Topic of PhD Thesis
“Analysis, Design and Control of DC-DC Converters for General Lighting Systems”
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Abstract

Lighting (or illumination) characterizes the way an area is taken known to the human eye through either natural or artificial light. Natural light emanates predominantly from the sun. The intensity of sunlight varies in accordance with the time of day and the location. Buildings and premises are often designed to improve the capture of natural daylight. Alternatively, artificial light is human-made and can emerge from sources including fire, gaslight, candlelight, electric lamps, and so forth. At present, however, the term 'artificial lighting' essentially refers to lighting that comes from electric lamps. Artificial light as a rule is simply manipulated to achieve the required lighting result. The light can be enhanced or reduced, directed, focused, and colored. This enables lighting to produce a range of effects conferring to the requirements of a space. The term ‘general lighting’ relates to the background levels of light in a specific area. In the majority of workplaces, the optimal level of general lighting is determined in accordance with the best practices to ensure human safety and empower everyday visual tasks to be carried out comfortably and efficiently. General lighting may be foreseen merely by artificial lighting or a combination of artificial and natural light. The type of artificial light source adapted is to be determined by the type of space the lighting is for such as indoor, outdoor, and so on, along with the quality and the energy consumption of the lighting luminaire. In recent years, it has been noticed an immense shift away from traditional incandescent filament light bulbs to more energy-savings alternatives. The exploration of new light sources such as the light-emitting diode (LED) has been made revolutionary changes in lighting design. Owing to its exclusive advantages, LED is replacing conventional light sources at a more rapid pace. When combined with advanced control gear, a clean, energy-efficient, and cost-effective lighting solution can be made for general lighting arrangements.

The LED driving technologies are primarily classified based on the required power demand. These are further classified on the basis of isolated or non-isolated outputs from the input AC mains. The conventional LED driving system comprises of DC-DC converters, which involves inferior control mechanism and excess component count that gives rise to unsatisfactory performances concerning power quality consideration and efficiency. In addition to this, the majority of converters are designed to operate within a short range of universal AC mains. The converter stability is quite unexplored and does not fulfill the constant voltage or constant current operation of the LED load. A large ripple in the LED drive current is often witnessed, which leads to unwanted flicker in the light produced. Moreover, due to increasing uses of artificial light sources, lighting also accountable for significant energy consumption over the past few years. As a consequence, several studies are conducted on energy-saving lighting solutions, which are reported in the literature.

In this research work, the analysis, design, control, and development of several DC-DC converters are carried out with the view of improving the aforementioned drawbacks. The DC-DC converters, which are explored as LED drivers are aimed at four fundamental aspects, namely the power quality improvement over a wide operational range, increasing converter efficiency, development of cost-effective dimming concepts, and reducing design complexity with improved stability. The research work is also focused on various lighting demands starting from very low power for household applications to high power industrial uses. In each stage, appropriate DC-DC converters are studied and developed in line with the foregoing aspects that give rise to satisfactory performances over the conventional topologies used in LED lighting systems. The trouble with poor efficiency in isolated converters, is further improved and eradicated the limitations of low power applications for single-stage converters. This research work has also explored the conventional single-stage DC-DC converters in high power lighting demands by shifting the operating trends from discontinuous conduction mode (DCM) to critical conduction mode (CrCM). Taking advantage of CrCM operation and proper controller design, improved power quality performances, and efficiency are achieved in the proposed DC-DC converters. Moreover, in high power LED loads, the need for improved power quality parameters and efficiency are more important along with the precise regulations. In order to satisfy the above criteria, two-stage converter solutions are implemented where the first-stage is responsible for the power factor correction (PFC) over universal AC mains, and the second-stage precisely controls the load regulation with isolation. In terms of converter stability during transient and dynamic operations, a comprehensive study of stability performances using the state-space analysis model for all the DC-DC converters, is carried out and implemented in hardware prototypes.

This research work also investigates on low-cost energy-savings dimming concepts, which are integrated into the DC-DC converters and completely retrofitted. The primary drawback of excessive harmonic contents in AC mains current during dimming operations in the conventional low-cost dimming practices, is addressed and improved power quality performances are made available through the proposed dimming concepts. Furthermore, all the converter topologies and dimming models are presented in this research work, are using minimal circuit components, reliable in operation, and applicable for upcoming LED lighting solutions.