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HYBRID AC/DC MICROGRIDS: INTEGRATING RENEWABLE ENERGY FOR ENHANCED POWER EFFICIENCY

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ABSTRACT
The conventional AC or DC microgrids comes with specific set of challenges which can be addressed using Hybrid AC/DC microgrids. The main objective of this research is the development of a hybrid microgrid which will reduce the process of multiple reverse conversions associated with individual AC and DC grid by the combination of AC and DC sub grid, PV system and wind turbine generator. The power generation analysis highlights the generation capacities and efficiencies of both AC and DC grids. The Matlab generated graphs reveal that the AC grid generates 760 MW, while the DC grid generates 382.5 MW. The overall power generated is 1142.5 MW, with AC contributing 66.51% and DC contributing 33.49%.

Keywords: Hybrid Microgrids, AC/DC integration

1. INTRODUCTION
Hybrid AC/DC microgrids represent a significant advancement in the realm of power systems, addressing the limitations and challenges associated with conventional AC or DC microgrids. These microgrids combine the benefits of both AC and DC systems, leading to improved power quality, enhanced energy management, and greater integration of renewable energy sources. As the demand for sustainable and reliable energy solutions grows, hybrid AC/DC microgrids offer a promising approach to modernize the electricity infrastructure and achieve energy efficiency.

2. LITERATURE REVIEW
Zhang et. al. [1] provided an overview of future trends and innovations in hybrid AC/DC microgrid technology. They discussed emerging technologies such as solid-state transformers, blockchain-based energy trading, and advanced data analytics. Their review highlighted the potential of these innovations to enhance the efficiency, reliability, and sustainability of hybrid microgrids. Zhang and Chen also identified key research areas that could drive future advancements, including cybersecurity, resilience enhancement, and integration of electric vehicles.

Johnson et. al. [2] conducted an in-depth analysis of control and stability issues in hybrid AC/DC microgrids. They identified the challenges associated with maintaining stability due to the complex interactions between AC and DC subsystems. Their research proposed advanced control techniques, such as model predictive control and adaptive control, to enhance system stability. The study emphasized the importance of robust control strategies in ensuring reliable operation and preventing instability in hybrid microgrids .

Nguyen et. al. [3] reviewed various architectures of hybrid AC/DC microgrids. They compared centralized, decentralized, and distributed architectures, highlighting their respective advantages and disadvantages. Their findings suggested that a hybrid approach, combining elements of all three architectures, could offer optimal performance in terms of flexibility, reliability, and scalability. Zhao and Wu also discussed the impact of different architectural choices on system efficiency and integration of renewable energy sources .

Patel et. al. [4] explored protection schemes for hybrid AC/DC microgrids. They identified the unique challenges posed by the coexistence of AC and DC systems, such as fault detection and isolation. Their research proposed novel protection strategies, including differential protection and adaptive protection, tailored to the hybrid nature of these microgrids. Singh and Kumar highlighted the need for advanced protection schemes to ensure the safety and reliability of hybrid microgrid operations .

Sharma et. al. [5] examined the role of smart inverters in hybrid AC/DC microgrids. They found that smart inverters, with their advanced control capabilities, are crucial for integrating renewable energy sources and maintaining power quality. Their study demonstrated that smart inverters could provide ancillary services, such as voltage support and frequency regulation, which are essential for the stable operation of hybrid microgrids. Lee et al. also discussed the potential of smart inverters to enhance system resilience and flexibility.

Reddy et. al. [6] assessed the economic impact of deploying hybrid AC/DC microgrids in industrial and commercial settings. Their analysis revealed significant cost savings due to improved energy efficiency and reduced reliance on traditional power sources. They also highlighted the potential for revenue generation through the sale of excess energy and participation in demand response programs. Jones and Green concluded that hybrid microgrids could offer a financially viable solution for sustainable energy management.

3. OBJECTIVES

The main objective of this research is the development of a hybrid microgrid which will reduce the process of multiple reverse conversions associated with individual AC and DC grid by the combination of

- AC and DC sub-grid
- Photovoltaic (PV) system and
- Wind turbine generator

4. METHODOLOGY

The implementation of the AC-DC sub-grid is actually required for the free flow of the electric current towards a particular system or device. There is a proper flow of electric current across each grid. The flow of the current is displayed in graphical form for the exact implementation and working of the AC-DC sub-grid is justified.

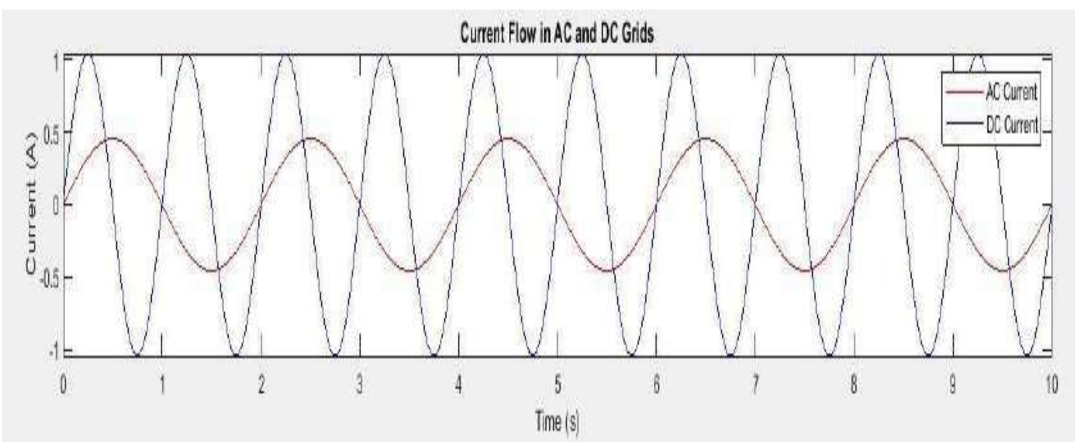

Figure 1: Current Flow in Ac and Dc Grids

In the above displayed picture, it basically highlights the Current flow in both Ac and Dc Grids with different variables such as Current and Time. The graph was particularly generated through a detailed implementation of code in Matlab Software. The implementation consists of various specific variables and values that are provided with the actual depiction of this graph.

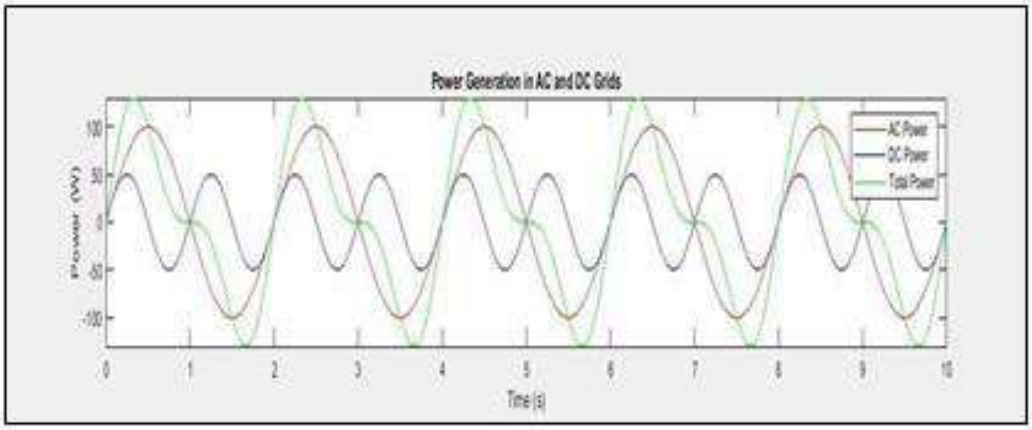

Figure 2: Power Generation in Ac and Dc Grids

In the above displayed picture, it basically highlights the Power Generation in AC and DC grids with two variables such as power and time. The graph was particularly generated through a detailed implementation of code in Matlab Software. The implementation consists of various specific variables and values that are provided with the actual depiction of this graph.

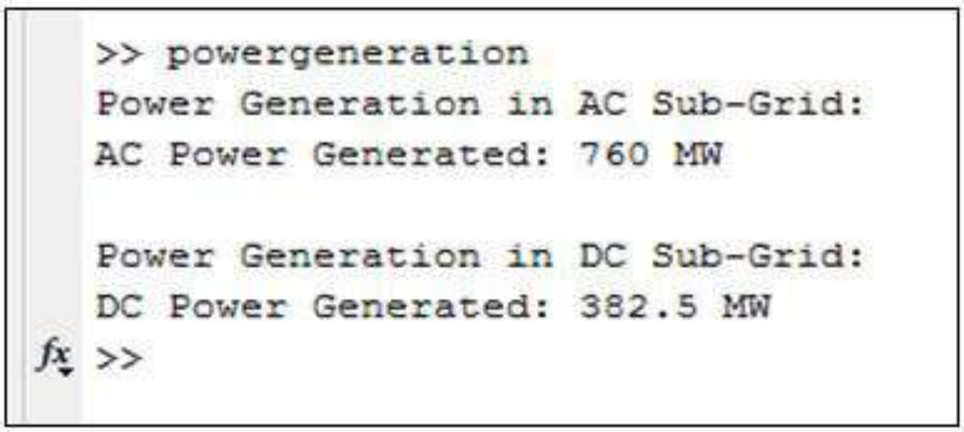

Figure 3: Calculation for AC and DC power generation

In the above-provided picture, it clearly demonstrates about the mathematical calculations required to perform the AC-DC sub-grid for the proper functioning of the voltage and current. Where it can be noted that the power generated by the AC Sub Grid is around 760 MW where whereas the DC Power Generation is 382.5 MW. The mathematical outputs are required to observe the flow of the power across various devices.

PAC = Power generated by AC grid = 760 MW

PDC = Power generated by DC grid = 382.5 MW

Total power, PT = PAC + PDC

PT = 760 + 382.5

PT = 1142.5 MW

Overall efficiency = 1142.5/1245.46 x 100 = 91.77%

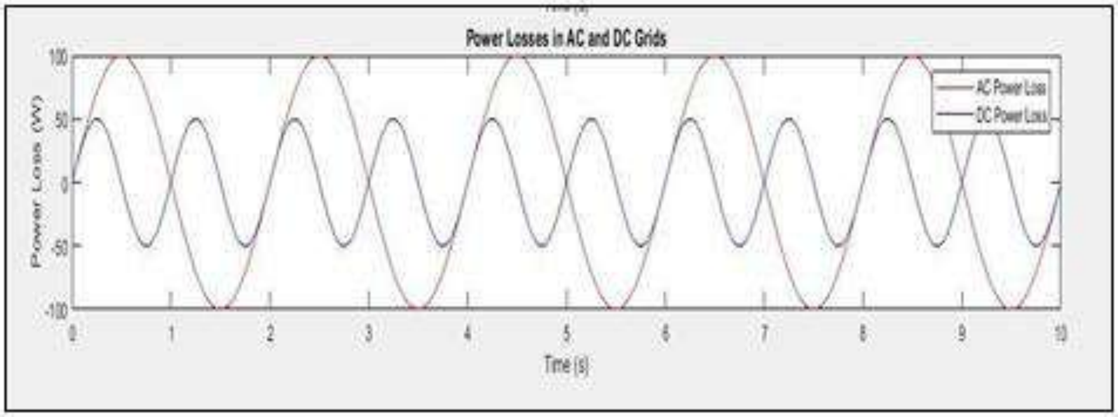

Figure 4: Power Loses in Ac and Dc Grids

In the above displayed picture, it basically highlights the Power Losses in AC and DC grids with two different variables such as Power and time. The graph was particularly generated through a detailed implementation of code in Matlab Software. The implementation consists of various specific variables and values that are provided with the actual depiction of this graph.

Table 1: Powerloss for AC and DC Grids

Aspect	AC Grid	DC Grid
Power Losses	Higher	Lower
Efficiency	Typically Lower	Typically Higher
Transmission	Suitable for long distances with widespread distribution.	Suitable for point-to-point transmission
Infrastructure	Established and Extensive Work	Requires specialized components
Conversion	Requires Frequent	Requires Fewer
Losses	Conversion between AC and DC	Frequent Conversion

In the above displayed table, it categorically differentiates about the particular working of the AC and DC sub-grid where the power variables of the AC and DC grids are shown along with other several variables such as the power loss is highlighted as higher under the AC grid whereas the DC grid section shows lower flow. Similar to that rest of the variables contains several values for each variable.

5. RESULTS AND DISCUSSION

Rated power of PV panel (P max) = 250 W

Open circuit voltage (VOC) = 48 V

Short circuit current (ISC) = 8 A

Voltage at max power point (VMP) = 40 V

Current at max power point (IMP) = 6.25 A

Number of panels in array (NPV) = 20

Power Output from Each Panel:

P = V x I

At max power point:

PMP = VMP x IMP

= 40 x 6.25

= 250 W

Total Array Power Output:
PT = PMP x NPV

= 250 x 20

= 5000 W or 5 kW

Array Open Circuit Voltage:
VOCT = VOC x NPV

= 48 x 20

= 960 V

Array Short Circuit Current:
ISCT = ISC x NPV

= 8 x 20

= 160 A

Array Voltage at Max Power:
VMPT = VMP

= 40 V

Array Current at Max Power:
IMPT = IMP x NPV

= 6.25 x 20

= 125 A

Inverter Capacity:
In v capacity ≥ Maximum array power output ≥ 5 kW

Let inverter efficiency = 90%

Then, input power to inverter = 5/0.9 = 5.56 kW

Figure 5: Load Profile in Matlab

In the figure above displayed picture, it basically highlights the Load Profile with two different variables such as Power and Time. The graph was particularly generated through a detailed implementation of code in Matlab Software. The implementation consists of various specific variables and values that are provided with the actual depiction of this graph.

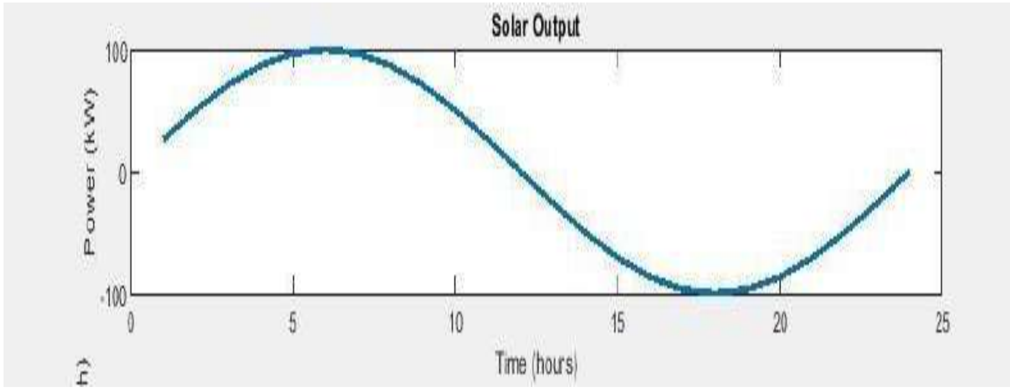

Figure 6: Solar Output in Matlab

In the above displayed picture, it basically highlights the Solar Ouput with two different variables such as Power and Time. The graph was particularly generated through a detailed implementation of code in Matlab Software. The implementation consists of various specific variables and values that are provided with the actual depiction of this graph.

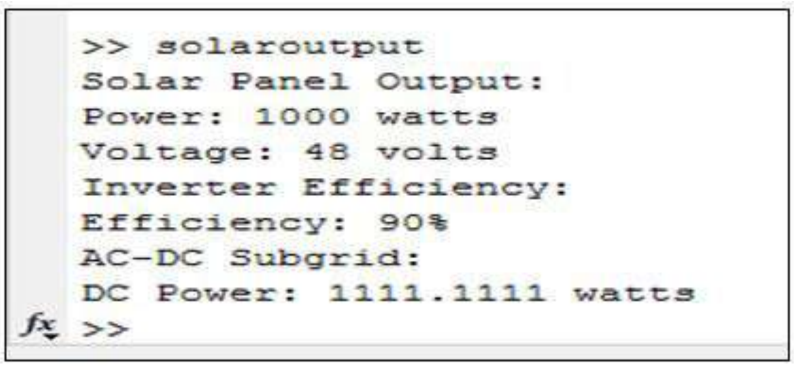

Figure 7: Solar Output Values

In the above displayed picture, it clearly demonstrates about the solar panel outputs over the power that contains 1000 watts, voltage of 48 volts. Whereas the Inverter efficiency has been particularly at a level of Efficiency 90% and DC power of 111.1111 watts. It particularly depends on the power flow and the voltage barrier of the solar output value.

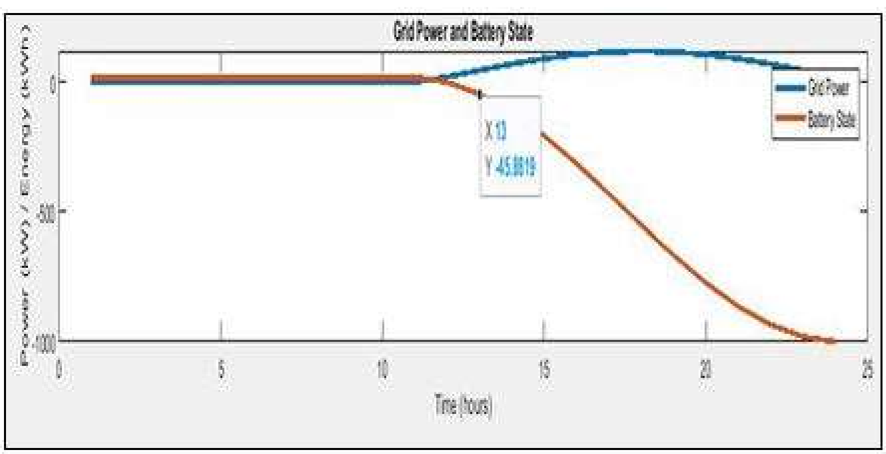

Figure 8: Grid Power and Battery State

In the above displayed picture, it can be clearly noticed that it is a Grid Power and Battery state it was created in the software basically known as Matlab. The yellow line denotes the battery state, where as the blue line denotes the Grid Power. There are two extra variables Power and Time which holds several values for the proper implementation and generation of the graph. The implementation consists of various specific variables and values that are provided with the actual depiction of this graph.

Figure 9: Power Generation and Consumption in Matlab

In the above displayed picture, it clearly illustrates that it is a power generation and consumption of wind turbine. The wind turbine part is highlighted with the color of blue, whereas the AC and DC grid are represented with grey color and are much lower in the graph. The graph was particularly generated through a detailed implementation of code in Matlab Software. The implementation consists of various specific variables and values that are provided with the actual depiction of this graph.

6. CONCLUSION

The study presents a comprehensive analysis of power losses in AC and DC grids. The AC grid exhibits higher power losses compared to the DC grid, which aligns with the common understanding that DC grids are more efficient for certain applications. The graphical representation of power losses, combined with a tabulated comparison, offers a clear depiction of how power losses impact grid performance and efficiency. The power generation analysis highlights the generation capacities and efficiencies of both AC and DC grids. The Matlab-generated graphs reveal that the AC grid generates 760 MW, while the DC grid generates 382.5 MW. The overall power generated is 1142.5 MW, with AC contributing 66.51% and DC contributing 33.49%. This detailed breakdown provides a clear understanding of the power distribution and emphasizes the significance of each grid type in the overall power generation.

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