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IMPACT OF EMBEDDED GENERATION AS A MEANS OF POWER SUPPLY IMPROVEMENT

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ABSTRACT: *Two power supply systems, namely supply from National Grid and Embedded Supply in Trans-Amadi industrial Layout Port Harcourt Rivers State, Nigeria are modelled. MATLAB/SIMULINK, was used to model a comparative reliability index to see the impact Embedded generation has had on a particular feeder that was previously connected to National Grid. The analysis also included a study of the impact Embedded Supply had on Revenue, Fault and Consumption pattern of the customers using Comparative (Mathematical) Analytical method. The analysis showed the increased performance experienced with Embedded Supply in the areas of reliability indices, faults, revenue and consumption. The results showed that SAIFI for embedded supply had 15 less interruptions and the customer also experienced 11 hours overall improvement in SAIDI and a 39% improved availability from the ASAI analysis. While CAIDI showed no improvement, load shaving improved by 4% and revenue of the feeder studied also improved by 36% this was mainly due to reduced outages on fault and improved consumption by 54%. The study will serve as a guide in informing decision makers on how to allocate scarce resources in the power industry to maximize benefit using what is already obtainable in the country. It will also better highlight the benefits of embedded generation for private investors who may want to venture into power supply.*

Keywords – *Reliability indices, Load Bifurcation, Load shedding, Load Shaving*

I. INTRODUCTION

Nigeria has an Installed generation capacity of 12,522MW as at 2017. Transmission wheeling capacity is about 5300MW this means they can comfortably evacuate current average generation of 3800MW [1]. The challenge becomes evident when we consider that this power generated is to serve a population of over 180 million. Average generation of 3,800MW is a far cry from 2019 national projection of 16494MW [2]. Generation is constrained by unavailability of fuels, poor maintenance of infrastructure and general lack of fund. In an event where generation can be improved to 50% of the installed capacity, it becomes glaring that evacuation of the generated power becomes a challenge.

Consequently, Nigeria only meets 23 – 29% of its power supply needs. This means that to meet this demand using current generation, supply can only be for about 5 hours per day nationwide. Given that this is impractical, load shedding becomes the only viable solution, i.e. cutting out load when supply is unable to meet the current demand. Frequent outages on the system also affects the supply when available, often leading consumers to bifurcate load between grid supply and captive generation (mostly diesel).

Limited supply and poor quality of actual supply has been the area of major studies and a bane in the Nigerian power sector. This project, sets out to analyse a pilot system of embedded supply deployed in Port

Harcourt, River state Nigeria, its impact on reliability, fault, consumption and revenue as a means of maximising the limited investment available to the power sector in Nigeria.

II. RELATED WORKS

In recent years, there have been inroads into the possibility that embedded generation brings into the electricity supply sector. Some of such works though not limited to them alone, are reviewed below:

In the thesis [3] which amongst other submissions defined embedded generation; the author's focus was mainly on the protection aspect of integrating embedded supply without distorting the existing protection arrangement.

- ❖ Embedded generation has applications in improving system voltage as seen in [4], [5] and other literatures. Embedded generation can be injected at a point in a network where the voltage profile is below acceptable voltage regulation, this also improves system stability.

- ❖ The 2004 paper in [6] Increasing Energy Access in Developing Countries Generation offered great insight and overview on the role embedded power can play in advancements towards better energy supply in developing countries. In analysing of embedded generation [7] the author proposed two approaches for reliability evaluation, namely Simulation (Monte Carlo) method and analytical method. The requirement of large number of drawings to obtain accurate results made this approach to be complex and inaccurate at times. The analytical approach relies on the solutions of mathematical models on assumption of statistical distributions of failure rates and repair times.

III. METHODOLOGY

The data analysed was obtained from Port Harcourt Electricity Distribution Company PHEDC for the period of 2014 - 2016. PHEDC has about 67 33kV Feeders and covers four (4) states. Our area of primary study was Port Harcourt Region where the bulk of capacity limitation is experienced. The Transmission station considered radiates ten (10) 33kV feeders and embedded generation is fed through a new network constructed for the purpose of evacuating power through FIPL gas turbine in the Same Area under consideration. From fig C2 a 33kV network feeds directly from a power station into the distribution network. The primary 33kV Feeder with the sole purpose of supplying the area has a primary injection Substation from which Four (4) 11kV Feeders also radiate to consumers as indicated in Fig C1.

Data from table 3.8 – 3.9 was fed into the MATLAB reliability Model designed specifically to calculate SAIFI, SAIDI, CAIDI and ASAI. A graphical user interface (GUI) was used for the model. This was done to allow for multiple entries for both grid supply and embedded. A graphical representation of month by month and year cumulative is also programmed into the model. Fig 3.1 shows the MATLAB GUI.

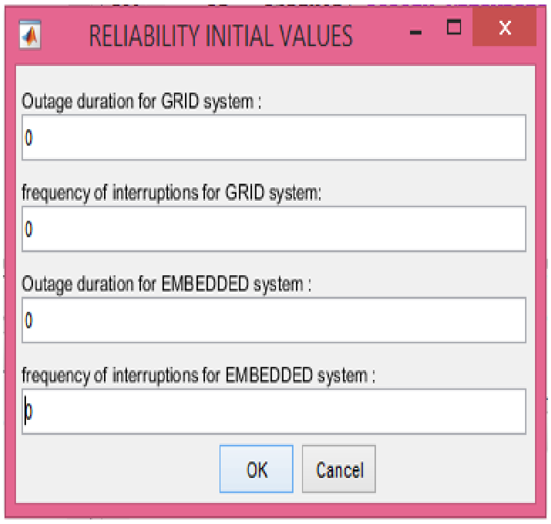

Figure 3.1: MATLAB Graphical User Interface

From Fig 3.1, it can be observed that we have only two sets of comparative values, namely:

i. Outage duration

ii. Outage frequency.

This was done for smoother functionalities. Variables such as:

i. Total number of customers

ii. Total number of customers affected

iii. Total hours in the year.

All factored directly into the program.

During gathering of data, it was observed that for the purposes of our study,

Total Customers = Total Customers affected.

This is a direct result of our study being based on a single feeder (Feeder 2) in which the entire customers are tied to one breaker. This by extension means that fault on any section of the feeder affects the entire customer base on the feeder.

Furthermore, customers can in cases of persistent localized faults be sectionalized to restore a percentage of the feeder but records of such when done were not usually being kept in the period under review.

The MATLAB program was designed to generate a two part result:

i. Comparative graph between each index considered (SAIDI, SAIFI, CAIDI and ASAI). The result is built to show the extent to which embedded system impacted on the indices thus considered.

ii. The MATLAB also generated a result sheet showing each individual result on grid and embedded respectively.

3.1 Reliability Indices

These indices are tools that are used in monitoring system reliability and measuring improvements or failures where obtainable.

3.1.1 System Average Interruption Duration Index

$$\text{SAIDI} = \text{Total Consumer Interruption Duration} / \text{Total Number of consumers}$$

$$= \sum(Di * Ni / Nt \qquad (3.1)$$

Where $\sum$ = Summation Function

Di = Duration of outage in Hours

Ni = Number of Consumers Affected
Nt = Total Number of Consumers

3.1.2 System Average Interruption Frequency Index (SAIFI)

This reliability index measures the frequency with which consumers experience outages. That is the average number of times that a customer experiences outage. It is given as:

SAIFI = $\text{Total Number of Consumers Interrupted} / \text{Total Number of consumers}$

SAIFI = $\sum Ni) / Nt$ = $\sum \lambda * Ni / Ni$ (3.2)

3.1.3 Customer Average Interruption Duration Index

CAIDI gives the average outage duration that any given customer would experience. It is obtained as the ratio between SAIDI and SAIFI:

CAIDI = $SAIDI / SAIFI$

CAIDI = $\sum CU / \sum FU$

CAIDI can also be expressed as: $\sum (Di * Ni / / Ni$ (3.3)

Where $\sum$ = Summation Function
Di = Duration of outage in Hours
Ni = Number of Consumers Affected

3.1.4 Average Service Availability Index (ASAI)

It measures availability demand with respect to availability achieved. It is given as the ratio of availability achieved to hours demanded and usually expressed in percentage.

ASAI = 1 - $(\sum Di * Ni) / (Nt * T)$ (3.4)

SAIFI measures how often a customer can expect to experience an outage, SAIDI measures average outage duration per customer, and CAIDI measures average outage duration if an outage is experienced, or average restoration time. While ASAI measures how long a customer will expect to have uninterrupted supply in an entire year or period under consideration.

Tables 3.1 and 3.2 will be used for the proposed analysis as obtained from Port Harcourt Electricity Distribution Company.

Table 3.1 Feeder 2 Average (3 Years) Supply Data Summary – Grid (Source: PHEDC)

Feeder 2	Voltage Level KV	Total Customers (Ni & Nt)	Availability (Hours)	Outage Frequency (λ)	Outage Duration Hours (Di)	Frequency of Outage Due to Faults	Duration of Outage Due to Faults	Hours in a Month	Customer Hours (Ni*Di)	Customer Frequency (Ni*λ)
March	33	3293	744	0	0	0	0	744	-	-
April	33	3302	668	12	52	3	15	720	188,708	43,548
May	33	3414	714	5	27	0	0	744	101,304	18,760
June	33	3438	720	0	0	0	0	720	-	-
July	33	3464	736	2	8	0	0	744	30,456	7,614
August	33	3442	736	2	8	0	0	744	30,264	7,566
September	33	3468	715	3	5	1	1	720	19,060	11,436
October	33	3470	734	3	10	1	2	744	38,140	11,442
November	33	3477	719	1	1	0	0	720	3,821	3,821
December	33	3483	723	2	21	0	0	744	80,388	7,656
January	33	3491	742	1	1	0	0	744	3,837	3,837
February	33	3498	669	1	3	1	3	672	11,535	3,845
		3498	8620	32	136	6	21	8760	507,513	123,040

Table 3.2 Feeder 2 2016 – 2017 Supply Data Summary - Embedded (Source: PHEDC)

Feeder 2	Voltage Level KV	Total Customers (Ni & Nt)	Availability (Hours)	Outage Frequency (λ)	Outage Duration Hours (Di)	Frequency of Outage Due to Faults	Duration of Outage Due to Faults	Hours in a Month	Customer Hours (Ni*Di)	Customer Frequency (Ni*λ)
March	33	3,290.00	663.00	36.00	73.00	22.00	27.00	744.00	240,170	118,440
April	33	3,299.00	559.00	45.00	164.00	21.00	68.00	720.00	541,036	148,455
May	33	3,411.00	585.00	51.00	164.00	26.00	80.00	744.00	559,404	173,961
June	33	3,435.00	561.00	45.00	160.00	24.00	57.00	720.00	549,600	154,575
July	33	3,461.00	643.00	31.00	102.00	27.00	62.00	744.00	353,022	107,291
August	33	3,439.00	561.00	40.00	183.00	24.00	70.00	744.00	629,337	137,560
September	33	3,465.00	582.00	41.00	139.00	23.00	78.00	720.00	481,635	142,065
October	33	3,467.00	577.00	46.00	169.00	28.00	82.00	744.00	585,923	159,482
November	33	3,474.00	649.00	37.00	73.00	26.00	44.00	720.00	253,602	128,538
December	33	3,480.00	679.00	31.00	67.00	23.00	50.00	744.00	233,160	107,880
January	33	3,488.00	654.00	41.00	91.00	23.00	43.00	744.00	317,408	143,008
February	33	3,495.00	615.00	36.00	68.00	19.00	28.00	672.00	237,660	125,820
		3,495.00	7,328.00	480.00	1,453.00	286.00	689.00	8,760.00	4,981,957	1,677,600

3.2 Impact Analysis

Here we analysed the effect of embedded generation on measurable quantities such as load bifurcation, load shaving, faults and revenue.

3.2.1 Impact on Fault

We now went on to compare the impact embedded generation had on the frequency and duration of fault occurrence based on the data being studied. We did a comparative analysis based on total frequency and duration of fault as follows:
From Table 3.5 and 3.6, Analysis of percentage outage due to fault is considered.

$$\% \, Fault\ Outage\ (Duration) = \frac{Total\ Outage - Outage\ due\ to\ Supply}{Total\ Outage} * 100 \qquad (3.5)$$

$$\% \, Fault\ Outage\ (Frequency) = \frac{Total\ Outage - Outage\ due\ to\ Supply}{Total\ Outage} * 100 \qquad (3.6)$$

From Table 3.1 and 3.2

From Table 3.1

$$\% \, Fault\ Outage\ (Duration) = \frac{68}{164} * 100$$

= 41%

$$\% \, Fault\ Outage\ (Frequency) = \frac{21}{45} * 100$$

= 47%

From Table 3.9

$$\% \, Fault\ Outage\ (Duration) = \frac{15}{52} * 100$$

= 29%

$$\% \, Fault\ Outage\ (Frequency) = \frac{3}{12} * 100$$

= 25%

Based on the calculations as stated above, we generated a table comparatively showing the impact of both grid and embedded supply on faults.

Table 3.3 Fault Frequency and Duration Analysis.

Feeder 2	% Outage Fault Frequency (Embedded)	% Outage Fault Duration (Embedded)	% Outage Fault Frequency (Grid)	% Outage Fault Duration (Grid)
March	0%	0%	61%	37%
April	25%	29%	47%	41%
May	0%	0%	51%	49%
June	0%	0%	53%	36%
July	0%	0%	87%	61%
August	0%	0%	60%	38%
September	33%	20%	56%	56%
October	33%	20%	61%	49%
November	0%	0%	70%	60%
December	0%	0%	74%	75%
January	0%	0%	56%	47%
February	100%	100%	53%	41%
	19%	**15%**	**60%**	**47%**

3.2.2 Impact Analysis (Load Shaving/Flexibility)

For flexibility, we considered the monthly energy allocation that would be saved from the grid on feeder 2 which has been supplied from embedded generation. The degree of flexibility here was assumed to be equal to the amount of energy that can be dispatched to other feeders and degree of demand that would be met. This energy is allocated to other feeders therefore increasing ability to incrementally shave off part of its unmet dispatch.

Table 3.4 Flexibility

Feeder 2	Total Delivery MW	Energy Saved MW	% Energy Otherwise Dispatched
March	235.54	8.14	4%
April	175.90	5.55	5%
May	189.93	6.36	5%
June	200.30	6.72	4%
July	248.77	8.84	4%
August	244.63	8.80	4%
September	258.50	9.65	3%
October	225.95	8.02	4%
November	264.51	10.98	3%
December	270.80	10.28	3%
January	337.50	16.32	3%
February	335.59	15.11	3%
	2,987.92	110.84	4%

For impact on load shaving, we compared energy sent out on three years average on grid alone and 2016 – 2017 with Embedded. The table obtained is as shown below.

3.5 Load Shaving Impact

3.2.3 Revenue Impact Analysis

Here we considered how much of an impact embedded generation had on the company's general performance index. While there are different Tariff classes, we would be taking an average billing rate (ABR) or average tariff of the particular feeder under consideration which is a function of the customer mix. Impact is as shown:

Months	*2013 Energy (GWhr)*	*2014 Energy (GWhr)*	*2015 Energy (GWhr)*	*3 Years Average (GWhr)*	*Grid-Feeder 2 ABR (Naira)*	*Grid-Revenue (MN)*	*2016 Embedded Energy (GWhr)*	*Embedded-Feeder 2 ABR (Naira)*	*Embedded-Revenue (MN)*
March	6.14	7.86	8.73	7.57	39.50	299.16	10.78	39.90	430.22
April	6.05	5.71	7.43	6.40	39.00	249.58	9.08	39.78	361.28
May	6.76	4.76	7.95	6.49	39.10	253.78	10.84	39.49	427.99
June	6.08	6.32	7.02	6.47	39.00	252.39	10.43	39.78	414.99
July	6.25	5.44	6.65	6.11	40.00	244.45	9.48	40.80	386.89
August	6.18	6.06	7.74	6.66	41.00	273.19	9.26	41.82	387.40
September	6.29	7.61	6.85	6.92	38.00	262.97	9.65	38.76	373.94
October	6.35	7.28	7.28	6.97	39.00	271.88	10.15	39.78	403.77
November	6.95	6.48	5.64	6.36	39.00	247.91	11.84	39.78	470.99
December	6.84	6.82	6.31	6.66	37.00	246.36	10.41	37.00	385.21
January	6.77	6.33	7.91	7.00	38.00	266.17	12.06	38.38	463.03
February	5.84	6.49	7.14	6.49	39.00	253.14	9.32	40.17	374.37
Total	**76.51**	**77.17**	**86.65**	**80.11**	**38.97**	**3,121.68**	**123.31**	**39.62**	**4,880.08**

Table 3.13 Revenue Impact (Source PHEDC)

Feed[illegible]	**Actual Deliver[illegible]**	**[illegible]t MW (2016[illegible]**	**Actual Deliver y MW**	**Short Fall**	**Embedde[illegible] Delivery MW[illegible] 2017)**	**Embedded Delivery MWh (2017)**	**[illegible]d Peak Dail[illegible]**	**[illegible]d Average Dail[illegible]**	**Embed Load MW 2017)**	**Total Deliver[illegible]**	**Load Shave**
M[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Apr	216.52	732.44	157.78	574.66	9,081.90	542.80	19.90	16.35	18.13	175.90	3%
M[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
June	218.51	732.44	181.81	550.63	10,432.17	543.57	20.10	16.87	18.48	200.30	3%
J[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aug	203.11	732.44	226.43	506.01	9,263.40	520.00	20.60	15.81	18.20	244.63	4%
Sept	176.84	732.44	240.11	492.33	9,647.60	518.10	20.30	16.48	18.39	258.50	4%
Oct	218.91	732.44	207.33	525.11	10,150.20	568.00	20.40	16.85	18.63	225.95	4%
Nov	218.91	732.44	244.24	488.20	11,839.83	590.35	22.12	18.42	20.27	264.51	4%
Dec	237.85	732.44	252.58	479.86	10,411.20	558.40	19.80	16.64	18.22	270.80	4%
Jan	213.44	732.44	317.43	415.01	12,064.30	602.10	21.90	18.24	20.07	337.50	5%
Feb	222.33	732.44	316.88	415.56	9,319.69	475.06	20.48	16.95	18.72	335.59	5%
	2,564.89	8,789.28	2,764.43	6,024.9	123,314.38	6,580.18	244.70	202.29	223.49	2,987.92	4%

IV. RESULTS AND DISCUSSIONS

The Transmission network reliability indices are not all internationally standard and can vary from one transmission utility to another. This is due to the difference in interpretation of concepts such as delivery points and reception points, the difference in operating scenarios (back feeding options, load status and interconnectivity) and the voluntary and involuntary load reductions. The Distribution indices are more internationally standard and consistent amongst the Distribution utilities, but difference in interpretation does exist.

With the above in mind, our focus will be solely based on comparative analysis of what was on ground before the introduction of embedded power and the percentage impact of embedded power.

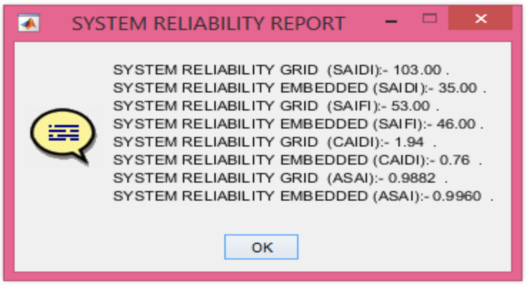

Fig 4.1 MATLAB Display Interface

Months	Grid				Embedded				Ratio of Embedded to Grid Improvement			
	SAIDI	SAIFI	CAIDI	ASAI	SAIDI	SAIFI	CAIDI	ASAI	SAIDI	SAIFI	CAIDI	ASAI
March	73	36	2.03	61%	0	0	0.00	100%	1:73	1:36	1:02	2:1
April	164	45	3.64	47%	52	12	4.33	93%	1:3	1:04	1:01	2:1
May	164	51	3.22	51%	27	5	5.40	96%	1:6	1:10	1:01	2:1
June	160	45	3.56	53%	0	0	0.00	100%	1:160	1:45	1:04	2:1
July	102	31	3.29	87%	8	2	4.00	99%	1:13	1:16	1:01	1:1
August	183	40	4.58	60%	8	2	4.00	99%	1:23	1:20	1:01	2:1
September	139	41	3.39	56%	5	3	1.67	99%	1:28	1:14	1:02	2:1
October	169	46	3.67	61%	10	3	3.33	99%	1:17	1:15	1:01	2:1
November	73	37	1.97	70%	1	1	1.00	100%	1:73	1:37	1:02	1:1
December	67	31	2.16	74%	21	2	10.50	97%	1:3	1:16	1:01	1:1
January	91	41	2.22	56%	1	1	1.00	100%	1:91	1:41	1:02	2:1
February	68	36	1.89	53%	3	1	3.00	100%	1:23	1:36	1:01	2:1
Average	121.08	40.00	2.97	60%	11.33	2.67	3.19	98%	1:11	1:15	1:01	2:1

Table 4.1 Grid Vs Embedded Reliability Indices at a Glance

From table 4.1 we can deduce that the frequency of outages experienced by the system reduced by an average of 15 interruptions which invariably means that at an average of 11 hours downtime per interruption, availability improved by 39%. Of particular interest is the behavior of CAIDI in the entire mix of this study which we would be looking at as well.

4.2 SAIFI (System Average Interruption Frequency Index)

As earlier stated, this measures the frequency of interruption the customer would experience usually per annum. Below is the result of our simulation that shows the impact of embedded generation on SAIFI.

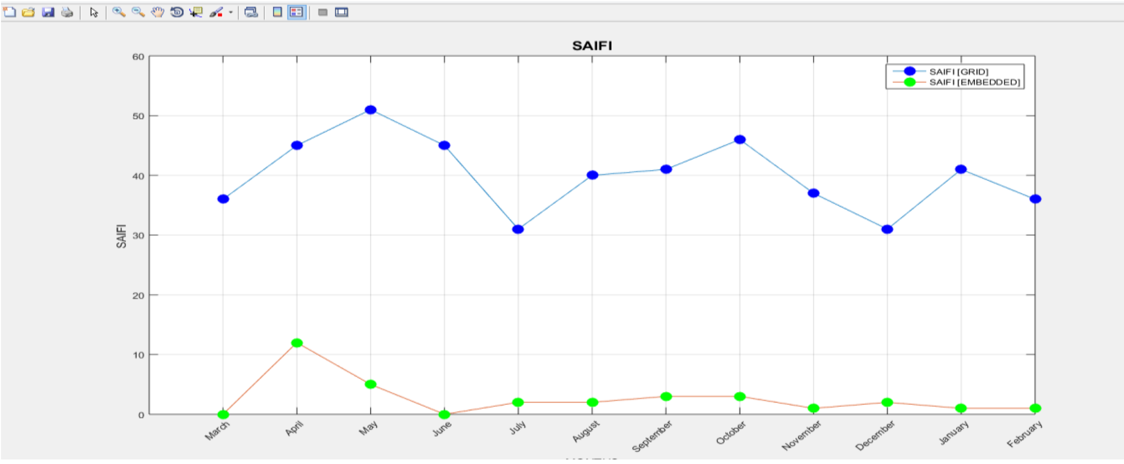

Fig 4.2 Impact of Embedded Generation on SAIFI

From figure 4.2, it can be seen that the customer experiences less interruptions between March and February when they were transferred to embedded generation. This would be translated to reduced sustained duration on outage in SAIDI. The chart above tells us that customers experienced and average of 15 Monthly interruptions less than when they were on grid. One of the objectives of sustainable power is reduction in interruption frequency. This not only reduces cost of power system operation (Fault clearing), but also improves the life span of certain equipment. The life span of some power equipment are usually tied to the frequency of operation. Circuit breakers of different classes, be it Vacuum, air, oil or gas have their life spans tied to the number of operations. Reducing the number of times they operate will overall reduce cost of replacement and downtime associated with breakdown of such equipment.

Generally, utilities want to improve overall SAIFI index for better profitability. Reduced outage frequencies translates to more energy sent out to consumers. In the Nigerian context, it also improves quality of supply no matter how little there is to give out. If in a given day the planned availability is for 12 hours to a given area, a good SAIFI index ensures that such areas get the light as at when due and are not affected by an unreliable system.

Nearness of the generation plant to the customer is also a factor that we can deduce affects SAIFI. In a grid system, energy travels from generator to transmission lines over long distances where they are stepped down only to travel again to injection substations over a considerable distance stepped down before being distributed to consumers at proper voltages.

4.3 SAIDI (System Average Interruption Duration Index)

As earlier stated, this measures the duration of sustained interruption the customer would experience usually per annum. Fig 4.3 shows the result of our simulation. The impact of embedded generation on SAIDI is clearly visible. Between March and February 2017, SAIDI improved by an average of 110 hours as against March and February of the previous three years when they were on grid.

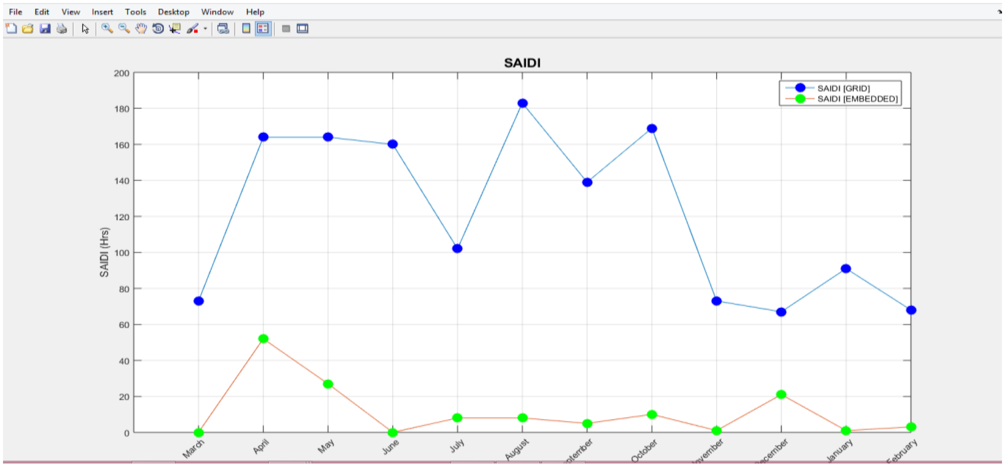

Fig 4.3 Impact of Embedded Generation on SAIDI

After the introduction of embedded generation, it is observed that SAIDI improved by more than 100%. Meaning customers experienced an average of 11hours decrease in duration of outage whenever there was an interruption on an embedded system as compared to when they were on the grid. This is not entirely attributed to better fault clearing but for the purposes of this study attributed to less interruptions as indicated by our SAIFI Chart.

4.4 CAIDI (Customer Average Interruption Duration Index):

This monitoring index is related to both SAIDI and SAIFI and can be noted to be the least impacted in terms of better value. It monitors the duration which a customer is out of supply once an interruption occurs. Consequently it measures fault clearing time and is more related to the operational dynamics of a utility company.

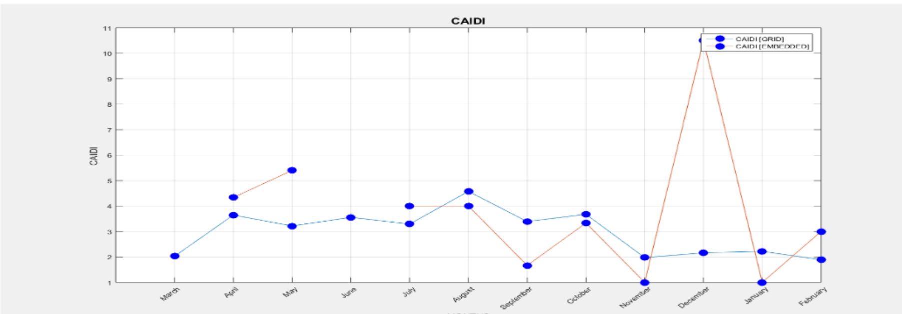

Fig 4.4 Impact of Embedded Generation on CAIDI

4.5 ASAI (Average Service Availability Index):

ASAI showed a 39% improvement on supply availability which represents 98% supply reliability or over 23hours of availability per day.

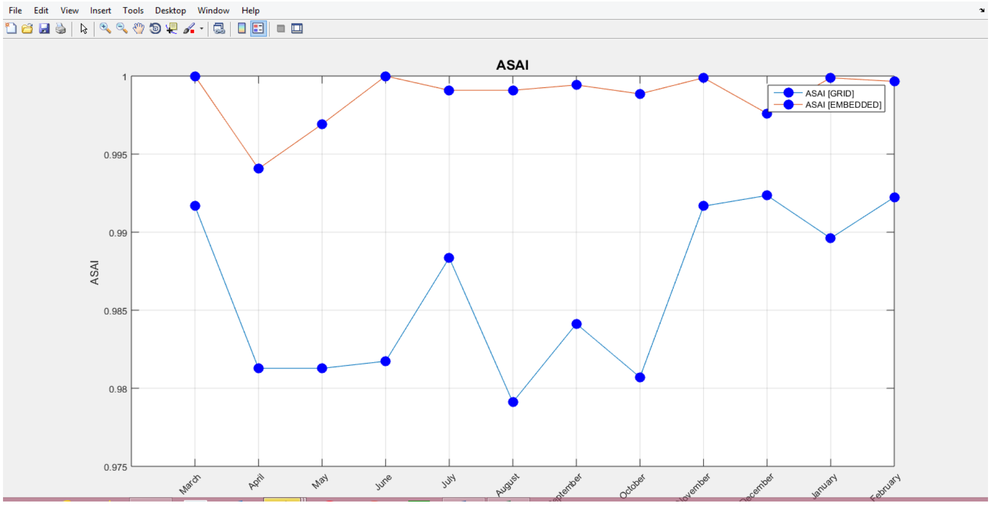

Fig 4.5 Impact of Embedded Generation on ASAI

Just as with SAIFI nearness to generation plant, less interruptions are some of the qualities of embedded generation that contributes to this improved availability.

4.6 Load Shaving Impact

Load shaving is a new term being introduced in the industry which means ability to meet peak demands by introducing other sources of power supply such as embedded to base power supply plants. The impact as can be seen by embedded generation to the entire Port Harcourt area as indicated below:

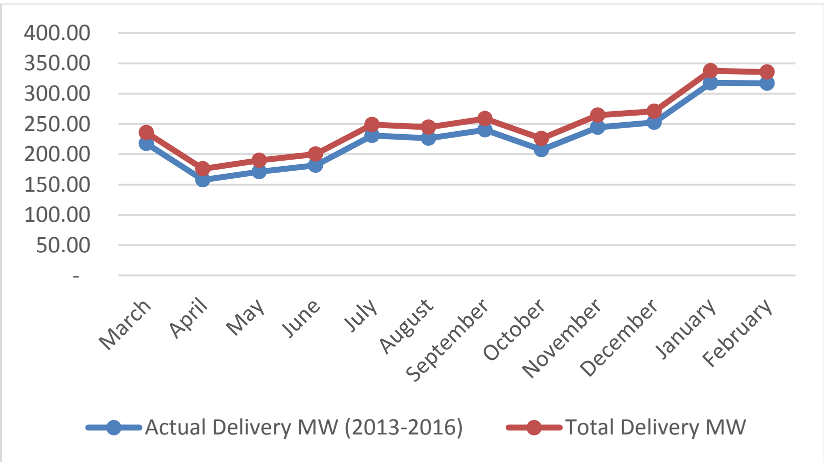

Fig 4.6 Load Shaving Impact

Introduction of embedded generation means that there was a 4% increase in energy that was available to consumers. This can go a long way in reducing the need for load shedding during peak periods.

4.7 Impact Analysis (Faults)

From Table 3.7, it is observed that frequency of fault improved by 41% when they are on embedded than when they are on grid. This represents 116 less tripping on forced outages.

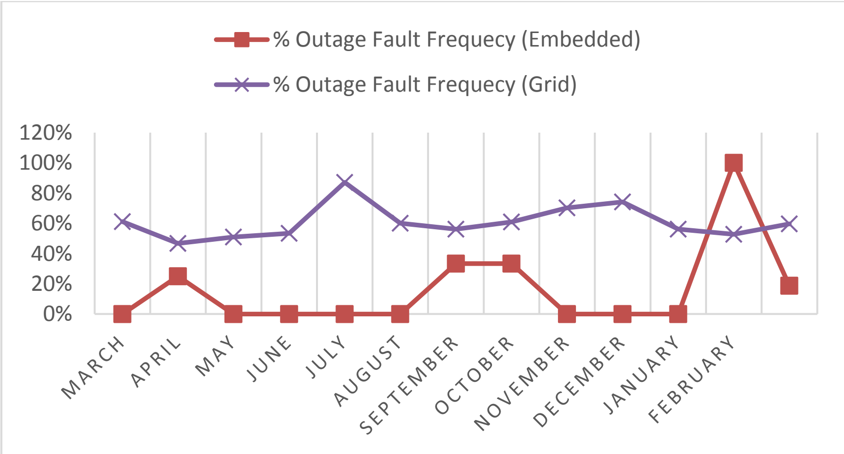

Fig 4.7 Fault Frequency Analysis (Grid/Embedded).

Also from Table 3.7, it is observed that duration of fault improved by 32% when they are on embedded than when they are on grid. This represents 220 hours less spent on outages.

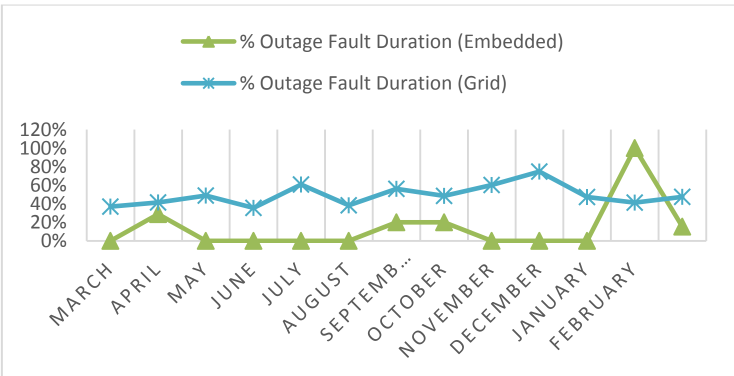

Fig 4.8 Fault duration analysis (Grid/Embedded)

Overall for the period under review, there was also a 2% increase in the feeders Average Billing Rate (ABR). This is mainly as a result of customers whose heavy and interruption sensitive equipment were now added to the supply from the company given the improvement in reliability indices as earlier discussed.

Table 4.3 Revenue Impact of Energy Saved on Reduced Outage Duration

Months	Grid - SAIDI	Embedded - SAIDI	Improvement in Duration of Supply (Hours)	Average Load of Embedded Supply (MW)	Consumption (MWhr)	Feeder 2 ABR	Revenue Impact (MN)
March	73	0	73	14.49	1,058.10	39.90	42.21
April	164	52	112	13.60	1,522.71	39.78	60.57
May	164	27	137	15.18	2,079.50	39.49	82.12
June	160	0	160	14.49	2,318.26	39.78	92.22
July	102	8	94	12.88	1,211.08	40.80	49.41
August	183	8	175	12.59	2,202.57	41.82	92.11
Sept	139	5	134	13.49	1,808.08	38.76	70.08
October	169	10	159	13.83	2,198.75	39.78	87.47
November	73	1	72	16.47	1,185.63	39.78	47.16
December	67	21	46	14.40	662.40	37.00	24.51
January	91	1	90	16.26	1,463.32	38.38	56.16
February	68	3	65	13.93	905.50	40.17	36.37
	121.08	11.33	109.75	16.47	1,807.26	39.62	740.41

From table 4.3 it is observed that there is an improvement of about N 740,410,000 (Seven Hundred and Forty Million Four Hundred and Ten Thousand Naira). This represents revenue that would otherwise have been lost on grid due to faults duration.

4.8 Energy Consumption Impact

As earlier stated, load bifurcation means that energy consumption is not always a true reflection of actual consumption. Increased reliability of the line meant that incremental load on the line increased by 36% even though consumers increased by only 1%. This invariably means that consumers either increased their load by purchasing power equipment or reduced their use of alternate source of supply. Consumption also increased by 54% which means that increased load also enjoyed better availability as is indicated by the consumption trend in Fig 4.9.

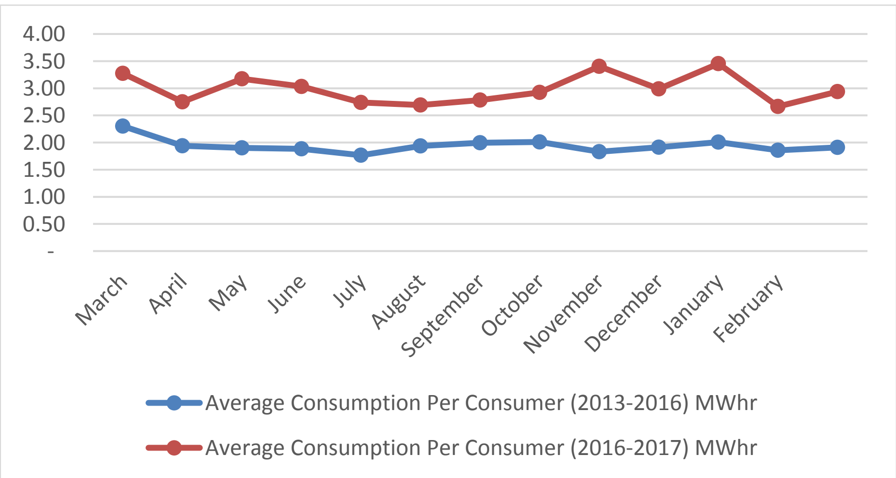

Fig 4.9 Average Consumption Variance per Consumer

V. CONCLUSION

While this study is not entirely tied to reliability indices, we needed a measurable quantity outside availability to monitor the impact of embedded generation. As can be seen, it has many benefits and is an area that is yet to be fully exploited. Integrating Embedded into the power system is associated with many challenges in terms of interconnection, protection, coordination and voltage regulation, increased reliability and reduced cost are the primary incentives of adding it to a power network. This can be achieved through installation of mini grids at various points within the network to bolster supply from the national grid.

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