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Improving Energy Efficiency through Reduction of Power Consumption in a Cell Site using Ann Controller

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ABSTRACT

The low performance of communication network base station is a technical malady as a result of high-power consumption that will reduce the economic growth of the establishment. This high-power consumption was tackled by introducing improved energy efficiency through reduction of power consumption in base station or a cell site using artificial neural network (ANN) controller. It is done first by characterizing the network understudy, then developing a SIMULINK model for the cell site understudy, and training ANN to enhance the energy efficiency of the base station and integrating the trained ANN to SIMULINK model for the cell site understudy. The results obtained are the lowest conventional congestion experienced in the base station is 1500b/s in 2s while the lowest congestion observed in the base station when ANN controller was imbibed in the system at the same 2s was 1376b/s, the stable conventional power consumed at the base station was 532kW and that occurred at time duration of 4s through 10s. On the other hand, when ANN controller was injected into the system its power consumption reduced to 520.6kW, the stable conventional energy efficiency in the base station was 54% at time of 4s through 10s. Meanwhile, when ANN controller is incorporated in the system the energy efficiency observed in the base station increased to 58.89% thereby enhancing the performance of the network. With these results, the percentage improvement in the energy efficiency when ANN controller is imbibed in the system was 4.89%.

Keywords: *Energy Efficiency, Power Consumption, ANN Controller*

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 (Abubakar, 2018). Meanwhile (Akbari et al, 2011) strictly highlighted that to boost energy efficiency ultra-capacitor should be incorporated in the system. An egalitarian author, Akhilesh & Ompal (2012) strongly emphasized that wireless communication should be redefined to enhance its efficacy. Bazzi et al. (2008) reemphasized that higher through put is the core functioning capability of multi radio efficiency.

2. Methodology

The following methodology were adopted in developing and designing a model for the improved energy efficiency through power reduction at a cell site;

(i) Characterization of the Network Understudy

To characterize the cell site understudy and determine its power consumption, the type of base station (**BS**), configuration model, transceiver, and power models were evaluated. The cell site or base station or base transceiver station (**BTS**) was 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 controls (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. The analysis of the characterization is shown in table 2.1.

Table 2.1: Characterizing the Network Understudy

No of days for peak period	*No of calls for peak period in these days*	*The total number of calls the network capacity could take at the peak period of seven days*	*No of calls been congested each day of the peak period*
1	43,000	41,250	1750
2	37,500	36,000	1500
3	42,300	40,000	2300
4	46,000	43,750	2250
5	51,000	48,500	2500

6	53,000	51,000	2000

The conventional power consumed at this process is 532kW at an energy efficiency of 54%

For day one.

No of congested call = Calls for peak period - Total number of calls the network capacity could take

No of congested call for day one = 43,000 - 41,250 = 1750

Congested calls in day two = 37,500 - 36,000 = 1500

Congested calls in day three = 42,300 - 40,000 = 2300

Congested calls in day four = 46,000 - 43,750 = 2250

Congested calls in day five = 51,000 - 48,500 = 2500

Congested calls in day six = 53,000 - 51,000 = 2000

Congested calls in day seven = 48,750 - 47,000 = 1750

To calculate the packet loss

$L = 8/ 3W^2$ ……… (1)

Where **L** is the packet loss.

W is the network congestion.

To find the packet loss for day one

$L = 8/ 3W^2$
$L1 = 8 / 3 \times 1750^2$
$L1 = 8 / 3 \times 3062500$
$L1 = 8 / 9187500$

$L1 = 0.000000871$

To find the packet loss for day two

$L2 = 8/ 3W^2$
$L2 = 8/ 3 \times 1500^{2}$
$L2 = 8/ 3 \times 1500^{2}$
$L2 = 8/3 \times 2250000$
$L2 = 8/ 6750000$
$L2 = 0.0000011852$

To find the packet loss for day three

$L3 = 8/ 3W^2$
$L3 = 8/ 3 \times 2300^2$
$L3 = 8/ 3 \times 5290000$
$L3 = 8/ 15970000$

L3 = 0.000000501

To find the packet loss for day four

$L4 = 8/ 3 \times 2300^2$
L4 = 8/ 3 x 5290000
L4 = 8/ 15970000
L4 = 0.000000501

To find the packet loss for day five

$L5 = 8/ 3W^2$
$L5 = 8/3 \times 2500^2$
L5 =8/ 3 x 6250000
L5 = 8/18750000
L5 = 0.0000004267

To find the packet loss for day six

$L6 = 8/ 3W^2$
$L6 = 8/3 \times 2000^2$
L6 = 8/12000000
L6 = 0.00000067

To find the packet loss for day seven

$L7 = 8/ 3W^2$
$L7 = 8/ 3 \times 1750^2$
L7 = 8/ 9187500
L7 = 0.000000871

To determine an ideal bit error rate convenient for the characterized network. Taking into consideration the worst-case scenario, the linear relationship between **BER** and packet error rate (**PER**) is expressed as:

PER= 8 × BER × MTU ×66/64………………………………………………………………………………… (2)

Where the **MTU** is the maximum transmission unit, and using the Ethernet standards it is set to 1500 bytes for the simulations and then the MTU is increased to improve performance. A conversion from 8 bits to 1 byte is shown,

Recall 1 byte = 8bits

1500bytes = 8 x 1500 = 12000bits
MTU = 12000bits

PER is packet loss and BER is bit error rate

PER= 8 × BER ×MTU ×66/64

To calculate the bit error rate in day one when packet loss is 0.000000871

Recall equation 2 and make BER the subject

BER = PER/8 x MTU x 1.03125
BER1 = 0.000000871 / 8 x 12000 x 1.03125
BER1 = 0.000000871 /99000
$BER1 = 8.8 \times 10^{-12}$

To calculate the bit error rate in day two when packet loss is 0.0000011852

BER2 = PER/8 x MTU x 1.03125
BER2 = 0.0000011852 / 8 x 12000 x 1.03125
BER2 = 0.0000011852/99000
BER2 = 1.2 $\times 10^{-11}$

To calculate the bit error rate in day three when packet loss is 0.000000501

BER3 = PER/8 x MTU x 1.03125
BER3 = 0.000000501 / 99000
BER3 = 5.1 $\times 10^{-12}$

To calculate the bit error rate in day four when packet loss is 0.000000501

BER3 = PER/8 x MTU x 1.03125
BER3 = 0.000000501 / 99000
BER3 = 5.1 $\times 10^{-12}$

To calculate the bit error rate in day six when packet loss is 0.00000067

BER6 = PER/8 x MTU x 1.03125
BER6 = 0.00000067/99000
BER6 = 6.8 $\times 10^{-12}$

To calculate the bit error rate in day seven when packet loss is 0.000000871

BER7 = PER/8 x MTU x 1.03125
BER7 = 0.000000871/99000
BER7 = 8.8 $\times 10^{-12}$

To determine the signal to noise ratio (SNR) of the analytical congestion obtained daily from the empirical data, this is shown in table 2.2.

Table 2.2: Daily Congestion in the Cell Site Understudy

Days	Congestion experienced daily
1	1750
2	1500
3	2250
4	2250
5	2500
6	2000
7	1750

$$SNR = \mu/\sigma \qquad (3)$$

$$\mu = \frac{X1 + X2 + X3 + X4 + X5 + X6 + X7}{n}$$

Where μ is mean of the given data

n = number of occurrences.

σ = Standard deviation

$$\mu = \frac{1750 + 1500 + 2250 + 2250 + 2500 + 2000 + 1750}{7}$$

μ= 11500 / 7

μ = 1642.86

$$\sigma = \sqrt{(X1 - \mu)^{\wedge}}$$

$$\sigma = \sqrt{(1750 - 1642.86)^2 + (1500 - 1642.86)^2 + (2250 - 1642.86)^2 + (2250 - 1642.86)^2 + (2500 - 1642.86)^2 + (2000 - 1642.86)^2 + (1750 - 1642.86)^2}$$

$$\sigma = \sqrt{(11478.98) + (20408.98) + (368618.98) + (368618.98) + (734688.98) + (127548.98) + (11478.98)}$$

$$\sigma = \sqrt{(1642842.86)}$$

σ =1281.73

$$SNR = \mu/\sigma$$

$$SNR = 1642.86/1281.73$$

SNR =1.282dB

(ii) Developing a Simulink Model for the Cell Site Understudy

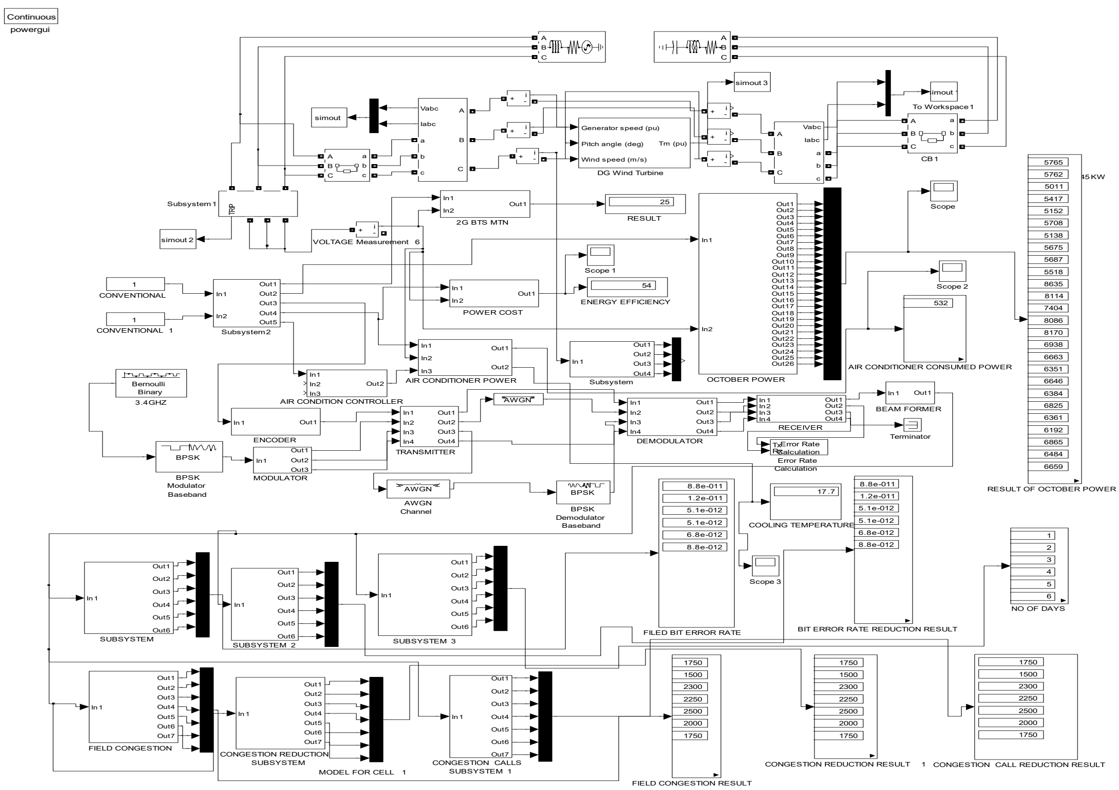

Fig. 2.1: Developed Simulink Model for the Cell Site Understudy

The Simulink model in figure 2.1 was developed based on the total power consumed in the cell site understudy for a day, the power consumed by the BTS for that day, and call traffic recorded within the off-peak period, all in conventional approach.

(iii) Training ANN to Enhance the Energy Efficiency of a Cell Site

The training is shown in figure 2.2

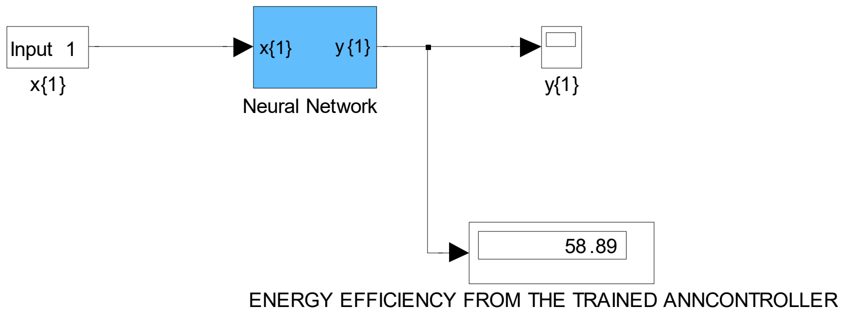

Fig. 2.2: Trained ANN to Enhance the Energy Efficiency of a Cell Site

Figure 2.2 shows trained ANN to enhance the energy efficiency of the base station. With the result obtained, it shows that the energy efficiency has been trained to increase from 54% to 58.89%. The training enhancement is shown in figure 3.

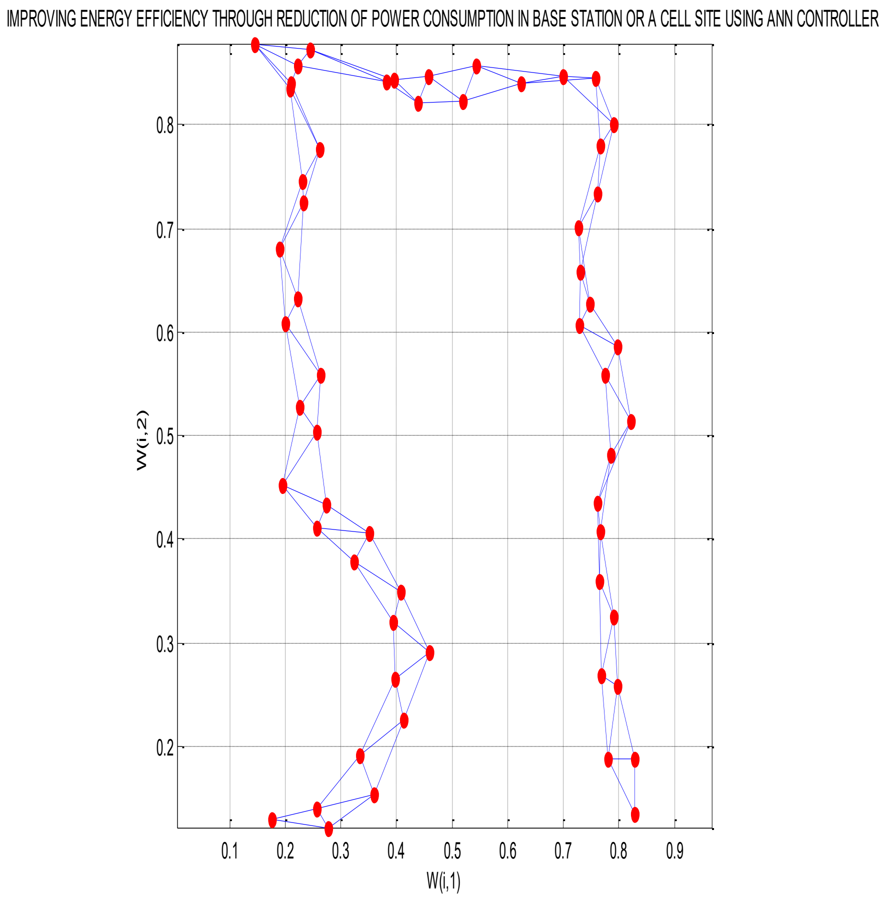

Fig. 2.3: Trained ANN to Enhance the Energy Efficiency of a Cell Site

Figure 2.3 shows trained ANN to enhance the energy efficiency of the base station. In fig 2.3 the number of neurons that look like human brain is 58 which signifies that the energy efficiency is 58%. On the other hand, as a result of tolerant it become 58.89% as shown in figure 2.3.

(iv) Integrating the Trained ANN to SIMULINK Model for the Cell Site Understudy

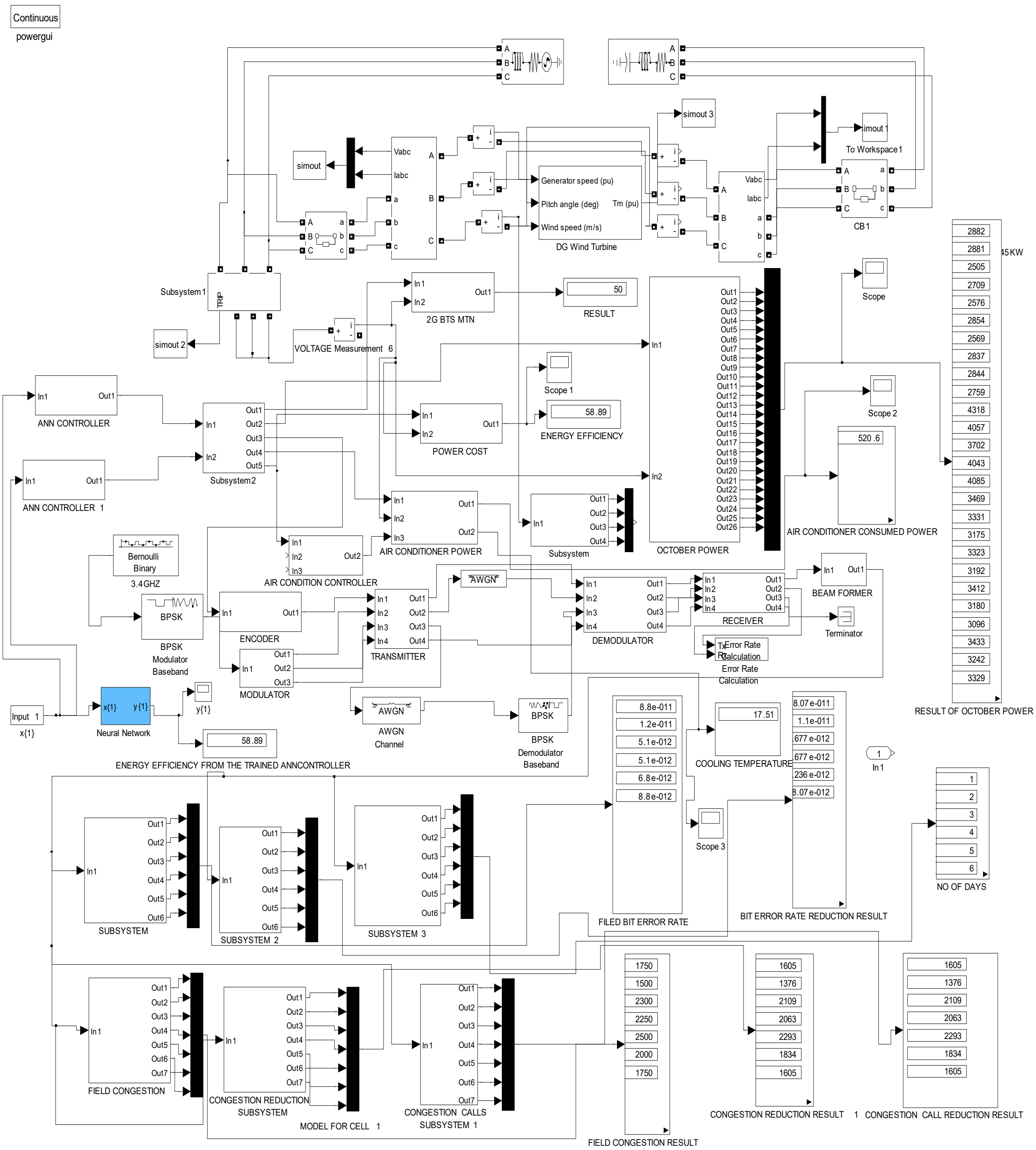

Fig. 2.4: Integrated Trained ANN to SIMULINK Model for the Cell Site Understudy

Figure 2.4 shows integrated trained ANN to SIMULINK model for the cell site understudy. The results obtained after simulation of the integrated model are as shown in figures 3.1, 3.2 and 3.7.

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3. Results and Discussion

Table 3.1: Comparison of Conventional and ANN Controller Congestion in Improving Energy Efficiency

Time (s)	*Conventional congestion improving energy efficiency through reduction of power consumption in base station (b/s)*	*ANN controller congestion in improving energy efficiency through reduction of power consumption in base station ((b/s)*
1	1750	1605
2	1500	1376
3	2300	2109
4	2250	2063
5	2500	2293
6	2000	1834
7	1750	1605

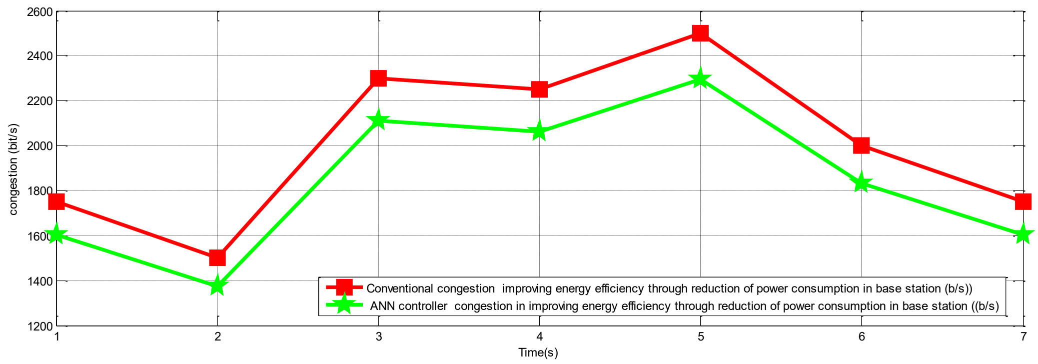

Fig. 3.1: Comparison of Conventional and ANN Controller Congestion in a Cell Site

Figure 3.1 shows comparison of conventional and ANN controller congestion in improving energy efficiency through reduction of power consumption in a cell site. In figure 3.1, the lowest conventional congestion experienced in the base station was 1500b/s in 2s while the lowest congestion observed in the base station when ANN controller was incorporated was 1376b/s.

Table 3.2: Comparison of Conventional and ANN Controller Power Reduction in Improving Energy Efficiency

Time (s)	*Conventional power reduction in improving energy efficiency through reduction of power consumption in base station (KW)*	*ANN controller power reduction in improving energy efficiency through reduction of power consumption in base station (KW)*
0	0	0
1	700	700
2	480	450
3	550	550
4	532	520.6
10	532	520.6

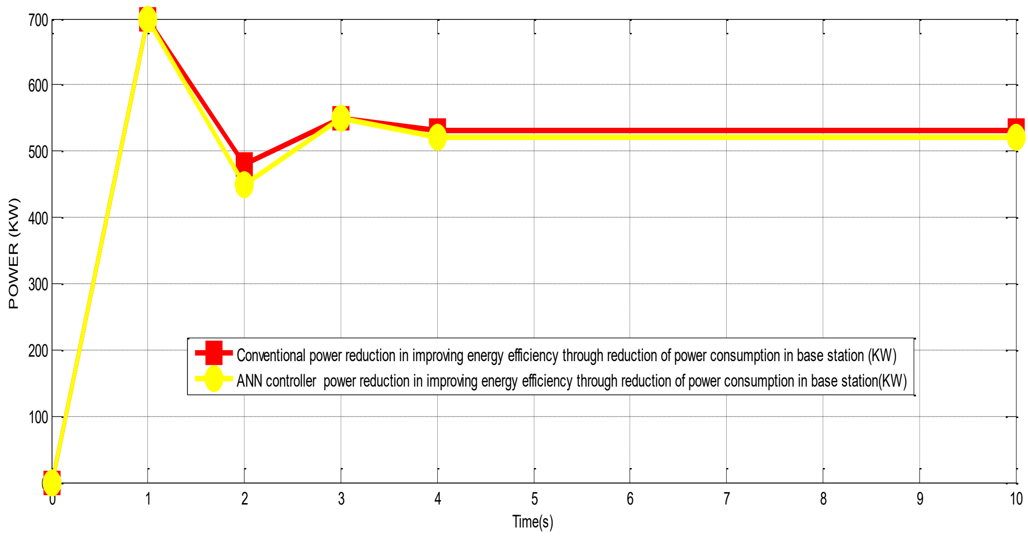

Fig. 3.2: Comparison of Conventional and ANN Controller Power Reduction in a Cell Site

Figure 3.2 shows comparison of conventional and ANN controller power reduction in improving energy efficiency through reduction of power consumption in a cell site. In figure 3.2, the stable conventional power consumed at the base station was 532kW and that occurred at time duration of 4s through 10s. When ANN controller is injected into the system its power consumption reduced to 520.6kW.

Table 3.3: Comparing Conventional and ANN controller efficiency in improving energy efficiency through reduction of Power Consumption in base station

Time (s)	*Conventional efficiency in improving energy efficiency through reduction of power consumption in base station (%)*	*ANN controller efficiency in improving energy efficiency through reduction of power consumption in base station (%)*
0	0	0
1	72	80
2	48	52
3	55	61
4	54	58.89
10	54	58.89

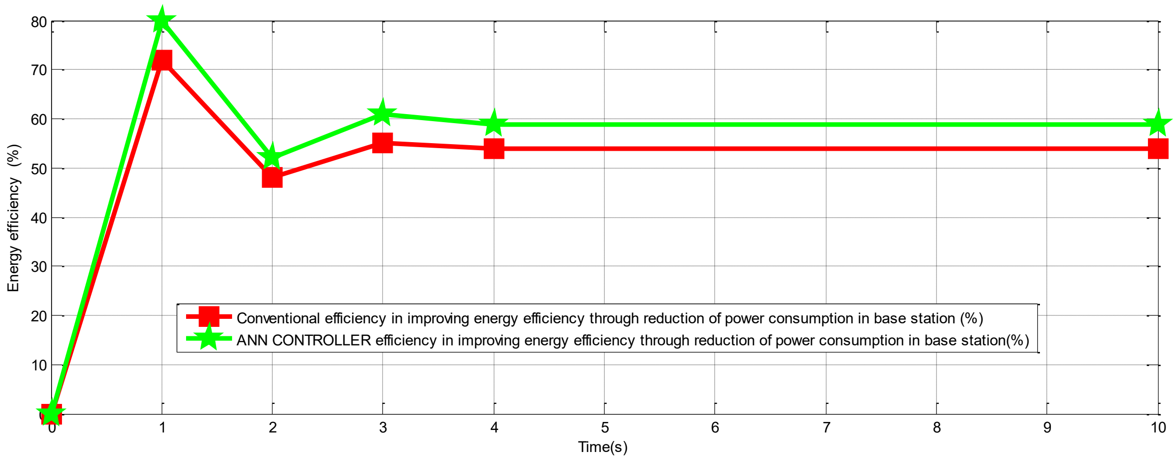

Fig. 3.3: Comparison of Conventional and ANN Controller Efficiency in a Cell Site

Figure 3.3 shows comparison of conventional and ANN controller efficiency in improving energy efficiency through reduction of power consumption in a cell site. In figure 3.3, the stable conventional energy efficiency in the base station is 54% at time of 4s through 10s. Meanwhile, when ANN controller was incorporated in the system the energy efficiency observed in the base station increased to 58.89% thereby enhancing the performance of the network. With these results, the percentage improvement in the energy efficiency when ANN controller was imbibed in the system gave 4.89%.

4. Conclusion

The failure in the communication base station performance has wittingly arisen as a result of low energy efficiency observed in the communication network. This low energy efficiency observed in the base station that is characterized with the network low performance was subdued by introducing improved energy efficiency through reduction of power consumption in base station or a cell site using ANN controller. With, characterization of the network understudy, developing a SIMULINK model for the cell site understudy, and training ANN to enhance the energy efficiency of the base station, when it was introduced in the cell site understudy. The results obtained are the lowest conventional congestion experienced in the base station is 1500b/s in 2s while the lowest congestion observed in the base station when ANN controller is imbibed in the system at the same 2s is 1376b/s, the stable conventional power consumed at the base station is532kW and that occurred at time duration of 4s through 10s. On the other hand, when ANN controller is injected into the system its power consumption reduced to 520.6kW, the stable conventional energy efficiency in the base station was 54% at time of 4s through 10s. Meanwhile, when ANN controller is incorporated in the system the energy efficiency observed in the base station increased to 58.89% thereby enhancing the performance of the network. With these results, the percentage improvement in the energy efficiency when ANN controller is imbibed was 4.89%.

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