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Modeling And Simulation of Renewable Energy Technology Based Grid Power Quality Improvement

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***Abstract*— In this paper a thorough examination of environmentally friendly power sources, for example, sun based, wind, geothermal and alternative energy with the goal to dissect their utility in power grid is introduced. It is realized that, fossil fuel based energy sources are restricted and furthermore considered as maker of green house gases in the environment. The nursery impact causes an Earth-wide temperature boost over 30% in India. In this manner Environmentally friendly Renewable Energy Sources (RES) are becoming well known step by step as an option in contrast to petroleum derivative based conventional energy sources. The sustainable power sources which are climate agreeable, accessible liberated from cost can be coordinated with stockpiling framework to shape hybrid energy system (HES) to satisfy the expectation for consistently expanding energy interest. This paper examines different environmentally friendly power sources, capability of environmentally friendly power sources, Environmentally friendly renewable energy technology (RET). A methodical survey of writing was completed. The current energy situation is introduced and furthermore examined obstructions to the improvement of environmentally friendly power grid. The analysis in this work will propel and make mindfulness in broad daylight, scientists and strategy creator towards the utilization of efficient power energy. The consequence of this study demonstrates the way that the overall energy emergency can be overseen by incorporating sustainable power sources. The scheme suggested in this paper can give higher power strength during healthy and faulty condition. Mathematical model of PV, Wind, FC based hybrid power plant connected to conventional grid is simulated in MATLAB environment. The result shows improvement in voltage and current profile of the system.**

***Keywords*—** Non-conventional Energy, Modeling and Simulation, Photovoltaic system, Wind Turbine, Fuel Cell

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 SOLAR CELL

A photovoltaic system, converts the light received from the sun into electric energy. PV power generation scheme is depicted in Fig.3. In this system, semi conductive materials are used in the construction of solar cells, which transform the self contained energy of photons into electricity, when they are exposed to sun light. The cells are placed in an array that is either fixed or moving to keep tracking the sun in order to generate the maximum power [7] [8]. These systems are environmental friendly without any kind of emission, easy to use, with simple designs and it does not require any other fuel than solar light. On the other hand, they need large spaces and the initial cost is high. PV systems generate DC voltage then transferred to AC with the aid of inverters.

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A. MODELING OF PV CELL

Single diode model is described from equation (1) to (4) and Fig. 1 represents the model of PV cell. Various solar cells constitute a solar module with many solar cells connected in series and parallel denoted by N_s and N_p in equation (4). The several modules connected to form a solar array. Equation (4) shows the expression of current from solar array [9] [10]. Load current I is given in equation (1), where as equation (2) shows solar generated current I_p. Further I0 is the diode saturation current as described in eq. (3).

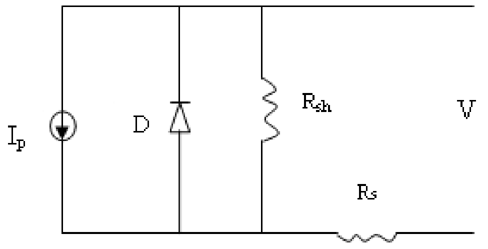

Figure 1 Fuel Cell Model

Mathematical equations are as mentioned below for a single diode model [11] [12].

$I = I_p – I_0 \{exp [(V+IR_s) / V_t a]-1\}-\{V+IR_s/R_{sh}\}$ (1)

Solar generated current is

$Ip = G/G_n [I_{p,n} + Ki (T-T_n)]$ (2)

Diode saturation current is given by

$I_0 = I_{0,n} (T/Tn)^3 exp[qEg/ak(1/T_n – 1/T)]$ (3)

The current from a solar array is explained by relation as shown below

$I = N_p I_{pv} – N_p I_0 [exp \{(V + I R_s (N_s/N_p)) /$ (4)

$V_t aN_s)\} – 1] – [\{V + I R_s (N_s/N_p)\} / Rp (N_s/N_p)]$

II. ELECTRICITY GENERATION BY WIND TURBINE

Wind turbines transform wind energy into electricity. The wind is a highly variable source, which cannot be stored, thus, it must be handled according to this characteristic. A general scheme of a wind turbine generation system is shown in Fig. 4. The principle of operation [11] of a wind turbine is characterized by two conversion steps. First the rotor extract the kinetic energy of the wind, changing it into mechanical torque in the shaft and in the second step the generation system converts this torque into electricity. Generally in common system, the generator system gives an AC output voltage that is dependent on the wind speed. As wind speed is variable, the voltage generated has to be transferred to DC and back again to AC with the aid of inverters. While, fixed speed wind turbines directly connect to the grid.

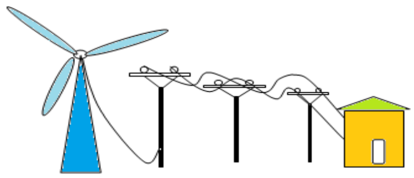

Figure 2Wind Turbine Generation

A. Modeling of Wind Turbine

The wind turbine model is described [11] 12] below with mathematical equations from (5) to (8).

Power output equation is given by

$P_m = 1/2ρΠλυ^3C_p (γ, β) R^2$ (5)

Tip speed ratio is given by

$γ = Rω /υ α$ (6)

Equation of aerodynamic torque is

$Tm = Pm / ω_{m =} 1/2ρΠλυ^2C_T (γ, β) R^3$ (7)

Where, torque coefficient

$C_T (γ, β) = C_p (γ, β) / γ$

The value of power coefficient is (8)

$C_p (γ, β) = C_1 (C_2 / γ_i – C_3 β – C_4) e^{C5/ γi}$

$C_6 γ_i$

Where, $C_1 – C_6$ are constants.

III. 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 [13] [14]. 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.

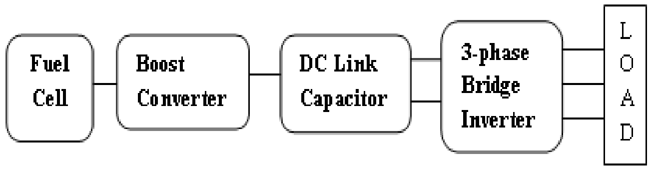

Figure 3 Fuel Cell Power Generation

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 [15] [16] 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.

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B.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 [17] [18] 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 [19] [20] and ageing of the electrolyte qualities, as well as its impact on the productivity and lifetime of the cell unit.

IV. MATHEMATICAL MODELING OF SOFC

Mathematical equations (9) to (18) of fuel cell model are presented below [21] [22] [23].

Output equation of single fuel cell is

$$V_{fc} = E_{nernst} - V_{act} - V_{ohmic} - V_{con} \qquad (9)$$

Thermodynamic potential is given by

$$E_{nernst} = 1.229 - 0.85x10^{10\text{-}3}(T\text{-}298.15)$$

$$+ 4.31x10^{10\text{-}5} x\ T\ [ln(P_{H2}+1/2ln(Po2)] \qquad (10)$$

Activation over potential is given by

$$V_{act} = -[\xi 1+ \xi 2xT+\xi 3xTln(CO2)+\xi 4xTln(i_{fc}) \qquad (11)$$

Ohmic over potential equation is

$$V_{ohmic} = i_{fc}(R_M + R_C) \qquad (12)$$

Concentration over potential is

$$V_{con} = -B\ x\ ln(1\text{-}\ J/J_{max}) \qquad (13)$$

For N cells, stack output is

$$Vs = N\ x\ V_{fc} \qquad (14)$$

Dynamic capacitor voltage is

$$dV_d/dt = (1/C\ x\ i_{fc})\text{-}(1/\tau\ x\ V_d) \qquad (15)$$

Electrical time constant is given by

$$\tau = C\ x\ Ra = C\ (R_{act} + R_{con}) \qquad (16)$$

Power output rendered

$$P_{fc} = i_{fc}\ x\ V_{fc} \qquad (17)$$

Efficiency expression is

$$\%\ \eta = \mu_f\ x\ ((V_{fc}/1.48)\ x\ 100 \qquad (18)$$

V. ELECTRICITY GENERATION BY HYBRID PLANT

Hybrid power generation includes multiple power generation sources. Conventional grid connected to non conventional power sources is a new trend and constitute the hybrid power generation system. It is more reliable, efficient and flexible system.The scheme of hybrid power plant generation is shown in the Fig. 4.

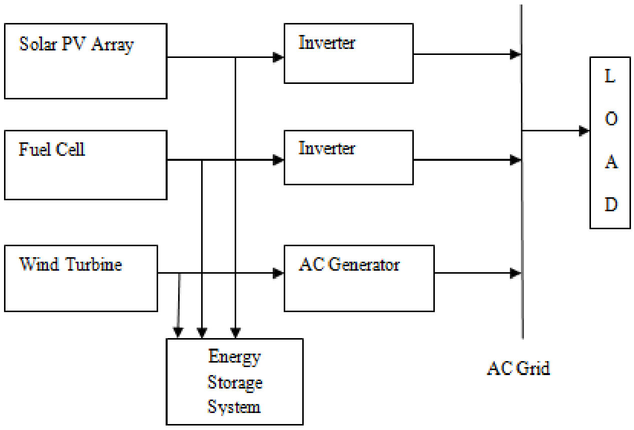

Figure 4 Hybrid Power System

VI. PROPOSED DESIGN SIMULATION

Three phase 11 KV power generation plant is designed in MATLAB connected to hybrid power generation plant [24] [25] [26] shown in Fig. 5 and the waveforms are shown in Fig 6. Three phase line to ground fault is created in the line and the model is simulated. The resulting waveform is shown in Fig 7. 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.

The output of hybrid power after amplification by boost converter is converted in to three phase ac by three phase bridge inverter. Simulink model of hybrid power generation system is developed [26] [27] and shown in Fig 5. Output of hybrid power plant is suitably processed to make compatible with grid.

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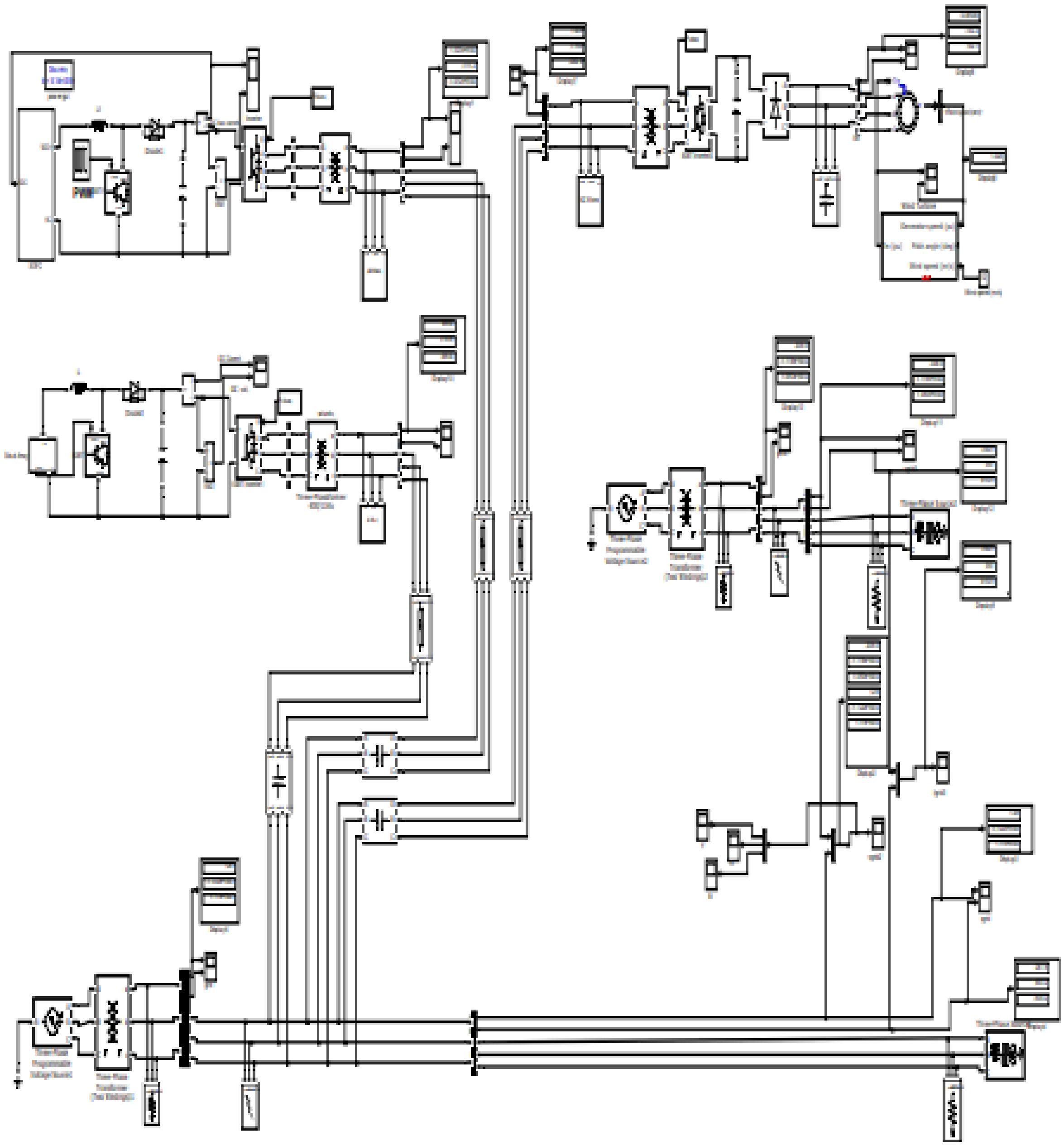

Figure 5 Simulink Model of Hybrid Power System

RESULTS AND DISCUSSION

Three phase line to ground fault is created for 0.3 ms time in proposed 11 KV three phase generation systems connected to hybrid power plant. Waveform under fault condition is shown in Fig 7. Grid parameters tabulated in table 1 represents considerable improvement in the voltage and current values when the grid is connected to combined PV,WT and Fuel Cell plant. During fault from 0.1ms to0.3 ms the short circuit voltage increased and short circuit current is reduced in considerable amount as compared to parameters without hybrid plant.

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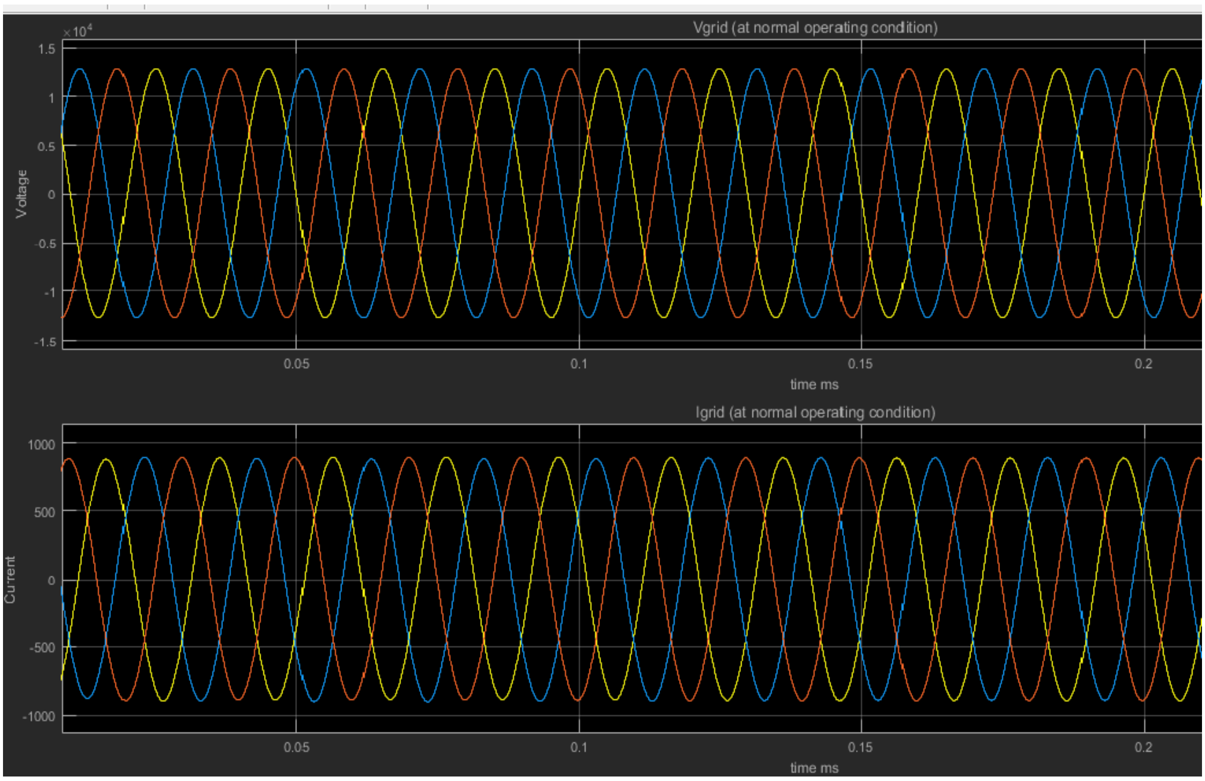

Figure 6 Three Phase Voltage and Current Waveforms

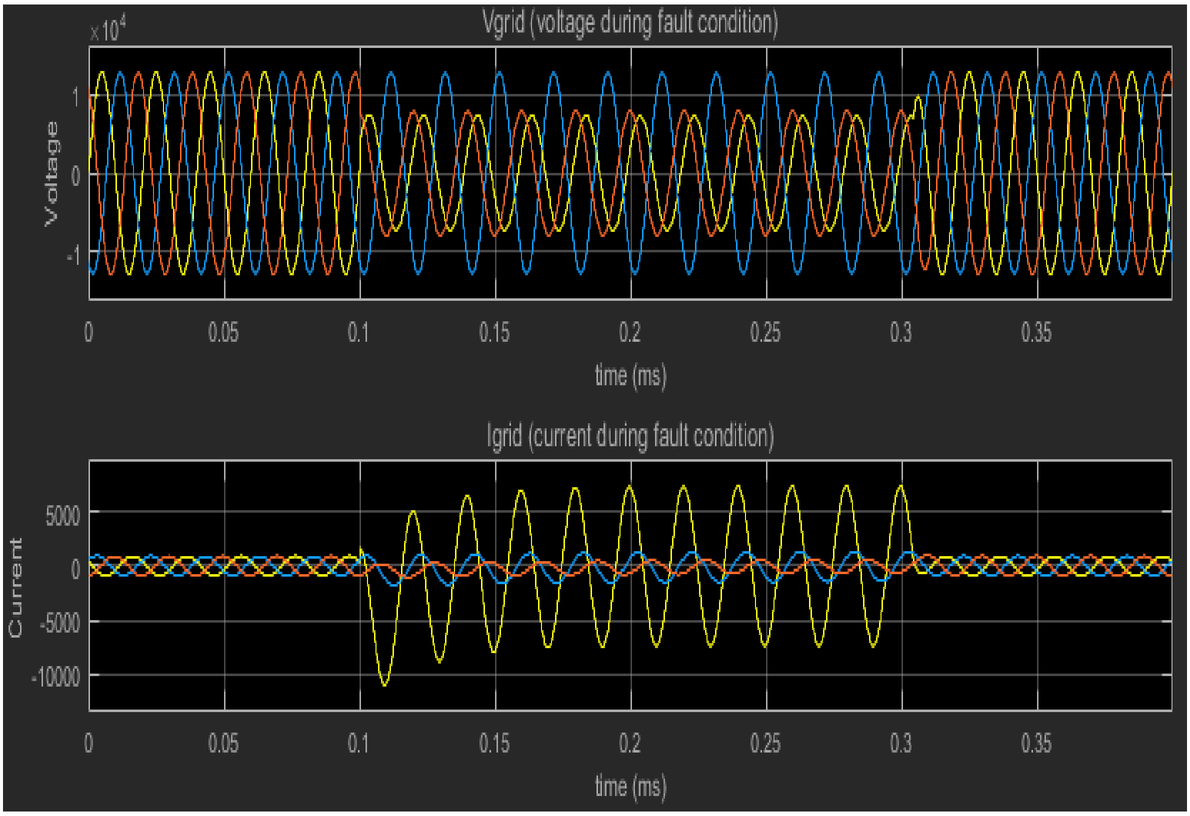

Figure 7 Voltage and Current Waveforms During Fault

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

Grid Voltage and Current	Not integrated with hybrid power plant	Integrated with hybrid power plant
Voltage at healthy condition	11.03 KV	11.31 KV
Current at healthy condition	601.1 A	589.2 A
Voltage at Faulty condition	6.952 KV	8.326 KV
Current at faulty condition	3789.68 A	3710.48 A

CONCLUSION

This paper indicates the effect of hybrid power 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 analysis verifies the improvement in system profile during symmetrical fault condition.

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