

# Energy Provision Management in Hybrid AC/DC Microgrid Connected Base Station in 5G Cellular Networks

Dharmaraja Selvamuthu

Department of Mathematics  
Indian Institute of Technology Delhi  
Delhi - 110016, India  
dharmar@maths.iitd.ac.in

Aman Chauhan

Department of Mathematics  
Indian Institute of Technology Delhi  
Delhi - 110016, India  
mt6190742@maths.iitd.ac.in

Avadhesh Prasad

Department of Mathematics  
Indian Institute of Technology Delhi  
Delhi - 110016, India  
Avadhesh.Prasad.mt619@maths.iitd.ac.in

Priyanka Kalita

Department of Mathematics  
Indian Institute of Technology Delhi  
Delhi - 110016, India  
priya.24723@gmail.com

Anisha Aggarwal

Department of Mathematics  
Indian Institute of Technology Delhi  
Delhi - 110016, India  
anishaaggarwal7895@gmail.com

**Abstract**—One of the most concerning issues in 5G cellular networks is managing the power consumption in the base station (BS). To manage the power consumption in BS, we proposed a hybrid AC/DC Microgrid (MG) connected to BS in this research work. One can manage the power consumption in BS by reducing the load of the main supply in hybrid AC/DC MG connected BS. To reduce the load of the main supply in BS, one has to increase the supply of solar/wind power, which is inexpensive. To validate the statement, we need to construct a simulation model using the MATLAB/Simulink environmental simulation platform for hybrid AC/DC MG-connected BS. The MG consists of DC and AC distributed energy resources (DERs) with different types of loads and distributed generation at two voltage levels. The simulation results prove that using solar/wind power in AC/DC MG connected BS: (1) the load of the main supply in BS has been reduced, and (2) Operational cost is minimized.

**Index Terms**—component, formatting, style, styling, insert

## I. INTRODUCTION

A cellular network or mobile network is a radio network distributed over a geographical region called cells. Due to tremendous demand, recently, 5G cellular networks have developed rapidly and are used in many countries. 5G cellular networks are meant to deliver ultra-low latency, more reliability, higher multi-Gbps peak data speeds, increased availability, massive network capacity, and a more uniform user experience to more users. Compared to 4G networks, 5G is 10 to 100 times faster, but the energy consumption is 3 to 4 times higher. Therefore, the management of energy consumption in Base stations (BSs) of 5G Cellular networks is a significant issue to be considered.

To manage the energy consumption in BSs of 5G cellular networks, we need to connect hybrid AC/DC MG with BSs. For the proper energy management and control strategy, MG

requires an interlinking AC/DC converter [10]. MG is a small-scale power grid that can operate independently or collaboratively with other small power grids. MGs are classified into two groups: Alternating Current (AC) MG and Direct Current (DC) MG. MGs are typically supported by non-renewable or renewable energy resources. If the MG is working through both renewable and non-renewable sources of energy, then it is known as a hybrid MG. Renewable sources of energy include solar, wind, hydropower, biomass, etc., while non-renewable sources of energy include natural gas, coal, nuclear energy, and diesel generator. A renewable energy system (RES) provides a new technology that is capable of reducing loads of the main power supply and fulfilling the demand for power supply in interconnected and isolated systems.

MGs are considered as a possible technology for the integration of variable renewable energy systems in the traditional grid. By using solar and wind power in MG, one can solve the energy consumption problem in 5G BS [9]. MG is a power supply that can effectively absorb renewable energy (which is less expensive) with the characteristics of randomness and intermittency. Therefore, it can reduce costs, improve the reliability of the power supply and save energy [11]. But only renewable energy sources connected to MG can not manage the whole energy consumption in BSs. To manage the whole energy consumption in BSs, we need to connect hybrid AC/DC MG with BSs.

Many researchers have discussed power control, and power management in hybrid AC/DC MG systems but in recent years, little literature has been recorded for hybrid AC/DC MG connected 5G BS. Since in 5G networks, BSs are consuming a very high amount of power so hybrid AC/DC MG is the effective source of energy to manage the power consumption. Liu et al. [12] proposed a hybrid AC/DC MG system

where hybrid AC/DC MGs are connected with 5G BSs. They provided technical support for the construction of a 5G BS and the active demand response scheduling optimization of distribution networks.

#### A. motivation and main contribution

Energy consumption is a major issue in BSs of 5G cellular networks. Compared to 4G networks, 5G is 10 to 100 times faster, but the energy consumption is 3 to 4 times higher than 4G networks. Reduction of energy consumption in BSs of 5G cellular networks is very difficult as the components need some fixed energy to operate the system and also if it provides quality of service. If the system engineer wants to operate a 5G BS that provides non-stop high-speed quality of service, the BS should be connected with hybrid AC/DC MG, and they also concern power consumption management. No work has been recorded for power consumption management in hybrid AC/DC MG connected 5G BS in the literature. This motivates us to study power consumption management of hybrid AC/DC MG connected BS in 5G cellular networks.

The hybrid AC/DC MG connected BSs work through maximum main supply and less diesel generator, battery bank, and solar/wind power. Therefore, to manage power consumption, one has to reduce the load of the main supply and maximize solar/wind power. To reduce the load of the main supply and maximize the solar/wind power, we have modeled the power consumption, management model. By simulation result, it is proved that by using solar/wind, battery bank in AC/DC MG connected BS (1) a load of main supply in BS has been reduced, (2) Operational cost is minimized.

In this paper, the study is carried out via simulation using a fully-fledged MATLAB-based simulator. The Simulink module of MATLAB is used to simulate the model of the BS. The simulation time is taken as 20 seconds. The sampling time for the simulation is taken as  $5 \times 10^{-5}$  seconds to achieve high accuracy in the results.

The rest of this article is organized as follows. The establishment of the system and model is presented in Section II; the simulation model is discussed in Section III. Moreover, the simulation and the theoretical results are presented and discussed in Section IV. Finally, the paper is concluded in Section V with future work.

## II. ESTABLISHMENT OF SYSTEM AND MODEL

### A. Equipment needed for hybrid AC/DC connected 5G BS:

The equipment needed for hybrid AC/DC connected 5G BS includes power supply equipment and communication equipment. The power supply equipment is composed of power supply sources solar/wind, a diesel generator, a main supply, and an energy storage battery, and the communication equipment consists of a baseband unit, rectifier, DC-DC, and antenna interface, which is shown in Fig. 1.

Based on 5G core networks, the main function of 5G communication equipment is to send, receive, and process wireless signals and it is the interface between user equipment, ultra-reliable low latency communication, Enhanced Broadband,

and 5G cellular networks [13]. The baseband unit processing detects errors, secures the wireless signal, and ensures that wireless resources are used effectively. DC-DC supplies direct current (DC) to the Base band unit. A rectifier converts 220v alternating current (AC) to 48v DC. The antenna converts electrical signals into radio waves. It also receives the signal and transmitting to different applications. That means the BS is working through AC and DC MG. The solar/wind power supply is 48v DC.

### B. Hybrid AC/DC MG connected BS model

An AC/DC MG is a hybrid power supply system that is presented for 5G BS see Fig. 1. There are five different units of power supply to our given circuit, namely, Main supply, Solar/photovoltaic, battery bank, diesel generator, and wind turbine.

Since the wind and solar models provide DC voltage as the output, their output goes into an inverter which converts the DC supply into 220V and 50hz AC supply. The final AC bus comprises the solar and wind, diesel generator, and main supply. After that, it goes into a three-phase rectifier where it is converted into a DC supply.

At the same time, the output of the wind and solar models and the battery bank goes into a charge regulator, which regulates the input voltage to provide a 48V DC supply as output. The final DC bar then goes into the DC-DC converter, which regulates and shifts down the magnitude of the DC input. The output of the DC-DC Buck converter is fed into the baseband unit, which modulates the DC signal to a higher value in the range of radio frequencies (RF).

The modulated signal goes into the RF block, where it is converted into radio frequency, and then using a power amplifier, it is amplified. This amplified signal is then transferred into the receiver antenna, where it gets attenuated and passed into the transmission antenna, from there, it transmits to the modified signal.

### C. Power consumption management Model:

Power consumption minimization in BSs of 5G cellular networks is very difficult as the components need some fixed energy to operate the system and also if it provides quality of service. To optimize the operational cost of the BS, one of the effective ways is to manage the power consumption of the BS. First, to manage the power consumption of 5G BS, it has to be connected with a hybrid AC/DC MG. The hybrid AC/DC MG connected BSs work through maximum main supply and less diesel generator, battery bank, and solar/wind power. Therefore to manage the power consumption, one has to reduce the load of the main supply and maximize the solar/wind power. The optimization objective function is calculated by-

Minimize  $F_{Mc}$  subject to the constraint maximize  $F_{sw}$  and  $F_B$ .

$$\text{AC/DC MG: } (F_{sw}, F_B) > F_{Mc}$$

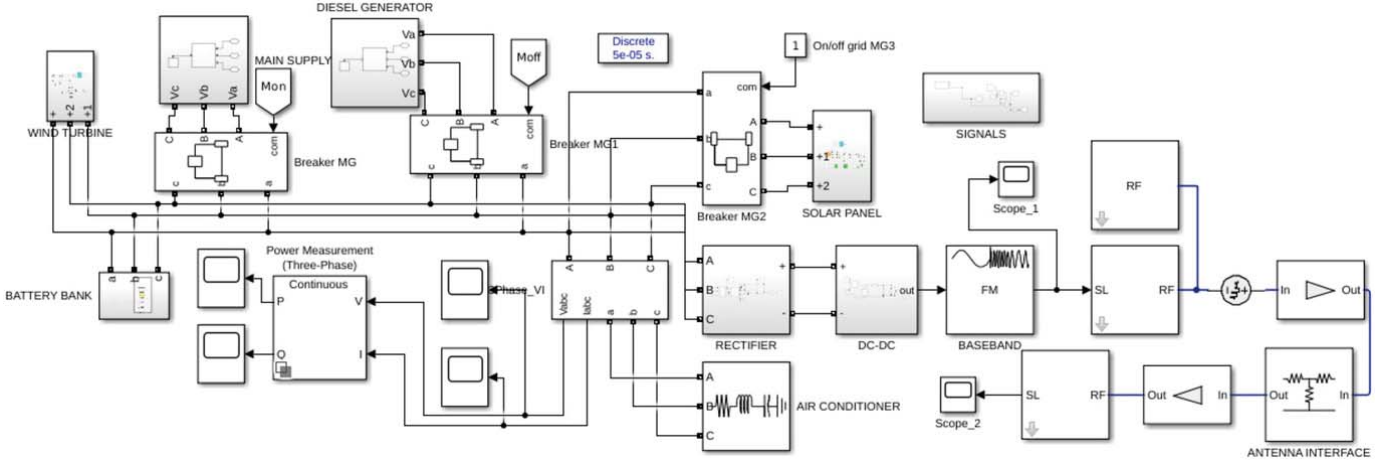


Fig. 1. Architecture of hybrid AC/DC microgrid connected BS

Where  $F_{Mc}$  represents the main supply load,  $F_{sw}$  and  $F_B$  represent solar and wind supply load.

$$\text{Min cost:}(F_{sw}, F_B) > F_{Mc}$$

Wind power, photovoltaic/solar, diesel generators, main supply, and energy storage are used to present the differences among MGs. The MG power balance and reserve constraints are calculated by

$$\begin{aligned} P_t^{MG} &= L_t^{MG} - I_t^{IL} \\ P_t^{MG} &= P_t^{DE} + P_t^{Wt} + P_t^{St} + P_t^{BE} \\ P_{t,max}^{MG} - (L_t^{MG} - I_t^{IL}) &\geq R_t^{MG} \\ R_t^{MG} &= b_1 L_t^{MG} + b_2 P_t^{Wt} + b_3 P_t^{St} \end{aligned}$$

where,  $P_t^{MG}$  represents the total power generation of MG,  $L_t^{MG}$  represents the load optimized by price response at time  $t$ ,  $I_t^{IL}$  denotes the interrupted power;  $P_t^{DE}$ ,  $P_t^{Wt}$ ,  $P_t^{St}$  and  $P_t^{BE}$  are the totals output (power supply) of diesel generator, wind power, solar power, and battery storage, respectively;  $P_{t,max}^{MG}$  denotes the maximum power generation of MG;  $R_t^{MG}$  represents the minimum reserve capacity of MG; finally,  $b_1$ ,  $b_2$  and  $b_3$  are the prediction error coefficients.

### III. SIMULATION MODEL

The following subsections discuss the topology created in the simulation environment and the steps required as per the proposed model to validate the statements.

#### A. The Topology of the architecture used in Simulation

The topology on which the implementation has been achieved makes use of the Simulink module of Matlab for simulation, which is shown in Fig. 2. Various in-built blocks from the Simulink library browser have been used for the BS model, and some circuits have been designed using the blocks.

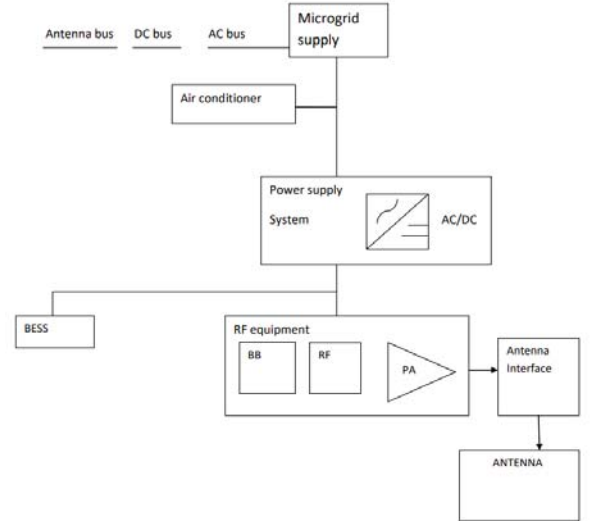


Fig. 2. Topology of a simulation model for Hybrid AC/DC MG connected BS in 5 cellular networks

The three-phase voltage measurement and the universal bridge blocks are used to design the rectifier circuit. Mosfets and Diodes are used to prepare the DC-DC Buck converter circuit. An in-built FM Modulator is used as the baseband. Various other blocks are used to design the models for the solar panel, wind turbine, and battery bank systems. The three-phase programmable AC MG is used for the Main Supply and the Diesel Generator. The various resistors, indicators, capacitors, etc., in the circuit, are used as the loads and reduce the ripples in the output.

#### B. Steps for the real-time simulation of Hybrid AC/DC MG connected BS in 5G cellular network

The steps for the simulation are as follows.

- Step 1: Run the parameter file to load the parameter values for the BS model variables.

- Step 2: Run the main Matlab model file to open and compile the Simulink model of our BS.
- Step 3: Add a power Gui block from the Simulink library browser for simulation.
- Step 4: Set the parameter for the power Gui block as discrete as we want to perform a discrete-time simulation.
- Step 5: Set the sample time for the simulation as 5e-5 seconds.
- Step 6: Set the model configuration parameters for the simulation as variable-step.
- Step 7: Set the solver configuration for the simulation as auto-solver.
- Step 8: Simulates for a time of 20 seconds.
- Step 9: Observe the results obtained and analyze them.

#### IV. SIMULATION AND THEORETICAL RESULTS

##### A. Simulation Environment

The simulation is achieved using the Simulink library of Matlab. Simulink is a Matlab tool through which various real-life models can be built. The working of the model can also be simulated using Simulink with the help of a power GUI block. For the benefit of visualization, the presented results are 20 seconds of simulated time.

##### B. Parameter settings

The parameter used for the simulation of the BS modeling is presented in Table 1 to 5. 220V AC supply has been used for the diesel generator and Main supply. The parameters are chosen with respect to hybrid AC/DC MG-connected BS.

##### C. Using Main Supply

Simulation of BS using the main supply has some parameters which are shown in the following tables.

TABLE I  
PARAMETERS FOR THE BATTERY BANK AND DIESEL GENERATOR AC SOURCE [1]

| Parameter                       | Value | Parameter | Value |
|---------------------------------|-------|-----------|-------|
| Battery Nominal Voltage         | 650V  | Amplitude | 220V  |
| Battery Rated Capacity          | 1.5ah | Phase     | 0     |
| Battery Initial State-Of-Charge | 40%   | frequency | 60hz  |
| Battery Response Time           | 30s   |           |       |
| Transformer Winding 1 Voltage   | 900V  |           |       |
| Transformer Winding 2 Voltage   | 220V  |           |       |

TABLE II  
PARAMETERS FOR THE AIR CONDITIONER LOAD AND MAIN SUPPLY [1]

| Parameter                 | Value   | Parameter | Value |
|---------------------------|---------|-----------|-------|
| Phase-to-Phase Voltage    | 1000V   | Amplitude | 220V  |
| Nominal Frequency         | 60hz    | phase     | 0 deg |
| Active Power              | 10kW    | Frequency | 60hz  |
| Inductive Reactive Power  | 100Var  |           |       |
| Capacitive Reactive Power | -100Var |           |       |

TABLE III  
PARAMETERS FOR THE BASEBAND BLOCK [3], RECTIFIER CIRCUIT [7] [8], DC-DC BUCK CONVERTER CIRCUIT [4]

| Parameter           | Value     | Parameter   | Value          |
|---------------------|-----------|-------------|----------------|
| Baseband Type       | Modulator | Voltage     | phase to phase |
| Frequency Deviation | 75hz      | Device      | Diodes         |
| Load Resistance     | 50hm      | Pulse width | 50             |
| Inductance          | 1mH       | Capacitance | 220 uF         |

TABLE IV  
PARAMETERS FOR RF AND CONFIGURATION BLOCKS, POWER AMPLIFIER CIRCUIT, ANTENNA INTERFACE [5]

| Parameter          | Value         | Parameter            | Value  |
|--------------------|---------------|----------------------|--------|
| Source Type        | Ideal Voltage | Available power gain | 0.5dB  |
| Carrier Frequency  | 5Ghz          | Input Impedence      | 50 Ohm |
| Envelope Bandwidth | 1Mhz          | Output Impedence     | 50 Ohm |
| Temperature        | 290K          | Attenuation          | 3dB    |

##### D. Observations

When the main supply is used to run the simulation, the diesel generator and battery bank are switched off, and therefore main supply is the only source to provide power in the simulation. Hence, in this case, the battery bank starts to get charged. The following are the results obtained using the main supply to power the simulation:-

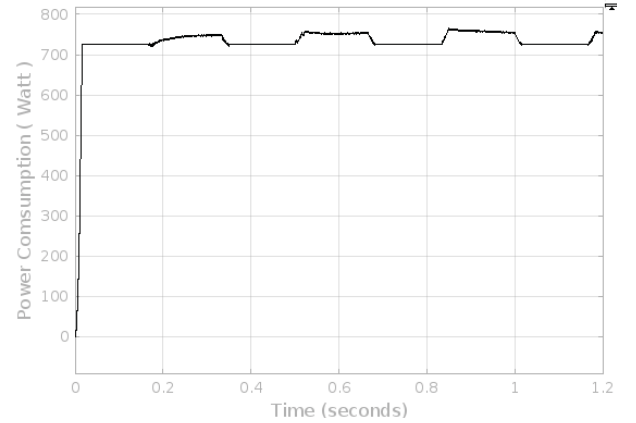


Fig. 3. Active power consumed by the air conditioner

##### a) Results:

- The active power consumed by the air conditioner load, as in Fig. 3, comes out to be 730 W, and it stays constant till the end of the simulation, indicating an uninterrupted power supply from the main source.
  - 1) Theoretical Results: The theoretical power output for the air conditioner load will be equal to  $3 * V_{rms} * I_{rms} * \cos(\phi)$ . Here  $V_{rms} = 220V$ ,  $I_{rms} = 1.8/\sqrt{2}(2)$  and phase difference is 30 degrees [2].
  - 2) Simulation Results: After simulation, the output power for the air conditioner load comes out to be about 730 W.
- It is observed from Fig. 4. that the output for power consumed by the rectifier circuit is the expected power.

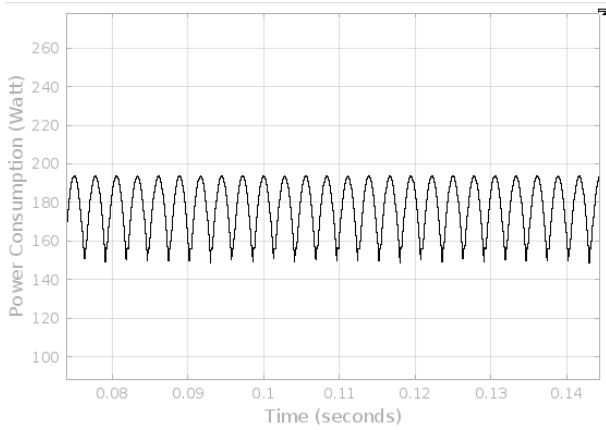


Fig. 4. Power consumed by the rectifier circuit

It can be seen that the average power comes out to be around 160 W which is close to the theoretically expected power [7].

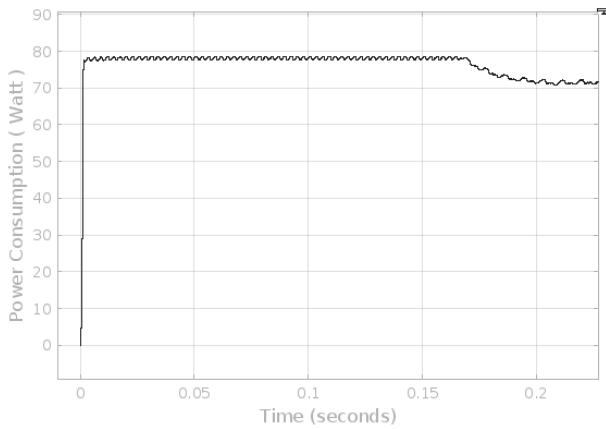


Fig. 5. Power consumed by the DC-DC Buck converter circuit

- From Fig. 5, it is observed that this graph is similar to the graph obtained for power consumed by the rectifier, but the magnitude is lower than the buck converter because the buck converter circuit regulates the voltage to a lower level and reduces ripples in the output. As a result, the power variation is only about 1 W. The power consumed is about 77 W which is reasonable because the buck converter circuit is a small circuit with just a few resistors and capacitors. Also, After a time of 0.17 second, the power consumption becomes decrease [7], [8].

#### E. Without Main Supply

When the Main Supply is switched off, or it is not working, then two cases arise. If the charging of the battery in the battery bank is less than 30%, then Diesel Generator is used to power the simulation, and if the Battery charge is greater than 30%, then the Battery Bank is used to supply the power, and Diesel Generator is switched off. The following are the

results obtained when the simulation is run in the absence of the Main Supply:-

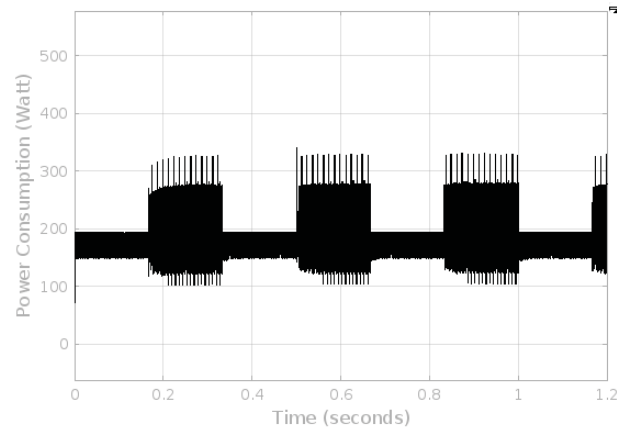


Fig. 6. Power consumed by the rectifier circuit

- From Fig. 6, it is found that when the main supply is not working and the battery bank is supplying power, the output is slightly inaccurate. The power starts at a low mean value of about 50 W but increases and becomes stable at a mean value of about 180-200 W. It can be concluded that the three-phase voltage that is fed into the rectifier is not very accurate, and that is because of the slight inaccuracy of the inverter in converting the DC supply from the battery bank to a three-phase AC supply [7].

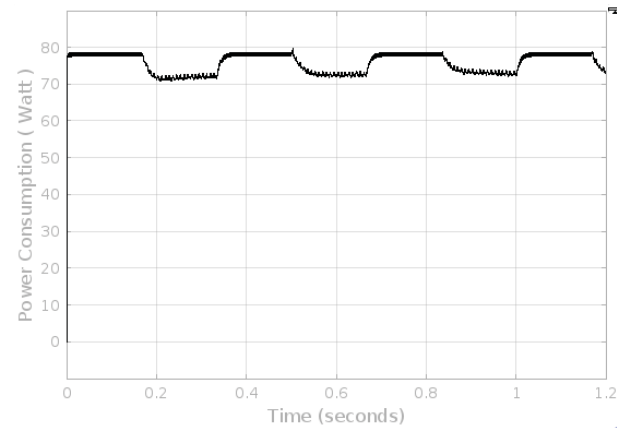


Fig. 7. Power consumed by the DC-DC Buck converter circuit

- From Fig. 7, it is found that a battery bank is used to supply the power, and it can be observed that the output is accurate. The power output starts from a low value of about 30 W and, within a very short time, increases to about 75 W, then becomes constant. The low power consumed by the buck converter is backed by theoretical data because the buck converter circuit just uses a few

loads and diodes to regulate voltage, and hence power loss is expected to be low [7], [8].

#### F. Use of Solar Energy

Based on 250-kW Grid-Connected PV Array, we have set the parameter for the Solar-Battery Charging System as presented in Table V:-

TABLE V  
PARAMETERS FOR THE SOLAR CHARGING SYSTEM [6]

| Parameter                 | Value                                                |
|---------------------------|------------------------------------------------------|
| Nominal Frequency         | 60hz                                                 |
| TsPower                   | 100/(33*60)                                          |
| TsControl                 | 10*TsPower                                           |
| Nominal Power             | 250kW                                                |
| Nominal Primary Voltage   | 25kV                                                 |
| Nominal DC Voltage        | 480V                                                 |
| Nominal Secondary Voltage | $0.85 \cdot \sqrt{3} \cdot 480 / (2 \cdot \sqrt{2})$ |
| Capacitive Reactive Power | 25kVar                                               |

#### G. Power consumption vs. different energy supply with/without solar and wind energy

Here, We observe the graphs for the power consumption of BS and energy supplied when the simulation is run:

- 1) without the use of solar and wind energy.
- 2) with the use of solar and wind energy.

This is to show how solar/wind energy will help to reduce the load of the main supply and battery bank.

In the following two graphs, the simulation is run with the main supply turned on till time  $t = 0.167s$ , and so the battery bank will be switched off at that time. After  $t = 0.167s$ , the main supply will be switched off, and the battery bank will be used to supply power to the circuit. In the first case, the simulation is run without the use of solar and wind energy, whereas in the second case, solar and wind supply is used in supplement with the main supply and the battery bank.

The power consumption of the BS is approx 1000 W (Fig.

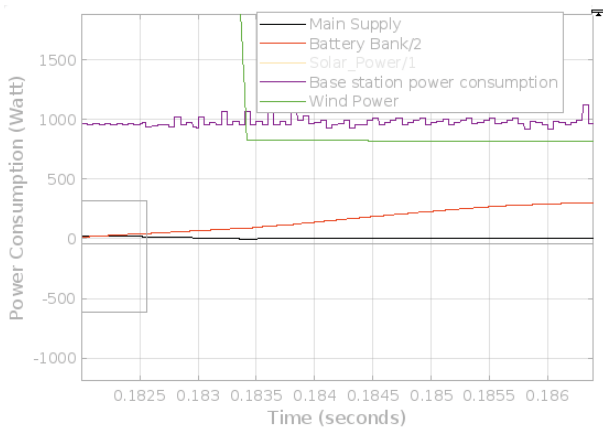


Fig. 8. Power consumption graph without solar power

8). It can be seen that power drawn from the main supply is

a little higher than the power consumed by the BS, and since the battery bank is switched off for the first 0.16 seconds, the main supply is the only energy source supplying power to the BS. After  $t = 0.167s$ , The power supplied by the main grid gradually drops to 0 as, at that instant of time, the main supply is switched off. Consequently, the power drawn from the battery bank shoots up, and now the battery bank starts supplying power to the BS.

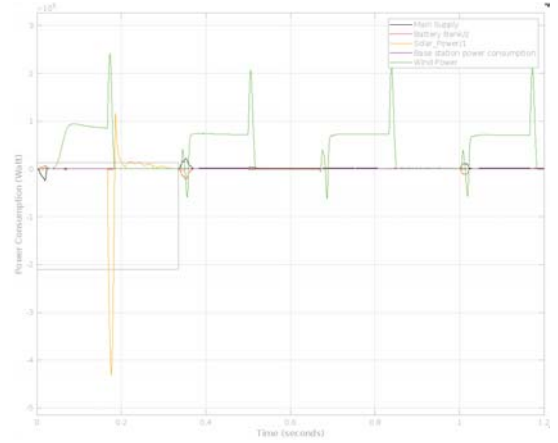


Fig. 9. Power consumption graph with solar power

- The red line in Fig. 9 indicates power drawn from the solar supply. The purple line indicates power drawn from the wind supply. Here solar supply is used with the main supply, and wind supply is used with the battery bank.
- It is found that the power supply from the main supply is greatly reduced when solar energy is used to supplement the main supply. Here solar energy becomes the primary power supplier for the BS model.
- One can also notice that as power drawn from the solar supply increases, at the same time, the power drawn from the main supply decreases. Similarly, after  $t = 0.167s$ , the main supply drops to zero as it is switched off, and the battery bank starts supplying power along with the wind supply. We can observe some spike in the circuit as at that point the circuit shifts from solar energy to wind energy as a supply source, and since the wind power starts from a very high initial value, we can see that the battery bank is getting charged initially. Here too, the power drawn from the battery bank is much lower than it was in the case of no solar/wind supply. Here the local maxima of the wind supply curve coincide with the local minima of the battery bank supply curve.

#### V. CONCLUSION AND FUTURE WORK

After running the real-time simulation and comparing the results obtained with theoretical results, it can be seen that our results are very consistent with the expected output when the main supply or diesel Generator is used to run the simulation.

On comparing graphs for the total power consumption of BS along with power drawn from various supply sources in the presence and absence of the solar/wind power supply, it is concluded that in the presence of power supply from the solar and wind block, the power supply from the main grid (supply) and battery bank is significantly reduced and as a consequence, the operational cost will also be reduced. Also, since the total dependency on the battery bank for power is less so, the time and money lost in charging the battery bank and using a diesel generator as a backup for the battery bank are also reduced. Hence, using solar/wind power can reduce the load of the main supply in 5G BS, and the cost is minimized. Further, solar or wind supply can be used as the primary source of power for small base stations.

#### REFERENCES

- [1] L. Ortiz, R. Orizondo, A. Águila, J. W. González, G. J. López, and I. Isaac, Hybrid AC/DC microgrid test system simulation: grid-connected mode. *Heliyon*, 5(12), e02862, 2019.
- [2] R. Khatri, and A. Joshi, Energy Performance Comparison of Inverter based Variable Refrigerant Flow Unitary AC with Constant Volume Unitary AC, *Energy Procedia*, 109, 18-26, 1876-6102, 2017.
- [3] <https://www.mathworks.com/help/comm/ug/fm-modulation-and-demodulation.html>
- [4] <https://www.mathworks.com/help/phymod/sps/ug/buck-converter.html>
- [5] <https://www.mathworks.com/help/simrf/ug/simulation-of-rf-systems-with-antenna-blocks.html>
- [6] <https://in.mathworks.com/help/phymod/sps/ug/250-kw-grid-connected-pv-array.html>
- [7] N. Faruk, A. A. Ayeni, M. Y. Muhammad, L. A. Olawoyin, A. Abdulkarim, J. Agbakoba, and M. O. Olufemi, Techniques for minimizing power consumption of base transceiver station in mobile cellular systems. *International Journal of Sustainability*, 2(1), 1-11, 2013.
- [8] <https://www.philadelphia.edu.jo/academics/mlazim/uploads/chapter03.pdf>
- [9] M. Gheisarnajad, M. H. Khooban, and T. Dragičević, The future 5G network-based secondary load frequency control in shipboard microgrids, *IEEE Journal of Emerging and Selected Topics in Power Electronics*, 8, 1, 836-844, 2020.
- [10] N. Eghtedarpour, and E. Farjah, Power control and management in a hybrid AC/DC microgrid, *IEEE Transactions on Smart Grid*, 5(3), 1494-1505, 2014.
- [11] N. Vafamand, M. H. Asemani, T. Dragičević, F. Blaabjerg, and M. H. Khooban, Fuzzy-observer-based predictive stabilization of DC microgrids with power buffers through an imperfect 5G network, *IEEE Systems Journal*, 14, 3, 4025-4035, 2020.
- [12] G. Liu, R. Zhang, Z. Shang, Wu, and Q. Song, Hierarchical Optimization Scheduling of Active Demand Response for Distribution Networks in 5G Base Stations, *Wireless Communications and Mobile Computing*, 8666749, 1-15, 2022.
- [13] I. Parvez, A. Rahmati, I. Guvenc, A. I. Sarwat, and H. Dai, A Survey on Low Latency Towards 5G: RAN, Core Network and Caching Solutions, in *IEEE Communications Surveys & Tutorials*, 1-29, 2017.