iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 Issue: VII Month of publication: July 2018

DOI: http://doi.org/10.22214/ijraset.2018.7047

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue VII, July 2018- Available at www.ijraset.com

Transient Analysis of Isolated Micro Grid using Droop Controller during Faults

Dr. V.S. Vakula[1], M.V. Rambabu[2], Mrs V.V. VijethaInti[3]
[1]*Assistant Professor & HOD, Department of EEE, UCEV, JNTUK, Vizianagaram, Andhra Pradesh, India*
[2]*PG Student, Department of EEE, UCEV, JNTUK, Vizianagaram, Andhra Pradesh, India*
[3]*Research Scholar, Department of EEE, JNTU Kakinada, Andhra Pradesh, India*

Abstract: Now a days the scenario is in the direction of renovating centralised power generation to distribution generation. Distribution generation is considered to be a supplementary source of power in addition to the centralized power generation. Micro resource and distributed generation through controllers, loads and storage space devices to create a micro grid(MG). The micro grid senses and switches to isle mode in case of interruption. For this purpose, P-F&Q-V Droop control method is adopted to observe its impact during transient stability period. The proposed work gives the impact of droop control technique and stability of DG based on inverter arrangement of micro grid. In this fast acting current limiter is also employed to reduce the short circuit current there by decreasing the heating effect of the transmission lines.
Keywords: DG (Distributed Generator), MG (Micro Grid), Transient frequency response, Droop characteristics, P-F control

I. INTRODUCTION

The performance of microgrid can be enhanced by providing the power electronic devices. Moreover, micro grids are the supplementary sources of electric power supply[1]. They can operate along with the grid i.e., grid tied mode or autonomous mode. The microgrid has to operate to satisfy the demand in case of any disruption [2] , with out any fluctuations in voltage and frequency of microgrid [3].

In real time, DG may be separated from the grid by intentionally or by accidentally. The main purpose of providing the DG is to deliver continuous power supply to the consumers[4] in any condition i.e., even during faults. Whenever fault arises on the DG, then it results either increase or decrease in voltage or current. If the DG consists of two or more sources, which supplies power to a common or separate load, the faults on such system may also results in the synchronization, which is due to the variations in voltage and frequency during the faults.

To reduce the variations in voltage and in frequency, a droop controller is provided. The droop controller is a fast-acting device which can sense the variations in voltage and frequency and reduce those variations. To limit the flow of high currents during the faults in the DG, a fast-acting current limiter has been used.

II. LITERATURE SURVEY

There are different research papers which provides information and control strategy on the transient stability in power system. For the improvement of transient stability different control strategies like master slave control strategy and droop control strategy in a micro grid are discussed [5] which comprises of diesel based generators and inverter based DG. Two control schemes are provided for the inverter based DG, they are real and reactive power control and current control method. Also the author concluded that the droop control technique is suitable for transient conditions and P-Q control technique is suitable for inverter based DG.

The author in [6]discusses a separate control technique as the mechanism of microgrid is different from that of traditional power grid. For that reason a new dynamic model is applied for transient stability studies in Microgrids. The differential algebraic equations composed to model the dynamic system. When a wind system is connected to the existing power grid, a new transient stability analysis method is needed [7].For the improvement of transient stability superconducting magnetic energy storage (SMES) based adaptive artificial neural network (ANN) is used. The operation of SMES is based on (i) sinusoidal pulse width modulation (PWM) (ii) voltage source converter (VSC) and (iii) an ANN controlled DC–DC converter using insulated gate bipolar transistors (IGBTs). Then a comparison is made for ANN with proportional integral (PI) based on SMES control which is enhanced by response surface methodology and genetic algorithm (RSM–GA) by the interpretation of both symmetrical and asymmetrical faults.

Another technique was introduced in [8], effectiveness of two different model of doubly fed induction generator (DFIG) wind turbine is compared i.e., DFIG with dynamic voltage restorer (DVR) and DFIG with Crowbar protection under different fault conditions. The reactive power production is more complex in the model of DFIG with cow bar protection. But the fault voltage is

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue VII, July 2018- Available at www.ijraset.com

compensated in the model of DFIG with DVR so that the DFIG wind turbine can deliver uninterruptable power supply as per the load demand without the necessity of any additional protection.

A battery energy storage system controller (BESS) based microgrid performance during fault conditions is discussed [9]. Where as BESS has restriction for the sustainable operation that is the relic energy of BESS must be zero. The microgrid under different conditions such as island operation, emergency control function is discussed [10].A new control procedure for microgrid operation in LV distribution networks is discussed [11]. Modelling of controllable loads which is in desperate need of load shedding is discussed [12]. When *n* number of inverter based DGs are connected in parallel to a microgrid system, there may arise problem in standalone operation [13] i.e., less inertia which leads to either supply or consume energy during transient period. To resolve this problem, the author in [14], [15] theoretically studied the small signal stability through Eigen value analysis.

III. CONTROL STRATEGY

When more micro sources are connected, the reliability and the stability of the system is achieved by the voltage regulation of the system. Thus, the voltage regulation provides to damp the oscillations in reactive power and voltage [16]. When multiple micro sources are interconnected in a complex power system, the power sharing between those micro sources is made proper with droop control. Droop control also helps the system in smooth disconnection and reconnection to the power system [17].

In the present work, the droop control is provided to control real power with the control frequency and reactive power with the control of voltage[18],[19].The frequency and the voltage regulation can be done by the modification of real and reactive power of the respective system. the block diagram of droop control is as shown in figure 1.

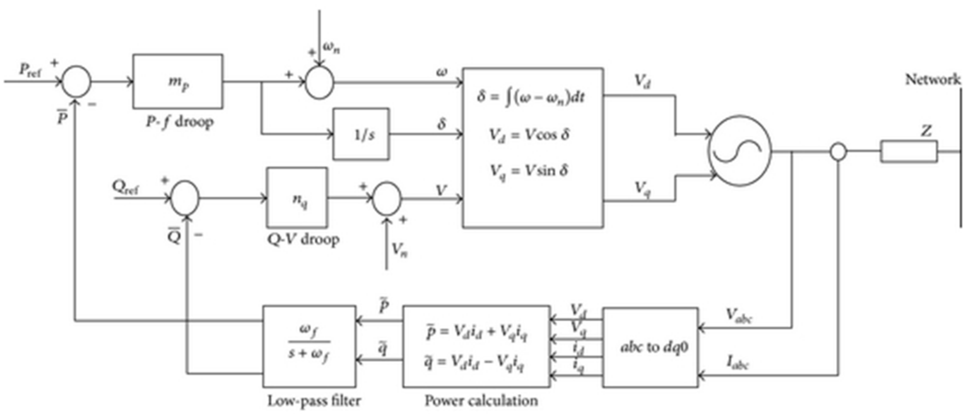

Fig1: Droop control block diagram.

The voltage of the system can be regulated by regulating the real and reactive power of the respective system. This is the basic of droop control.

For a transmission line, the equation for real and reactive power are given by,

$P = \frac{V_1 V_2}{X}\mathrm{Sin}\delta$ (1)

$Q = \frac{V_1^2}{X} - \frac{V_1 V_2}{X}\mathrm{Cos}\delta$ (2)

For a transmission line, the resistance, R, is neglected as it is much lower than the inductance, L. Also we know that, in a transmission line, the power angle is also less.

$\delta = \frac{XP}{V_1 V_2}$(3)

$V_1 - V_2 \cong \frac{XQ}{V_1}$(4)

Therefore, from the equations above, it is obvious that power angle, can control by controlling the real power, P. The voltage of the system can be controlled by controlling the reactive power, Q of the system. The frequency control in turn is the controlling of power angle, which controls the real power flow of the system. Hence, the voltage and the frequency of the system are regulated by controlling the reactive and real power of the system [20]. Then the equations that represent this is given by,

$f - f_0 = k_p (P - P_0)$ (5)

$V - V_0 = K_q(Q - Q_0)$(6)

The above equations gives the relation between real power-frequency and reactive power-voltage. This can also be represent as,

$f = f_o + K_P(P - P_O)$ (7)

$V = V_0 + K_q(Q - Q_0)$ (8)

Where,

f, V =The frequency and Voltage at a new operating point.

P,Q = Active and reactive power at a new operating point.

V_0, f_0 = Base voltage and frequency.

P_0, Q_0 = Temporary set points for the real and reactive power.

k_p, K_q = Droop constant

IV. STABILITY OF MICROGRID

Stability of the system is considered to be the most important factor in recent studies. It is because of the fact that, the stability of the system improves the consistency of the system during the occurrence of the faults. The best way to analyse the stability of the system is by exposing the system to severe faults. There are different types of stability issues in the system [21], but this work majorly considers transient stability. The transient effects depending upon the conditions like [22], (i) conditions of system before islanding and (ii) conditions which cause the islanding. In any case, the microgrid needs to be working, so that it needs to enhance the dynamic response of the system [23].

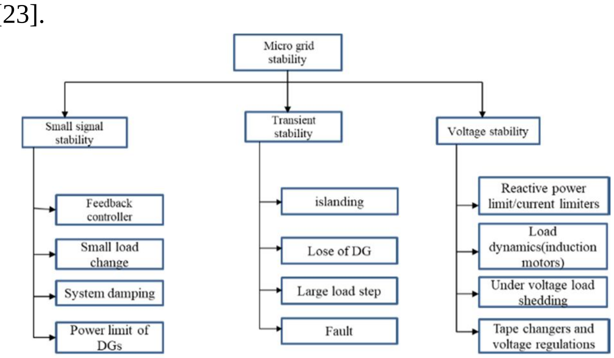

Fig 2:Different stability issues in microgrid.

A. *Transient stability*

The microgrid has the ability to supply load even during the conditions of large disturbances. Due to faults in transmission line and switching large loads there is a chance of occurrence of large disturbances in the power system [24]. These disturbances may lead to the synchronisation loss of the system which will affect the stability of the system. This type of stability issue is called transient stability [25]. During the disturbances, to continue its operation without negatively affecting the stability of the system, microgrid changes its operation from the grid tied mode to the island mode. The type of microgrid, the micro sources used and the adapted control strategy are the main parameters of stability issues [26]. The micro sources are connected along with power electronic devices. Hence the control method used for the power electronic devices controls the stability of the system.

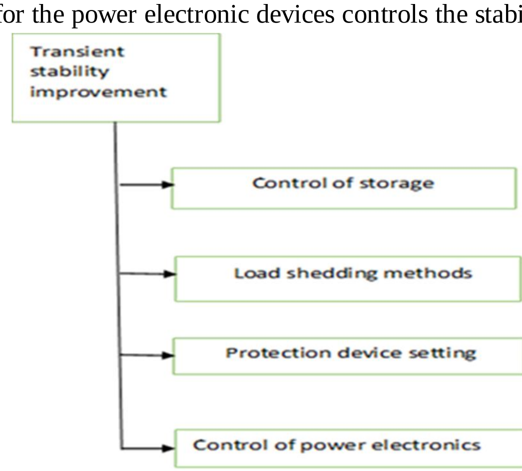

Fig 3:Different transient stability improvement methods.

V. SIMULATION MODEL

The microgrid under study is proposed with two sources having a DC source for input and also the PF and the QV droop control strategies are provided for each source. During starting, RL type of load is connected. A nonlinear load is also connected to obtain the performance difference of microgrid with the linear and the nonlinear loads. The provided induction motor will be switched at 0.75 sec and switched off at 2.5 sec. Then the activity of microgrid with RL load during the occurrence of fault is analysed. To analyse the system, different types of faults are incorporated into the system from 1 to 1.5 secs. The microgrid system is designed and simulated in Matlab/Simulink environment.

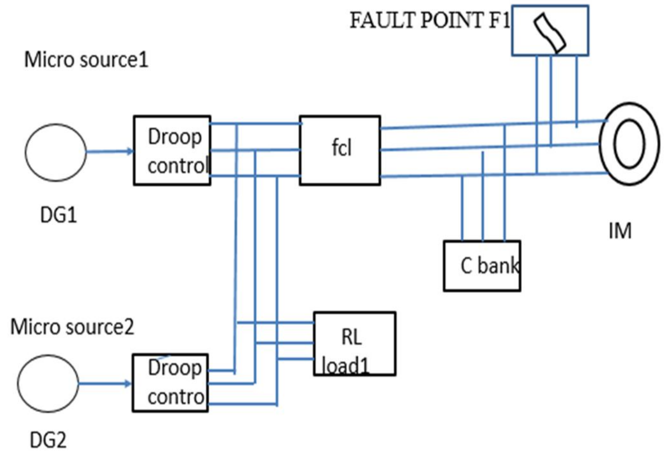

Fig 4:Single line layout of the utility and microgrid.

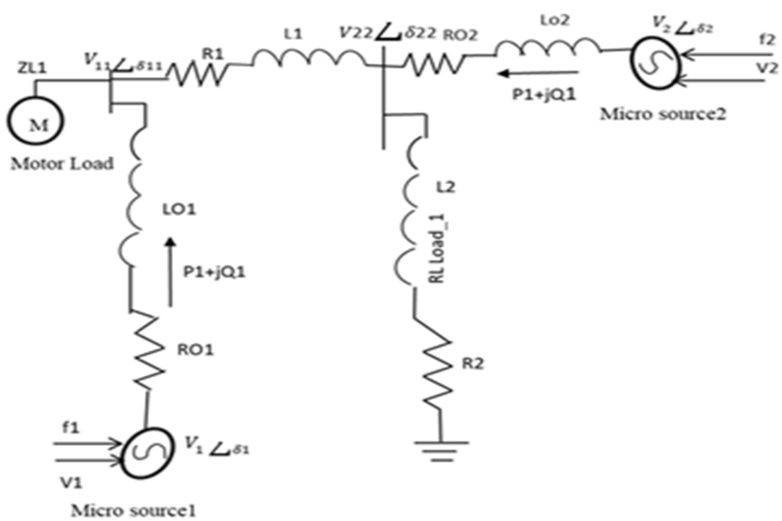

Fig 5: Equivalent model of the microgrid systems.

The autonomous microgrid system is developed and analysed when subjected to different types of faults in the Matlab Simulink. The system is analysed with the parameters like fault current, fault voltage, real and reactive power. To limit the fault current the FCL was employed. The comparative analysis of parameters are presented with and without FCL.

VI. SIMULATION RESULTS

A. LLLG faults

The LLLG fault occurs at the fault position F1 on the load side for a period of 1 sec to 1.5 sec. and the IM load is connected at 0.75 sec, so the IM load starts instantly when voltage is 440v and stops when the fault occurs at 1 sec then the voltage reaches to zero in the fault period. Figures below shows that the fault current was measured as 2000A and it is reduced to 1000A when FCL as implemented. The droop control strategies are implemented to keep active power and reactive power within the limits during the fault period. The behaviour of all the parameters are presented below.

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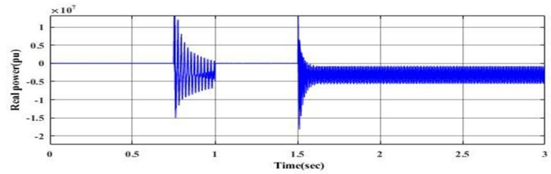

Fig 6: Real power during LLLG fault

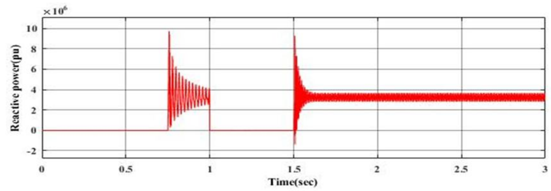

Fig 7: Reactive power during LLLG fault

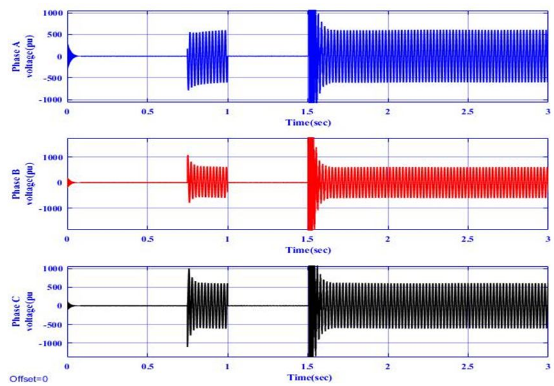

Fig 8: Fault voltage during LLLG fault

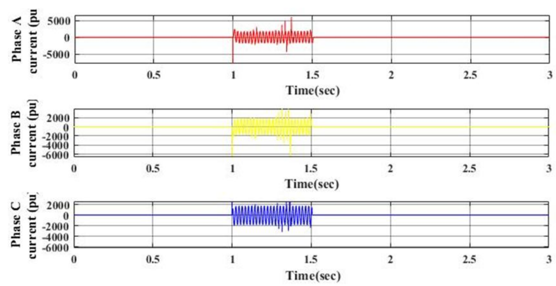

Fig 9: Fault current during LLLG fault

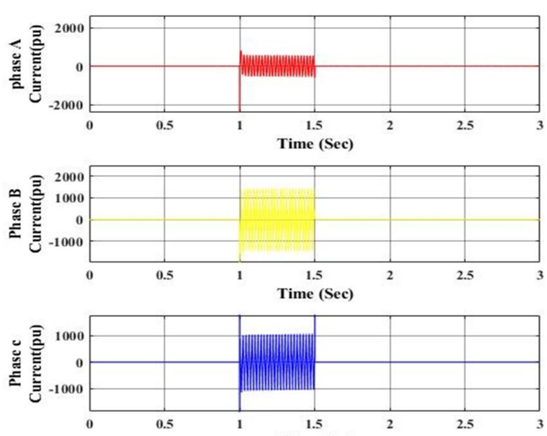

Fig 10:Fault current during LLLG fault with FCL

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B. LLG fault

The ground fault occurs on phase A and phase B to in the fault period from 1 sec to 1.5 sec. From below plots we concluded that fault effected the phase A and phase B but not phase C. and the fault current in A and B phases are very high and which is adjusted to certain level by the FCL. And the active and reactive power are plotted blow shows that more power was dawned in the fault period. At 1.5 sec IM load connects to supply of 440v when circuit breaker connects.

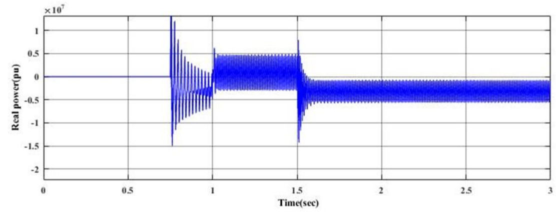

Fig 11: Real power during LLG fault

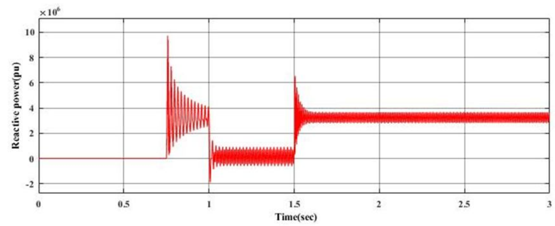

Fig 12:Reactive power during LLG fault

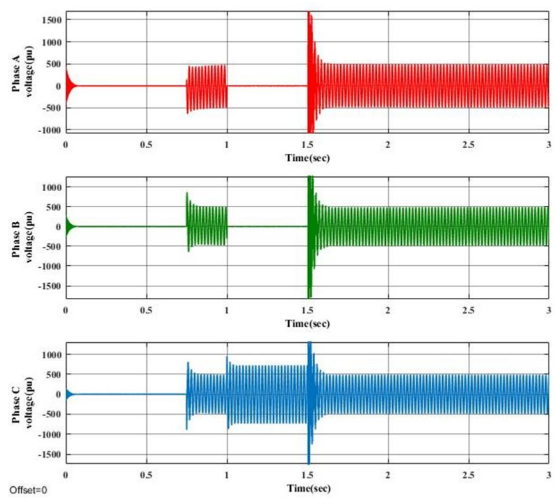

Fig 13: Fault voltage during LLG fault

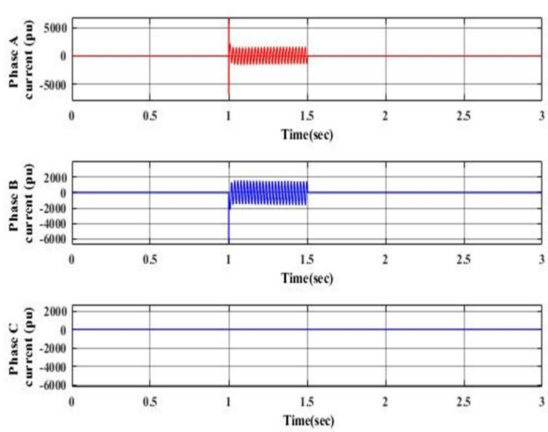

Fig 14: Fault current during LLG fault

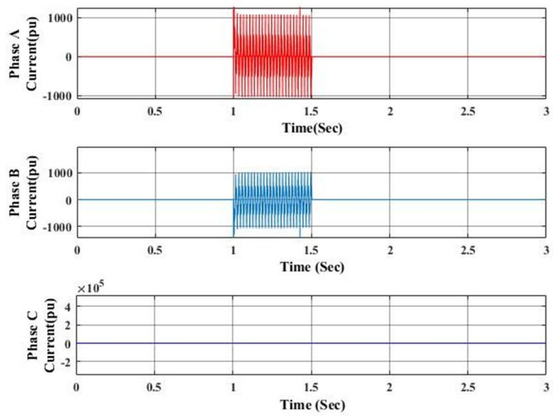

Fig 15: fault current during LLG fault with FCL

C. LL fault

The line to line faults occurs on phase A and phase B. the below figure illustrated that the real and reactive power was swelled in the fault period. And the fault current in phase A and phase B was shoots to maximum value i.e. 2000A and shouted value was decreased to 1000A by FCL showed in figures below. And the active power is swelled to high value in this line to line fault. Voltage is swelled in the period of fault in the phase C and zero in phase A and phase B. IM load stats after the 1.5 sec and stopped in the fault period.

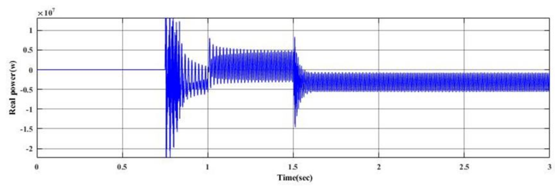

Fig 16: Real power during LL fault

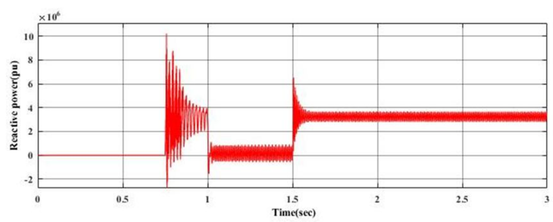

Fig 17: Reactive power during LL fault

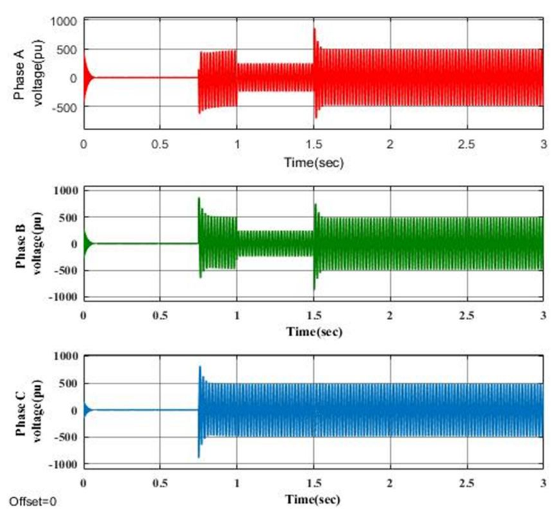

Fig 18: Fault voltage during LL fault

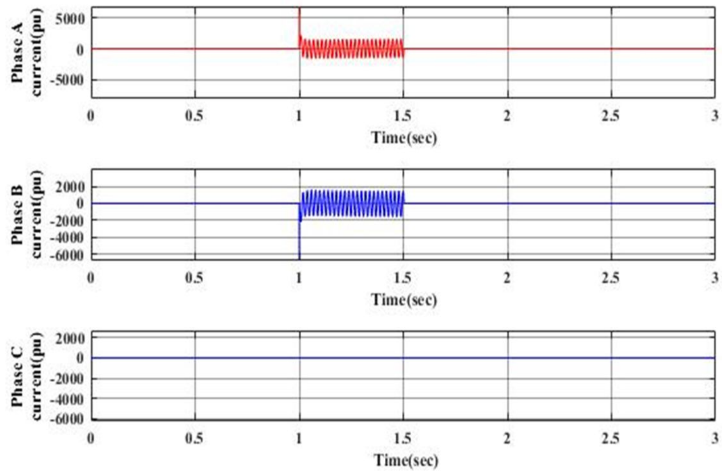

Fig 19: Fault current during LL fault

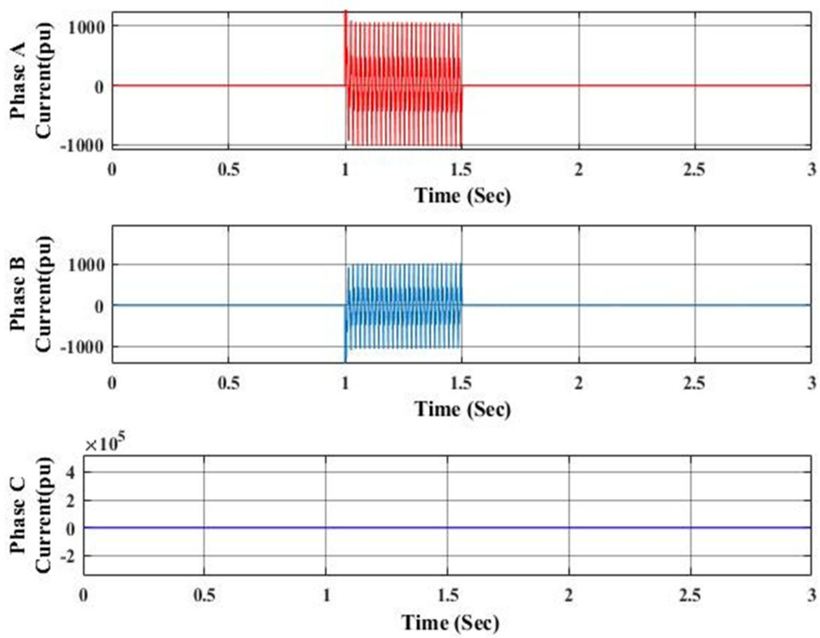

Fig 20: Fault current during LL fault with FCL

D. LG fault

The IM load starts running from 0.75sec but stops in the fault period and again starts running from 1.5 sec when fault was cleared. The voltage in the fault period is zero in the phase A and the Fault current shoots to maximum value. And that high current value is limited to small value by FCL. The nature of real and reactive power behaviour is illustrated in the Fig 21 and Fig 22.

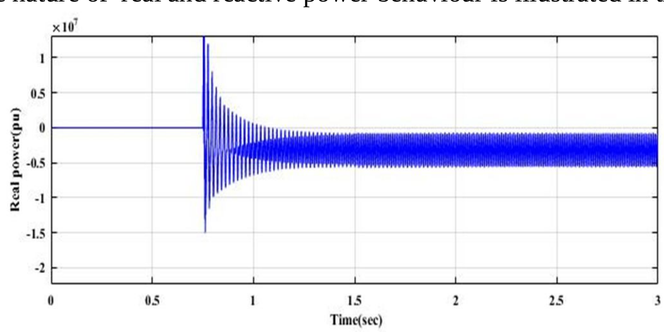

Fig 21: Real power during L-G fault

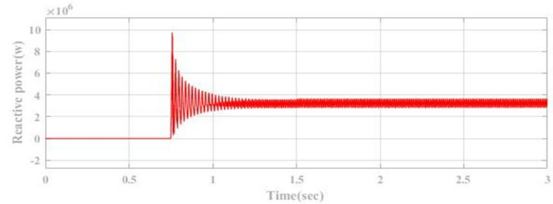

Fig 22: Reactive power during L-G fault

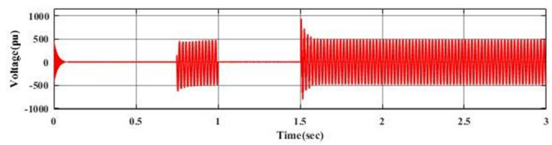

Fig 23: Fault voltage during L-G fault

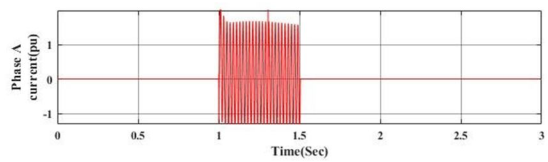

Fig 24: Fault current during L-G fault

VII. CONCLUSION

This paper presents the behaviour of the microgrid when subjected to different faults like asymmetrical and symmetrical faults. To improve the performance of the system during the fault conditions, a droop control technique is used. Here, P-F and Q-V droop control techniques are used to improve the transient stability of the concerned system during the fault conditions. The results obtained from the matlab simulation reveals the behaviour of the system when subjected to various faults when connected to the induction motor and RL loads. The results thus confirmed the droop control can improve the transient stability of the system.The fault current limiter (FCL) is used to limit the fault current flowing in the system.

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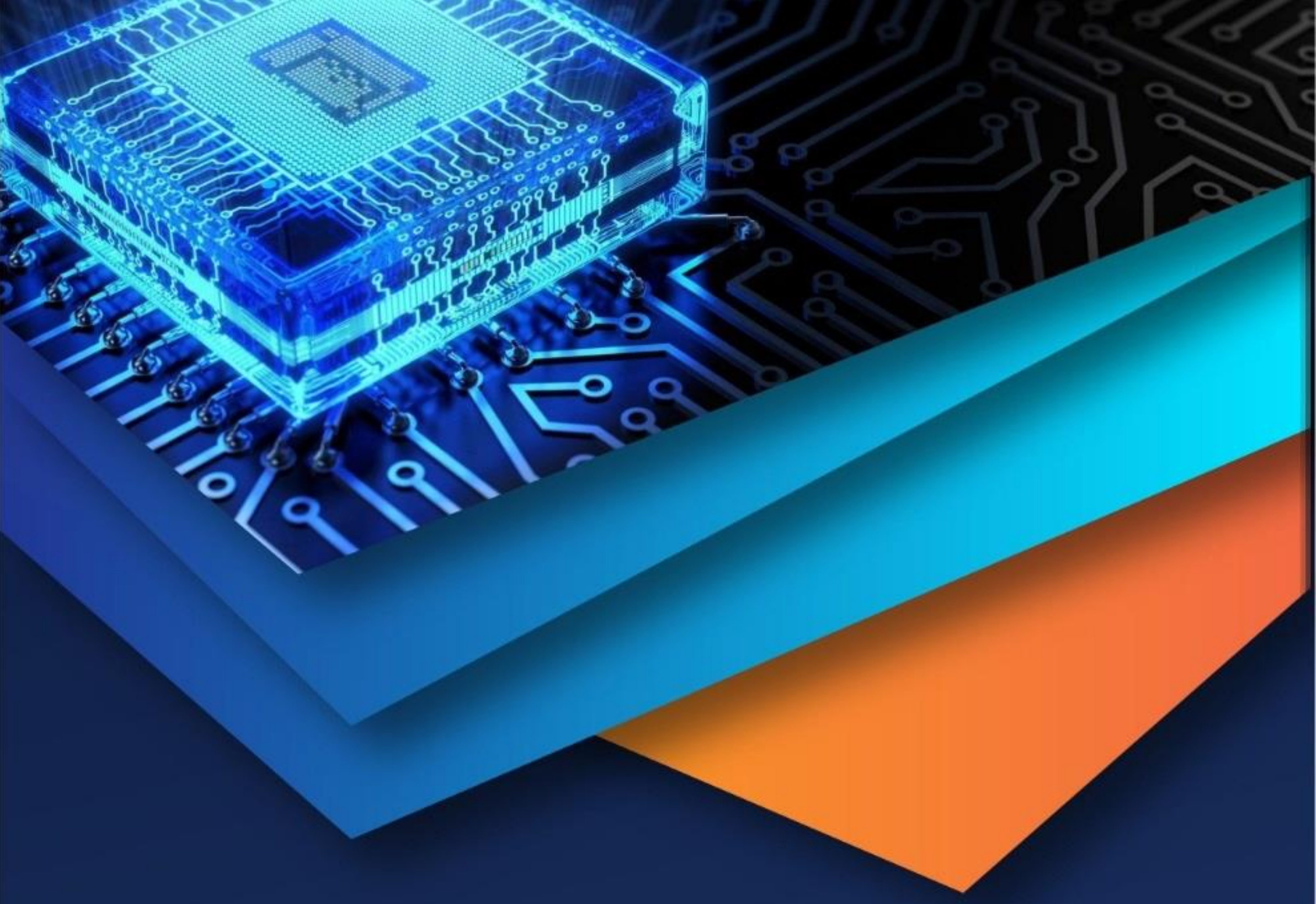

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