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Recent progress and development on power DC-DC converter topology, control, design and applications: A review

M.Z. Hossain[a], N.A. Rahim[a,b], Jeyraj a/l Selvaraj[a,*]

[a] UM Power Energy Dedicated Advanced Centre (UMPEDAC), Level 4, Wisma R&D, University of Malaya, 59990 Kuala Lumpur, Malaysia
[b] Renewable Energy Research Group, King Abdulaziz University, Jeddah 21589, Saudi Arabia

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ABSTRACT

Over the last few decennia, power DC/DC converters have been the subject of great interest due to its extensive increment of utilization in different applications. A thorough review on recent developed power DC/DC converters is presented in this paper. The study is focused on the topologies in different applications such as renewable energy, automobile, high-voltage and medium-voltage DC power systems, telecommunication, etc. In addition, an overview of the modulation techniques, the state-of-the-art of control strategies of well-established converters are discussed. Photovoltaic (PV) systems as the noticeable renewable energy resources generally suffer from poor conversion efficiency with instability and intermittent characteristics. Therefore, DC/DC converter with Maximum Power Point Tracking (MPPT) algorithm is essential to ensure maximum available power harnessed from the PV. Important features of DC/DC converters with MPPT are also figured with various performances. Furthermore, the design and optimization of different parameters are addressed systematically. Finally, the researcher's future challenges and focusing trends are briefly described. For the next-generation converters design and applications, these are considered in details, and will provide useful framework and point of references.

1. Introduction

A considerable measure of interest is recently building up of Power DC/DC Converters (PDDCs) recently in the industry and the educated community as one of the favored options in medium/ high-power applications for the purpose of electronic power conversion [1–3]. They have effectively advanced into the industry and therefore can be taken into account as a mature and demonstrated technology. Right now, they are popularized in standard and redone items that power an extensive variety of applications, for example, photovoltaic (PV) power systems [4], offshore wind turbines (OWT) [3], electric / hybrid electric / plug-in-hybrid electric/ fuel cell vehicles (EV/ HEV/ PHEV/ FCV) [2,5], medium-voltage DC (MVDC) and high-voltage DC (HVDC) power systems [6,7], telecommunication power supply [8], on ship-board power system [9] and in offshore petroleum and gas applications of subsea compressors [10], FC based power supply [11] etc. In spite of the fact that it is an established and as of now proven innovation, PDDCs exhibit a lot of difficulties, and considerably all the more essentially, they offer such an extensive variety of potential outcomes that their innovative work is as yet developing in depth and width. As a result, in recent years, many researchers throughout the world are concentrating their efforts towards specialized improvement in conversion efficiency, power density, reliability, control techniques, simplicity and cost of PDDC as well as spreading its applications. Furthermore, the very common DC/DC converters, usually suitable for low-power applications, cannot scale-up very well for high-power (HP)/ medium-power (MP) applications because of their unsatisfactory performances [12,13].

Recently, several review reports related to DC/DC converters have been figured out in literature. Review works on non-isolated DC/DC converter for PV application have discussed in [14] and [15], where, DC/DC converters for grid connected with high conversion ratio, and characteristics of few basic DC/DC converters have described respectively. The high efficiency with high voltage gain DC/DC converter topologies for renewable applications in the aspect of non-isolated and isolated architectures has been reviewed in [16]. Review on DC/DC converters with multilevel topologies for automotive and HP applications, and with HP density (HPD) and high-efficiency characteristics for HEV and fuel cell electric vehicle (FCEV) applications are summarized in [17] and [18] respectively. In addition, EV related reviews have also described in [19,20], where, different DC/DC converters are discussed with the other power electronic devices. Furthermore,

* Corresponding author.
E-mail addresses: mzakir@um.edu.my (M.Z. Hossain), nasrudin@um.edu.my (N.A. Rahim), jeyraj@um.edu.my (J.a. Selvaraj).

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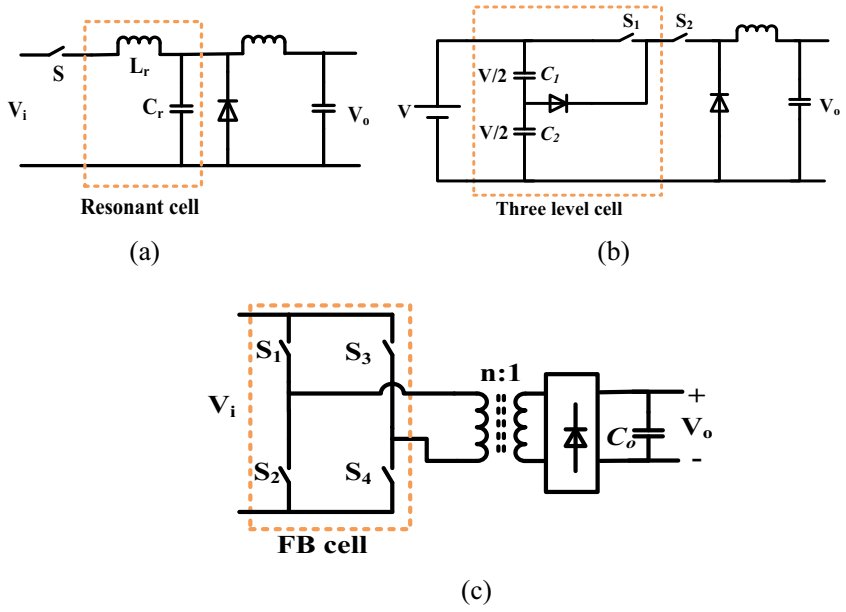

Fig. 1. Classical PDDC topologies. (a) Series resonant (SR). (b) three-level (3 L) buck. (c) Full-bridge boost.

literature [21,22] overview the DC/DC converter architectures, those are applicable to FC-ultracapacitor based hybrid system and FC power system respectively. In the same way, review works in the relation between the FC technologies and electronic interfacing, and power converter interfacing with electrochemical based energy storage devices including few DC/DC conversion systems have reported in [23] and [24] respectively. The review is focused on AC/DC and DC/DC converters based high-frequency power distribution system (HFPDS) [25], for space, telecommunications, and computer applications, in where DC/DC converters topologies along with other features are not the main concern of discussion. A review on DC/DC converters for high-frequency (HF) HF-link conversion system has reported in [26], considering only the isolated bidirectional dual active bridge (DAB) architecture among the several topologies. Few DC/DC converters topologies only for wind energy collection and transmission system like HP power applications have briefly described in [27]. However, from the aforementioned discussions, it is clear that review on various established and proved power DC/DC converter topologies, modulation and control strategies, design and optimization, and emerging applications are still not addressed properly, which are the main focuses of the present review paper. This research provides better understanding of the DC/DC converter specially designed for medium or high power applications (≥1 kW), even prototype has implemented for lower power, excluding few exceptions. This study is focused on the architectures in various applications for example, renewable energy, vehicle, HVDC and MVDC power systems, telecommunication, and so on. Likewise, an outline of the modulation strategies, the cutting edge of control techniques of well-established converters are talked about. The PV system as the noteworthy renewable energy resources generally experiences by miserable conversion ability with instability and intermittent behaviors. Hence, DC/DC converter with MPPT algorithm is vital to guarantee maximum available power output from the PV. The salient features of PDDC in PV system are additionally figured with various performances. Moreover, the design and enhancement of various parameters are addressed systematically. At long last, the researcher's future difficulties and focusing patterns are briefly discussed to inspire further study in this field.

The rest of the paper is organized as follows: Section 2 describes the basic topologies of PDDC. This is followed by the overview of recent progress of PDDCs topologies with their operational issues and challenges are described in Section 3. Section 4 covers the latest and widely used various modulation and control strategies, and control devices. As the PV energy is the fast growing share among the renewable energy, PDDCs with MPPT algorithm used in PV system are explained in Section 5. In Section 6, the general design of active and passive parameters of PDDC, and its optimizations are included. Reputed and coming promising applications of PDDC are described in Section 7, which is followed by the design procedure, future challenges and research trends in Section 8. Finally, the concluding remarks are concluded in Section 9.

2. Classical PDDC topologies

For integrity and clear understanding of the recently developed PDDC technologies, it is essential to provide a brief summary of their used before the last decade. It is quite difficult to point out the first dc-dc converter topology developed for medium or high power applications. However, it is seen that at the early 1970s; a thyristor controlled buck type dc-dc converter was proposed for high-power (HP) dc power supply research-based applications [28]. In which, a simple switching circuit with two silicon-controlled rectifiers (SCR) was utilized to control the power to the load by periodic switching. In the mid -1970s [29], a series resonant dc converter topology was developed for HP industrial size [30]. Just a few later, in the late 1970s, a three-level high power dc-dc converter was proposed [31], which is presently recognized as multilevel converter (MC) topology. This buck-boost type converter was controlled by time-sharing high-frequency thyristor with energy-storage and -transfer reactor coupling links for the high-frequency (HF) inverter and large-scale dc power supplies. A dual bridge dc-dc converter (BC) topology of HP density was proposed for HP applications in [32], at the early 1990s. It consists of a three-phase dual-bridge inverter operating in HF and soft-switching (SS) technique and a three-phase symmetric AC link transformer. Currently, these three topologies (resonant, multilevel and bridge/ multiphase-bridge (MPB)) could be considered as traditional or classical PDDC topologies that were made in an earlier age for various power applications. Generally, the conventional buck, boost and buck-boost (bB) type basic converters are also used for HP / MP applications in the form above mentioned topologies. As the examples, these three topologies are shown in Fig. 1. These converters are offering different parameters such as power rating, operating frequency, semiconductor devices used, and control principles, among other technical specifications.