International Journal on Emerging Trends in Electronics & Communication Engineering
Vol. 4, Issue 1 – 2020
ISSN: 2581-558X

Locational Bias to Unscheduled Interchange (UI) Scheme for UI Price in India

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Abstract

The Unscheduled Interchange (UI) scheme has been introduced in India to maintain grid discipline, security and frequency within a frequency band. The present UI price scheme depends on grid frequency. It does not include the system losses occurring due to the UI deviation. Because of this UI account does not settle over a day. This paper suggests a scheme of locational bias to current UI price to include system losses due to UI deviation. This locational bias is found by allocating the losses to system buses. The simulation carried out on IEEE 14 bus system, IEEE 30 bus system and western regional grid 73 bus system.

Keywords: Socio-Availability Based Tariff, Unscheduled Interchange, Loss Allocation, Locational Bias.

Introduction

The Central Electricity Regulatory Commission (CERC) of India has introduced a commercial mechanism, known as Availability Based Tariff (ABT) in the year 2003 to control the frequency of the system. This scheme penalizes or incentivizes the participants for the deviations from the schedule depending on the frequency of the whole system.The ABT consists of three components:

- Capacity Charge
- Energy Charge
- UI (Unscheduled Interchange) Charge

The first component is the payment of the fixed cost to the plant and is linked with to the availability of the plant i.e. its declared capacity to supply MW's. The total amount payable to the generating company towards fixed cost depends on average availability of the plant over a year [2].

The second component 'Energy Charge' is the payment of the variable cost (i.e. fuel cost) to the plant based on the scheduled generation. The rate, at which payment is done, depends on plant to plant [2].

The third component is UI charge whose price rate depends on the prevailing frequency of the grid [4]. This is the payment for the unscheduled or deviations in power from the scheduled power for a 15-minuite time block. Charges for frequency deviation for each 0.01 Hz step is equivalent to 35.60 Paise/kWh in the frequency range of 50.05-50.00 Hz, and 20.84 Paise/kWh in frequency range 'below 50 Hz' to 'below 49.70 Hz'. The UI charge is define as

UI charge (in Rs.) = UI (in kWh) UI Rate (Rs. /kWh)* … (1)

Limitation Of Ui Mechanism

Though the frequency linked UI mechanism has done a reasonably good job in maintaining frequency constant and grid security since its implementation, some important issues have aroused which depict the shortcomings of this efficient mechanism. That the major drawbacks of the UI pricing scheme, in its original form, is that it works on the concept of virtual lossless pool of power and does not take into account the losses which occur in system due to deviation (UI) in power. In the schedule power status the grid losses are consider but losses due to deviation are not consider.

These UI deviation losses create disparity in spot transaction and UI pool account. The net sum of the UI pool account over a day does not settle to zero. In other words, the collective UI amount to be paid to system operator does not match to the collective amount paid by the system operator. Thus, the system operator either accrues some money or is in deficit of money [1] mathematically

$$\sum_{i=1}^{96}\sum_{b=1}^{N}(UI)_i^b \times (UIrate) \neq 0(overt\quad eday)\ldots (2)$$

Where, $(UI)_i^b$ is unscheduled interchange at bus b in interval i,

$(UIrate)$is UI price in interval i,

N is the total number of buses.

The above relation arises because of presence of losses in the system which the present UI scheme neglects and the same UI rate throughout the system

Solution To Problems

Equation (2) will become equality if the losses occurring due to deviation in power can be taken into account by somehow. One way is to measure the losses in actual case and allocate these to every participant according to their usage of the network. This will change the UI (in MW) for each bus. But this can be done after the deviation has occurred, while participants should be able to know the UI amount which beforehand they will have to pay if they deviate from their scheduled case.

Another way is to vary the UI rate at each bus depending on its location. This means providing a location bias (LB) to UI rate at each bus. The locational bias at each bus is provided by allocating losses occurred due to deviation in power to each bus. Now each bus will have a separate UI rate and UI pool account over a day can be balanced [1].

Technique For Loss Allocation

In order to provide the locational bias at each bus the system losses due to deviation in power are allocated to each bus using the loss allocation technique. The method adopted in this work is marginal participation factor (MPF).This is a power flow based method, which depends on use of line sensitivity factor and makes use of 'extent of use' criterion to allocate charge among the system participant. This method also called "area of influence" method in Argentina. In this method, it is possible to find the usage index of central grid network for a particular time period (a day, a week, a month, and a year).An important performance of Marginal Participation Factor (MPF) is that the system generation dispatch responds optimally when the consumer load and generator output are increase [3].

This method is based on the selection of reference bus (slack bus) to run the power flow. The values of participation factor change once the slack bus (reference bus) is changed. The usage is defined as incremental, i.e. the incremental power flow change in each line (corridor) is computed for a 1MW incremental change of demand or generation at each bus (node). This generation and load increment is maintained from the operation of the time period. The power flow variation in each line is calculated by changing power injection of each participant for a particular time period.

Using this information, usage index for each node for a particular time span is calculated as follows:

$$U_{bl} = \sum_l \left(\left| F_l^b \right| - \left| F_l \right| \right) * P_b \;;\; \left| F_l^b \right| - \left| F_l \right| > 0 \qquad .... (3)$$

Where, F_l is the power flow of line 'l'

F_l^b is the power flow in line 'l' when the nodal injection of bus 'b' is increased by 1MW

P_b is the nodal power injection of bus 'b'

U_{bl} is the usage index for bus 'b' over line 'l'

Only positive increments in the power flow are considered as this is how to it has been implemented traditionally whenever it is used, but a version can be developed where negative charge in power flow are considered and paid instead of being charged for calculating usage index. Since this is a marginal method, it is necessary to weight each factor U_{bl} by the amount of power injected. The marginal participation factor (MPF) of the bus (node) 'b' over the line 'l' is:

$$MPF_{bl} = \frac{U_{bl}}{\sum_b U_{bl}} \qquad .... (4)$$

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Loss Allocation Using Mpf

Marginal participation factors (MPFs) are used to allocate the losses occurring due to deviation in power among the buses whether it is generator bus or load bus. For this, we require loss occurred in each line and then participation of each bus in line losses can be obtained by multiplying the line loss by the participation factor of that bus [3]. The loss allocated to bus 'b' can be obtained as follows:

$$\Delta L_b = \sum_l MPF_{bl} * Loss_l \quad \text{.... (5)}$$

Where, ΔL_b: Loss allocated to bus 'b'

$Loss_l$: Loss of line 'l'

Locational Bias To Ui Rate Using Loss Allocation

The loacational bias can be calculated by allocating the deviation losses to the system participants. The losses due to UI deviation is allocate according the use of grid network. The concept involves allocating the difference in losses arising because of UI deviation to provide Locational bias (LB) at a bus.

The Locational bias (LB) at a bus 'b' in 15-minute time interval 'i' is given by

$$LB_b^i = (+|-)\left(\frac{\Delta L_b^i}{UI_b^i}\right) P^i \quad \text{.... (6)}$$

Where,

LB_b^i: Locational bias of bus 'b' in interval 'i'.

ΔL_b^i **:** Loss due to deviation allocated to bus 'b' in interval 'i'.

UI_b^i: Deviation in power at bus 'b' in interval 'i'.

P^i : UI price in interval 'i'.

$(+)$ Sign for load buses as UI deviation measured at load buses is net drawal which does not considers losses. Hence, load should pay more in order to participate in losses if losses increase.

$(-)$ Sign for Generator buses as UI deviation measured at load buses is net injection considering losses also. Hence, Generator should get less payment in order to participate in losses if losses increase.

The price at which a bus pays for its UI is given by,

$$= P^i + LB_b^i = \left(1 \pm \left(\frac{\Delta L_b^i}{UI_b^i}\right)\right) P^i \quad \text{....(7)}$$

Simulation Result

The above methodology of providing locational bias to system buses has been applied on three system namely IEEE 14 bus systems, IEEE 30 bus systems and western grid of India (73 buses) system. Then UI account settlement has been carried out for a particular time period. The results obtained are as follow,

Results Of Ieee 14 Bus Systems

Fig. 1 and 2 shown below shows the UI deviation and corresponding Locational bias (LB) for each bus. For this case, deviation in power of 5 MW is created at all load buses and deviation at generator buses is obtained using load flowsolution.The difference in losses occurred because of deviation is 2.175 MW. These losses are allocated to each bus using MPFs and Locational Bias at each bus is calculated using equation (6).

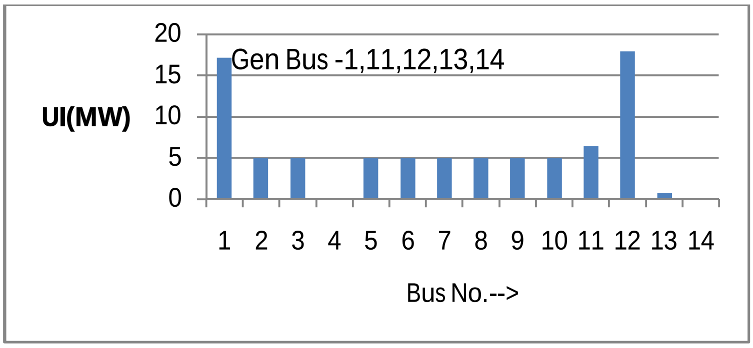

Figure 1.UI Deviation for IEEE 14 Bus Systems

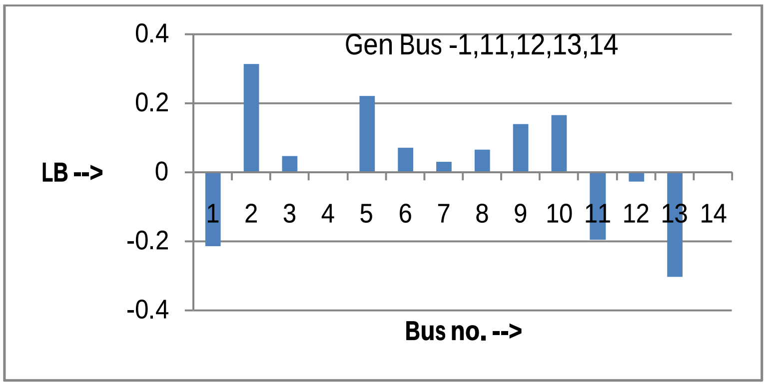

Figure 2.Locational Bias for IEEE 14 Bus Systems

Bus no. 4 and 14 has no generation and load. Hence their Locational Biases is zero. The Locational bias of generator buses is negative and highest is for bus no. 13. It is because that UI deviation of bus 13 is small but its participation factor is large so loss allocated to it is more. Using these Locational biases, UI account settles to zero balance while without considering Locational bias, the net sum of UI account is -10.87 INR.

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Results Of Ieee 30 Bus Systems

For this case, deviation in power of 2 MW is created at all load buses and deviation at generator buses is obtained using load flow solution. The difference in losses occurred is 0.763 MW which are allocated to each bus using their MPFs. Fig. 3 and 4 shown below shows the UI deviation and corresponding Locational bias (LB) for each bus.

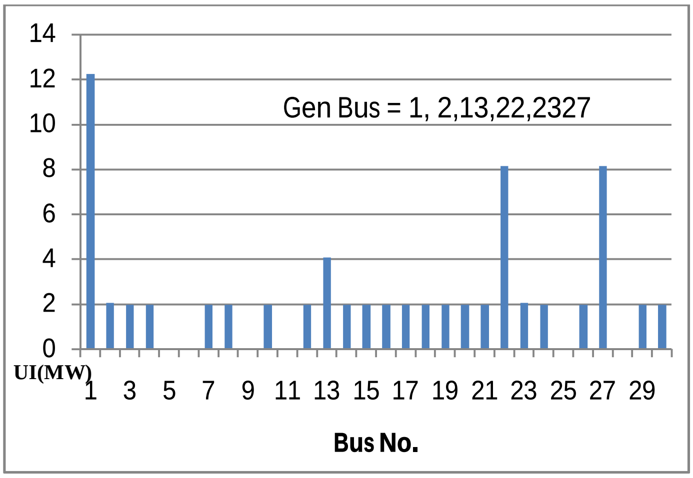

Figure 3.UI Deviation for IEEE 30 Bus Systems

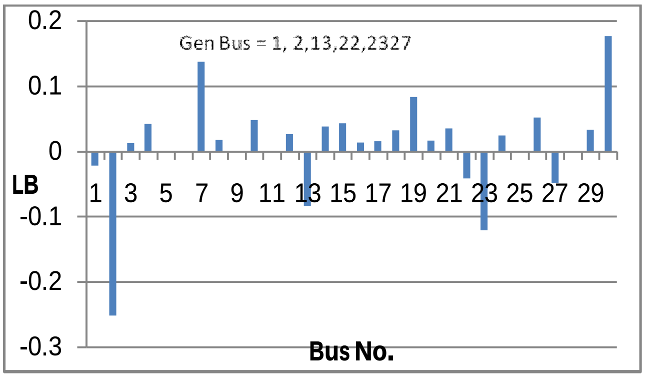

Figure 4.Locational Bias for IEEE 30 Bus Systems

Buses 5, 6, 9,11, 25 and 28 have no generation and load. Hence their Locational Biases is zero. The Locational bias of generator buses is negative and highest is for bus no. 2. It is because of that UI deviation of bus 2 is small but its participation factor is large so loss allocated to it is more. Using these Locational biases, UI account settles to zero balance while without considering Locational bias, the net sum of UI account is -3.9 INR.

Results On Western Grid Of India (73-Bus System)

The Western Region Grid of India consists of 73 buses, 96 lines and 14 generating units. It consists of constituent like Maharashtra (Zone3), Madhya Pradesh (Zone1), Gujarat (Zone4), and Chhattisgarh (Zone 2), Goa etc. It is connected to Eastern, Northern and Southern power grids of India. Zone 1 andZone 2 areas are generation surplus areas while zone 3 and 4 are generation deficit areas. Therefore, normal direction of power flow is from zone 1 and 2 to zone 3 and 4.

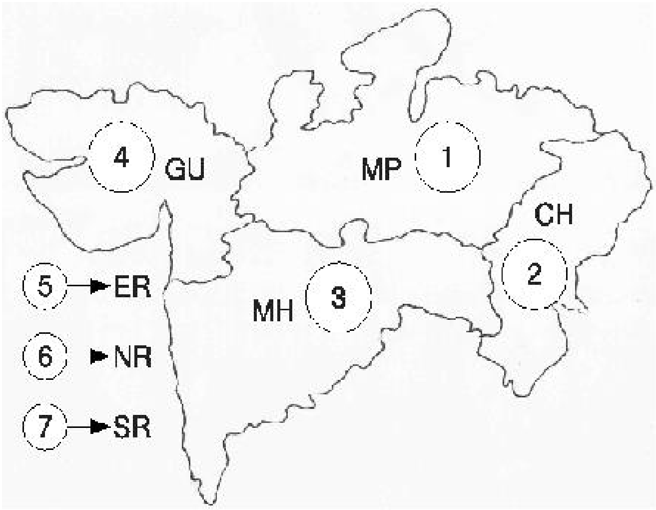

Figure 5.Western grid interconnection

The fig. 5 below shows the Locational bias at each bus when 5 MW deviations in power are made at load buses in zone 3, 4 and 5.

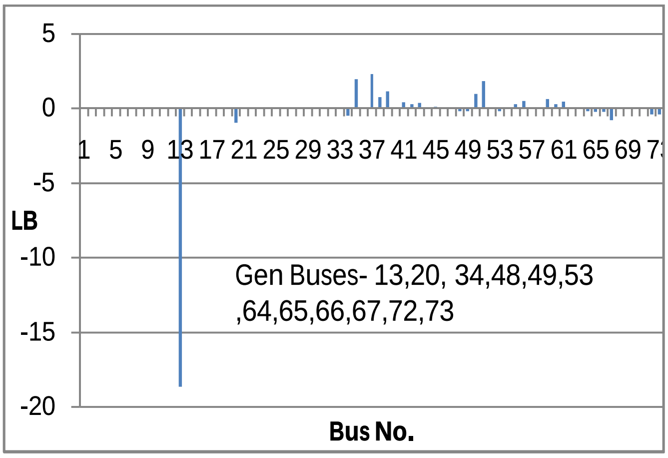

Figure 6.Locational Bias for Indian Western Grid

The difference in losses occurred because of deviation is 42.176 MW. These losses are allocated to each bus using MPFs. The Locational bias at bus 13 is highest (negative) because of high marginal participation in total network. Therefore, a small deviation in power creates a large change in power flows over the lines.

The negative Locational bias at generator buses in zone 1 and 2 confirms the usual direction of power flow from MP (Zone1) and Chhattisgarh (Zone2) to Maharashtra (Zone3) and Gujarat (Zone4). The Locational bias at all load buses in zones 3 and 4 is positive. The UI settlement without Locational bias is -210.88 INR and with Locational bias is – 26.4 INR which is better than previous case.

Conclusion

The frequency linked UI mechanism has successfully worked in arresting frequency within a tighter band and maintaining the grid discipline in India. Under this scheme, UI rate, which is a function of prevailing frequency during a certain time block, is used to settle the deviations in that block. Currently, the UI settlement does not take into account the losses occurring due to deviation and hence, same UI rate is applies across the grid. Because of this, UI pool account does not settle to zero over a day. The pool operator either accrues some money or is in deficit of money. To overcome this drawback, the Locational bias (LB) to the existing UI rate is provided.

The work done in this project work is about providing Locational bias to UI rate in India. A scheme is developed wherein the difference of losses of scheduled case and metered case is used to provide Locational bias to UI rate. This Locational bias is provided using loss allocation techniques. The marginal participation factor (MPF) method is used to allocate loss. The results are obtained on IEEE 14 bus system, IEEE 30 bus system and Western Regional grid of India. The results obtained are good in zero balance settlement of UI pool account

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