

Lecture Notes in Networks and Systems 608

Sandeep Kumar · Harish Sharma ·
K. Balachandran · Joong Hoon Kim ·
Jagdish Chand Bansal *Editors*

Third Congress on Intelligent Systems

Proceedings of CIS 2022, Volume 1

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Lecture Notes in Networks and Systems

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Preface

This book contains outstanding research papers as the proceedings of the 3rd Congress on Intelligent Systems (CIS 2022), held on September 05–06, 2022, at CHRIST (Deemed to be University), Bengaluru, India, under the technical sponsorship of the Soft Computing Research Society, India. The conference is conceived as a platform for disseminating and exchanging ideas, concepts, and results of researchers from academia and industry to develop a comprehensive understanding of the challenges of the advancements of intelligence in computational viewpoints. This book will help in strengthening congenial networking between academia and industry. We have tried our best to enrich the quality of the CIS 2022 through the stringent and careful peer-review process. This book presents novel contributions to Intelligent Systems and serves as reference material for advanced research.

We have tried our best to enrich the quality of the CIS 2022 through a stringent and careful peer-review process. CIS 2022 received many technical contributed articles from distinguished participants from home and abroad. CIS 2022 received 729 research submissions from 45 different countries, viz. Algeria, Australia, Bangladesh, Belgium, Brazil, Bulgaria, Colombia, Cote d’Ivoire, Czechia, Egypt, Ethiopia, Fiji, Finland, Germany, Greece, India, Indonesia, Iran, Iraq, Ireland, Italy, Japan, Kenya, Latvia, Malaysia, Mexico, Morocco, Nigeria, Oman, Peru, Philippines, Poland, Romania, Russia, Saudi Arabia, Serbia, Slovakia, South Africa, Spain, Turkmenistan, Ukraine, UK, USA, Uzbekistan, and Vietnam. After a very stringent peer-reviewing process, only 120 high-quality papers were finally accepted for presentation and the final proceedings.

This book presents first volume of 60 research papers data science and applications and serves as reference material for advanced research.

Bengaluru, India

Kota, India

Bengaluru, India

Seoul, South Korea

New Delhi, India

Sandeep Kumar

Harish Sharma

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Design and Analysis of Genetic Algorithm Optimization-Based ANFIS Controller for Interleaved DC-DC Converter-Fed PEMFC System



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Abstract The Maximum Power Point Tracking (MPPT) controllers are used for enhancing the working performance of proton exchange membrane fuel cell (PEMFC)-related power generation systems. In this article, a genetic optimization-based Artificial Neuro-Fuzzy Inference System (ANFIS) concept is applied to the interleaved non-isolated boost converter-interfaced fuel cell stack system in order to improve the operating efficiency of a transformerless DC-DC converter. The proposed MPPT controller is compared with the other conventional adaptive Perturb & Observe controller in terms of settling time of peak power point, oscillations related to fuel cell output voltage, and tracing time period of MPPT controller. The second objective of this work is design of an interleaved DC-DC converter for improving the output voltage profile of the fuel block. The characteristics of this converter are wide output operation, less potential stress, and more voltage gain.

Keywords Duty ratio · Genetic algorithm · High MPP tracking speed · Interleaved DC-DC converter · Low oscillations of MPP

1 Introduction

Nowadays, most of the global industries as well as human beings are focusing on automotive systems because of its fast growth, low maintenance cost, less dependence on fossil fuels, and high profits [1]. In addition, the availability of fossil fuels is

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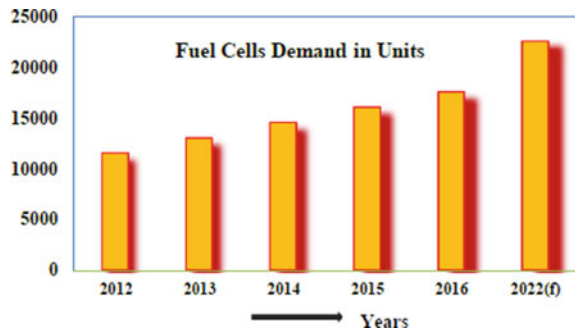
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reducing slowly. Hence, the power generation cost of fossil fuel-dependent systems is very high. From the literature review, the conventional or nonrenewable power production systems are illustrated as thermal, nuclear, oil, and natural gasses [2]. The disadvantage of conventional energy systems is global warming [3]. All over the world, coal is the very inexpensive and efficient way to produce electricity. The features of thermal power plants are cheap in coal use and require less space for installing [4]. The demerits of coal power production systems are that it requires high cost for starting the boilers and is difficult in an ash handling plant [5]. However, the demerits of coal systems are limited by using the oil power stations. The merits of oil power generation systems are high energy density, encourage the economy of the world, and are moderately reliable [6]. But, the drawbacks of oil power systems are high air pollution and ozone depletion.

In article [7], nuclear power systems are utilized for converting explosion radius energy into useful active power. The merits of nuclear power plants are low carbon energy source, less carbon footprints, less cost in operation, and high energy density [8]. The disadvantages of nuclear power production systems are high initial cost and high impact on human life [9]. There are many disadvantages due to the conventional energy systems which are limited by using the nonconventional energy systems. The nonconventional energy systems are illustrated as solar, wind, tidal, and fuel stack. The features of wind power generation systems are cost-effective, clean energy, less working cost, and efficient utilization of land space and create more economy for human lives [10]. The drawbacks of wind energy systems are unpredictable, continuous interruptible power supply, less flexible, and high impact on wildlife [11]. Solar is a natural source which is available freely in nature. The working nature of solar is similar to the normal $P-N$ junction diode [12]. The features of solar PV are less maintenance cost and environmental free source of energy. The only disadvantage is less continuity in supply. So, in this article, a PEMFC is used for automotive systems in order to run the vehicle without any distortions [13]. The fuel stack demands every year are mentioned in Fig. 1.

The major consideration of fuel cells is nonlinear behavior which is solved by using the maximum power point finding controller. At various temperature conditions, the fuel cell gives various peak power points on the I-V curve. In article [14],

Fig. 1 Yearly fuel stack production strategy in terms of units

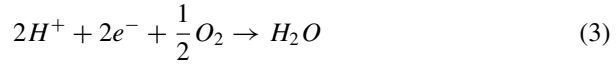
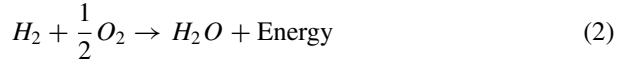


a P&O controller is utilized for continuous tracing of MPP. Here, the perturbation of power has been done and it is equated with the previously stored data. The equated results give the positive signal, and then the perturbation moves in identical direction or else the variation moves in inverse direction. The disadvantages of the P&O method are more oscillations in fuel cell output voltage, requiring more sensors to sense the fuel stack output variables [15]. Due to this situation, an incremental conductance methodology is used in article [16] for fast improving the entire hybrid system performance. This incremental conductance concept gives less power oscillations and high MPP tracing speed when equated with the other conventional controller. The only drawback is more implementation cost. However, the disadvantages of above-explained MPPT techniques are compensated by using an adaptive variable step size P&O controller [17]. In this adaptive controller, at first, an extreme step value is utilized for making the fast convergence speed of fuel cell MPP. After that, the power point finding controller step length is optimized to determine the accurate position of MPP. But, this MPPT method is most suitable for the uniform working temperature of the fuel stack. At the dynamic working temperature of a fuel cell, an ANFIS is used for optimizing the overall system size.

2 Operation of Fuel Cell Power System

At present, there are different types of fuel stack modules offered in the market. The major types of fuel cell modules are alkaline fuel module, direct methanol fuel module, PEMFC, and solid oxide-based fuel module [18, 19]. In article [20], the authors used the phosphoric acid-based fuel cell module for running the battery-related electric vehicle system. The most attractive features of this fuel cell are available in commercial, high lifetime, and low market cost when compared to the other fuel cell topologies. The molten carbonate fuel cell is used in article [21] for enhancing the efficiency of internal fuel processing. This type of fuel cell works at high temperature conditions. The molten carbonate fuel cell stack has the instability in electrolyte and produces high carbon dioxide content. So, in this work, PEMFC is considered for electric vehicle application. The features of PEMFC are high lifetime period, low power losses, and most adoptable by automotive systems. The operation of the selected fuel cell is explained by using Fig. 2. From Fig. 2, the hydrogen chemical and water membrane are converted to electricity by utilizing the redox chemical reaction. Here, each fuel module provides uninterrupted energy until supplying the hydrogen input. Whereas in batteries, the fuel is available by inbuilt and the working of batteries is completely dependent on the oxidant material's chemical reaction. The applications of fuel cell technology are residential, commercial, and industry-related systems. The fuel cell design constants and its power curves are shown in Table 1 and Fig. 3. Based on Fig. 2, the chemical oxidation of fuel cell is obtained as,





$$V_0 = N * V_{FC} \quad (4)$$

$$V_{Oh} = E_{Ot} - V_{FC} - V_{Ac} - V_{Co} \quad (5)$$

$$V_{FC} = E_{Ot} - V_{Oh} - V_{Ac} - V_{Co} \quad (6)$$

As related to Eq. (1), it is clearly determined that the input supply of a fuel cell is hydrogen and this hydrogen is converted into hydrogen ions along with the electrons. The separated electrons flow to the external circuit in order to generate the light energy. After that, the hydrogen ions are transferred from the gas diffusion layer to the cathode. In the cathode layer, the oxygen is combined with the input fuel for delivering the water. Here, each and every fuel cell gives very less power

Fig. 2 Working strategy of proton exchange membrane fuel cell system

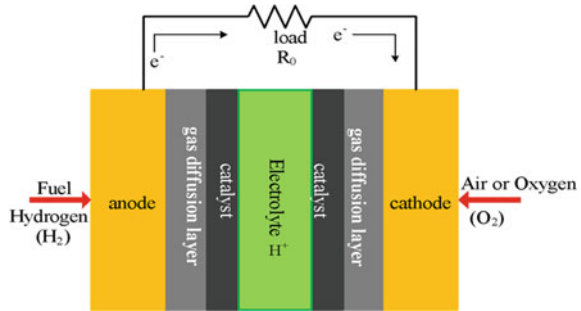


Table 1 Complete design parameters of fuel module at various working temperatures

Variables	Specifications
Peak working current of stack (I_{MPP})	52A
Peak working voltage of PEM fuel cell (V_{MPP})	24.0 V
Utilized open circuit potential of PEMFC (V_{OC})	42.00 V
Maximum generated power of PEMFC	1260 W
Pressure of oxygen on PEMFC	1.00 bar
Flow rate of air in fuel stack (I_{npm})	$2.4 \cdot 10^3$
Hydrogen-related partial pressure on fuel stack	1.5 bar
Basic air utilizing quantity in PEMFC (I_{pm})	$4.615 \cdot 10^3$
Total cells utilized (n)	42.00

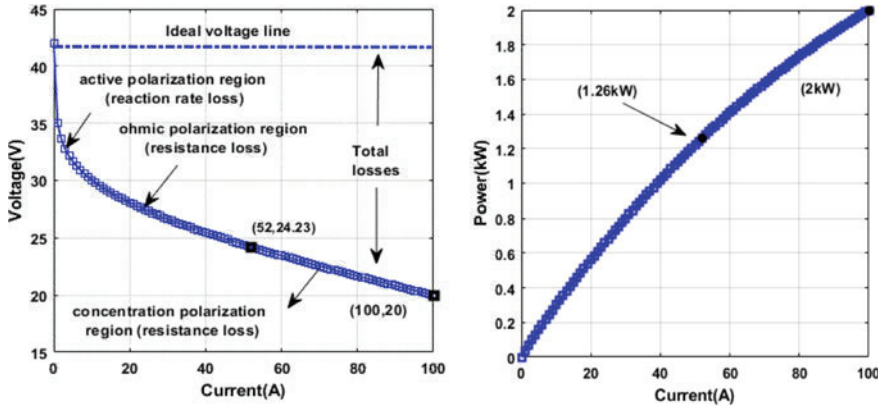


Fig. 3 PEM fuel cell output, **a** voltage versus current characteristics, plus, **b** power versus current characteristics

which is not useful for industry application. So, there are multiple types of fuel cells that are interconnected for improving the power supply capability of fuel-dependent electric vehicle systems. The total selected fuel cells for forming a module are given in Eq. (4). In Eq. (4), the variable ‘ N ’ gives the entire amount of cells in the fuel stack, and V_0 is total cell output voltage. Similarly, the variable V_{FC} is defined as one fuel cell potential which is obtained by using Eq. (5). The detailed working considerations of the fuel system are shown in Table 1. The ohmic polarization loss, active, and concentrated ohmic polarization losses are defined as V_{Oh} , V_{Ac} , and V_{Co} , respectively.

3 Analysis of Transformerless Interleaved DC-DC Converter

From the previous published articles, the power converters are illustrated as isolated with transformer, and non-isolated power converters. The isolated converters require an extra rectifier circuit for protecting the semiconductor switches from high input power supply. In article [22], the authors used the isolated based zero voltage switching-related power converter for hybrid fuel cell grid-connected systems in order to make the constant grid voltage. The features of this topology are high voltage gain, more flexible, less manufacturing cost, and wide output operation. But, it gives more power conduction losses. So, to compensate for the disadvantages of conventional power converters, in this article, an interleaved methodology is used for designing the transformerless boost converter.