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CONCOMITANT POWER CONTROLLING BY MULTIPORT DC–DC CONVERTER FOR RENEWABLE ENERGY SOURCES USING PI CONTROLLER

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ABSTRACT

In this paper, for providing the optimal operation of multiport dc–dc converter for renewable energy sources, PI Controller has been implemented. Here, the proposed controller is utilized to achieve the concurrent power management of compound renewable energy sources, which are of various types and capacities. Initially, the modeling and control topology is designed after that, the principle and operations are analyzed. The suggested dc–dc converter uses only one switch for control in every port where the source is associated. The photovoltaic (PV) and Wind Turbine Generator (WTG) are considered as the sources and these are associated with the converter. The PV is worked in view of the maximum power point tracking (MPPT) controller and WTG is associated with the battery source. In MATLAB/Simulink environment, anticipated method is implemented and their performances have been evaluated. The performance of the suggested method is compared with the existing controller. The simulation results are shown to validate the effectiveness of the proposed converter. Then the efficiency of the converter is also determined to evaluate simultaneous power management of the PV and WTG panels for converter.

Keywords: multiport DC-DC converter, PI controller, WTG, PV.

INTRODUCTION

The power converters have as of late gotten a ton of consideration because of the expanding need to frameworks with the capacity of vitality exchange. A power electronic converter is utilized as an interfacing gadget. Essential dc-dc converters, for example, buck, boost etc., help converters and its subsidiaries don't have bidirectional force stream ability [5]. The fundamental downside of the Dual Active Bridge (DAB) converter is that it can't deal with an extensive voltage range. In such a case, the delicate exchanging district of operation will be altogether decreased. In the previous decades, customary force converter topologies have been advancing in different headings, a few bidirectional topologies, for example, full-extension and half-connect topologies, have been produced. These two topologies use numerous switches with entangled drive and control circuits [3].

A multiport converter, a promising idea for option vitality frameworks, has pulled in expanding research intrigue as of late [6] [7]. It has less savvy, adaptable, and more proficient vitality preparing by using just a solitary force stage. The multiport dc-dc converters are utilized to accomplish the force exchange amongst sources and load. Because of the upsides of multi-port converters, numerous topologies have been proposed, which can be partitioned into the disengaged multi-port converters and non-segregated partners. The segregated dc–dc converter has numerous info ports for interfacing distinctive sources, for example, photovoltaic (PV) boards, wind turbine generators (WTGs), energy units, and so on., [4] [8]. The converter not just manages the low-level dc voltages of the sources to a steady abnormal state required by the inverter but also additionally gives other essential control capacities, for example, most extreme force point following (MPPT) [1] [2].

PI BASED MULTIPORT DC-DC CONVERTER

In this section, the multiport DC-DC converter performance is designed and analyzed their performances using the proposed controller. The proposed controller is the PI Controller to provide the simultaneous power management. Actually, the multi-port converter with ‘m’ number of inputs (1 to m) can be implemented. But in this paper, for convenience, two inputs (one PV and one WTG) are taken as inputs. The block diagram of proposed PI based multiport DC-DC converter with hybrid generation system is depicted in Figure-1. It represents the PV panel, Wind Turbine Generator (WTG) and Battery is connected with the proposed converter. For the renewable resources, two capacitors and two switches are connected to get the optimal operation. The flow of change of wind is added significantly rather than the solar irradiance and the temperature. Before analyzing the proposed control strategy, the operations of the offered multiport DC-DC converter is analyzed and the detailed description is explained as below.

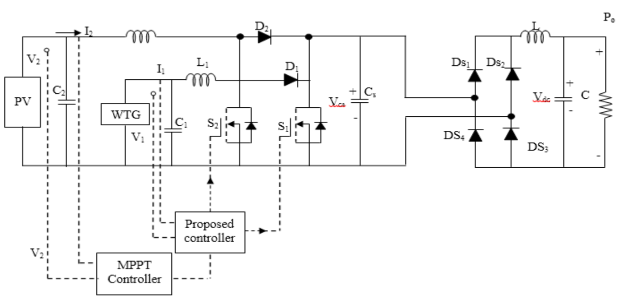

Figure-1. Block diagram of multiport DC-DC converter with proposed method.

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Operation mode of multiport DC-DC converter

In the subsection, the suggested multiport DC-DC converter operations are analyzed. The equivalent circuit diagram of the proposed isolated multiport DC–DC converter is illustrated in Figure-2. It comprises of a Low-Voltage Side (LVS) circuit and a High-Voltage-Side (HVS) circuit and energy storage capacitor. The LVS circuit comprises of one energy storage capacitor Cs. The circuit includes three modes of operations. i) All switches are on ii) S1 Switch is off while at least one of the other switches is on and iii) All Other switches are off. From Figure-2, for effective working of two sources, the following necessities should be satisfied: the switch S_k (k=2,… m) should be turned off after S1 is switched off; otherwise, energy will be stored continuously by L_k through S1 though S_k is off, which is not preferred [9]. The following inequality must be satisfied to meet the above constraint.

$$d_1 \leq \min\{d_2,....,d_m\} \quad (1)$$

The above restriction is met if the input voltage at port1 is the leading and the subsequent inequality is fulfilled.

$$\max\{V_2, V_3,....., V_m\} \leq V_1 \quad (2)$$

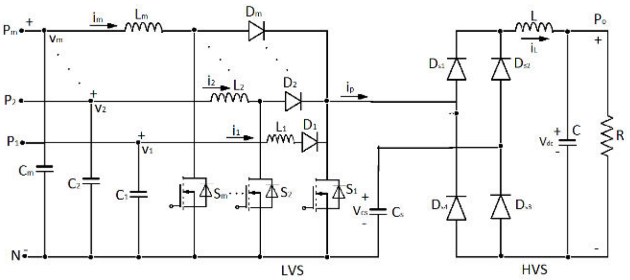

Figure-2. Illustration of the proposed multi-port DC-DC converter.

It should be noted that in the aforementioned two scenarios, by proper controlling of the duty cycles of the corresponding switches, the sources connected to other ports (i.e., Ports 2–m) can still be controlled concurrently and autonomously in the MPPT mode. The design of inductance and voltage of the multiport DC-DC converter is specified as below,

$$V_k = L_k \frac{\Delta I_k}{D_k.T_s} \qquad k = 1,2,....,m \quad (3)$$

$$L_k = \frac{V_k.D_k}{f_s.\Delta I_k} \qquad k = 1,2,....,m \quad (4)$$

Here, the switching frequency of the converter is f_s. The voltage across the secondary inductor L is calculated as follows when S_1 is on.

$$L = \frac{(V_1/n - V_{dc}).D_1.T_s}{\Delta I_L} = \frac{V_1.(1-2D_1).D_1}{f_s.n.\Delta I_L} \quad (5)$$

$$L_{\max} = \frac{V_1}{8 f_s.n.\Delta I_L} \quad (6)$$

The inductor current is identical to the source current in each input port in steady state, and the ripple current of the inductor is provided by capacitor C_k (k=1,...,m),

$$\Delta I_k = C_k \frac{\Delta v_k}{D_k.T_s} \qquad k = 1,2,....,m \quad (7)$$

$$C_k = \frac{\Delta I_k.D_k}{f_s.\Delta v_k} \qquad k = 1,2,....,m \quad (8)$$

Modes of operations

Mode 1: In the first mode of operation, the two switches are operated in the condition ON. Then the inductor performances are analyzed and the energy is extracted from the sources. Simultaneously, in the previous switching cycle, the energy stored in the capacitor Cs is delivered to the HVS through the diodes Ds_2 and Ds_4.

Mode 2: In this mode of operation, switch S1 is off and the other switch is ON. Actually, in this mode, 2m-1-1 scenarios are present depending on the states of the other (m−2) switches S_2,...,S_k−1,S_k+1,...,S_m. As an example, one scenario is demonstrated, in which all switches are off except only one switch S_k is on.

Mode 3: In this mode of operation, all the switches are OFF.

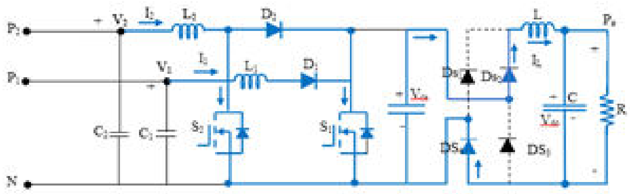

Figure-3(a). Operation mode of proposed converter in Mode -1.

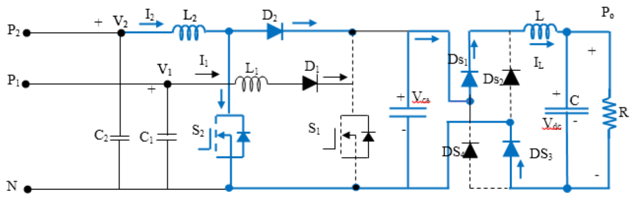

Figure-3(b). Operation mode of proposed converter in Mode -2.

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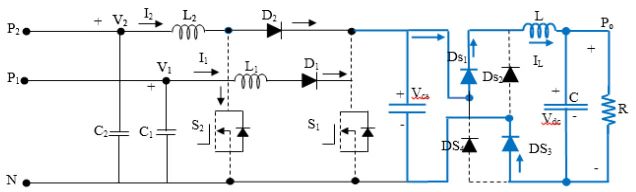

Figure-3(c). Operation mode of proposed converter in Mode -3.

In this segment, the control approach of multiport DC-DC converter is analyzed with the proposed PI controller. In the control strategy, PI controller is utilized to generate the optimal switching pulses of the converter. By using gain parameter of the PI controller, the regulation of the capacitor voltage is achieved. Here, the error voltage and change in error voltage is applied to input of the PI controller. From the output of the function, the error function should be minimized. The gain parameter of the PI controller is specified by the following equations,

$$k_p(\delta) = k_p(\delta - 1) + \Delta k_p(\delta - 1) \tag{9}$$

$$k_i(\delta) = k_i(\delta - 1) + \Delta k_i(\delta - 1) \tag{10}$$

The error voltage is evaluated by using the following equation,

$$EV(\delta) = V_{dc}^{*}(\delta) - V_{dc}(\delta) \tag{11}$$

From the above equations, the K_p and K_i are evaluated for achieving the optimal results. For achieving the optimal results, the duty cycles are generated and given to the converter.

RESULTS AND ANALYSIS

In this section, the performance of the proposed controller is examined and is implemented with multiport DC-DC converter in MATLAB/Simulink. In order to analyze the proposed control technique, the existing base controller is first implemented. The performance of multiport DC-DC converter is enhanced based on their switching pulses and their mode of operation. In the proposed PI controller, the inputs of the controller are the error voltage and change in error voltage. Based on their inputs, the control signals are generated and which is given to the PWM. After that, the PWM generate the switching pulses for controlling the operation of suggested converter shown in figure4. Here, the two sources are WTG with 48V output and PV panel with 17.4V and 6.3A rating are taken. These two inputs are connected to Port 1 and Port 2 respectively at a time and duty cycles of switches S_1 and S_2 are gradually increasing from a low value (0) to a high value (1), leading to ongoing change of the operating points of the WTG and PV. The duty ratio varies faintly around the optimal duty ratio from time to time because of the small oscillations of the operating points caused by the traditional algorithm. Those oscillations of inductor currents are given are shown in Figures 5(a) &5(b). These oscillations are moderately small compared with the average current value and are tolerable.

In order to analyze the effectiveness of the proposed converter, the efficiency is also analyzed. In the efficiency analysis, the suggested system gives better results when compared to the already existing method. Figures 7(a) & 7(b) shows the measured efficiency with respect to the output of the converter for existing method as well as proposed PI controller.

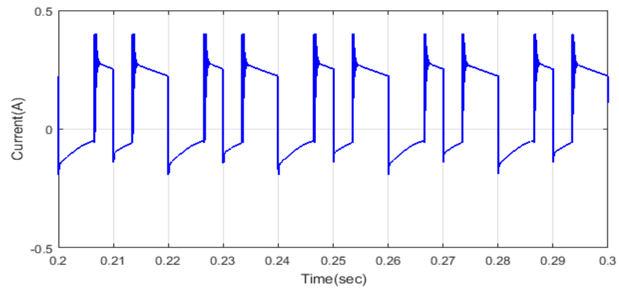

Figure-4. Analysis of control pulse for Switch S_1 & S_2.

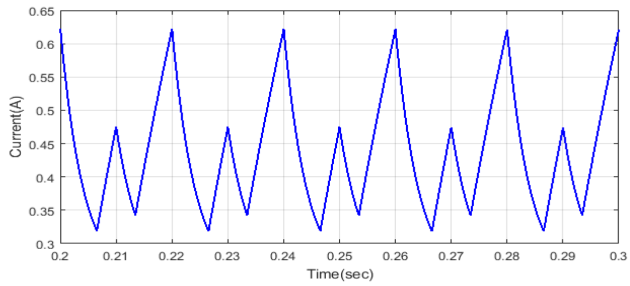

Figure-5(a). Current analysis for Inductor L_1.

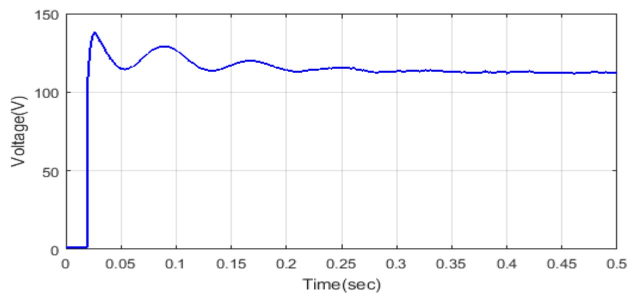

Figure-5(b). Current analysis for Inductor L_2.

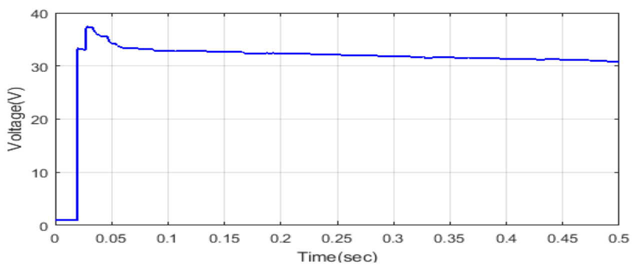

Figure-6(a). O/P Voltage for Existing Controller.

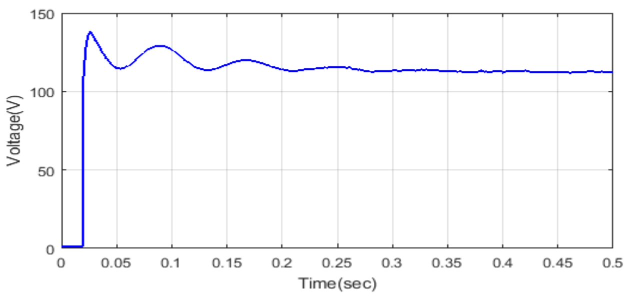

Figure-6(b). O/P Voltage for proposed controller.

In the proposed method, the efficiency first rises with the rising of the output power. Particularly, when the output power is 50 W, the maximum efficiency reaches to 94%. Then, the efficiency gradually decreases with the increase of the load but is always higher than 90%. While contrasted with existing topology, the proposed controller accomplished excellent efficiency.

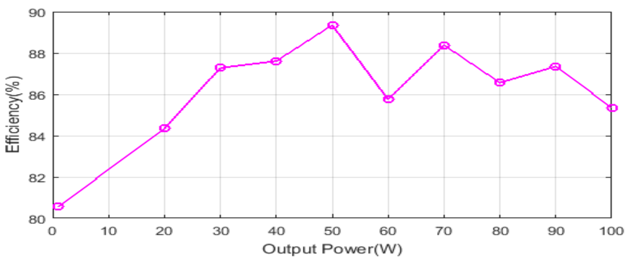

Figure-7(a). Efficiency analysis for existing controller.

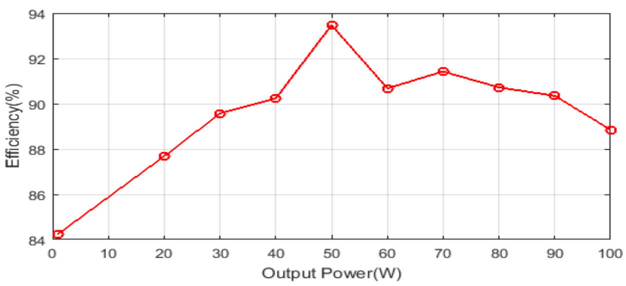

Figure-7(b). Efficiency analysis for proposed controller.

CONCLUSIONS

In the paper, an efficient controller has been developed for the optimal operation and obtaining the simultaneous power management of DC-DC multiport converter. The WTG and PV are analyzed for the converter operation, which has worked under the MPPT controller. The inputs of the PI controller are error voltage and change in error voltage, the output of the PI controller is generating the control pulses. Here, the multiport dc–dc converter that uses the less number of switches for concurrent power management of various renewable energy sources. In MATLAB/Simulink environment, the proposed controller has been implemented. In order to prove the effectiveness of the suggested method, the performances are analyzed and compared with the existing controller. Moreover, the efficiency of the converter is also analyzed using different controllers for getting the optimal operation of multiport dc-dc converter. The simple structure of topology and concurrent power management for renewable energy sources is the big asset of suggested converter. The obtained results shows the maximum output power, less disturbances of the switching pulses of the converter and achieve maximum efficiency in each time interval with adequate and control of converter.

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