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Graphical analysis of a DC-DC converter effect on a fuel cell: D-transformation

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Abstract

In practical cases, the use of a renewable energy device with a DC-DC converter is preferred to a single device alone for the purpose of compensating unstable output power and intrinsic limitations of the device. However there has not been fundamental understanding how to transform the device internal properties not only the output current and voltage. Therefore, a fundamental understanding of the DC-DC converter is urgently required. In this study, we investigate the fundamental role of a DC-DC converter when connected with renewable devices. We use a graphical and mathematical method for qualitative and quantitative analysis. The analysis is model-based and done for boost, buck and buck-boost converters, respectively. We find that the essential role of the DC-DC converter is to transform the fundamental electrical properties of a device to suitable properties for the load.

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Keywords: Fuel cell; DC-DC converter; graphical approach;

1. Introduction

Due Figure 1 illustrates how the current that is supplied to an electrical load is determined without a converter, which is called a passive operation. In a fuel cell, the internal resistance has to be adjusted in order to properly conduct the current supplied to the load. And, in a battery, the open-circuit voltage (OCV) is adjusted to supply current to the load because a change in the internal resistance has a relatively smaller effect than a change in the OCV.

However, previous studies on coupling fuel cells and DC-DC converters have focused on developing an effective DC-DC converter to compensate for the intrinsic drawbacks of fuel cells, such as slow response and difficulty with cold starting. The research directions regarding the converter are classified

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into two main areas: developing novel control logic [1, 2] and developing hardware [3, 4] for power sharing of each energy device. Many powerful efficient control logic schemes and robust topologies have been proposed in previous studies. These studies are not considered to be fundamental for the role of DC-DC converters and the characteristics of devices.

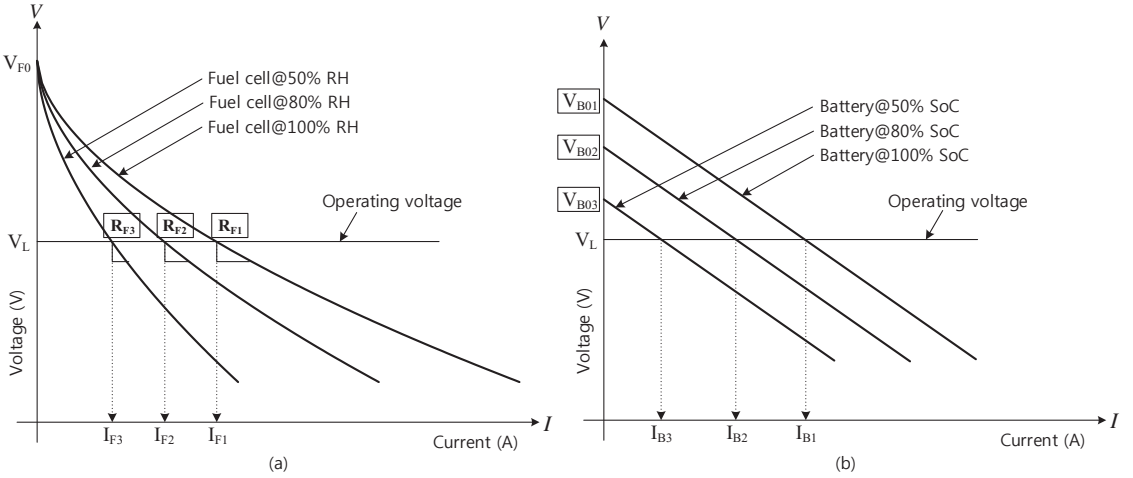

Fig. 1. I-V characteristics change without a converter: (a) fuel cell with humidity control; (b) battery with state of charge control

In this study, we investigate the practical role of a DC-DC converter for energy devices such as fuel cells. We propose essential factors for describing the relationship of the energy device and the DC-DC converter. First, we determine how the DC-DC converter improves the current supplying capability to an electrical load with a graphical analysis. Second, we explain the practical roles of a DC-DC converter by deriving precise and practical equations that quantitatively describe the relationships among the fuel cell, DC-DC converter, and electrical load.

2. D-transformation

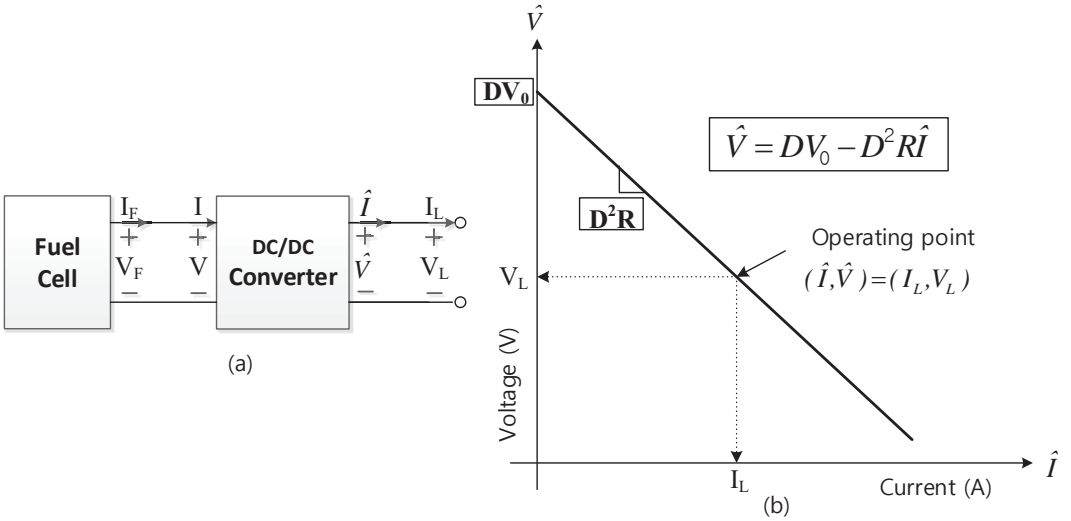

Fig. 2. (a) Fuel cell connected with a DC-DC converter; (b) voltage and resistance transformation by converter operation