

Coordinated Measurements for governor operations in the Southern Indian Grid

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Abstract- The Southern grid of the Indian power system is a network with an installed capacity of about 37000 MW. It comprises of several thermal and hydel units. The network allows the operating frequency to vary over a band from + 0.5 Hz to -1.0 Hz from the nominal 50 Hz. This is due to the historical chronic shortage of power in the network. Since 2004 about 460 special energy meters with 0.2 class accuracy have been erected across the network. Normally despatch is done every 15 minutes with set point control. On one occasion an experiment involving governor operation across all hydro units and thermal units in excess of 200 MW was carried out for a period of three hours. Records of frequency profile, state generation, inter-regional flows etc., are available at sampling of 1 minute over six hours. We have analyzed the performance of the free governor mode operation (FGMO) based on site data. It is shown that the response for the hydro units swamped those of the thermal units in the three hour duration. Operation under governor control of all units could not be sustained for more than fifteen minutes. Several hydro units tripped during the experiment. A simulation model with a 2 unit system shows that smaller machines tend to move out of synchronism for load variations close to their capacity. One machine in the network shows this classic behaviour.

I. Introduction

The southern Indian grid comprises 4 states with an overall installed capacity of about 37000 MW. A mix of hydro and thermal units exist in the network. Figure 1 shows a schematic of the southern grid. Here SEB1 to SEB4 represent each of the four states. The CGS is a central pool which is synchronous with the network. HVDC ties connect the network to other areas but are not important for the present study. The unique feature of the network is that the frequency band is not tightly controlled but is allowed to float from 49 Hz to 50.5 Hz with a nominal value of 50 Hz. The historical reasons for this are discussed in [1]. In the existing situation load dispatch is done by each state utility in 96 time blocks of 15 minutes each, 24 hours ahead. A mechanism called availability based tariff [2] is used address commercial issues arising of deviations from committed values. A majority of the plants work with set point control and only the central generating stations follow governor control. It necessarily follows that frequency variations over the day can be wide. As an exercise to study the feasibility of working all units under governor control an experiment involving the entire network was done for three hours on Feb 9, 2008 [3].

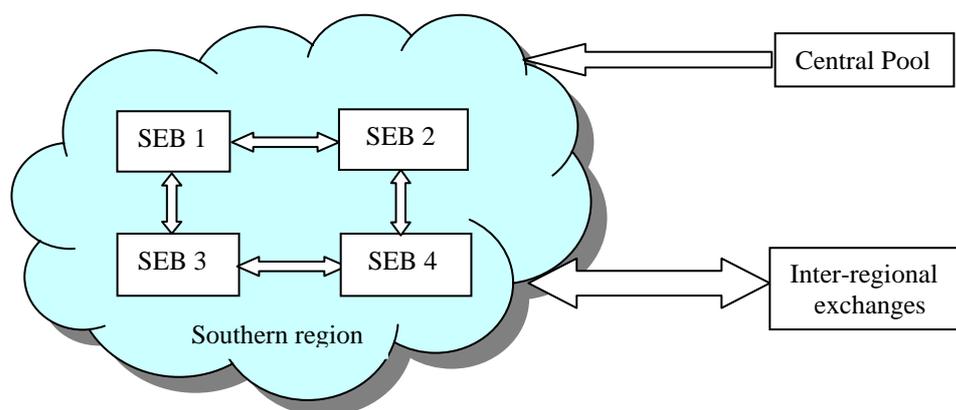


Figure 1. Schematic of the Southern grid of the Indian Power network

The measuring system comprises over 460 special energy meters of 0.2 class spread across the 400 kV networks of the grid. The objective of this work is to study all the relevant measurements done during this exercise and arrive at appropriate conclusions.

II. Free governor mode of operation

In India speed governors have been prevented from responding by the utilities, with dead band configuring from 47.5 Hz to 51.5 Hz. Emergency unloading of a unit is available only when frequency reaches 51.5 Hz [1]. As a consequence excursions in frequency are common upto 1 Hz in a time block of 15 minutes. For the sake of better control efforts are being made to enable the frequency governors to respond to entire range of frequency. This is called free governor mode of operation (FGMO).

A trial operation with FGMO was conducted in the Southern region between 8:30 a.m to 11.30 a.m on 9th Feb 2008 by the Southern Regional Load Dispatch Centre (SRLDC) in order to study the network performance under governor control. Thermal units of 200 MW and above and all hydro units were required to be on FGMO during this period. About eleven thermal generating stations (of a total installed capacity of 7550 MW), eighty five hydro stations (of a total installed capacity of 10977 MW) and central generating stations (of a total installed capacity of 8090 MW), participated in the experiment. The frequency profile for the day is shown in Figure. 2 and an enlarged view of the frequency profile during the FGMO period is shown in Figure. 3. It does appear that the frequency profile has improved during the period of FGMO as the average frequency is more and deviations are less than those during the rest of the day. However closer analysis shows that all was not well with the grid during the experiment.

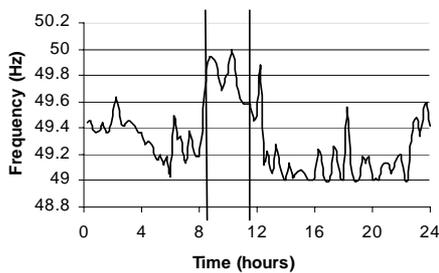


Figure 2. Frequency profile of Southern region on 9th Feb 2008

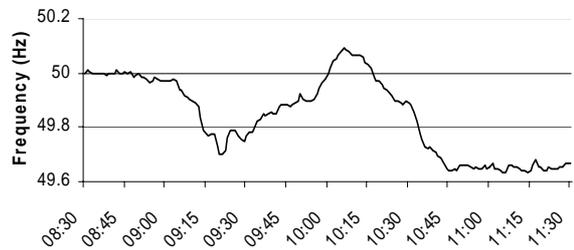


Figure 3. Frequency profile during FGMO in Southern region (9th Feb 2008)

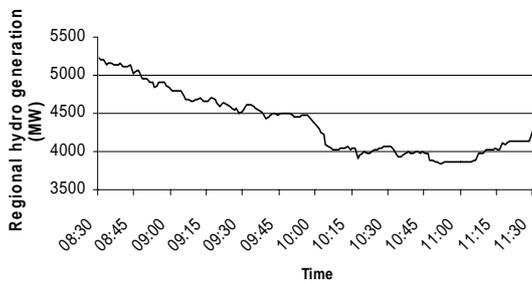


Figure 4. Hydro generation during FGMO in Southern region (9th Feb 2008)

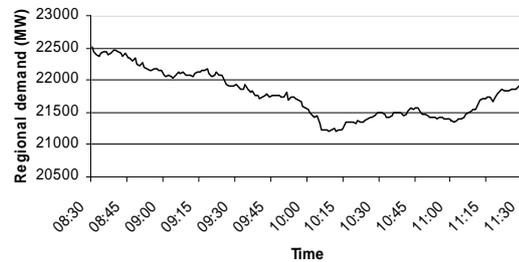


Figure 5. Regional demand during FGMO in Southern region (9th Feb 2008)

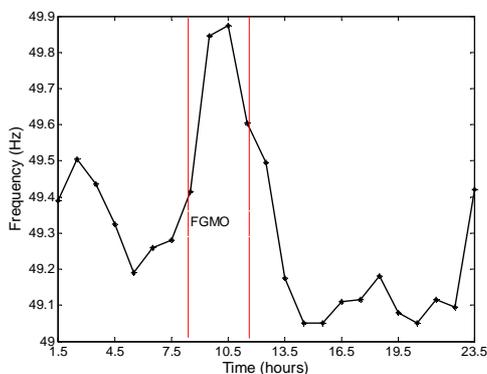


Figure 6. Hourly average frequency on 9th February 2008

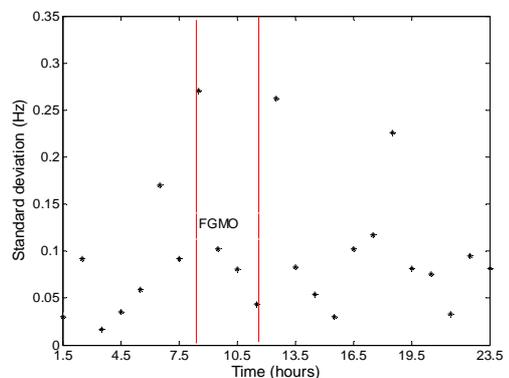


Figure 7. Hourly standard deviation in frequency on 9th February 2008

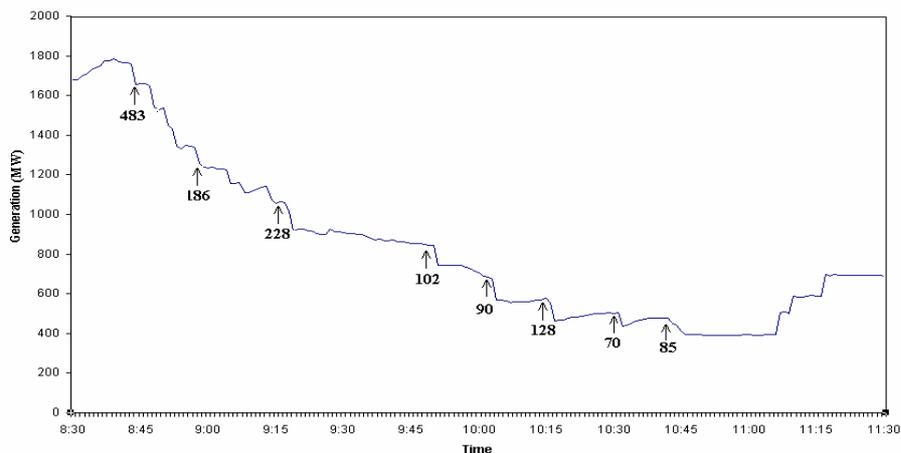


Figure 8. Loss in hydro generation during FGMO in Andhra Pradesh Utility (9^h Feb 2008)
 (Numbers in text refer to loss of generation due to tripping)

The major observations are

- The minimum and maximum grid frequencies attained during the three hours of FGMO (from Figure 3) are 50.1 Hz and 49.6 Hz respectively. This is much greater than +/- 0.1 Hz of deviation expected in a good governor control.
- From Figure 4 it can be observed that hydro generation has reduced from 5250 MW to 3850 MW during the FGMO period. A very uncomfortable situation arose as a total of 16 hydro units tripped during this period. The improvement in frequency from 9:30 a.m to 10:00 a.m is due to reduction in regional demand during that period. This can be realized from the figures 3 and 5.
- The hourly average frequency (Figure 6) has dropped to 49.6 Hz during the third hour of FGMO (10:30 a.m to 11:30 a.m).
- Though there is a decrease in hourly standard deviation of frequency during the period of FGMO, there are much lesser deviations obtained during the remaining part of the day which was not under governor control. (Figure 7)
- Of the 16 hydro units tripped, 13 belong to Andhra Pradesh, 2 in Kerala and 1 in Karnataka. The amount of hydro generation lost in Andhra Pradesh during the FGMO duration is shown in Figure 8.

III. Analysis of FGMO experiment

One possible reasoning for the tripping of the hydro units could be that with the years of manual operation, the performance of the network with wide variations in load and frequency could not be efficiently handled with governor control. Most of these hydro units are of small size (order of 100 MW to 150 MW) and with a sudden increase in load, they have hit their maximum limits and tripped. Real time data of one such unit of 150 MW capacity is shown in Figure 9. The Y-axis gives generation in MW and frequency in Hz and X axis gives time in hours.

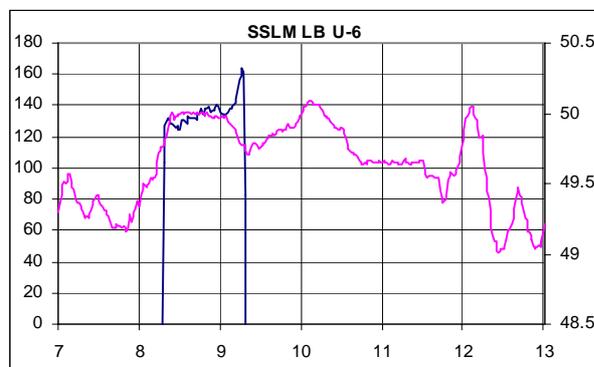


Figure 9. Operation of a 150 MW hydro unit during the FGMO experiment
 (showing loss of synchronism at 9.15 hrs)
 (courtesy : www.srlcdc.org)

From Figure. 9 it can be observed that at 9am there is an increase in load (indicated by the fall in frequency) and the hydro unit has ramped up. But the ramp up rates are very high such that the unit hits its maximum limits and is tripped. We show below a hypothetical test system (Figure10) to provide a plausible explanation of this situation. The test system is a two machine network with the rating of one machine being 5000 MVA and the other is 50 MVA on a 13.8 kV bus. The rating of the bigger machine is taken close to the total regional hydro generation on 9th Feb. We show two cases, one with both systems stable and ramping up to meet the load and the other with the smaller machine tripping off. This shows that lack of proper governor coordination cannot handle larger loads. The simulation is done in EMTP. IEEE3 governor model and SEXS exciter model (available in EMTP) are used for modelling the governor and AVR. The permanent droop coefficient is taken as 0.05 and transient droop coefficient is taken as 0.3 for both the machines. Typical machine parameters are assumed.

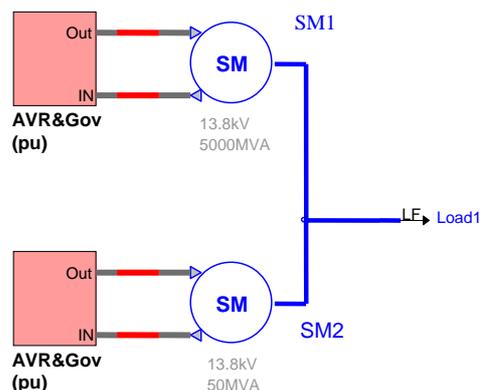


Figure 10. EMTP model of a 2 machine system (5000 MW, 50 MW) with combined governor and AVR model

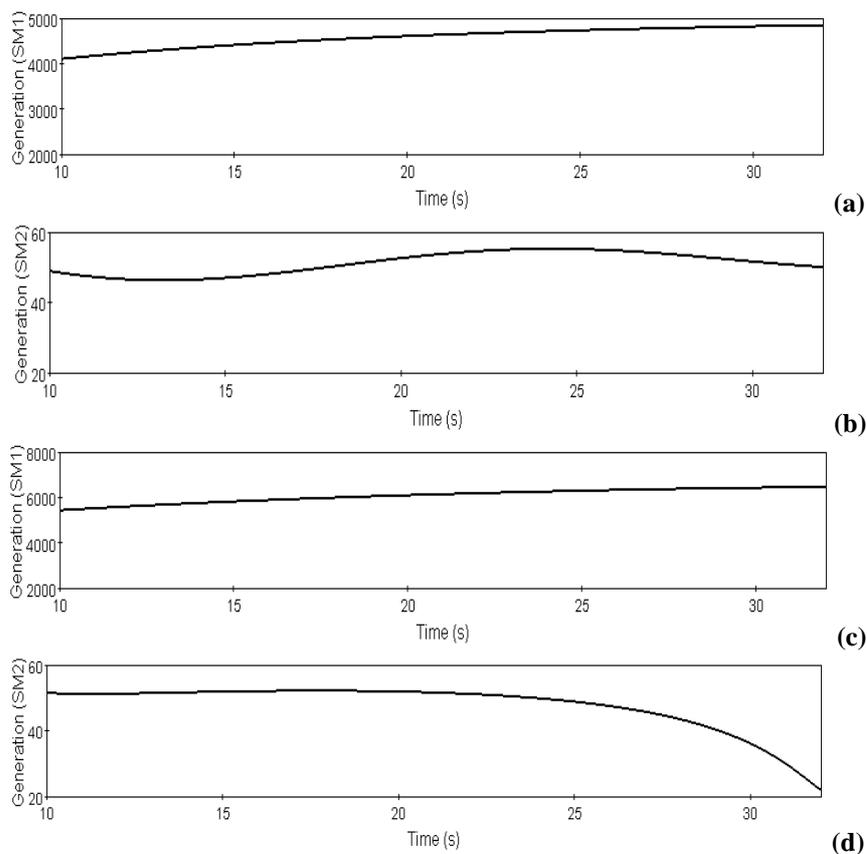


Figure 11. EMTP simulation of a two machine system showing cases of limiting sustained operation and loss in synchronism (model details in Figure. 10)

The results are zoomed on a period of 35 seconds during which the smaller machine tries to maintain stability. When the applied load is 5050 MW both units are stable and ramp up to meet the load (Figure 11a and 11b). When the applied load is 6500 MW SM2 trips while SM1 is stable and ramping up (Figure 11c and 11d). The results indicate that with an increased demand smaller units are likely to get tripped which necessitates proper coordination of governor mechanism.

IV. Conclusion

Free governor mode of operation was tried in the Southern region of India for duration of three hours. Though there was an improvement in the average frequency and the deviations seemed to be less than the profile of the previous day, it is clear that the system is not geared for complete governor control. The frequency was maintained close to 50 Hz for duration of 15 minutes only (8:30am to 8:45 am). With cascaded tripping of three hydro units in APSEB at 8:40 am, the frequency started deviating downwards. This was followed by tripping of another 13 hydro units across the region. Around 1500 MW of hydro generation was lost. The results of the FGMO experiment clearly indicate that a detailed study of coordinated governor control has to be carried out before further implementing FGMO. We have shown a test system with realistic values and evaluated one possible reason of the smaller hydro units reaching their upper limits and tripping off.

V. References

- [1] A.Roy, S.A.Khparde, P.Pentayya, S.Pushpa, "Operating Strategies for generation deficient power system", *IEEE Power Engineering Society General Meeting*, Vol. 3, pp. 2738-2745, San Francisco, California, USA, 2005.
- [2] B.Bhushan, A.Roy, P.Pentayya, "The Indian Medicine" *IEEE Power Engineering Society General Meeting*, Vol. 2, pp. 2336-2339, Denver, Colorado, 2004.
- [3] Details available at www.srlc.org