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Energy Auditing of an Electricity Distribution System in Nigeria: A Case Study of Port Harcourt Electricity Distribution Company.

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ABSTRACT

In practical terms, energy losses in electrical power systems are inevitable. Power system losses, especially in distribution systems are usually high and result in increasing the cost of operations to the electricity utilities and the price tag of electricity to the consumers. The main objective of this research is to make an appraisal of an existing power distribution sector in Nigeria with special focus on loss reduction and efficiency improvement in power supply. Different major aspects of technical and non-technical losses have been identified and based on that, a few remedial measures have been suggested for loss reduction and to facilitate the improvement of overall efficiency of the power distribution system Aggregate Technical, Commercial and Collection (ATC & C) Losses is a reliable parameter that reveals the true energy and revenue loss conditions of distribution systems. This study presents a pragmatic feeder-wise method for establishing the ATC & C losses in a typical Nigerian distribution system. Mathematical models were developed for the determination of key factors Billing efficiency, Collection efficiency, and ATC&C losses using the Garden City Main Integrated Business Centre network of the Port-Harcourt Distribution Company (PHEDC) of Nigeria as a case study. The analysis was achieved through extensive field survey and critical study of the schematic diagram of the network area. The average Billing efficiency, Collection efficiency and ATC&C losses for the period under review were found to be 68.60%, 76.29%, and 49.54% respectively. An understanding of appraisal of these losses is important to the power system Engineers, energy policy makers, and the power firms as it enables areas of high losses in the network to be identified, which will give room for credible investment plans, subsequent monitoring of the losses and ultimately result in profitability to the electricity utility.

KEYWORDS: Energy Audit, Energy Management, Billing Efficiency, Collection Efficiency, Aggregate Technical, Commercial and Collection Losses.

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1.0 INTRODUCTION

Energy audit is an engineering procedure used to build up the example of energy use and distinguishing proof of how and where the energy losses are happening (Ijumba & Ross, 2006). Electrical Energy is undetectable; subsequently regularly it is squandered or stolen in secret besides toward the month's end when energy is being audited. Energy review particularly resolves these issues of energy losses. Thus, any investment funds in energy utilization and misfortunes straightforwardly prompts the productivity of the utility. Energy is integral to maintainable turn of events and neediness decrease endeavours. It influences all parts of improvement social, financial, and ecological including livelihoods, admittance to water, horticultural efficiency, wellbeing, populace levels, instruction, and sexual orientation related issues. None of the Millennium Development Goals (MDGs) can be met without significant enhancements in the quality and amount of energy administrations in agricultural nations.

Electric force framework includes how electric power is created and circulated. The pace of transmission and conveyance misfortunes in Nigeria has been very high dependent on an article distributed by the World Bank bunch (2012) assessing the yearly loss of Nigeria because of power burglary to be in the billions of Naira. As per the World Bank bunch, about 25% of

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power power

produced incomes obliged are really recovered making Nigeria's condition one of the most exceedingly awful.

For the most part, the working expense of electric utilities is expanded by framework misfortunes in this manner reflecting in the expense of power. It is out of line to the purchasers assuming then again, the weight of these misfortunes, regardless of the greatness, were given completely to them. Consequently, there would be no motivation for service organizations to place as a result misfortune decrease measures. This is on the grounds that the specific misfortunes brought about by working failures of the service organizations would be passed on moreover. Then again, it is additionally unjustifiable if the whole weight of framework misfortunes is left for the service organizations to deal with. Singh and Verma (2008) alluded the expression "dispersion misfortunes" to the distinction between the measure of energy conveyed to the circulation framework and the amount of energy customers are really charged. Along these lines, in the end everybody is influenced by framework misfortunes, the electric utilities, the customer and the country all in all. These electrical transmission and conveyance line misfortunes that electrical service organizations are enormously influenced by are comprised of two significant constituents: specialized and business misfortunes (Kumbhar and Joshi, 2012).

1.1 Aim and Objectives

The aim of this paper is to implement Energy auditing for improvement of power distribution system in Nigeria, using the Port Harcourt Distribution Company as a case study. The objectives include:

i. To assess the existing energy consumption profile of the system and to evaluate the energy input and energy utilized/sold to the system.

ii. To evaluate the energy (Aggregate Technical, Commercial & Collection) losses in the system and the efficiency of the system.

iii. To evaluate the cost-effective energy saving factors of the system.

iv. To give recommendations on how to make the system efficient, technically, and financially sustainable.

The vacuum in existing knowledge is that no work implemented energy auditing for improvement on the distribution system in Nigeria while highlighting key factors. Therefore, this research work will fill this gap by providing a suitable energy audit method which will aid the identification of factors affecting the energy consumption and subsequent sources of losses in a power distribution company. Also, the method will help to identify and scale the cost-effective energy saving opportunities for energy consumption.

2. MATERIALS AND METHODS

2.1 Materials

The materials used in this research include:

i. Data of facilities
ii. Operational process data
iii. Six (6) months Grid energy input
iv. Billing details

These materials were collated from the Port Harcourt Electricity Distribution Company (PHEDC), Rivers state, Nigeria using the Garden City Main Integrated Business Centre as a case study by auditing the energy pumped into the network. The electrical energy audit process included three major steps- collection of data, analysing the collected data and finding energy conservation/ loss reduction opportunities. Now this collated data was analysed to get the information of energy used by company. Collected data helped the energy auditor in reducing energy wastage.

2.2 Methods

A statistical research strategy was utilized for this review. This was considered fitting since review configuration for the most part can be utilized to adequately examine energy misfortunes in sensible settings. The study strategy permitted the analyst to inspect a few factors and use multi-variation statistics to analyze data from primary and secondary sources.

The method was based on the standard method for short energy audits and it included the following:

i. Collating the utilization, organization creation rate, the rundown of energy frameworks and energy buyers.
ii. Determination of energy pointers for the organization.
iii. Visitation of the chosen stations.
iv. Determination of energy losses and computation of energy equilibrium and energy trends.
v. Evaluation of energy efficiency measures and applicable Energy Conservation possibilities.

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vi. Evaluation of executing limits of the locales for Energy Management Systems (EMS) introduction and Reporting on results of energy auditors.

2.2.1 Preparation of single line diagram

A single line diagram is a graphical representation of a three-phase power system which may include generation, transmission and distribution. In a single line diagram electrical elements such as bus bars, circuit breakers, isolators, current transformers, capacitors and conductors are shown in its standardized symbols. While calculating ATC&C loss, it is important to have the proper single line diagram of the project area. By analyzing the single line diagram, the task of identifying the export and import lines to the project area was simplified.

2.2.2 Computation of Energy Losses

Net input loss within the network is the obtained as the difference between the Incomer Transformers and the outgoing 33kV feeders and it is given by;

$$\text{Eloss (KWH)} = \sum_{i=1}^{n} Mi - \sum_{j=1}^{n} Nj \qquad (1)$$

Where

M_i (i = 1,2, 3, n) represents 132kV transformers recording energy imported to the network and n = number of incomer meters in the network, N_j (j=1,2, 3, n) represents 33kV feeder meters recording export of energy to the network, and n = number of feeder meters in the network.

2.2.3 Computation of Energy Received

The total energy received into the network is obtained by sharing the energy losses across the 33kV feeders supplying the network area. This is given by:

$$\text{Energy Received (KWH)} = \{\text{Feeder Energy} + [\text{Energy losses } x \left(\frac{\text{Feeder Input Energy}}{\text{Total Feeders}}\right)]\} \qquad (2)$$

2.2.4 Collation of Energy Billed, Amount Billed and Revenue Collected

The bills in terms of energy sales and equivalent billed amount in Naira, and revenue generated in the project region was calculated by adding the total energy consumed during the defined period by the metered customers and unmetered customers. For the unmetered customer, the distribution company follows evaluation that is implemented by state regulatory commission. Therefore, certain calculation against mixed feeders was obtained on the grounds that only customer's bills within the region under study was needed for calculation of total energy bills and revenues generated.

2.2.5 Computation of Billing Efficiency

Billing efficiency implies that the extent of energy that has been provided to the network region which has been billed to the customer. This billed energy includes both metered and unmetered energy consumed. The equation to determine the billing efficiency is given below. Billing efficiency is the proportion of Net energy billed of the network region in kWh to the Net input energy of the network region in kWh.

$$\text{Billing efficiency} = \frac{\text{Total Energy Billed (kWh)}}{\text{Total Energy Received (kWh)}} \qquad (3)$$

2.2.6 Computation of Collection Efficiency

Every one of the customers billed are dependent on energy used by them which was gotten from meter reading and evaluation of unmetered energy users. The billed sum is collated based on the tariff fixed by regulatory commission for different customer classification. Notwithstanding, there are a number of customers who have potential to fail in their payments for different reasons. In this way, the utility company can't recuperate whole sum billed by it, bringing about commercial losses. Collection efficiency is a pointer of the extent of the sum that has been collated from customers with respect to the sum billed to them. Collection efficiency was computed using Equation 4.

$$\text{Collection efficiency} = \frac{\text{Revenue Collected (Naira)}}{\text{Billed amount (Naira)}} \qquad (4)$$

2.2.7 Computation of ATC and C Losses

Aggregate Technical & Commercial (AT&C) loss is an actual measure of performance of a power distribution system as it includes both technical losses and commercial losses. It shows the gap of input energy into the system and the units for which the payment is collected. The aggregate technical and commercial losses was measured using Equation 5.

$$\text{ATC\&C Losses \%} = \{1 - (\text{Billing Efficiency } x \text{ Collection Efficiency})\}\, x\, 100 \qquad (5)$$

Figure 1 shows the single line diagram of the Garden City Main network area comprising of Transmission stations, 132/33kV Power transformers, 33kV feeders and their distribution transformers. A, B, C, D and E are the 132/33kV Incomers Transformers T1A, T2A and T3A at the Port Harcourt Mains Transmission station, T2B and T1A at the Port Harcourt Town Transmission Station.

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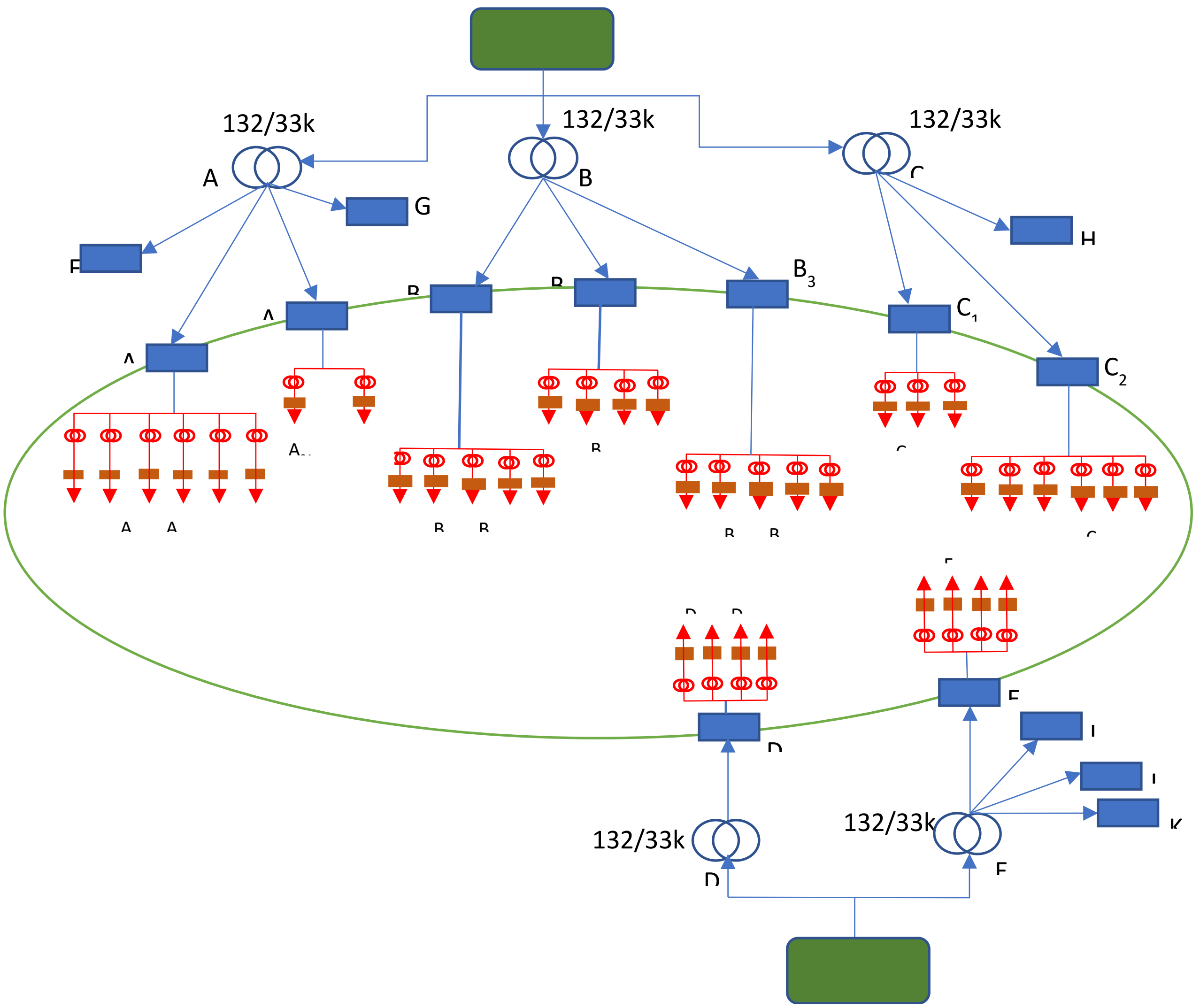
Port Harcourt Mains Transmission Station



Port Harcourt Town

Fig. 1: Single line diagram of the Garden City Main Network

Feeders A_1, A_2, B_1, B_2, B_3, C_1, C_2, D_1 and E_1 are 33kV feeders within the network namely Abuloma, RSPUB-1, Rainbow, Trans-Amadi, Refinery2, Rumuola, Akani, Secretariat and Borokiri respectively while Feeders outside the network are F, G, H, I, J and K namely Rumuodumaya, Refinery1, Airport, UTC, Rumuolumini and Silverbird 33kV Feeders respectively.

The input energy, energy received, energy billed, amount billed, amount paid, billing efficincey, collection efficiency and ATC&C losses data was collated and calculated over a 6-months period using the adopted formula in order to monitor the Feeders ATC&C trends. These parameters were computed for the month of June 2020 using the Microsoft Excel software as shown in Table 1.

Furthermore, Figures 2 to 10 projects the graphs showing the relationship between the Billing efficiency,

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Collection efficiency and the ATC&C losses of each of the nine 33kV feeders within the network over the 6-months period under review.

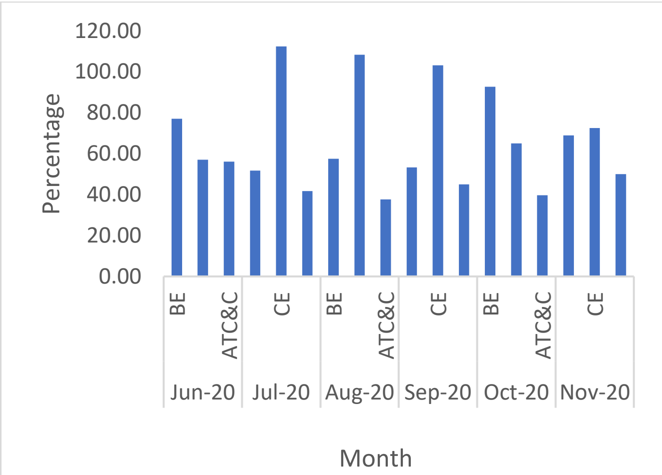

Fig. 2: 6-Months Billing Efficiency, Collection Efficiency and ATC&C for Abuloma 33kV Feeder.

Figure 2 is used to describe the relationship between the Billing Efficiency, the Collection Efficiency and the resulting ATC&C losses for Abuloma 33kV feeder over a six-month trend.

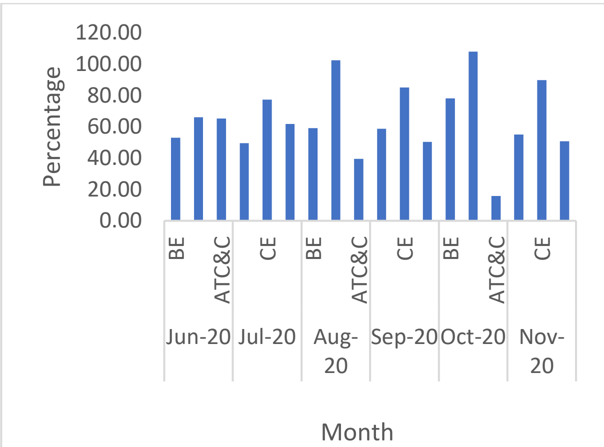

Fig. 3: 6-Months Billing Efficiency, Collection Efficiency and ATC&C for RSPUB-1 33kV Feeder.

Figure 3 is used to describe the relationship between the Billing Efficiency, the Collection Efficiency and the resulting ATC&C losses for RSPUB-1 33kV feeder over a six-month trend.

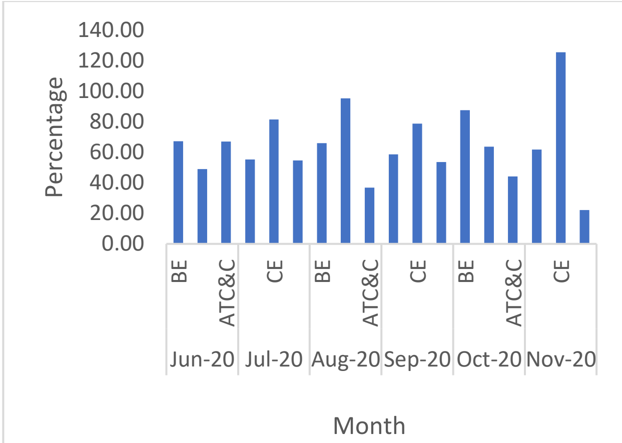

Fig. 4: 6-Months Billing Efficiency, Collection Efficiency and ATC&C for Rainbow 33kV Feeder

Figure 4 is used to describe the relationship between the Billing Efficiency, the Collection Efficiency and the resulting ATC&C losses for Rainbow 33kV feeder over a six-month trend.

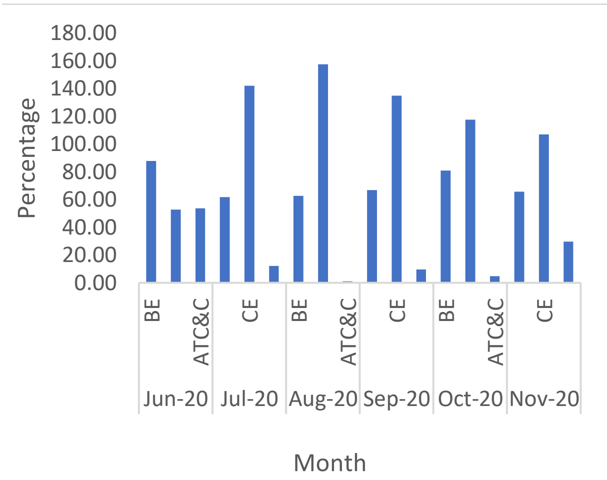

Fig. 5: 6-Months Billing Efficiency, Collection Efficiency and ATC&C for Trans-Amadi 33kV Feeder.

Figure 5 is used to describe the relationship between the Billing Efficiency, the Collection Efficiency and the resulting ATC&C losses for Trans-Amadi 33kV feeder over a six-month trend.

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Table 1: ATC&C Analysis for June 2020

S/N	ZONE	33KV FEEDERS	Input Energy (MWH)	Share of Energy Losses (MWH)	Energy Received (KWH)	Energy Billed (KWH)	Amount Billed (=N=)	Payment Posted (=N=)	Billing Efficiency	Collection Efficiency	ATC & C Loss %
1	Garden City Main	ABULOMA	4480.61	225.73	4,706,340.89	3,624,311.32	157,689,177.94	89,854,826	0.77	0.57	**56.12**
2		RSPUB-1	6017.61	303.16	6,744,394.18	3,565,415.87	130,544,860.42	86,127,097	0.53	0.66	**65.12**
3		RAINBOW	5437.78	273.95	5,711,732.64	3,848,032.02	154,325,862.58	75,564,673	0.67	0.49	**67.01**
4		TRANS AMADI	7336.37	369.60	7,705,972.65	6,766,522.39	298,212,188.85	157,397,647	0.88	0.53	**53.65**
5		REFINERYLINE 2	6861.08	345.66	7,206,737.78	3,235,470.56	140,360,106.01	135,106,377	0.45	0.96	**56.79**
6		RUMUOLA	6604.79	332.75	6,937,536.02	1,743,367.94	65,756,348.80	50,829,353	0.25	0.77	**80.58**
7		AKANI	5346.92	269.38	5,616,295.16	7,437,909.81	310,046,333.16	110,485,111	1.32	0.36	**52.81**
8		SECRETARIAT	4135.45	59.25	4,194,700.00	5,780,396.09	227,920,159.11	104,566,057	1.38	0.46	**36.78**
9		BOROKIRI	2975.79	252.22	3,228,010.06	166,448.30	5,718,502.26	2,369,320	0.05	0.41	**97.86**

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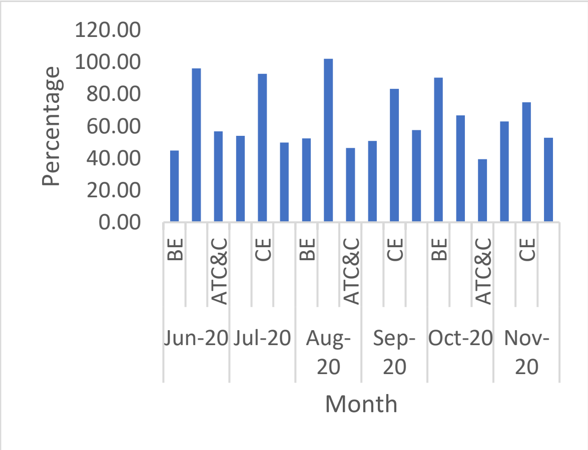

Fig. 6: 6-Months Billing Efficiency, Collection Efficiency and ATC&C for Refinery line 2 33kV Feeder

Figure 6 is used to describe the relationship between the Billing Efficiency, the Collection Efficiency and the resulting ATC&C losses for Refinery line 2 33kV feeder over a six-month trend.

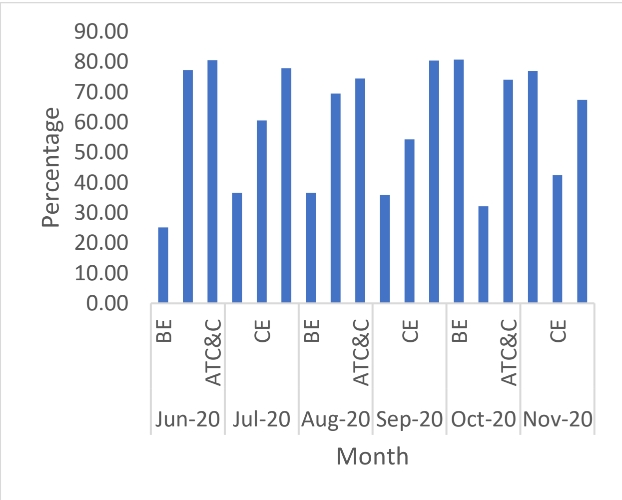

Fig. 7: 6-Months Billing Efficiency, Collection Efficiency and ATC&C for Rumuola 33kV Feeder

Figure 7 is used to describe the relationship between the Billing Efficiency, the Collection Efficiency and the resulting ATC&C losses for Rumuola 33kV feeder over a six-month trend.

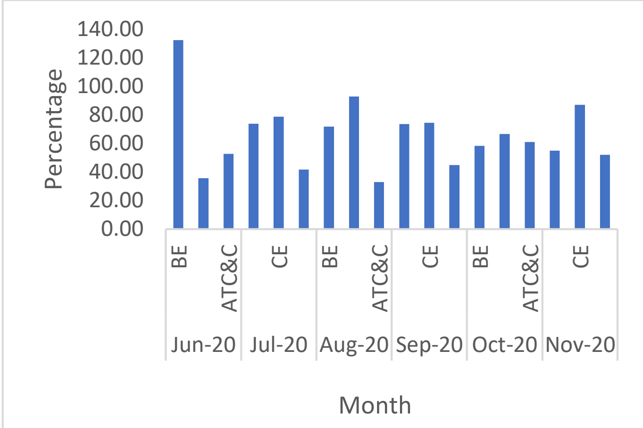

Fig. 9: 6-Months Billing Efficiency, Collection Efficiency and ATC&C for Akani 33kV Feeder

Figure 9 is used to describe the relationship between the Billing Efficiency, the Collection Efficiency and the resulting ATC&C losses for Akani 33kV feeder over a six-month trend.

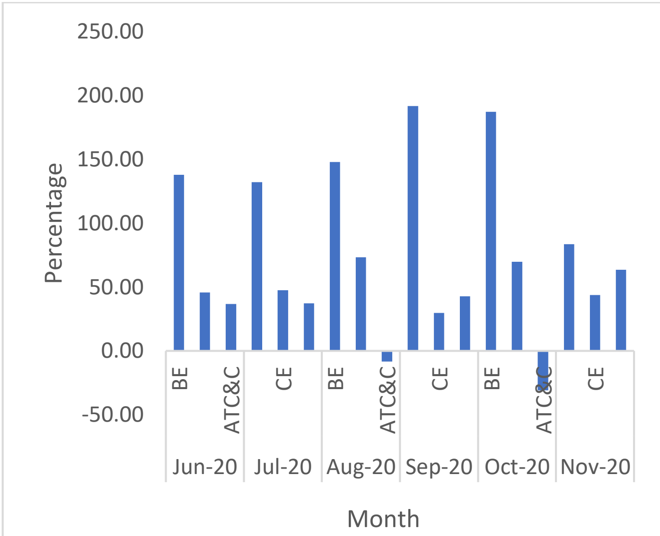

Fig. 8: 6-Months Billing Efficiency, Collection Efficiency and ATC&C for Secretariat 33kV Feeder.

Figure 8 is used to describe the relationship between the Billing Efficiency, the Collection Efficiency and the resulting ATC&C losses for Secretariat 33kV feeder over a six-month trend.

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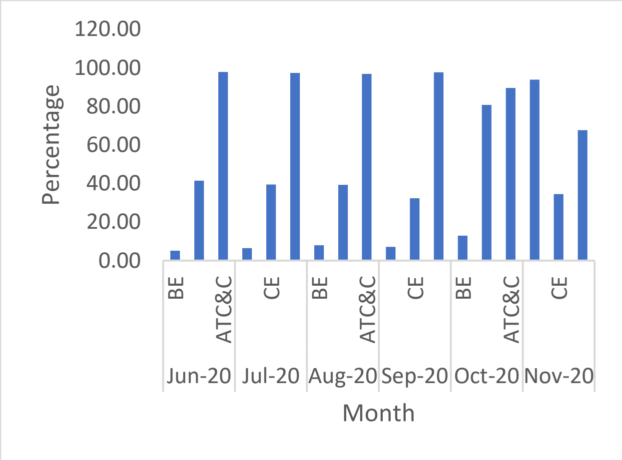

Fig. 10: 6-Months Billing Efficiency, Collection Efficiency and ATC&C for Borokiri 33kV Feeder

Figure 10 is used to describe the relationship between the Billing Efficiency, the Collection Efficiency and the resulting ATC&C losses for Borokiri 33kV feeder over a six-month trend.

3. RESULTS AND DISCUSSION

Effects of Billing Efficiency and Collection Efficiency on ATC&C

Senerio 1: High Billing Efficiency, Low Collection efficiency

In November 2020, Borokiri 33kV feeder billed 93.92% meaning that the feeder was unable to bill 6.08% of the energy it received. There was a Collection efficiency of 34.43% in the same month meaning the feeder was unable to collect 65.57% of the amount billed. The resulting ATC&C loss is seen to be 67.66% as seen in Figure 10.

Senerio 2: Low Billing Efficiency, High Collection efficiency

In June 2020, Refinery line 2 33kV feeder billed 44.90% meaning that the feeder was unable to bill 55.10% of the energy received. It had a Collection efficiency of 96.26% in the same month meaning the feeder was unable to collect 3.74% of the amount billed. The resulting ATC&C loss is seen to be 56.79% as seen in Figure 6.

Senerio 3: Low Billing Efficiency, Low Collection efficiency

In September 2020, Borokiri 33kV feeder billed 7.09% meaning that the feeder was unable to bill 92.91% of the energy received. It had a Collection efficiency of 32.34% in the same month meaning the feeder was unable to collect 67.66% of the amount billed. The resulting ATC&C loss is seen to be 97.71% as seen in Figure 10.

Senerio 4: High Billing Efficiency, High Collection efficiency

In October 2020, Abuloma 33kV feeder billed 92.76% meaning that the feeder was unable to bill 7.24% of the energy received. It had a Collection efficiency of 65.10% in the same month meaning the feeder was unable to collect 34.90% of the amount billed. The resulting ATC&C loss is seen to be 39.62% as seen in Figure 2.

Table 2 below shows the relationship between the Billing Efficiency, Collection Efficiency and the ATC&C losses.

Table 2: Billing efficiency, collection efficiencty and ATC & C Summary

BE	CE	ATC&C
HIGH	LOW	HIGH
LOW	HIGH	HIGH
LOW	LOW	HIGH
HIGH	HIGH	LOW

This is further observed in the 6-Months Total average Billing Efficiency, Collection Efficiency and ATC&C losses of the Garden City Main Integrated Business center as a network as shown in Table 3.

In Summary, for every month either of the key factors affecting the ATC&C losses is low, the ATC&C losses experienced will be high. Subsequently, efforts should be made to ensure a very high Billing efficiency and Collection efficiency is achieved so as to minimize the ATC&C losses.

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Table 3 6 month average Billing Electricity, Collection Efficiency and ATC&C Summary

S/N	ZONE	33KV FEEDERS	6-MONTHS AVERAGE		
			BE	CE	ATC&C
1	Garden City Main	ABULOMA	66.90	86.45	45.01
2		RSPUB-1	58.83	87.99	47.22
3		RAINBOW	66.19	82.41	46.45
4		TRANS AMADI	70.96	118.70	18.54
5		REFINERY LINE 2	59.27	86.08	50.49
6		RUMUOLA	48.66	56.05	75.81
7		AKANI	77.57	72.66	47.62
8		SECRETARIAT	146.72	51.67	23.53
9		BOROKIRI	22.26	44.63	91.18
TOTAL AVERAGE			**68.60**	**76.29**	**49.54**

4. CONCLUSION

Based on the above discussions, having extensively evaluated the input energy, energy losses, billed enrgy, amount collected and ultimately obtaining the ATC & C losses, it was found that the key factors responsible for ATC & C losses which are the billing efficiency and collection efficiency need to be maximized. As it is extremely difficult to eliminate all the causes simultaneously in our country, key measures should be taken to decrease or minimize the significant causes of losses. The power distribution technical losses can be additionally lowered by proper choices of distribution transformers, feeders, correct re-organization of distribution network, vandalization control, adoption of upgraded technology (SCADA) and skilled training of the operations staff bring about further developed framework activity. The distribution companies ought to be prepared for starting venture keeping taking into account future reserve funds in energy.

The commercial/collection losses can be reduced by Theft Detection Drive, new metering innovations, for example, remote metering, pre-paid metering instrument with recording components should be embraced, Accurate feeders metering, efficient billing and prompt collections. In the improving power sector reforms, the center has appropriately been moved to working on its effectiveness to diminish losses. Reducing these losses guarantee that the cost of energy to consumers will be lowered and thus the effectiveness of the distribution organization will be improved. Eventually, this might contribute during the time spent by and large public turn of events and great quality and reliability of energy supply to customers.

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