Analysis of Massive MIMO Antenna, Sleeping Mode Technology as a Power Optimization Tool and Hybrid Power Generation System Design for 5G Implementation

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Abstract

Power optimization has become a vital issue in wireless networks in order to meet demands for increased capacity, better data speed and service quality of the next-generation networks as well as carbon footprint reduction for a safer future. The study mainly focuses on two power optimization techniques, energy efficiency and consumption, and a hybrid power generation system for the delivery of power to the base station. The power optimization part has been depicted by MATLAB simulation where the terminologies are coverage area, beamforming, return loss, impedance and sleeping mode of the massive MIMO antenna during low transmission time. The summarized architecture of the integrated energy system (Biomass, Solar and Grid) which is expected to produce sufficient power to support an entire base station using the renewable energy sources and monthly load measurement for the station, simulated by Homer Pro has been illustrated. Finally, A 5G power optimization architecture for smart city using green communication has been presented.

1. Introduction

With the rapid expansion of ICT field, energy consumption has skyrocketed, in specific, mobile operators are ranked to be one of the top most consumers. As 4G raised the bar even more, 5G is expected to increase the wireless traffic by 1000 times in next 10 years[1]. Many new techs such as large multi-input and multi-output (MIMO) antennas, millimeter (MM) waves, sleeping modes and small cell systems have been developed to enable high speed wireless networking. A growing need for greener connectivity is rising and the main emphasis is on the integrated energy optimization approach[2]. A hybrid power station is a must to implement 5G for a developing country like Bangladesh, but will be compatible as it is an agricultural one where agricultural residues, urban solid wastes and animal manures are the major sources of biomass energy and unlimited solar power from the sun[1]. This electricity generation model is not only environmentally friendly but also maintains a promising prospect of utilizing potential renewable energy resources.

2. Proposed Model

2.1 5G Network Model

The model is proposed for a 200m^2 area. Here the base station is established with Massive MIMO antenna and sleeping mode. There are two small cells and all base stations are connected with the cloud storage. The power of the base station is delivered from the hybrid power generation system.

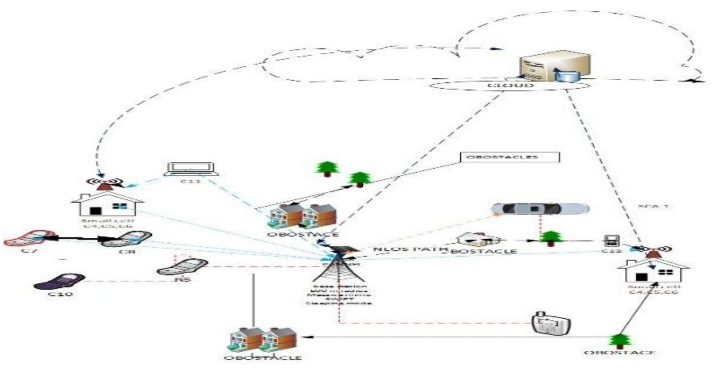

Figure 3.1 Proposed 5G Model for Smart City using Green Communication

2.2 Hybrid Power Generation Model

All energy from three sectors, biomass, solar and grid are converted by a 220V converter and then supply to the base station.

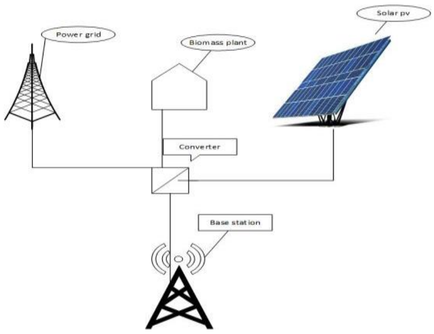

Figure 3.2 Hybrid Power Generation Model

3. Data Analysis

3.1 Massive MIMO antenna

MIMO or Multiple-input and multiple-output is a multi-path networking method for increasing network connectivity capability[16]. MIMO has become an essential element in the wireless communication protocols including IEEE 802.11n (Wi-Fi), IEEE 802.11ac, HSPA+ (3G), WiMAX (4G) and Long-Term-Evolution (LTE) standards[17].

3.2 Coverage analysis of MIMO antenna

It is spread through land areas, known as "cells," often supported by three cell sites or base transceiver stations[2]. Such base stations maintain the network coverage of the cell which can be used to relay voices, data and other service types[18]. A cell typically uses a different range of cell frequencies to prevent interference and to guarantee quality of service inside each cell[19]. Here is the flow chart of the simulated coverage area:

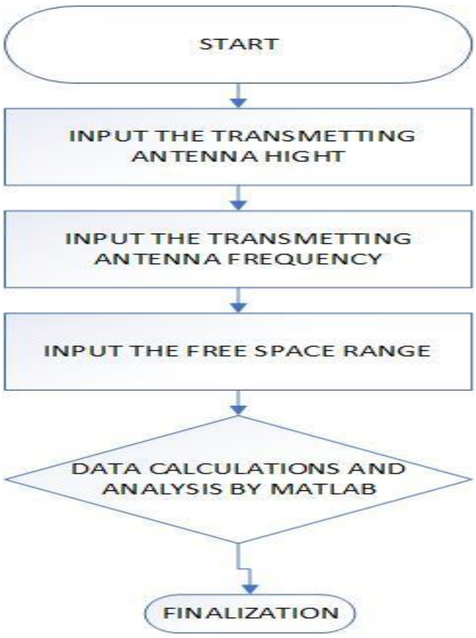

Figure 4.1 Flow Chart of the Simulated Coverage Area

The antenna downlinks in degree, outer radius of the antenna, inner radius of the antenna can be found from the coverage area of the antenna.

$$\text{Downlink Angle } \mathbf{A_{DT}} = \mathbf{tan^{-1}}\left(\frac{\mathbf{h_T - h_R}}{\mathbf{D}}\right)$$

$$\text{Coverage radius } \mathbf{R_{outer}} = \frac{\mathbf{h_T - h_R}}{\mathbf{tan}\left(\mathbf{A_{DT}} - \frac{\mathbf{Q_{BW}}}{\mathbf{2}}\right)}$$

$$\text{Inner coverage } \mathbf{R_{inner}} = \frac{\mathbf{h_T - h_R}}{\mathbf{tan}\ (\mathbf{A_{DT}} + \frac{\mathbf{Q_{BW}}}{\mathbf{2}})}$$

Table 4.1 Symbol And notation For Calculating Coverage Area.

$\mathbf{A_{DT}}$	Antenna downlink in degrees
$\mathbf{h_T}$	Height of the transmitting antenna
$\mathbf{h_R}$	Height of the receiving antenna
D	Distance between antenna
$\mathbf{R_{outer}}$	Outer radius of coverage
$\mathbf{R_{inner}}$	Inner radius of coverage
$\mathbf{Q_{BW}}$	Beamwidth of antenna in degree

3.3 Beamforming

Signal shaping or spatial filtration is a technique for signal manipulation in sensor arrays used to transmit or receive directed signal[20]. The combination of antenna array element to signify positive interference from a particular angle when disruptive interference happens to others[9]. Transmission and receipt for spatial selectivity can be used for transmission and receiving purposes. Beamforming is essentially the linear combination of the product outputs, which can be measured using a beam[21].

$$\boldsymbol{\zeta}(\boldsymbol{\theta}) = \sum_{\mathbf{K=0}}^{\mathbf{k=N}} \mathbf{a_k}(\boldsymbol{\theta}).\mathbf{X_k}$$

Table 4.2 Symbol and Notation for calculating Beamforming

N	Number of elements
K	An index Variable
$\mathbf{a_k}$	Complex coefficient of the $\mathbf{k^{th}}$ element

$\mathbf{X_k}$	Voltage response from the $\mathbf{k^{th}}$ element
$\boldsymbol{\zeta}$	The beam response
$\boldsymbol{\theta}$	The angle of the beam.

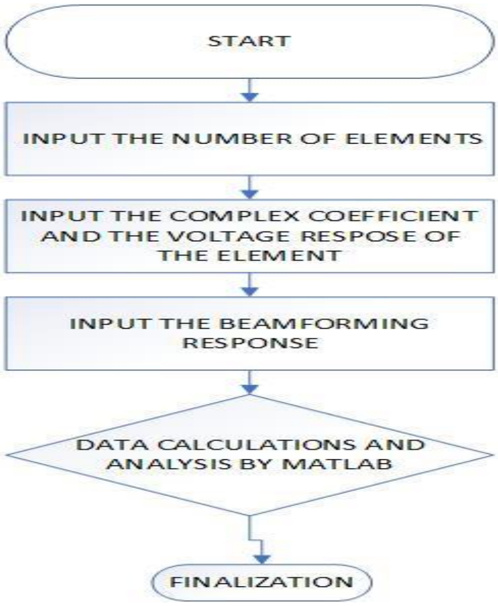

Figure 4.2 Flow Chart of Beamforming

3.4 Return Loss

Return loss is the power loss in the signal reported / reflected in the transmission line or optical fiber in telecommunications Return loss is related to both the SWR and the reflection coefficient[22]. Return losses are due to the lower SWR corresponds to increased return loss. The return loss is a function of the matching between equipment or lines. If the return loss is small, a match is fine. The high cost of return is beneficial and the loss of incorporation is that. This disruption may be unacceptable to the terminating load or to a system inserted into the track[22][18]. The ratio in decibels (dB) is generally indicated. The formula of measuring the return loss is: $\mathbf{R_L = 10\log(\frac{P_{in}}{P_r})}$

Table 4.3 Symbol and Notation for Calculating Return Loss

$\mathbf{R_L}$	Return Loss
$\mathbf{P_{in}}$	Input Power
$\mathbf{P_r}$	Return Power

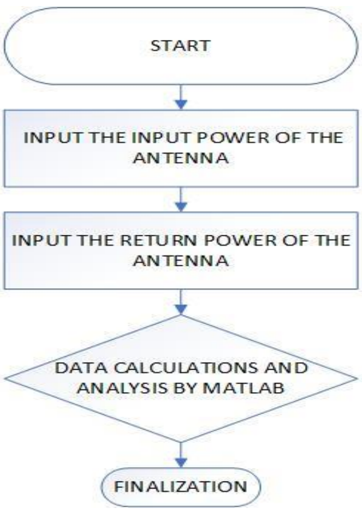

Figure 4.3 Flow Chart of Return Loss

3.5 Impedance of MIMO antenna

Antenna impedance applies to the voltage at the antenna origin[8]. The voltage is in line with the current, as the impedance is a real number. The impedance has a magnitude[7].

The phase of the antenna = $\mathbf{tan^{-1}\left(\frac{Im(Z)}{Re(Z)}\right)}$

That is, in contrast to the voltage waveform the current waveform is overdue. To define it, if the voltage (with frequency f) is given in the antenna terminals, $\mathbf{V(t) = cos(2\pi ft)}$

The electric current is, $\mathbf{I(t) = \frac{1}{magnitude} cos\left(2\pi ft - \frac{\pi}{180}.45\right)}$

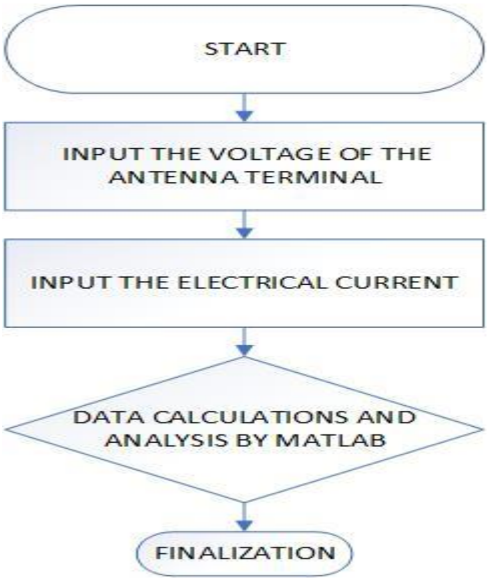

Figure 4.4 Flow Chart of Impedance

3.6 Gain of the MIMO antenna & SISO antenna

Power gains or simply gains from an antenna is a key performance figure, matching the orientation of the antenna with electric efficiency[23]. MIMO antenna requires 8 kW power. The equation to find the gain of the antenna: $\mathbf{G = \frac{4\pi u_m}{p_{in}}}$

3.7 Efficiency of massive MIMO antenna & SISO antenna

The antenna output is a measure of the energy provided to the antenna compared to the antenna power. The bulk of the energy at the origin of the antenna is radiated by a high efficiency antenna.[23] A low-efficiency antenna loses most of its power as defects in the antenna or as a result of a defect in its impedance: $\boldsymbol{\varepsilon_r = \frac{P_{rad}}{P_{in}}}$

3.8 Power consumption with sleeping mode

Load is proportional to the required power[24][25]. Power is at peak during office hours and rest of the time the necessity is not much but the base station remains active all time.

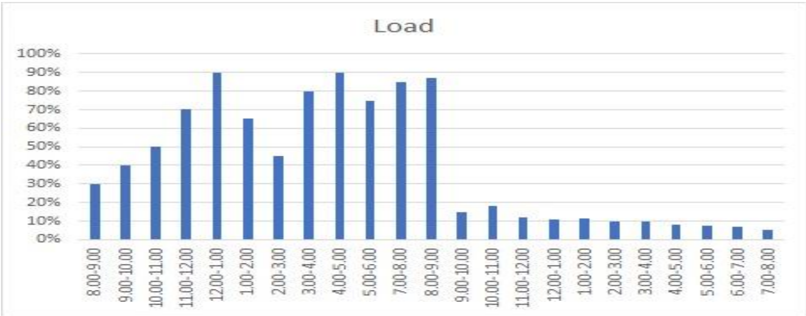

Figure 4.5 Data Traffic Statistics on Hourly Basis.

3.9 Power Delivery from Hybrid Model

In 5G, running one single base station requires 192 kW power to cover 200 $\mathbf{m^2}$ [16]. Thus, many small base stations are also required of which are connected to the main base station[26]. This is because 5G requires high frequency data rate. Frequency and wavelength are interrelated and higher frequency demands shorter wavelength[27]. Because of shorter wavelengths, higher spectrum band is needed and hence more small cells[28][29]. Because 5G only transmit data, more power is necessary to during high data traffic office hours but can be minimized during offload period with the activation of sleeping mode[12][30].

3.10 The Analysis of Hybrid Power System

To analysis the hybrid power generation system, some data from the MSW collection and energy efficiency research or investigations in Bangladesh have subsequently been collected[15][13]. A new model designed as a proposal for Bangladesh's new work. For calculating and simulating this paper, homer software has been used.

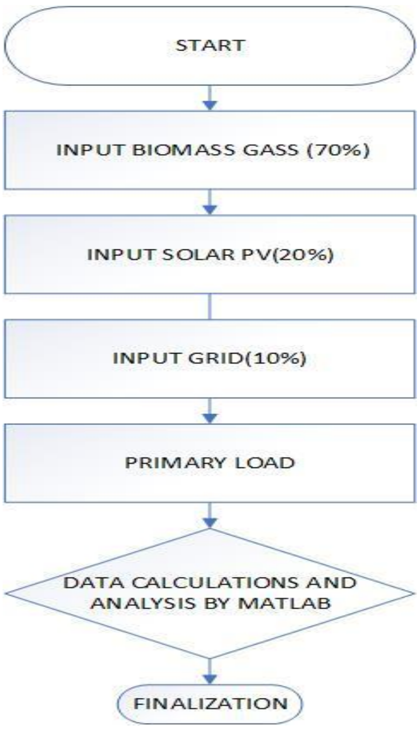

Figure 4.6 Flow Chart of Hybrid Power Generation System

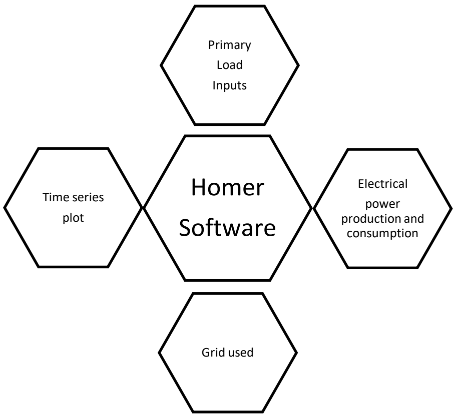

Figure 4.7 Design of Hybrid Power Generation System

The power generation system is established for a small area where a base station can cover 200 $\mathbf{m^2}$. Where running one base station per day need 8kw power per hour. The HOMER representation of the11kw/h system of Hybrid System is given below:

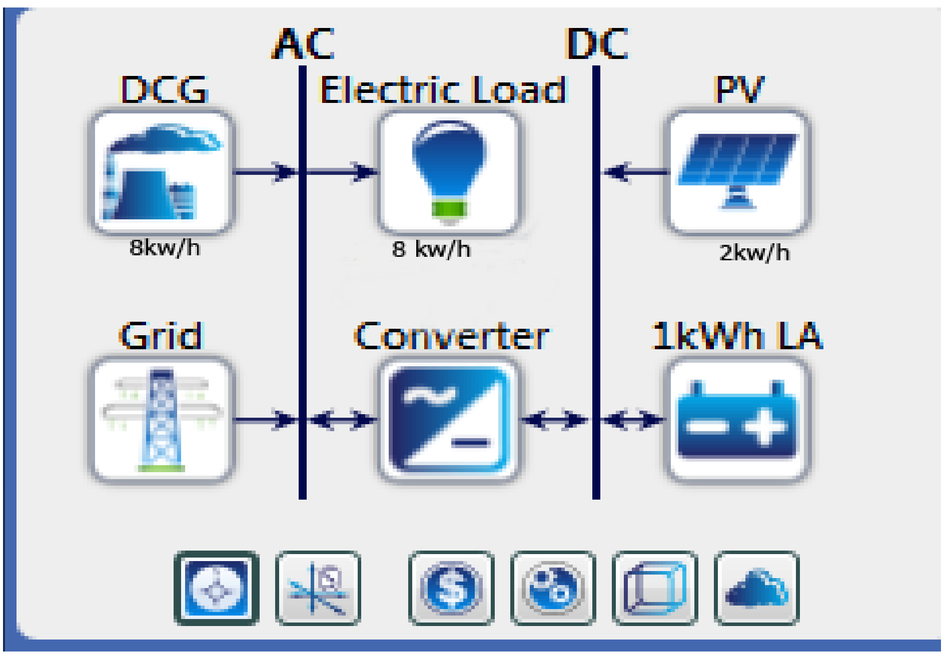

Figure 4.8 HOMER Representation of Hybrid Power Generation System

4. Results

4.1 Coverage of MIMO antenna

Here the height of the antenna is 30m and it can cover 200 $\mathbf{m}^2$ minimum. From this coverage the downlink angle 0.8594-degree, coverage radius router 5.88 feet and inner coverage radius 5.487 feet can be found.

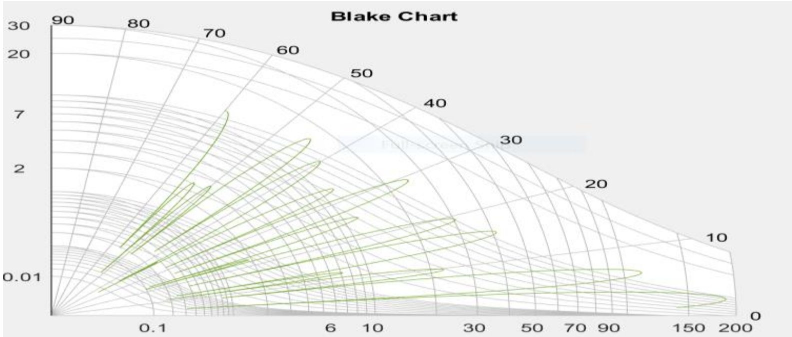

Figure 4.9 Coverage Area of MIMO antenna.

4.2 Beamforming

The beamforming graph shows the point to point MIMO OFDM system.

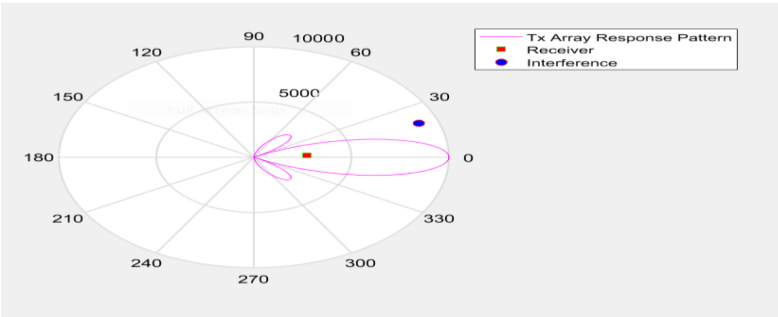

Figure 4.10 Beamforming of MIMO antenna

4.3 Return loss

The return loss in MIMO antenna for 200 m^2 is 6.02 db. Which means 25% refection and 75% power in antenna.

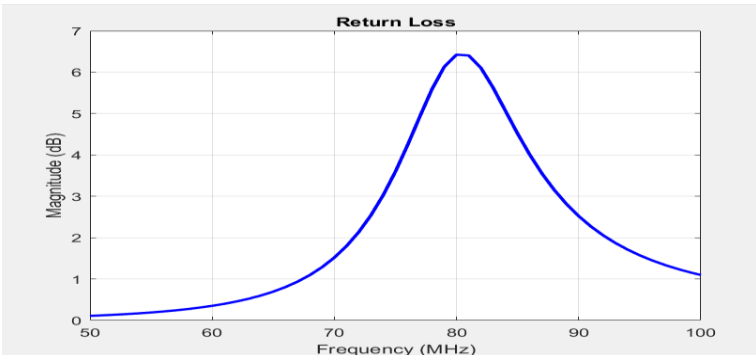

Figure 4.11 Return Loss of Massive MIMO Antenna

The return loss of SISO antenna is approximate 15 dB and the MIMO antenna is 6.02 dB So, the return loss of MIMO antenna is less than the SISO antenna.

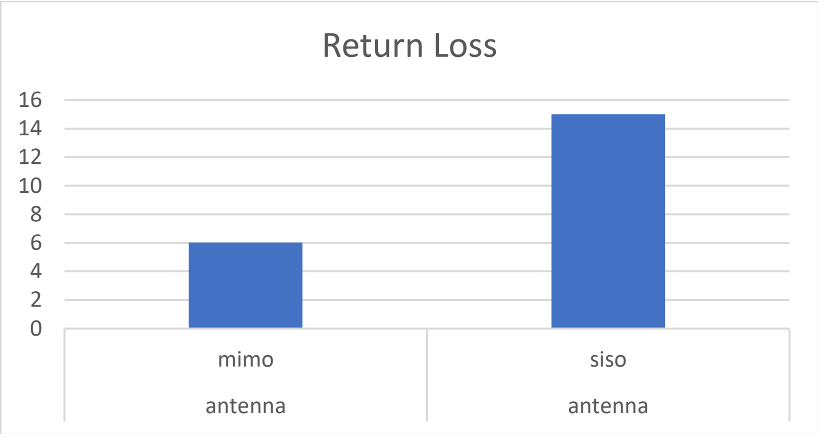

Figure 4.12 Comparison Between Return loss of MIMO vs SISO

4.4 Impedance

With distance from the antenna the impedance changes and shows contrary comportments for the dipole and the circuit. The dipole, the electric field's primary radiation source, shows a small distance from the radial ring, α/2μ while the magnetic dipoles that can be called a circle shows a limit in the impedance. The field underneath the radius sphere displays the first crossing over 377 meters. This crossover takes place very close to the system and the strong separation means that we are in receptive vicinity. The wave impedance for the dipole and the layer decreases and increases respectively beyond the radius sphere distance (β/2α). The impedance continues to converge towards the value of free space of μ=37 pounds. The wave impedance has not even converged at a distance from the antennas of 5 μ/2ד-1μ which means that it is still not far enough. The values of wave impedance are almost equal to 377 regulars at a distance of kα/2α=1 and higher. Beyond 10 λ, the wave impedance stabilizes and the region of space can be termed as the far-field for these antennas at the frequency of 1GHz.

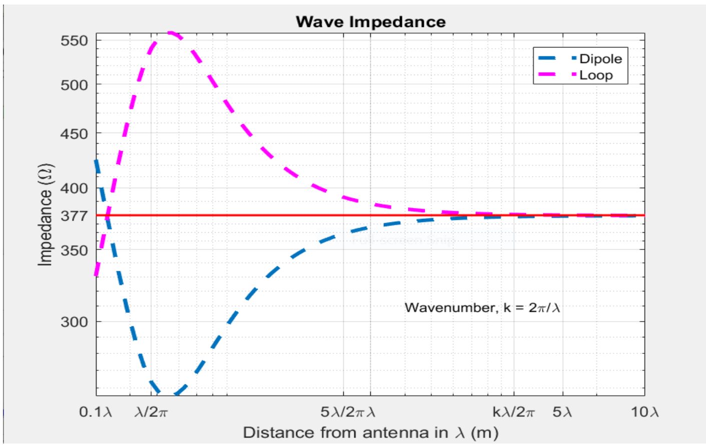

Figure 4.13 Impedance of Massive MIMO Antenna

4.5 Gain of Massive MIMO vs SISO antenna

The gain of massive MIMO and SISO antenna are 10.85 and 9.25 respectively. A more directional antenna than a low-gain one has a higher gain. So, MIMO antenna is better than the counterpart.

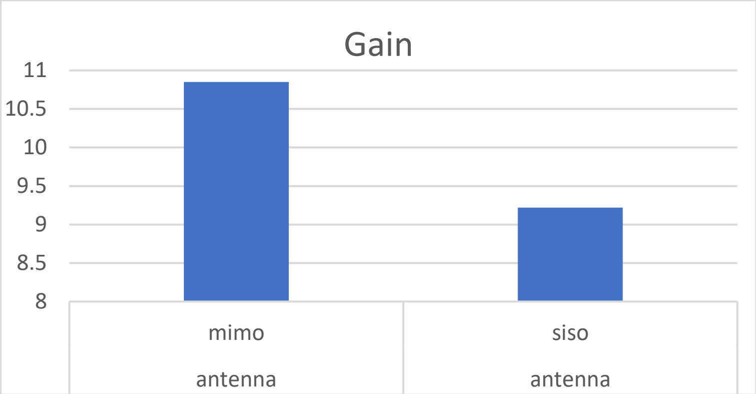

Figure 4.14 Gain of the massive MIMO vs SISO

4.6 Energy efficiency of massive MIMO vs SISO antenna

The efficiency of massive MIMO is 93.75% and the SISO antenna is 75%. So, MIMO is more efficient than the SISO.

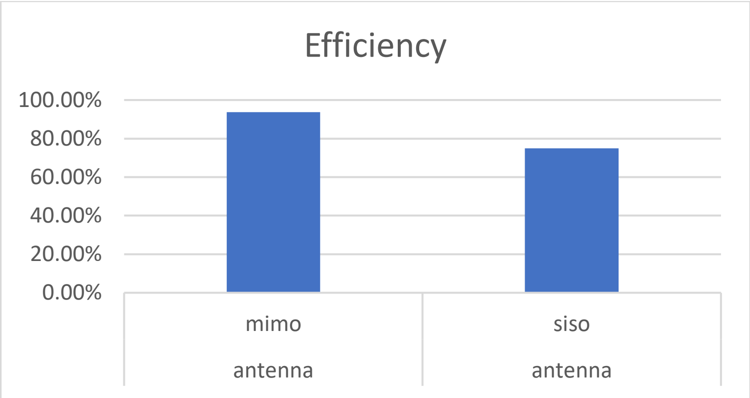

Figure 4.15 Comparison of Energy Efficiency between MIMO vs SISO

4.7 Power consumption

When the base station goes into the sleep mode during the low power transmission time it used 60% of the power. If it remains active during the low power transmission time it need 100% of the delivery power. So, during sleeping time it can consume 40% of the power.

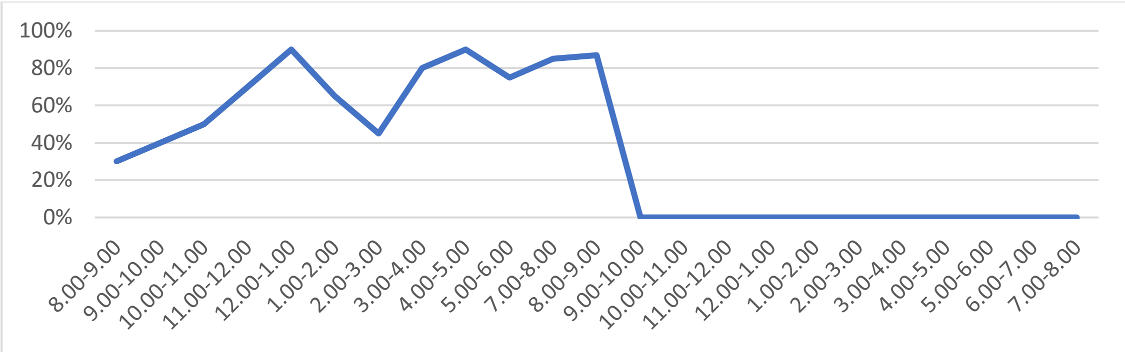

Figure 4.16 Power Usage during Sleep Mode

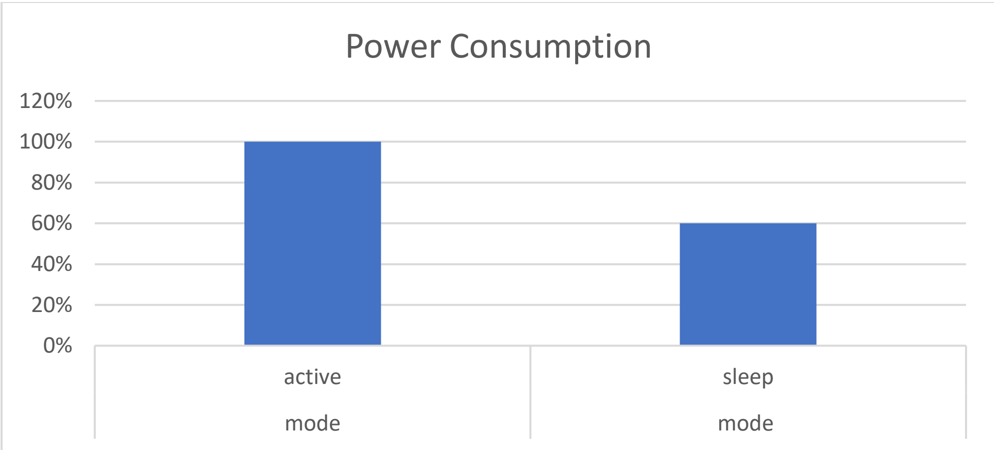

Figure 4.17 Comparison of Power Consumption between Active and Sleep mode

4.8 Power Delivery by Hybrid Power Generation System

The variation of the hybrid power generation system per month has been shown in Figure 6.18 Per day for a base station which covers 200 m^2 area and needs 11 kW power. So, monthly it needs 330 kW and yearly it need 3960 kW. But the necessity of the power is varied hourly.

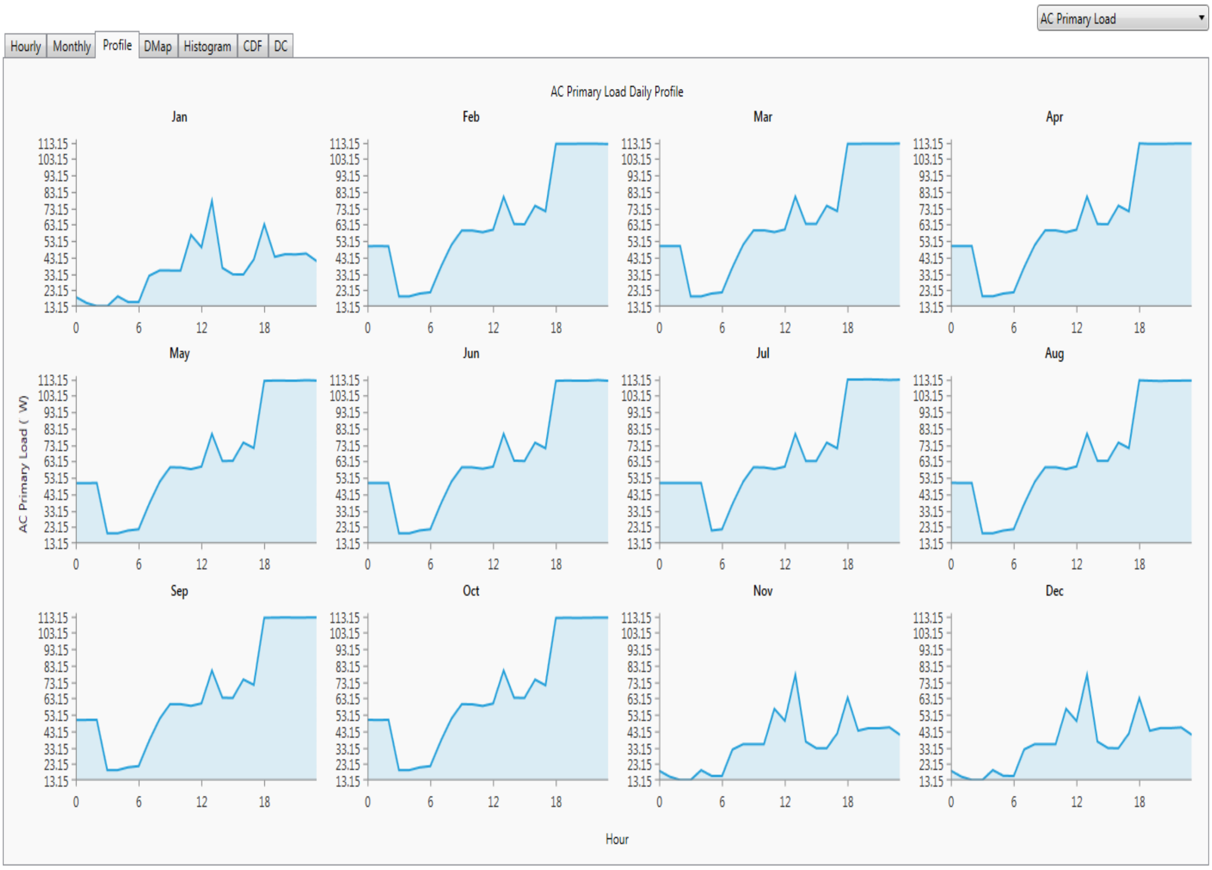

Figure 4.18 Hourly Power Variation for 12 Months

Conclusion

The study showed the increasing need for power optimization and the necessity of greener connectivity for next generation mobile network. It has also been addressed the importance of choosing the correct EE metric. Massive MIMO antenna for base station and sleeping mode technology has been discussed here to strengthen two crucial parts of power optimization, efficiency and consumption. As 5G only transmits data at high frequency, the idea of implementing 5G throughout the whole country should be eliminated. Rather to tackle the huge electricity issue and ensure proper utilization of power, automatic sleeping mode should be activated in the 5G covered industrial area for only office hours and standard LTE mode for the rest of hours. Overall, a model has been developed to further accelerate the power optimization and renewable resources-based hybrid power generation system for 5G implementation in developing countries like Bangladesh. Two major limitations are the implementation of small cell technology under one base station and the area measurement for the establishment of hybrid power generation system on which currently extensive research is undergoing.

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