

IMPACT OF UI RATE ON AUTOMATIC GENERATION CONTROLLER OF PARTICIPATING GENERATORS UNDER FREQUENCY LINKED TARIFF SYSTEM

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Abstract: In Indian deregulated market scenario redespaching of the generating units is made through frequency linked pricing signal known as *Unscheduled Interchange (UI)*. Central Electricity Regulation Commission (CERC-India) is responsible for deciding the UI rates for unscheduled interchange interstate transmission of electricity. In this paper a maiden attempt has been made to perceive the effect of UI rate declared by CERC in different years on frequency linked Price Based Automatic Generation Control (PBAGC) of participating generators and profit earned by them. This article also covers the case of sudden loss of large generation to see whether the PBAGC control can handle such event or not.

Keywords: Load frequency control, Availability based tariff, Unscheduled interchange, Price based automatic generation control, Deregulated electricity market, Generation control error

I. INTRODUCTION

Power systems allover the world have to make provisions for achieving a balance between realtime demand and supply. Generally in developed countries power markets have concept like control area and area control error which measure the instataneous frequency deviation and net excess flow out of a control area due to deviation in scheduled interchange named as load frequency control. This task also become more challenging in present dereglated electricity market. Several load frequency control stretagies based on roubest, optimal and intelligent approach have been devloped by power system engineers suitable to deregulated envirnomet. Details of various load frequency control strategies in dergualted market have been found from Refs. [1-11]. Frequency linked real time pricing scheme is other approach of load frequency control in restructured electricity market. Researchers have presented the Frequency linked price based control service in deregulated electricity market [12-17].

In indian deregulated electricity market scenario, where huge generation shortage is there automatic load frequency control concept is incompetible. But in India a break-through occurred during 2002, with the implementation of the three part Availability Based Tariff (ABT) at the regional level. ABT has dramatically improve the grid frequency profile and also the third component of this tariff so called Unscheduled Interchange (UI), a frequency linked pricing which provides the manual secondary generation control for the Indian electricity grid [18]. Automated frequency linked pricing schemes suitable

for Indian deregulated electricity market can be found from Refs. [17, 19-24].

The objective of this paper is to analyze the impact of different UI rate through Price Based Automatic Generation Control (PBAGC) scheme on participating generators. The rest of the article is structured as follows. Section II presents an overview about ABT and UI mechanism prevailing in India. Section III describes about the price based automatic generation control scheme. In section IV, mathematical model for the PBAGC scheme is presented. While in section V equation of steady state frequency error for PBAGC scheme has been derived. Section VI consider the simulation studies and result analysis for selected test system with various cases. Finally, section VII carries the main conclusions of the study.

II. ABT & UI MECHANISM

The term Availability Based Tariff particularly in the Indian context, stands for a rational three part tariff structure for power supply from generating stations, on a contracted basis. In India ABT is implemented in the starting from mid-2002 at regional level. The first part of ABT is being a fixed component which 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 an unscheduled interchange to account for deviations from schedule. This third part (UI) has frequency linked pricing as per Fig. 1 and Fig. 2. As and when there are deviations from schedule, this third component of ABT comes into picture. Deviations from schedule are determined in 15 minutes time blocks through special metering and are priced according to the system condition prevailing at that time [25, 26].

In UI based generation control mechanism, all generating stations can self-dispatch, based on frequency actuated UI rate signal available at any wall socket. The station operator has only to compare his own variable cost and current pool price based on UI curve, to decide whether the generation should be increased or decreased to achieve new equilibrium [27]. This mechanism also offers opportunity to participants (load) to exchange as and when available surplus energy at a price determined by prevailing frequency conditions. Utilities can deviate from their schedules, as long as the deviation does not cause a

transmission constraint or a grid contingency. However in case of contingency, the schedule can be revised by system operator [28].

The shape of UI price vs. frequency curve has been a subject of much debate among the sector participants. The UI rate therefore needs to be re-adjusted whenever the energy costs of generation in the country get revised. At regular interval UI curve has been modified under the regulation ordered by CERC since it was introduced in year 2002 [29].

In the year 2009 UI price was set between 49.2 Hz and 50.3 Hz. The minimum price was zero Rs. /Mwh at 50.3 Hz and maximum price was 7,350 Rs. /Mwh at 49.2 Hz. Each 0.02 Hz step is equivalent to 120 Rs. /Mwh in the 50.3-49.5 Hz frequency range and to 170 Rs. /Mwh in the 49.5-49.2 Hz frequency range [30].

In the year 2012, as per CERC regulation UI price was set between 49.48 and 50.20Hz. The minimum price is zero Rs. /Mwh at 50.20 Hz and maximum price is 9000 Rs. /Mwh at 49.48 Hz. Each 0.02 Hz step is equivalent to 165 Rs. /Mwh in the 50.2-50.00 Hz frequency range, 285 Rs. /Mwh in 50.00- 49.80 Hz frequency range and 281.20 Rs. /Mwh in 49.80 -49.48 Hz frequency range [31]. In the year 2013, UI price was proposed to be between 49.94 and 50.05Hz [32].

Recently for the year 2014, UI price has been set between 49.69 to 50.05Hz. The minimum price is zero Rs. /Mwh at 50.05 Hz and maximum price is 8240.4 Rs. /Mwh at 49.69 Hz. Each 0.01 Hz step is equivalent to 356 .00Rs./Mwh in the 50.05-50.00 Hz frequency range and 208.00 Rs. /Mwh in the 50.00-49.69Hz frequency range [33].

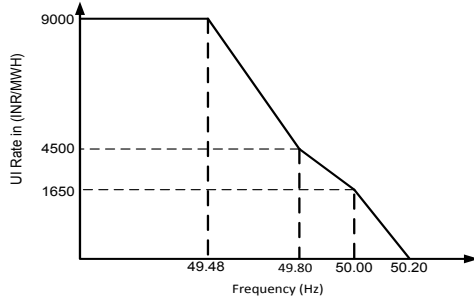


Fig. 1: UI rate (CERC, 2012)

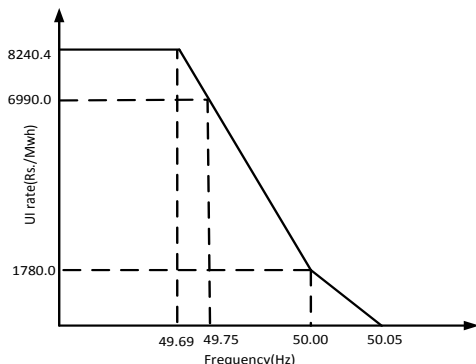


Fig. 2: UI rate (CERC, 2014)

III. PRICE BASED AUTOMATIC GENERATION CONTROL MECHANISM

After the implementation of ABT in Indian electricity sector, the generation units are expected to respond to UI price signal in real-time but they respond to the UI price signal manually, often resulting in a delayed response which leads to deterioration of frequency profile and hence affect the performance of the grid.

This section explains a price based automatic generation control mechanism ensuring that generators respond to the UI price signal automatically and in a desirable manner. First time in the year 2004 Tyagi and Srivastava [19] presented an automatic generation control scheme based in UI price. According to this control primary control remains same that of conventional but secondary automatic control uses UI price signal. As per this control each generator individually monitors the UI price p and compares with its marginal cost γ . Then generated error signal is given to the integral controller which further changes the governor setting to change the input power and hence readjust the frequency to its nominal value. But this scheme suffers from the drawback that when load is as per schedule then also it results in UI among generators at nominal frequency. Then authors in Ref. [21] have proposed modified PBAGC scheme which overcomes the above mentioned drawback.

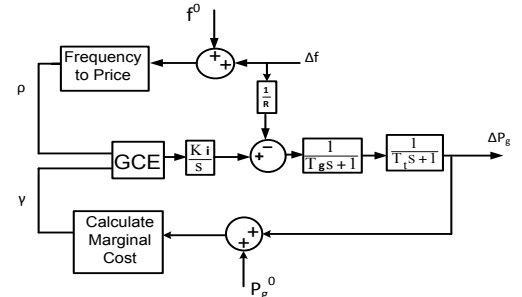


Fig. 3: Modified price based automatic generation control mechanism [21]

The basic principle of modified control is illustrated in Fig.3. According to this scheme each generator individually monitors the UI price p and compares with its marginal cost γ and derives an error signal. Then this error signal is fed to GCE logic block. Output of which can be termed as generation control error (GCE) signal and further it is fed to an integral controller block. A positive GCE signal indicates that the generator will profit by increasing generation level while negative GCE signal indicates that Generator will profit by decreasing the generation level [21]. Detail logic of GCE block is given in equations 9-19. In this paper modified PBAGC scheme has been used to see the impact of different UI rate on frequency control and profit earned by participating generators.

IV. MATHEMATICAL MODEL

It is assumed that generators of single area are generating power at their scheduled value and

Now, for any case when step load change of P Mw occurs in the system, it results in deviation Δf in the supply frequency.

At this frequency signal S1 (f) corresponding UI price signal S2 (p) can be calculated as per UI rate v/s frequency regulation issued by CERC of given year.

$$S2(\rho) = 9000 \text{ Rs./Mwh}$$
$$S5(\text{gce}) = S2(\rho) - \rho^0; \quad (18)$$

For S5 (gce) signal from equation number (11) and (16) steady state frequency error equation is given by following relation

$$\Delta f^{\text{ss}} = 0\text{Hz} \quad (25)$$

Fig. 4: Price based model for system under study

- The modified PBAGC scheme described in above has been simulated and tested using an isolated area system having a capacity of 5000 MW supplied by four generating stations. The detailed schematic of four generators single area with UI based secondary control is as shown in Fig. 4. The necessary relevant data is given in Appendix. All models are created using MATLAB/SIMULINK.

- To verify the impact of UI rate, four different cases have been considered as 1) system marginal cost more than nominal UI rate, 2) system marginal cost less than nominal UI rate, 3) system marginal more or less than nominal UI rate and 4) consider loss of large generation at peak load condition for UI rate 2012.

• **Case 1:**

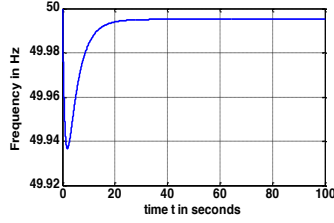


Fig. 5(a) Freq. v/s Time
(UI rate, 2013)

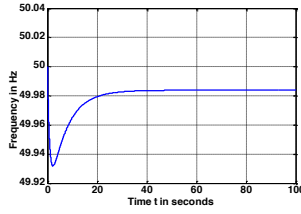


Fig. 5(b) Freq. v/s Time
(UI rate, 2012)

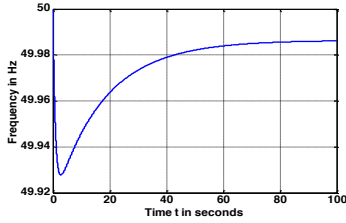


Fig. 5(c) Freq. v/s Time
(UI rate, 2009)

When system marginal cost of single area four generator system is 1850 Rs. /Mwh (more than any of the three year's nominal UI rate), all generators of the given system receive the positive $S5(gce) = S2(p) - S4(\gamma)$ error signal, resulting in steady state frequency error. Also this error depends on slope of UI curve. As the slope of curve increases, steady state frequency error decreases. Slope of UI curve of year 2014 is very large compared to curve for year 2012 and 2009 hence for it, frequency error is very less. Fig. 5(a), 5(b), 5(c) shows the response of frequency/s time for case 1 with different UI rate.

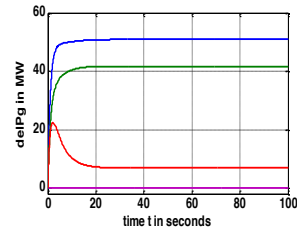


Fig. 6(a) ΔPg v/s Time
(UI rate, 2014)

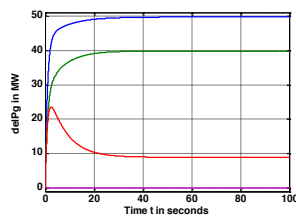


Fig. 6(b) ΔPg v/s Time
(UI rate, 2012)

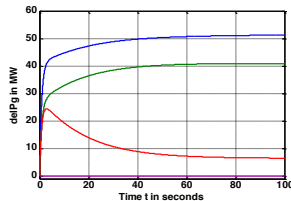


Fig. 6(c) ΔPg v/s Time
(UI rate, 2009)

For ΔPg: ΔPg1 ΔPg 2 ΔPg3 ΔPg4

Simulation results for change in generation for each UI rate is as shown in Fig. 6(a), 6(b), 6(c). It can be observed from all the above figures that, as generator one is running at its full capacity, it does not increase its generation while generators two and three are partly loaded and hence, shares the maximum increment in load as per their economic scheduling criteria. Also, generator four is the costliest generator so increment of its generation is least, proves that UI based secondary control regulates the merit order dispatch of generator too.

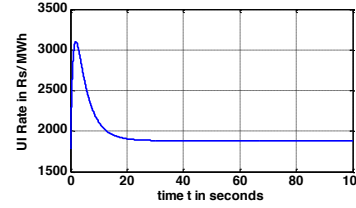


Fig. 7(a) UI v/s Time
(UI rate, 2014)

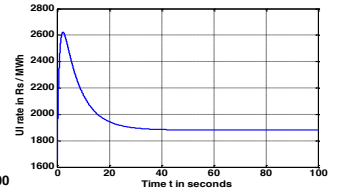


Fig. 7(b) UI v/s Time
(UI rate, 2012)

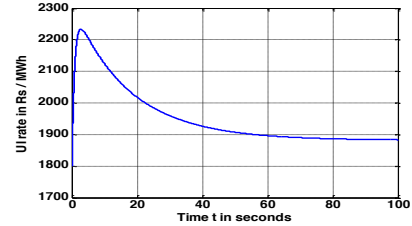


Fig. 7(c) UI v/s Time
(UI rate, 2009)

Fig. 7(a), 7(b), 7(c) shows the response of settled value of UI rate after step load disturbance for case 1 with different UI rates.

• **Case 2:**

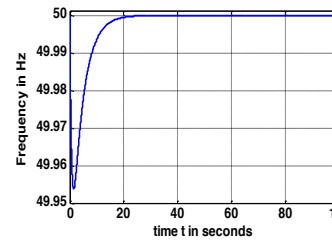


Fig. 8(a) Freq. v/s Time
(UI rate, 2014)

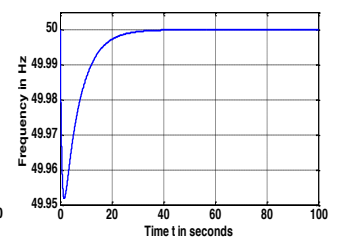


Fig. 8(b) Freq. v/s Time
(UI rate, 2012)

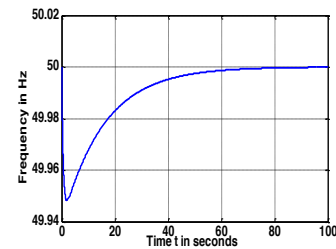


Fig. 8(c) Freq. v/s Time
(UI rate, 2009)

When system marginal cost of single area four generator system is 1500 Rs./Mwh (less than any of the three year's nominal UI rate), all generators of the given system receive the positive $S5(gce) = S2(\alpha) - \alpha^0$

error signal, resulting in zero steady state frequency error. Fig. 8(a), 8(b), 8(c) shows the response of frequency v/s time for case 2 with three different UI rate.

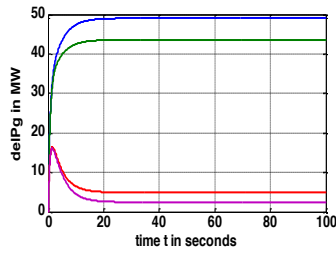


Fig. 9(a) ΔP_g v/s Time
(UI rate, 2014)

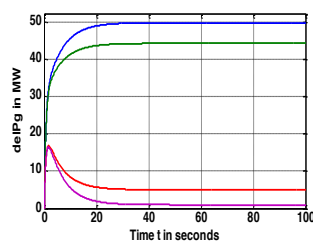


Fig. 9(b) ΔP_g v/s Time
(UI rate, 2012)

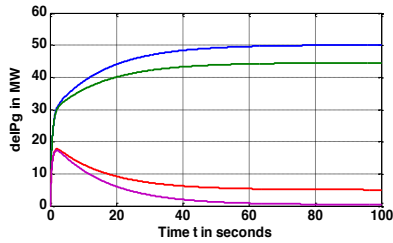


Fig. 9(c) ΔP_g v/s Time
(UI rate, 2009)

For ΔP_g : ΔP_{g1} ΔP_{g2} ΔP_{g3} ΔP_{g4}

Fig. 9(a), 9(b), 9(c) shows the response for change in generation of all the four generators for different UI rates. It can be seen from all the above response that generator one and two are partly loaded hence they share the maximum increment in load as per their economic scheduling criteria while generator three and four contribute to few amount of generation being a costliest generators following a merit order dispatch automatically.

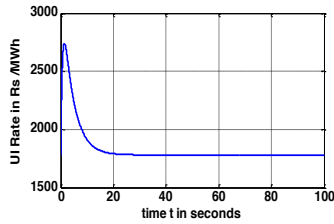


Fig. 10(a) UI v/s Time
(UI rate, 2014)

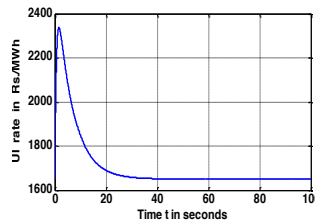


Fig. 10(b) UI v/s Time
(UI rate, 2012)

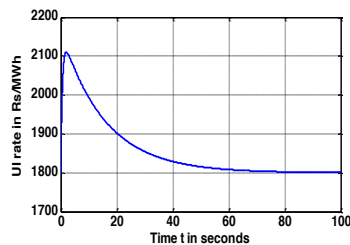


Fig. 10(c) UI v/s Time
(UI rate, 2009)

Fig. 10(a), 10(b) and 10(c) shows the response of settled value of UI rate after step load disturbance for case 2 with different UI rates.

• Case 3:

When system marginal cost of single area four generators is 1650Rs. /Mwh, it equals to nominal UI rate for the year 2012, hence a step load change, gives a steady state frequency error, while for the years 2009 and 2014, the system marginal cost 1650 Rs./Mwh is less than their respective nominal UI rates, so step load change in these two cases give a zero steady state frequency error.

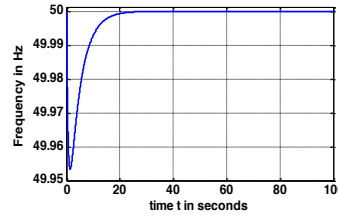


Fig. 11(a) Freq. v/s Time
(UI rate, 2014)

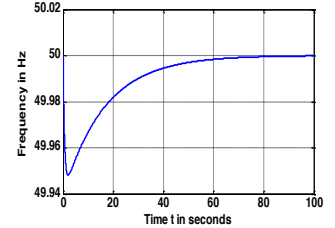


Fig. 11(b) Freq. v/s Time
(UI rate, 2012)

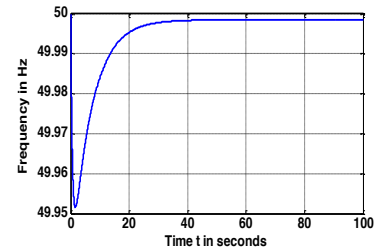


Fig. 11(c) Freq. v/s Time
(UI rate, 2009)

Fig. 11(a), 11(b), 11(c) shows the response of frequency v/s time for case 3 with three different UI rate.

• Case 4:

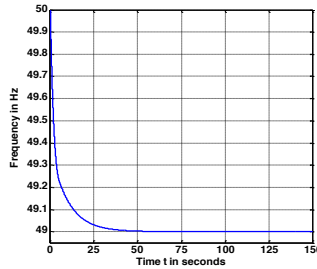


Fig. 12(a) Freq. v/s Time
(UI rate, 2012)

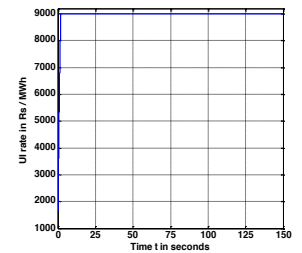


Fig. 12(b) UI v/s Time
(UI rate, 2012)

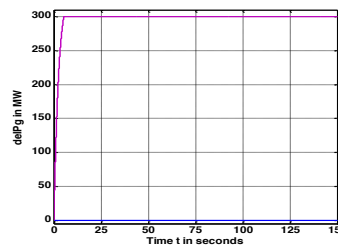


Fig. 12(c) ΔP_g v/s Time
(UI rate, 2012)

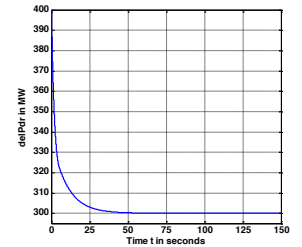


Fig. 12(d) ΔP_{dr} v/s Time
(UI rate, 2012)

For ΔP_g : ΔP_{g1} , ΔP_{g2} & ΔP_{g3} ΔP_{g4}

Additionally, with system under consideration when working on its peak load condition, a loss of 400 Mw power generation has been simulated for UI rate of

year 2012. This can be simulated as sudden increase in load of 400 Mw. In this case generator one, two and three are running at their full capacity and generator four has only 300 Mw surplus capacity to respond to change in load. Generator four responds to initial fall in frequency by increasing its generation up to 300Mw (Fig. 12(c)) and thereby running at its full capacity. Still there is 100 Mw gap between generation and demand, which could be further met by load reduction due to load frequency response. Fig. 12(d) shows the change in net load change ΔP_{dr} . Where, $\Delta P_{dr} = \Delta P_d + D \cdot \Delta f$. Also, frequency error (Fig. 12(a)) is found to be -1.00 Hz which mainly depends upon load frequency component D. As the steady state frequency error is very high and beyond unacceptable limit, system operator has to take emergency measures to restore the frequency back to within permissible range. So, system operator can seek for on the spot energy integration options like distributed generation, captive power etc.

• Profit Earned by Generators :

Profits earned by participating generators for various cases with different UI rates have been mentioned in Table 4.1, Table 4.2 and Table 4.3. Observation of above tables conclude that through frequency linked unscheduled interchange component of ABT, generators can earn profit by re-dispatching power in real time at their most economic point. When system marginal cost is less than nominal UI rate profit earned by generators depend on value of nominal UI rate. Higher the value of nominal UI rate more is the profit earned by generator. Also, when the system marginal cost is more than nominal UI rate, profit earned by generators depends on settled value of UI rate.

VII. CONCLUSIONS

The effect of different UI rates on participating generators in frequency linked PBAGC scheme has been studied through three different case of system marginal cost. From this analysis it has been accomplished that the frequency linked PBAGC may or may not drive the frequency error to zero but depends on cost co-efficient of participating generators, slope of the UI curve and value of system marginal cost. It has been also proved that this scheme handle the sudden loss of large generation. Profit earned by the participating generators depends on UI rate values at existing frequency. Also, in future by considering the optimized controller gain of integral controllers, UI exchange for different cases can be further analyzed.

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NOMENCLATURES

f^0	Nominal supply frequency in Hz
Δf	Change in supply frequency
c	Incremental cost co-efficient of generating unit in Rs. /Mw ² h.
b	Incremental cost co-efficient of generating unit in Rs. /Mwh.
P_g^0	Scheduled generation of generator in Mw
ΔP_g	Change in generation
ρ^0	UI rate at nominal frequency 50 Hz in Rs./Mwh (1780Rs. /Mwh-(2014), 1650 Rs. /Mwh - (2012) and 1800 Rs /Mwh - (2009))
P	Step load in Mw.
K_U	Slope of UI curve, value corresponds to UI price ρ^0 in Hz. Rs. / Mwh
D	Damping co- efficient in Mw/Hz.
M	System inertia in Mw. Sec. /Hz.
R_i	Speed regulation in Hz. /Mw
k_i	Integral controller gain of i^{th} generating unit
γ_i	Marginal cost of i^{th} generating unit Rs./Mwh

APPENDIX

1: System Data:

Area capacity (Mw)	5000
M(Mw-s/Hz)	1000
D(Mw/Hz)	100
F^0 (Hz)	50
ΔP_d (Mw)	100
$R_1=R_2=R_3=R_4$ (pu)	6
$T_{g1}=T_{g2}=T_{g3}=T_{g4}$ (sec)	0
$T_{t1}=T_{t2}=T_{t3}=T_{t4}$ (sec)	0

2: Generator Data:

Parameters	Generators			
	G1	G2	G3	G4
Capacity(Mw)	1500	1500	1000	1000
b (Rs./Mwh)	800	1000	1600	2000
c (Rs./Mw ² h)	0.3	0.3	0.4	0.4

3: Generator Scheduling for Various System Marginal cost:

System Marginal Cost (Rs./Mwh)	Gen. 1 Mw(P_{g1}^0)	Gen. 2 Mw(P_{g2}^0)	Gen. 3 Mw(P_{g3}^0)	Gen. 4 Mw(P_{g4}^0)
1850	1500.00	1416.66	0312.50	0000.00
1500	1166.66	0833.33	0000.00	0000.00
1650	1416.67	1083.33	0062.50	0000.00
2560	1500.00	1500.00	1000.00	0700.00

4. Profit earned by Generators:

Table 4.1:

UI rate as per CERC regulation 2014 and system marginal cost 1850 Rs. /Mwh										
Time in (seconds)	Avg. Freq. in (Hz)	Change in (UI) (Rs./Mwh)	Average change in gen. (MW)				Profit in (Rs.)			
			ΔPg1	ΔPg2	ΔPg3	ΔPg4	Gen1	Gen2	Gen3	Gen4
0-900	49.9947	1889.6	0	50.9477	41.5696	6.9491	0	24067.7	19637.5	3282.7
901-1800	49.9952	1880.6	0	50.0292	41.6595	6.6286	0	23521.2	19586.2	3116.4
1801-2700	49.9952	1880.6	0	50.0292	41.6595	6.6286	0	23521.2	19586.2	3116.4
2701-3600	49.9952	1880.6	0	50.0292	41.6595	6.6286	0	23521.2	19586.2	3116.4
Total							0	94631.4	78396.1	12632.0
UI rate as per CERC regulation 2012 and system marginal cost 1850Rs. /Mwh										
Time in (seconds)	Avg. Freq. in (Hz)	Change in (UI) (RS./Mwh)	Average change in gen. (MW)				Profit in (Rs.)			
			ΔPg1	ΔPg2	ΔPg3	ΔPg4	Gen1	Gen2	Gen3	Gen4
0-900	49.9834	1886.3	0	49.5118	40.2470	8.5627	0	23348.5	18979.5	4037.95
901-1800	49.9839	1879.8	0	49.6106	40.3520	8.2450	0	23314.2	18963.4	3959.32
1801-2700	49.9839	1879.8	0	49.6106	40.3520	8.2450	0	23314.2	18963.4	3959.32
2701-3600	49.9839	1879.8	0	49.6106	40.3520	8.2450	0	23314.2	18963.4	3952.32
Total							0	93293.1	75869.7	15915.91
UI rate as per CERC regulation 2009 and system marginal cost 1850Rs. /Mwh										
Time in (seconds)	Avg. Freq. in (Hz)	Change in (UI) (Rs./Mwh)	Average change in gen. (MW)				Profit in (Rs.)			
			ΔPg1	ΔPg2	ΔPg3	ΔPg4	Gen1	Gen2	Gen3	Gen4
0-900	49.9852	1889.0	0	51.2114	40.4779	6.8097	0	24184.5	19115.6	3215.8
901-1800	49.9865	1880.9	0	51.5296	40.7471	6.3747	0	24230.5	19160.3	2997.5
1801-2700	49.9865	1880.9	0	51.5296	40.7471	6.3747	0	24230.5	19160.3	2997.5
2701-3600	49.9865	1880.9	0	51.5296	40.7471	6.3747	0	24230.5	19160.3	2997.5
Total							0	96876.0	76596.6	12208.3

Table 4.2:

UI rate as per CERC regulation 2014 and system marginal cost 1500 Rs. /Mwh										
Time in (seconds)	Avg. Freq. in (Hz)	Change in (UI) (Rs./Mwh)	Average change in gen. (MW)				Profit in (Rs.)			
			ΔPg1	ΔPg2	ΔPg3	ΔPg4	Gen1	Gen2	Gen3	Gen4
0-900	49.9997	1786.1	48.9254	43.5054	4.9749	2.5596	21846.4	19326.2	2221.4	1142.9
901-1800	50.0000	1780.00	49.0373	43.5887	4.9037	2.4703	21821.6	20732.0	2182.1	1099.3
1801-2700	50.0000	1780.00	49.0373	43.5887	4.9037	2.4703	21821.6	20732.0	2182.1	1099.3
2701-3600	50.0000	1780.00	49.0373	43.5887	4.9037	2.4703	21821.6	20732.0	2182.1	1099.3
Total							87311.2	81522.1	8767.8	4440.7
UI rate as per CERC regulation 2012 and system marginal cost 1500 Rs. /Mwh										
Time in (seconds)	Avg. Freq. in (Hz)	Change in (UI) (Rs./Mwh)	Average change in gen. (MW)				Profit in (Rs.)			
			ΔPg1	ΔPg2	ΔPg3	ΔPg4	Gen1	Gen2	Gen3	Gen4
0-900	49.9988	1656.0	49.6288	44.1384	5.0851	1.1020	20546.3	18273.3	2105.2	456.2
901-1800	50.0000	1650.0	49.7962	44.2633	4.9796	0.9609	20540.9	18258.6	2054.0	396.3
1801-2700	50.0000	1650.0	49.7962	44.2633	4.9796	0.9609	20540.9	18258.6	2054.0	396.3
2701-3600	50.0000	1650.0	49.7962	44.2633	4.9796	0.9609	20540.9	18258.6	2054.0	396.3
Total							82169.1	73049.1	8267.2	1645.3
UI rate as per CERC regulation 2009 and system marginal cost 1500Rs. /Mwh										
Time in (seconds)	Avg. Freq. in (Hz)	Change in (UI) (RS./Mwh)	Average change in gen. (MW)				Profit in (Rs.)			
			ΔPg1	ΔPg2	ΔPg3	ΔPg4	Gen1	Gen2	Gen3	Gen4
0-900	49.9981	1871.0	49.6414	43.5087	5.9059	0.8255	23219.7	20351.2	2762.0	386.2
901-1800	50.0000	1800.0	50.0926	43.8310	5.6354	0.4409	22541.7	19723.9	2535.9	198.4
1801-2700	50.0000	1800.0	50.0926	43.6106	5.6354	0.4409	22541.7	19723.9	2535.9	198.4
2701-3600	50.0000	1800.0	50.0926	43.8310	5.6354	0.4409	22541.7	19723.9	2535.9	198.4
Total							90844.8	79523.1	10369.7	981.4

Table 4. 3:

UI rate as per CERC regulation 2014 and system marginal cost 1650 Rs. /Mwh										
Time in (seconds)	Avg. Freq. in (Hz)	Change in (UI) (RS./Mwh)	Average change in gen. (MW)				Profit in (Rs.)			
			ΔPg1	ΔPg2	ΔPg3	ΔPg4	Gen1	Gen2	Gen3	Gen4
0-900	49.9997	1786.4	34.3429	34.3429	28.5936	2.6844	15337.5	15337.5	12769.9	1198.8
901-1800	50.0000	1780.0	34.3798	34.3798	28.6498	2.5907	15299.0	15299.0	12749.2	1152.8
1801-2700	50.0000	1780.0	34.3798	34.3798	28.6498	2.5907	15299.0	15299.0	12749.2	1152.8
2701-3600	50.0000	1780.0	34.3798	34.3798	28.6498	2.5907	15299.0	15299.0	12749.2	1152.8
Total							61234.5	61234.5	551017.4	4657.4

UI rate as per CERC regulation 2012 and system marginal cost 1650 Rs. /Mwh										
Time in (seconds)	Avg. Freq. in (Hz)	Change in (UI) (Rs./Mwh)	Average change in gen. (MW)				Profit (Rs.)			
			ΔPg1	ΔPg2	ΔPg3	ΔPg4	Gen1	Gen2	Gen3	Gen4
0-900	49.9988	1677.2	34.8302	34.8290	28.4730	1.6726	14604.3	14603.8	11938.7	701.32
901-1800	49.9985	1670.9	34.8906	34.8892	28.5447	1.5286	14574.5	14574.0	11923.8	638.53
1801-2700	49.9985	1670.9	34.8906	34.8892	28.5447	1.5286	14574.5	14574.0	11923.8	638.53
2701-3600	49.9985	1670.9	34.8906	34.8892	28.5447	1.5286	14574.5	14574.0	11923.8	638.53
Total							58328.3	58325.8	47710.1	2616.9
UI rate as per CERC regulation 2009 and system marginal cost 1650Rs. /Mwh										
Time in (seconds)	Avg. Freq. in (Hz)	Change in (UI) (Rs./Mwh)	Average change in gen. (MW)				Profit (Rs.)			
			ΔPg1	ΔPg2	ΔPg3	ΔPg4	Gen1	Gen2	Gen3	Gen4
0-900	49.9989	1806.5	35.0144	35.0144	29.0880	0.7719	23219.7	20351.2	2762.0	386.2
901-1800	50.0000	1800.0	35.1487	35.1487	29.2906	0.4119	22541.7	19723.9	2535.9	198.4
1801-2700	50.0000	1800.0	35.1487	35.1487	29.2906	0.4119	22541.7	19723.9	2535.9	198.4
2701-3600	50.0000	1800.0	35.1487	35.1487	29.2906	0.4119	22541.7	19723.9	2535.9	198.4
Total							90844.8	79523.1	10369.7	981.4