Role of Deviation Price in Automatic Generation Control of Generators

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***Abstract*— ABT stands for techno commercial tool for bringing rational tariff structure for supply of electricity from generating station to beneficiaries on a contracted basis. It is a system for the scheduling and dispatch of power, with rewards and penalties as per the day ahead schedule for both generators and beneficiaries. ABT helps to improve the power quality and curtails the following:**

1. **Rapid and high frequency deviations.**
2. **Frequent grid disturbances results in generator tripping, power outages and grid instability.**

ABT mainly includes:

1. **Power scheduling and dispatch which includes current day and day ahead scheduling.**
2. **Tariff structure which includes fixed charges, variable charges and the deviation charges.**

The proposed MATLAB software based frequency control model is used for automatic frequency control of generator using the prevailing deviation price for the deviation from the schedule.

***Index Terms*— Availability based tariff (ABT), Central Electricity Regulatory Commission (CERC), Deviation Settlement, Generation Control Error (GCE), Marginal Cost, Unscheduled Interchange (UI)**

I. INTRODUCTION

Previously the Indian power sector was mostly owned by the state government and managed by vertically integrated State Electricity Boards. It was a monopoly business. There were five regional grids and the central generating stations were made on regional basis for the distribution of power to different states.

The new tariff mechanism known as Availability Based Tariff was implemented in regional grids so as to impose grid discipline. Deviation Settlement, one of the component of ABT is a mechanism to improve grid efficiency and grid discipline by imposing charges on those who deviate from their schedule generation or drawal. The Indian Electricity Grid Code (IEGC) and the Availability Based Tariff (ABT) have given a direction for the issues of scheduling, metering, accounting and pool settlement. All power plants have fixed and variable costs. The fixed cost comprises of interest on loan & working capital, return on equity, O&M expenses, insurance, taxes and depreciation. The variable costs are the fuel costs. In ABT these two are treated separately. ABT comprises of splitting the monolithic energy charge structure into three components i.e the capacity charge, energy charge and deviation charge. It is the last component that contributes to the desired grid discipline.

A. Capacity Charge

These are the fixed charges that are payable to the generating station by the beneficiaries. These are payable against the availability of the generating station. ABT also has the provision for penalizing the generating utility for over/ under declaration of the availability. Fixed charges are payable by the beneficiaries in proportion to the allocated capacity and does not depend on the actual consumption.

B. Energy Charge

Variable charges are to be paid against the scheduled energy.

C. Deviation Charge (p)

The deviation charges are payable under the following conditions:

1) Generator generates more/less than the schedule causing the grid frequency to deviate upwards/downwards.
2) A beneficiary draws more/less than the schedule causing grid frequency to deviate downwards /upwards.

The penalty imposed varies with the grid condition.

II. THE NECESSITY FOR ABT

Before ABT was introduced, the grid operated in a much undisciplined manner. There were large frequency deviations from the rated frequency i.e 50 Hz. Low frequency condition aroused when the total generation was less than the total load. High frequency aroused due to the generating stations not backing down during the off peak hours. The two part tariff mechanism did not provide any incentive for either backing down generation during off peak hours or for reducing consumer load or enhancing generation during peak load hours.

The ABT directly addressed these issues by giving incentives for enhancing the output capability of generating stations so as to meet more consumer load during peak hours. It also provided incentives for backing down the generation during the off peak hours. With ABT the shares of the beneficiaries in the generating station acquired a meaning.

III. DEVIATION SETTLEMENT MECHANISM IN INDIA

1) There are five regional Load Dispatch Centres in India i.e NRLDC, SRLDC, ERLDC, WRLDC and NERLDC
2) Each region has State Load Dispatch Centre in each state of that region.
3) SLDCs are responsible for the scheduling of state generating units and RLDCs are responsible for the scheduling of Central Generating Units.
4) Each day has 24 hours starting from 00.00 hours which has been divided into 96 time blocks of 15 minutes each. The generating stations are required to make advance declaration of its capacity for generation for each time block of the next day.
5) The generating station declare the availability by 09:00 hrs.
6) As per the declared availability the RLDC declare the entitlements to the various beneficiaries as per their share in the generating unit by 10:00 hrs.
7) The beneficiaries then declare their requisitions and the bilateral agreement to the RLDC by 15:00 hrs.
8) Comparing the declared availability and the requisitions from the generation units and the beneficiaries respectively, the RLDC then declares the injection schedule to the generating station by 17:00 hrs.
9) If there is any change in the declared capability of the generating station, then the same can be revised by 22:00 hrs.
10) As per the revised declared capability the RLDC declares the final injection and the drawal schedule for the generating units and the beneficiaries respectively.

IV. SETTLEMENT SYSTEM

For the settlement of the deviation price Special Energy Meters are commissioned at required generating stations to collect the data for the billing purpose. The data such as MW, MVAR and frequency etc are collected for each 15 min time block. The actual values are then compared with the scheduled values to obtain the deviations from schedule. The deviations in a particular time block are priced at the corresponding deviation rate and settled through an account maintained by RLDC.

V. IMPACT OF ABT

A. Generating Utilities

The major changes as specified in ABT such as computation of capacity charges, assessment of plant availability, deviation charges etc will be of direct significance to power generation companies. The generating stations are now more focused on maximum reliability than on maximum power.

B. Grid Operators

A grid operator manages the power transmission infrastructure. Its main aim is to ensure smooth operation of the grid and to ensure adequate load generation balance in the grid.

C. Consumers

The main aim of ABT is to improve the reliability and quality of power grid. The first beneficiary of such an improved system would be the consumers.

VI.PROPOSED MODEL

The proposed model is based on frequency control with the deviation settlement mechanism. With the implementation of ABT, the deviation price signal is available in real time as it is dependent on the grid frequency.

The proposed model of Frequency Control with deviation settlement mechanism makes sure that the generators respond to the deviation price (p)

automatically as shown in Fig.1. The generating unit will monitor the deviation price and will compare it with its marginal cost. The error signal obtained is termed as generation control error (GCE). When GCE is positive, it indicates that the generator will profit by increasing generation level. A negative

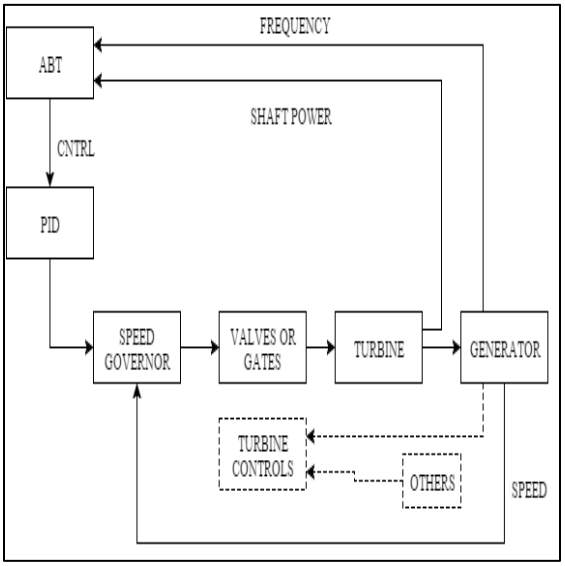


Fig 1. Block Diagram of ABT Based Isolated Power System

GCE indicates that generator will profit by decreasing the generation level.

The model also incorporates the new CERC notification 132. As per the new notification if the generating unit deviates from the schedule in excess of 12% (Over injection or under injection), the corresponding price for the deviation will be zero. The flowchart for the above model is given below:

The deviation price at 50.00 Hz i.e 198.84 Paise/kWh will be used as reference for the proposed model.

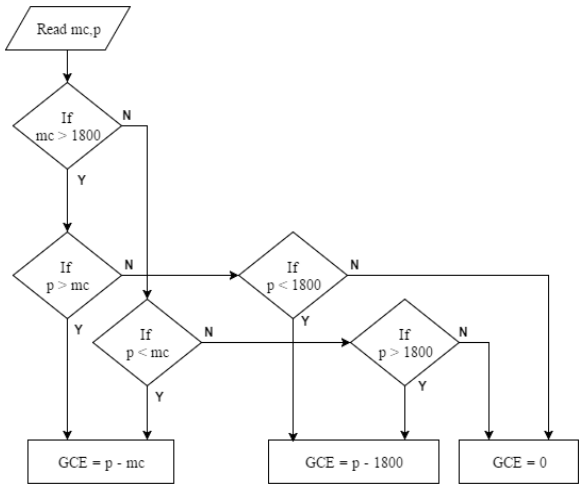


Fig 2. GCE Calculation Algorithm

A. Marginal Cost Calculation

$$\text{Marginal Cost (mc)} = b_i + 2c_i * PG_i \quad (1)$$

B. Frequency to Price Conversion Calculation

For this model, CERC 2009 regulation has been considered. The minimum price is zero INR/kWh at 50.5 Hz and maximum price limit is 7.35 INR/kWh at 49.2 Hz.

```
If F<=49.2
p = 7350;
elseif F<=49.5
p=4800+8500*(49.5-F);
elseif F<=50.3
p = 6000*(50.3-F);
else
p=0;
end
```

VII. SIMULATION RESULT

To illustrate the above model we simulate an isolated area system having a capacity of 5000 MW supplied by four generating stations.

TABLE I. AREA DATA

Capacity	5000 MW
H	25000 MWs
D	100 MW/Hz
f0	50 Hz
R1=R2=R3=R4 (pu)	6

Capacity	5000 MW
Tg1= Tg2= Tg3= Tg4 (sec)	0
Tt1= Tt2= Tt3= Tt4 (sec)	0

TABLE II. GENERATOR DATA

		Generator No.			
		Gen 1	***Gen 2***	***Gen 3***	***Gen 4***
Capacity (MW)		1500	1500	1000	1000
Cost Coefficients	b_i (INR/MWh)	800	1000	1600	2000
	C_i (INR/MWh^2)	0.3	0.3	0.4	0.4

TABLE III. GENERATOR SCHEDULE (MW)

Case	**Generator**			
	Gen 1	***Gen 2***	***Gen 3***	***Gen 4***
Case 1	1500	1333.33	250	0
Case 2	1500	1500	83.33	0
Case 3	1500	1500	250	0

Case1: Generators are scheduled in merit order and the system marginal cost is 1800 INR/kWh with the load remaining unchanged

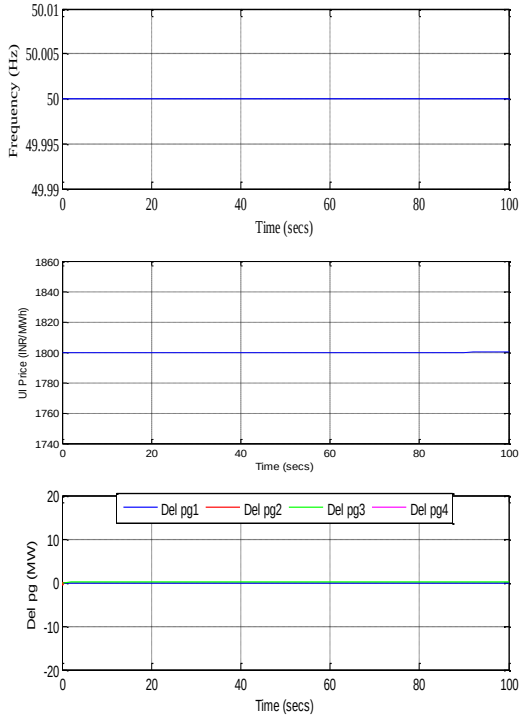


Fig 3. Case 1

Case2: Generators are not scheduled in merit order and the system marginal cost is 1800 INR/kWh with the load remaining unchanged

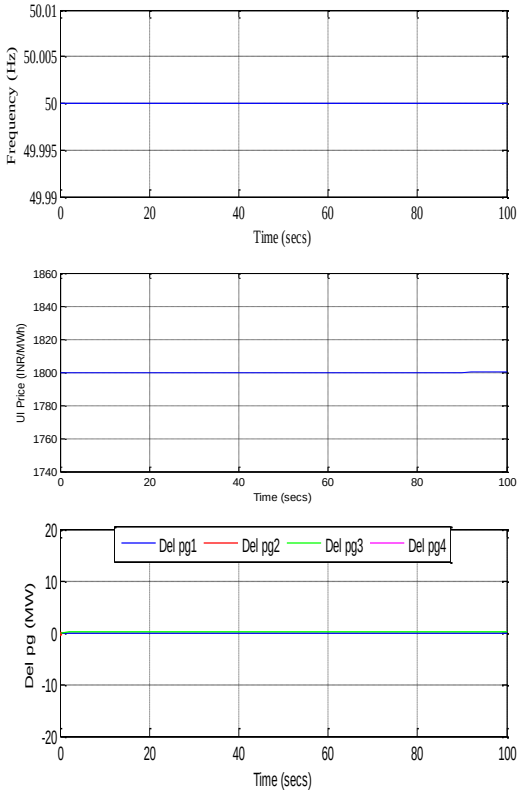


Fig 4. Case 2

Case er and the system marginal cost is higher than 1800 INR/kWh with the load remaining unchanged.

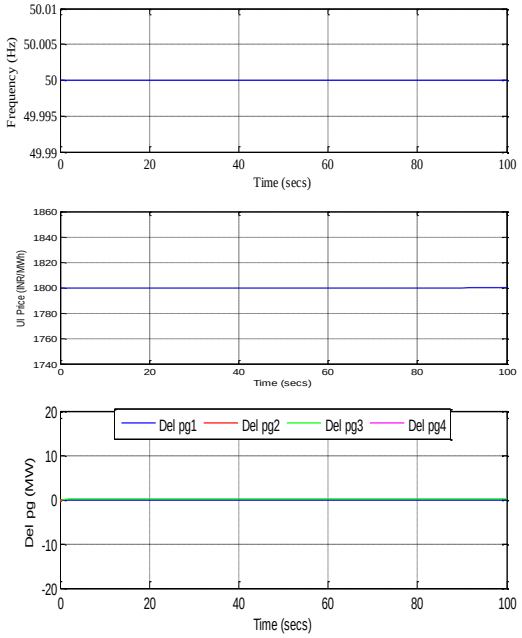


Fig 5. Case 3

Case4: Generators are not scheduled in merit order and the system marginal cost is 1800 INR/kWh with a step load change of 10 MW

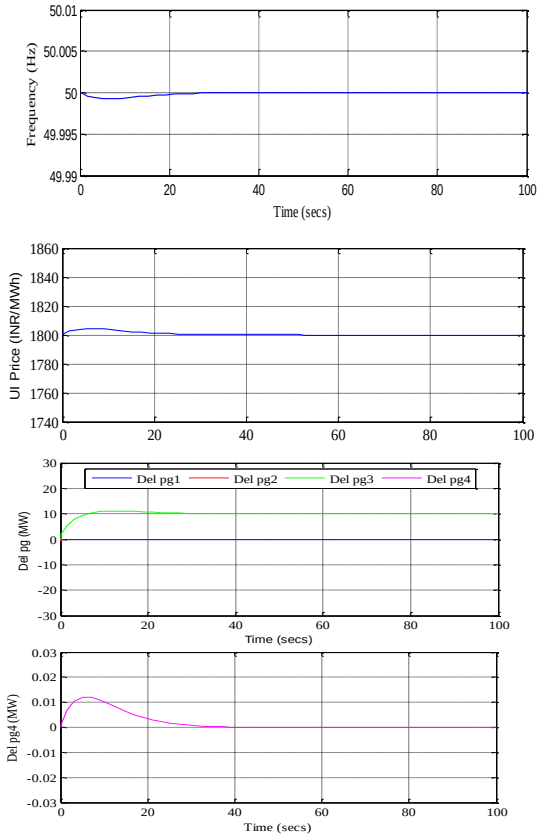
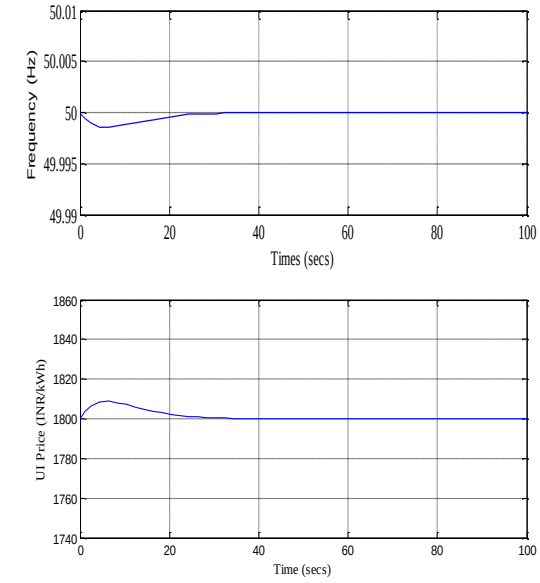


Fig 6. Case 4 (+10 MW step load change)

Case5: Generators are not scheduled in merit order and the system marginal cost is higher than 1800 INR/kWh with a step Load change of 20 MW.



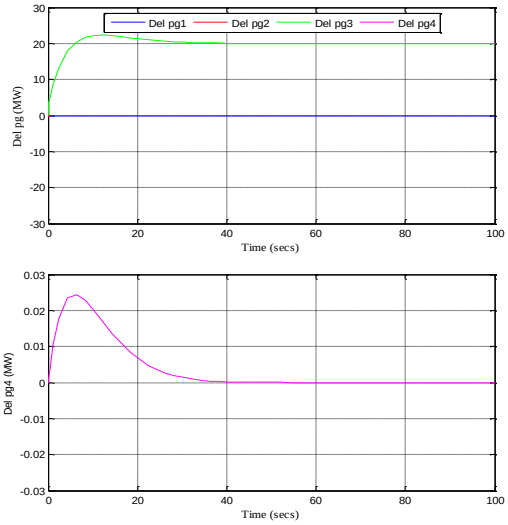


Fig 7. Case 5 (+20 MW step load change)

Case6: Generators are not scheduled in merit order and the system marginal cost is higher than 1800 INR/kWh with a step Load change of 35 MW to check the 12% condition

As per the new CERC notification 132, 2014 if the deviation from the schedule is more than 12% (Over injection or under injection), the corresponding price for the deviation will be zero.

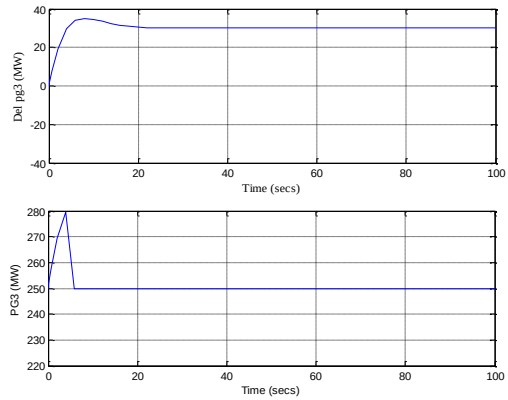


Fig 8. Case 6 (12% check condition)

This paper discusses the deviation settlement which acts as a secondary control for the generation control. When the deviation price is higher than the marginal price, the generator earns profit by increasing its generation. When the frequency is above the allowable limit, the generator earns profit by decreasing the genertation and still gets paid for its availability. The working of the model is verified through simulation of various scenarios. The results

of simulation show that the control is successful in maintaining the grid frequency to 50 Hz.

Recently, Central Electricity Regulatory Commission has issued "Ancillary Services Operation Regulations,2015". The objective of these regulations is to restore the frequency at desired level and to relieve the congestion in the transmission network. Thus with ABT mechanism and role of Reserve Regulation Ancillary Services Provider, the grid frequency is likely to be stable and very close to the normal/rated operating frequency of system.

In future the same model can be tested also considering the multi area system.

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