# Modelling and Analysis of Three Port Isolated DC-DC Converter for Hybrid Renewable Energy Systems

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**Abstract -** The use of Renewable Energy has increased due to many of its advantages such as eco-friendliness. Yet it is not used pre-dominantly due to unreliability. The aim of this paper is to make a hybrid Renewable Energy system capable of storing energy and providing extra power when necessary by employing control strategy in a Interleaved Boost Converter. This project employs interleaved boost full-bridge converter with pulse width modulation and phase-shift control for hybrid renewable energy systems. The MOSFETs are driven by phase shift PWM signals where both phase angle and duty cycle are controlled variables. The power flow between the two inputs is controlled through the duty cycle, whereas the output voltage can be regulated effectively through the phase shift. The load terminal voltage at a constant value by phase shift control and duty cycle control of MOSFETs which results in stability of the system. The surplus energy is stored in the energy storage element at any instant by continuously monitoring the input and the load. The load is supplied with the necessary power at any instant with the help of energy storage element

**Key Words: Duty cycle, Phase-shift, MOSFETS, PWM, Interleaved.**

## 1.INTRODUCTION

The application of clean and renewable energy, such as solar, wind and hydrogen has been a focus in academic and industry over the last decade. Due to the intermittent feature of renewable energy sources, energy storage units are needed in order to balance the electricity generation and consumption within a power system having a high renewable energy penetration.

Moreover, multiple energy sources hybridization can distinctly improve various aspects of performance, such as decreasing cost ,isolating energy sources from load fluctuations and enhancing the system dynamics. Hence, hybrid energy conversion systems are well suited for applications in which average power demand is low whereas the load dynamics are relatively high. As a result ,merging the renewable energy sources elements together as a hybrid power conversion systems, as well as controlling the power flows effectively has become topic of interest. Due to the environmental problem ex., climate change and political and economical reasons, ex., less dependence on the foreign countries energy import ,high oil price , renewable energy has attracted enormous attention. Investment worldwide in renewable energy has gone below $10 billion in 1995 to$ 70 billion in 2007 Since 2000, renewable electricity installation capacity. Wind power and solar power are the fastest growing renewable energy sector.

In order to fulfill the different system requirements various hybrid configurations and converter topologies have been proposed and investigated. In applications where galvanic isolation is required , there are basically two categories classified as multiple-port conversion and multiple -converter conversion . In multiple converter configurations , power converters are connected in parallel or in series in order to couple the energy sources and load .

By contrast, multiple- port power conversion systems have high power density and low cost, due to the fact that some of the components and circuits in various power ports , such as transformers , rectifiers and output filters , can be shared as a common part along the power conversion path.

Therefore , multiple-port converters [2] have been receiving increased attention in recent years. A general solution to obtain an isolated multiple -port converter is adopted the magnetic coupling method, where various input power sources can be coupled with transformer windings or independent transformers.

In this solution, the multiple-port converter can be constructed from the basic high frequency switching cells including the half bridge (HB),full bridge(FB) , boost full bridge (BFB) and their combinations ,according to system constraints imposed by the features of input power sources. Based upon this principle a number of three port (TPC) bidirectional dc-dc converters ,which can fully isolate [1] the various power ports and control the power ports.

Moreover, this converter is superior to its LLC [5] counterparts due to lower complexity of the modulation and control. Compared to previous research on TPC topologies, modelling and analysis of dynamic performance with multiple control parameters are seldom reported. The major contribution of this paper is to analyse the relation between the two control variables, phase-shift and duty cycle, and the system dynamics based on the converter small-signal model. The derived mathematical model is verified by simulations.

### 1.1 CIRCUIT DIAGRAM

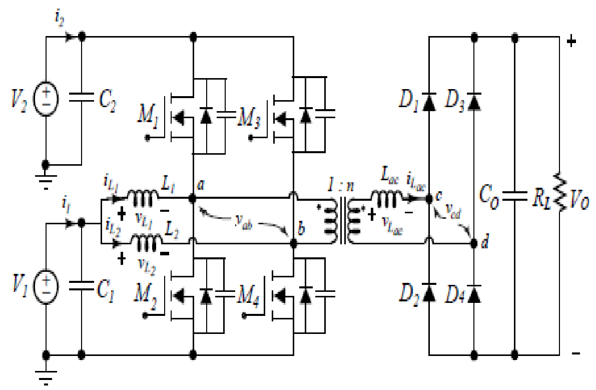



**Fig -1**: Circuit Topology of the TPC

There are two input inductors L1 and L2 and an ac inductor Lac, four power MOSFETs M1, M2, M3, M4, and a high frequency transformer with a turns ratio of 1: n. The ac inductor, which is the sum of the leakage inductance and the auxiliary inductance, is the power interface element between primary and secondary sides of the transformer. Switches M1, M2 and M3, M4 are driven by gate signals with a dead band. V1 and V2 represent the input voltages. iL1 and iL2 are the input inductor currents. $V_{ab}$ is the voltage between the midpoints of the bidirectional interleaved boost switching legs, and iLac is the current of the secondary side winding. Inductors L1, L2 and capacitors C1, C2, and CO are big enough and the dead band effect is negligible.

### 1.2 METHODOLOGY

The Converter can be operated in three modes:
Through the phase-shift with duty cycle control, and according to the availability of the renewable energy source and the load demand, the proposed converter can operate in various modes such as **Dual Output(DO), Dual Input(DI), Single Input Single Output(SISO)** .

Two Control loops are employed to regulate the output voltage. Input control loop senses the renewable energy voltage or current and energy storage port's voltage and current, produces the duty cycle value according to that. Output control loop senses the changing load and produces appropriate phase shift .The MOSFETs are triggered according to the duty cycle and phase shift values.

**Dual Output(DO)**

When the input voltage is more than the load voltage, the extra energy is stored in the batteries. when the input power is higher than the load power demand and the energy storage element balances the power by storing the excess energy.

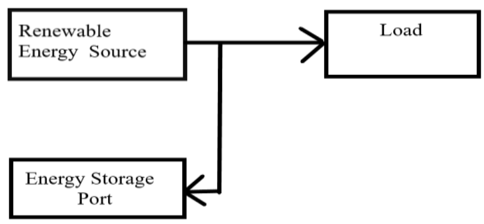



**Fig -2**: Dual Output Operation

**Dual Input(DI)**

When the load demand is higher than the available power from the renewable energy source and the energy storage element delivers the extra energy to the load. - when the input voltage is less than the load

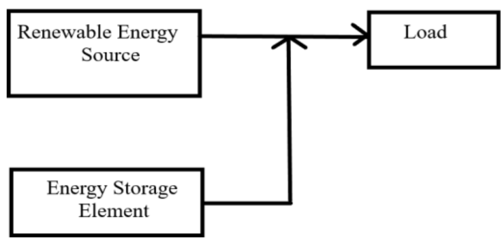



**Fig -3**: Dual input Operation

**Single Input Single Output mode(SISO)**

when power transfers between the two inputs or from one of the inputs to the output.

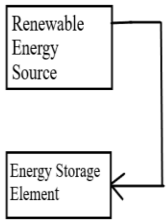



**Fig -4**: Single Input Single Output Operation

### 1.3 PORTS OF THE CONVERTER

RENEWABLE ENERGY PORT:

V1 is the renewable energy source such as fuel cells or photo-voltaics, the voltage or current is controlled by the duty cycle D.

ENERGY STORAGE PORT:

V2 is an energy storage unit, for example, a battery or a super-capacitor, is controlled depending on the power at the renewable energy source and the output load power.

OUTPUT LOAD PORT:

The Load is monitored continuously to keep the output terminal voltage constant.

CONTROL OF THE PORTS

At the **renewable energy port**, either voltage or current can be selected to be regulated depending on the type of the selected renewable energy source. At the **energy storage port**, constant voltage (**CV**) and constant current (**CI**) regulators are implemented, and at the **output port**, voltage regulation is performed.

CONTROL STRATEGY

In order to decouple the two inputs, V1 and V2, and regulate the output voltage accurately, both the duty cycle and the phase-shift angle are adopted as the control variables simultaneously. The **duty cycle** of the power switches is used to adjust the power among the two independent sources. The **phase-shift** angle between the midpoints of the full bridge is employed to regulate the power flow to the output port.

### 1.4 BLOCK DIAGRAM

In the case of a photovoltaic (PV) panel as the renewable energy source, the control variable will be taken as the converter input voltage, since the PV voltage does not present strong variations with irradiation changes . In the case of a fuel cell, strong variations with irradiation changes . In the case of a fuel cell, input current control will be selected in order to operate the fuel cell at a constant load level.

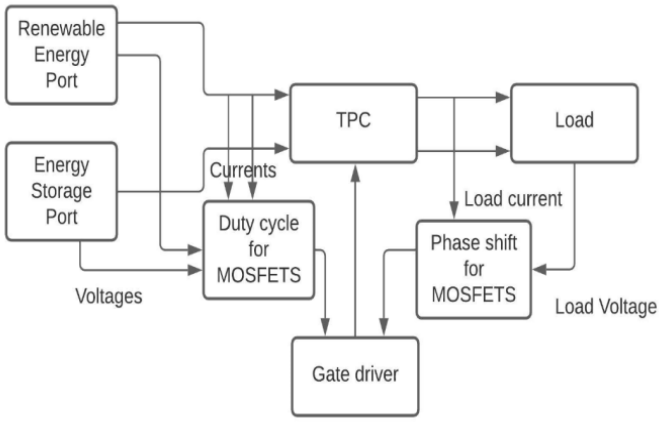



**Fig -5**: Block Diagram for Control Strategy

input current control will be selected in order to operate the fuel cell at a constant load level. Moreover, the parameters of the energy storage port can be monitored and the control scheme changed to voltage or current control on the battery depending on its state of charge (SOC).

Two Control loops are employed to regulate the output voltage. Input control loop senses the renewable energy voltage or current and energy storage port's voltage and current, produces the duty cycle value according to that. Output control loop senses the changing load and produces appropriate phase shift .The MOSFETs are triggered according to the duty cycle and phase shift values

## 2.SIMULATION RESULTS

The Voltage across the load is shown in the graph in which we can deduce that the output voltage is attaining a constant value and the objective of voltage regulation in attained .The voltage is regulated by the combined action of the de-coupled variables duty cycle and the phase-shift of the MOSFETS.

OUTPUT VOLTAGE –Voltage Across the load

The Voltage across the load is shown in the graph in which we can deduce that the output voltage is attaining a constant value and the objective of voltage regulation in attained. .The voltage is regulated by the combined action of the de-coupled variables duty cycle and the phase-shift of the MOSFETS.

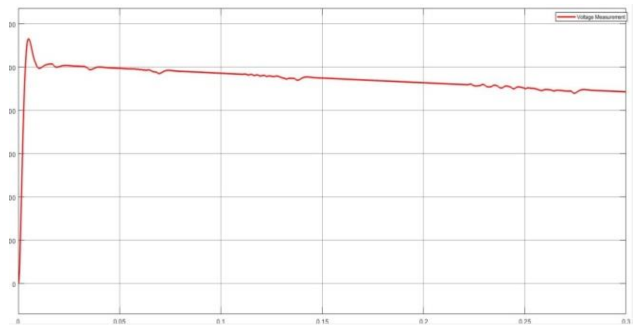
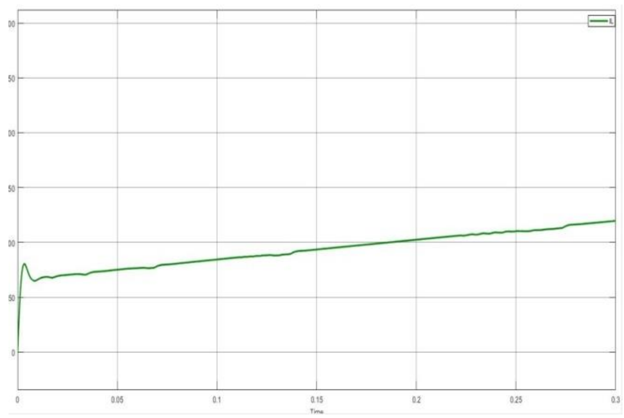


**Fig -6**: DC Load Voltage.

SECONDARY INDUCTOR CURRENT



This shows the increasing inductor current and it is increasing gradually in the given time period .

**Fig -7**: Load Side Inductor Current

BATTERY VOLTAGE

Though supply is given and taken continuously at any instant , the voltage across the energy storage element is maintained constant. The battery terminal voltage is sensed at every instant and it's value is maintained constant by continuos monitoring.

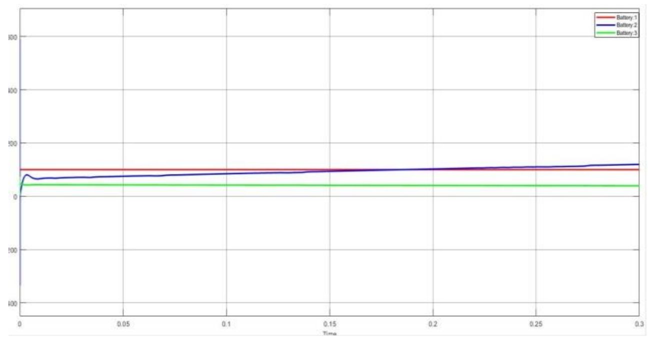


**Fig -8**: Battery Terminal Voltages

## 3. CONCLUSIONS

In order to control the power flow between the different ports, a duty cycle and phase-shift control scheme is adopted. The duty cycle is used to control the power flow between the two independent sources, whereas the phase-shift angle is employed to regulate the output voltage. The advantage of the proposed topology is that it can be dynamically modeled as individual converters, which makes it possible to design a control strategy with totally uncoupled control variables. This topology is a very interesting solution in renewable energy applications where an energy storage element is required, since full reutilization of the converter primary side switches is achieved, without having a negative impact in the controllability of the converter.

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