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Price Based Automatic Generation Control in A Two Area Thermal -Thermal Interconnected Restructured Power Systems

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ABSTRACT - This paper focuses on the Availability Based Tariff (ABT) technique which has been acquainted in Indian framework predominantly to ensure the grid security, grid efficiency and grid indiscipline prevailing in the system. Unscheduled Interchange (UI) charge - one of the parts of ABT, acts a mechanism for controlling the frequency of the grid. In the meantime, this system offers chance to participants to trade or to exchange as and when accessible surplus vitality at a cost dictated by prevailing frequency conditions. Despite the fact that the hidden rule on which UI system of ABT works is very not the same from the conventional load frequency control mechanism, it can still be viewed as a price based secondary generation control mechanism. Presently, the generators are responding to price signals manually. In this paper, a model for price based automatic generation control is presented. A modified control scheme is proposed which will prevent unintentional unscheduled interchanges among the participants. The proposed scheme is verified by simulating it on a model of two area thermal-thermal system. It has been shown here that such control mechanism, if adopted by all generating stations, can improve the control of frequency and bring down the UI obligation of participants.

Keywords – ABT, Unscheduled Interchange, Load frequency.

I. INTRODUCTION TO AVAILABILITY BASED TARIFF

Availability Based Tariff (ABT) is a frequency based pricing scheme adopted in Indian Power Sector to maintain Grid discipline by implementing incentive / disincentive during unscheduled power interchange (UI). This scheme was introduced in the year of 2002. It is imperative here to understand the need for ABT, for better understanding the concept.

1.1 Need of Availability Based Tariff (ABT):

Indian Power System is characterized by low frequency system due to continuous power deficit for most of the time. There is always supply and demand mismatch. The power demand is always more than the power supply. Due to this the frequency of Grid remains on lower side. Before the introduction of Availability Based Tariff, Generating Stations used to deliver the same amount of MW in spite of need for lower MW demand during the period of lower power demand. This causes the Grid frequency to be at higher side. Similarly during the period of higher power demand, Generating Stations used to supply same MW. Subsequently, the Grid frequency reduces. This type of Grid operation did not have any provision to maintain a discipline.

Under normal condition, the Grid_frequency is expected to be constant at 50 Hz. But during peak load period the frequency goes down to 48-48.5 Hz for many hours a day. Similarly during off-peak hours, the frequency goes up to 50.5-51 Hz for many hours a day. Sometimes there is wide frequency variation like up to 1 Hz in 10 to 15 minutes for many hours. All theses contribute to the Grid disturbance leading to tripping of connected Generators and tripping of lines. Tripping of lines leads to interruption of power supply to large block of consumers.

ABT is a three-part tariff scheme. First part being a fixed component is linked to the availability of generating stations, second part is a variable component linked to the energy charges for scheduled interchange and third part is a frequency dependent component linked with the unscheduled interchange. In the given generation shortage scenario of Indian power system, the third component of ABT – the UI charge acts as a mechanism for regulating the grid frequency. At the same time, this mechanism offers opportunity to participants to exchange as and when available surplus energy at a price determined by prevailing

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frequency conditions (Bhushan et al., 2004). Although the underlying principle on which UI mechanism of ABT operates is quite different from the conventional load frequency control mechanism, it can still be viewed as a price based secondary generation control mechanism. Currently, the nature of this control is manual as generators see the price signal and respond to it by increasing or decreasing their output manually. An automatic generation control scheme based in UI price has been presented by Tyagi and Srivastava (2004). This paper attempts further investigation on a price based automatic generation control (PBAGC) in Indian power system and how it can be modeled accurately. A modified control scheme is proposed which will prevent unintended unscheduled interchanges among the participants if PBAGC is introduced. It has been shown here that such mechanism, if adopted by all generating stations, can improve the control of frequency and bring the UI price down.

Fixed Cost is basically imposed on beneficiaries in proportion to their entitled power from the Generating Station. This means fixed cost is directly proportional to the plant capacity shared by the beneficiaries. This is the reason Fixed Charge is often called Capacity Charge. But this does not mean that Generating Station can claim any amount of fixed cost irrespective of its availability. The reimbursed Fixed Charges payable to Generating Station is dependent on the availability of plant. If the plant availability for a year is more than the set norm, the generating station gets paid higher. In case the plant availability is less than the set norm over a year, the generating station is going to be paid lower. This is why this tariff is called Availability Based Tariff. In earlier tariff, fixed charge was dependent on Plant Load Factor but in Availability Based Tariff, it is linked with Plant Availability.

Variable charge is the cost incurred by Generating Station to produce MW day to day. Variable charge is also called Energy Charge. It comprises of Fuel charge (like coal for thermal power plant, Nuclear Fuel Bundle for Nuclear Power Plant, Gas for Gas Power Plant etc.), Operating expenses etc.

1.2 Unscheduled Interchange Charge:

Unscheduled Interchange means deviation from the scheduled generation of plant or deviation from scheduled drawl of power by beneficiary. Suppose a generating station is scheduled to deliver 600 MW but actually on a day it is supplying 700 MW, even then the station will be paid Energy Charges for scheduled generation i.e. for 600 MW. For surplus 100 MW, the rate of energy charge will depend upon the prevailing Grid frequency at the time. This energy charge for surplus supply i.e. 100 MW (for our example) is called Unscheduled Interchange Charge (UI Charge). The UI charge is linked with Grid frequency. If the Grid frequency is higher i.e. more than 50.2 Hz, the rate of UI charge is zero. This means Generating Station will not be paid for excess generation of 100 MW when Grid frequency is more than 50.2 Hz. Thus the station is forced to reduce its generation to maintain Grid frequency.

- ❖ By giving incentives for enhancing the output capability of power plants, it enables more consumer load to be met during peak hours.
- ❖ By separating fixed charges based on availability from variable charges, backing down during off peak hours no longer results in financial loss to generating stations. Therefore, earlier incentive for not backing down and raising system frequency during off-peak hours no longer exists.
- ❖ By charging separately for unscheduled interchanges, the problem of over-drawal during peak load condition, resulting in lowering of frequency, has been controlled. UI rate is high during the low frequency condition, which discourages the over-drawal of power.

Apart from these intended benefits, the ABT mechanism has provided a vast scope of unscheduled interchange of as and when available surplus energy in the grid.

II. PRICE BASED AGC

A Price Based AGC will ensure that generators respond to the UI price automatically and in a desirable manner.

The desirable properties of this controller are:

• It should ensure that frequency control is as smooth as possible.

• It should ensure that UI price is minimum possible.

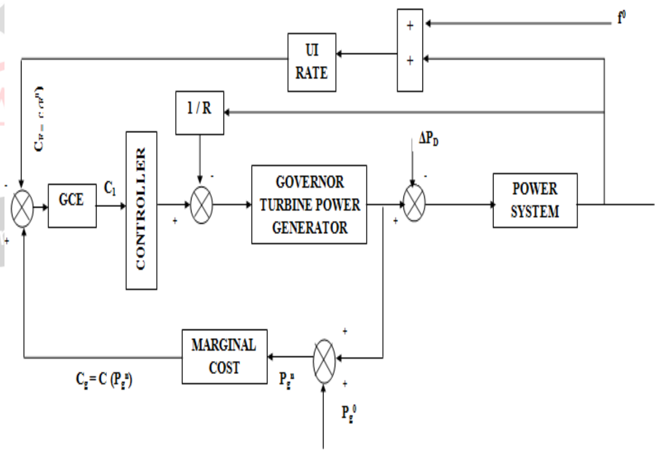

Fig.1. Price Based Automatic Generation Control

GCE - Generation control error is the difference between incremental cost (cg) of generation for load change & UI cost at the same instant.

Algorithm for Price based AGC:
Step 1:Start
Step 2: Initialize $f^n = \Delta f + f^0$
Step 3: If $f^n > 50.2$; $C_f =$ ₹ *0 / MWhr*
Step 4: If $50 < f^n \le 50.2$; $C_f = 8250.\ f^n$
Step 5: If $49.8 < f^n \le 50$; $c_f = 1650 + 14250\ (50 - f^n)$ ₹ */ MWhr*
Step 6: If $49.8 < f^n \le 49.8$; $c_f = 4500 + 140625(49.8 - f^n)$ ₹ */ MWhr*

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Step 7: If 49.48<f^n≤49.48;c_f = 9000 ₹ / MWhr
Step 8: C_f and c_g are compared as follows
Step 9: C_g=2cp_g^n+b ₹/ MWhr
Where c and b are incremental past co eff which depends on the type of plant
Step 10: $P_g^n=P_g^0+\Delta p_g$ MW
Where 'P_g^0' Initial scheduled power generation
Step 11: If C_g>CP_g^0 then go to equation 2.1
Else; go to equation ' i'
Step 12: If C_f > C_g then go to equation 2.2 ---- (2.1)
Else; go to equation 'ii'
Step 13: C_1=C_f - C_g ---- (2.2)
Step 14: If C_f < CP_g^0 then go to equation 2.3 ---- (ii)
Else ; go to equation 2.4
Step 16: C_1=C_f - CP_g^0 ---- (2.3)
go to stop
Step 17: C_1=0 ---- (2.4)
Step 18: If C_f < c_g then go to equation 2.2
Else ; go to equation 'iii'
Step 19: If C_f > CP_g^0 then go to equation 2.3 ---- (iii)
Else go to equation 2. 4
Step 20: Stop

The basic principle of this control is illustrated in Fig.1. Each generator individually monitors the UI price ρ and compares with its marginal cost γ. It derives an error signal, which is the difference of current UI price and its own marginal cost. This error signal, which can be termed as *generation control error* (GCE), is fed to an integral controller. A positive GCE indicates that the generator will profit by increasing generation level. A negative GCE indicates that Generator will profit by decreasing the generation level. Since under ABT, the payments received by generators for UI are separate from the payments for SI, the generators earn profit in both cases.

III. SIMULINK MODEL FOR PRICE BASED AGC

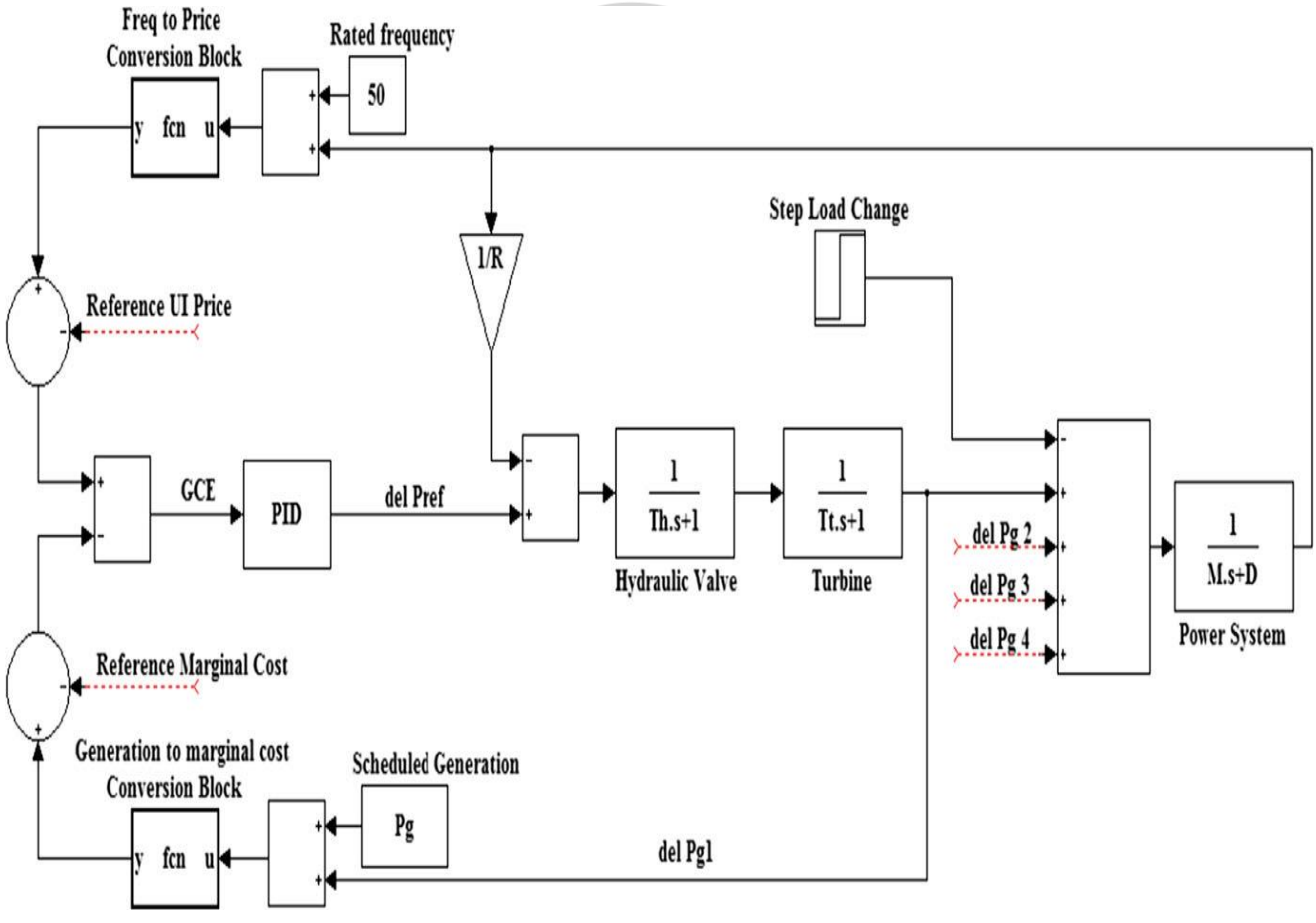

Fig.1. Block representation of Price Based Automatic Generation Control

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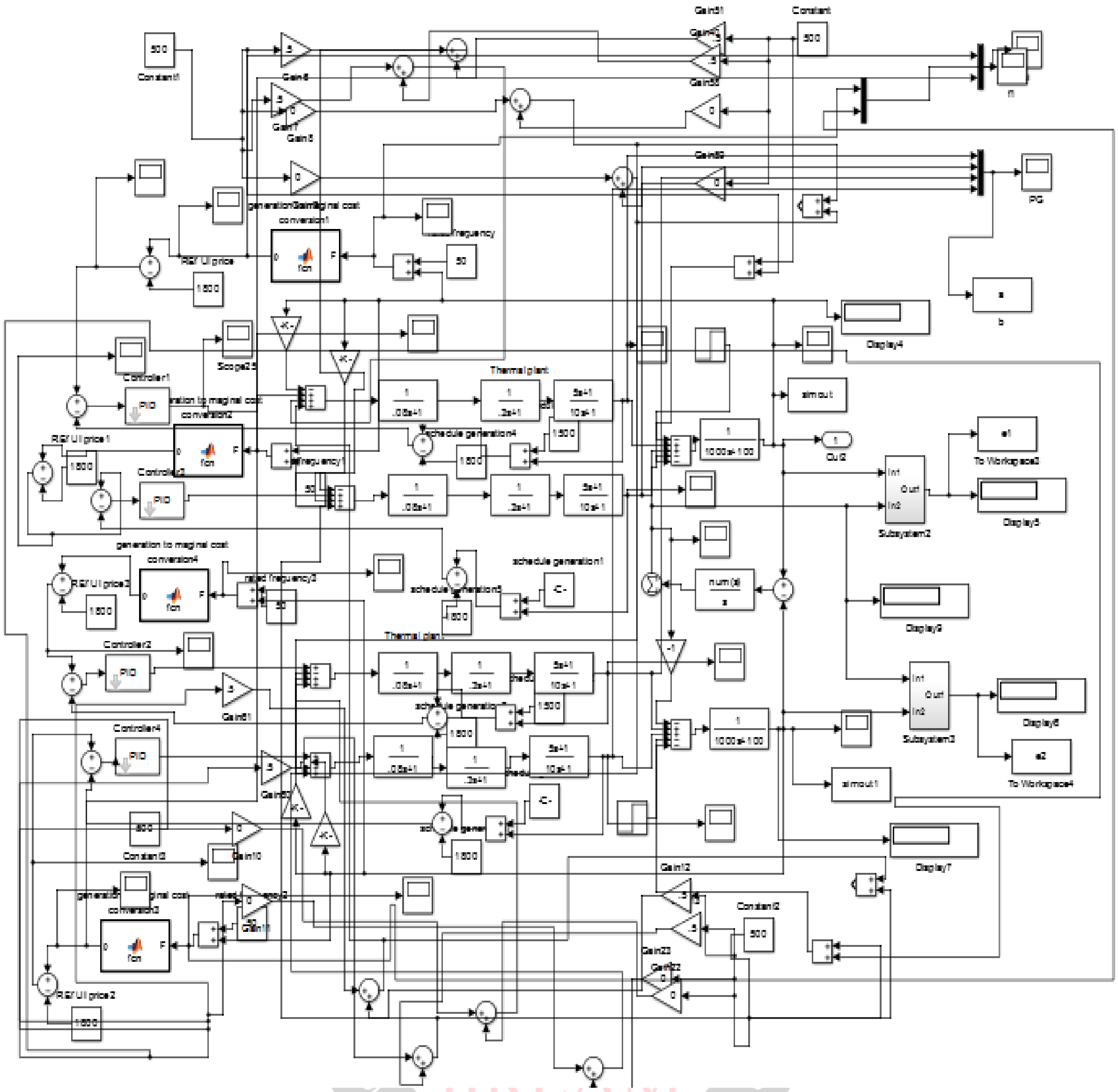

Fig.2. Linearized model for Price Based Automatic Generation Control

IV. RESULTS AND DISCUSSIONS

A step load change of -250 MW (0.25 p.u) is applied to check the performance of the proposed control under load decrement. The results are shown in (Fig.9.3 – Fig.9.8). A rise in frequency is observed and consequently the UI price falls to around 1450 INR/MWh. Only Generators 1, 2, and 3 are capable of reducing their outputs. At scheduled load, marginal cost of Generators 1, 2, 3 are 1700, 1900 and 1800 INR/MWh respectively. All generators including Generator 1, whose marginal cost is less than 1800 INR/MWh, get a negative GCE. As a result of corrective action taken by these generators, the UI price rises to 1800 INR/MWh and frequency is restored to 50 Hz. Since the generators were loaded out of merit initially, there is sufficient capacity available with Generator 2, who has the highest marginal cost, to absorb reduction of 100 MW. The generators been loaded in merit order, a load reduction of 100 MW would have certainly resulted in small frequency rise. It is observed that proposed control scheme gives satisfactory results in terms of frequency control and UI reduction for a variety of operational conditions.

(i) Under Normal Conditions

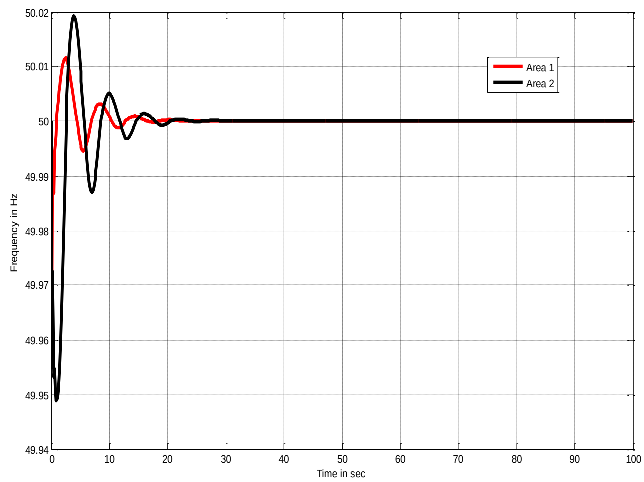

Fig. 4. Change in Frequency deviation of Area-1 and Area-2 under normal conditions

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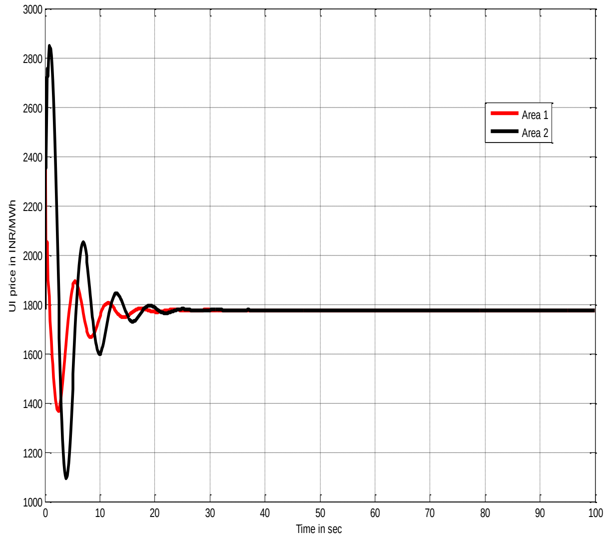

Fig. 5. Optimized UI rate for Area-1 and Area-2 under normal conditions

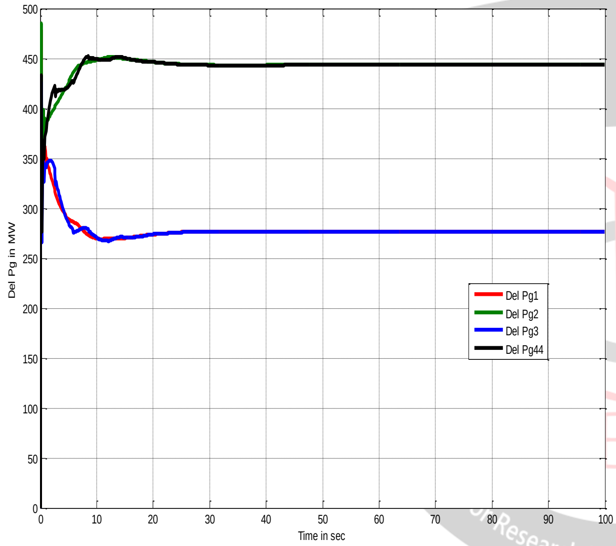

Fig. 6. Change in generation for Area-1 and Area-2 under normal conditions

(ii) With increased 0.25 p.u

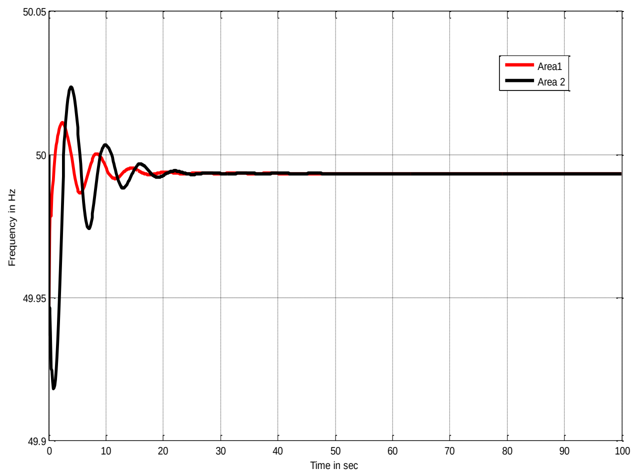

Fig. 7. Change in Frequency deviation of Area-1 and Area-2 under increased generation conditions

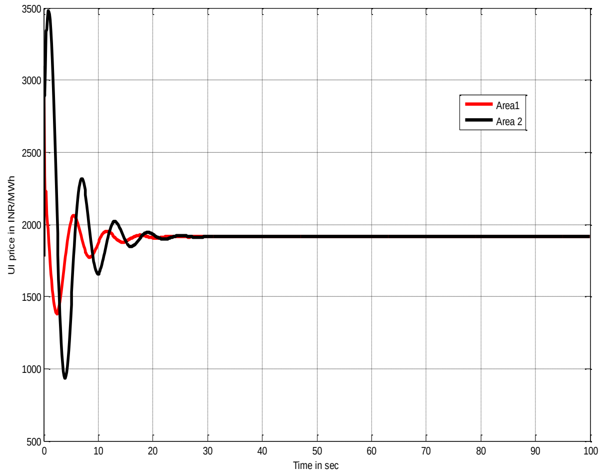

Fig. 8. Optimized UI rate of Area-1 and Area-2 under increased generation conditions

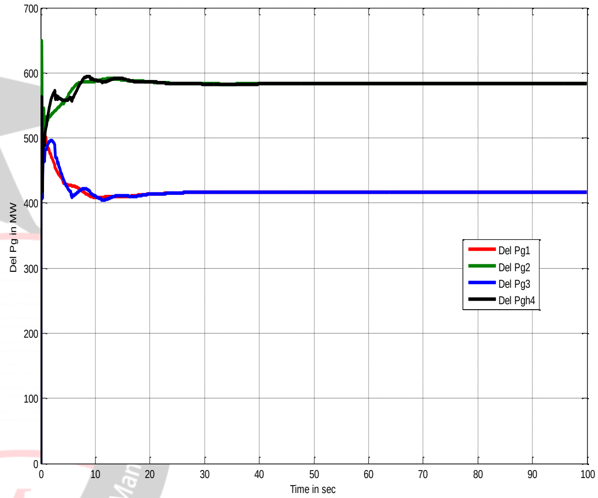

Fig. 9. Change in generation of Area-1 and Area-2 under increased generation conditions

A step load change of -250 MW (0.25 p.u) is applied to check the performance of the proposed control under load decrement. The results are shown in (Fig.3 – Fig.8). A rise in frequency is observed and consequently the UI price falls to around 1450 INR/MWh. Only Generators 1, 2, and 3 are capable of reducing their outputs. At scheduled load, marginal cost of Generators 1, 2, 3 are 1700, 1900 and 1800 INR/MWh respectively. All generators including Generator 1, whose marginal cost is less than 1800 INR/MWh, get a negative GCE. As a result of corrective action taken by these generators, the UI price rises to 1800 INR/MWh and frequency is restored to 50 Hz. Since the generators were loaded out of merit initially, there is sufficient capacity available with Generator 2, who has the highest marginal cost, to absorb reduction of 100 MW. The generators been loaded in merit order, a load reduction of 100 MW would have certainly resulted in small frequency rise. It is observed that proposed control scheme gives satisfactory results in terms of frequency control and UI reduction for a variety of operational conditions.

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V. CONCLUSION

Unscheduled Power Interchange (UI) mechanism of ABT as a price based secondary control is manual in nature for price based automatic generation control was implemented in a two area Thermal-Thermal interconnected restructured power system. It can be noted that this control, if not suitably modified, will result in undesirable UIs. A modified controller is proposed which is able to deal with fixed nature of UI curve for two area thermal-thermal systems. The working of modified controller is verified through simulation of various scenarios and it is shown that it is able to avoid undesirable UIs. The successful operation of modified PBAGC is further tested by applying a step load disturbance. The results of simulation show that the control is successful in bringing down the frequency deviation. The final frequency under this control may not settle to nominal value, but to a value equivalent to system marginal cost (on UI price vs. frequency curve) while serving the load. Implementation of proposed control on all central and state generating stations will not only result in better control of frequency, but merit order dispatch of generation can also be ensured at the same time. The UI obligations of participants can be drastically reduced through this mechanism. In this paper, modified PBAGC is applied to an isolated area test system. In future, the impact of such mechanism on frequency, UIs and tie-line exchanges can be observed by taking multi-area systems.

REFERENCES

[1] Shital M. Pujara and Chetan D. Kotwal, "Optimized integral gain controllers for price based frequency regulation of single area multi-unit power system", International Journal on Electrical Engineering and informatics, Vol.6, No.2, pp: 306-323, 2014.

[2] Yadav R.G., Roy A., Khaparde S.A., Pentayya P., India's fast-growing power sector. IEEE Power and Energy Magazine. Vol. 3, No. 4, pp. 39-48, 2005.

[3] Central Electricity Authority, Load Generation Balance Report 2009-10. CEA, New Delhi, India. Available online: http://cea.nic.in/god/gmd/lgbr_report.pdf, 2009.

[4] Central Electricity Regulatory Commission, ABT Order. CERC, New Delhi, India. Available online: http://www.cercind.gov.in/orders/2-1999GOIABT040100.pdf, 2000.

[5] Bhushan B., ABC of ABT: A primer on availability tariff. Available online: http://www.nrldc.org/docs/abc_abt.pdf, 2005.

[6] Central Electricity Regulatory Commission, 2009. Unscheduled interchange charges and related matters regulation, CERC, New Delhi, India. Available online: http://www.cerc.gov.in, 2009.

[7] Gupta A.P. and Sathaye J., Electrifying India. IEEE Power and Energy Magazine. Vol. 7, No. 5, pp. 53-61, 2009.

[8] Roy A., Khaparde S.A., Pentayya P. and Pushpa S., Operating Strategies for Generation Deficient Power System. Proc. IEEE PES General Meeting, San Francisco, USA. Vol. 3, pp. 2738-2745, 2005.

[9] Indian Electricity Grid Code, Available online: http://cercind.gov.in/Regulations/Indian-Electricity-Grid-Code-2006.pdf, 2006.

[10] The Gazette of India, Extraordinary, The Electricity Act, 2003 Part II Section 3 Sub-section (ii) June 10, 2003. Ministry of Power, Government of India, New Delhi., Available online:http://www.powermin.nic.in/acts_notification/electricity_act2003 /pdf/The%20Electricity%20Act_2003.pdf, 2003.

[11] Tyagi B. and Srivastava S.C., A mathematical framework for frequency linked availability based tariff mechanism in India.National Power Systems Conference, IIT Madras, Chennai, India, Vol. 1, pp. 516-521, 2004.

APPENDIX

Table 1 Generator Data

Parameters	Generators			
	G1	G2	G3	G4
Capacity (MW)	1500	1500	1000	1000
b (INR/MWh)	800	1000	1600	2000
c (INR/MW2h)	0.3	0.3	0.4	0.4

Table 2 System data

Parameters	Value
M (MW-s/Hz)	1000
D(MW/Hz)	100
F^0 (Hz)	50
ΔP_d(MW)	100

Table 3 Droop, Governor and Turbine time constant

Parameters	Machine-1	Machine-2	Machine-3	Machine-4
Droop R	6%	6%	6%	6%
Governor time constant T_g (Secs)	0.3	0.3	0.3	0.3
Turbine time constant T_t (Secs)	0.5	0.5	0.5	0.5

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