Implementation of Fuel Cell based Distributed Generation System with DSTATCOM

Jagan Mohana Rao Malla

Abstract—This paper shows the operation of the distributed generation system with and without DSTATCOM. It compares the results of the system and highlights the benefits of using DSTATCOM in the system. The purpose of DSTATCOM is to mitigate the voltage sag and to make proper power flow control in the system. An inverter is required for connecting fuel cell to grid. A DSTATCOM control for this inverter is proposed here, so this controller mitigates sag, compensate reactive power and improve voltage stability, so by using proposed control, system maintains good power quality at load. Voltage sags will occur at source side only and sometimes it may occur due to large variations in load. In this paper, the design guidelines, operation principle are presented along with the simulation results. Based on extensive simulation results using MATLAB/SIMULINK it has been established that the performance of the controllers both in transient as well as in steady state is quite satisfactory.

Keywords-Fuel cell, DSTATCOM, Distributed generation, sag, Reactive power compensation.

I. Introduction

The distributed generation system plays a key role in power supply to all over the world by utilizing various energy resources. Power production should be made available at all the seasons and hence even during the period of non-availability of renewable energy sources like wind, hydro, etc. and non - renewable energy sources like thermal, etc. we opt the possibility of using fuel cell as the source of constant power supply and this can also be made as alternate source i.e. it can be used as an integrated source with wind power plant or hydro power plant too. The Fuel Cell (FC) is one of the most promising sources of renewable energy. They can be considered as green power because they are automatically clean. The advantages of using fuel cells are as follows: (a) Fuel cells convert hydrogen and oxygen directly into electricity and water, with no combustion in the process. The resulting efficiency is between 50 and 60%, about double that of an internal combustion engine. (b) Fuel cells are clean. If hydrogen is the fuel, there are no pollutant emissions from a fuel cell itself, only the production of pure water. (c) Fuel cells are quiet. A fuel cell itself has no moving parts, although a fuel cell system may have pumps and fans. As a result, electrical power is produced relatively silently. (d) Fuel cells are modular. That is, fuel cells of varying sizes can be stacked together to meet a required power demand. As mentioned earlier, fuel cell systems can provide power over a large range, from a few watts to megawatts. (e) Fuel cells are environmentally safe. They produce no hazardous waste products, and their only by-product is water (or water and carbon dioxide in the case of methanol cells).Fuel cells may give us the opportunity to provide the world with sustainable electrical power. However, the power thus produced by fuel cell can be used effectively by DSTATCOM which helps in proper power flow control and mitigation of voltage sags and maintain power quality at load (i.e., Point of Common Coupling (PCC)).

II.SYSTEM OVERVIEW

The distributed generation system comprises of the fuel cell as source of power supply in this paper. The fuel cell operates at a voltage level of 410V and which gets boosted up to 710 V by DC-DC boost converter and then fed into IGBT based inverter. The DC link voltage controller controls the pulse fed to DC –DC converter as shown in Fig 1.

From the inverter , the output voltage obtained as 444 V AC is checked at the PCC for any voltage disturbances or if there is any need for power flow control by using the current regulator and power regulators. Based upon the requirements of proper control in power and voltage, the regulator operates and provides better voltage and power supply.

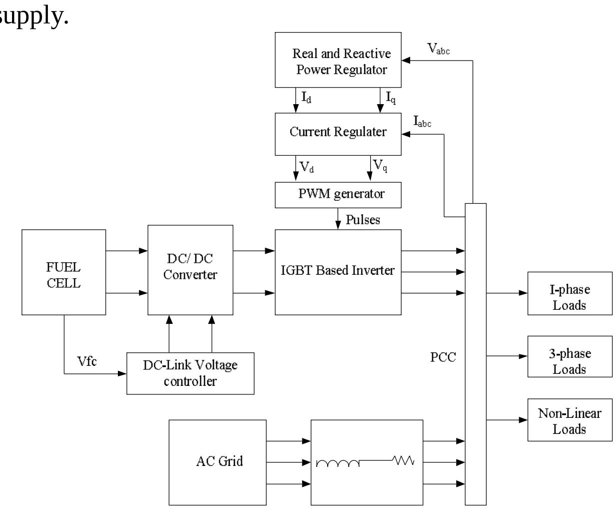

Fig 1 block diagram of the system with DSTATCOM

III.SIMULATION AND RESULTS

The simulation model of the system is shown in the following figures below.

Case-I. Without DSTATCOM :

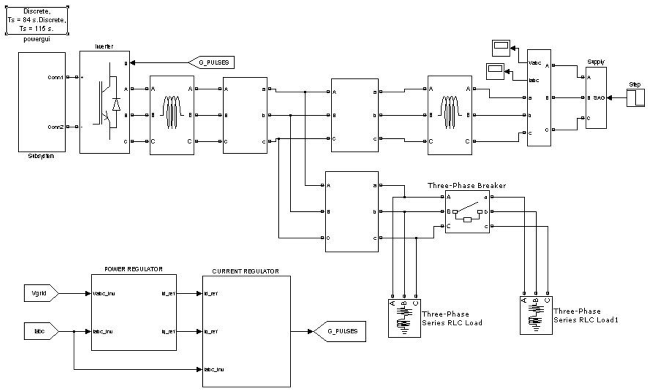

Fig 2 simulation model of entire system

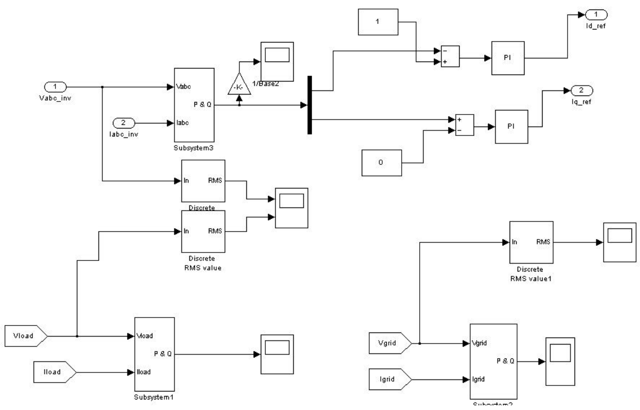

Fig 3 simulation model of power regulator

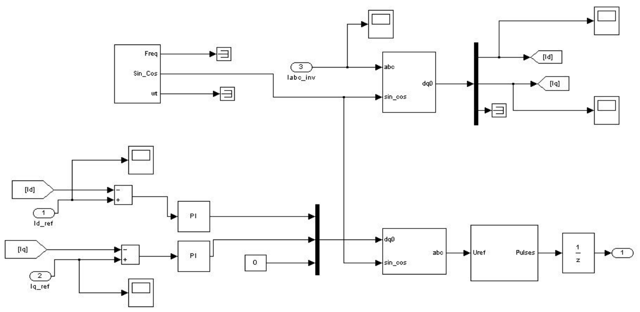

Fig 4 simulation model of current regulator

The Fig. 2 shows the simulation model of the entire distributed generation system. The Fig. 3 and 4 represents the simulation model of the current regulator and power regulator which operates fuel cell at maximum power generation level.

In the Fig. 5, from 2.5 to 3sec,power produced at the load connected at PCC is more than the FC generation (maximum capacity) and before 2.5 and after 3 sec load is less than that of maximum generation of FC. The respective real and reactive power diagram of load is shown in Fig.6. Hence, during 2.5 to 3sec required real power flow from grid to load, before 2.5 and after 2.3, grid is taking some power from fuel cell and the respective real and reactive power is shown in Fig 7.

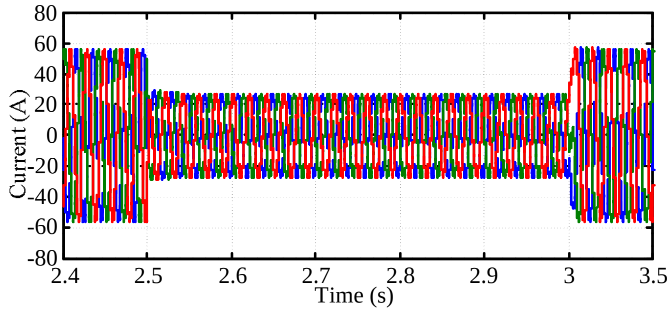

Fig 5 Grid current waveform

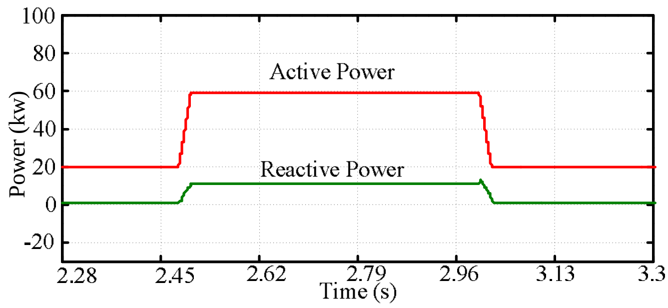

Fig 6 load power

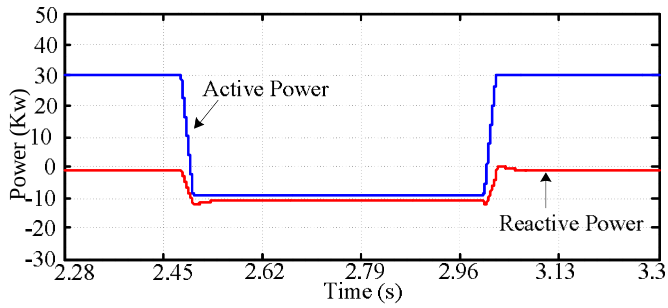

Fig 7 grid power

In Fig.7,negative power means grid is giving power and positive means grid taking power and here grid is supplying reactive power to load, how much reactive power connected to load and so, inverter didnot compensate reactive power (i.e: inverter reactive power is 0)and it is shown in fig 8. The corresponding dc link voltage is shown in Fig.9.From Fig.9, dc to dc controller working properly, and it maintains its reference value in all conditions.

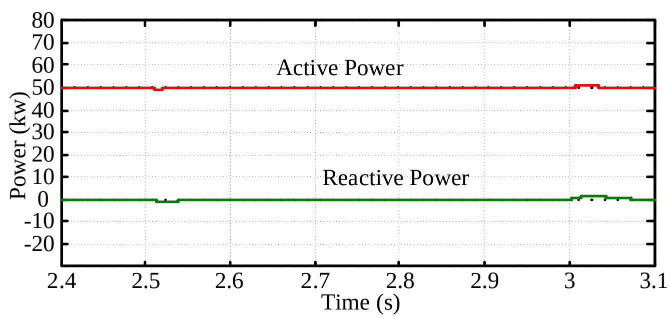

FIG 8 INVERTER POWER

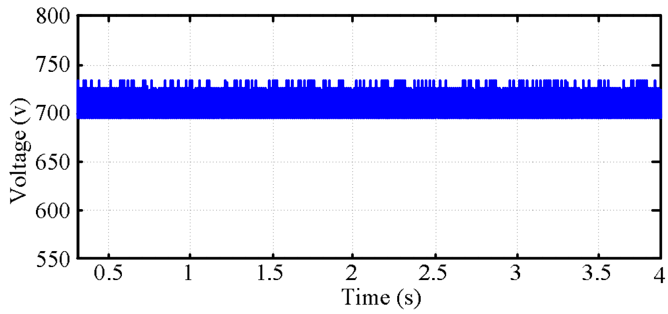

Fig 9 Voltage across DC converter

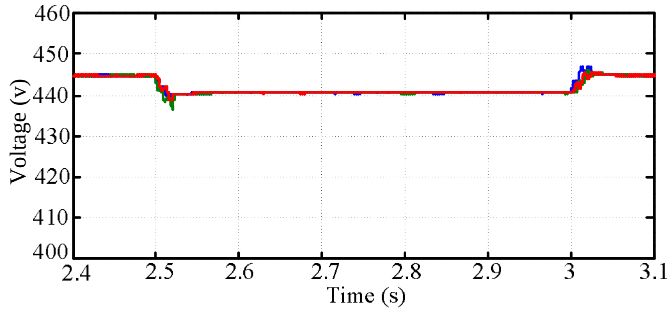

Fig 10 rms voltage waveform at PCC

Here, the system does not maintain voltage stability at PCC with the general controller (without DSTATCOM). When load is applied, the rms voltage fall down, it does not maintain reference voltage because here reactive power compensation is not done , so load voltage depends on how much reactive power flowing from grid to load. , because of this reason rms voltage (444V) cannot be maintained as constant at PCC.

In order to overcome this problem in this paper, DSTATCOM based controller is proposed for fuel cell based power generation system connected to grid.

Case-II. With DSTATCOM

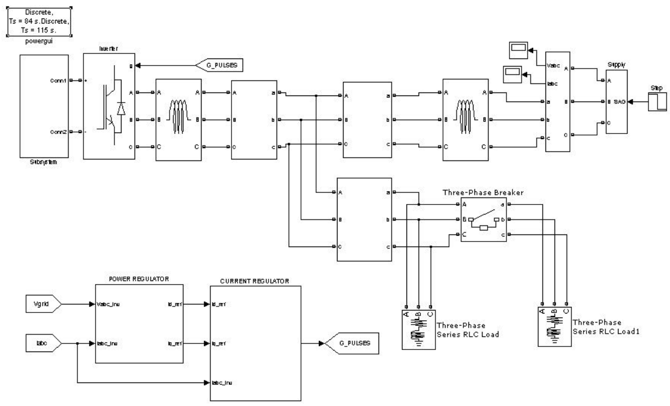

Fig 11 simulation model of entire system

The Fig. 11 shows the simulation model of the entire distributed generation system. The Fig 12 and 13 represent the simulation model of power regulator and the current regulator, which helps in mitigating voltage sag and reactive power compensation and also makes FC to operate at maximum power level.

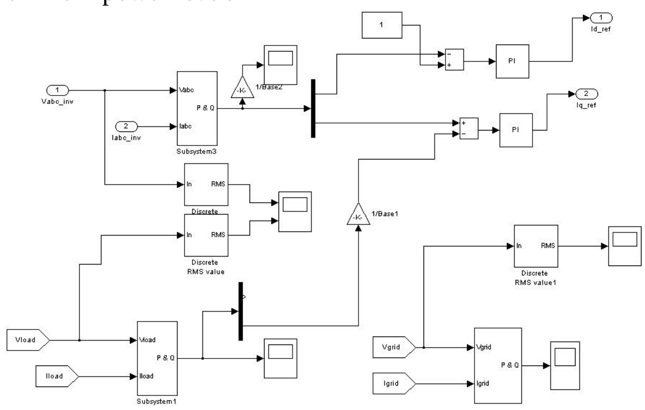

Fig 12 simulation model of power regulator

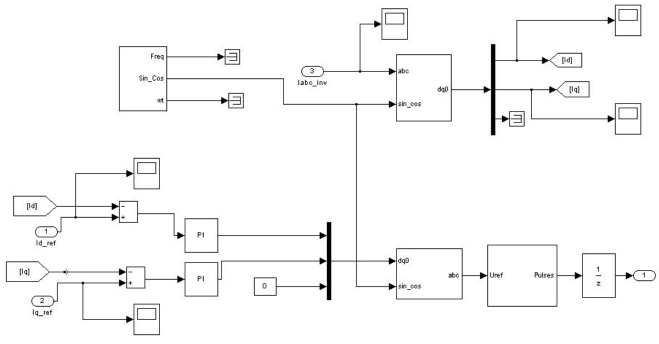

Fig 13 simulation model of current regulator

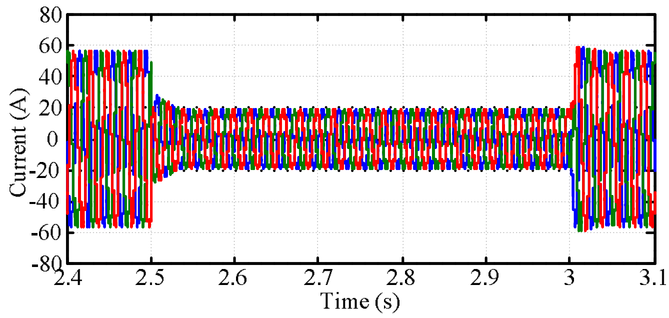

Fig 14 Grid current waveform

In the Fig.14, from 2.5 to 3sec load connected at PCC is more than the FC generation (maximum capacity) and before 2.5 and after 3 sec load is less then that of fuel cell maximum generation so during 2.5 to 3 required real power flow from grid to load, before 2.5 and after 2.3, grid is taking some power from fuel cell and the respective real and reactive powers of load is shown in Fig 15.

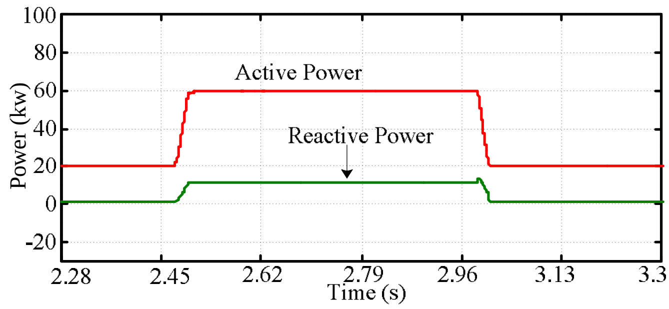

Fig 15 load power

In the figure shown above ,i.e, Fig 15, load power is more than that of generation of fuel cell , so grid provide only remaining real power to load but grid donot supply any reactive power to load (i.e., reactive power supplied/taking by the grid to PCC is zero). This is achieved by reactive power compensation by proper control of DSTATCOM.

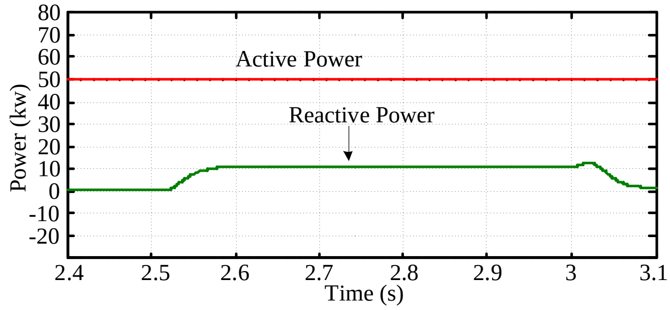

Fig 16 inverter power

In the Fig shown above, i.e, Fig 16, inverter compensate reactive power that how much reactive power is connected to PCC and this control allows to operate FC at maximum level of power generation.

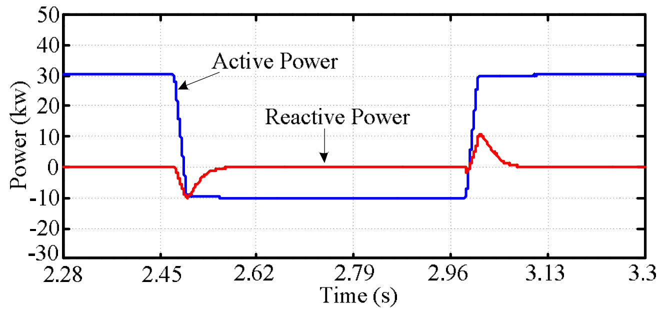

Fig 17 grid power waveform

After compensated reactive power by inverter or DSTATCOM, reactive power supplied or consumed by grid is zero and the flow of active power is depends on both generation of FC and active load power connected to the PCC. This is shown in Fig. 17.

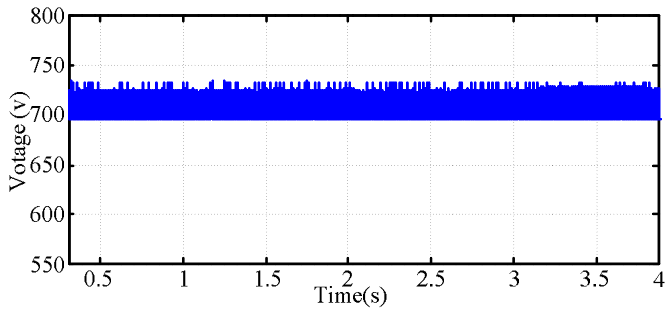

Fig 18 voltage across DC converter

In the figure shown above, i.e, Fig 18,the voltage produced across DC converter is 710 V dc which is boosted from 410V dc all the cases this dc-link voltage is maintained at its reference value (710V).

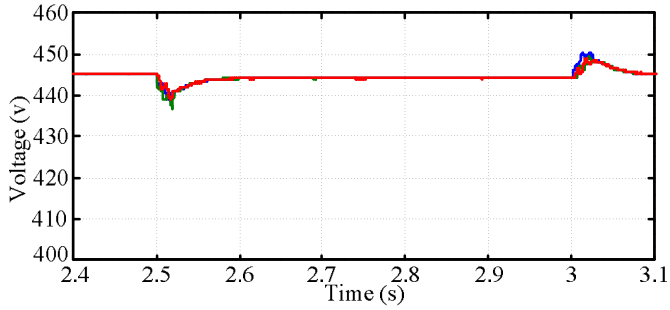

Fig 19 rms voltage waveform at PCC

In the figure shown above,i.e, Fig 19,the rms voltages are maintained at its reference value (444V) in all the cases. Hence the proposed control compensates reactive power and as well as improve the power quality by maintains good stability of voltage. From Fig. 10 and Fig 19, we can achieve regulated voltage at PCC by using proposed controller.

Maximum operation of distribution having the effect of sag and because of many reasons, sag will occur in distribution system. If sensitive loads are connected to PCC, such type of loads will affected by sag. So in order to reduce the effect of sag, mitigation of sag is required for both improving power quality as well as safe operation of load. Hence the proposed controller is designed in such a fashion to mitigate the sag. Hence the controller will work in all the cases. The sag occurred at grid is shown in Fig. 21. Here sag occurred during the time interval of 1 to 1.5 sec., the respective rms voltage of load is shown in Fig. 22. From the Fig. 22, the proposed controller (DSTATCOM) maintains the rms voltage at its reference value (444V).

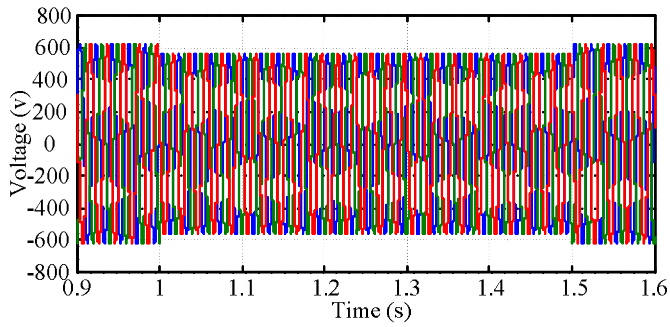

Fig 21 Grid voltage during sag

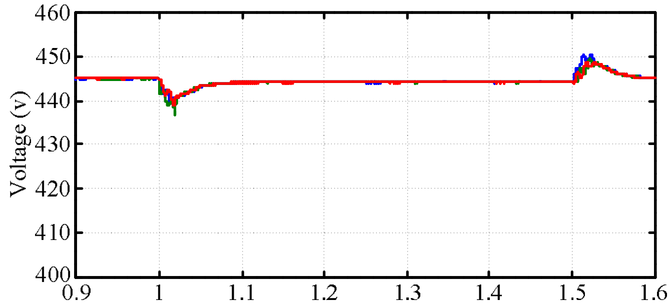

Fig 22 rms Voltage at PCC (Load)

V.CONCLUSION

From these results, it can be inferred that the system with DSTATCOM can produce regulated voltage and power than compared to system without DSTATCOM control (proposed controller). The proposed controller is also working for mitigation of sag. During sag time, the proposed controller regulates the voltage at PCC at its reference value (444 V). And the proposed controller also can compensate reactive power and it allows operating FC at its maximum generation level of power.

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