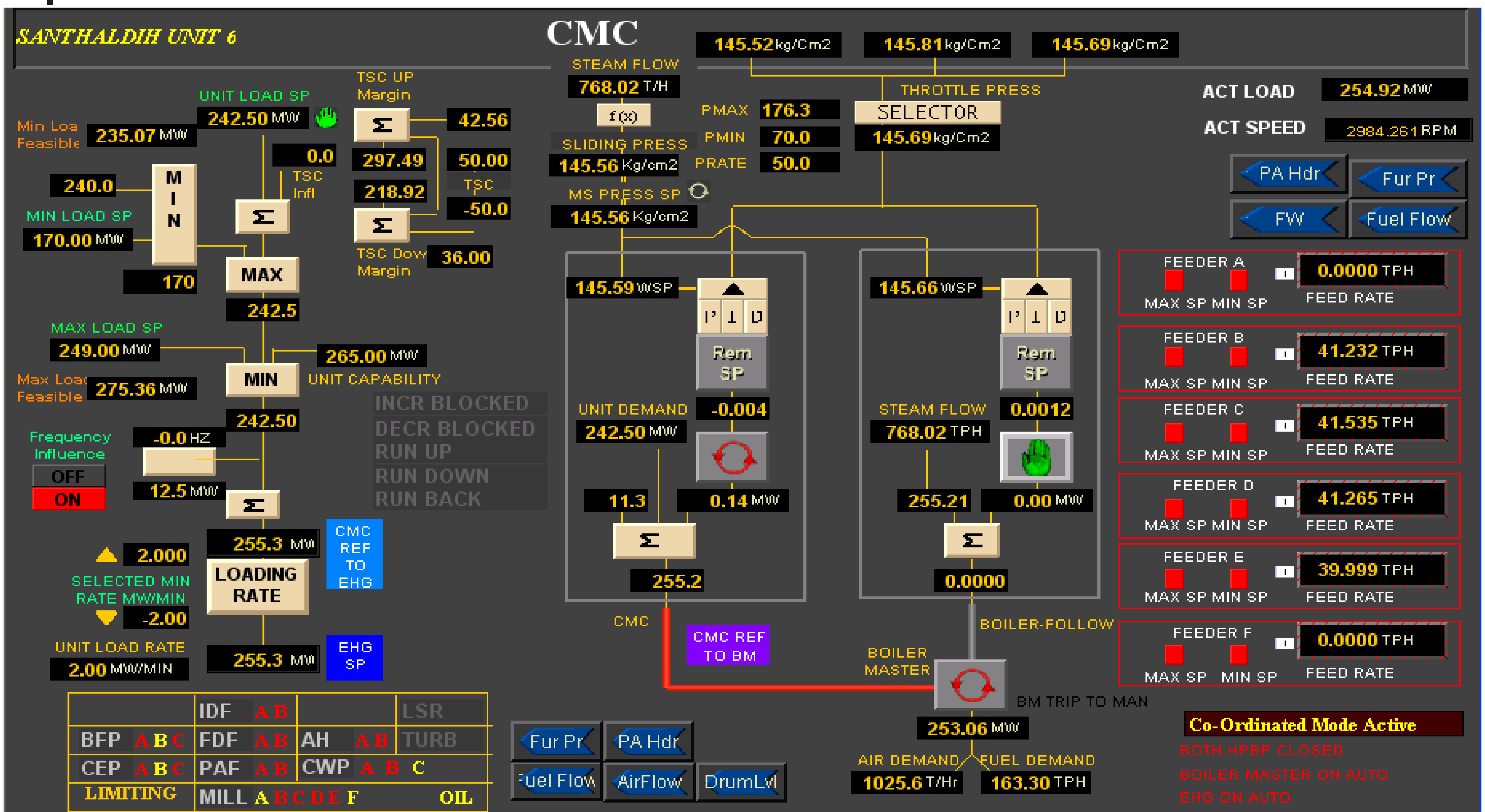
RGMO Influence Trend In UNIT#6



Governor Response RGMO In UNIT#6



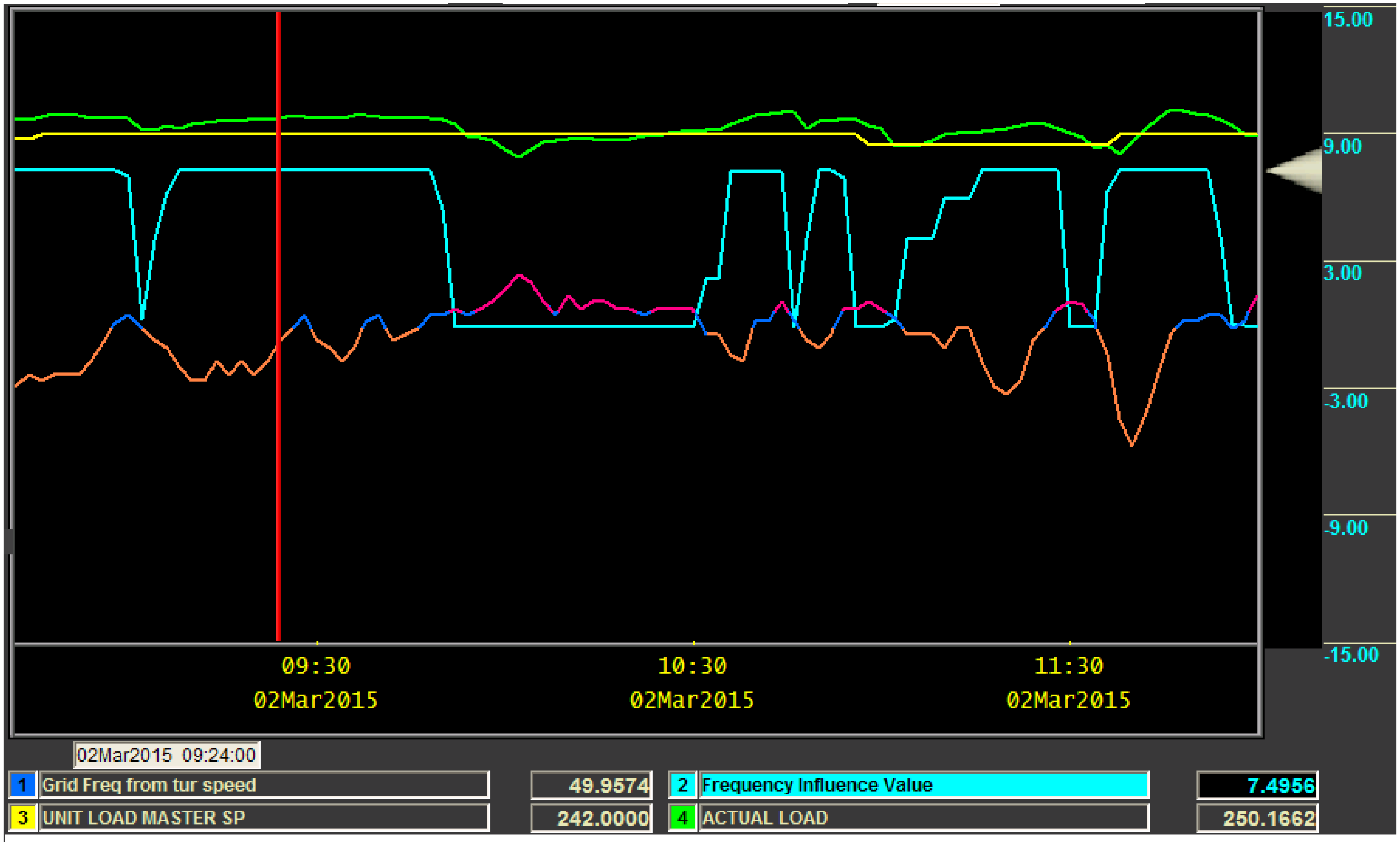
CMC RGMO Influence UNIT#6



Instance of RGMO In UNIT#5

Date	Time (HH::MM)	Occurrence of Frequency influence on RGMO
27th Feb '15	00:00 to 24:00	27
28th Feb '15	00:00 to 24:00	28
1st March '15	00:00 to 24:00	21

RGMO Influence Trend In UNIT#5



Control Action

- At STPS Both Units are running in CMC with Sliding Pressure Control Mode.
- On detection of falling freq Unit Load Set Point is increased by influence value @1. 67 MW/RPM maximum up to 12.5 MW based on quantum of freq deviation till the freq is >= 50.05 Hz.

Control Action Contd…

- Modified Set Point directly actuates EHG to VWO condition as primary response to achieve the load from the spinning reserve of Boiler.
- Modified Sliding Pressure Set Point is maintained by auto Boiler Combustion Control.

Control Action Contd…

- On detection of freq. >50.05 Hz Unit Load Set point ramp back to original value which enables the Governor to act in reverse direction to throttle the Control Valves and accordingly fuel firing is maintained in auto mode.
- Time taken to ramp up or ramp down normally 4 -5 Minutes @ 1% (2.5 MW/Min).

Salient Points Regarding Observation

- It has been observed that real time frequency lies below 50.05 Hz most of the times and incidences of RGMO have been realized sometimes in a range of 25 to 30 a day.
- So at present scenario if Unit load set point is maintained at rated capacity i.e. 250 MW, most of the time Unit will be run at 262.5 MW i.e. at 105% of rated capacity.

Salient Points Regarding Observation Contd..

- During this period if there is any sudden fall of Grid freq the machine will not be in a position to contribute extra load and that can be tackled only if more no. of machines run with RGMO in service.
- This puts undue strain on turbine to some extent due to frequent change in Governor response between approx 75% to approx 95 %.

Salient Points Regarding Observation Contd..

- Also deviation between SG and actual generation exists most of the times due to Frequency Influence.
- Sometimes excursion of load during ramp up and ramp down has been observed on account of fluctuations in calorific value of coal being fired and due to slow response of boiler that has to be fine tuned.
- For ensuring consistent RGMO performance tuning works in STPS are still in progress.


THANK
YOU