Innovative LED Lighting Driver Strategies for Vertical Farming

Enhancing Reliability, Maintenance, and Thermal Management

The increasing adoption of LED lighting technology in controlled environment agriculture (CEA) presents opportunities to revolutionize farming practices. LED lighting offers numerous advantages, such as energy efficiency, extended lifespan, precise control over the light spectrum, and reduced heat output, all of which contribute to enhanced crop growth and increased yields. The extended life of LED chips enables the development of improved system-level solutions concerning LED drivers. This study investigates various LED driver strategies for vertical farming and their impact on reliability, maintenance, thermal management, and cost. Key findings suggest that remote driver configurations and centralized remote DC driver systems offer the greatest benefits to the CEA farm.

1. Introduction

Vertical farming has gained significant attention in recent years as a sustainable solution to the challenges of population growth, urbanization, and climate change (Despommier, 2010). LED lighting technology has emerged as a cornerstone of vertical farming due to its energy efficiency, extended lifespan, and spectral control (Nelson & Bugbee, 2014). By employing LED lighting in controlled environment agriculture, growers can optimize plant growth, increase yields, and reduce operational costs. However, despite the numerous advantages of LED grow lights, the overall system's reliability and performance can be significantly affected by the interaction between the LEDs and the driver. Both components are vital for delivering consistent, high-quality illumination.

2. LED Lighting in Vertical Farming: An Overview

Until recently, indoor agriculture lighting solutions were dominated by technologies like high-pressure sodium (HPS), ceramic metal halide (CMH), and fluorescent (Nelson & Bugbee, 2014). The typical lifespan for these older lighting technologies ranged from approximately 10,000 to 25,000 hours, although it is not uncommon for growers to replace HPS bulbs every 4,000 hours or so. By contrast, high-quality LEDs can last between 50,000 to 100,000 hours (Pattison et al., 2018). Consequently, the most common point of failure in a well-designed LED grow light is not the LED chip but the LED driver. LED drivers generally have a lifespan of around 30,000 to 50,000 hours, which matches well with legacy lighting technologies but becomes the weakest link in an LED luminaire's reliability profile.

High Pressure Sodium

Ceramic Metal Halide

Fluorescent

LED

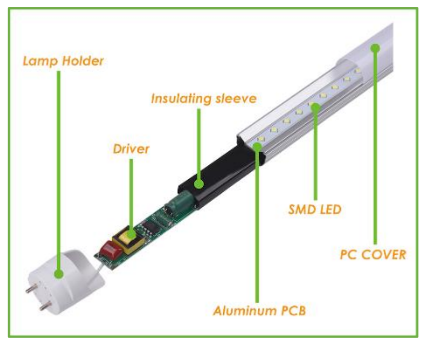
LEDs are currently the primary lighting technology employed in vertical farming due to their high energy efficiency, which increases profit margins and enhances the industry's economic viability (Morrow, 2008). The reduced heat output of LED grow lights can prevent plant tip burn, an issue commonly associated with alternative solutions like fluorescent lighting (Pattison et al., 2018). Grow light manufacturers recognize that the LED chip is likely to outlast the driver, and they have developed product configurations to optimize the overall performance, reliability, and cost of the lighting system.

3. LED Grow Light and Driver Configurations for Vertical Farming

This section provides an overview of several LED grow light and driver configurations for vertical farming, examining their advantages and disadvantages in terms of reliability, maintenance, thermal management, and cost.

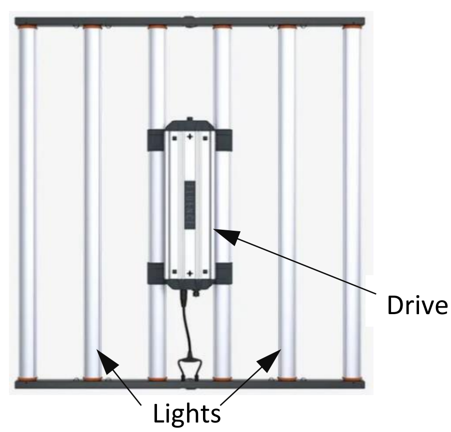
3.1 Internal Driver (1 driver for 1 light)

Many LED grow lights on the market feature an internal driver controlling a single light. This configuration does not leverage the longer lifespan of the LEDs compared to the driver since the entire light fixture is normally replaced if the driver fails. Replacing only the driver is typically not cost-effective. The advantage of this approach is that each individual light can be controlled for intensity (dimming) and spectral composition (Lefsrud et al., 2008).



3.2 External Driver (1 driver for several lights)

Another common strategy is to use a single driver to power multiple lights. In this configuration, the external driver is more accessible, making it easier to replace or repair if it fails. The driver remains external to the lights but is still incorporated into the luminaire and located near the canopy. Consequently, the heat generated by the driver must be managed (Nelson & Bugbee, 2014).



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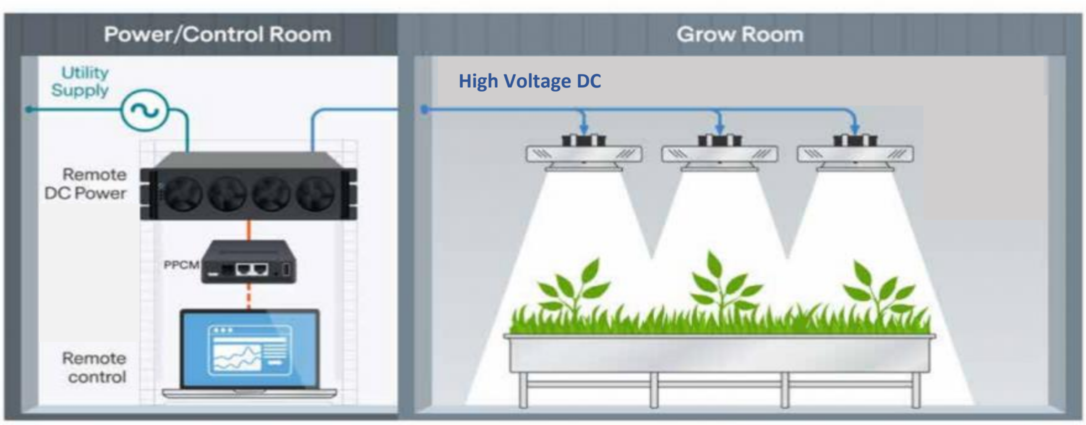
3.3 Remote Driver (1 driver for 10s of lights)

Some manufacturers offer high-power drivers that control numerous lights from a single power supply. For example, Thrive Agritech provides an 880W driver that can be paired with up to 24 of its 30W Strata vertical farming lights (Thrive Agritech, n.d.). High-power drivers can be situated away from the canopy, simplifying driver service or replacement. Remotely locating the drivers also removes heat from the canopy, reducing HVAC cost and complexity (Morrow, 2008). In general, high-quality LED drivers can achieve efficiencies ranging from 85% to 95% (Bickford, 2019). Driver efficiency indicates the proportion of input power used to power the LED lights and the amount lost as heat during the conversion process.

Although heat removal may account for only 5%-15% of the total power supplied to the canopy, this can still have a significant impact. For a vertical farm using 10,000 30W lights, remotely locating 95% efficient drivers would reduce the canopy's heat load by 15,000W (or more than 50,000 BTU/hour). This reduction in heat load results in direct HVAC cost savings for the grower.

3.4 Centralized Remote DC Driver (1 driver system for 100s of lights)

Expanding on the concept of high-power drivers, very high-power direct current (DC) driver systems can be implemented in vertical farms. DC drivers for LED grow lights present several advantages over AC drivers, offering benefits such as increased efficiency, extended lifespan, flicker-free lighting, improved dimming capabilities, compact size, reduced electromagnetic interference, and enhanced safety (Bickford,



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2019). The superior efficiency of DC drivers stems from the elimination of power losses during AC to DC conversion, resulting in energy savings and decreased utility bills. These drivers are often grouped together in rack mounts situated in separate rooms, effectively removing the heat generated by the driver from the grow room. Excess heat can be vented outside during summer or redirected into the growing area in winter. Using high voltage and low current allows for thinner wires, reducing costs and weight. Additionally, lower currents minimize wiring losses (Bickford, 2019).

Centralized remote DC drivers are available at power levels exceeding 10 kW, capable of powering over three hundred 30W LED grow lights (Bickford, 2019). This advanced driver configuration further enhances the efficiency, reliability, and thermal management of vertical farming lighting systems.

The majority of LED grow lights are designed to operate with an AC power source, making it essential to confirm the compatibility of the light with the chosen driving strategy. Thrive Agritech offers versions of its vertical farming Strata light and its Pinnacle HP high-power greenhouse light that are compatible with remote DC drivers (Thrive Agritech, n.d.). These tailored lighting solutions ensure seamless integration with advanced driver configurations, allowing growers to leverage the benefits of remote DC drivers.

4. Summary & Conclusions

A summary of the pros & cons of the various LED light and driver strategies is presented in the table below. The primary benefit of the internal driver is the ability to individually control each light for intensity and color. The external driver configuration offers improved driver accessibility, but this benefit is not as significant as with remote drivers. Remote driver configurations clearly provide advantages in leveraging the long life of the LED chip, enhancing ease of installation and maintenance, and optimizing system-level reliability and overall cost-effectiveness.

	Internal Driver	External Driver	Remote Driver	Centralized DC Remote Driver
Individual Lights - Dimming and Spectrum Control				
Group of Lights - Dimming and Spectrum Control				
Remove Driver Heat from Canopy				
Ease of Installation & Maintenance				
Overall Cost & Reliability				

In conclusion, the selection of an appropriate LED driver strategy for vertical farming is crucial for maximizing the benefits of LED lighting technology. This study has demonstrated that remote driver configurations and centralized remote DC driver systems offer the most advantageous options in terms of overall system performance, reliability, maintenance, thermal management, and cost. By adopting these advanced driver configurations, growers can leverage the full potential of LED lighting technology, enhancing crop growth and yield while minimizing operational costs.

Future research in this area should focus on the development of even more efficient and reliable LED driver technologies, as well as the exploration of innovative LED lighting and driver strategies tailored to the unique requirements of specific crops and growing environments. Such advancements will continue to drive the evolution of vertical farming, ultimately contributing to a more sustainable and efficient global food production system.

5. References

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