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Design of a Power Distribution System for a Residential DC Microgrid

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***Abstract* - This research investigates the design and optimization of a direct current (DC) distribution framework tailored for residential applications. The study evaluates critical parameters, including conductor sizing, appliance efficiency, and peak power demand, to develop a functional low-voltage infrastructure. A primary goal is to maximize system-wide efficiency by mitigating transmission losses through the selection of an ideal main bus voltage. To achieve this, four distinct voltage levels (24V, 48V, 60V, and 120V) are rigorously tested under varying load conditions to reflect real-world usage. By analyzing the inherent trade-offs between different designs configurations, this project identifies the most effective voltage standard that balances performance requirements with the dynamic needs of a modern DC-powered home.**

Keywords: DC Power Distribution, Residential DC House, Low-Voltage Distribution System, DC Powerhouse, Power Efficiency, Power Loss Reduction, Main Bus Voltage, Energy-Efficient Loads, Electrical Distribution Design, DC Electrical System, Voltage Optimization, Wire Size Analysis, Renewable Energy Integration.

I. INTRODUCTION

Extensive academic discourse has highlighted the potential of DC microgrids and distribution networks to revolutionize building energy systems. These systems offer significant advantages, such as minimizing conversion stages, enhancing power reliability, and integrating DC-native technologies more seamlessly [1–6]. Consequently, DC architectures have already gained traction in specialized sectors like data centers and commercial lighting [7, 8]. However, there is an ongoing debate regarding their broader integration into residential settings. Currently, half of the energy used in buildings is either consumed directly as DC or converted to DC for motor and electronic control. Relying on the traditional AC grid for these loads often results in substantial energy waste due to inefficient rectification processes [9]. By utilizing local DC sources, such as photovoltaic (PV) systems, dedicated DC circuits can bypass unnecessary inversion and rectification cycles.

The residential industry represents a vital frontier for DC adoption, accounting for roughly 22% of U.S. energy consumption and 21% of total greenhouse gas emissions—the majority of which stem from electricity use [10, 11]. Since lighting, electronics, and various appliances (comprising 35% of home energy demand) can run on DC, the transition is technically viable [12, 13]. This shift is further supported by the falling costs of solar modules and favorable policy frameworks, which continue to drive the expansion of residential PV systems [14, 15].

Prior research in the commercial domain suggests that DC-based power can lower lifecycle costs and improve electronic system resilience [2, 4]. For instance, a study on a 48,000 ft² office space indicated that DC LED lighting could reduce capital and annual costs by up to 21% compared to conventional AC setups [16]. While commercial implementations are already being deployed by firms like Redwood Systems [17], residential research has branched into three main pillars: technical feasibility, architectural challenges, and energy-saving estimations.

Studies have confirmed that most modern household appliances are compatible with DC power [12]. While technical discussions regarding standard voltage levels continue, organizations like the Emerge Alliance and Lawrence Berkeley National Laboratory have proposed specific frameworks [18–22]. Regarding efficiency, some estimates suggest that centralizing AC-to-DC conversion could save 25% of residential energy [9]. Other simulations for "direct-DC" homes equipped with PV show electricity savings ranging from 5% (without storage) to 14% (with storage) [12, 19].

This paper builds upon existing literature by introducing a more granular analysis. It incorporates real-world efficiency curves from manufacturer data, precise cable specifications for various voltages, and diverse load profiles. This approach ensures a higher degree of accuracy in assessing the technical and financial viability of residential DC systems, specifically regarding protection costs and component ratings.

II. DEVELOPMENT AND CONSTRUCTION

"For the purpose of this research, a unipolar topology was selected, as it is particularly effective for residential structures with modest energy requirements. The proposed photovoltaic

(PV) framework is configured to power a standard residence consisting of a living area and two bedrooms, the layout of which is illustrated in Figures 1 and 2. To evaluate the performance of the system under pure PV generation, the study examines four prevalent DC bus voltage standards: 24 V, 48 V, 60 V, and 120 V."

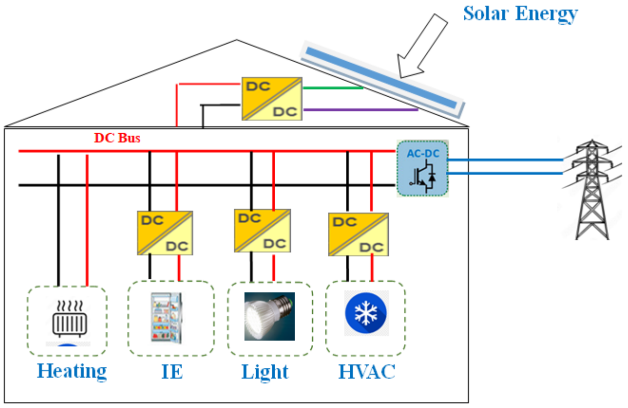


Figure 1: Adopted unipolar topology of DC Residential house

To compare the overall efficiency of different power distribution systems, we consider a typical residential house with 1 floor, as shown in Figure 1. The house has a power distribution network that connects two sources (the utility grid and solar panels) to the household loads through distribution conductors. Utility power is the primary source of electrical energy, with solar power as a supplementary source, as is common in residential homes.

Previous research in this field suffered from the lack of realistic data, such as converter efficiency curves that prevent accurate results. Realistic data for load and generation, converter efficiency curves, and wiring models for small buildings were used in our project.

Figure 2 shows the adopted two-bedroom DC house plan, the appliance placement, and the electrical wiring diagram.

Elements considered in system efficiency include MPPT CC, DC-DC converters, PV generation, wire size, wire type, and appliances. The construction of these elements will be given in detail in this chapter.

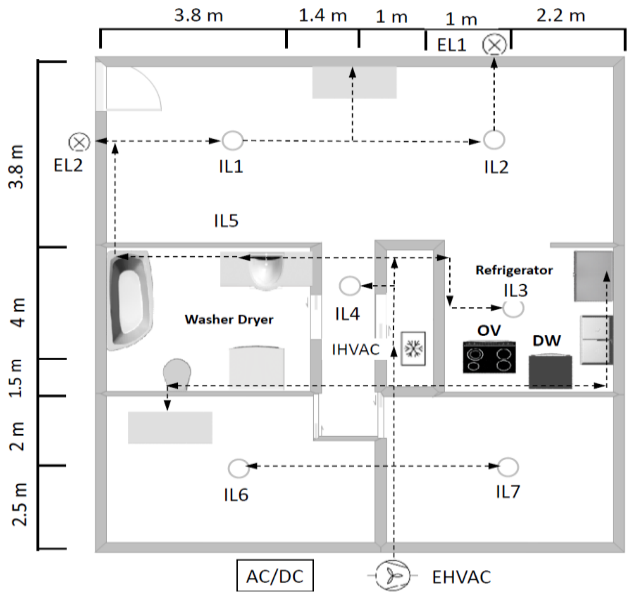


Figure 2: Electrical wiring diagram of one living room and two-bedroom house

2.1 Loads

There are several examples of loads in residential and commercial buildings that operate on DC power. Here are some common examples:

1. LED Lighting: Light-emitting diode (LED) lighting systems natively operate on DC power. LEDs are low-voltage devices that require direct current for operation. By directly supplying them with DC power, the need for AC to DC conversion is eliminated, resulting in more efficient lighting systems. Lighting technology used in the Residential is LED lighting requires.

2. Interior Equipment (IE): Many electronic devices and appliances, such as smartphones, laptops, tablets, and televisions, operate on DC power internally. These devices typically include built-in rectifiers to convert the incoming AC power to the required DC voltage. By utilizing DC power directly, the efficiency of these devices can be improved. Table 1 shows some loads.

DC refrigerators/freezers can be found on the market as interior equipment, and they are the principal power consumers in this category. A 424 L refrigerator/freezer is common for a two-person household. According to the manual WRT106TFD, the minimum annual power usage is 311 kWh, and the maximum annual power consumption is 455 kWh. At its lowest and highest power use, a DC refrigerator of the same capacity consumes 200 kWh and 316 kWh per year, respectively. As a result, the average AC refrigerator consumes nearly 1.5 times the electricity of its DC equivalent. According to the statistics, interior equipment consumes about

1121.6 kWh per year, whereas a standard AC refrigerator consumes 344 kWh per year.

Table 1: Consumption of some interior equipment

Load	Power	
	Min	Max
LED	3	15
Laptop	30	90
TV	50	150
Fan	10	35
Charger	5	20
Speaker	5	50
Hier dyer	500	1500
Toothbrush	5	15
Printer	300	700

3. HVAC Systems: Heating, ventilation, and air conditioning (HVAC) systems often employ variable speed drives or DC motors for improved control and energy efficiency. These components operate on DC power and integrating them into a DC power distribution system eliminates the need for additional AC to DC conversion stages.

In hot-humid climates an AC current Heating, ventilation, and air conditioning system of 24 KBTU capacity is suitable. Table 2 gives the equivalent DC HVAC system that can be used given the same cooling/heating. We remark that the rated power scaling factor is about 0.67.

Table 2: AC and DC HVAC specifications

Type	Model	Cooling (BTU)	Heating (BTU)	Rated Power (W)
DC	SWWR-7.2IM	24000	25000	2039
AC	GSZ16-0241B	24000	24000	3010

4. Renewable Energy Systems: Solar photovoltaic (PV) systems, which generate electricity from sunlight, produce DC power. Integrating these systems with a DC power distribution network allows for a more seamless integration of renewable energy sources, as the generated DC power can be directly utilized by the loads without the need for conversion.

5. Water Heater DC: The water heater is a very important appliance, especially during cold days. In the market, this appliance is considered rare; nevertheless, DC water heating components with capacities of up to 2000 W are available in 48 V, 24 V, and 12 V. [23] Given that water heater components can be easily made at any DC low voltage and their power ratings may be modified, DC water heaters are expected to be accessible in the future. During the project the DC heater will be directly connected to the DC bus without the need to use any power converter.

By identifying and utilizing DC-powered loads in residential and commercial buildings, it becomes possible to create more efficient and sustainable systems by avoiding unnecessary AC to DC conversions and minimizing energy losses.

2.2 Electrical wiring

Another important consideration is the wiring. To begin, the size of the cable is determined by the voltage level. A LVDC distribution system for a two-bedroom house is explored in this project, with one voltage level. The number of wires required is determined by the amount of current to be sent, and the amount of current is determined by the voltage level of the bus in the house's distribution system. As a result, greater voltage levels result in fewer currents, requiring smaller cables. Furthermore, conduction losses are proportional to the square of the current, therefore the lower the current, the smaller the losses.

The electrical design must meet standard regulations. The conditions which determine the wire diameter are:

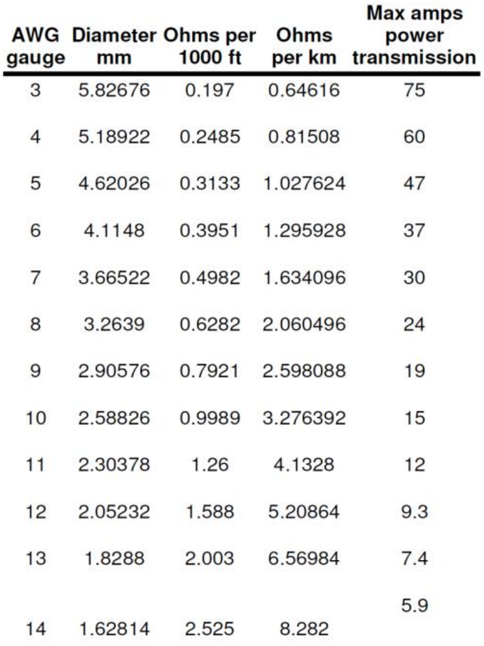
- Highest tolerable temperature of conductors.
- Allowable voltage drops.
- Maximum impedance at which short circuit protection still works.

The selection of the wire cable type is based on NEC requirements. Wire sizes, including cost per meter, are taken from [3]. The wire selected is a 2-conductor flexible wire, UL-listed, stranded type THHN/THWN AWG.

Table 4 gives a more detailed description of the wire type chosen and the cost associated with choosing AWG No. 10.

Selecting the appropriate American Wire Gauge (AWG) is pivotal for optimizing system efficiency. While increasing conductor cross-sections incurs higher capital costs, it is essential for handling significant loads and their associated inrush currents. Undersized cabling not only restricts current delivery—potentially leading to equipment malfunction—but also poses safety risks. In accordance with NEN 1010 regulations, cable sizing in this study is constrained by a maximum thermal threshold of 70°C for conductors. Furthermore, to comply with NEC safety standards, the maximum cable length is determined based on a permissible voltage drop limit of 5%.

Table 3: AWG Characteristics



AWG gauge	Diameter mm	Ohms per 1000 ft	Ohms per km	Max amps power transmission
3	5.82676	0.197	0.64616	75
4	5.18922	0.2485	0.81508	60
5	4.62026	0.3133	1.027624	47
6	4.1148	0.3951	1.295928	37
7	3.66522	0.4982	1.634096	30
8	3.2639	0.6282	2.060496	24
9	2.90576	0.7921	2.598088	19
10	2.58826	0.9989	3.276392	15
11	2.30378	1.26	4.1328	12
12	2.05232	1.588	5.20864	9.3
13	1.8288	2.003	6.56984	7.4
14	1.62814	2.525	8.282	5.9

To determine the required conductor lengths and cross-sectional areas, the total number of circuits within the DC residence was established. As illustrated in Figure 2, this study assigns dedicated circuits to individual rooms and high-power appliances. The wire gauge for each circuit was derived by analyzing load requirements against maximum allowable current ratings. According to the data in Table 4, AWG 12 serves as the primary cable size for general wiring. However, substantial components such as the HVAC system, water heater, and PV arrays necessitate larger conductor gauges, particularly at lower operating voltages. This highlights a critical economic trade-off: lower DC voltage levels require increased conductor cross-sections to manage higher current densities, subsequently driving up overall installation costs.

Table 4: Wire size, length, and total wire cost at each voltage level

Voltage Level (V)	Estimated Wire Length (m)					Total Wire Cost ($)
	AWG 12	AWG 6	AWG 2	AWG 2/0	AWG 4/0	
24	357.4	20.4	11.6		20.4	1505
48	357.4	20.4	11.6	20.4		1190
60	357.4	32	20.4			795
120	357.4	52.4				528

2.3 Power Converters

DC appliances are often built to work at certain DC bus voltages, most commonly 24V and 48V. As a result, voltage conversion stages are required for integrating these appliances into a DC nanogrid Renewable Energy (DC-NRG) system because the existing DC appliances run at different voltage levels than the overall system voltage. These stages ensure that the appliances and the DC-NRG system are compatible. Power can be delivered to appliances more effectively by converting the system voltage to match the appliance voltage.

DC-DC converters are essential in voltage conversion stages. They are used to increase or decrease the DC voltage to the required level. Step-up converters boost voltage while step-down converters lower it. These converters are available in a variety of configurations, including buck converters, boost converters, and buck-boost converters may be used.

LED lighting systems are frequently powered by low DC voltages such as 12V or 24V. LED drivers control the voltage and current sent to LEDs, guaranteeing optimal performance and longevity.

It is critical to guarantee compliance with relevant standards and regulations when incorporating power converters into a DC-NRG system. This includes criteria for safety, efficiency, and compatibility with other system components. The use of certified and compliant power converters contributes to the safe and dependable functioning of the DCNRG system.

At each voltage level, the MPPT CC, rectifier, inverter, and LED drivers are required. In the dc nanogrid, a market-ready power converter is selected for each appliance or source, as shown in Table 5. A sufficient number of converters are connected in parallel to satisfy the power rating need based on the power rating required. Some DC appliances, such as the HVAC unit, do not require DC-DC converters; for example, the DC air conditioner (HVAC) unit can operates without the use of a DC-DC converter at 48-60 V DC; that is, the HVAC unit is directly connected to the DC bus at 48 V and 60 V; however, it needs a DC/DC converter to be connected to the 24 V or 120 V DC bus. The rectifier, MPPT charge controller, and LED drivers are required at each voltage level.

Table 5: Converters, their prices, and efficiency (full load) at each voltage level

Converter	Voltage level	24	48	60	120
AC–DC	Model	LCM3000Q-T	LCM3000W-T	CP3000/3500A	HEP-1000-100
	Unit price ($)	652.93	652.93	761.27	422.25
	Required No	2	2	2	6
	Efficiency (%)	91	91	89	96
MPPT	Model	XTRA4415N	XTRA4415N	TS-MPPT-60-600V-48	SRXHV 300/30
	Unit price ($)	249.99	249.99	1009.95	809
	Required No	2	2	1	1
	Efficiency (%)	96	98	96.5	98.5
HVAC	Model	CFB600-24S48	-	-	DDR-480D-48
	Unit price ($)	232.30	-	-	191.52
	Required No	5	-	-	5
	Efficiency (%)	92	-	-	92.5
LED Driver	Model	LDD-700L	LDD-700H-DA	LDD-600H	PLC-30-15
	Unit price ($)	3.15	11.41	4.39	22.43
	Required No	9	9	9	9
	Efficiency (%)	95	95	96	87
Interior Equipment	Model	-	CQB150W	CHB150	CHB150
	Unit price ($)	-	174.52	150	150
	Required No	-	1	1	1
	Efficiency (%)	-	86	93	93
Total cost ($)		2979.49	2083.05	2722.00	4651.97

The total converter cost for 48 V is less than other voltage levels. The total converter cost for 24 V and 60 V DC-RNGs are close and less than 120 V DC-RNG. 120 V DC-RNG converter cost is more than twice that of 48 V DC-RNG.

2.4 Protection

The LVDC system is a newer concept that operates on DC power and aims to provide safety levels that are equal to or higher than traditional AC distribution systems. The protection scheme discussed in this section considers the LVDC system, starting from the DC district and extending up to the customer-end protection. The analysis covers both grounded TN (Terrestrial Neutral) and ungrounded IT (Insulated Terrestrial) grounding arrangements.

In a DC system, respecting the current direction has a remarkable importance; therefore, it is necessary to correctly connect the loads by respecting the polarities, since, in case of a wrong connection, operation and safety problem could arise.

III. CIRCUIT BREAKER

When selecting a DC circuit breaker, it's crucial to consider factors such as voltage rating, current rating, arc interruption capabilities, coordination with protection systems, and compliance with applicable standards and regulations. Consulting with electrical engineers and referring to manufacturer specifications and guidelines are essential steps in choosing the appropriate DC circuit breaker for a given application.

To estimate circuit breaker cost for the DC-RNG residential nano grid, as presented in Table 6, circuit breakers are considered for the kitchen, living room, bedrooms, bathroom, and high-power appliances, such as HVAC and water heater, battery bank, and one main circuit breaker for the DC-RNG. In a conventional house’s protection, circuit breakers are dedicated to the refrigerator, dishwasher, microwave, and electric range circuits in the kitchen. Although specific DC appliances are not chosen for these loads in this paper, four different circuit breakers with the same current ratings are selected for the kitchen circuit to evaluate the protection cost accurately.

Table 6: Circuit breakers and their cost

DC Bus Voltage (V)	24		48	
Circuit Breaker	Product ID	Price ($)	Product ID	Price ($)
Kitchen	1SDA068092R1	813.65	1SDA066808R1	196.82
Room 1	1SDA066807R1	166.53	1SDA066804R1	133.64
Room 2	1SDA066807R1	166.53	1SDA066804R1	133.64
Living Room	1SDA066808R1	196.82	1SDA066805R1	134.77
HVAC	1SDA066807R1	166.53	1SDA066804R1	133.64
Water Heater	1SDA100566R1	1379.78	1SDA066806R1	252.68
Bathroom	1SDA068058R1	627.66	1SDA066807R1	166.53
Battery	1SDA067020R1	427.01	1SDA066809R1	252.68
Main Circuit Breaker	1SDA100762R1	2671.64	1SDA100416R1	1499.59
Total Price ($)	9057.10		3494.45	

DC Bus Voltage (V)	60		120	
Circuit Breaker	Product ID	Price ($)	Product ID	Price ($)
Kitchen	1SDA066807R1	166.53	1SDA066804R1	133.64
Room 1	1SDA066803R1	133.12	1SDA066800R1	131.55
Room 2	1SDA066803R1	133.12	1SDA066800R1	131.55
Living Room	1SDA066804R1	133.64	1SDA066801R1	130.52
HVAC	1SDA066803R1	133.12	1SDA066801R1	130.52
Water Heater	1SDA066808R1	196.82	1SDA066805R1	134.77
Bathroom	1SDA066806R1	157.91	1SDA066803R1	133.12
Battery	1SDA066808R1	196.82	1SDA066805R1	135.21
Main Circuit Breaker	1SDA100415R1	1272.97	1SDA068059R1	738.22
Total Price ($)	3023.64		2200.02	

Circuit breakers with multiple poles can be configured in either series or parallel arrangements. While series configurations are typically reserved for high-voltage environments, parallel setups excel in high-current, low-voltage scenarios. Given the low-voltage characteristics of DC-RNG systems, a parallel pole configuration is an ideal choice for the protection architecture. Implementing two parallel poles allows for a capacity of 1.6 times the standard DC breaker rating, whereas a triple-pole parallel arrangement extends this to 2.25 times. For safety and performance, the selected breaker rating should represent 125% of the total load current

3.1 Wire, converters, circuit breaker cost analysis

In evaluating the efficiency of a DC-RNG across various LVDC levels, the selection of converters and conductor gauges plays a pivotal role, making component expenditure a critical factor in comparative analysis. Furthermore, the implementation of a DC-RNG necessitates protection systems tailored to specific voltage requirements. Since parameters such as voltage ratings, nominal current, and short-circuit capacity vary by level, this study incorporates the capital costs of cabling, power converters, and protective hardware into the overall assessment.

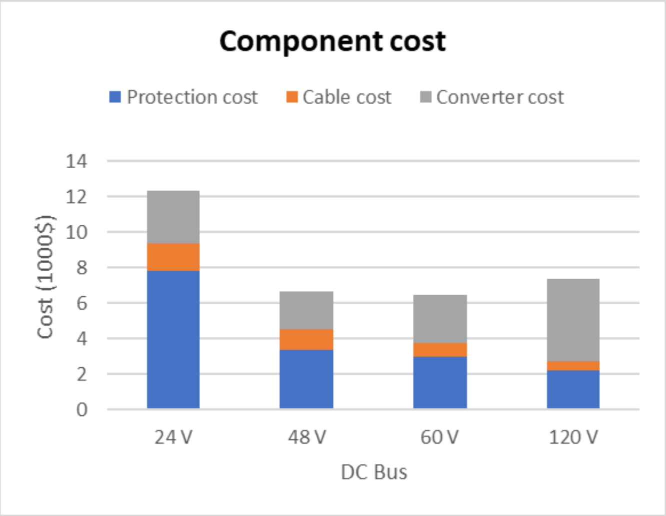


Figure 3: Total component cost at each voltage level

As shown in Figure 3, the total component costs for the 24 V and 48 V DC-RNG implementations are the highest and lowest, respectively. Protection costs are the primary driver of the total expenditure at both of these voltage levels. However, moving from 24 V to 48 V yields a significant reduction in converter, cabling, and protection costs.

When the DC bus voltage is increased to 60 V, cabling and protection costs continue to decrease, but converter costs begin to rise, making the total component cost slightly higher than that of the 48 V system. At 120 V, while cabling and protection costs reach their lowest points, the high cost of converters results in a total system cost that exceeds both the 48 V and 60 V configurations.

Following the cost analysis in the previous chapter, this chapter evaluates the energy efficiency of the DC nanogrid distribution system and establishes a general framework for its implementation. The primary objective is to identify the optimal bus voltage that maximizes system efficiency, accounting for wire sizing, varying load profiles, and the efficiency curves of real-world power converters. To ensure accuracy, the system—including specific wire lengths, cross-sections, and converter models—was modeled and simulated using ETAP (Electrical Transient Analyzer Program), with power flow analysis serving as the primary metric for efficiency assessment.

As illustrated in Figure 3, the total component costs for the 24 V and 48 V DC-RNG implementations represent the highest and lowest expenditures, respectively. At both 24 V and 48 V, protection costs are the primary contributor to the total investment. However, moving from 24 V to 48 V results in a simultaneous reduction in converter, cabling, and protection costs.

When the DC bus voltage is increased to 60 V, cabling and protection costs continue to decline, but converter costs begin to rise, leading to a total component cost slightly exceeding that of the 48 V system. At 120 V, while cabling and protection costs reach their minimum, the substantial increase in converter costs causes the total expenditure to surpass both the 48 V and 60 V configurations.

Building upon the cost analysis presented in the previous chapter, this chapter evaluates the energy efficiency of the DC nanogrid distribution system and establishes a framework for its implementation. The primary objective is to identify the optimal main bus voltage that maximizes system efficiency. This analysis accounts for critical variables, including wire gauge, diverse loading conditions, and the specific efficiency curves of real-world power converters. To ensure a high degree of accuracy, the system—including precise wire lengths, cross-sections, and converter characteristics—was modeled in ETAP (Electrical Transient Analyzer Program), utilizing power flow analysis as the core tool for efficiency assessment.

IV. SIMULATION AND RESULTS

In this type of DC residential nanogrid, loads can be supplied in three ways: through PV panels, through the AC grid, or a combination of both. However, for this project, the choice has been made to exclusively draw all the power required by the loads from PV panels.

A 4 kW PV panel system was utilized as the power source, and it was connected to the DC Bus. The objective was to determine the most efficient DC Bus voltage among four different options: 24V, 48V, 60V, and 120V. The efficiency of the system was evaluated based on these different voltage configurations.

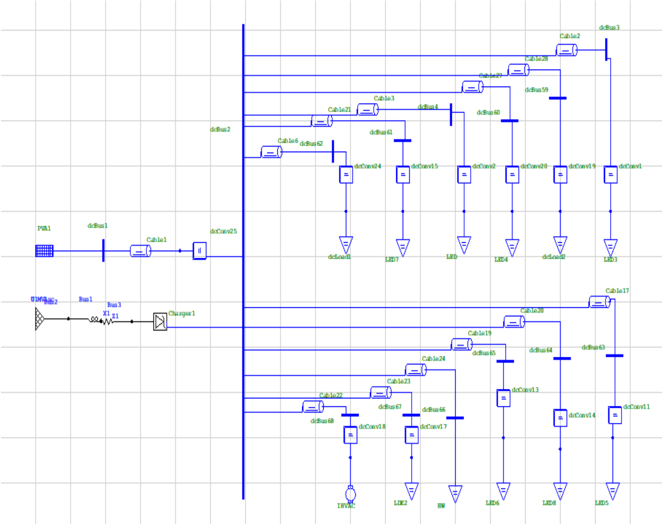
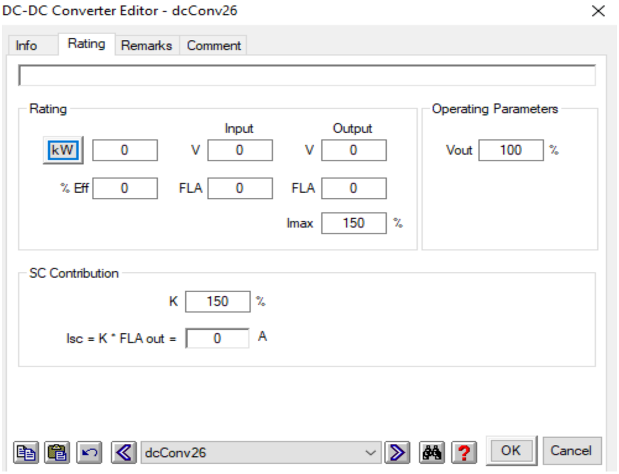


Figure 4: The DC nano grid implementation in ETAP

The architectural and electrical layout of the residence, including PV array placement, DC bus architecture, conductor lengths, power converters, and connected loads, is detailed in Figure 4 (based on the design from Figure 2). To overcome the limitations of ETAP software, which assumes a fixed efficiency for power converters regardless of load fluctuations, this study incorporates dynamic efficiency modeling. As illustrated in Figure 5 and the efficiency curves in Figure 6, empirical data from manufacturer specifications were utilized to establish the precise correlation between load percentages and converter performance. This integration ensures a more realistic simulation of the system's overall energy throughput.



DC-DC Converter Editor - dcConv26

Rating

kW: 0

Input V: 0

Output V: 0

% Eff: 0

Input FLA: 0

Output FLA: 0

Imax: 150 %

Operating Parameters

Vout: 100 %

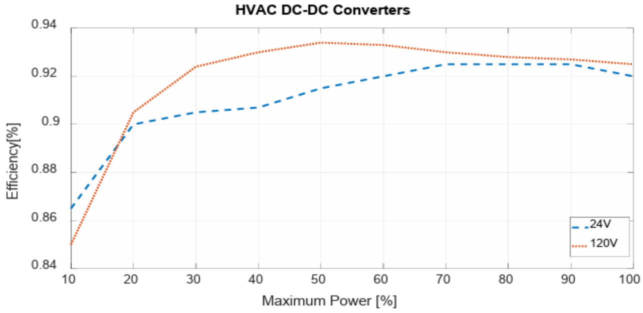
SC Contribution

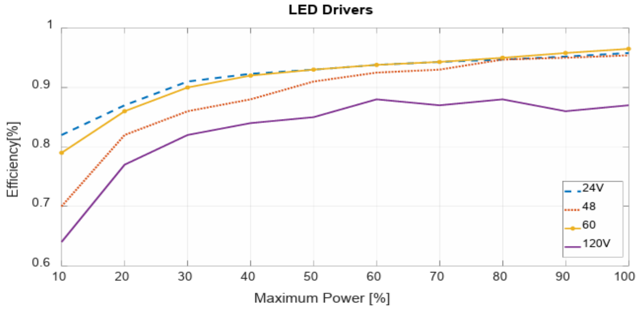
K: 150 %

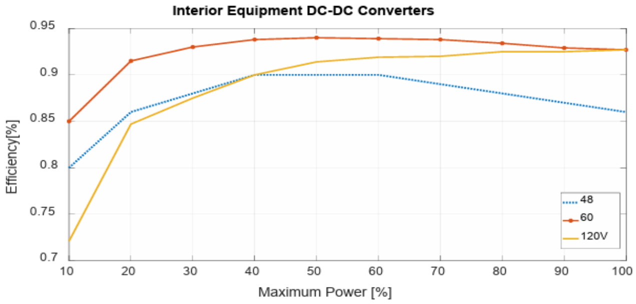
Isc = K * FLA out = 0 A

Figure 5: Converter in ETAP

"By leveraging manufacturer specifications and the derived efficiency curves, this study precisely determined converter performance relative to specific loading conditions. This methodology acknowledges the dynamic nature of power conversion, ensuring that the impact of partial loading on system efficiency is accurately reflected in the final analysis."







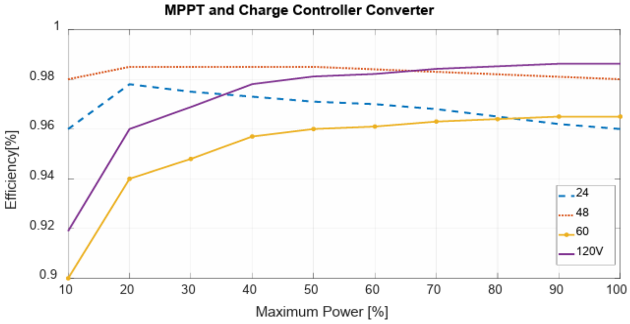


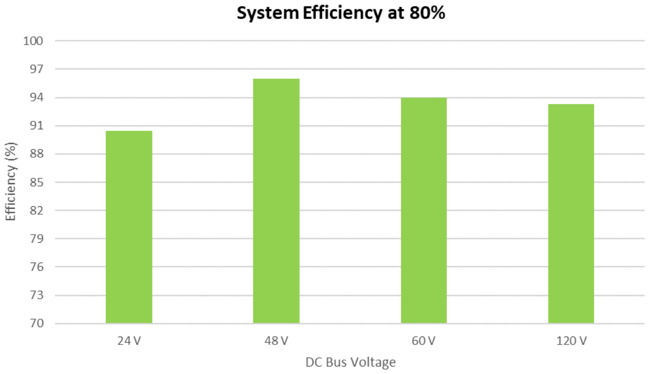
Figure 6: Efficiency curves of the converters for different voltage levels

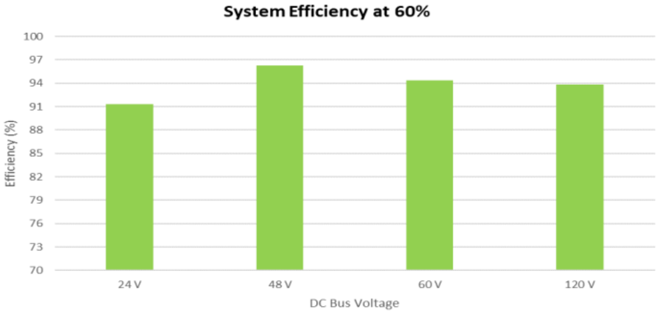
1. Efficiency of the DC-RNG at different voltage levels

Figure 3-4 presents the results of simulations conducted using real data for loads, wires and converter efficiency curves. These simulations aimed to assess the efficiency of the DC-RNG at different voltage levels.

According to the findings depicted in Figure 7, the efficiency of the DC-RNG exhibited a trend in relation to voltage levels. As the voltage level increased from 24V to 48V, the efficiency of the DC-RNG also increased. However, there was a drop in efficiency when the voltage level was further increased from 48V to 120V.

Specifically, the results indicate that the DC-RNG with a 48V DC distribution demonstrated higher efficiency compared to other voltage levels. On the other hand, the DC-RNG with a 24V distribution exhibited the lowest efficiency among the tested voltage levels.





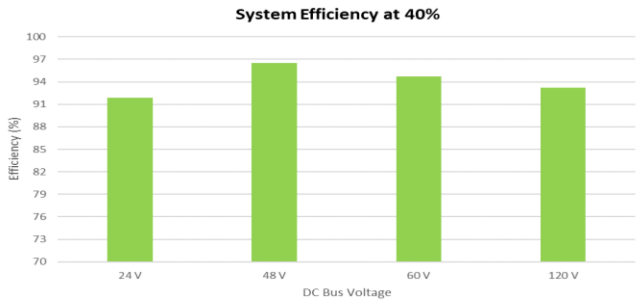


Figure 7: System Efficiency at Different Load (%)

2. Wires and power converters losses at different voltage levels

When evaluating the power efficiency of the DC-RNG, it is important to understand the different types of power losses that occur within the system. These power losses are categorized into two main types: converter losses, and wiring losses.

Power converters play a vital role in DC grids, enabling the efficient and reliable flow of power between different sources, loads, and storage devices. They perform essential functions such as voltage conversion, power conditioning, and isolation. The losses incurred in power converters can significantly impact the overall efficiency of a DC grid and need to be taken into account when evaluating the overall energy efficiency of the system.

- Wiring losses are another important factor to consider. When electricity flows through wires, there is resistance in the wire material, which leads to energy losses in the form of heat. The longer the wire and the higher the current flowing through it, the greater the wiring losses. Therefore, the length and gauge of the wiring used in the DC-RNG system play a role in determining the amount of power lost.

To accurately evaluate the energy efficiency of the DC-RNG system, it is necessary to model and quantify the components that contribute to power loss. This involves considering the specific characteristics and efficiency ratings of the converters, the length and gauge of the wiring used. By accounting for these factors, a more comprehensive assessment of the system's overall energy efficiency can be obtained.

Figure 3-5 represents the amount of energy loss in converters and wires to the total energy consumed by the DC-RNG. Figure 8a indicates that at high voltages, the wire loss decreases dramatically, but the loss of the converters does not follow a consistent pattern. Converter loss is the dominant source of power loss in the DC-RNG, converter loss is the dominant source of power loss, depending on the voltage level.

Among the different voltage levels in the DC-RNG, the 24 V system is the least efficient due to high converter and wiring losses. By contrast, the 48V system is the most efficient mainly because of the lower converter loss.

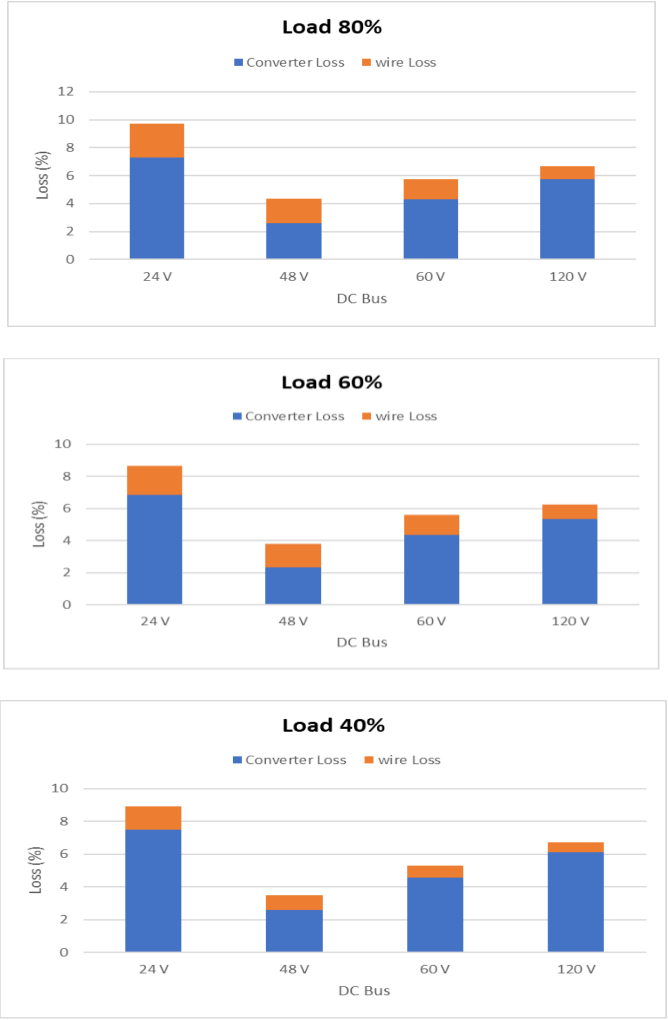


Figure 8: DC-RNG loss at Different Load (%)

During the analysis, it was observed that the PV panel converter and the HVAC converters accounted for the highest losses in the system, see figure 9. However, an interesting finding was that at the 48V and 60V voltage levels, no losses were incurred by the HVAC converter. This was because the HVAC system at these voltage levels did not require a converter for operation.

Based on this observation, it becomes evident that developing a standardized DC voltage level and corresponding products can help mitigate losses associated with converters. By establishing a standard voltage level, it would be possible to design and manufacture products that are compatible with this standard. This would eliminate the need for additional converters, reducing losses and increasing overall system efficiency.

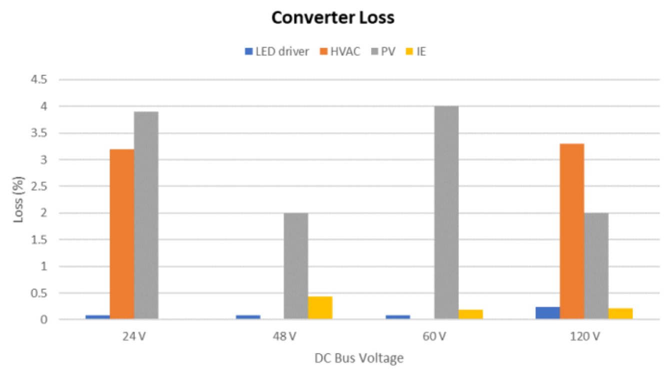


Figure 9: Converters loss of different load

V. CONCLUSION

The results showed that the efficiency of the DC nano grid exhibited a trend in relation to voltage levels. The system demonstrated higher efficiency at a 48V DC distribution compared to other voltage levels. Conversely, the 24V distribution exhibited the lowest efficiency. This information is crucial for determining the most efficient DC bus voltage for the system.

Furthermore, the project highlighted the importance of understanding and quantifying power losses within the DC nano grid system. Converter losses and wiring losses were identified as significant factors affecting energy efficiency. The length and gauge of the wiring, as well as the characteristics and efficiency ratings of the converters, played a role in determining the amount of power lost. By considering these factors, a comprehensive assessment of the system's energy efficiency was obtained.

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