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Development and Implementation of Two Stage LCL Boost using Fuel Cell as an Input source in RES application

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Abstract: The paper presents the development and implementation of two stage LCL boost converter using fuel cell as an input source in renewable energy system applications, as there are many advantages of using fuel cell instead of using DC as an input source. At Constant input voltage SRC with LCL pattern can preserve Zero Voltage Switching (ZVS) for wide-ranging load discrepancy. For that reason, two stage configurations by means of a zero-voltage Transition (ZVT) with boost face step chased by the Series Resonant Converter in LCL configuration with capacitive output filter.

Two stage boost SRC with LCL configuration for capacitive output filter application is having no duty loss, efficiency, lesser transformer turns ratio, lesser problems of ringing in the output rectifier circuit, difficulty of output rectifier, and very narrow duty cycle. Fuel cell is used as an input source due to its advantages against battery operated systems namely cleanliness, higher efficiency, cost effectiveness etc.

Keywords: Fuel cell, electrolyser, SRC with LCL boost converter, ZVT (Zero Voltage Transition).

1. INTRODUCTION

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat. A renewable energy system (RES) transforms the energy found in sunlight, wind, falling water, waves, geothermal heat, or biomass into a useable form, such as heat or Electricity. Renewable energy storage in the form of hydrogen may overcome the inherent weakness of battery-based energy storage methods like physical size, in adequate life span, and initial

Capital cost of the battery bank coupled with transportation, maintenance, and battery disposal issues. [1].

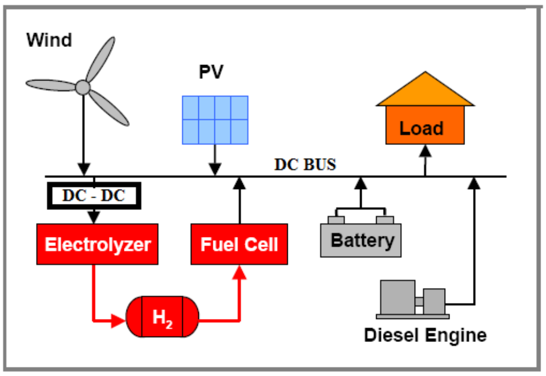

Fig 1. Block diagram of typical RES system [5]

At the times when the renewable resources exceed the load demand, hydrogen would be produced and deposited through water electrolysis. For this purpose, electrolyzer that breaks water into hydrogen and oxygen is used as an essential part of RES in Fig. 1. At the times when the load demand exceeds the renewable resource input, a fuel cell operating on the stored hydrogen would deliver the balance of power. To ensure proper flow of power between the system elements, the existing energy from different sources is coupled to a low voltage dc bus. A direct connection of dc bus to the electrolyzer is not appropriate because it lacks the ability to control the power flow between the renewable input source and the electrolyzer. Therefore, a power conditioning system, typically a dc–dc converter, is required to couple the electrolyzer to the system bus.

2. Fuel Cell

2.1Working of Fuel cell

Oxygen is supplied to the cathode side at the time when hydrogen is permitted into the anode region of the fuel cell.

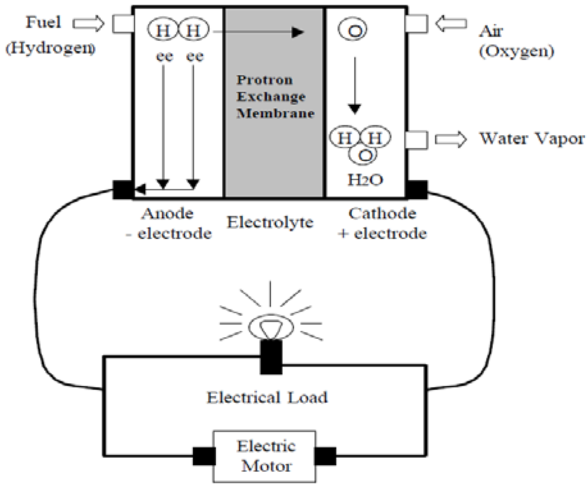

Fig 2. Fuel cell

The electrons of the hydrogen are not able to enter membrane at the times when hydrogen protons pass over (PEM) Proton exchange membrane. The membrane used i.e. PEM is an electrolyte which permits the passage of protons but not the electrons. As the electrons are not allowed for passing they look for the least resistance path to flow from the anode side to the fuel cell with the help of an electrical circuit to the devices or for feeding the loads and are returning to the fuel cell with the help of cathode. The by-

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product of the fuel cell is received by the linking of electrons with hydrogen and oxygen within the cell and forms a water molecule.

2.2 Fuel cell Stack

Fuel Cell Stack (FCS) with minimal power of 6kW and voltage as 45Vdc. The converter is loaded by6kW with a time constant of 1 sec using an RL element. All through the first 10secs, at the nominal value the hydrogen is utilized as constant (Uf_H2 = 99.56%)

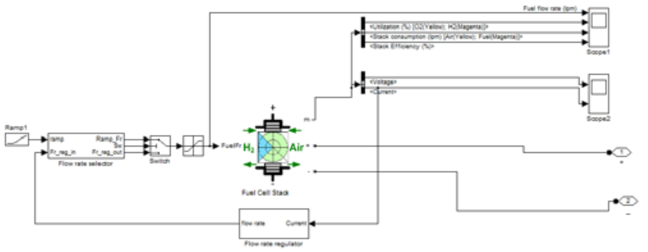

Fig 3. A 6 KW,45V DC Fuel cell Stack

The flow rate regulator is sidestepped after 10 seconds and fuel rate is increased up to the maximum value of 85 lpm in order to perceive the difference in the stack voltage which in turn affects the consumption of fuel, efficiency of the stack, and the air consumption.

Fuel cell voltage, current, DC/DC converter voltage and DC/DC converter current signals are presented on the Scope2. Fuel flow rate, fuel and air intake, Hydrogen and oxygen utilization and efficiency are obtainable on the Scope1.

The DC/DC converter applies 100Vdc to the RL load at t=0 sec (i.e. the current of the load at the initial stage is 0A). The nominal value of 99.56% is set to the fuel cell application and the current increases to 133A rating. In order to sustain the nominal fuel intake the flow of the fuel is set. The DC bus voltage can be seen at the scope 2 and it is well structured by the converter. At the transient state of the voltage regulator the inauguration of simulation is performed at the peak voltage of 122V dc.

The Fuel flow rate is amplified from 50 liters per minute (lpm) to 85 liters per minute (lpm) at t=10sec is amplified to 50 liters/min. Due to this the Nernst voltage is increased and therefore the fuel cell current will drop thus causing the weakening of the stack and ultimately reducing the efficiency as can be seen in scope 1

3. Two Stage LCL Boost Converter with SRC configuration

SRC with LCL configuration for capacitive
output filter application is having no duty loss, efficiency, lesser transformer turns ratio, lesser problems of ringing in the output rectifier circuit, difficulty of output rectifier, and very narrow duty cycle.

However, this converter used in the application will not be able to sustain Zero Voltage
Switching for utmost energy and necessitate lossy snubbers used for MOSFETs and it is not reliable to find the very small value of resonant inductor.

Most of the common problem with the use of all other converters is wide dissimilarity in load and supply.

At Constant input voltage SRC with LCL pattern can retain Zero Voltage Switching for extensive load discrepancy. For that reason, two stage configurations by means of a zero-voltage Transition (ZVT) with boost face step chased by the Series Resonant Converter in LCL configuration with capacitive output filter.

$Vbus$, i.e. the direct current bus input energy of the SRC in LCL configuration is superior to a energy greater than the input voltage deviation. Therefore, the recommended arrangement fulfils many of the plus points of SRC used in LCL configuration with capacitive output filter and continues to preserve dissimilarities in load and supply conditions. The benefits of SRC used in the LCL configuration for capacitive output filter and preserves the Zero voltage switching for wide variations at load and supply. The losses or fatalities in the main surface of switches of series resonant converter with LCL configuration are minimized and the key voltage to the subsequent phase is practically big also it is originates that resonant components can be almost recognized.

For the specified value of input voltage (i.e. 40 to 60 V) to the resonant converter, the 2 stage
approach using a ZVT (Zero volt transition) boost converter of the value of 100 V is generated approximately. Voltage received at the output is Vo = 60 V. By using or following this approach we can achieve zero voltage switching for each and every one switch. It also make simpler the mean of the resonant gears used i.e. L_r and C_s.
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3. Design of Model

Performance for Two Stage SRC Boost with LCL configuration along with the for capacitive output filter using fuel cell as an Input source is designed as shown in Figure 4.8 and. is anticipated for diverse load circumstances with yield electrical voltage of $V_o = 60\,V$ and the examination for the least key input electrical voltage$V_{in} = 40\,V$. The outcomes achieved are represented in Fig. 4.9.The Various components used in the experiment have the Design values and components used were1) Zero Voltage Transition increase: L_b represents boost inductor having value equals to $50\,\mu H$; L_a represents the resonant inductor having value equals to $300\,nH$; C_b represents the snubber capacitor having value equals to $220\,nF$, L_r represents resonant inductor with LCL configuration in SRC having value equals to $3.3\,\mu H$, C_s represents resonant capacitor having value equals to $1\,\mu F$, L_t represents parallel inductor having value equals to $12\,\mu H$, and $Cn1\ to\ Cn4$ represents the no. of snubber capacitors each having values equals to 6.8 nF, and the High Frequency transformer(i.e. HF) represents the turns ratio having value equal to 10: 6.

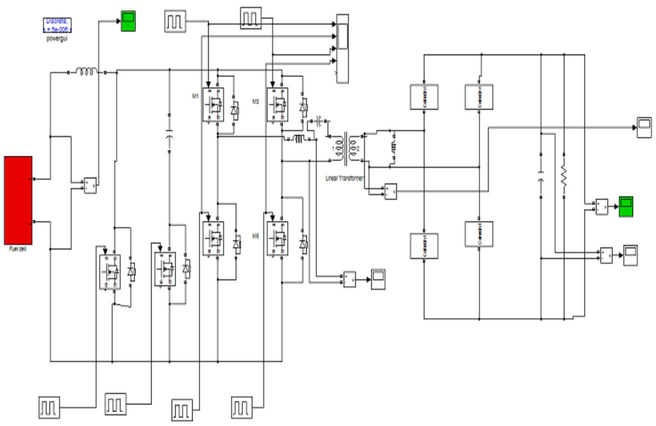

Fig 4.Two Stage Boost LCL boost with SRC configuration along with the capacitive output filter using fuel cell as an Input source

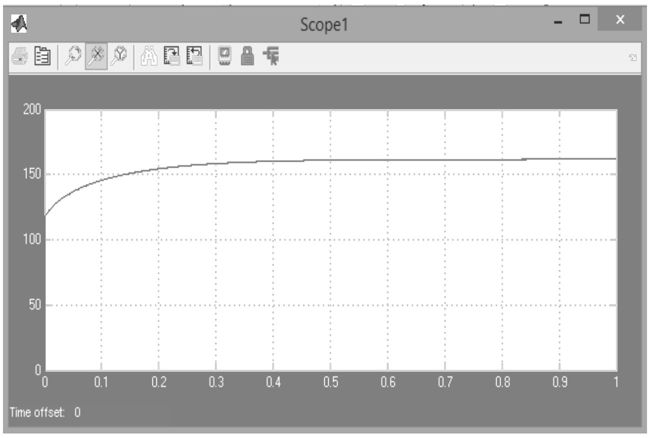

Fig 5. Result for Two Stage SRC Boost with LCL configuration along with the capacitive

4. Conclusion

This paper presents two stage SRC with LCL configuration & output obtained is as shown in the simulation result shown above. The recommended arrangement i.e. SRC in LCL configuration with capacitive output filter continues to preserve dissimilarities in load and supply conditions. The benefits of SRC used in the LCL configuration for capacitive output filter and preserves the Zero voltage switching for wide variations at load and supply. For the specified value of input voltage (i.e. 40 to 60 V) to the resonant converter, the 2 stage approach using a ZVT (Zero volt transition) boost converter of the value of 100 V is generated approximately. Voltage received at the output is Vo = 60 V. By using or following this approach we can achieve zero voltage switching for each and every one switch. It also makes simpler the mean of the resonant gears used i.e. L_r and C_s.Modeling renewable energy sources for a large-scale powersystem incorporation simulation is more important today, because these simulation tools will be a part of optimal design and intelligent management process.

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