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Analysis of Voltage Drop and Illuminance Performance in 24 VDC LED Lightning System Using Different Driver Capacities

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ABSTRACT

This study examines how driver capacity influences voltage distribution and illuminance in a 24 VDC LED lighting installation. In many practical projects, differences in driver ratings are often assumed to have minimal impact as long as the load requirement is satisfied; however, voltage drop along the cable may affect the actual performance at the luminaire. An experimental measurement was conducted using identical LED fixtures connected through a 12-meter cable while varying the driver capacities at 20 W, 35 W, and 100 W. For each configuration, the output voltage from the driver, the voltage received at the LED terminals, and the resulting illuminance were recorded after stable operating conditions were reached. The observations show that higher driver capacity tends to provide slightly better voltage regulation at the load side, and this improvement is followed by an increase in measured illuminance. Although the voltage differences are relatively small, the trend consistently indicates the importance of proper driver selection in maintaining system effectiveness, especially in low-voltage installations with distribution distance. The results are expected to serve as a practical reference for electrical and lighting engineers in determining suitable driver specifications to achieve reliable and optimal lighting performance.

Keywords : LED lighting system; driver capacity; voltage drop; illuminance

INTRODUCTION

The rapid development of light emitting diode (LED) technology has significantly improved energy efficiency, lifetime, and controllability of modern lighting systems. Along with these advantages, practical installations increasingly employ low-voltage architectures in which the electrical performance of distribution lines and driver

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capability become critical factors in determining the final light output. Several studies have emphasized that the photometric behavior of LEDs is strongly influenced by electrical supply conditions, meaning that voltage quality at the load side cannot be separated from luminous performance (Czyżewski, 2023).

Driver design plays a central role in maintaining stable operation. Reviews of LED driver topologies indicate that regulation strategy, conversion method, and available power margin directly affect current stability delivered to the light source (Esteki et al., 2023). Variations in supply voltage or insufficient headroom may therefore propagate into measurable differences in illuminance, particularly in low voltage DC applications. Research on dimming and control techniques further demonstrates that electrical adjustments intended to enhance efficiency may produce different outcomes when operating conditions deviate from nominal values (Ho et al., 2021).

Beyond theoretical design, field investigations repeatedly show that real installations introduce additional variables such as cable resistance, connector quality, and load distribution. These aspects often generate voltage drops that influence the effective energy received by the luminaire (Qurraisyn et al., 2023; Soedjarwanto et al., 2024). Similar conclusions are reported in reliability-oriented studies, where voltage stress and instability are linked to performance degradation and potential failure mechanisms in LED systems (Hadikusuma & Santoso, 2025).

Measurement methodology is equally important. Accurate determination of luminance or illuminance requires controlled geometry, proper instrumentation, and consistent procedures to ensure that observed deviations are attributable to electrical phenomena rather than measurement artifacts (Letha et al., 2022). Practical lighting assessments in educational or working environments also underline how differences between designed and actual lighting levels frequently emerge during operation (Setyaningsih et al., 2022; Syafi'i et al., 2023).

With the global transition toward more efficient lighting infrastructures, understanding how supply characteristics influence delivered performance becomes increasingly valuable for practitioners. Energy and system-level analyses suggest that optimization must consider not only component efficiency but also distribution effectiveness (Katzin et al., 2021; Pennock et al., 2022). Therefore, comparative experimental evaluation under real installation conditions remains a necessary step.

This study addresses the issue by examining several driver capacities within a 24 VDC LED system while maintaining identical cable length and luminaire configuration. By recording voltage at the driver, voltage at the load, and the resulting illuminance at the same measurement point, the work aims to clarify how improvements in supply capability translate into photometric performance. The results are expected to provide direct guidance for engineers in selecting appropriate drivers and minimizing unwanted losses in low-voltage lighting installations.

METHODOLOGY

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This study adopted an experimental approach to analyze how different driver capacities influence voltage delivery and illuminance in a 24 VDC LED lighting system. The experiment was carried out in a real installation environment to represent practical operating conditions commonly encountered in field applications. To ensure a fair comparison, all parameters related to the luminaire, cable length, spatial arrangement, and measurement position were kept constant throughout the tests. The only variable intentionally modified was the driver power rating.

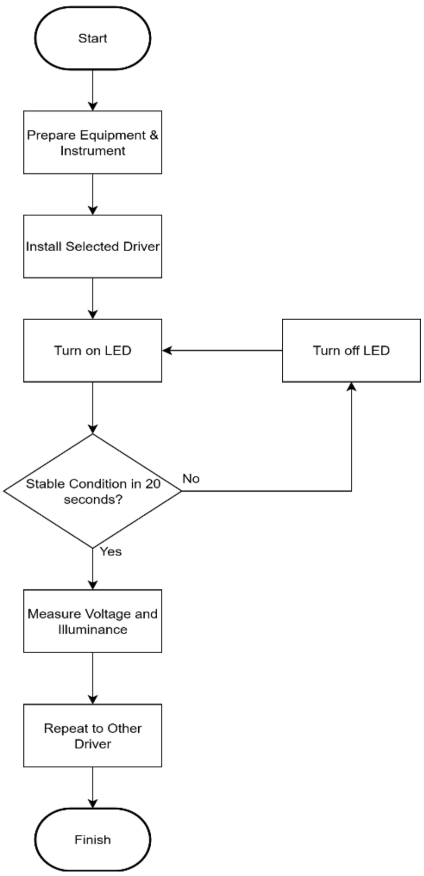

Figure 1. *Flowchart research*

Structured workflow was implemented so that each measurement followed identical steps and conditions. The detailed research sequence is illustrated in figure 1, which describes the process starting from equipment preparation to data acquisition and repetition for different drivers.

Prepare Equipment and Instrumentation

Before conducting the experiment, all required components and measuring instruments were prepared and inspected. The lighting load consisted of a 24 VDC luminaire that remained unchanged during the entire study.

Three drivers with different rated capacities were selected for comparison:

- 20 W driver
- 35 W driver
- 100 W driver

These ratings represent typical supply options used in practical installations, ranging from minimum sufficient capacity to higher reserve capability. By evaluating multiple power levels, the experiment aimed to observe whether larger capacity contributes to improved voltage stability at the load side.

Electrical measurements were performed using a digital multimeter with DC voltage capability. Illuminance measurements were obtained using a portable lux meter. Prior to use, instruments were powered on and verified to provide stable readings. This preparation step was important to minimize unexpected deviations caused by equipment malfunction.

System Configuration

The experimental setup consisted of the LED luminaire connected to the driver through a cable with a fixed length of 12 meters. This distance was maintained for

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every trial in order to preserve identical distribution characteristics.

Two voltage observation points were at the output terminals of the driver,and at the input terminals of the LED luminaire.

By maintaining the same wiring route, connectors, and environment, any difference measured between configurations could be attributed primarily to the driver capability rather than external factors.

The luminaire mounting position and surrounding conditions were not altered between tests. No additional light sources were introduced during measurement sessions. This ensured that illuminance variation originated from the electrical supply differences only.

Measurement Method

The illuminance measurement arrangement is shown in Figure Y.

Figure 2. Lux Measurement Method

The lux meter was placed at a fixed observation point facing the luminaire with consistent orientation and distance for all driver variations. Maintaining geometric consistency is crucial because small positional changes can produce different lux readings.

After installing the selected driver, the system was energized and allowed to run for approximately 20 seconds. This waiting period was applied to allow electrical and thermal conditions to stabilize. Measurements taken too early may represent transient behaviour and not the actual operating state.

Once stable operation was assumed, the following steps were performed:

- record the output voltage at the driver,
- record the voltage at the LED terminals,
- measure and document the illuminance.

All results were logged before the system was turned off and replaced with the next driver rating. The same sequence was repeated until data for all drivers were collected.

Data Analyst

Voltage drop for each configuration was calculated by subtracting the voltage measured at the LED terminals from the driver output voltage. The calculated drop was then compared with the corresponding illuminance result.

Because the luminaire, cable, and measurement geometry were identical, differences in lux level were interpreted as the effect of driver performance in delivering electrical energy to the load. The comparative approach allows identification of trends without requiring complex modeling.

The analysis focused on observing whether higher driver capacity leads to

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better voltage preservation and whether this improvement is accompanied by an increase in illuminance.

RESULT AND DISCUSSION

The experimental results obtained from the procedure described in the previous section are presented and analyzed in this part. The objective of the discussion is to identify how differences in driver capacity affect voltage conditions at the load and how these electrical variations translate into illuminance performance.

Measurement Result

The primary measurement outcomes for each driver configuration are summarized in Table 1. The dataset includes the rated driver capacity, the output voltage at the driver terminals, the voltage measured at the LED input, and the illuminance recorded at the observation point.

Table 1. Measured voltage and illuminance under different driver capacities

Driver Capacity	Voltase Out Driver	Voltase In LED	Lux
20 Watt	24.30 V	24.01 V	428 Lux
35 Watt	24.21 V	23.93 V	436 Lux
100 Watt	24.12 V	23.85 V	447 Lux

Because the luminaire, cable length, and measurement geometry were identical throughout the experiment, the variation shown in Table 1 mainly represents the effect of the power supply capability.

Voltage Drop Analysis

Voltage drop was determined as the difference between the driver output voltage and the voltage received at the LED terminals. From Table 1, it can be observed that all configurations experience a reduction between the sending and receiving points. However, the magnitude of this reduction varies depending on the driver rating.

Drivers with higher capacity tend to maintain slightly better voltage levels at the load. The largest drop is associated with the lowest power rating, while the smallest deviation occurs when the highest capacity driver is used. This indicates that increased supply capability improves voltage preservation along the same distribution path.

Although the differences appear relatively small in absolute value, low-voltage LED systems are sensitive to such variations because current regulation inside the driver and LED module depends on the available terminal voltage.

Illuminance Performance

A similar tendency is visible in the illuminance data. As the driver capacity increases, the recorded lux value also increases. The improvement is gradual but consistent across the tested configurations.

This relationship suggests that better voltage delivery supports more effective energy transfer to the light source, resulting in higher luminous output. The finding demonstrates that two drivers supplying the same nominal load can still produce different lighting levels depending on their regulation strength.

Discussion

The outcomes show that driver capacity affects both the voltage at the luminaire and the illuminance. Load side voltage levels are better for higher-rated

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drivers than for lower capacity drivers, which create more voltage drops on the cable. Although the differences are small, they are consistent for all the measurements.

The regulation and power margin of the driver explains this behavior. Higher capacity driver units are able to keep terminal voltage better because they are less stressed. Small voltage improvements create large increases to the light output because the LEDs need stable voltage to drive them.

The experiment shows that satisfying the nominal wattage/power rating of drivers is not enough to achieve the same lighting effect/create the same lighting output. In situations where the cable placement and other aspects of the wiring are not as easy to modify, choosing a higher rated driver is the most effective way to achieve consistent light distribution.

CONCLUSION

This study experimentally evaluated the influence of driver capacity on voltage delivery and illuminance performance in a 24 VDC LED lighting system while maintaining identical installation conditions. The results show that higher-rated drivers provide slightly better voltage preservation at the load side, and this improvement is consistently accompanied by increased illuminance. Although the electrical differences are relatively small, the findings confirm that LED output is sensitive to supply quality. Therefore, driver selection should consider not only the minimum wattage requirement but also the ability to maintain stable voltage along the distribution path. The outcome of this work provides practical insight for engineers in optimizing lighting reliability and achieving expected performance in real installations.

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