Fuzzy Logic Controller Based SEPIC Converter for Maximum Power Point Tracking

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Abstract—This paper presents a fuzzy logic controller (FLC) based single-ended primary-inductor (SEPIC) converter for maximum power point tracking (MPPT) operation of a photovoltaic (PV) system. The FLC proposed presents that the converter distribution of the membership function offers faster response than the symmetrically distributed membership functions. The fuzzy controller for the SEPIC MPPT scheme shows a high-precision in current transition and keeps the voltage without any changes, in variable-load case, represented in small steady state error and small overshoot. The proposed scheme ensures optimal use of photovoltaic (PV) array and proves its efficacy in variable load conditions, unity and lagging power factor at the inverter output (load) side. The real-time implementation of the MPPT SEPIC converter is done by digital signal processor (DSP); TMS320F28335. The performance of the converter is tested in both simulation and experiment at different operating conditions. The performance of the proposed FLC based MPPT operation of SEPIC converter are compared to those of the conventional PI based SEPIC converter. The results show that the proposed FLC based MPPT scheme for SEPIC can accurately track the reference signal and transfer power around 4.8% more than the conventional PI based system.

Index Terms—Fuzzy control, dc-dc power converters, photovoltaic cells, proportional-integral controller, real-time system.

I. INTRODUCTION

Due to its output gain flexibility, single-ended primary-inductor converter (SEPIC) acts as a buck-boost DC-DC converter, where it changes its output voltage according to its duty cycle. The selection of proper DC-DC converter plays an important role for maximum power point tracking (MPPT) operation. The criteria for PV converter selection depend on many factors such as cost, efficiency, flexibility, and energy flow. In this case, the flexibility represents the ability of the converter to maintain the output with the input varying, while the energy flow is assured by the continuous current of the converter. Among known converters, the SEPIC, conventional buck-boost, and Cuk converters have the ability to step up and step down the input voltage. Hence, this converter can transfer energy for all irradiation levels. Another desirable feature is continuous output current, which allows converter output parallel connection, or conversion to a voltage source with minimal capacitance. The buck or boost converters are not preferable due to the lack of output voltage flexibility. For example, for PV system battery charging, both buck and boost converters are unable to charge the battery continuously with MPPT operation because, the power-voltage curve changes with irradiation level, and hence, the voltage corresponding to maximum power changes.

There are many factors that can be considered for proposing the DC-DC converters such as input/output energy flow, cost, flexibility, and PV array effect. Unlike buck-boost converter, the SEPIC has a non-inverted output, and it uses a series capacitor to isolate input from output [1]. The Buck and buck-boost converters have discontinuous input current, which causes more power loss due to input switching. The boost converter usually has higher efficiency than the SEPIC; however, its output voltage is always larger than the input which causes inflexibility in maximum power extraction. Both the SEPIC and the Cuk converters provide the choice to have either higher or lower output voltage compared to the input voltage. Furthermore, they have contentious input current and better efficiency compared to buck-boost and fly-back converters [2]. There is no general agreement in the literature on which one of the two converters is better; the SEPIC or the Cuk [3]-[10]. This paper seeks to use the SEPIC converter because of the Cuk converters inverted output.

The MPPT algorithm represents optimal load for PV array, producing opportune voltage for the load. The PV panel yields exponential curves for current and voltage, where the maximum power occurs at the curves mutual knee [11], [12]. The applied MPPT uses a type of control and logic to look for the knee, which in turn allows the SEPIC converter to extract the maximum power from the PV array. The tracking method used, perturb and observe (P&O) [13], [14], provides a new reference signal for the controller and extracts the maximum power from the PV array.

Researchers have been working on traditional PI controllers to apply for DC-DC converters as in literature [15]-[20]. Rahim et al. [15] used a five-level inverter to reduce the THD level of the output wave employing the PI controller. However, the cost of the system increased and the control of the inverter became complicated. Furthermore, the THD level did not decrease that much at the expected level. Sera et al. [16] applied optimization for MPPT using PI controller for their converter. Femia and Fortunato et al., in [17] and [18], respectively, used one-cycle control for MPPT and single-stage inverter while in [11] and [15], the authors used conventional PI controllers along with MPPT scheme. The limitations of