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OPTIMIZED ENERGY EFFICIENCY THROUGH REDUCTION OF POWER CONSUMPTION IN A TELECOMMUNICATION BASE TRANCEIVER STATION (BTS) SITE USING MACHINE LEARNING

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Keywords: *Optimized, Energy Efficiency, Reduction of Power Consumption, Telecommunication Base Transceiver Station, Machine Learning*

Abstract: *The high consumption of power by modules of a cell site has paralyzed the activities of such site. This is vehemently surmounted by introducing optimized energy efficiency through reduction of power consumption in a telecommunication base transceiver station (BTS) site using machine learning. To vehemently achieve this, it is done in this process , reviewing the related works to know its short comings, characterizing and determining the power consumption of the modules of the cell site under study, developing a SIMULINK model for the cell site under study, optimizing the established high power consumed by the modules of the cell site to a minimal, designing a machine learning rule base that will monitor the power consumed on the modules and minimize it if high and training ANN in the designed machine learning rules for a reduced power consumption in the cell site thereby enhancing its network performance. Then, developing an algorithm that will implement it. Finally, developing a power consumption model for the network under study based on the result obtained when the algorithm is integrated in it and validating and justifying the percentage improvement of energy efficiency in the cell site with and without the application of machine learning. The results obtained after extensive simulation is the highest conventional power consumed by the cell site is5764KW while that when machine learning is inculcated in the system is4733KW. With these results, it signifies that the percentage improvement in the reduction of power consumed in the cell site when machine learning is incorporated in the system in day one is17.9%, the highest conventional power consumed in the cell site in day 3 is5191KW while that when machine learning is integrated in the system is 4731KW.With these results achieved, it shows that the percentage improvement in power consumption reduction in the cell site when machine learning technique is imbibed in the system in day 3 is 8.9%, the highest conventional power consumed in the cell site is5417KW. On the other hand, when machine learning is integrated in the system, it reduced drastically to4448KW which is 17.9% power consumed by the cell site reduction and the highest conventional power consumed by the cell site is5708KW while that when machine learning is injected in the system is4687KW which is 17.9% better that the conventional approach as regards power consumption reduction in the cell site.*

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1.1 Introduction

The issue of energy efficiency is one of the major challenges facing wireless cellular network providers around the world today. In Nigeria, some cellular network providers have been greatly affected, resulting in the closing down of sites due to the problem of energy efficiency. To handle this situation, which deals with Power consumption reduction in a base station, various approaches have been adopted that led to the introduction of green communication techniques.

Power Amplifier Improvement (PA) - PAs have attracted much attention because they consume the greatest proportion of the energy consumption of BSs. In mobile communications, the power amplifier in a macrocell BS consumes the most energy, as much as 65% of the total energy consumed by all BS elements. The Doherty designs of radio frequency (RF) power-amplifier systems (Raab, 1987), and use of gallium Nitride (GaN) in manufacturing power transistor (Claussen *et al*, 2008) helped in PA improvement up to 50% and save power consumption.

The problem still remain that the PA energy efficiency is achievable only with the internal equipment, but not possible in external conditions like not knowing the number of users requesting access to the BS at time, hence altering the energy efficiency achieved with internal equipment. It is generally accepted that high bit error rate constitutes telecommunication low performance (Abubaka2018). Meanwhile (Akbari,20011) strictly highlighted that to boost energy efficiency ultra capacitor should be incorporated in the system. An egalitarian author (Akhilesh,2012) strongly emphasized that wireless communication should be redefined to enhance its efficacy. (Bazzi,2008) reemphasized that higher through put is the core functioning capability of multi radio efficiency.

In optimization problems we are looking for the largest value or the smallest value that a function can take. We saw how to solve one kind of optimization problem in the Absolute Extrema section where we found the largest and smallest value that a function would take on an interval.

Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from. Machine learning teaches computers to do what comes naturally to humans: learn from experience. Machine learning algorithms use computational methods to "learn" information directly from data without relying on a predetermined equation as a model. The algorithms adaptively improve their performance as the number of samples available for learning increases. There are some basic common threads, however, and the overarching theme is best summed up by this oft-quoted statement made by (Arthur Samuel , 1959)"[Machine Learning is the] field of study that gives computers the ability to learn without

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being explicitly programmed."And more recently, (Tom, 1997)) gave a "well-posed" definition that has proven more useful to engineering types: "A computer program is said to learn from experience E with respect to some task T and some performance measure P, if its performance on T, as measured by P, improves with experience E."

3. Methodology

To characterize and determine the power consumption of the modules of the cell site under study

In order to characterize the cell site under study and determine its power consumption, the type of base station (BS), configuration model, transceiver and power models were inspected. The cell site or base station or base transceiver station (BTS) is a microcell managed by IHS Towers West Africa Limited, with site No. IHS-EN-T4670 – 2G/3G/4G networks (Indoor / Outdoor Site), housing MTN Nig Ltd and Airtel Nig Ltd base station equipment at Mount Street by Idaw River Layout Awkunanaw, Enugu. The site control (hop) about thirty (30) other MTN / Airtel base stations (Terminal and Fiber sites) within its coverage area, it handles transmission (TX) and reception (RX) of voice, data and streaming services.

A period of Twenty-Seven (27) days was used to monitor and carry out the measurements. The days include morning period (peak), afternoon (off peak) and evening/night (main Peak).

The readings are shown in tables C1to C27 of appendix C. The method used for data collection was repetitive method of measurement for twenty- seven (27) days at the cell site under study.

In each day, measurements were taken at a period of two (2) hours, with an interval of every fifteen (15) minutes for eight (8) times. At the end, an average for the eight (8) intervals was taken for each day for all equipment.

For instance, in day 1, the 2G BTS MTN with current of 25Amps as the average of eight (8) intervals for every fifteen minutes in the two hours period, has the following current readings of 25.4A; 24.6A; 25.8A; 24.3A; 25.6A; 24.4A; 24.7A; and 25.4A for the intervals. The average is;

$$Average = \frac{25.4 + 24.6 + 25.8 + 24.3 + 25.6 + 24.4 + 24.7 + 25.4}{8}$$

= 25.03Amps ≅ 25Amps

Sample of the measurement process for the 2G BTS MTN is in table C1 of Appendix C.

The measurements were first carried out in the BTS equipment cabin, it is the backbone of the cell site housing the transmitter and receiver modules. The BTS also is interconnected with equipment on the tower for transmission and hopping activities with other cell sites linked to the tower through the RF and microwave antennas.

At the end of the measurement taken, summary of Twenty-Seven (27) days were calculated using;

3.3 To determine the module to go on sleep mode and its power requirement

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Power consumed = $P_{Con} = V_{Aver} \times I_T$ (Watt) (3.2)

Where P_{Con} is the power consumed in (Watt)

V_{Aver} is the average voltage calculated from each day measurement (Volt).

I_T is the average total current consumed by the equipment in the cell site (Amps).

Day 1 at 13:30HRS – 15:30HRS on 3rd October 2018.
Total current = I_T = 109.8 Amps
Average Voltage = V_{Aver} = 52.5 Volts
Power consumed = P_{Con} = $I_T \times V_{Aver}$ = 109.8 x 52.5
= 5764.50 Watts

Day 2 at 11:00HRS – 13:00HRS on 4th October 2018.
Total current = I_T = 102.4 Amps
Average Voltage = V_{Aver} = 50.7 Volts
Power consumed = P_{Con} = $I_T \times V_{Aver}$ = 102.4 x 50.7
= 5191.68 Watts

Day 3 at 15:00HRS – 17:00HRS on 5th October 2018.
Total current = I_T = 110.8 Amps
Average Voltage = V_{Aver} = 52 Volts
Power consumed = P_{Con} = $I_T \times V_{Aver}$ = 110.8 x 52
= 5761.60 Watts

Day 4 at 10:00HRS – 12:00HRS on 6th October 2018.
Total current = I_T = 94.9 Amps
Average Voltage = V_{Aver} = 52.8 Volts
Power consumed = P_{Con} = $I_T \times V_{Aver}$ = 94.9 x 52.8
= 5010.72 Watts

Day 5 at 14:00HRS – 16:00HRS on 9th October 2018.
Total current = I_T = 105.6 Amps
Average Voltage = V_{Aver} = 51.3 Volts
Power consumed = P_{Con} = $I_T \times V_{Aver}$ = 105.6 x 51.3
= 5417.28 Watts

Day 6 at 10:30HRS – 12:30HRS on 11th October 2018.
Total current = I_T = 98.5 Amps
Average Voltage = V_{Aver} = 52.3 Volts
Power consumed = P_{Con} = $I_T \times V_{Aver}$ = 98.5 x 52.3
= 5151.55 Watts

Day 7 at 16:00HRS – 18:00HRS on 12th October 2018.
Total current = I_T = 107.9 Amps
Average Voltage = V_{Aver} = 52.9 Volts
Power consumed = P_{Con} = $I_T \times V_{Aver}$ = 107.9 x 52.9
= 5707.91 Watts

Day 8 at 12:00HRS – 14:00HRS on 15th October 2018.
Total current = I_T = 97.5 Amps

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Average Voltage = V_{Aver} = 52.7 Volts

Power consumed = P_{Con} = I_T x V_{Aver} = 97.5 x 52.7
= 5138.25 Watts

Day 9 at 15:30HRS – 17:30HRS on 17th October 2018.

Total current = I_T = 108.3 Amps

Average Voltage = V_{Aver} = 52.4 Volts

Power consumed = P_{Con} = I_T x V_{Aver} = 108.3 x 52.4
= 5674.92 Watts

Day 10 at 14:30HRS – 16:30HRS on 19th October 2018.

Total current = I_T = 106.9 Amps

Average Voltage = V_{Aver} = 53.2 Volts

Power consumed = P_{Con} = I_T x V_{Aver} = 106.9 x 53.2
= 5687.08 Watts

Day 11 at 13:00HRS – 15:00HRS on 20th October 2018.

Total current = I_T = 104.7 Amps

Average Voltage = V_{Aver} = 52.7 Volts

Power consumed = P_{Con} = I_T x V_{Aver} = 104.7 x 52.7
= 5517.69 Watts

Day 12 at 19:00HRS – 21:00HRS on 23rd October 2018.

Total current = I_T = 160.8 Amps

Average Voltage = V_{Aver} = 53.7 Volts

Power consumed = P_{Con} = I_T x V_{Aver} = 160.8 x 53.7
= 8634.96 Watts

Day 13 at 18:00HRS – 20:00HRS on 26th October 2018.

Total current = I_T = 151.1 Amps

Average Voltage = V_{Aver} = 53.7 Volts

Power consumed = P_{Con} = I_T x V_{Aver} = 151.1 x 53.7
= 8114.07 Watts

Day 14 at 20:00HRS – 22:00HRS on 27th October 2018.

Total current = I_T = 144.3 Amps

Average Voltage = V_{Aver} = 52.4 Volts

Power consumed = P_{Con} = I_T x V_{Aver} = 141.3 x 52.4
= 7404.12 Watts

Day 15 at 18:30HRS – 20:30HRS on 28th October 2018.

Total current = I_T = 151.7 Amps

Average Voltage = V_{Aver} = 53.3 Volts

Power consumed = P_{Con} = I_T x V_{Aver} = 151.7 x 53.3
= 8085.61 Watts

Day 16 at 19:30HRS – 21:30HRS on 2nd November 2018.

Total current = I_T = 153 Amps

Average Voltage = V_{Aver} = 53.4 Volts

Power consumed = P_{Con} = I_T x V_{Aver} = 153 x 53.4

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= 8170.20 Watts

Day 17 at 06:30HRS – 08:30HRS on 3rd November 2018.
Total current = I_T = 131.4 Amps
Average Voltage = V_{Aver} = 52.8 Volts
Power consumed = P_{Con} = I_T x V_{Aver} = 131.4 x 52.8
= 6937.92 Watts

Day 18 at 07:00HRS – 09:00HRS on 6th November 2018.
Total current = I_T = 125 Amps
Average Voltage = V_{Aver} = 53.3 Volts
Power consumed = P_{Con} = I_T x V_{Aver} = 125 x 53.3
= 6662.50 Watts

Day 19 at 08:00HRS – 10:00HRS on 7th November 2018.
Total current = I_T = 121.2 Amps
Average Voltage = V_{Aver} = 52.4 Volts
Power consumed = P_{Con} = I_T x V_{Aver} = 121.2 x 52.4
= 6350.88 Watts

Day 20 at 07:30HRS – 07:30HRS on 9th November 2018.
Total current = I_T = 124 Amps
Average Voltage = V_{Aver} = 53.6 Volts
Power consumed = P_{Con} = I_T x V_{Aver} = 124 x 53.6
= 6646.40 Watts

Day 21 at 06:45HRS – 08:45HRS on 16th November 2018.
Total current = I_T = 122.3 Amps
Average Voltage = V_{Aver} = 52.2 Volts
Power consumed = P_{Con} = I_T x V_{Aver} = 122.3 x 52.2
= 6384.06 Watts

Day 22 at 06:00HRS – 08:00HRS on 17th November 2018.
Total current = I_T = 127.8 Amps
Average Voltage = V_{Aver} = 53.4 Volts
Power consumed = P_{Con} = I_T x V_{Aver} = 127.8 x 53.4
= 6824.52 Watts

Day 23 at 07:45HRS – 09:45HRS on 20th November 2018.
Total current = I_T = 120.7 Amps
Average Voltage = V_{Aver} = 52.7 Volts
Power consumed = P_{Con} = I_T x V_{Aver} = 120.7 x 52.7
= 6360.89 Watts

Day 24 at 08:15HRS – 10:15HRS on 22nd November 2018.
Total current = I_T = 117.5 Amps
Average Voltage = V_{Aver} = 52.7 Volts
Power consumed = P_{Con} = I_T x V_{Aver} = 117.5 x 52.7
= 6192.25 Watts

Day 25 at 08:15HRS – 10:15HRS on 26th November 2018.

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Total current = I_T = 128.8 Amps
Average Voltage = V_{Aver} = 53.3 Volts
Power consumed = P_{Con} = I_T x V_{Aver} = 128.8 x 53.3
= 6865.04 Watts
Day 26 at 08:30HRS – 10:30HRS on 27th November 2018.
Total current = I_T = 122.1 Amps
Average Voltage = V_{Aver} = 53.1 Volts
Power consumed = P_{Con} = I_T x V_{Aver} = 122.1 x 53.1
= 6483.51 Watts
Day 27 at 06:15HRS – 08:15HRS on 28th November 2018.
Total current = I_T = 125.4 Amps
Average Voltage = V_{Aver} = 53.1 Volts
Power consumed = P_{Con} = I_T x V_{Aver} = 128.8 x 53.3
= 6658.74 Watts
Total = 170098.78watts =170.09878kw = 170.1kw(approximation)
Number of hours for 27days = 27 x 2 = 54hours
KWH = 170.1 x 54 =9185.4KWH
#60 = 1KWH
9185.4KWH = # 9185.4 x 60 = #551124
To optimize the established high power consumed by the modules of the cell site to a minimal

Table 1 established much power consumed from the characterized cell site under study

Days	Time	Power consumption Watts
1	13:30HRS	5764.50
2	11:00HRS	5191.68
3	15:00HRS	5761.60
4	10:00HRS	5010.72
5	14:00HRS	5417.28
6	10:30HRS	5151.55
7	16:00HRS	5707.91
8	12:00HRS	5138.25
9	15:30HRS	5674.92
10	14:30HRS	5687.08

Minimize
$P = X + 13.3Y$
SUBJECT TO
$X + 13.3Y \leq 5764.50$
$7X + 16Y \leq 5707.91$

Where;
P is the minimum power consumed by the cell site
X is the day the power is consumed in the cell site

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Y is the hour the power is consumed in the cell site

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%
% Minimize P = X + 13.3Y
% Subject to
% X + 13.3Y ≤ 5764.50
% 10X + 14. 3Y≤ 5687.08
%
% Where;
% P is the minimum power consumed by the cell site
%X is the day the power is consumed in the cell site
%Yis the hour the power is consumed in the cell site
f= [-1; -13.3];
A= [1 13.3;7 16];
b= [5764.50;5707.91];
Aeq= [0 0];
beq= [0];
LB= [0 0];
UB= [inf inf];
[X, FVAL, EXITFLAG] =linprog(f,A,b,Aeq,beq,LB,UB)
Optimization terminated.
X =
 0.0000
 356.7444
FVAL =
 -4.7447e+003
EXITFLAG =
 1
>>
```

To design a machine learning rule base that will monitor the power consumed on the modules and minimize it if high.

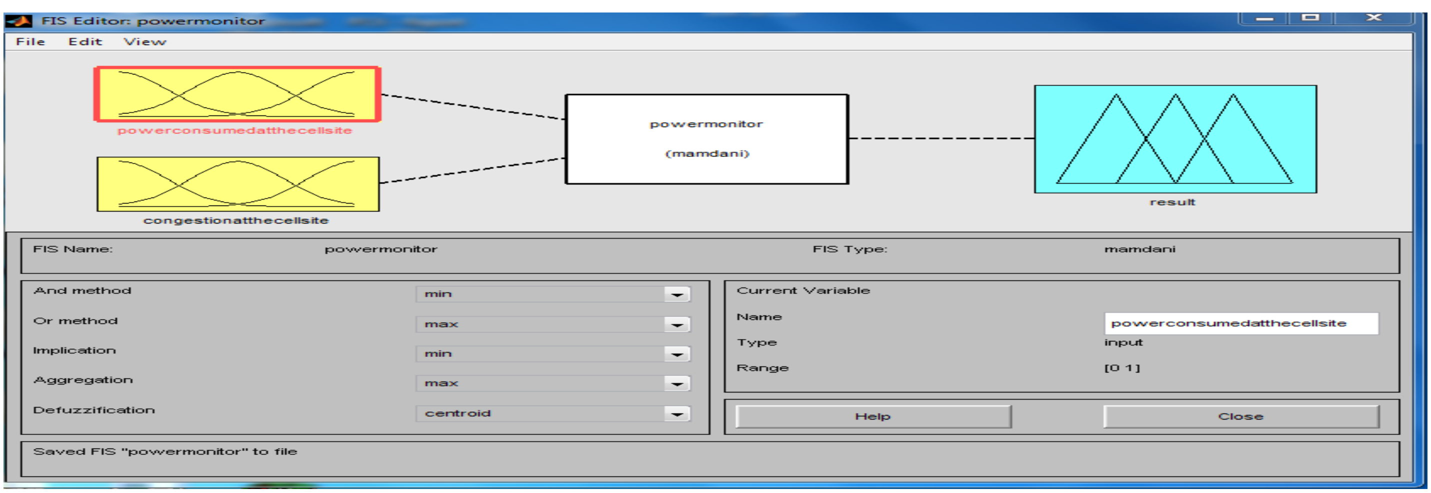

Fig 1 designed machine learning fuzzy inference system that will monitor the power consumed on the modules and minimize it if high.

Fig 1 has two inputs of power consumed at the cell site and congestion. It also has an output of results.

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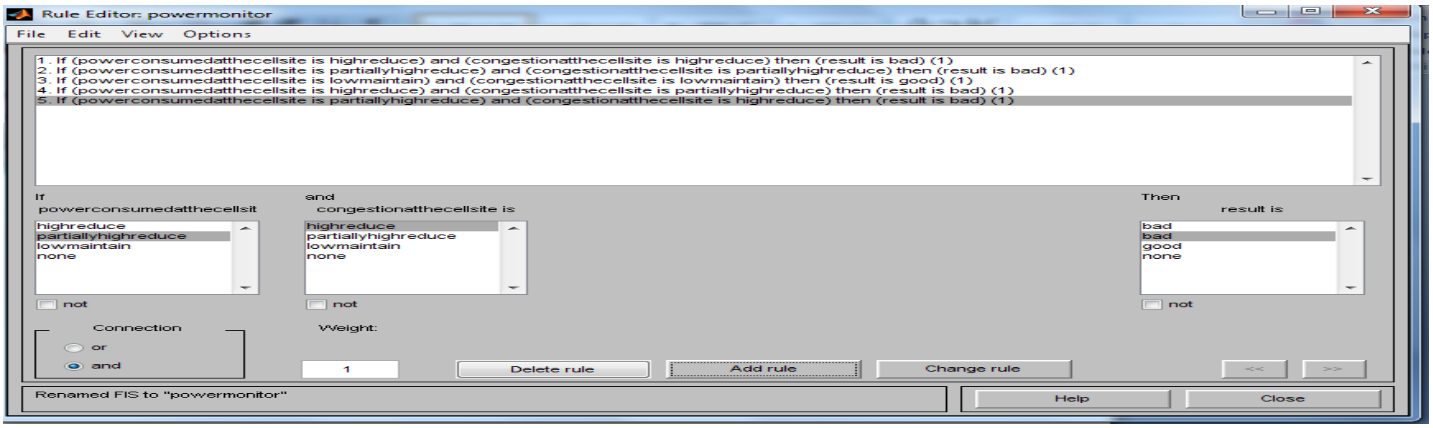

Fig 2 designed machine learning rule base that will monitor the power consumed on the modules and minimize it if high. Fig 3.3 monitors the power consumed by the modulus of the cell site and minimizes it when detected high. A comprehensive analysis of the rules is as shown in table 2

Table 2 details of designed machine learning rule base that will monitor the power consumed on the modules and minimize it if high

1	If power consumed at the cell site is high reduce	And congestion at the cell site is high reduce	Then, result is bad
2	If power consumed at the cell site is partially high reduce	And congestion at the cell site is partially high reduce	Then, result is bad
3	If power consumed at the cell site is low maintain	And congestion at the cell site is low maintain	Then, result is good
4	If power consumed at the cell site is high reduce	And congestion at the cell site is partially high reduce	Then, result is bad
5	If power consumed at the cell site is partially high reduce	And congestion at the cell site is high reduce	Then, result is bad

To train ANN in the designed machine learning rules for a reduced power consumption in the cell site thereby enhancing its network performance.

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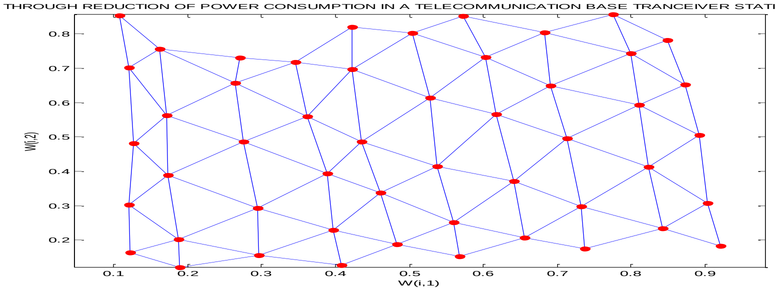

Fig 3 trained ANN in the designed machine learning rules for reduced power consumption in the cell site thereby enhancing its network performance.

In fig 3 ANN was trained ten times in the machine learning five rules to give fifty neurons that look like human brain 10 x 5 = 50. This neuron mimics human intelligence and does what it is instructed to do.

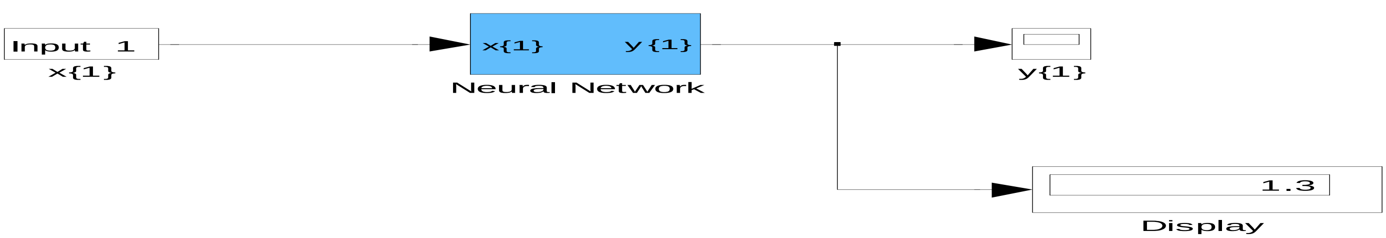

Fig 4 model that resulted in the training

Fig 4 will be incorporated in the machine learning to enhance its efficacy in terms of reducing the power consumed in the cell site thereby enhancing the financial status of the site.

To develop an algorithm that will implement 4, 5 and 6

1. Identify the much power consumed by the module of cell site.
2. Optimize the identified much power consumed by the module of the cell site to a minimal.
3. Apply designed machine learning rule base that will monitor the power consumed on the modules and minimize it if high.
4. Apply the trained ANN in 3 to retain minimal power consumption in the module of the cell site.
5. Does the power consumption at the module of the cell site minimized after the application of 4?
6. No go to 4
7. Yes, go to 9
8. Minimized power consumption by the module of the cell site.
9. Stop.

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10. End

To develop a power consumption model for the network under study based on results obtained.

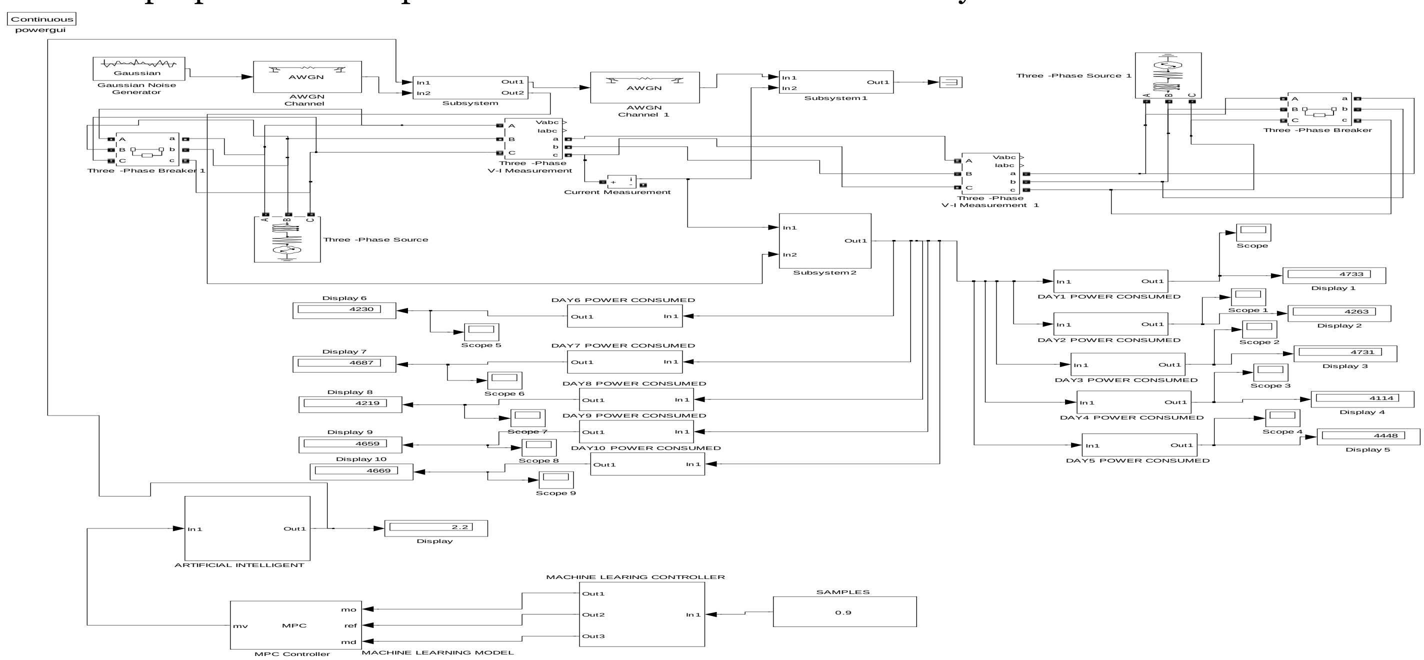

Fig 5 developed power consumption model for the network under study based on results obtained.

The results obtained after simulation are as shown in figures 6, 7, 8 and 9

3.0 Discussion of Result

Table 3 Comparing conventional and machine learning power consumed in cell site in day 1

Time (s)	Conventional power consumed in cell site in DAY 1(KW)	Machine learning power consumed in cell site in DAY1(KW)
0	0	0
1	3800	3000
2	5000	4100
3	5300	4500
4	5764	4733
10	5764	4733

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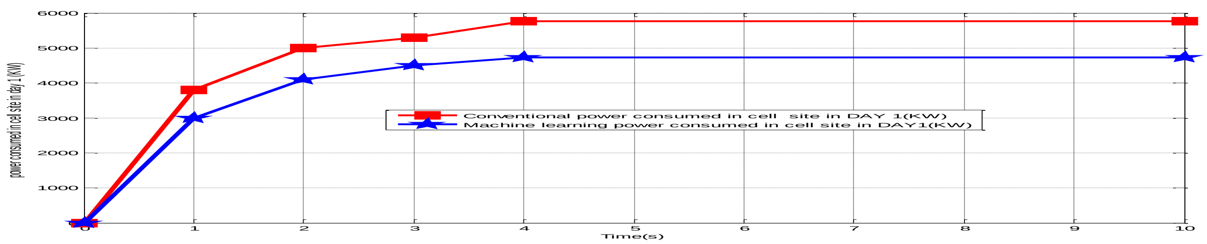

Fig 6 Comparing conventional and machine learning power consumed in cell site in day 1Fig6 shows comparing conventional and machine learning power consumed in cell site in day 1. In fig 6 the highest conventional power consumed by the cell site is5764KW while that when machine learning is inculcated in the system is4733KW. With these results, it signifies that the percentage improvement in the reduction of power consumed in the cell site when machine learning is incorporated in the system in day one is17.9%.

Table 4 Comparing conventional and machine learning power consumed in cell site in day 3

Time (s)	Conventional power consumed in cell site in DAY 3(KW)	Machine learning power consumed in cell site in DAY3(KW)
0	0	0
1	3700	3000
2	5000	4100
3	5500	4500
4	5191	4731
10	5191	4731

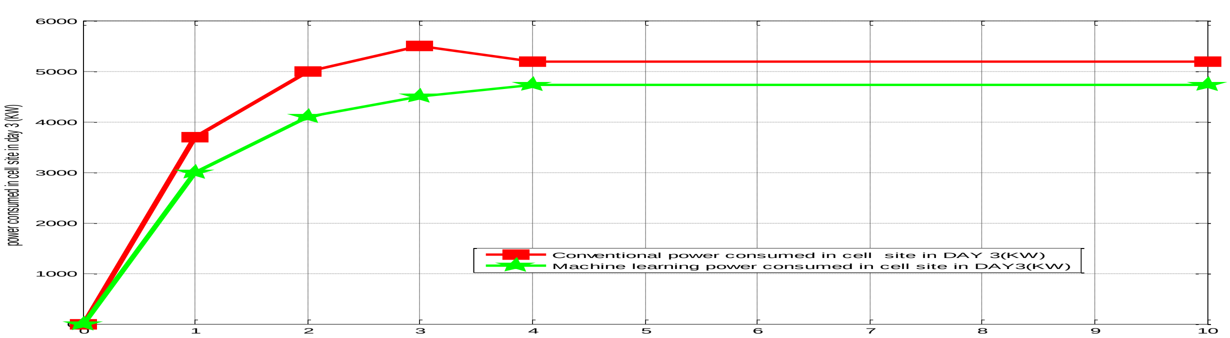

Fig 7 Comparing conventional and machine learning power consumed in cell site in day 3

Fig 7 shows that the highest conventional power consumed in the cell site in day 3 is5191KW while that when machine learning is integrated in the system is 4731KW.With these results achieved, it

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shows that the percentage improvement in power consumption reduction in the cell site when machine learning technique is imbibed in the system in day 3 is 8.9%

Table 5 Comparing conventional and machine learning power consumed in cell site in day 5

Time (s)	Conventional power consumed in cell site in DAY 5 (KW)	Machine learning power consumed in cell site in DAY 5 (KW)
0	0	0
1	3200	2700
2	4700	3800
3	5200	4900
4	5417	4448
10	5417	4448

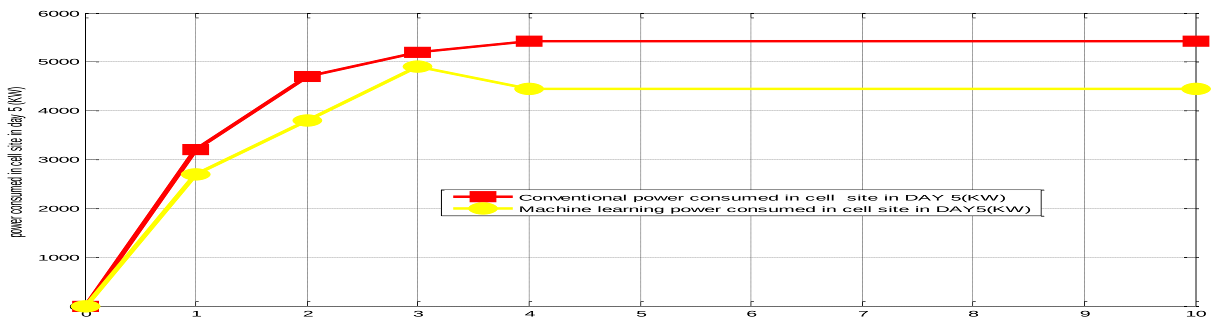

Fig 8 Comparing conventional and machine learning power consumed in cell site in day 5.

In fig 8 it is crystal clear that the highest conventional power consumed in the cell site is5417KW. On the other hand, when machine learning is integrated in the system, it reduced drastically to4448KW which is 17.9% power consumed by the cell site reduction.

Table 6 Comparing conventional and machine learning power consumed in cell site in day 7

Time (s)	Conventional power consumed in cell site in DAY 7 (KW)	Machine learning power consumed in cell site in DAY 7 (KW)
0	0	0
1	3400	3000
2	5000	4000
3	5500	4500
4	5708	4687
10	5708	4687

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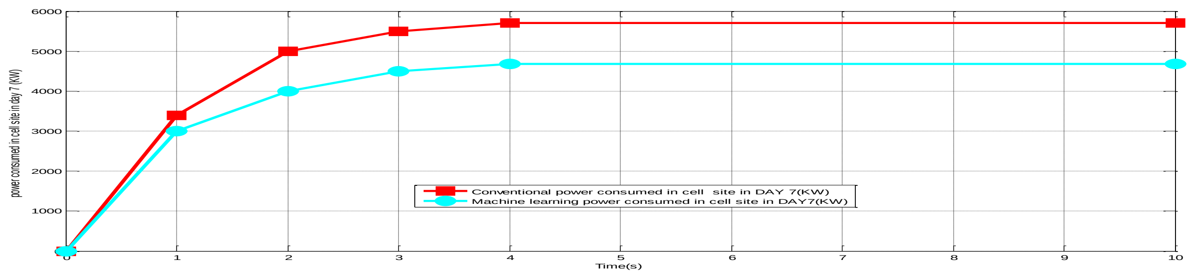

Fig 9 Comparing conventional and machine learning power consumed in cell site in day 7

Fig 9 symbolizes that the highest conventional power consumed by the cell site is5708KW while that when machine learning is injected in the system is4687KW which is 17.9% better that the conventional approach as regards power consumption reduction in the c

4.0. Conclusion

The consistent much power consumed in the cell site has retrogressed the financial status of some of these cell sites. This ugly situation of much power consumed in the cell site is subdued by introducing optimized energy efficiency through reduction of power consumption in a telecommunication base transceiver station (BTS) site using machine learning. To vehemently achieve this, it is done in this process , reviewing the related works to know its short comings, characterizing and determining the power consumption of the modules of the cell site under study, developing a SIMULINK model for the cell site under study, optimizing the established high power consumed by the modules of the cell site to a minimal, designing a machine learning rule base that will monitor the power consumed on the modules and minimize it if high and training ANN in the designed machine learning rules for a reduced power consumption in the cell site thereby enhancing its network performance. Then, developing an algorithm that will implement it. Finally, developing a power consumption model for the network under study based on the result obtained when the algorithm is integrated in it and validating and justifying the percentage improvement of energy efficiency in the cell site with and without the application of machine learning. The results obtained after extensive simulation is the highest conventional power consumed by the cell site is5764KW while that when machine learning is inculcated in the system is4733KW. With these results, it signifies that the percentage improvement in the reduction of power consumed in the cell site when machine learning is incorporated in the system in day one is17.9%, the highest conventional power consumed in the cell site in day 3 is5191KW while that when machine learning is integrated in the system is 4731KW.With these results achieved, it shows that the percentage improvement in power consumption reduction in the cell site when machine learning technique

is imbibed in the system in day 3 is 8.9%, the highest conventional power consumed in the cell site is5417KW. On the other hand, when machine learning is integrated in the system, it reduced drastically to4448KW which is 17.9% power consumed by the cell site reduction and the highest conventional power consumed by the cell site is5708KW while that when machine learning is injected in the system is4687KW which is 17.9% better that the conventional approach as regards power consumption reduction in the cell site.

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