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Distributed Generation Opportunity under Availability Based Tariff and Reliability Considerations

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Abstract

Availability Based Tariff (ABT) has been implemented in all the regional grids of India for improving grid discipline by frequency dependent pricing. Currently it is limited to short-term energy transactions between the beneficiary States and Central generating stations without the need for negotiations on price or quantum in real time. In the present scenario, Independent Power Producers (IPP), Captive Power Plants (CPP), small Distributed Generation (DG) like mini-turbine, fuel cell, etc., are not considered under ABT. DG units are normally modular in size and they can be placed close to consumers so as to reduce the T&D costs and losses. Hence, they need to be encouraged so as to meet the ever-increasing electricity demands of Indian power sector within the financial constraints. In this paper, impact of IPPs, CPPs and DGs on intra-State ABT is studied. This paper also proposes to study the impact of grid connected DG on network availability and reliability. The improvement in system reliability is studied after evaluating reliability indices like SAIFI, SAIDI, etc., with the inclusion of DG.

KEYWORDS: Distributed Generation (DG), Availability Based Tariff (ABT), Reliability

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1. Introduction

The electricity industry in India is facing a lot of challenges. They range from inadequate capacities in generation, transmission, and distribution, outdated technologies especially in T&D, poor maintenance, financial constraints, etc. [CERC, Website]. As per the Regulatory Commissions Act 1998, the Central Electricity Regulatory Commission (CERC) is authorized to regulate bulk electric power tariffs, viz. the tariff for generation and transmission of power. This will promote competition thereby improving operational efficiency and safeguarding consumer interests. The new concept of ABT tariff has been implemented in the mid of year 2002 and currently it is limited up to inter-State level. The ABT mechanism is based on the financial principals, wherein all the Central Sector generators and beneficiaries (i.e., various States) must declare a schedule for generation and drawal for every 15 minutes one day in advance. Any deviation from the schedule is charged at the rates, which are frequency dependent. Previously, before implementation of ABT, there was frequent problem of power overdrawal from one of the State beneficiaries, leading to the grid instability. But the new frequency based tariff has brought lot of grid discipline. Still this inter-State ABT is a partial solution of the problem because currently there is a huge amount of peak power shortage experienced by majority of the State utilities. In addition to this the transmission corridors are getting congested while bringing the excess amount of power from the remote location to the load centers. The only viable alternative in such case is small, modular dispersed generators, which can be located directly near the load centers. This will defer T&D expansion, improve the voltage profile of the system and reduce line losses [Agalgaonkar et al., 2003]. The intra-State ABT mechanism is currently under consideration so as to encourage additional amount generation locally near the load centers. In this paper, the DG viability under intra-State ABT is proposed with the help of frequency based price signal. The strategically placed DG will also improve the distribution system reliability in case of sustained interruptions on the utility system. The exact quantification of reliability improvement with the inclusion of DG is also proposed for the practical system under study.

2. Availability Based Tariff

ABT is a tariff structure meant for bulk power. It is mainly aimed at bringing about more responsibility and accountability in power generation and consumption through a scheme of incentives and disincentives. ABT is applicable to only Central generating stations having more than one State Electricity Board (SEB) / State / Union Territory as its beneficiary. Through this scheme, the

Central Electricity Regulatory Commission (CERC) looks forward to improve the quality of power by curtailment of large frequency deviations and frequent grid disturbances [Kalki, Website].

Presently there are five regional grids operational in India along with the Central sector generation and transmission systems. As the States did not have any surplus capital, the Central sector generation is shared by all the States within a region. Earlier, both the fixed cost and the variable cost of a generating station were charged to the beneficiaries in proportion to the actual energy drawn by them during that period. Under ABT regime, the fixed charges are shared among the beneficiaries in the ratio of their entitlement for power from that station and energy charges are charged as per the scheduled drawal by the beneficiary [CERC, Website]. The scheduling procedures in ABT encourage constituent utilities to follow the given schedules for generation and drawal (usually 15 minutes schedule on a day ahead basis).

The bifurcation of fixed and variable charges helps in enhancing the incentive for trading in power. Apart from the two charges, a third charge in the ABT scheme is for the unscheduled interchange of power (UI charges). The UI charges are payable/receivable depending upon deviation from the schedule and also subject to the grid conditions (in terms of frequency) at that point of time. This is the element, which is expected to bring about discipline in the system.

The main components of inter State ABT tariff can be described in detail as follows [Kalki, Website]:

2.1 Capacity Charges:

Fixed charges are payable against the availability (declared capacity) of the generating facility. Fixed charges excluding Return On Equity (ROE) are payable on a prorated basis for 0-30% availability. Prorated ROE is payable from 30-70% availability. Incentive is payable to the generating station for availability beyond 70%. The incentive is pegged at 0.4% of equity for each percent increase in availability in the 70-85% range. Thereafter, the incentive falls to 0.3%. This decrease in incentive after 85% is aimed at discouraging the generating facility from overloading the units at the cost of maintenance and equipment life. ABT also contains 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.

2.2 Variable Charges:

Variable charges are to be paid against the actual energy consumed, i.e., all the actual energy that is drawn is charged as per the variable energy charge of the station from which power is being drawn.

2.3 Unscheduled Interchange (UI) charges:

The UI charges are frequency dependent charges for deviation from the schedule. UI charges are payable if a generator generates more/less than the schedule and if beneficiary draws more/less than the schedule causing deviation in the grid frequency. The penalty imposed varies with the grid condition at the time of the indiscipline and the magnitude increases with the severity of the frequency deviation caused.

3. Distributed Power Generation

DG, which includes the application of small generators scattered throughout the distribution network, offers a valuable alternative to traditional sources of electric power for industrial and residential applications. A series of technological innovations, particularly within the last decade and the advent of compact, highly efficient generation units have laid the foundation for the emergence of DG [Height, 2000]. The function of an electricity generator is to transform one form of energy (e.g., chemical energy in fuels or kinetic energy in wind) into electrical energy as efficiently as possible. As such, the choice of generation technology is strongly dependent on the primary energy supplies available at the point of generation. DG uses some form of conventional fossil fuel, like gasoline, diesel, natural gas, propane, methane or gasified coal, to produce electric power. Due to steady depletion of conventional fossil fuels, the recent research and development activities in the field of fuel cell and all renewable energy sources such as wind, photovoltaic, etc., are gaining momentum.

The necessity for flexible electric systems, changing regulatory and economic scenarios, energy savings and environmental impact along with the need to protect sensitive loads against network disturbances will provide impetus to the development of DG. Studies have projected that DG may account for up to 20% of all new generation going online by the year 2010 [Barker and De Mello, 2000].

DG makes a large use of the latest modern technology and can be efficient, reliable and simple to own and operate; hence it can compete with conventional generation systems. The various advantages of DG can be summed up as follows [Willis and Scott, 2000]:

1. DG units are modular in size and modularity has two major advantages; firstly the units are standardized to common designs, site requirements and operating methods, which simplifies engineering and installation, thus lowering the cost.

Secondly modular units are available “Off-the-shelf”, with a little lead-time and at a standard price.

2. DG units are closer to the customers so that T&D costs and losses are avoided or reduced.

3. Usually DG plants require shorter installation time and the investment risk is not so high.

Optimal placement and penetration level assessment of DG needs to be determined [Kulkarni et al., 2003] for reduction in losses and for improving voltage profile with due consideration of fixed and variable costs. Currently Independent Power Producers (IPP), State owned generation, Captive Power Plants (CPP), small DGs like mini-turbine, fuel cell, etc., are not considered under inter State ABT. The scheduling and despatch of DGs and IPPs within the State is discussed in the next section.

4. DG Viability Under Intra-State ABT

In pre-ABT scenario the IPPs were paid by two-part tariff, i.e., capacity charges and energy charges. After the possible implementation of intra-State ABT the new frequency based component (UI charges) will play an important role.

4.1 Intra-State ABT Mechanism [MPERC, Website]:

All distribution licensees and proposed open access users should draw up the day-ahead schedules and intimate the same to State Load Dispatch Centre (SLDC). Based on this, the SLDC shall intimate the State generators and within-the-State IPPs of their dispatch schedule on overall merit order (based upon the prices of Central sector stations). It will also intimate the Regional Load Dispatch Centre (RLDC) of requirements for merit order dispatch of Central generating stations, IPPs, etc. The process for the intra-state ABT mechanism shall be designed on the lines of current ABT mechanism. Initially, the SLDC shall receive requirements in 15-minute blocks from bulk purchasers of power in a day-ahead fashion. The SLDC shall also receive the availability from each of the State generators, IPPs, Central sector generation, etc. Based on the information available to the SLDC for all the sources of power available in the State grid, it can prepare a 15-minute schedule for the drawal by the Users / Consumers and dispatch for all the generating stations in merit order. Thus, SLDC shall be responsible for ensuring that the dispatch instructions and the schedule sent to the RLDC match to the requirements and schedules it has received from the Users.

4.2 Proposed Methodology:

In this particular study the frequency pattern in each season for a period of one year is studied and the economic viability of all proposed DG resources up to 1 MW is analyzed under intra-State ABT regime. It is assumed that the energy available from the DG will be treated as an unscheduled interchange in the system.

The seasonal frequency pattern for some specific days in the month of February, July and December 2003 is as shown in Fig. 1. This is the practical data measured by Western Region Load Dispatch Centre (WRLDC) for the each time block of 15 minutes in a day (total 96 blocks). For the time being it is assumed that the State has some despatchable Distributed resources like reciprocating engine, fuel cell, mini gas turbine, etc. The initial cost, percentage efficiency, percentage availability, life and customer level cost of these DG units is as shown in table I [Willis and Scott, 2000]. In inter-State ABT, the frequency dependent UI charges are determined as shown in Fig. 2. The same formula is used for deciding the economic viability of DG under intra-State ABT. Accordingly, it is observed that for some specific time intervals out of the above mentioned three days (especially in the peak period), the UI charges (in case of any deviation from schedule) will be quite high than that of the customer level cost of the DGs as shown in Fig. 3. Hence this clearly indicates that small DGs can be attractive and should be encouraged in intra-State ABT regime.

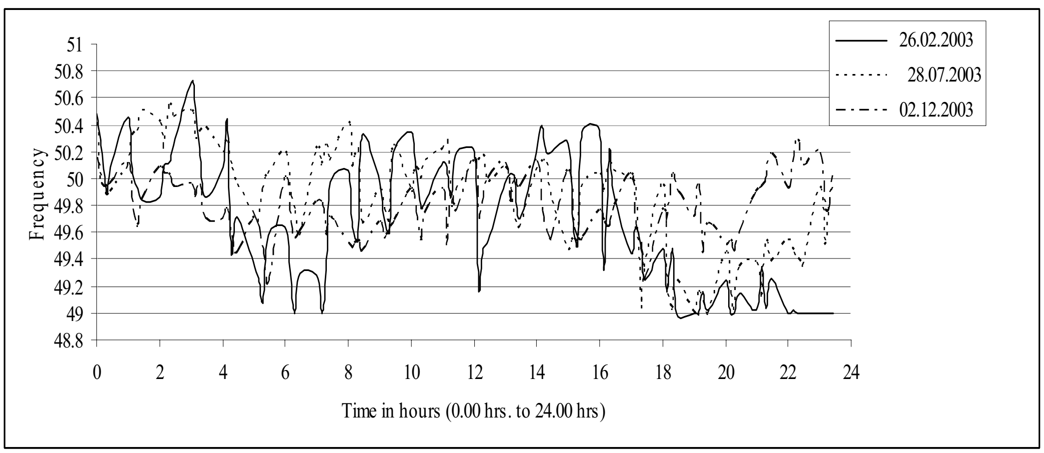

Fig. 1 Seasonal frequency variation

Table I Cost of energy with various types of DG [6]

Type of DG	Typical Capacity in MW	Initial Cost in Rs./kW	Percentage Efficiency	Percentage Availability	Life in years	Customer level cost Rs./kWh	
						Base	Peaking
Reciprocating Engine	1	20067.38	0.40	0.97	20	3.24	5.09
Fuel Cell	1	34758.75	0.42	0.97	10	3.47	6.07
Mini Gas Turbine	1	19464.90	0.29	0.97	20	4.07	5.56

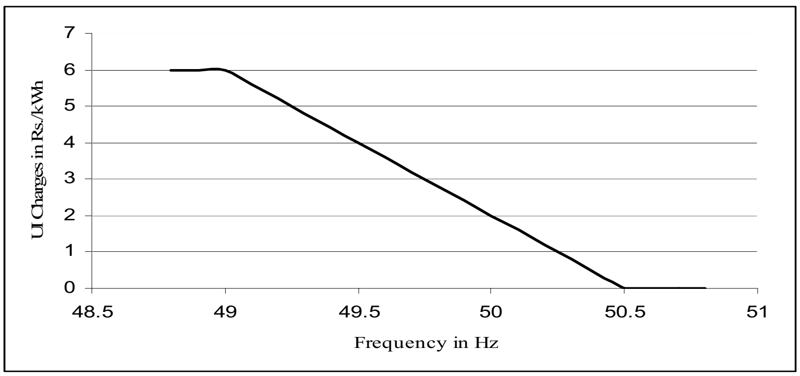

Fig. 2 Frequency dependent UI charges

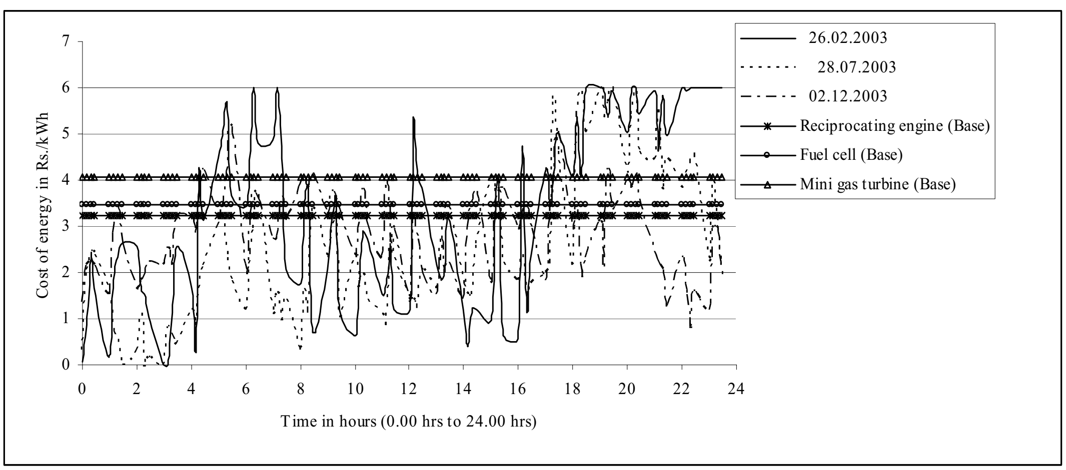

Fig. 3 DG viability under intra-State ABT

5. Distribution System Reliability

A distribution system is relatively cheap as compared to capital intensive generating stations. Generation inadequacy can have widespread catastrophic consequences whereas distribution system outages have a much localized effect. However, the analysis of customer failure statistics of most utilities shows that the distribution system makes the greatest individual contribution to the unavailability of supply to a customer [Billinton and Allan, 1984]. Hence reliability is the most important feature of electric power distribution system. Quantification of distribution system reliability indices is the best indicative of whether the consistent supply of electricity is available to the users or not. A widely accepted definition for reliability is comprised of two elements [EPRI, Website]: the first one is adequacy, i.e., the ability to satisfy market demand at all times, and the other one is security, i.e., the ability to withstand sudden disturbances such as short circuits or unanticipated loss of system elements.

The distribution system performance during the operational phase can be very well analyzed by using sustained interruption indices. These indices are basically customer-related measures evaluated from system interruption data. Utilities commonly evaluate following sustained indices [IEEE Standard 1366, 2001]:

5.1 System Average Interruption Frequency Index (SAIFI):

This index is designed to give information about the average frequency of sustained interruptions per customer over a pre-defined area. In words, the definition is:

$$\text{SAIFI} = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers served}}$$

5.2 System Average Interruption Duration Index (SAIDI):

This index is commonly referred to as customer minutes of interruption or customer hours, and is designed to provide information about the average time the customers are interrupted. In words, the definition is:

$$\text{SAIDI} = \frac{\sum \text{Customer interruption durations}}{\text{Total number of customers served}}$$

5.3 Customer Average Interruption Duration Index (CAIDI):

CAIDI represents the average time required to restore service to the average customer per sustained interruption. In words, the definition is:

$$\text{CAIDI} = \frac{\sum \text{Customer interruption durations}}{\text{Total number of customer interruptions}}$$

5.4 Customer Average Interruption Frequency Index (CAIFI):

This index gives the average frequency of sustained interruptions for those customers experiencing sustained interruptions. The customer is counted once regardless of the number of times interrupted for this calculation. In words, the definition is:

$$\text{CAIFI} = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers interrupted}}$$

These indices are excellent measures for assessing how well a system has performed its basic function of satisfying the needs of its customers. The indices can be calculated for overall system or for subset of the system, e.g., individual feeders, service areas, etc., depending on the requirements for the performance measures [Jenkins et al., 2000].

6. Impact of DG on Reliability

DG can provide policy makers, regulators and customers with multiple options to increase reliability [EPRI, Website]. DG can be installed within the distribution system or at a customer's site, as per the requirement, i.e., according to the application the sizing and siting of the DG can be decided. DG may improve reliability by:

- addition of generation capacity at the customer site
- addition of system generation capacity
- deferring transmission and distribution expansion
- supporting power system maintenance/ restoration operations with generation of temporary backup power

DG can be operated selectively, such as during peak load conditions or when the probability of outages are highest or when there are some continuous process customers which may get affected adversely due to outages. DG can also be used as a backup for highly sensitive loads like hospitals, railways, etc. Alternatively, DG can be operated continuously either in parallel with the electric power system to provide a portion of normal demand, or as a complete stand-alone source of power to satisfy total demand. DG can also be implemented directly at the customer site.

To study the impact of DG on reliability analysis, the small part of the practical distribution system of M/S Tata Power Company, Mumbai, India is considered. The system configuration is as shown in Fig. 4, where two 22 kV feeders are the main incoming feeders in the station. It is followed by two 10 MVA, 22 kV / 11 kV transformers. Both these transformers share the total load of about 2 MW with around 5900 consumers. The load break switches are also provided so as to have redundancy in the system. It is also assumed that all the LT consumers from society 1 are served by feeder 1 as shown in Fig. 4. Similarly all the LT consumers from society 2 are served by feeder 2. If there is a fault on feeder 1 as shown in Fig. 4, all the consumers from society 1 get affected due to this fault. If the fault leads to sustained interruption then no alternate feed is available to society 1 from any other feeder. In such situation, the strategically placed DG will be able to serve all the consumers from society 1 as shown in Fig. 5. Intuitively this will improve the overall reliability of the system. The quantification of reliability improvement is discussed in the next section.

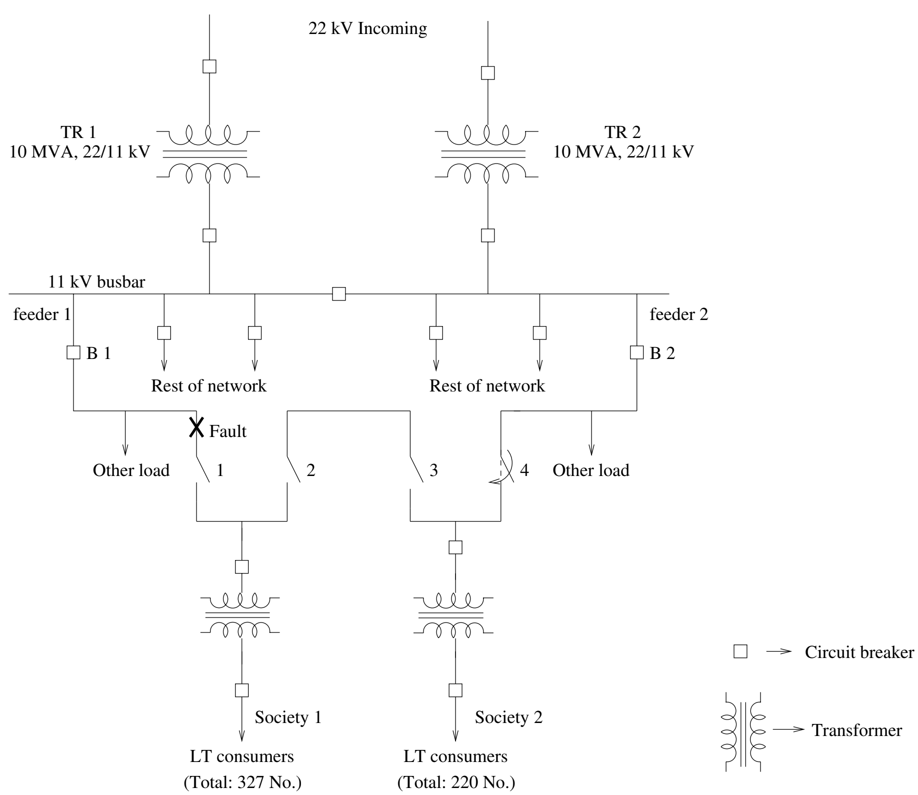

Fig. 4 Practical distribution system with fault on feeder 1

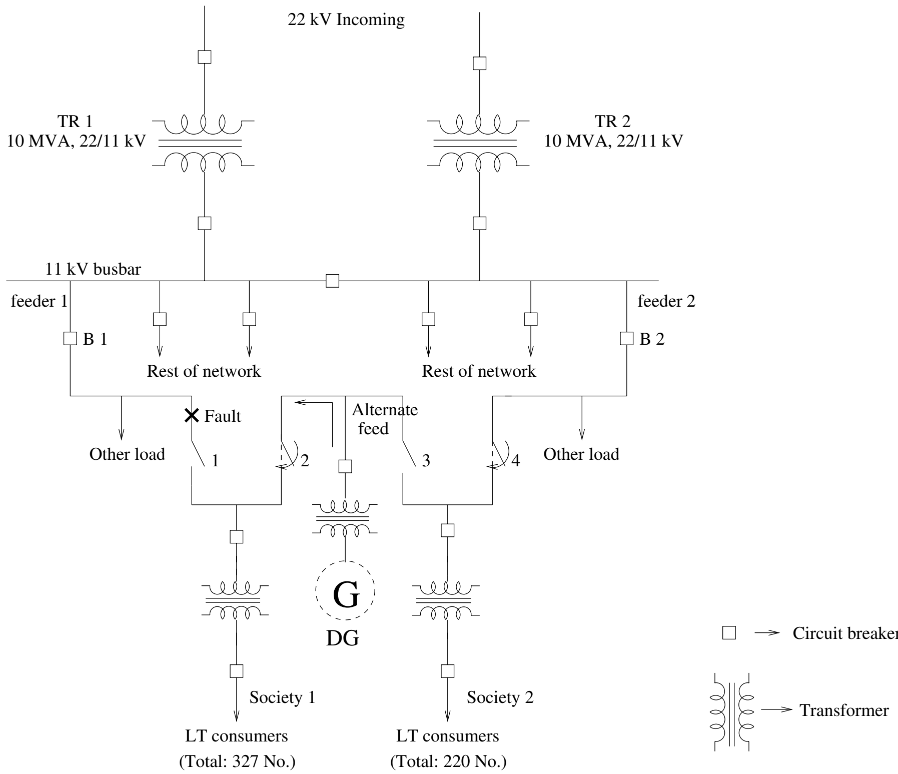

Fig. 5 Inclusion of DG for supplying isolated load

7. Results

The sustained reliability indices are evaluated for 220 kV substation feeding around 15000 LT consumers with the total load of 16 MW. This analysis is done on a seasonal basis for a period of one year with the help of detailed statistical data gathered from M/S Tata Power Company. All the HT consumers are not considered for the purpose of study.

The small part of practical distribution system is considered as discussed in the previous section. There are 327 consumers in society 1 and 220 consumers in society 2. The total load of each society is around 250 kW. Accordingly it is assumed that the DG of 250 kW capacity can be located as shown in Fig. 5. In case of any sustained fault on feeder 1 or feeder 2, the DG will provide an alternate feed to the consumers which in turn will cause an improvement in the distribution system reliability indices. Table II indicates the compilation of preliminary consumer data at 220 kV substation with and without DG. The respective reliability indices are as shown in table III.

Table II Customer related data for reliability analysis

	Total no. of customer interruptions	Sum of interruption durations in Minutes	No. of affected customers		Total no. of customers served	
			without DG	With DG	without DG	with DG
Feb. 2003	2020	74537	2018	1691	12336	12663
Aug. 2003	6106	241012	4334	4007	15101	15428
Dec. 2003	5012	66983	4916	4589	15497	15824

Table III Sustained reliability indices

	CAIFI		SAIFI		SAIDI	
	without DG	with DG	without DG	with DG	without DG	with DG
Feb. 2003	1.000	1.194	0.163	0.159	6.042	5.886
Aug. 2003	1.409	1.523	0.404	0.396	15.96	15.62
Dec. 2003	1.02	1.09	0.323	0.316	4.322	4.233

As seen from the above results, all the reliability indices got improved after the inclusion of DG. It is observed that the percentage improvement for CAIFI, SAIFI and SAIDI in the month of Feb. 2003 is 19.4%, 2.45%, 2.58% respectively. This improvement may be significant in case of a DG supplying larger part of the network.

8. Conclusions

The major thrust of the restructuring process in Indian power sector is to bring in healthy competition so as to improve the efficiency of the system. The implementation of Electricity Act 2003 and ABT tariff are some of the concrete steps initiated for achieving this goal. The inter-State ABT has significantly improved the grid discipline. However, the question of major mismatch of total generation and total load especially in the peak period still remains unanswered.

In this paper the role of DG in intra-State ABT is discussed. In intra-State

ABT the frequency based price signal is the most encouraging incentive for IPPs / CPPs and DGs as evident from the case studies reported in this paper. These alternative generating sources are also useful for improving the reliability of the system. In contingency situation, DG may be able to maintain the supply intact in the affected part of the system thereby improving the overall reliability of the system. The results discussed in this paper are quite indicative of this fact.

Under the unbundled scenario of Indian power sector, DG is expected not only to bridge the gap between the demand and supply but it can also provide attractive alternative under ABT regime during peak load conditions. In addition DG can improve reliability indices of the system, which will indicate the robustness of system operation in deregulated environment.

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