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Performance Analysis of a Hybrid Energy System based on PV Cell - WECS using Different Boost Converter Topologies

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Abstract: ***In order to save our world from the black outs and energy crisis in the near future, more intensive research must be done in the renewable and power electronics area. In order for the hybrid system to be connected to a grid system or whether the system is a stand alone system, it requires a boost converter to boost up the voltage at the output of the converters. The study focuses on the comparison of performance of a hybrid system using different boost converter topologies like interleaved and basic converter and converter with capacitors at the output. The performance analysis can be conducted by comparing current outputs, voltage outputs possible harmonics, efficiency etc.***

Keywords: PV cell, WECS system, Hybrid system, Boost converter

1. Introduction

The basic boost converter which can be connected to the hybrid system has many limitations along with its boosting up of the voltage. so various other topologies of boost converter can be implemented to the hybrid system to improve the performance or efficiency of entire system in general.[1]. The Pv systems used in the present world has better efficiency in middle east countries. Different countries in the world adopt pv cell strategy because it provides greater efficiency with lesser economic burden. The study concentrates on economy of using pv cell strategy considering economy and efficiency in three regions in europe. [10].The study was conducted considering the conversion efficiency of solar panels.

The checking and development of efficiency of a converter is very important for increasing the overall efficiency of hybrid devices connected. The double input bridge type converter can include two sources with inductor and capacitor at the output side. The converter can be connected to hybrid sources like pv-fuel cell, pv- wecs etc. [2]. The proposed bi directional converter is giving better characteristics for major energy requirements. The converter has lower harmonics and better response which increases the efficiency.

Boost derived hybrid converter topology is used for nano grid applications and it works well for operation in continuous mode but for operation in discontinuous mode the operation is not satisfactory. [3] The converter for various load conditions provide unnatural ripples in the output dc voltage which affects its overall performance. The converter cannot be used for standalone functions. This limitation is overcome by placing an anti parallel switch with diode which makes the converter for use in continuous operation.

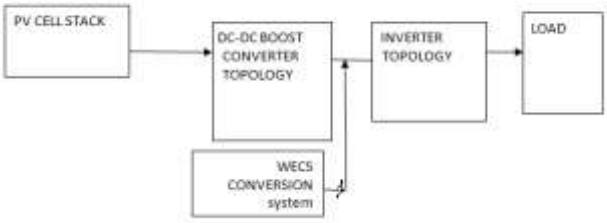
The high gain floating output transformer less converter has significance in terms of its design and performance. If a parallel connection of non- floating and floating boost converter is made higher output with lesser ripples can be obtained. [6]

A pv- wecs system is highly economical and effective compared to diesel power plants if some capacity shortage is allowed. The grid connected system reduces emissions of harmful gases to the atmosphere. Sensitivity analysis conducted on renewable resources can give a clear idea about the economy of the resources and systems which are used. According to analysis if 20% is reduced for cost of installation it can reduce per unit cost of electricity to 9-12%.[9]

2. Theoretical and Conceptual Framework

The theoretical and conceptual frame work of this research focuses on the performance analysis of a hybrid energy system based on pv cell and wecs which utilizes boost converter topologies constrained to be used in Bahrain. For the study the weather conditions and places where the topology can be installed can be evaluated.

The boost converter topology works with the concept $V_{out}>V_{in}$.



The problems of a hybrid network working as a standalone system can be analysed and then assessed with comparison of different techniques used. The following topology can be assessed for boost converter topologies like interleaved converter and converter with capacitor switching which can be connected to a dc bus . The simulation will be done for each of these configurations with the analysis on input current, output current , output voltage, input voltage, power output, and efficiency.

In a continuous conduction mode the gain of a boost converter is given as

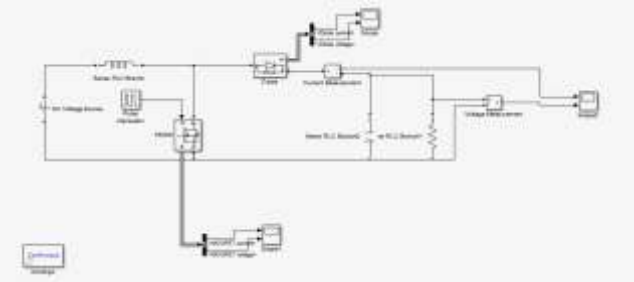
Gain, $g=V_0/V_i$
Gain g=1/(1-D).

The boost converter topologies will be operated with different duty cycles and their performance will be analyzed.

3. Design of the System

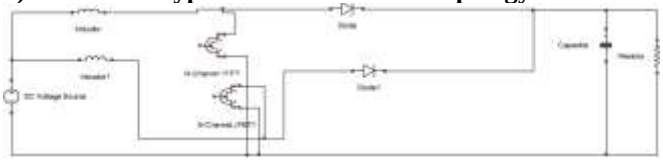
The design requirements of the topic include a photo voltaic stack with a wind turbine which acts as a hybrid energy conversion system, a boost converter topology, inverter configuration connected to a load. The entire system can be a grid connected one or a standalone system depending upon the requirements. The simulation parameters are set up according to the requirements of a prototype. Different boost topologies are compared with different parameters and the most suitable topology of the hybrid system with the boost topology is implemented.

3.1 Boost converter topologies

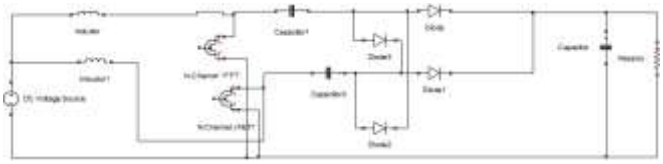


The above diagram represents the mat lab simulink circuit representation for a boost converter topology which is commonly employed in hybrid circuits.

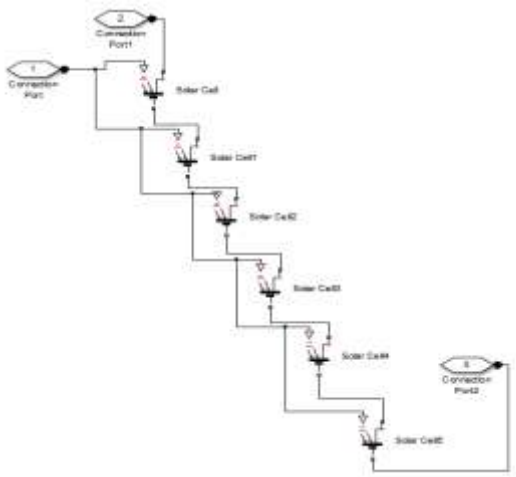
a) Interleaved type of boost converter topology



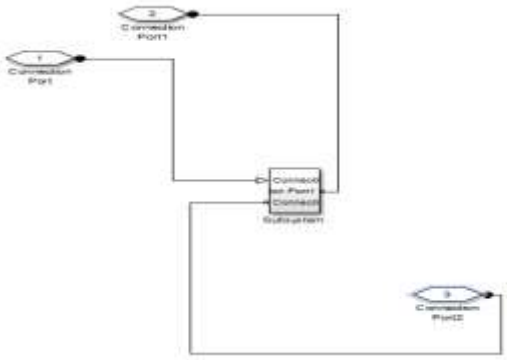
b) Interleaved converter boost topology with capacitors connected



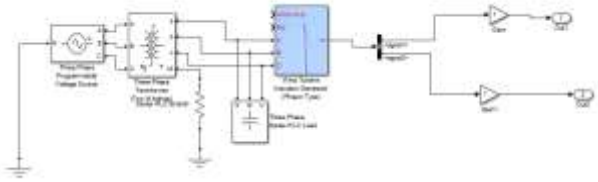
c) PV Array design



d) Subsystem of pv cell array



e) WECS Model



3.2 Design specifications

The following values are required for the collection of the data the photo voltaic cell requirements, wecs requirements like the inputs, converter topology requirements of inductors, voltage sources etc.

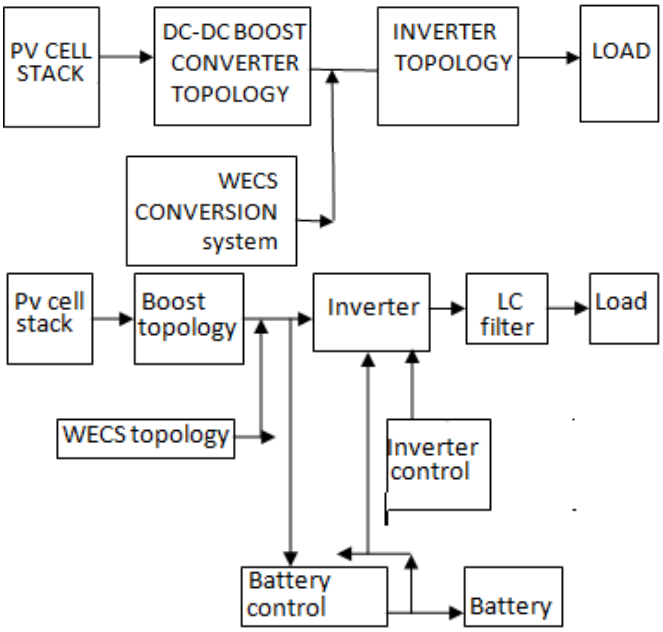
The pv cell array is constructed by connecting different pv cells in series with the following design considerations

The pv array is parameterize by short circuit current and open circuit voltage with
Short circuit current =4.75 A
Open circuit voltage =0.6 V
Irradiance factor= 1000W/m^2
Quality factor=1.5
Series resistance = 5.1e-3 ohm
For the wecs system

Wind turbine connected with the Induction generator is used, connected to an RLC load.

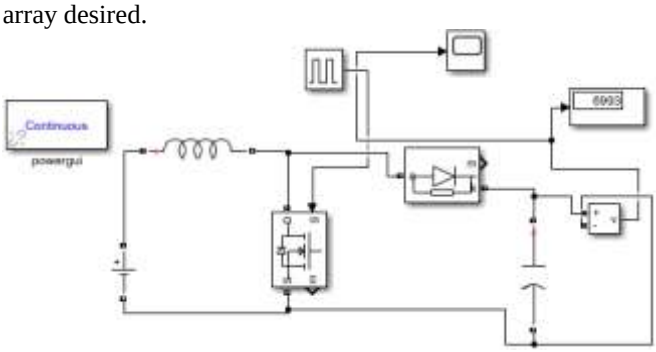
The main method of analysis is the usage of a simscape simulink tool matlab. A hybrid system model of pv cell stack

and wind conversion system has to be connected to the boost converter based on the below topology.

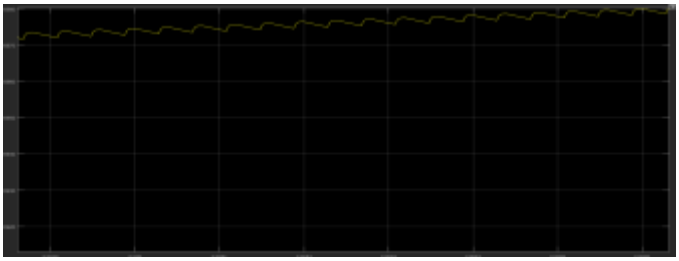


3.3 Results and Discussions

The topology for the boost converter was constructed with an input voltage for the pv cell system as 881 V.
Instead of the Pv array initially the topology was constructed with a dc voltage supply having the same output of the pv array desired.

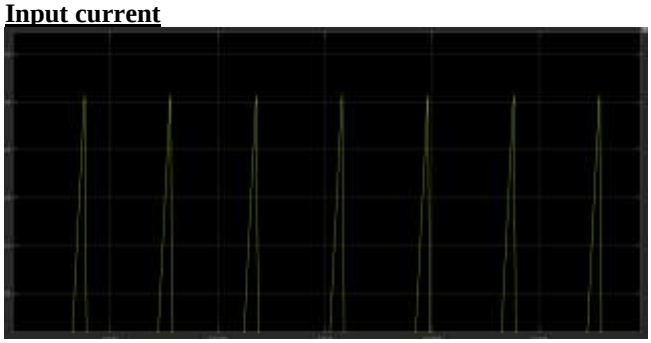


The components designed are the following
Inductor = 1mH
Capacitor= 33 micro farad.
The output voltage is boosted up
Output voltage is given below

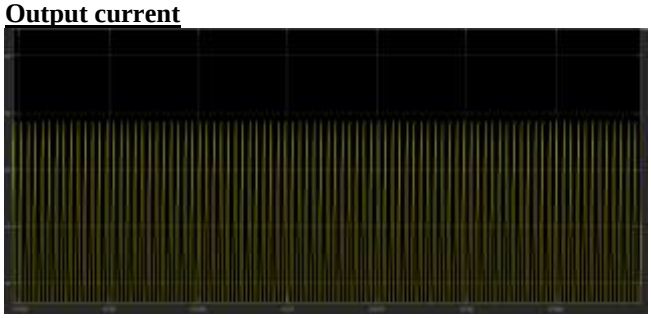


Some amounts of ripples are present and boost converter topology was found out to be quite unsteady and harmonics are very difficult to eliminate altogether.

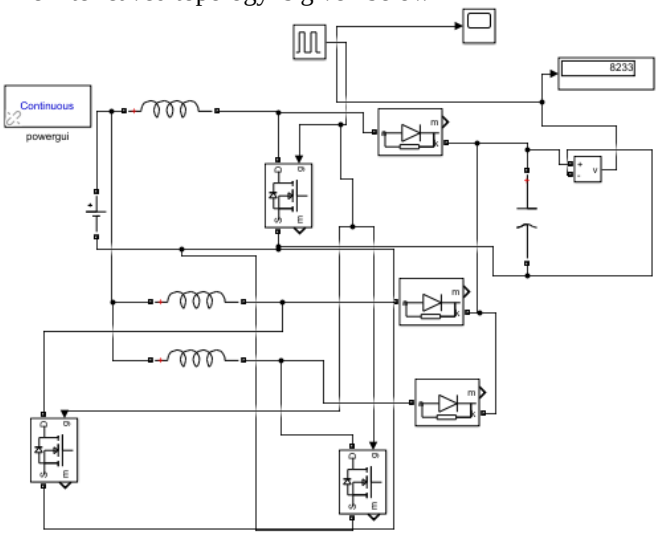
Input current



Output current

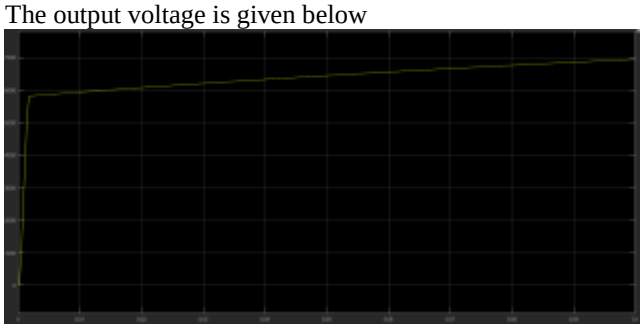


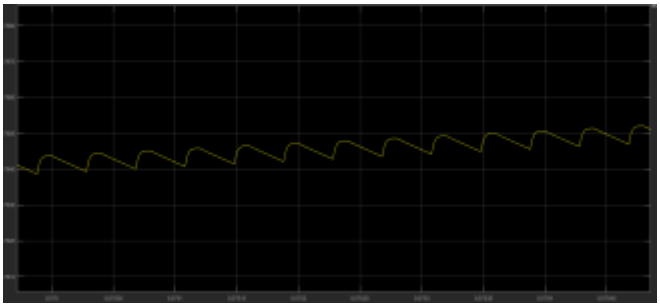
The interleaved topology is given below



From the above topology the output voltage is boosted up greater than the level of the boost topology

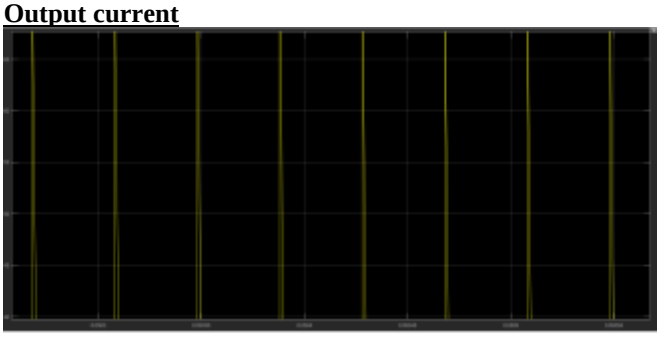
The output voltage is given below



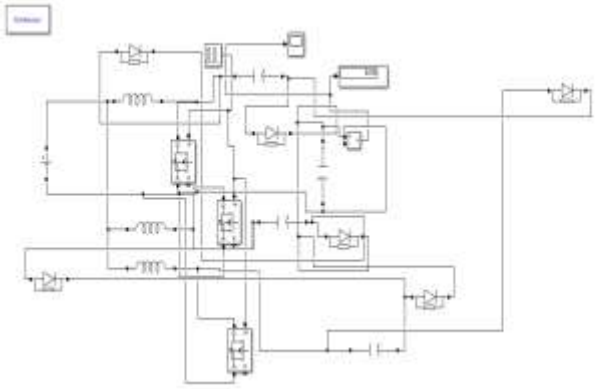


The harmonics were found to be comparatively lesser and output voltage was boosted to a greater voltage.

Output current

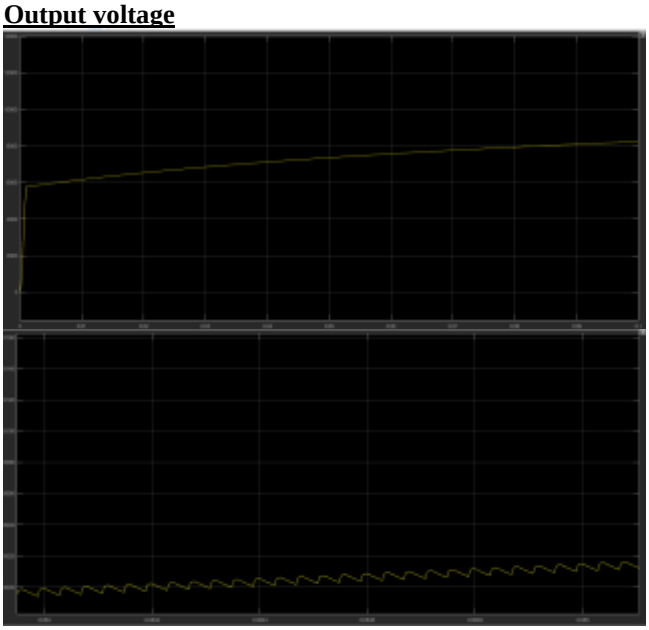


The topology for the interleaved with switched converters is given below

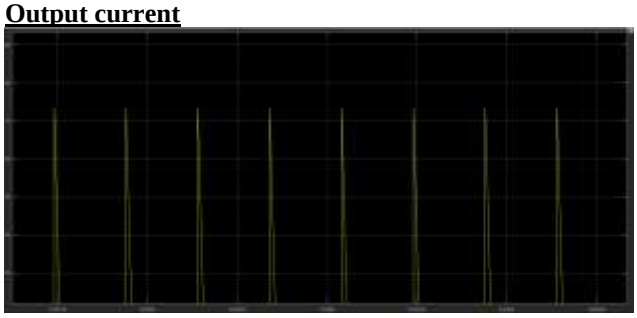


The ouput voltage was boosted up to a greater value in an interleaved

Output voltage



Output current



If a boost converter topology is considered the gain is given as output voltage to the input voltage g= V_0/V_i. The boost converter topology suffers high voltage and current ripples. The output voltage is highest for the boost converter with interleaving and switched capacitors. owing to the fact the switching capacitor act as a multiplier which increases the output voltage.

From the above results it is clear that the boost converter topology with switched capacitors has the greater performance owing to the fact that it has comparatively lesser harmonics and more output voltage.

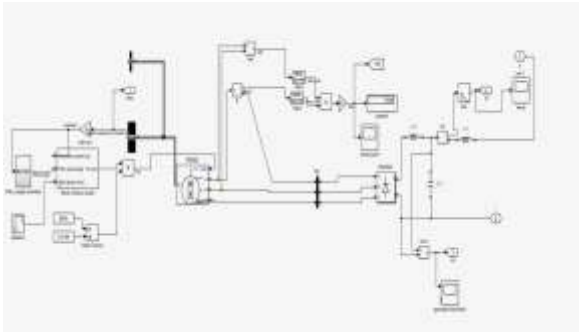
3.4 Comparison Table

Table 1: Comparison of different topologies

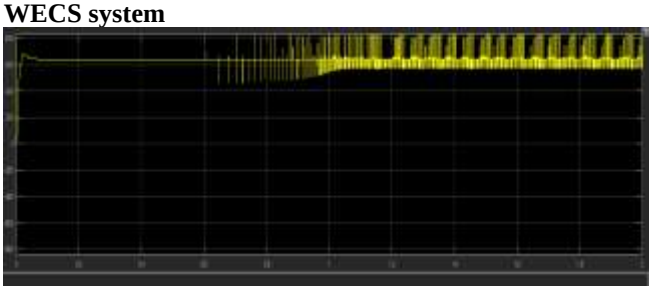
Parameter	Boost	Interleaved topology	Interleaved with switched capacitor topology
Output voltage	Boosting up minimum	Boosting up intermediate	Boost up maximum
Ripples in the output voltage	Ripples are present in the system owing to instability of topology	Ripples are lesser than boost and almost the same as that of interleaved with switched capacitors	Ripples present are almost the same as that of interleaved topology
Voltage gain	Minimum compared to other two	Maximum at full load	Excellent voltage gain
efficiency	least	Almost the same as that of interleaved with switched capacitors	Efficiency maximum

3.5 Hybrid system with pv cell and wecs system

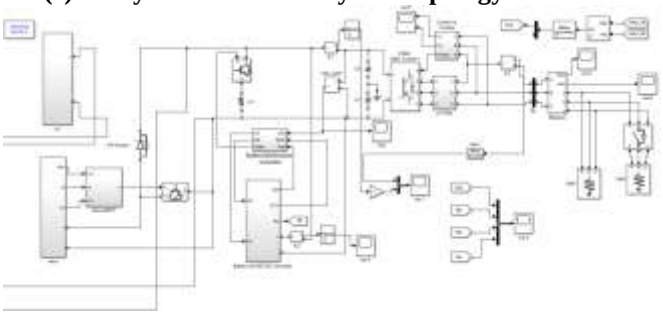
3.5 (a) WECS Model



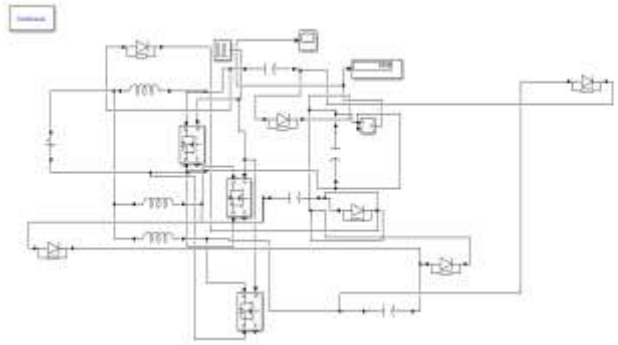
3.5 (b) Output voltage at the generator terminal of WECS system



3.5 (c) PV system with wecs hybrid topology

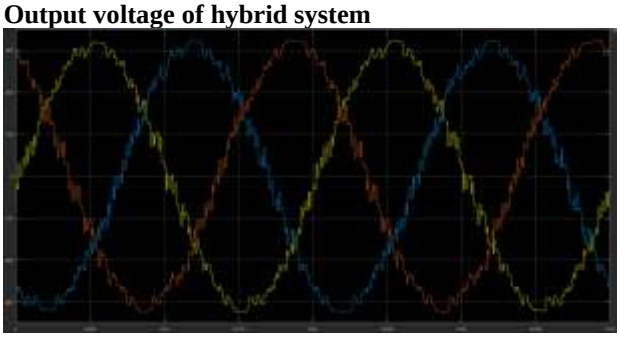


3.5 (d) The interleaved system connected

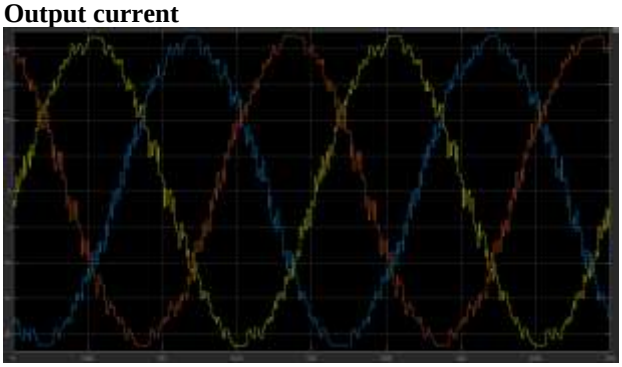


The output ripples is found to be almost the same with interleaved with switched capacitors and interleaved one.

Output voltage of hybrid system



Output current



3.6 Literature Review

The study[1] concentrates on fuel cell system. The boost converter is connected to the output of the hybrid energy system among different boost converters interleaved shows lesser harmonics and better response, but the switched capacitors have better boostingThe Pv systems used in the present world has better efficiency in middle east countries. Different countries in the world adopt pv cell strategy because it provides greater efficiency with lesser economic burden. The study concentrates on economy of using pv cell strategy considering economy and efficiency in three regions in europe. [10].The study was conducted considering the conversion efficiency of solar panels.

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Boost derived hybrid converter topology is used for nano grid applications and it works well for operation in continuous mode but for operation in discontinuous mode the operation is not satisfactory. [3] The converter for various load conditions provide unnatural ripples in the output dc voltage which affects its overall performance. The converter cannot be used for standalone functions. This limitation is overcome by placing an anti parallel switch with diode which makes the converter for use in continuous operation.

The high gain floating output transformer less converter has significance in terms of its design and performance. If a parallel connection of non- floating and floating boost converter is made higher output with lesser ripples can be obtained. [6]

A bidirectional converter can supply surplus power to the load from the additional battery which is connected without impacting on dc link voltage. A three-phase VSI vector control can be used to control output side voltage[7] .A number of inputs with non isolated topology can also improve the performance. The converter topology with multiple input is unique and can have greater efficiency. It can be operated in buck/boost/buck–boost modes of operation. It can also have bidirectional power flows in either direction, how to control and manage power in such system is also discussed. [8]

A pv- wecs system is highly economical and effective compared to diesel power plants if some capacity shortage is allowed. The grid connected system reduces emissions of harmful gases to the atmosphere. Sensitivity analysis conducted on renewable resources can give a clear idea about the economy of the resources and systems which are used. According to analysis if 20% is reduced for cost of installation it can reduce per unit cost of electricity to 9-12%.[9]

4. Equations

The gain of the interleaved with switched capacitors is found out to be

$g= V_0/V_i$ (1)

g= M+1/1-D (2)

M= number of stages of the switched capacitors

D= duty cycle

So the minimum converter gain is 2, which is the result when M=1.

5. Conclusion and recommendations

Based on the results and discussions, it can be concluded that the interleaved with switched capacitors has the maximum efficiency owing to the fact that the multiplier capacitors added to the topology will boost up the voltage to maximum. If the full load is desired the interleaved is preferred over the interleaved with switched capacitor topology. Ripples were almost the same in the output voltage of the 3 converters but the boost topology is quite unstable which can give rise to ripples hence the interleaved with switched capacitor is preferred topology for the wecs- wind energy system with low capacity pv arrays and wecs hybrid system to have good voltage gain and efficiency. The output of the hybrid system can be further smoothened by an additional filter circuit connected before the load.

The performance of the converters can be compared by considering different load levels and other hybrid systems conjugated like fuel cells. A boost converter topology can also be designed for wecs converter which will further boost up the voltage considering the fact the wind energy conversion system output depends upon wind speed and direction types of blades used in turbines and generator type and capacity.

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