Modeling and Control of Bidirectional DC-DC Converters for DC Power Systems with Renewable Energy

フサーム, アーメド ラマダン アーメド

https://doi.org/10.15017/1500744

出版情報：九州大学, 2014, 博士（学術）, 課程博士
バージョン：

（別紙様式 2）

氏　　名　：フサーム アーメド ラマダン アーメド

論 文 名　：Modeling and Control of Bidirectional DC-DC Converters for DC Power Systems with Renewable Energy
（再生可能エネルギーを利用した直流電源システムに用いる双方向 DC-DC コンバータのモデリングと制御に関する研究）

区　　分　：甲

論 文 内 容 の 要 旨

Bidirectional dc-dc converters (BDC) have recently received a lot of attention due to the increasing need to systems with the capability of bidirectional energy transfer between two dc buses. Apart from traditional application in dc motor drives, new applications of BDC include energy storage in renewable energy systems, fuel cell energy systems, hybrid electric vehicles (HEV) and uninterruptible power supplies (UPS).

The fluctuation nature of most renewable energy resources, like wind and solar, makes them unsuitable for standalone operation as the sole source of power. A common solution to overcome this problem is to use an energy storage device besides the renewable energy resource to compensate for these fluctuations and maintain a smooth and continuous power flow to the load. As the most common and economical energy storage devices in medium-power range are batteries and super-capacitors, a DC-DC converter is always required to allow energy exchange between storage device and the rest of system. Such a converter must have bidirectional power flow capability with flexible control in all operating modes. The modeling and control of bi-directional DC-DC converters is an important issue. By using conventional modeling method, two different models are needed. One model for each power direction (each operation mode). Furthermore, the control loop also should be changed according to the direction of the power flow. Therefore, analyzing and controlling of a bi-directional DC-DC converter became very complex. For the sake of solving this problem, unified dynamic models of bi-directional DC-DC converters are proposed in this thesis. Furthermore, the stability issue for the bi-directional DC-DC converters is investigated in this thesis. The thesis consists of five chapters, which can be organized as follows:

Firstly, Chapter 1 conveys the detailed introduction of the research background, a literature review of bidirectional DC-DC converters, their types (isolates and non-isolated), modeling and control. Moreover, it presents the thesis objective and outlines.

Then, in Chapter 2, a unified model for bi-directional DC-DC converters for both directions of power flow is presented. The bi-directional DC-DC converter is analyzed using a seamless dynamic model with an independent voltage source and an independent current source, which polarity depends on the direction of the power flow. A small signal model is derived using a state space averaging method. Furthermore, the transient response and the frequency characteristics are discussed. Example circuits for bi-directional DC-DC converter are investigated analytically, using simulation, and experimentally.

Afterwards, Chapter 3 introduces a new control strategy for bidirectional DC-DC converter, as well. This strategy aims at controlling a bidirectional DC-DC converter to behave like a multi-level virtual conductor. As a matter of fact, the voltage difference between the terminals of any conductor is zero volts. Conversely, the main target of this proposed control strategy is to keep the voltage difference between the converter terminals constant at a certain value. In other words, this strategy permits the DC-DC converter to transfer the power between two nodes at different voltage levels. In this way, the converter performs like a conductor, but unlike the normal conductor, has a voltage difference between its terminals. Thus, the authors call it a virtual conductor. This virtual conductor is considered a base for power routing in dc networks; as it can transfer the electric power between nodes at different voltage levels. Furthermore, it allows an easy plug-and-play feature. The proposed bidirectional DC-DC system configuration is investigated analytically, using PSIM simulator, and experimentally.

Further, in Chapter 4, a new criterion for the stability assessment in a dc power system is presented. This criterion is the node impedance criterion. The concept, mathematical, simulation, and experimental analysis of node impedance criterion, are investigated, as well. The results of the node impedance criterion are compared with those of the conventional criterion. The comparison shows the validity of the node impedance as a stability criterion. Moreover, the node impedance criterion is applied to a dc power system using a MLVC to assess it stability.

Finally, Chapter 5 summarizes the conclusions of this thesis and the future work.