A Novel Improved Fused Converter Based Hybrid System with MPPT Control for Rural Telephony

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Abstract— Nowadays, the need for renewable energy becomes important in electricity production. The remote telecommunication systems make use of renewable energy resources to meet its requirement due to their technological advancements and lower costs. The telecom base transceiver station (BTS) requires continuous power supply to provide reliable communication services. At present the problem is tackled by using diesel generators. Diesel generator systems require regular maintenance and it is costly. It generates noise pollution. Transportation and storage of diesel is also a major problem in remote areas. This paper gives the discussion about a dual input converter for hybrid solar–wind energy systems to supply telecom in rural areas. An improved version of this dual converter is also suggested using parallel power conversion technique. Investigations are also made with MPPT Controllers for each of the power sources. Results show that the proposed system eliminates the need for MPPT Controllers. Hence, the cost of the system reduces. Also, an elaborate element wise comparison between the two topologies is reported.

Keywords— Fused Cuk-Buck converter, Hybrid Solar-Wind topology, Parallel power conversion technique, MPPT Controller

I. INTRODUCTION

Electricity can be produced by conventional energy sources or by non-conventional energy sources. The conventional energy sources (Oil, Gas, and Coal) are finite and it generates pollution. As the environmental pollution increases, the current policies search for more efficient power generating systems, employing the existing resources in the best way. The alternative energy sources like wind, fuel cell, solar, tidal, etc. are available abundant in nature. They have the advantages of sustainability, renewability and pollution reduction. They can also bring economic benefits to many regional areas that are located away from cities.

In recent years, the hybrid generation system has become significant because of the complementary characteristics among the new and renewable energy resources. Solar energy and wind energy are the two renewable energy sources most common in use. The wind and solar energy systems are highly unreliable due to their unpredictable nature.

When a source is unavailable or insufficient in meeting the load demands, the other energy source can compensate for the difference. So, hybrid system with the combination of solar-wind with backup system is an attractive method to power in remote rural areas.

When neither the wind nor the solar systems are producing, power can be supplied by the batteries and/or a generator powered by conventional fuels, like diesel. If the batteries are low, the diesel generator can provide power and recharge the batteries [1]. The use of a maximum power point tracking technique (MPPT) algorithm is necessary to extract as much power as possible from the solar and wind when the irradiation and wind speed changes. Most common method to achieve MPPT in solar and wind systems is Perturb & observe (P&O) algorithm [2].

Many research works on various types of converter topologies have been proposed on the basis of single source like wind/solar/fuel systems etc., with single route power flow between the source and the load [3]. In all these methods, the individual sources of a hybrid system feed power to a DC bus from which the load power is taken. Such systems are complex because of lot of interfacial circuits used. In order to address the short comings of existing techniques for renewable energy systems, fused converters can be used [4]. The fused converter proposed in this paper is obtained by fusing the converter PV fed cuk and wind fed buck converter. The improved version is obtained by applying parallel power conversion technique. The converters are fused as improved dual input cuk-buck topology. Two sources solar and wind supply power simultaneously or individually according to the availability [8]. The proposed improved dual input cuk-buck converter is designed and the results are reported using MATLAB/SIMULINK. Hybrid solar-wind sources with MPPT, without MPPT based fused converters are investigated.

This paper is organized as follows. The first section is a short overview of the literature. In the second and third section, block diagram and system description of solar/ wind with fused converters using PPC technique; Modeling of each block is presented.
Fourth section contains the simulation results and calculation of the same. Finally, the findings of the investigations are highlighted in the conclusion.

II. SYSTEM DESCRIPTION

A. Fused Converter Topology

The block diagram of the improved solar-wind hybrid system with MPPT based fused converter is shown in Fig.1. It consists of renewable energy systems (solar/wind), maximum power point tracking technique controller, cuk-buck fused converter, telecom load and battery.

In the present work, a new converter topology for hybridizing the wind and solar energy sources has been used. Solar fed cuk converter and wind fed buck converter are fused resulting in a Cuk-Buck fused converter eliminating the need of various dc/dc converters for each source. The average output voltage produced by the system will be the sum of the inputs of these two systems. Both wind and solar energy sources are incorporated together using a combination of cuk and buck converters. The cuk-buck fused converters support step up and step down operations for each renewable energy sources with individual and simultaneous operations. By applying parallel power conversion technique to the cuk-buck fused topology, the efficiency can be improved. All these advantages of the proposed hybrid system make it highly efficient and reliable. The topology of proposed cuk-buck converter based solar-wind hybrid system [4] is shown in Fig.2

B. Parallel Power Conversion Technique

PPC technique is shown in Fig.3. Contrary to cascaded power conditioning systems, where only a single route for the flow of power between the source and the load exists, the parallel power conversion technique (PPCT) employs parallel routes for power flow between the source and the load.

• Controlling the power flow by providing two paths using a parallel power transfer (PPT) technique results in reduced power loss in the converter.
• The parallel power transfer approach is to split the power flowing into the load into two paths as:
  (1) Power flowing to the load through the converter (P1)
  (2) Power flowing directly to the load without the converter (P2)
• Powers P1 and P2 are converted at efficiencies $n_1$ and $n_2$ respectively.
For the special case where \( \theta_1 = \theta_2 \), the effective power conversion efficiency is not changed by the addition of the parallel path is shown in Figure 3. When a high efficient parallel power path, \( \eta_2 \), is however supplemented to \( \theta_1 \), the total effective efficiency is increased. With this parallel power transfer technique, the losses in the converter are reduced. Hence the efficiency is improved.

Figure 4 shows the topology of improved Cuk-Buck Converter. The comparison of Cuk-Buck and improved Cuk-Buck is presented in [4].

![Fig.4. Topology of improved Cuk-Buck Converter](image)

C. Working of Fused Converter

The operating principle of improved cuk-buck fused converter is discussed below. There are four different modes of operation depending upon the conduction states of the switches S1 and S2. The equivalent circuits for various modes of operation are given in Fig.6a to Fig.6d.

The output voltage expression can be written as:

\[
V_o = (d_{pv} \cdot V_{pv}) + d_w \cdot (1-d_{pv}) \cdot V_w \quad \text{………(1)}
\]

Where

- \( d_{pv} \) = Duty cycle of PV source
- \( d_w \) = Duty cycle of wind Source
- \( V_{pv} \) = Solar voltage
- \( V_w \) = Wind Voltage

The voltage and current of various modes of operation [1] are shown below in Fig.5

![Fig.6a. Mode-1 Both S1, S2- ON](image)

![Fig.6b. Mode-2 S1- ON, S2- OFF](image)
In Fig. 6a. When both the systems are supplying S1 and C1 are connected in series to charge the battery and inductor L2. From Fig. 6b. it is clear that D2 provides path for inductor L2. Energy stored in C1 is transferred to L2 and solar charges the inductor L1.

In Fig. 6c. L1 and C1 are connected in series. Energy stored in L2, wind source capacitor is transferred to C2 and battery. In Fig. 6d, both the diodes D1, D2 are connected to charge inductor L1, inductor L2 and battery. Thus in improved topology some portion of the power is delivered directly to the battery.

III. RESULTS AND DISCUSSION

The system shown in fig. 4 is simulated with and without MPPT Controllers. The output voltage, current, gating pulses, switching stresses, inductor currents for the improved Cuk-Buck converter without MPPT are shown in figures 7a,7b,7c,7d,7e respectively [4]. The switching stresses are less and efficiency is more compared to the Cuk-Buck topology reported in [4].
Fig. 7d. Current through Inductor L1 & L2

Fig. 7e. Current through Capacitor C1

Fig. 7c, 7d, 7e [4] shows the voltage and current through the capacitor C1 and inductor L1. From Fig. 7c it is clear that Vc1 = 59V in improved cuk-buck topology compared to 96V in dual input cuk-buck topology. Comparing the current waveforms of L1, L2, C1, it is seen that the currents through improved cuk-buck topologies are lesser. This reduces the conduction losses. Thus simulation results show higher efficiency in improved cuk-buck converter topologies in all aspects.

The above investigations are repeated with MPPT Controllers for variable wind velocities and solar irradiations. The result comparing improved converter with and without MPPT controller is shown below.

Fig. 8a. Output voltage and Output Current

Fig. 8b. Voltage across inductor L1 and Current through inductor L1

Fig. 8c. Voltage across inductor L2 and Current through inductor L2

Fig. 8d. Voltage across capacitor C1 and Current through capacitor C1

The results for change in irradiation with and without MPPT are shown in figures 9a & 9b. It shows that for varying solar irradiations, the solar MPPT controller produces maximum power from the PV module.
However, from the investigations carried out without MPPT it is understood that the wind system always compliments the solar, such that the output is always met. Hence, the need of MPPT for solar is eliminated. Similar studies are carried out for the hybrid system with MPPT controller on the wind source. The results obtained indicate that the MPPT on wind side is also redundant as the solar system compliments the wind source.

Figure 9.a shows variation in power supplied by the SPV and wind sources for change in Solar irradiation with MPPT for SPV at constant wind speed=12m/s and Figure 9.b variation in power supplied by the SPV and wind sources for change in Solar irradiation without MPPT for SPV at constant wind speed=12m/s.

This topology allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. The above investigations show that the proposed system eliminates the need of MPPT Controller for both the sources. Hence the cost of the overall system is much lesser compared to the conventional systems used for such applications.

REFERENCES


