Design, Issues and Protection of Microgrid

Manjushree Patil
Dept. of Electrical and Electronics
PES University
Bangalore, India

Mrs.Sangeeta Modi
Associate Prof,
Dept. of Electrical and Electronics
PES University
Bangalore, India

***Abstract*— This paper demonstrates the Design, Modelling and Simulation of the Micro grid as contemporary project where it delivers the power based on load requirement. For different type of loads the paper reflects the usage of the renewable energy resources taken into consideration. Here various energy delivering and storage criteria for Micro grid has been designed with the aspect of continuously sourcing the power during any circumstances. Photovoltaics which has less efficiency is boosted with MPPT Technique and Battery Energy Storage System which is designed with Bidirectional DC-DC Converter for controlling the charging and discharging based on load plays a vital role in the integration with the Utility grid. The power to intermediate levels is being supplied taking into the concern of power quality issues and suitable protection scheme is adopted to clear the Faults that is occurring within the system. For Fault clearance the algorithm for tripping action of circuit breaker is developed and Fault impedance is being calculated on analyses of scope results.**

Keywords—Microgrid,PVArray,Utilitygrid,Bidirectional DC- DC Converter,Bidirectional DC-AC Converter,Battery Energy Stoarge System(BESS),Circuit Breaker.

I. INTRODUCTION

Microgrid is the trade of Electricity generation where it acts in isolated mode or islanded mode thus maintaining the same voltage level as that of the Utility Grid at the Point of Common Coupling(PCC). Microgrids [1] are built with miscellaneous energy delivering systems to forecast the users need by maintaining efficient growing technology, stability, reliability, it avoids the power congestion, reduction in the usage of fuel, less losses and carbon print in the environment. At Generation Unit it acts as an Emergency source in the autonomous site.

The working principle of Micro grid is the trends in mere future in various location of rural areas where the chaos of regular power cuts or Grid failure is taking place at every intervals, Hence dealing with the real time burdensome activities an suitable buzzing technology with the availability of abundance of resources in the nature is implemented to enhance the performance of the energy sources So Micro grid is a scheme adopted worldwide to enhance the energy policy and deliver the power to load without any hindrance ,where the issues of power quality[2] and continuous demand flow with the protection scheme[17] is been met.

To fulfil the utilization of Industrial and commercial needs the usage of renewable energy source should be increased as the conventional energy sources are depleting day-by-day. Hence the only way to use the renewable sources is by microgrid project which is has less critical infrastructure.

II. PREVIOUS WORK

The design of PV Array with MPPT Technique [10] has come up with the model of SEPIC Converter where it has significant losses linked to additional inductor and capacitor used in the converter topology and these losses arise mainly from the power dissipation in the (parasitic) series resistances values associated with this extra inductor and capacitor and the improvisation from the interleaved boost converter [11] is implemented in this paper to increase the efficiency of output voltage, less ripple in output current and faster response to variations in irradiation is taken care. BESS [14] [15] here the concept of overcharging may lead to reduce the factor of battery life and temperature variations affect the efficiency of the system, thus the concept of BESS with the Controller for Bidirectional DC-DC Converter [16] is been picturized in this paper by integrating the system to DC, AC grid or to use the power to dissipate to DC loads. The Fault and protection schemes [17] explains the sense of working on various types based on location and type of fault by using current sensors which are not accurate in acquisition of Fault action, the typical solution to overcome Fault [18] evolves on the Low Voltage DC System which is practically not acceptable in High Voltage Distribution Transmission lines, Further to uplift this proposal [19] evaluating with Digital Relays to eradicate the Fault leads to complex analysis and slower response So in this paper framework focus on Voltage Level, Fault Impedance Calculation, Direction of current flow and ease of clearance of Fault [21] at respective fault action is highlighted.

III. SYSTEM DESCRIPTION

The Micro grid system consists of various naturally availing resources that helps in venture of delivering power to the load using the power electronics techniques.

Here no Transmission lines or Underground Cables are used which further avoids the critical infrastructure and losses in the system.

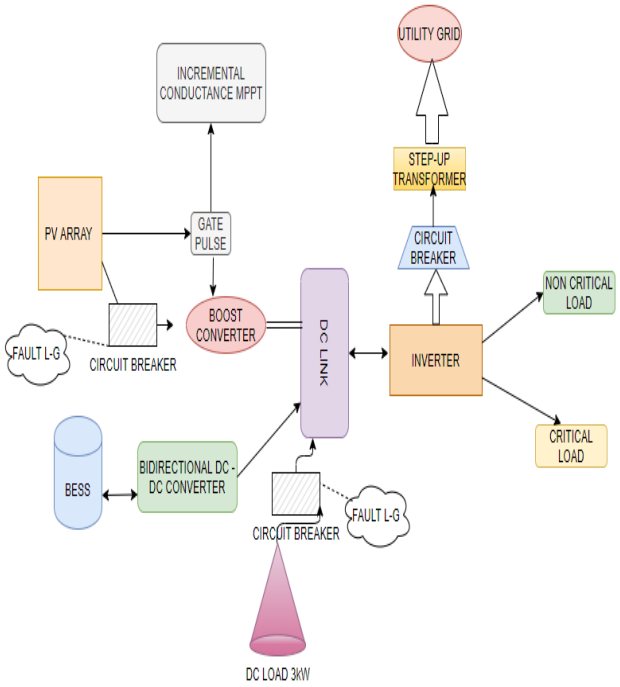

Figure 1. Schematic block of Micro grid

As indicated in the Fig1. Using DC-DC Converter the output voltage from the PV array is being boosted with control of switching action from Incremental Conductance MPPT and BESS is used to charge and discharge according to the load requirements during day-night transition using Bidirectional DC-DC Converter with Controlling source, Suitable ratings of DC loads are considered which is been interlinked to DC Bus and Bidirectional DC-AC Converter is used to integrate with the Utility Grid with the help of Step-up transformer 350V /25kV. To ample with the Different kinds of load dealt practically, Critical and Non Critical load concept is inherited, as the view of protection schemes to be implemented faults is being analyzed at the two sites one is at the PV array and other one at the DC load side where Line – Ground fault is created and Circuit breaker is being used with the controllable time for tripping action.

IV. SYSTEM MODELLING

A. *MODELLING AND SIMULATION OF INCREMENTAL CONDUCATNCE APPROACH USING BOOST CONVERTER FOR PV ARRAY.*

The efficiency of a solar PV Array is 22.8%. In order to increase the efficiency. This is a technique used to obtain the maximum possible power from a variable source with respect to weather transition. In photovoltaic system the I-V [9] curve is non-linear, hence it is difficult to serve the power to a load. This is done by utilizing a boost converter whose duty cycle is adjusted by using a MPPT algorithm

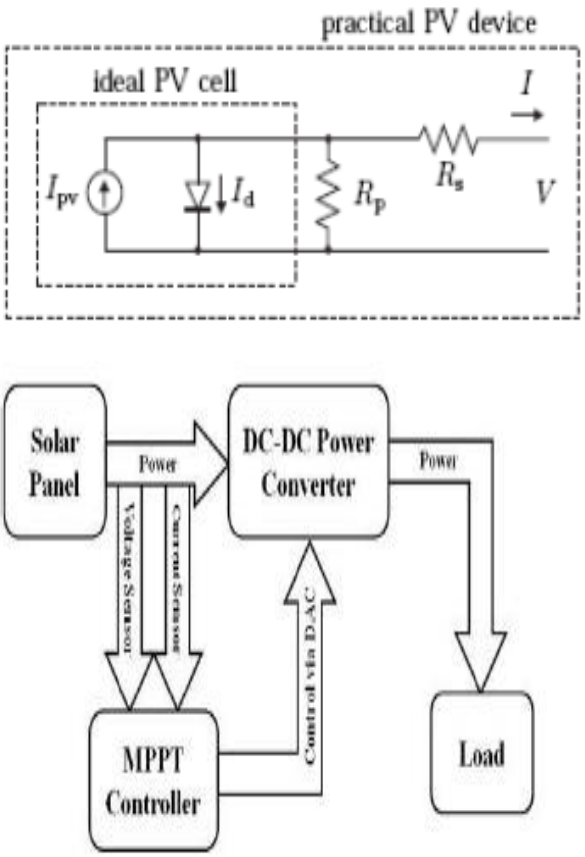

Figure 2. Circuit diagram of PV cell and the Schematic diagram of MPPT architecture.

The flowchart of Incremental conductance [22] best describes the rate of control of Duty cycle for the switch in boost converter.

This method helps in sensing the change of irradiation conditions

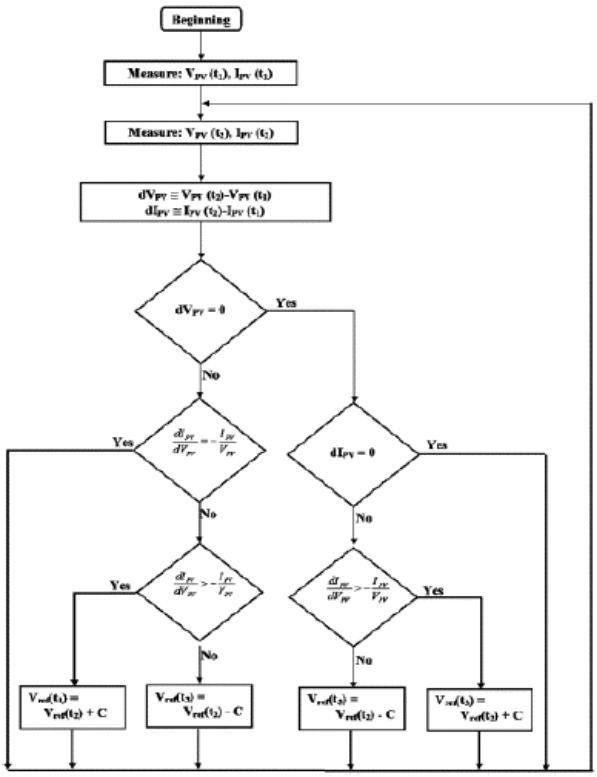

Figure 3. Flowchart of Inc. Cond for Maximum output

Boost converter is modeled to enhance the output of PV, it has sequence of control from switching frequency, duty cycle, suitable value of Inductor and Capacitor. From PV Panel 50*10 Cells with Ratings of Solotech 1STH implemented.

Table 1. Values of elements in Boost Converter

Duty cycle	0.5
Inductor	6000uH
Capacitor	9500uF

Solar panel taken into consideration in the project has following ratings;
Solotech 1STH-215-P per cell;
Maximum Power – 213.15W
Open circuit voltage – 36.3V
Short circuit current – 7.84
Maximum Voltage – 29
Maximum Current– 7.35
Duty Cycle – 0.5
Switching frequency – 10 kHz

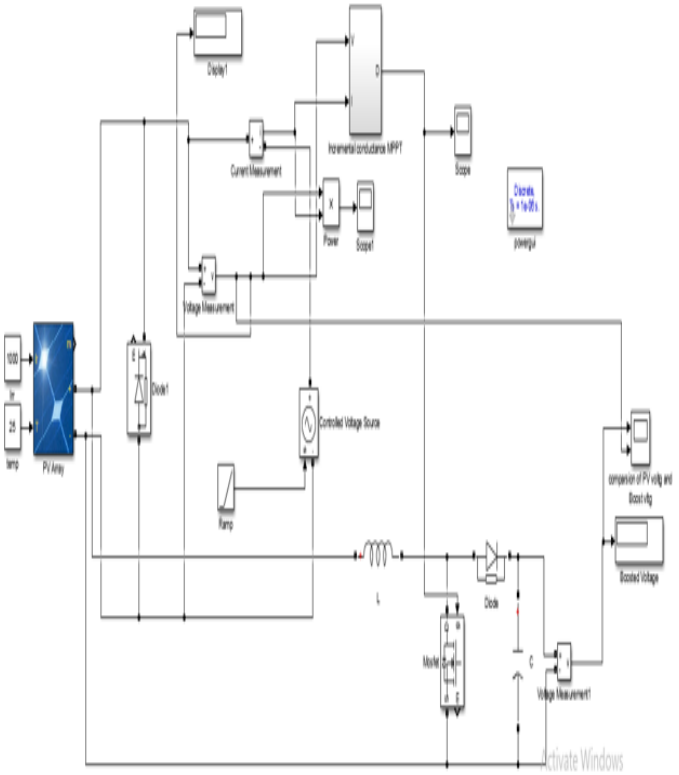

Figure 4. Modelling of PV array with MPPT in MATLAB.

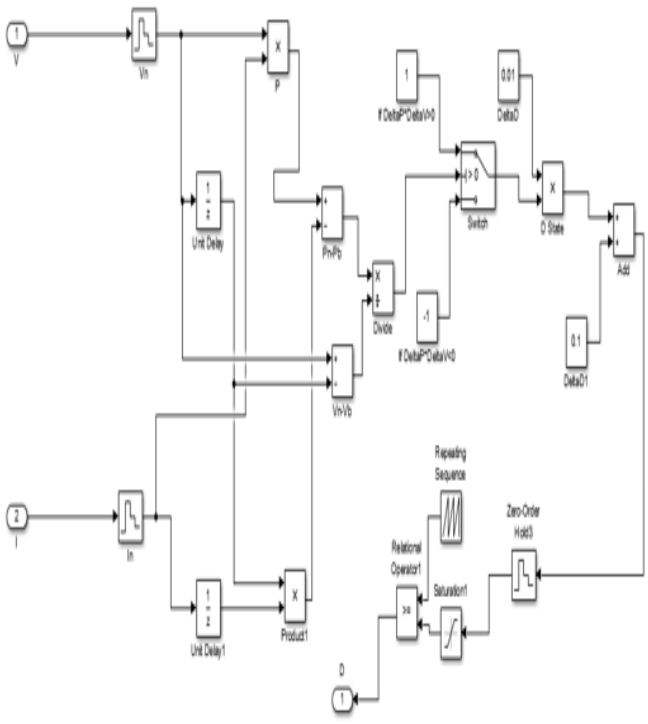

Figure 5. Modelling of Incremental conductance in MATLAB

Incremental Conductance is the optimal way of achieving higher efficiency in MPPT Techniques. Here the algorithm tracks down the maximum power and results the corresponding output voltage. The method to control the switching action is also analyzed here, thus this technique requires many sensors [22] to have the impact of varying

weather conditions which is complex in nature but it results in more accurate value.

B. *MODELLING AND SIMULATION OF BATTERY ENERGY STORAGE SYSTEM (BESS) WITH BIDIRECTIONAL CONVERTER*

Battery energy storage system is a promising technology and most suitable with most of the renewable sources like solar and wind energy. To overlook on integration with the Utility grid, these paper layouts a bidirectional converter which is connected to DC bus link of 350V [6].

The bidirectional converter is capable of charging and discharging the battery reliably [16]. Charging and discharging is based on the state of charge of the battery (SOC) and direction of the current with the Controller which prevents the reverse current flow and to maintain the power balance within the system [16]

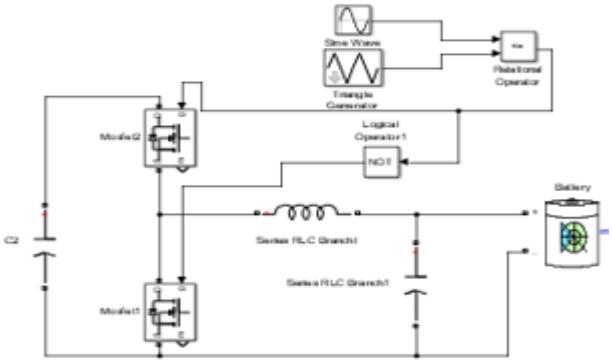

Figure 6. Modelling of BESS in MATLAB

To reduce the current ripple and stress, capacitor and inductor based on Battery specification is designed as C=10uF and L=5mH (by design as followed for boost converter so the same for buck mode is been utilized) and C2=1000uF to merge with DC link.

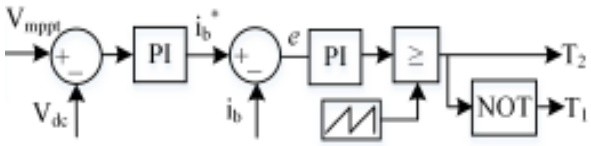

Figure 7. PI Controller design to control duty cycle of BESS

Here in the above figure T2=S2 and T1=S1

The algorithm of Micro grid power flow [15]

- Case 1: if solar PV Array Power > power of load

Charging to the battery, converter operated in buck mode

- Case 2: if solar power < load power

Discharging from battery, converter operated in boost mode

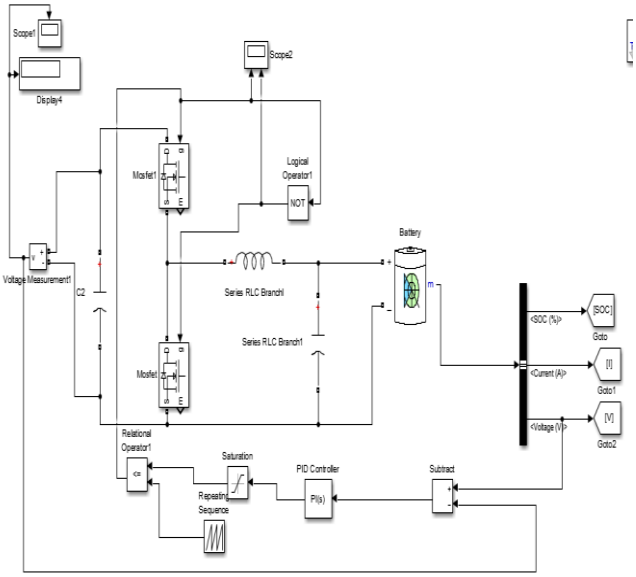

Figure 8. The design of Battery energy storage system with Bidirectional DC-DC Converter

The above figure details the BESS with Bidirectional DC-DC Converter with PI Controller to maintain the constant voltage and current without any distortion while charging or discharging to the load.

C. *MODELLING AND SIMULATION OF BI-DIRECTIONAL CONVERTER WITH UTILITY GRID SIDE*

An inverter is a system that converts DC to AC. these inverters are widely used for both domestic and industrial applications based on power usage such as AC motor drives.

With the consideration of practical household needs the daily basis requirement is forecasted in the project with sorts of loads.

Here Critical load is considered as Induction motor [20] with Squirrel type rotor and nominal power of 3kW Voltage(L-L) is 100 V, Frequency of 50Hz, Stator resistance and inductance of 0.02013 and 0.02919, Rotor resistance and inductance of 0.02067 and 0.02919

Mutual inductance is Lm is 15 pu, inertia constant 0.1, friction factor001569, pole pairs 2.

And Non critical load is 350 V(rms) and Nominal Frequency 50 Hz and Active power 2kW

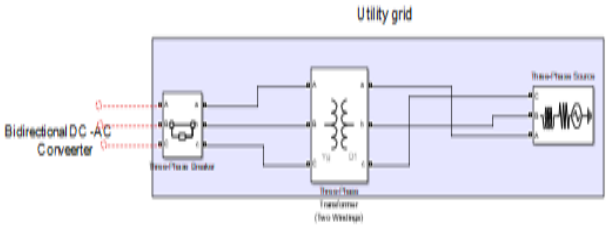

Figure 9. Block Diagram of AC Micro Grid Feeder

The Extra power from DC Micro grid is supplied to Utility Grid [5] with the breaker to avoid from interruptions caused by faults and the voltage from Inverter is approximately 320 V which is step up to 25 kV with a Three phase (Star – Delta) connected transformer.

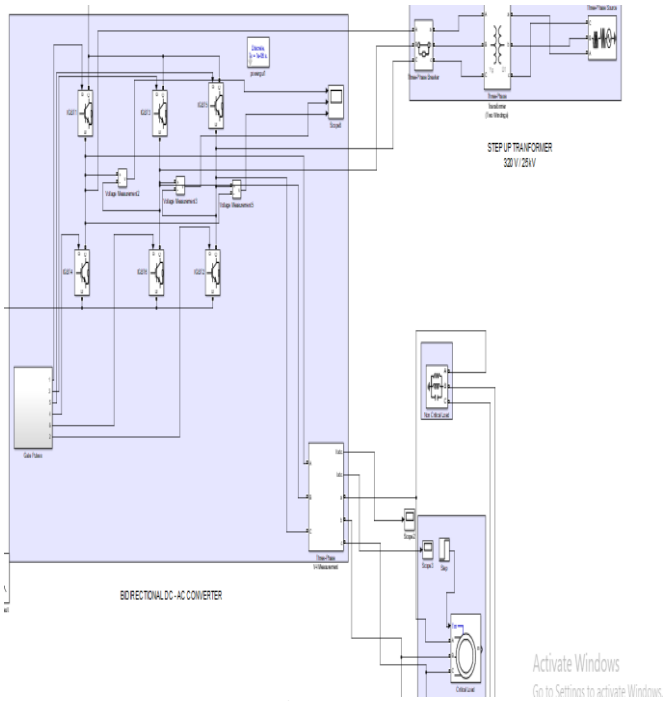

Figure 10. Modelling of AC Microgrid in MATLAB

The figure10. explains Modelling of the AC Micro grid where the Inverter converts DC to AC and this power is delivered to load and extra power is fed to Utility grid with the help of suitable rating transformer.

D. MODELLING AND SIMULATION OF FAULTS IN DC MICROGRID

Every system in real time as to have the protection schemes in all the phase of time to get rid of the natural circumstances occurring in day to day life. Thus Faults has to be every well studied and analyzed to protect the devices.

To have the consideration of the various type of faults occurring in dc system such as Line to Line fault and Single Line to ground fault [18]

Line-Line Fault; In transmission systems a line fault occurs when there is contact between two lines and are shorted. In underground cables this type of fault is created because of lack of insulation failure. This is most harmful fault for the system than single line to ground fault.

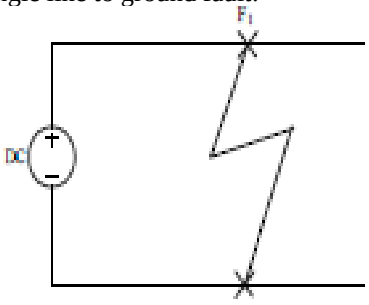

Figure 11. L-L Fault

Single line to ground Fault; Due to Heavy rains, cyclones etc. one of the conductor in Transmission lines break and fall This causes the line to ground fault. This fault reduces the reliability and continuity of supply. This is most common type of fault.

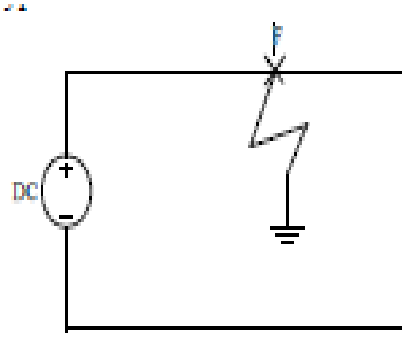

Figure 12. L-G Fault

When Fault occurs on DC side, DC circuit breaker operate and completely de-energies the DC Link from AC system.

In this paper the Line to ground Fault at PV Array and on DC load(3kW) is considered and the fault impedance is being calculated from Fault Current(If) (The Simulation Scope)

The L-G fault and Circuit breaker tripping is programmed in matlab editor

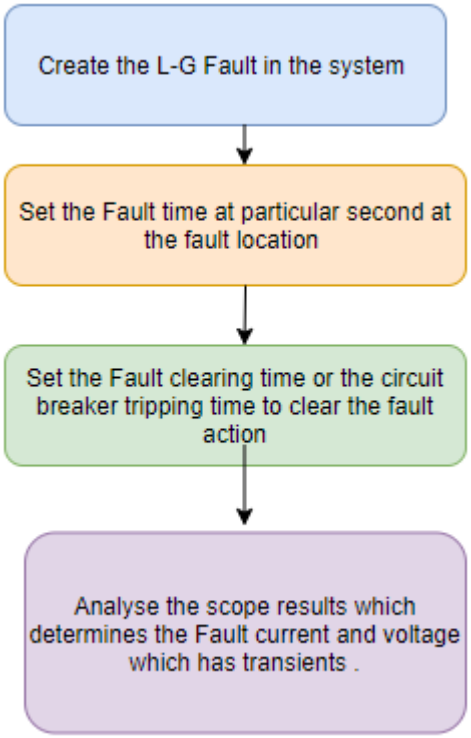

Figure 13. Flowchart of the Fault Analysis.

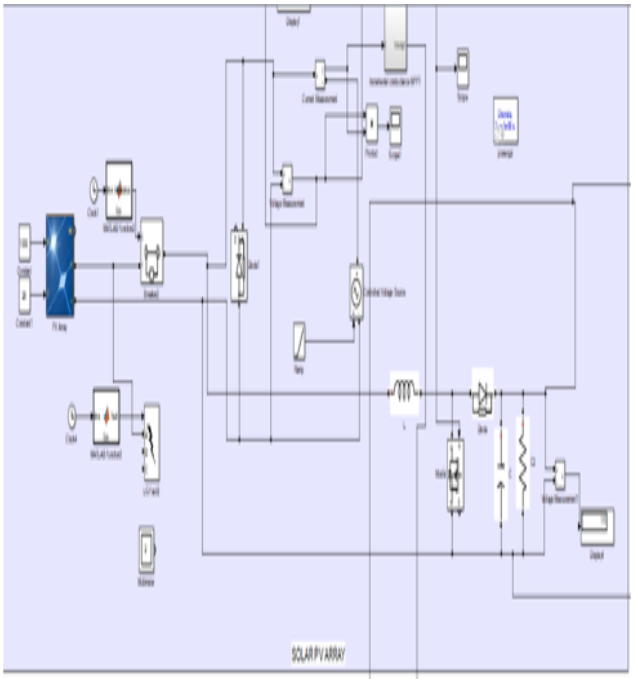

Figure 14. Simulation model of Fault at PV Array

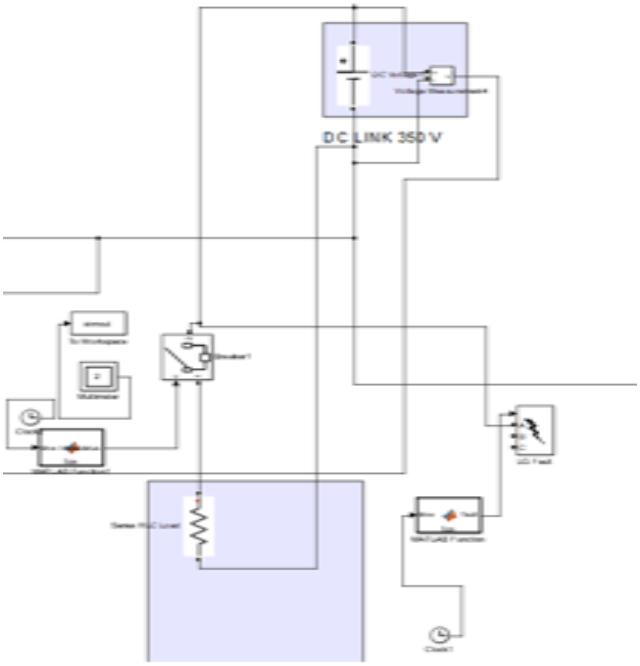

Figure 15. Simulation model of Fault at PV Array

V. DISCUSSIONS AND RESULT ANALYSIS

The simulation block of Micro grid is being analysed and required phase of results are obtained using PV Array, BESS and feeder Inverter and step-up transformer.

Even the prior challenge of Fault and protection scheme is being implemented in different technique without the usage of any kind of relays.

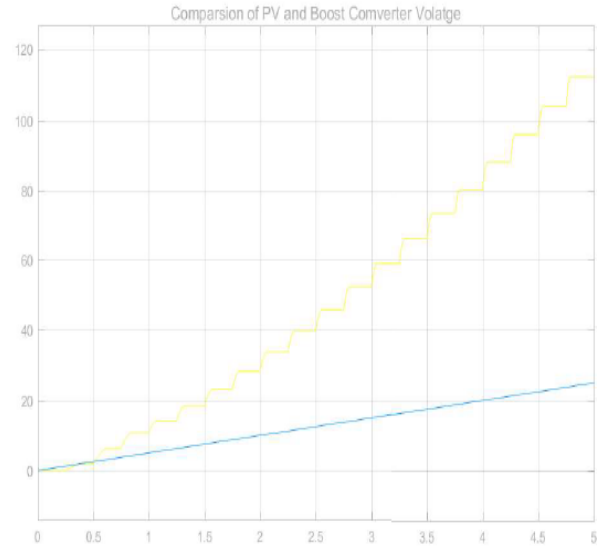

Figure 16. Comparison of output with and without Boost converter in simulation.

The fig16. depicts that the Simulation was done for a 1000 W/m^2 and temperature for 27 ºC and t=5s and The graph of Boost Voltage of 112.4 V and PV voltage of 25V is shown. [22] [19].

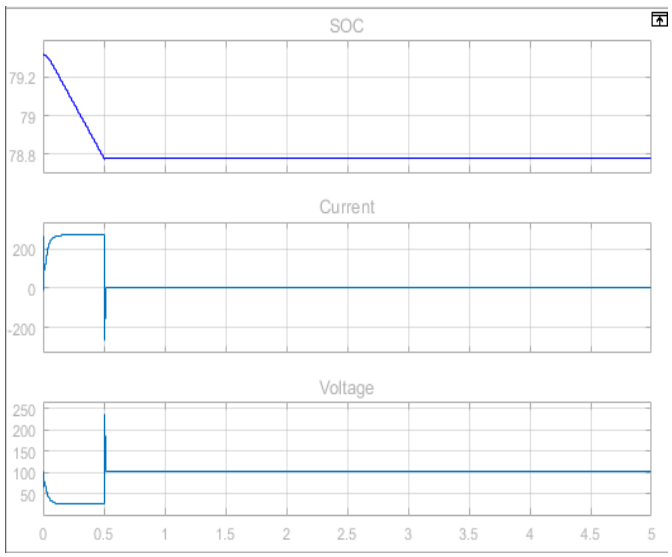

Figure 17. Scope results of the SOC, output Current and Voltage

The figure17. depicts the Simulation was done for a Battery voltage of 96V, Capacity of 10Ah, SOC 80% and due to the controller design the Charging and discharging takes places based on the load requirement and hence the SOC is adjusted finally [15]

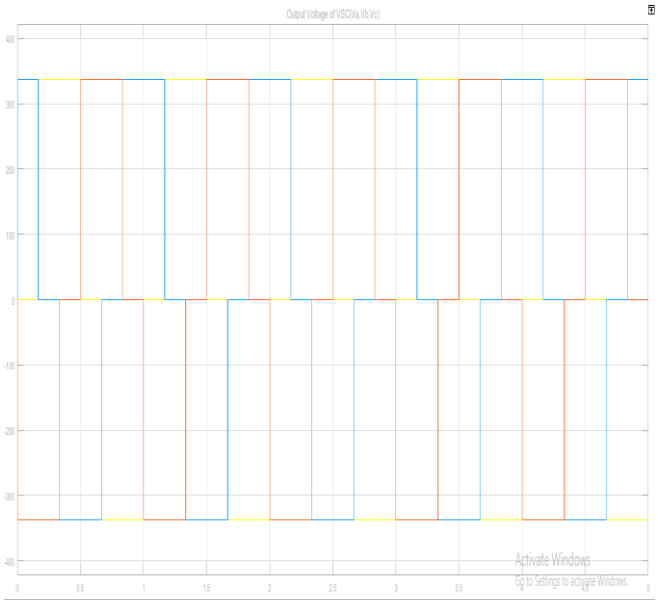

Fig 18. Three phase inverter Voltage levels

The figure 18. depicts the simulation of the Three phase inverter which is connected to the DC Bus 350 V and the plot of each phase of Voltage is depicted (Va, Vb, Vc) in MATLAB [20]

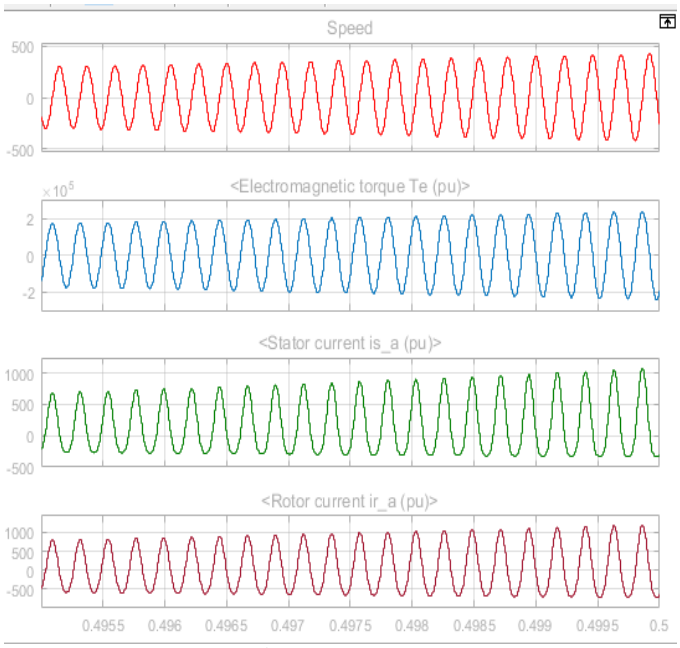

Figure 19.Scope results of Critical load i.e Unloaded Induction motor.

The figure 19. depicts simulation results of the Speed, Torque, Stator Current and rotor current of the Unloaded Induction motor where it is considered as a critical load in the project [20]

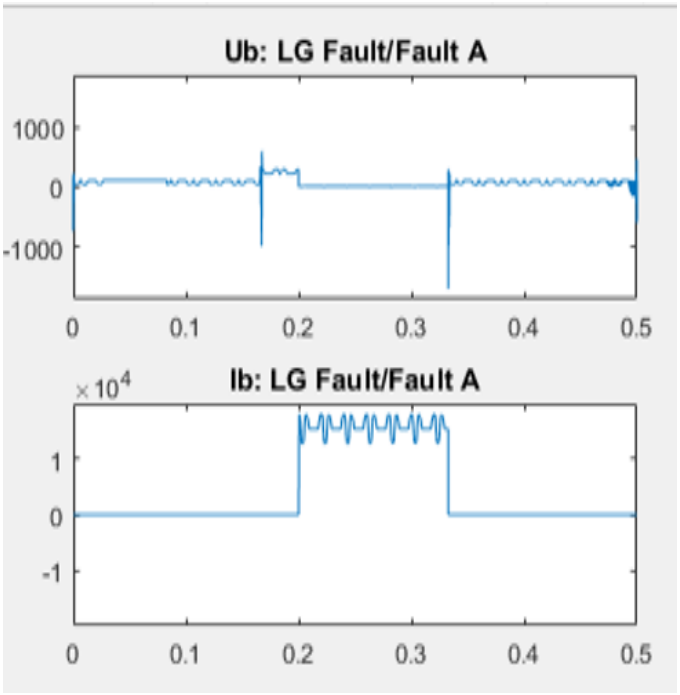

Figure 20. Simulation results of the Fault Current and Voltage in PV array for fault time 0.2 to 0.3s

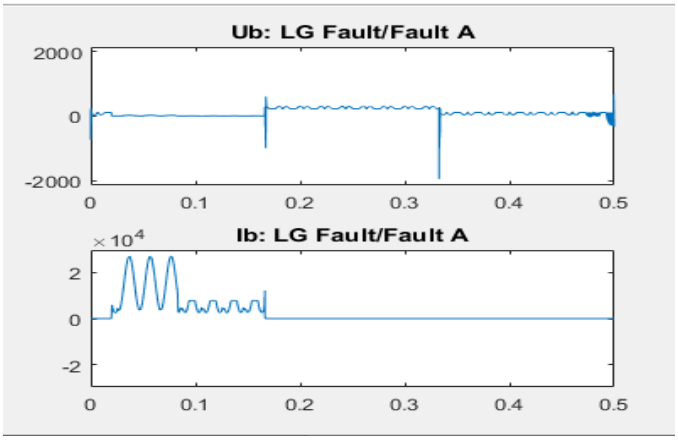

Figure 21. Simulation results of the Fault Current and Voltage in DC Load(3kW) considering fault time 0.02-0.2 s.

Fault Impedance calculation from the scope results for PV Array is 98.85 ohms and for the DC load(3kW) is 100.26 ohms, the fault current from Fig 20,21. is $1.8*10^4$ A and $3*10^4$ A. the transients in the fault waveform depicted is due to high di/dt and low dv/dt. (Relatively high di/dt is due to the difference in sending and receiving current of the system that leads to sudden transients after the fault is settled) is resolved using the Circuit breaker tripping action at the instance of fault time.

VI. CONCLUSION

In this project PV array with MPPT technique is adopted to increase the output via the Boost converter whose efficiency is increased nearly to 52%, Battery energy storage system outlines the charging and discharging as per the requisites of load by PI Controller producing ripple free output. Voltage source inverter layers with the utility grid for minimum losses. The adverse challenge in Micro grid is Fault. So to resolve the fault which is been created this paper focused on the method

of clearing the off the fault based on the algorithm(Fig.13) (detailing the fault occurring and clearance) where the circuit breaker trips at the fault time and disconnects the system from affecting the DC Link, but leads to slower response with small oscillations even after the fault is being segregated.

VII. ACKNOWLEDGEMENT

The authors would like to extend thanks to Department of Electrical and Electronics, PES University Bangalore for guidance and technical support throughout the project.

VIII. REFERENCES

[1] Rabindra Mohanty, A. K. Pradhan "Protection of DC and Hybrid AC-DC Micro grids with Ring Configuration" 2017 7th International Conference on Power Systems (ICPS) College of Engineering Pune, India. Dec 21-23, 2017.
[2] Saranjeet Kaur, Bharti Dwivedi "Power Quality Issues and their Mitigation Techniques Microgrid System-A Review" 978-1-5090-4530-3/16 ©2016 IEEE.
[3] M.H.F Ahamed*, U.D.S.D Dissanayake, H.M.P De Silva, H.R.C.G.PPradeep,N.W.A. Lidula "Modelling and Simulation of a Solar PV and Battery Based DC Microgrid System" International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) – 2016.
[4] Song HuiHuan Zacchaeus, Wesley Poh Qi Tong, R.T. Naayagi "Modelling and Simulation of DC microgrid" 978-1-5386-8257-9/18 ©2018 IEEE.
[5] Genesis Alvarez1, Hadis Moradi1, Mathew Smith2, and Ali Zilouchian1 "Modelling a Grid-Connected PV/Battery Microgrid System with MPPT Controller".
[6] Deepak Singh, Alok Agrawal,Rajesh Gupta "Power Management In Solar PV Fed Microgrid System With Battery Support" 978-1-5386-4318-1/17©2017 IEEE.
[7] Yinghao Shan, Jiefeng Hu, Ka Wing Chan, Josep M. Guerrero "Model Predictive Control of Bidirectional DC–DC Converters and AC/DC Interlinking Converters—A New Control Method for PV-Wind-Battery Microgrids" IEEE Transactions on Sustainable Energy, Vol.10, No.4, October 2019.
[8] Faizan Khan, M. Yasin Ali, and V.K. Sood "Simulation of Microgrid System with Distributed Generation"2017 IEEE Electrical Power and Energy Conference (EPEC).
[9] Snehamoy Dhar, R. Sridhar, Varun Avasthy "Modelling and Simulation of Photovoltaic Arrays".
[10] S,Sheik Mohammed, D.Devaraj "Simulation of Incremental Conductance MPPT Based Two Phased Interleaved Boost Converter using MATLAB/Simulink"
[11] M. LathaDevi, Mr.M. Chilambarasam, Dr.C. Selva Kumar" Modelling and Simulation of Incremental Conductance MPPT Using Self lift SEPIC Converter" 2014 International Conference on Circuit, Power and Computing Technologies [ICCPCT].
[12] Sridhar Sholapur, K.R. Mohan, T.R. Narsimhegowda "Boost Converter Topology for PV System with Perturb and observe MPPT Algorithm" IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN:2278-1676, ISSN:2320-3331, Volume 9, Issue 4 Ver.II (Jul-Aug.2014), pp 50-56.
[13] Yogesh S.Bhavsar, Prasad V.Joshi , Sonaili M.Akolkar "Simulation of Microgrid with Energy Management System" 2015 International Conference on Energy Systems and Application Dr.D.Y. Patil Institute of Engineering and Technology, Pune, India 30 Oct-01 Nov,2015.
[14] Jigar Patel, Dr.Hina Chandwani, Vinod Patel, Hiren Lakhani "Bidirectional DC-DC Converter for Battery Charging – Discharging Applications using Buck-Boost switch 2012 IEEE Student's Conference on Electrical, Electronics and Computer Science.
[15] Sunny kumar , Maheshwarapu sydulu "Bidirectional DC-DC Converter for integration of Battery energy storage system with DC Grid" International Journal of Industrial Electronics Engineering,ISSN 2347-6982,Volume-2,Issue-3,March-2014
[16] Shatakshi ,Bhim Singh, Sukumar Mishra "Dual Mode Operational Control of Single Stage PV-Battery Based Microgrid.2018 IEEE.
[17] Almutairy, Western Michigan University, USA "A Review of Coordination Strategies and Techniques for Overcoming Challenges to Microgrid Protection".
[18] Ganesh Patil, M.F.A.R. Satarkar "Autonomous Protection of Low Voltage DC Microgrid" 2014 IEEE
[19] A. Meghwani, S.C. Srivastava, S. Chakrabarti "A New Protection Scheme for DC Microgrid using Line Current Derivative" 2015 IEEE.
[20] Vinod kumar, Syed Sarfaraz Nawaz "Design and Implementation of Inverter for driving Induction Motor using DSPACE" IJRASET IC value:13.98, ISSN:2321-9653Volume 4 Issue XI, November 2016
[21] YouTube Reference "How to create Fault on Transmission Lines Matlab/Simulink".
[22] Saurav Satpathy "Photovoltaics Power Control using MPPT and Boost Converter" Thesis, National Institute of Technology, Rourkela May 2012