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Flexible Power Grid Parameter Improvement Connected to Fuel Cell Plant under Symmetrical Fault

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Abstract - **The freedom of the energy market and the new circumstances in the energy field are driving towards the finding of additional effective methods of energy creation and flexible system. The presentation of groundbreaking thoughts fit for fostering the new circumstances can prompt better arrangements when contrasted with any glitches which the proposed model can make. Energy demand is supposed to develop at extremely high rate before long. Appropriate technique of power production in view of power module and sustainable power sources, with distinct monitoring and control procedure is applied. Non conventional fuel based generation alongside customary framework to shape hybrid power generation framework is another methodology in the power sector to satisfy the electrical energy need and development in a most effective way. The power device is utilized to allude for generation alongside capacity storage like batteries, hydrogen storage tank etc. Standalone power generation is a methodology that utilizes limited scope innovations to create power near end consumers of power. Sustainable energy based generation associated with grid offer various potential advantages like productive age and extremely low carbon footprints. The scheme suggested in this paper can give higher power strength during healthy and faulty condition. Mathematical model of fuel cell plant connected to conventional grid is simulated in MATLAB environment. The result shows improvement in voltage and current profile of the system.**

Keywords - ***Sustainable Energy, Fuel Cell, Modeling and Simulation, Non conventional Energy Sources***

INTRODUCTION

Integrated sustainable non-conventional energy based grid with energy storage capacity incorporated with traditional fuel based power plants structure a resilient hybrid power system [1] [2]. The portrayal of environmentally friendly power system requires solar, wind, fuel cell, hydro, geothermal and biomass information of the available source in addition to data for the estimation of the source information, reliability of the information and geographic elements that influence the assurance of the genuine accessible sustainable source. The solar power plant relies firmly upon season and weather environment, the wind breeze has enormous scope depends on climatic flow designs and geographic impacts, the hydro source for nearby precipitation patterns and geology and the biomass source on local natural manufacturing. Sustainable energy sources [3] [4] might differ massively by area and may have strength seasonally and hour-to-hour unpredictable. The idea of the accessible inexhaustible source influences the potential and financial matters of sustainable power frameworks. RES are used with planning for inexhaustible power generation as they are combined and coordinated with conventional power grid [5] [6] to shape a reliable hybrid power plant.

I. ELECTRICITY GENERATION BY FUEL CELL

A. Fuel Cell

Fuel cells generates electricity in DC form which is suitably converted to three phase AC by inverter technology [7]. The generation of electricity by fuel cell comprises a chemical reaction in to the cell with water and heat as a offshoot. Fig.1 presents block diagram of fuel cell based electricity generation.

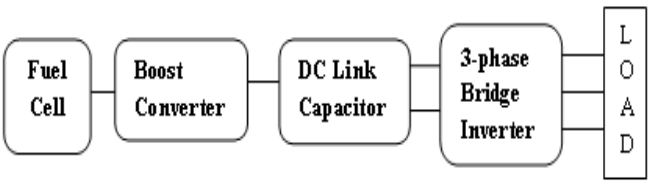

Figure 1 Electricity Generation by Fuel Cell

Fuel cell utilizes hydrogen and oxygen present in the air intake as fuel components for electricity production. The process of electricity production includes reaction between hydrogen and oxygen in presence of suitable electrolyte through which ion conducts. The fuel cell based generation is highly reliable and efficient in comparison to fossil fuel based generation because no moving part is present in the fuel cell. Fuel cell operates as a battery without run down and need no recharging. It generates uninterrupted DC electric voltage as long as fuel is provided to the cell. The conventional grid integrated with fuel cell plant shows significant improvement in voltage and current profile under normal operating condition [8] as well as during fault condition [9].

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Mathematical modeling of the conventional grid connected with and without fuel cell plant is designed. Simulink model of the proposed system simulated in the MATLAB environment. The resulting waveforms depicts considerable grid parameter enhancement. The scheme is attractive for power production and vehicular applications as associated with low carbon emission, high power density and fast start features.

II. SCHEME OF OPERATION

Fuel cell based electricity generation shows more efficient way out to conventional power generation system. The literature survey point out the shortcomings of traditional power generation system and suggest new means of power generation.

Fuel Cell operates like a battery that is persistently accused of a fuel gas with high hydrogen content. Solid oxide fuel cell (SOFC) is efficient and fast acting in response. This is the charge of the electric power module along with air, which supplies the necessary oxygen for the combined response. The power device uses the response of hydrogen and oxygen with the guide of a particle directing electrolyte to deliver an induced DC voltage [10] [11]. The DC voltage is changed over into AC voltage utilizing suitable inverters and afterward is supplied to the conventional power grid. Fuel cell energy likewise creates heat and water alongside electric power however it has a high running expense, which is its significant impediment. The fundamental benefit of the unit is that there is no moving parts, which increment the dependability of this technology and no commotion is created. In addition, they can be worked with a wide range of conventional fuels with higher effectiveness than some other generation system. Then again, it is important to observe the effect of the contamination outflows and ageing of the electrolyte qualities, as well as its impact on the productivity and lifetime of the cell unit.

III. MATHEMATICAL MODELING OF SOFC

Mathematical equations of fuel cell model are presented below [12] [13].

Output equation of single fuel cell is

$$V_{fc} = E_{nernst} - V_{act} - V_{ohmic} - V_{con} \quad (1)$$

Thermodynamic potential is given by

$$E_{nernst} = 1.229 - 0.85x10^{10-3}(T-298.15) + 4.31x10^{10-5}x\ T\ [\ln(P_{H2}+1/2\ln(Po2)] \quad (2)$$

Activation over potential is given by

$$V_{act} = -\ [\xi 1+ \xi 2xT+\xi 3xTln(CO2)+\xi 4xTln(i_{fc}) \quad (3)$$

Ohmic over potential equation is

$$V_{ohmic} = i_{fc\ (}R_M + R_C) \quad (4)$$

Concentration over potential is

$$V_{con} = -B\ x\ ln(1-\ J/J_{max}) \quad (5)$$

For N cells, stack output is

$$Vs = N\ x\ V_{fc} \quad (6)$$

Dynamic capacitor voltage is

$$dV_d/dt = (1/C\ x\ i_{fc})-(1/\tau\ x\ V_d) \quad (7)$$

Electrical time constant is given by

$$\tau = C\ x\ Ra = C\ (R_{act} + R_{con}) \quad (8)$$

Power output rendered

$$P_{fc} = i_{fc}\ x\ V_{fc} \quad (9)$$

Efficiency expression is

$$\%\ \eta = \mu_f\ x\ ((V_{fc}/1.48)\ x\ 100 \quad (10)$$

Based on mathematical equations for fuel cell plant simulink model is designed in MATLAB [14] [15] [16]. The output of fuel cell after amplification by boost converter is converted in to three phase ac by three phase bridge inverter. Simulink model of fuel cell power generation system is developed [17] [18] and shown in Fig 2. Output of fuel cell plant is suitably processed to make compatible with grid.

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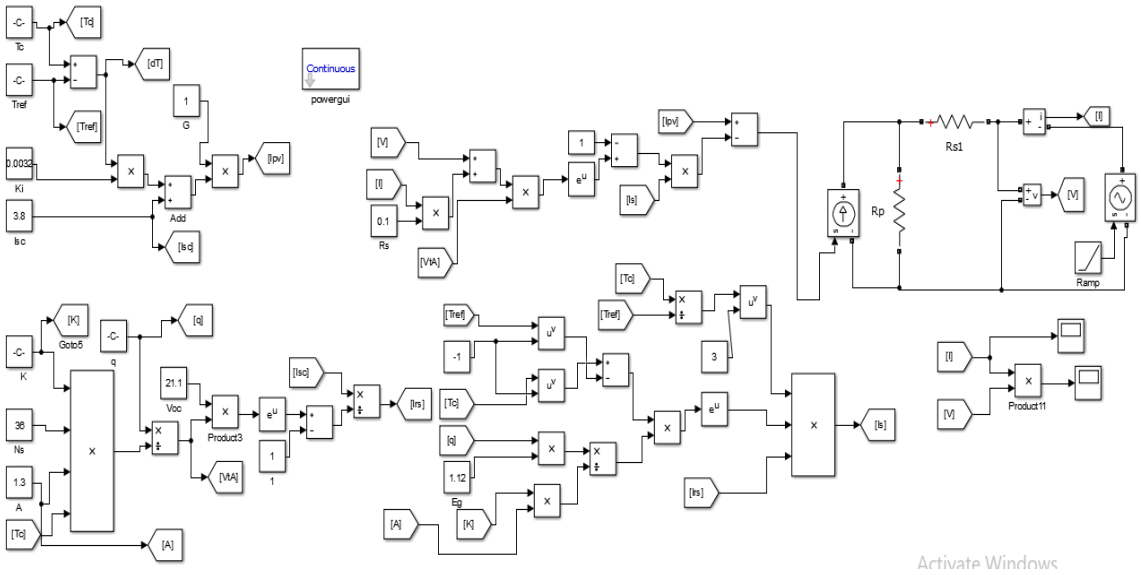

Figure 2 Simulink Model of SOFC Plant

IV. PROPOSED DESIGN

Three phase 11 KV power generation plant is designed in MATLAB connected to fuel cell electricity generation plant [19] [20] [21] and the waveforms are shown in Fig 3. Three phase line to ground fault is created in the line and the model is simulated. The resulting waveform is shown in Fig 4. The values of grid voltage and current under faulty condition are presented in table 1 and compared with the values under normal condition of operation.

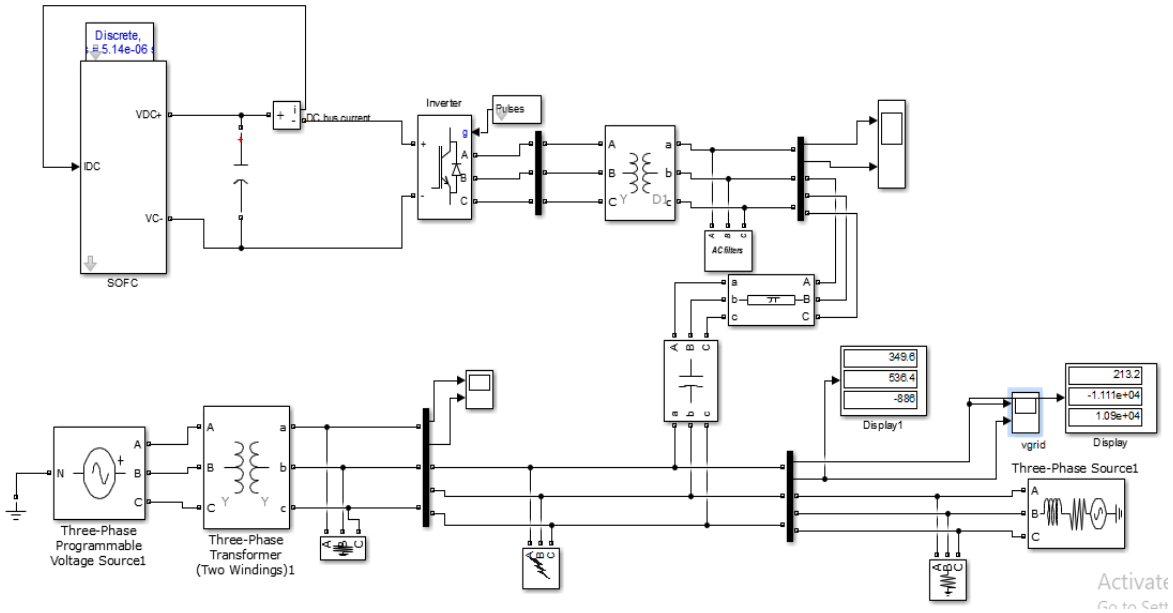

Figure 3 Fuel Cell Plant Integrated to Grid under Fault Condition

V. RESULTS AND DISCUSSION

Three phase line to ground fault is created for 0.3 ms time in proposed 11 KV three phase generation system connected to fuel cell plant. Waveform under fault condition is shown in Fig 5. Grid parameters tabulated in table 1 represents considerable improvement in the voltage and current when the grid is connected to fuel cell plant.

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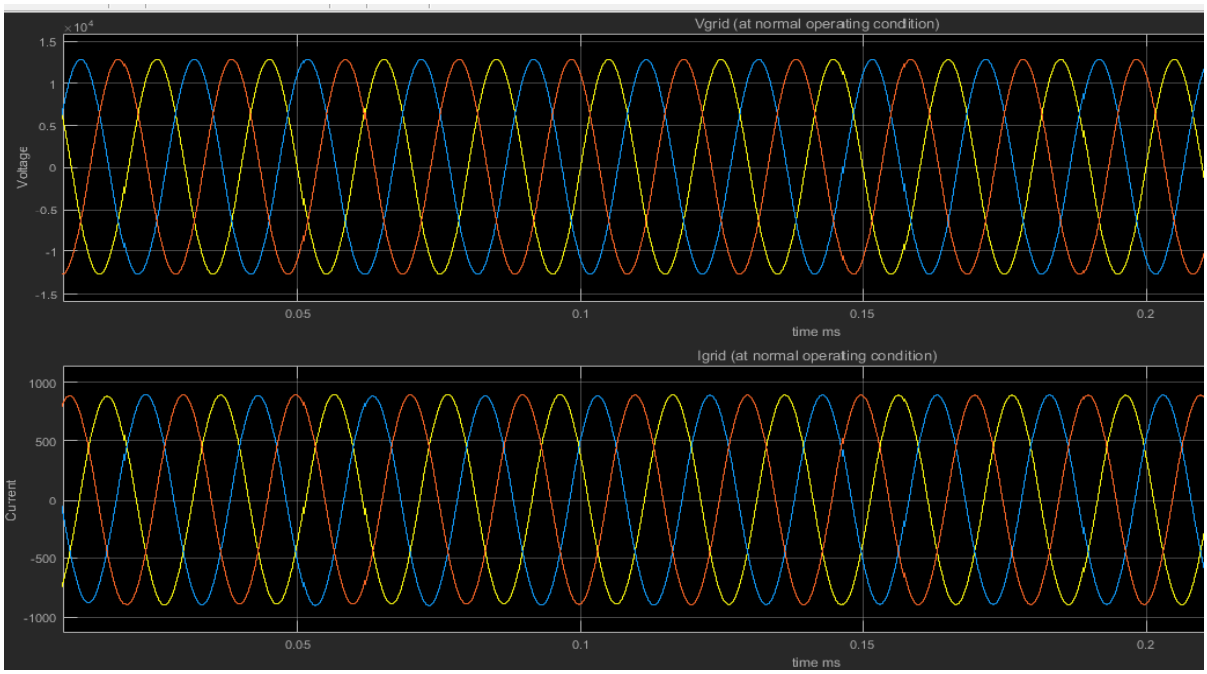

Figure 4 Three Phase Voltage and Current Waveforms

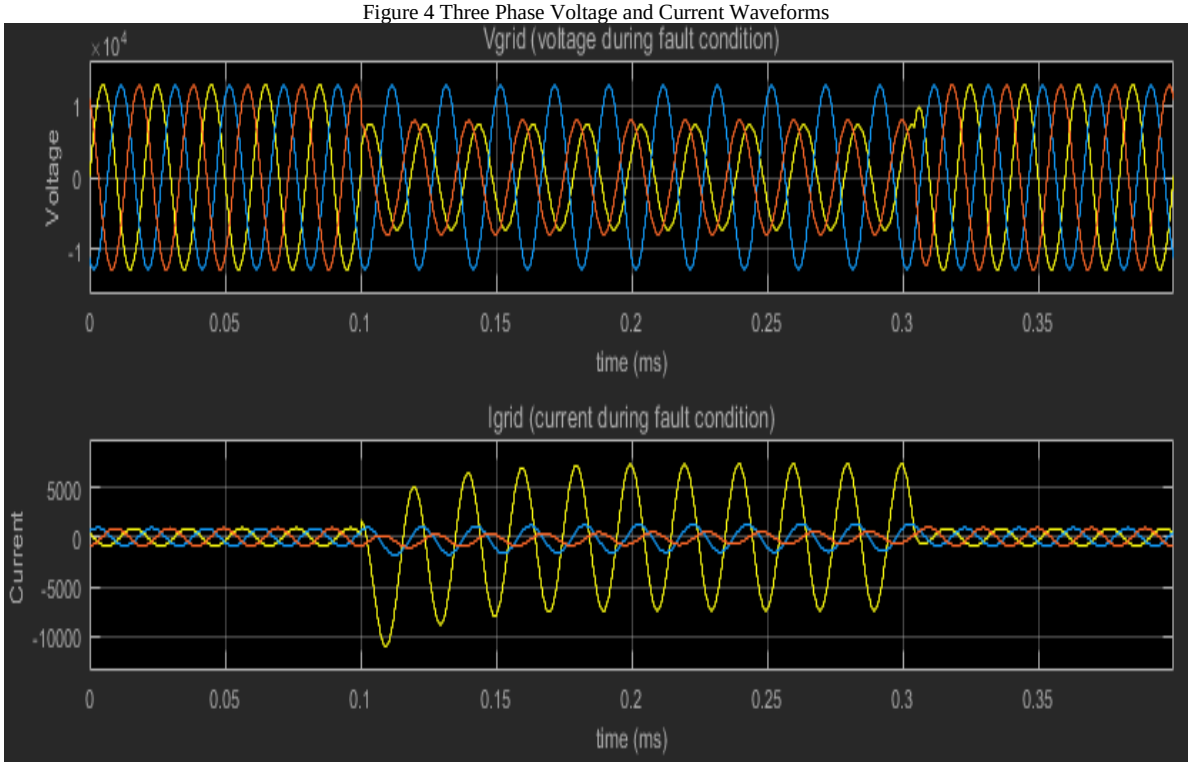

Figure 5 Fuel Cell connected Grid Voltage and Current Waveforms under Fault condition

During fault from 0.1ms to0.3 ms the short circuit voltage increased and short circuit current is reduced with considerable amount as compared to parameters without fuel cell plant.

TABLE 1: COMPARATIVE STUDY OF VOLTAGE AND CURRENT VALUES AT DIFFERENT OPERATING CONDITIONS

Grid Voltage and Current	Not integrated with fuel cell plant	Integrated with fuel cell plant
Voltage at healthy condition	11.08 KV	11.23 KV

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Current at healthy condition	580.9 A	568.2 A
Voltage at Faulty condition	7.265 KV	7.444 KV
Current at faulty condition	3883.33 A	3846.15 A

CONCLUSION

This paper indicates the effect of fuel cell plant to stability of power grid. Simulink model of fuel cell plant is developed and connected to three phase KV grid which is developed in MATLAB environment. Simulation results are observed. The result analysys verify the improvement in system profile during symmetrical fault condition.

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