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# A novel approach for UI charge reduction using AMI based load prioritization in smart grid

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## Abstract

System frequency is vital part for power system balance. As per India Electricity Grid code frequency should be in the range of 49.5 Hz–50.5 Hz. Deviation from above mentioned range is charged as Unscheduled Interchange (UI) charge. This paper proposes a new method for load and frequency control based on control of third parameter of three-part Availability Based Tariff (ABT) i.e. Unscheduled Interchange charges. New circuit is designed considering prioritization of load and using Advanced Metering Infrastructure (AMI) under Smart Grid environment.



*Keywords:* Unscheduled interchange; Availability based tariff; Advanced metering infrastructure; Smart grid

## 1. Introduction

Grid management in India is carried out on regional basis. Five regions namely Northern, Eastern, western, north-eastern and southern. On 31st December, 2013 the southern grid is connected synchronously with rest all regions and India has achieved one nation, one grid and one frequency mission. To maintain discipline of grid Central Electricity Regulatory Commission CERC has introduced Availability Based Tariff, ABT based on financial principles. Where in all the central section generators and beneficiaries must declare a schedule for dispatch and drawl for every 15-min time block, one day in advance. Any deviation from the schedule is charged at Unscheduled Interchange rates, which are frequency dependent. System frequency is a major indicator of the power balance in the system; frequency is closely related to real power balance in the system. As per Indian Electricity Grid Code, frequency limit is 49.5 Hz–50.5 Hz. Frequency instability leads to massive and cascade blackout in the power system. Restoration after blackout takes time, its essential task to timely recover the system back to normal.

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There are three components of ABT fixed cost, variable cost and UI. When there is a deviation from actual generation and deviation of frequency the third component of ABT comes into the picture. ABT metering which is one of the components of Advanced Metering Infrastructure (AMI) gives real-time monitoring of control of frequency. AMI of smart grid technology makes it possible to work traditional grid in smarter way by better utilization of information and communication technology. This paper proposes the idea of control of frequency considering load prioritization to reduce Unscheduled Interchange charges penalties currently being paid by state utility to central utility. Paper is written to provide answers to following research questions.

1) How to eliminate or minimize the Unscheduled Interchange (UI) charges to avoid penalty paid by state utility?
2) How to design a load management scheme to control frequency deviation considering prioritization of loads?

### *1.1. Review of literature*

The literature survey has been done considering three aspects.

1) Smart grid overview and development in India
2) Smart grid communication technology and Advanced Metering Infrastructure (AMI)
3) Availability Based Tariff and UI mechanism

Paper Mukhopadhyay et al. (1892) is about drivers of smart grid. Drivers for the smart grid, Advanced Metering Infrastructure, network reliability and security and integration of renewable energy are described. Ma et al. (2013) Q4 have explained the comparison of smart grid and conventional grid, communication networks in smart transmission and distribution grid, communication security and challenges and opportunities in communication. In paper Ma et al. (2016) smart grid communication infrastructure and technologies, technical challenges in communication and security Q5 are given. Sabbah et al. (2013) have done survey on protocols used in smart grid. Paper Holmukhbea et al. (2010) is the review paper of ABT and its impact on industry players. In paper Manoj et al. (2016) micro controller based load model is explained. Pre ABT and Post ABT scenario, power exchange and UI mechanism is explained in Vijayapriya et al. (2010). In paper Hou et al. (2014) ABT basic concepts and UI mechanism is explained to understand ABT Issues, its components, mechanism, benefits and the impact of grid on different players like generation utilities, grid operator, consumers involved in power generation, transmission and distribution. This paper describes the basic features of smart grid, comparison of conventional grid and smart grid (Imam Journal Article, 2009) and explains basic components of smart metering. In Paul et al. (2014) overview of India's power market initiatives taken considering technical and non-technical approaches are explained. Paper Bala et al. (2012) is about Client server communication in Android Based Platform, basic service layers of architecture and polling pushing techniques. In Yang et al. (2013) new features of AMI, relationship of power supply and applications of AMI in smart grid are explained. AMI overall design is explained. Android based client server communication is explained considering TCP IP protocols (Luhua et al., 2010). Paper Truong and Vu (2012) focuses on Pros and cons of existing frequency mechanism is discussed. To maintain real time balance between demand and supply, all generators are compiled to operate under free governor mode of running. Short coming of the method is huge wear and tear losses (Parida et al., 2008). In paper Santosh et al. (2011) working of UI mechanism is explained loss allocation techniques have been developed and implemented for IEEE 30 bus system. Comparison for various methods is explained. Frequency linked pricing as an instrument for Frequency Regulation Market and ABT mechanism is about the role of Regional Load Dispatch Center (RLDC) and economic dispatch as a useful tool for reduction of cost and promoting Merit Order Dispatch (MDO) under ABT regime (Reddy et al., 2006), Paitan kar and Bhide (2016) fundamental system of power system protection book provides useful information about smart meter. The primer ABC of ABT deals with ABT and UI mechanism basic concepts, scheduling Q6 process intrastate trading open access wheeling (ABC of ABT Bhushan Bhanu, 2005). Patki et al. (2005) explains ABT metering communication network and client server communication is explained taking case study of Mumbai network. Intrastate ABT, UI mechanism is explained. Structure and components of ABT is explained by Forum of Indian regulatory commissions. AMR, AMI, Modbus and various protocols of metering are explained to understand Q7 ABT metering in paper Pradish et al. (2009). Power system restoration after blackout is explained considering optimal algorithm, learning outcome is power system topology and load prioritization (Recommendations, 2016). White papers from kalkitech (Impact of ABT on different stake holders, 2016; Integrated Availability based Tariff, 2016) provides useful information for impact of ABT on generating utilities, impact on grid operators and impact on consumer. It



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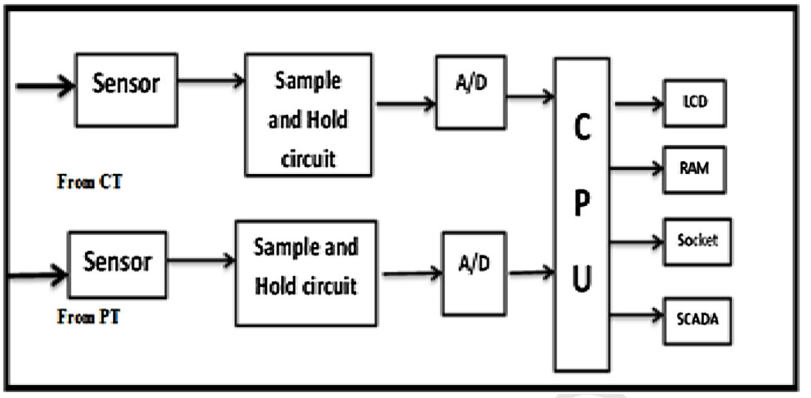


Fig. 1. Working of ABT meter (Reddy et al., 2006).

focuses on functionalities of ABT and integrated ABT discussing various modules of ABT. CERC REPORT (2016) is CERC report having latest data of UI.

## 2. Existing system of load management

In the existing techniques for load management and frequency regulation, load is cutoff on basis of three parameters namely load current, voltage and frequency. By providing Over Current Relay, Under Voltage Relay and Frequency Trend Relay, load management is done in existing system. Under Frequency Relays (UFRs) are instantaneous relays which instantly trip, three frequency settings are 48.8 Hz, 48.6 Hz, 48.2 Hz. The feeders are connected as per priority of load for this frequency setting. The disadvantage of UFR is it does not take momentary fluctuation in the frequency and cuts off the entire feeder. It is desired to observe the frequency for some short period since the fall in frequency may be momentary. From literature survey and after visiting the actual system of load management and frequency regulation, it is concluded that majority of work has been carried out for frequency regulation in conventional grid environment where Advanced Metering Infrastructure and GSM technology is not used. Load management techniques developed based on manual control cuts off the load and system results in complete blackout. Motivated by recent development in information and communication technology utilities have been seeking optimum solution for conventional grid problems. One of the major problems is supply and demand mismatch. System frequency is major indication of equilibrium in the system. Due to grid indiscipline problem of low frequency and variation of scheduled generation, state utilities must pay penalties in millions of rupees annually to central utility. Minimization of UI charges penalties is the motivation of this research.

### *2.1. Working of ABT meter*

Signals from CT and PT are sampled after passing through anti-aliasing filter. Higher frequency components contained within the sampled waveform may not only fail to be identified due to the actual sampling rate and the computational algorithm applied, but may also be falsely represented as a lower frequency component. The effect of a high frequency component in a sampled ac waveform that appears as a low frequency signal is called aliasing. Sampling is the process of converting a continuous time signal, such as a current or voltage, to a discrete-time signal. Sampled and held value is passed to the ADC through multiplexer. Under control of the microprocessor, the multiplexer will sequentially connect the output to each of the inputs, one at a time. The incoming digital values are stored in RAM of the microprocessor. The microprocessor can communicate with other numeric meters (Fig. 1).

## 3. Proposed system for load management and frequency control

### *3.1. Unscheduled interchange and frequency*

Before implementation of Availability Based Tariff, it was two parts tariff namely capacity cost and fixed cost. Apart from above two charges third charge is included by CERC, India in ABT for Unscheduled Interchange of power. System

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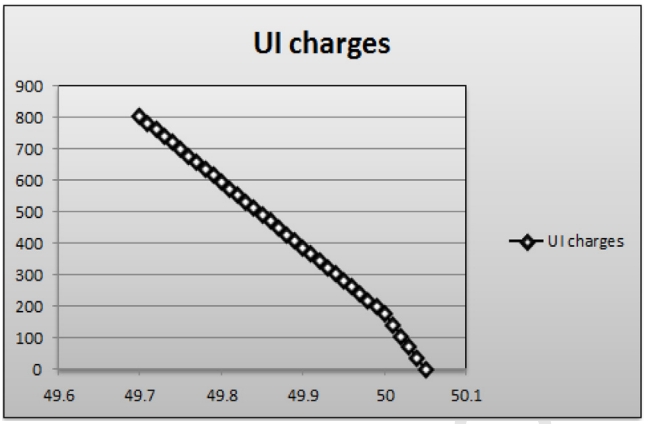


Fig. 2. Curve showing relation between UI charges and frequency.

frequency is a major indicator of the power balance in the system; frequency is closely related to real power balance in the system. As per Indian Electricity Grid Code, frequency limit is 49.5 Hz–50.5 Hz. Deviation from schedule are determined in 15 min time block (96 blocks in day). Graph of UI vs frequency is prepared considering latest data of UI taken from CERC report dated 6/01/2014 (Fig. 2).

### 3.2. Load prioritization

Type A load refers to significant loads like loads of ammunition factories hospitals, airport, broadcasting stations etc. Interruption of type A load causes massive economical loss. Second category is type B load which includes some

Table 1
Q13 AMI based load prioritization for 22 kV Shri Ram feeder Surat India.

| Frequency | Load A | Load B | Load C |
|---|---|---|---|
| 49.93 | ON | ON | OFF |
| 50.03 | ON | ON | ON |
| 50.00 | ON | ON | ON |
| 50.07 | ON | ON | ON |
| 50.07 | ON | ON | ON |
| 50.02 | ON | ON | ON |
| 50.07 | ON | ON | ON |
| 50.06 | ON | ON | ON |
| 50.02 | ON | ON | ON |
| 49.97 | ON | ON | OFF |
| 50.06 | ON | ON | ON |
| 49.98 | ON | ON | OFF |
| 49.99 | ON | ON | OFF |
| 50.03 | ON | ON | ON |
| 50.11 | ON | ON | ON |
| 49.95 | ON | ON | OFF |
| 49.96 | ON | ON | OFF |
| 49.97 | ON | ON | OFF |
| 49.99 | ON | ON | OFF |
| 49.94 | ON | ON | OFF |
| 50.02 | ON | ON | ON |
| 49.89 | ON | ON | OFF |
| 50.04 | ON | ON | ON |
| 50.06 | ON | ON | ON |
| 49.91 | ON | ON | OFF |



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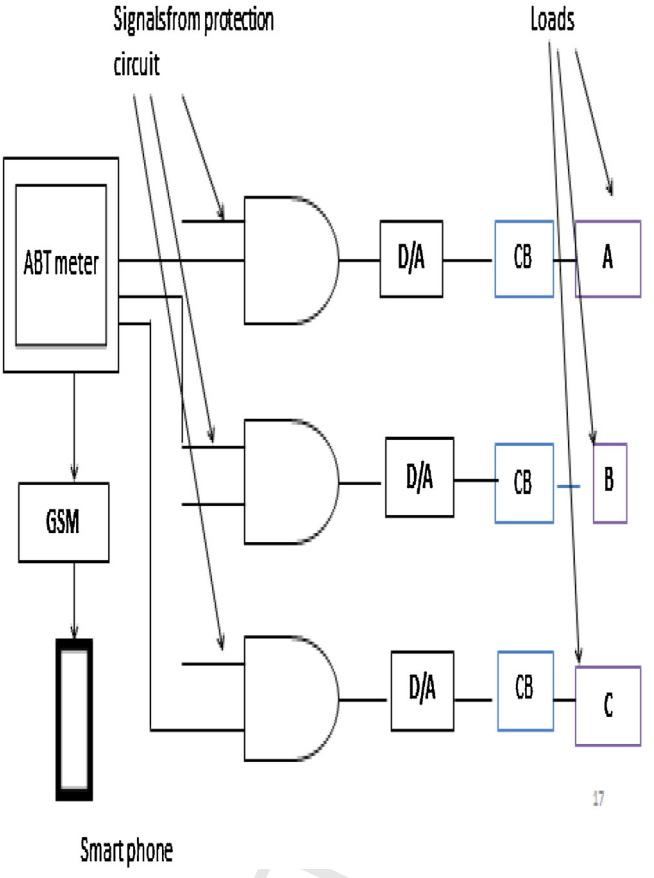


Fig. 3. UI charge reduction.

industrial loads, interruption of industrial load causes loss but its importance is lesser than category A. Third category is type C load which is lightning load not having much importance on loss of economy. Idea of load prioritization and control of frequency and hence control of UI is represented in Fig. 3.

Fig. 4 represents proposed circuit diagram for load and frequency control. If load management scheme based on frequency control and hence based on control of third parameter of ABT is developed considering prioritization of load, then instability and indiscipline of grid can be controlled which gives controlled penalty paid for UI charges. Prioritization of load can be done by dividing load in three categories based on reliability, requirement and its effect on overall economy of the system. Fig. 5 represents flow chart of load Prioritization

### *3.3. Flow chart for load prioritization*

### 3.4. Case study

Algorithm mentioned in Fig. 5 is implemented on 22 kV Shri Ram feeder of 66 kV Vesu Substation Surat India for validation of idea of proposed circuit of UI charge reduction and load prioritization. Load will get cut-off as per change in frequency.

For 22 kV Shri Ram feeder, load C which is domestic load will be cut-off. As frequency is not changing 49 Hz or below 49 Hz it will not affect load B which is industrial load. Load A being highest priority which is hospital, airport etc. will remain in the system. Table 1 shows ON and OFF pattern of load every hour. Load prioritization will control frequency and hence UI charges payable to central utility. Table 2 shows data of frequency variation on 29th September 2016 for 24 h.



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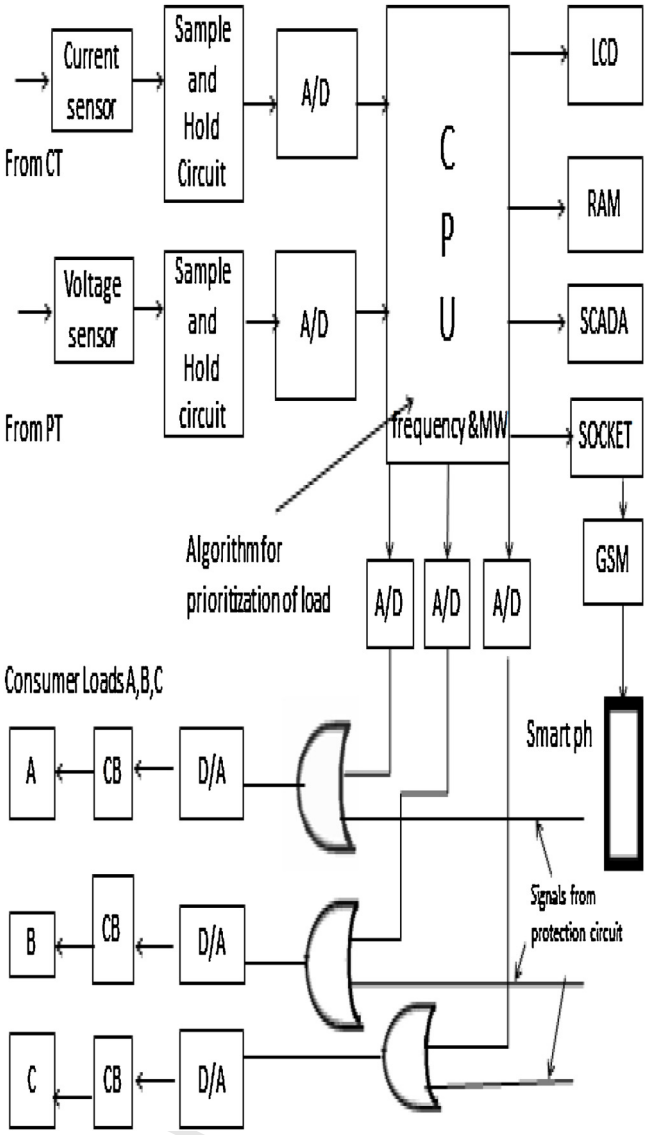


Fig. 4. Proposed circuit design for UI charge reduction.

Table 2
Frequency data, 22 kV Shri Ram feeder for implementation of load prioritization. September 29, 2016.

| Time (h) | Frequency (Hz) |
|---|---|
| 00:02 | 49.93 |
| 01:02 | 50.03 |
| 02:02 | 50:00 |
| 03:02 | 50.07 |
| 04:02 | 50.07 |
| 05:02 | 50.02 |
| 06:02 | 50.07 |
| 07:02 | 50.06 |
| 08:02 | 50.02 |
| 09:02 | 49.97 |
| 10:02 | 50.06 |



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Table 2 (*Continued*)

| Time (h) | Frequency (Hz) |
|---|---|
| 11:02 | 49.98 |
| 12:02 | 49.99 |
| 13:02 | 50.03 |
| 14:02 | 50.11 |
| 15:02 | 49.95 |
| 16:02 | 49.96 |
| 17:02 | 49.97 |
| 18:02 | 49.99 |
| 19:02 | 49.94 |
| 20:02 | 50.02 |
| 21:02 | 49.89 |
| 22:02 | 50.04 |
| 23:02 | 50.06 |
| 00:02 | 49.91 |



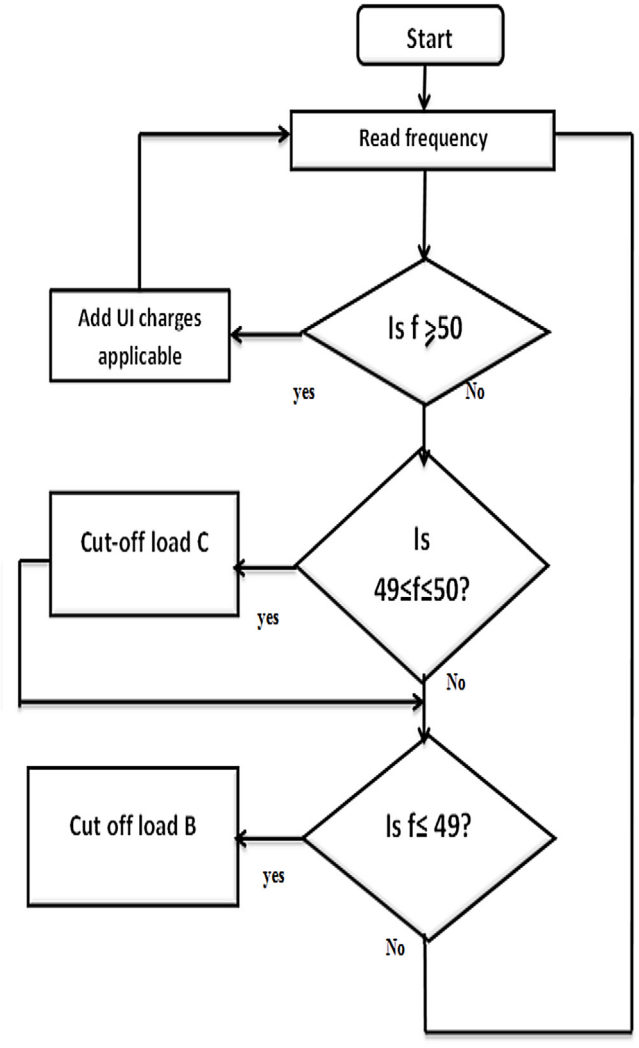


Fig. 5. Proposed flow chart for load prioritazation.

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## 4. Conclusions

This paper proposes a new method of reducing UI charges thereby improving stability and avoiding grid disturbance of the system. Use of GSM and mobile computing allows easy communication among utilities and from utility to consumer in Advanced Metering Infrastructure under smart grid environment (Paul et al., 2014). Research problem is formulated after literature survey and after vising actual existing system of frequency and load control under conventional grid environment. Novel approach has been proposed for load and frequency control and circuit diagram is designed for the same. This would help to minimize UI charges payable by the licensee/consumer or state utility. The Algorithm is implemented considering data of actual system and load prioritization is done as per frequency variation, which will control Penalty paid for Unscheduled Interchange.

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