Fuzzy logic controller-based Luo converter for light electric vehicles

Rangaswamy Balamurugan[1], Komarapalayam Subramaniam Vairavel[2], Marimuthu Kalimuthu[3], Veerappan Kiruthiga Devi[4]
[1]Department of Electrical and Electronics Engineering, K.S. Rangasamy College of Technology, Tiruchengode, India
[2]Department of Electronics and Instrumentation Engineering, Bannari Amman Institute of Technology, Sathyamangalam, India
[3]Department of Electronics and Communication Engineering, Sri Krishna College of Technology, Coimbatore, India
[4]Department of Electrical and Electronics Engineering, K.S.R College of Engineering, Tiruchengode, India

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ABSTRACT

A brushless DC motor (BLDC) drive fed by a Luo converter is presented in this paper for the use in electric vehicle (EV) applications. The proposed Luo converter provides stable and ripple free output for EV. An approach for getting the stable output voltage is by using a fuzzy logic controller to control the Luo converter. It helps to generate the appropriate pulse with respect to the feedback voltage. This proposed system has the advantages like voltage increase, high-gain output with low ripples and high efficiency. The performance of this proposed drive is tested through hardware prototype at varying line voltage levels and results are demonstrated. A comparative analysis is presented to justify the effectiveness of the proposed Luo converter fed EV motor.

Corresponding Author:

Rangaswamy Balamurugan
Department of Electrical and Electronics Engineering, K.S. Rangasamy College of Technology
Tiruchengode, India
Email: drnrbals@gmail.com

1. INTRODUCTION

The need for environmentally sustainable transportation options has grown over the past few decades because of rising pollution, decreasing fossil fuel reserves, spiking fuel prices, and enacted environmental legislation. As a result, electric motor-based vehicle technologies are becoming more prevalent with the intention of replacing the traditional mechanical engine-based transportation system. Depending on the level of electrification, EVs are divided into many types and mostly hybrids. The most common being hybrid EVs, plug-in hybrid EVs, and battery operated EVs (BEVs). Notably, light battery operated EVs (LEVs), such as two and three connected wheelers, contribute significantly to the growth of BEVs, particularly in new technology emerging countries like India [1]-[3].

However, LEVs driving range, maintenance costs, and initial cost seem convincing. The effectiveness of their charging scheme seems inadequate in the current environment. Conventional LEV charging systems violate performance benchmarks established by numerous international organizations. The usual technique uses a diode bridge rectifier (DBR) and massive capacitors that are combined in a cascade at the supply end, which significantly reduces the operational power factor (PF) and distortion factor of the charger. For getting improved efficiency with reduced component count, the DBR should be removed at the supply end. Numerous AC-DC derived converters like buck-boost-derived Cuk, SEPIC, Zeta, and Luo converter-based bridgeless AC-DC topologies, as well as others, have been studied in the literature.

Certainly, SEPIC and Cuk converters are used more frequently in charging systems due to their good performance features. Despite the fact that the bridgeless Luo converter [4], [5] requires a large number of devices and has the polarity negative, its utility in LEVs charging applications is currently underutilized.

2. PROPOSED LUO CONVERTER FOR ELECTRIC VECHICLES

The new series of DC-DC step-up (boost) converters known as Luo converters was created using the voltage lift approach and is depicted in Figure 1. It increases DC-DC voltage from positive to positive while having a high power density, excellent efficiency, and a simple design [6]-[10]. The benefit of the Luo converter is that it enables a controlled conversion from uncontrolled input source to a controlled output voltage [11]-[20]. The suggested control approach for the BL Luo converter fed BLDC motor for an EV application is shown in Figure 2.

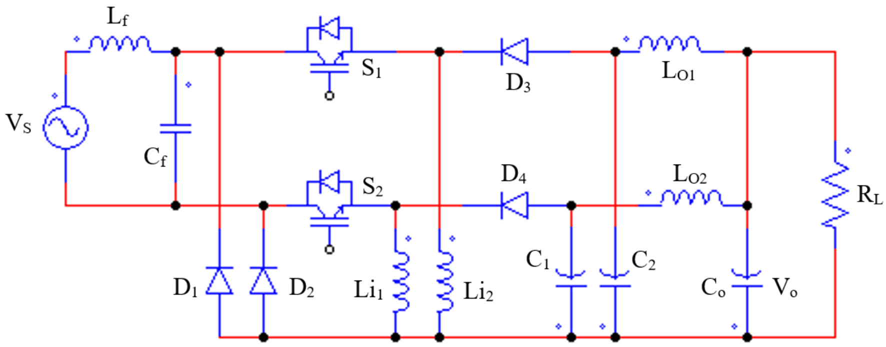

Figure 1. Luo converter for EV

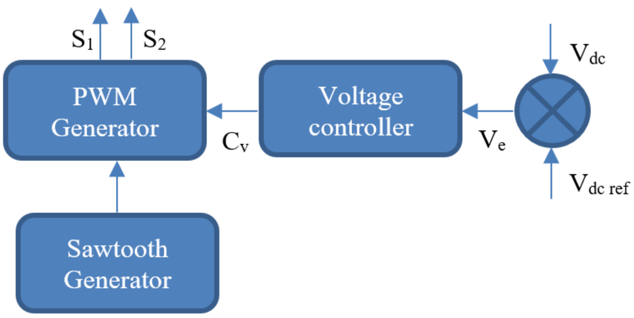

Figure 2. Control block diagram of proposed Luo converter for EV

Both switches are controlled by a single drive circuit, which eliminates the requirement for sensing the polarity of voltage. Costs associated with implementation and control complexity are significantly reduced. In this work, the Luo converter is controlled using a fuzzy logic controller. With the help of this controller, the Luo converter generates a constant and controlled output voltage. The sensed output voltage at the output end of the Luo converter is connected as feedback to FLC. It analyses the feedback and produces the right pulses for the Luo converter to ensure a constant output voltage at its terminal.

3. METHOD

The suggested system incorporates the fuzzy logic controller (FLC) to regulate the Luo converter's output. It offers effective voltage regulation, improves output, and has fewer ripples [21]-[23]. Using triangle membership functions as the variables, Mamdhani fuzzy inference is applied here [24]. Voltage and voltage error are provided as inputs to the fuzzy logic controller [25]. The output of the Luo converter is taken, and the feed-back voltage is provided to the FLC. The needed pulses for the Luo converter are produced using the created rule base. Table 1 displays the set of guidelines for managing the Luo converter to achieve a consistent output voltage. The suggested system's flowchart with FLC implementation is shown in Figure 3.

Table 1. Rule base for the proposed work

e|ce	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NM	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

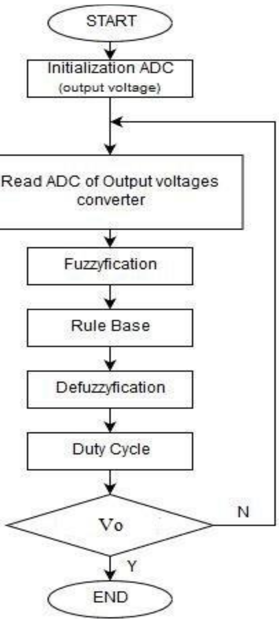

Figure 3. Flow chart for FLC implementation

Figure 4 depicts the entire experimental configuration of the suggested Luo converter for EV application. Hardware implementation is used to analyze the proposed Luo converter's performance under steady state conditions and dynamic test situations. The controller establishes the stable output control in the Luo converter. The PIC16F877A based control system is fabricated to validate the efficiency of the hardware prototype. FLC is programmed in the PIC microcontroller for getting the desired voltage profile in the Luo converter. The proposed system performance is investigated by connecting the BLDC motor as a load. Test is performed in the prototype model for rated and variable input voltage and results are observed.

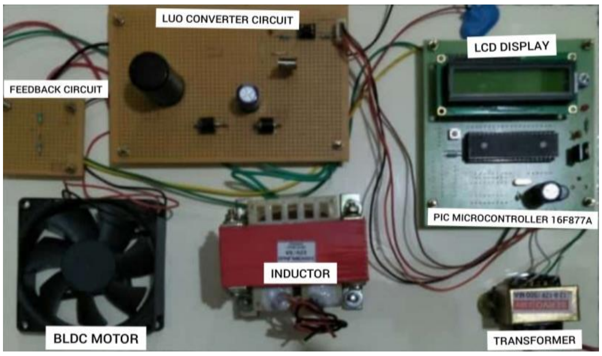

Figure 4. Overall experimental setup

4. RESULTS AND DISCUSSION

Figure 5 demonstrates the evaluation of Luo converter for the EV application. The variation of voltage is given as input to Luo converter and results are observed for various test load conditions. The improvement in the proposed FLC based Luo converter is envisaged and illustrated in the Figure 5. It gives the comparison of the both conventional converter and proposed Luo converter. The input voltage for the Luo converter is varied from 5V to 10V and results are observed for the output voltage which is maintained as constant by 12V. Based on the observed values of the input and output, efficiency has been calculated and presented as comparative chart for conventional converter and proposed Luo converter.

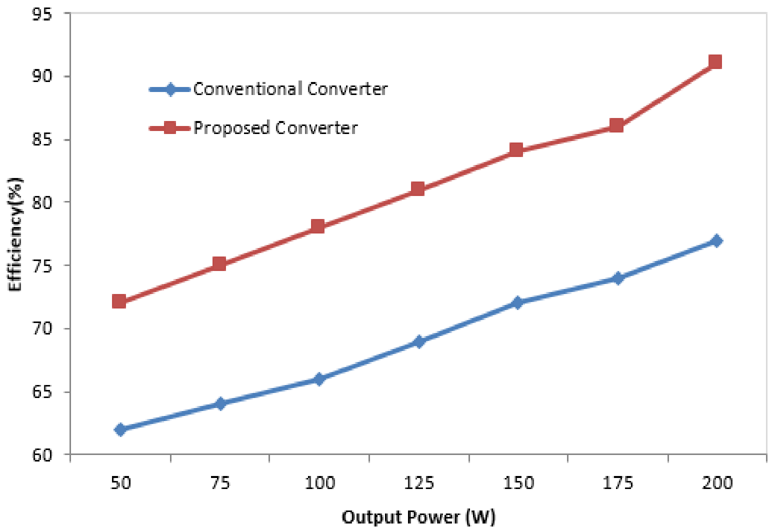

Figure 5. Comparative analysis for conventional converter and Luo converter for EV

5. CONCLUSION

In this paper, a streamlined control technique for a BLDC motor fed by an FLC-based Luo converter is provided. Variations in the input supply are shown, and steady output voltage maintenance is shown. The FLC control ensures stable output voltage at the Luo converter terminals as well as steady state operation under dynamic conditions. The effectiveness of the suggested system shows that the FLC-equipped Luo converter complies with the constant voltage profile regardless of voltage variance and is the most appropriate choice for EV applications.

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BIOGRAPHIES OF AUTHORS

Rangaswamy Balamurugan received his B.E. degree in Electrical and Electronics Engineering from Anna University Chennai, India in 2005 and he completed his post graduate studies in Power Electronics and Drives from Anna University Chennai, India in 2007. He completed his Ph.D. in the area of power electronics from Anna University Chennai, India in 2012. Presently, he is working as associate professor in the Department of Electrical and Electronics Engineering, K.S. Rangasamy College of Technology, Tiruchengode, India. He has published 59 papers in the International Journals/ Conferences. He is a life member of Indian Society for Technical Education (ISTE), New Delhi and Institute of Engineers (IEI) Kolkata. His current interests include power electronics, renewable energy systems, power quality, intelligent control and PFC converters. He can be contacted at email: drnrbals@gmail.com

Komarapalayam Subramaniam Vairavel received his B.E. (Electronics and Instrumentation Engineering) degree from Bharathidasan University, Tiruchirappalli, India in April 2001, M.E. (Applied Electronics) degree from Anna University, Chennai in June 2007, and Ph.D. (Information and Communication Engineering) degree from Anna University, Chennai in October 2018. He is presently working as an associate professor & head, Department of Electronics and Instrumentation Engineering, Bannari Amman Institute of Technology, Sathyamangalam, India He has 21 years of teaching experience in various engineering colleges. His research interest includes, sensors and transducer, control systems, process control, biometrics, and image processing. He is the life member in ISTE, IET and annual member in ACDOS. He has published 27 papers in international and national journals, and 28 papers in international and national conferences. He has done consultancy project to Pricol Industry, Coimbatore, India. He can be contacted at email: vairavelks@bitsathy.ac.in.

Marimuthu Kalimuthu is from the city of Kumbakonam, India. He currently works as an assistant professor in the Department of Electrical and Computer Engineering at Sri Krishna College of Technology, Coimbatore, India. He also pursuing his Ph.D. in the school of electronics engineering at VIT University, Chennai. Earlier he completed his Master's in Embedded Systems at VIT University, Chennai. He completed his bachelor's degree in Electronics and Instrumentation Engineering at St. Joesph's College of Engineering, Chennai, India. He did his PG diploma in Industrial Automation System Design in NIELIT, Calicut, India from DeitY. He had done his PG internship in Greenvironment India (P) Ltd. Incubated in IITM Research Park and his UG internship in Ashok Leyland, Ennore Chennai, India. He has published 10+ international journals including 6 Scopus with 1 WoS and published 6 patents. His hands-on experience includes development boards like Raspberry–Pi, Arduino, Mbed board, freedom board, etc., and PLC, DCS, SCADA, and DAQ (NI-LABVIEW). His practical exposure includes IoT and its platforms, sensor interfacing techniques & calibration, communication modules like BLE, Xbee, and LoRa, and communication protocols like I2C, UART, and SPI. He can be contacted at email: kalimuthu.m@skct.edu.in.

Veerappan Kiruthiga Devi received her B.E. degree in Electrical and Electronics Engineering from K. S. Rangasamy College of Technology, Tiruchengode, India in 2017 and he completed her post graduate studies in power systems engineering from K. S. Rangasamy College of Technology, Tiruchengode, India in 2019. She is pursuing her Ph.D. in the area of renewable energy sources and electric vehicle. Presently, she is working as an assistant professor in the Department of Electrical and Electronics Engineering, K.S.R College of Engineerin, Tiruchengode, India. She has published 3 papers in the international journal, conference. She has completed AICTE-NITTTR 8 module course for assistant professor. She has completed 2 NPTEL course with Elite+Silver, and 1 NPTEL course with Elite. She is a life member of Institute of Engineers. Her current interests include renewable energy, electric vehicle. She can be contacted at email: kiruthigadeviv@gmail.com.