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IMPROVING THE PERFORMANCE OF HUB BASE TRANSCEIVER STATION USING HYBRID OF ADAPTIVE INTERFERENCE CANCELLER AND HIBERNATION MODE TECHNIQUE

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Abstract

The paper proposes a hybrid of adaptive interference canceller and fuzzy hibernation controller for improving the performance of a hub base transceiver station. The research involved analyzing the power consumption pattern and load traffic demand of an MTN FR1 5G base transceiver station in Nigeria, modelling it in Simulink, designing a fuzzy hibernation controller, and designing an adaptive interference canceller. The hybrid system reduced the total power consumption by 5.30%, reduced energy costs by 25%, and increased the base station's Signal to Noise and Interference Ratio (SNIR) by 82%. The hybrid technique is effective in minimizing power consumption, reducing energy costs, and improving signal quality.

Keywords: ***Energy conservation, Base Transceivers Station (BTS), access network, power consumption, SNIR.***

1. INTRODUCTION

Telecommunication has attained indispensability in the present day society. Every facet of the society has undergone and is still undergoing transformations orchestrated by the deployment of modern telecommunication infrastructures.

Radio Frequency (RF), baseband, control, and transmission are the four primary modules of a standard base station. Transmitting and receiving signals and converting them to digital data is the job of the RF module. The encoded signal is processed by the baseband module before it is sent or received by the transmission module from the core network. Igor (2014) states that a control module is responsible for maintaining coordination between these three functions. The BTS has 3 antennas, each covering 120 degrees and forming that familiar hexagonal “cell” shape. All voice and data traffics that come to the base station have to then be transmitted upstream to the switching centres. Without the transceiver the 5G BTS with multi capabilities would have been practically impossible or too expensive to afford because it would have been too large and complex. The evolution of hub base transceiver station while boosting network penetration has compounded some problem initially bedevilling the smooth operation of base transceiver stations. Given this, it is paramount to find a way to mitigate these problems, especially considering the numerous benefits that are associated with hub base transceiver stations. The problem of interference is as old as telecommunication itself, thus there has been many techniques developed to tackle the problem. However, as the problem becomes more complicated, it is evident that those conventional techniques do not match the problem any longer. Hence, there is a need to look deeper so as to develop new techniques that can effectively solve the problem. If an effective technique could be developed to mitigate the multiple interference and huge cost of power supply to the HBTS, no doubt the prominence of HBTS will be overly magnified. It is obvious that these problems of power and interference are of different nature and even unrelated. It is difficult to tackle them simultaneously, yet minimizing one and leaving the other is counterproductive.

Therefore, this paper intends to tackle both problems simultaneously by finding a way to conserve and minimize the amount of power consumed at the hub or central station as well as devising a means to cancel the multiple interferences impressed on the scattered antennas of the HBTS. In this way, there will be a significant improvement in the operation of HBTS. One way to achieve this objective is to develop a hibernation mode for the HBTS and also develop an adaptive interference canceller for the receiver. A hibernation mode will ensure that there is no wastage of even a modicum of power at the central station (hub) by making sure that idle equipment do not consume power and also ensuring that active equipment do not lack power. The beauty of this technique is that it is independent of the power source. It can be incorporated into green power based HBTS or a diesel power base HBTS, etc.

2. THEORY OF WORK

2.1. Base Transceiver Station

Equipment that allows User Equipment (UE) to wirelessly communicate with a network is called a Base Transceiver Station (BTS). UEs include things like PCs that can connect wirelessly to the internet, mobile phones, and Wireless Local Loop (WLL) phones. Wide area networks (WANs) can use a variety of wireless communication technologies, including GSM, CDMA, Wi-Fi, WiMAX, wireless local loop, and others (Satoshi, et al., 2002). The BSS relies on two primary pieces of hardware: the Base System Controller (BSC) and the Base Transceiver Station (BTS). One BSC may have control over multiple BTSs; the BTS is responsible for ground coverage, while the BSC oversees its operations. According to Popoola et al. (2009), its main responsibilities involve managing traffic switching, signaling to and from BTS and the Mobile Switching Centre (MSC), and overseeing the handovers performed by BTSs that are under its supervision. Since there are far more BTSs than BSCs in a network, a single cell site can hold both types of nodes.

The BTS's fundamental design and operation are independent of the underlying wireless technology (Satoshi, et al., 2002).

A BTS's primary function is to facilitate reliable data transfer between several mobile nodes (Ajibola, et al., 2015). The radio channels, each with its own Absolute Radio Frequency Channel Number (ARFCN), as well as the antennas used for transmitting and receiving signals make up the base station. A tower's strategic placement of these antennas, most of which are directional antennas for mobile telecommunications, allows them to serve certain geographic regions. The positioning of a base station (BTS) and the communication antennas' strategic inclination are critical factors that affect the quality of service provided to clients. Some base stations are sited on hilly areas, away from obstructions, so they can provide better coverage and connectivity (Ajibola, et al., 2015). Depending on the user density in the cell, each BTS has anything from one to sixteen transceivers.

2.2. Performance of Hub Base Transceiver Station

The requirement for wireless network optimization has been triggered by the need to communicate with new operators that are joining the market. Planning involves a lot of moving parts, including things like traffic, coverage, geography, system capability, and propagation characteristics. Depending on the number of units, the traffic allocation, the coverage, and the propagation environment, the location of the unit (cell) can be determined. The condition of BTS is crucial to the overall system layout design because interference within the cell is becoming more common as the frequency channel becomes more congested and the transmission environment becomes more complicated. The base transceiver station (BTS), an integral component of the cellular arrangement's environmental setup, encloses a certain area, called a unit (cell). The challenge of locating the BTS and determining the variables for each BTS is tackled in unit (cell) development in order to provide the greatest performance possible while reducing arrangement expenditure. What defines the performance and expenses are: Calculations for Power Plans: Both the uplink and downlink quality of a unit (cell) can be guaranteed if the power of the Mobile Station (MS) and the Base Transceiver Station (BTS) are balanced at its boundary. This is a list of useful outcomes provided by the power plan calculations: A balanced communication connection, where the downlink and uplink performances are identical for a given MS and BTS receiver, antenna, MS spreader, and feeder wire distinctiveness, is provided by the Base Transceiver Station (BTS) Spread Power (Sandeep & Pooja, 2016). The coverage threshold defines the downlink signal power at the covered region boundary for a certain position possibility, and isotropic path loss is the greatest pathway loss between the mobile station and the base station according to the defined communication network performance requirements. The coverage range of cells is an atypical indicator of cell choice across different sorts of regions (Sandeep & Pooja, 2016). Calculating Path Losses: Okumara-Hata explains the global route loss equation in her work cited in Sandeep and Pooja (2016).

$$PL = Q_1 + Q_2(log f) - a(hm) - 13.82 \\ log\, log(Hbts) + \\ \{44.9 + Q_0 - 6.55\, log\,(hbts)\} \\ log\,(d) \qquad (1)$$

Where $PL =$ path loss in db, $f =$ Frequency in MHZ, $d =$ Distance between BTS and mobile ($1 - 20kms$), Hbts = base station height in meters ($30 - 100m$), a(hm) = correction required if mobile height is more than 1.5 meter and is given by a(hm) = $\{1.1\, log\,(f) - 0.7\}hm - \{1.56\, log\, log(f) - 0$ for urban areas (2)

a(hm) = 3.2{log (11.75hm)2−4.97} for dense urban areas (3)

hm = mobile antenna height ($1 - 10m$)

Q1 = 69.55 for frequencies from 150 to 1000MHZ
46.3 for frequencies from 1500 to 2000MHZ
Q2 = 26.16 for 150 to 1000MHZ
33.9 for 1500 to 2000MHZ
Q0 = 0 db for urban
3 db for dense urban

3. METHODOLOGY

The power consumption of the base station was computed using the realistic power consumption of base station sites in Nigeria as adopted from Rahman et al. (2009). The relationship between the load traffic demand and power consumption of the base station was derived and shown in equation 4 below:

$$A = \frac{w_{Bm}}{\frac{2a}{8(2+\gamma)R^2}R^2 + \gamma \times (1-B)} \qquad (4)$$

Where, A = the load traffic Demand, $w_{Bm} = Totaloutputpowerofthebasestation$

$$a = constant\ (factor)\ of proportionality$$

$$\gamma = Awholenumberbetween\ 2\ and\ 5$$

$R = Cellradius, B = Calllossprobability$

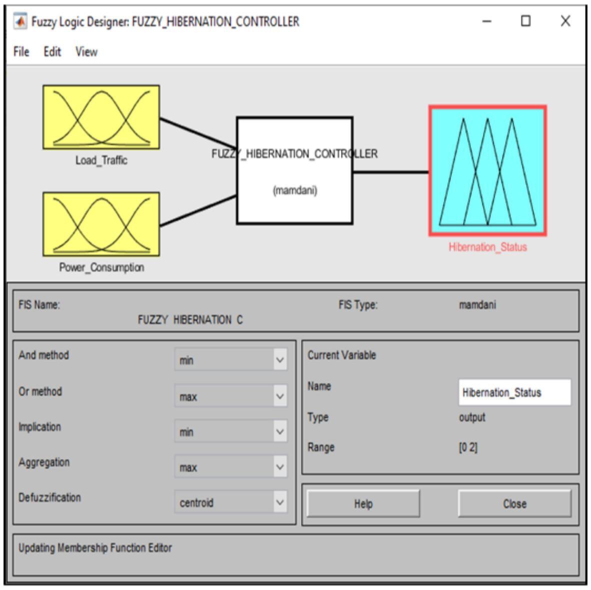
Similarly, the SNIR of the base station was determined using equation (5)

$$SNIR = \left(\frac{S}{N+I}\right) = S_{dB} - N_{dB} - I_{dB} \qquad (5)$$

Next the model of the characterized MTN FR1 5G macro base transceiver station was developed using the Matlab/Simulink environment. Thereafter, a fuzzy logic system/controller was developed for switching ON/OFF power to redundant units using fuzzy logic toolbox of Simulink. In the fourth step, an adaptive filter was designed for minimizing the Noise/Interference power in the base station using the particle swarm optimization (PSO) algorithm. In the fifth step, the developed model of the MTN FR1 5G macro base transceiver station was integrated with the hybrid of adaptive interference canceller and fuzzy hibernation controller and simulations were carried out in the sixth step without and with the hybrid system integrated.

3.1. Design of a fuzzy logic system/controller for switching ON and OFF power to redundant units using the fuzzy logic tool box.

Membership functions is two representing hibernation ON which is in the range of 0 to 0.99 and hibernation OFF which is in the range of 1 to 1.99.



FIS Name: FUZZY HIBERNATION C
FIS Type: mamdani
And method: min
Or method: max
Implication: min
Aggregation: max
Defuzzification: centroid
Current Variable
Name: Hibernation_Status
Type: output
Range: [0 2]
Updating Membership Function Editor

Figure 1: Designed fuzzy logic system for achieving hibernation control

3.2.

The designed membership function for traffic demand and its corresponding power consumption was presented with a figure. As can be seen from the load traffic data, the number of membership functions is four representing the low traffic which is in the range of 0.0286 ERL to 0.818 ERL, the slightly low traffic which is in the range of 0.611 ERL to 1.39 ERL, the medium traffic which is in the range of 1.147 ERL to 2.025 ERL and the high traffic which is in the range of 1.8 ERL to 3.599 ERL.

Similarly, as can be observed from the power consumption figure, the total number of membership functions is 4 representing low power consumption which is in the range of 80 Wh to 106 Wh, slightly low consumption which is in the range of 99.2 Wh to 146 Wh, moderate power consumption which is in the range of 138 Wh to 193.6 Wh and high power consumption which is in the range of 180 W to 231 W.

The designed output membership function for hibernation status was presented in a figure. As was observed from the figure, the total number of output

$$where, S_{dB} = Signalpower$$

$$N_{dB} = Noisepower, I_{dB} = Interferencepower$$

Figure 1 shows the designed fuzzy logic system for achieving hibernation control in the base station. The figure confirmed that the load traffic and power consumption are the two inputs to the fuzzy logic controller whereas the hibernation status is the only output to the fuzzy logic system.

Figures were used to present the designed fuzzy rule base for achieving hibernation control in the base station. As can be observed from the designed fuzzy rule base, a total of 24 rules were used to achieve hibernation control at the base station. The formation of the rules involves pairing each of the input and output membership functions and mapping them to the desired output membership function. A close inspection of both figures shows that the hibernation status is set to ON at rule 4 and rule 24 respectively. In rule 4, it is desired that the system hibernates if the load traffic is low or that the power consumption is high. Similarly in rule 24, it is desired that the system hibernates if the power consumption is high and regardless of whether the traffic is low or high. For all other rules, it is desired that the system does not hibernate. The rule viewer of the proposed fuzzy logic system was generated.

3.3. Design of an adaptive filter for minimizing the Noise/Interference power in the base station using the particle swarm optimization (PSO) algorithm.

From equation 5, the Signal to Noise and Interference Ratio (SNIR) is given by:

$$SNIR = \left(\frac{S}{N+I}\right) = S_{dB} - N_{dB} - I_{dB} \quad (6)$$

So, maximizing the SNIR will in turn minimize the noise and interference power which will lead to enhanced operation of the network. From equation 6, let

$S = x(1)$; N = $x(2)$ and I = $x(3)$

Using one line of the values obtained by simulation of the SNIR model, the adaptive filter optimization problem model therefore becomes,

$$\text{Maximize } SNIR = log_{10}\left(\frac{x(1)}{x(2)+x(3)}\right) \quad (7)$$

Subject to the constraints

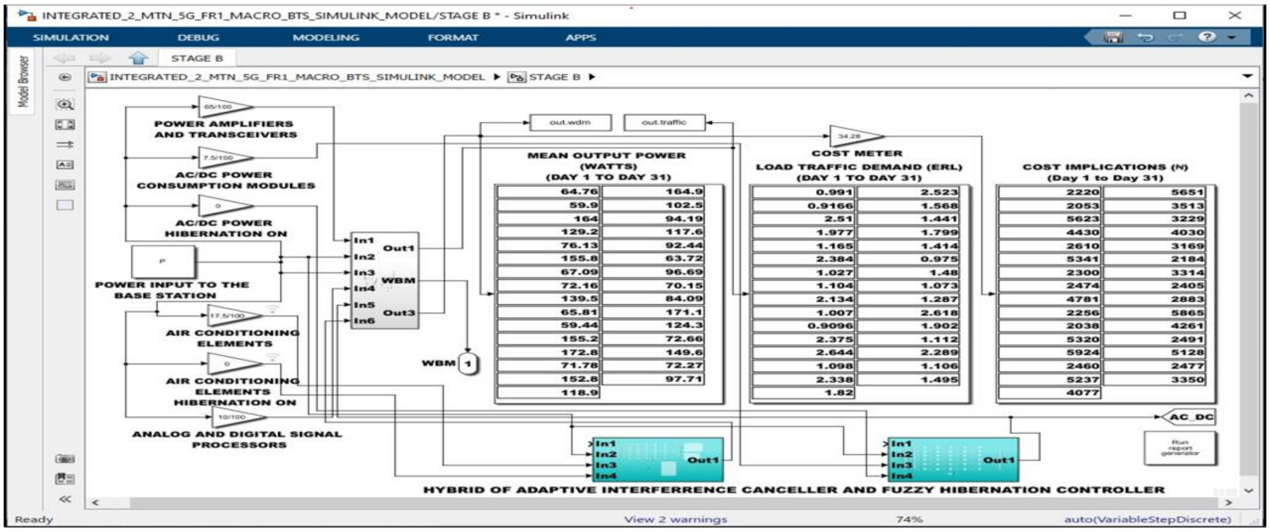
$x(1) > 0$ (Maximizes the signal power)

$x(2) < 0$ (Minimizes the noise power)

$x(3) < 0$ (Minimizes the interference power)

3.2. Integration of the developed model of the MTN FR1 5G macro base transceiver station with the hybrid of fuzzy hibernation controller and adaptive filter for achieving adaptive interference cancelling and minimizing power consumption in the base station.

The integration of he developed model of the MTN FR1 5G macro base transceiver station with the hybrid of fuzzy hibernation controller and adaptive filter was achieved using switches, multiplexers, de-multiplexers and adaptive ratios. The designed fuzzy hibernation controller was duplicated into 31 blocks each representing the hibernation control for the 31 days which was considered in the research.



MEAN OUTPUT POWER (WATTS) (DAY 1 TO DAY 31)

64.76	164.9
59.9	102.5
164	94.19
129.2	117.6
76.13	92.44
155.8	63.72
67.09	96.69
72.16	70.15
139.5	84.09
65.81	171.1
59.44	124.3
155.2	72.66
172.8	149.6
71.78	72.27
152.8	97.71
118.9	

LOAD TRAFFIC DEMAND (ERL) (DAY 1 TO DAY 31)

0.991	2.523
0.9166	1.568
2.51	1.441
1.977	1.799
1.165	1.414
2.384	0.975
1.027	1.48
1.104	1.073
2.134	1.287
1.007	2.618
0.9096	1.902
2.375	1.112
2.644	2.289
1.098	1.106
2.338	1.495
1.82	

COST IMPLICATIONS (₦) (Day 1 to Day 31)

2220	5651
2053	3513
5623	3229
4430	4030
2610	3169
5341	2184
2300	3314
2474	2405
4781	2883
2256	5865
2038	4261
5320	2491
5924	5128
2460	2477
5237	3350
4077	

Figure 2: Integration of the Hybrid of Interference canceller and Hibernation controller

The subsystem of the adaptive interference canceller was presented in a figure. The adaptive ratios for the various signals were determined as:

$$Adaptiveratioofthesignalpower = \frac{S_{optimized}}{S} = \frac{74.2240}{74.2240} = 1$$

$$Adaptiveratioofthenoisepower = \frac{N_{optimized}}{N} = \frac{0}{45.791} = 0$$

$$Adaptiveratiooftheinterferrencepower = \frac{I_{optimized}}{I} = \frac{0}{27.443} = 0$$

Just like an adaptive filter, the 1 value allows the signal power to pass through whereas the 0 values cancels both the noise and interference power disturbing the station.

4. RESULTS

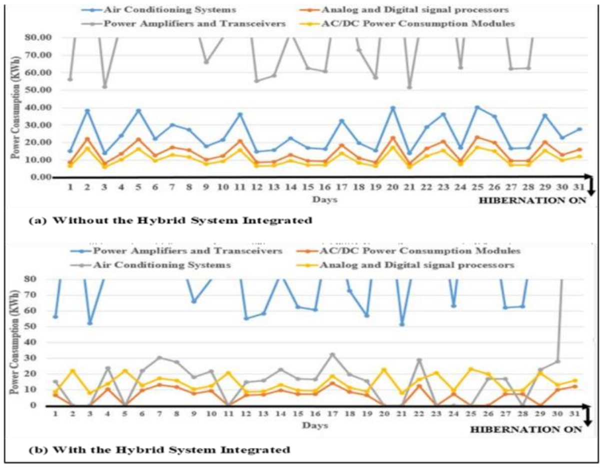


Figure 3: Comparison of power consumption pattern of the different base station components

Figure 3 shows the behavior of the different base station components when simulated without and with the hybrid of adaptive interference canceller and fuzzy hibernation controller integrated. Figure 3 confirms that when the base station traffic is low or power consumption is high, the fuzzy hibernation controller will trigger the hibernation status to ON (ie. No disconnection of components) whereas it will trigger the hibernation status to OFF (ie zero power consumption for the AC/DC power consumption modules and the air conditioning systems) when the base station traffic is not low or power consumption is not high. On comparing figures 3a and b, it can be observed that in a, none of the curves reached the zero mark of the graph whereas in b, the curve for the AC/DC power consumption modules as well as the air conditioning systems reached the zero mark in some occasions and thus signifying the activation of the hibernation mode.

Whereas the minimum and maximum power consumption for the power amplifiers and transceiver maintained their values as 59.52 Wh and 149.76 Wh respectively after the integration of the hybrid system, the minimum power consumption for the AC/DC power consumption modules decreased from 5.94 Wh to 0 Wh whereas it maximum power consumption decreased from 17.28 Wh to 13.94 Wh.

For the Air conditioning systems, the minimum power consumption decreased from 13.87 Wh to 0 Wh whereas its maximum power consumption decreased from 40.32 Wh to 32.54 Wh. Similarly, for the analog and digital signal processors, the minimum and maximum power consumption remained the same as 7.93 Wh and 23.04 Wh respectively with the integration of the hybrid system.

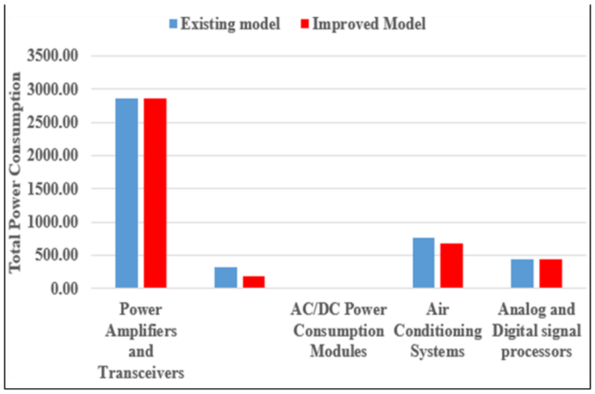


Figure 4: Comparison of total power consumption by base station components

From figure 4, it can be seen that the power consumption for power amplifiers and transceivers as well as the analog and digital signal processors did not reduce since they were not part of the hibernation scheme. They are very important components in the base station as setting them to hibernate in some occasions will cause more harm than good to the telecom company and their customers. Similarly for the AC/DC power consumption modules as well as the Air conditioning systems, their power consumption reduced by 54.85% since they were the base station components that were set to hibernate in several occasions and thus contributing to the overall power consumption reduction for the base station.

Figure 5 shows the comparison of the power consumption results of the base station without and with the hybrid system integrated.

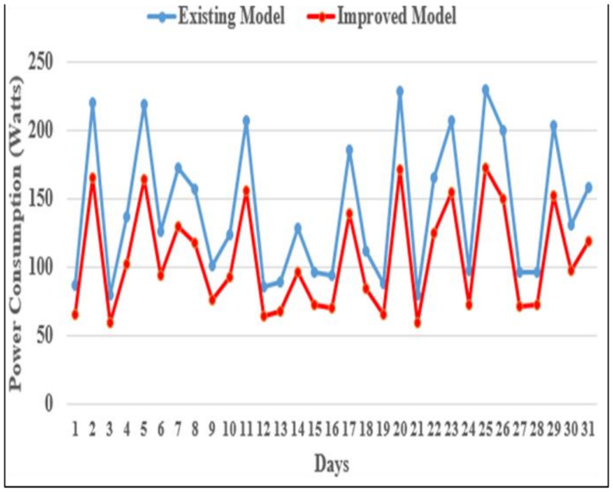


Figure 5: Comparison of power consumption pattern of the base station without and with the hybrid system integrated.

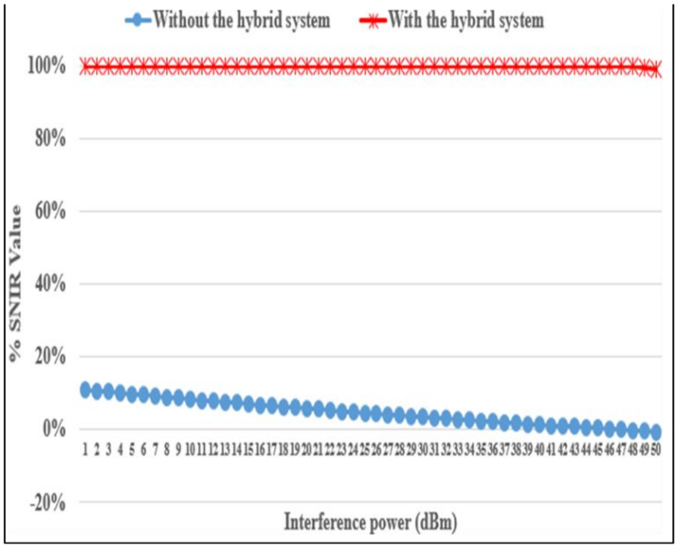


Figure 6: Comparison of the base station SNIR without/with the hybrid system integrated

The blue curve indicates that the hybrid system was not integrated when the simulation was carried out whereas the red curve indicates that the hybrid system was integrated when the simulation was performed. From figure 5, it can be observed that the red curve is slightly lower than the blue curve thus signifying a reduction in overall power consumption of the base station. From tabulated results, it was observed that the total power consumption of the base station without the hybrid system integrated is 60762 W whereas it is 52429.8 W with the hybrid system integrated and thus yielding a percentage reduction in the overall power consumption of the base station as:

$$\%\, reductioninoverallpowerconsumption = \left(\frac{4398.81 - 4165.88}{4398.81}\right) \times 100 = 5.30\%$$

Figure 6 shows the comparison of the base station SNIR curve without and with the hybrid system integrated. A close inspection of figure 6 shows that the SNIR values of the base station increased by about 82% with the integration of the adaptive interference canceller. This signifies a better performance of the base station since the increase in the SNIR values of the base station implies that the noise power and interference power of the base station has been canceled and its signal power utilized at almost its full capacity.

4.1. Cost Analysis

Figure 7 shows the comparison of cost incurred by the BTS without and with the hybrid system integrated. From Figure 7, it is evident that there was reduction in power consumption cost of the BTS with the hybrid system integrated. The percentage reduction in cost is calculated as:

$$\% \, reductionincost = \frac{150791.7 - 113093.7}{150791.7} \times 100 = 25\%$$

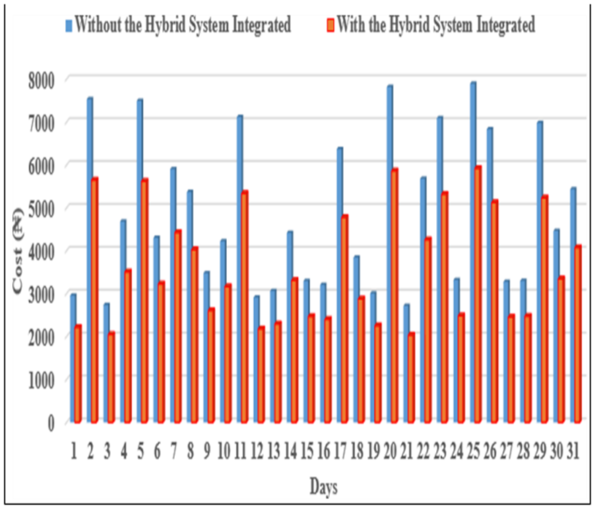


Figure 7: Comparison of costs without and with the Hybrid System Integrated

5. CONCLUSION

The developed Matlab/Simulink model of the MTN FR1 5G macro base transceiver station was integrated with the hybrid of adaptive interference canceller and fuzzy hibernation controller and simulations were carried out both without and with the integration of the hybrid system. The following were the major findings of the research:

1) No deviation occurred between the experimental and simulated values of power consumption for the base station.
2) A 3.61% deviation occurred between the experimental and simulated SNIR values of the base station. This deviation is however acceptable in practice since it is not more than 5% and thus validates the developed base station model.
3) No reduction in power consumption occurred for the power amplifiers and transceivers as well as the analog and digital signal processors with the integration of the hybrid system.
4) A 54.85% reduction in power consumption occurred for the AC/DC power consumption modules as well as the Air conditioning systems.

5) The total power consumption of the base station without the hybrid system integrated is 4398.81 KWh whereas it is 4165.88 KWh with the hybrid system integrated and thus yielding a percentage reduction in the overall power consumption of the base station as 5.30%.

6) The SNIR values of the base station increased by about 82% with the integration of the adaptive interference canceller.

With the above stated findings of this research, it is therefore concluded that the hybrid of adaptive interference cancelling and hibernation mode technique is capable of minimizing power consumption, improving the signal quality as well as improving the overall performance of a hub based transceiver base station.

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