International Journal of Innovative Research in Engineering
Volume 7, Issue 2 (March - April 2026), PP: 313-320.
https://www.doi.org/10.59256/ijire.20260702039
www.theijire.com
ISSN No: 2582-8746

Microgrid Design and Analysis Using ETAP

P. Srinivasa Reddy[1], T. Sai Jayesh[2], M. G. Bhanu Prakash Reddy[3], H. V. Manjunath[4], N. Vamsi Krishna[5]
[1,2,3,4,5] UG Students, Department of EEE, G. Pulla Reddy Engineering College (Autonomous), Kurnool, Andhra Pradesh, India.

How to cite this paper:
P. Srinivasa Reddy[1], T. Sai Jayesh[2], M. G. Bhanu Prakash Reddy[3], H. V. Manjunath[4], N. Vamsi Krishna[5], "Microgrid Design and Analysis Using ETAP", IJIRE-V7I2-313-320.

Abstract: *This paper presents the design, modeling, and performance evaluation of a standalone microgrid system using ETAP (Electrical Transient Analyzer Program) software. The proposed system consists of multiple diesel generators operating in parallel to supply an institutional load, ensuring reliable and continuous power delivery. The study addresses limitations of conventional centralized power systems such as voltage instability, transmission losses, and poor reliability in remote or isolated locations. The microgrid is analyzed using load flow, short circuit, and optimal power flow (OPF) studies. Load flow analysis evaluates voltage profiles, power distribution, and load sharing among generators, while short circuit analysis determines fault current levels to ensure proper protection and system safety. Furthermore, optimal power flow analysis enhances system performance by improving voltage regulation and minimizing deviations. The results indicate that the microgrid operates within acceptable voltage limits and maintains stable performance under both normal and fault conditions, with effective load sharing among generators. The study demonstrates that multi-diesel generator microgrids are technically feasible and suitable for standalone applications, providing a strong foundation for future integration of renewable energy sources and advanced control strategies.*

Key Words: *Microgrid; ETAP; Diesel Generator; Load Flow Analysis; Short Circuit Analysis; Optimal Power Flow; Standalone Power System.*

I.INTRODUCTION

Electrical energy is a fundamental requirement for modern society, and the demand for a reliable and high-quality power supply is continuously increasing. Conventional centralized power systems often face challenges such as transmission losses, voltage instability, limited reliability, and difficulty in supplying power to remote or isolated areas, which has led to the development of alternative power system architectures like microgrids. A microgrid is a localized power system consisting of distributed generation sources, loads, and control systems that can operate either in grid-connected or standalone (islanded) mode, offering improved reliability, better power quality, and operational flexibility. These systems are widely used in institutional, industrial, and rural applications where uninterrupted power supply is critical. Among various generation sources, diesel generators play an important role in microgrids due to their fast response, controllability, and high reliability, and their parallel operation ensures effective load sharing and system stability. In this context, this paper focuses on the design and analysis of a standalone microgrid using ETAP (Electrical Transient Analyzer Program) software. The system performance is evaluated through load flow, short circuit, and optimal power flow analyses to assess voltage stability, fault handling capability, and overall efficiency. The objective of this study is to demonstrate the feasibility, reliability, and safety of a multi-diesel generator microgrid for institutional applications.

II.MATERIAL AND METHODS

This study presents the design and analysis of a standalone microgrid system using ETAP (Electrical Transient Analyzer Program) software. The study was carried out as a simulation-based analytical investigation in the Department of Electrical and Electronics Engineering at G. Pulla Reddy Engineering College (Autonomous), Kurnool, India. The objective of the study is to evaluate the performance, stability, and safety of a microgrid system under different operating conditions.

Study Design: Simulation-based analytical study

Study Location: Department of Electrical and Electronics Engineering, G. Pulla Reddy Engineering College (Autonomous), Kurnool, India

Study Duration: Academic year 2025–2026

System Configuration: The proposed microgrid consists of three diesel generators with ratings of 8 MW, 2 MW, and 2 MW operating in parallel. The generators are connected through transformers, buses, and distribution lines to supply an institutional load of approximately 4 MVA. The system is designed to operate in standalone (islanded) mode without connection to the main grid.

Modeling and Simulation Method: The microgrid system is modeled in ETAP by defining all electrical components with appropriate parameters, including generator ratings, transformer specifications, bus voltages, and load characteristics. Standard assumptions such as balanced load conditions, steady-state operation, and nominal system frequency are considered during modeling.

Analysis Techniques: The system performance is evaluated using three key analyses: Load Flow Analysis is performed to determine voltage profile, power distribution, and load sharing among generators using the Newton–Raphson method. Short Circuit Analysis is conducted to calculate fault current levels under three-phase fault conditions and to assess system protection requirements. Optimal Power Flow (OPF) Analysis is carried out to improve voltage regulation and enhance overall system efficiency.

Inclusion criteria:

1. The system must represent a standalone (islanded) microgrid without connection to the main utility grid.
2. The microgrid model should include multiple diesel generators operating in parallel as distributed generation sources.
3. All system components such as generators, transformers, buses, and loads must be modeled with standard and practical electrical parameters in ETAP.
4. The connected load should represent a realistic institutional load with defined active and reactive power components.
5. The system should be capable of performing load flow, short circuit, and optimal power flow analyses.
6. Balanced load conditions and steady-state operation are considered for accurate simulation results.

Exclusion criteria:

1. Microgrid systems connected to the main utility grid (grid-connected mode) are not considered in this study.
2. Renewable energy sources such as solar photovoltaic, wind energy systems, and battery energy storage systems are excluded due to software limitations.
3. Dynamic analysis such as transient stability, protection coordination, and real-time control strategies are not included in this study.
4. Unbalanced load conditions and harmonic effects are not considered in the system modeling.
5. Advanced energy management systems and economic analysis are beyond the scope of this study.

Procedure methodology

The proposed standalone microgrid system was designed and analyzed using ETAP (Electrical Transient Analyzer Program) software. Initially, the system components including diesel generators, transformers, buses, transmission lines, and loads were defined based on standard electrical parameters. The microgrid consists of three diesel generators with ratings of 8 MW, 2 MW, and 2 MW, operating in parallel to supply an institutional load of approximately 4 MVA. All components were interconnected using a single line diagram (SLD) developed within the ETAP environment.

The system modeling was carried out by assigning appropriate ratings, voltage levels, impedance values, and operating conditions to each component. Generators were configured to operate under swing and PQ modes to enable proper load sharing. Transformers were modeled with specified capacity, voltage ratios, and percentage impedance. Loads were defined with active and reactive power components to represent a realistic institutional demand. Standard assumptions such as balanced load conditions, steady-state operation, and nominal system frequency were considered throughout the study.

Load Flow Analysis was performed using the Newton–Raphson method to evaluate voltage profiles, current distribution, and real and reactive power flow across the system. The results were analyzed to ensure that all bus voltages remained within permissible limits and that load sharing among generators was achieved effectively.

Short Circuit Analysis was conducted by applying a three-phase fault at a critical bus to determine the maximum fault current level. This analysis was used to assess system safety and to ensure proper selection of protective devices such as circuit breakers.

Optimal Power Flow (OPF) Analysis was carried out to improve system performance by optimizing generator outputs and enhancing voltage regulation. The results obtained from OPF were compared with load flow results to evaluate improvements in voltage profile and system efficiency. All simulations were performed using the same modeling conditions to maintain consistency and accuracy throughout the study.

Statistical analysis

The simulation results obtained from ETAP were analyzed to evaluate the performance and reliability of the proposed microgrid system under different operating conditions. Key electrical parameters such as bus voltage magnitude, real and reactive power flow, line currents, and fault current levels were recorded and compared across various analyses. Load flow analysis results were used to assess voltage stability and load sharing among generators, while short circuit analysis provided the maximum fault current values for system safety evaluation.

Comparative analysis was performed between load flow and optimal power flow (OPF) results to determine improvements in voltage profile and system efficiency. Percentage variations in voltage levels and performance indices were calculated to quantify system enhancement under optimized conditions. The minimum and maximum values of system parameters were considered to identify critical operating points and ensure that all values remained within acceptable limits.

All analyses were carried out under consistent modeling assumptions, and the results were interpreted based on standard power system engineering criteria. The overall system performance was evaluated qualitatively and quantitatively to validate the feasibility, stability, and reliability of the proposed standalone microgrid system.

III. RESULT

After performing simulation studies on the proposed standalone microgrid using ETAP, the system performance was evaluated under load flow, short circuit, and optimal power flow conditions. Load flow analysis results indicate that the total generation from the three diesel generators is sufficient to meet the connected load demand of approximately 4 MVA. Proper load sharing among generators was achieved based on their ratings, ensuring stable operation of the system.

The voltage profile across the microgrid buses remained within acceptable limits. The source bus maintained a voltage of 100%, while intermediate buses such as Bus–10 and Bus–25 recorded voltages of 98% and 96%, respectively. The minimum voltage observed was 94.81% at Bus–54, which is within permissible limits, confirming stable system operation without any voltage violations.

Short circuit analysis was carried out by applying a three-phase fault at Bus–3. The maximum fault current recorded was 7.094 kA, representing the most severe fault condition. This value is used for proper selection of protective devices and confirms that the system can safely withstand fault conditions without equipment damage.

Optimal Power Flow (OPF) analysis further improved system performance. The minimum bus voltage increased from 94.81% to 97.16%, demonstrating enhanced voltage regulation and better utilization of generation resources. The OPF results also indicate reduced voltage deviations and improved overall system efficiency.

Table no 1 shows the specifications of the diesel generators (DGs) used in the proposed standalone microgrid system. The system consists of three generators, namely DG-1, DG-2, and DG-3, with rated powers of 8 MW, 2 MW, and 2 MW respectively, all operating at a rated voltage of 11 kV and a power factor of 0.8 lagging. DG-1 is designated as the swing (slack) generator, which is responsible for maintaining system voltage and balancing the active and reactive power mismatch. DG-2 and DG-3 operate in PQ mode, supplying specified active and reactive power to the system. This configuration enables effective load sharing, ensures system stability, and provides reliability through parallel operation of multiple generators.

DG No.	Rated Power (MW)	Rated Voltage (kV)	Power Factor	Operating Mode
DG-1	8	11	0.8 lagging	Swing/Slack
DG-2	2	11	0.8 lagging	PQ
DG-3	2	11	0.8 lagging	PQ

Table no 1: The diesel generators used in the system has the following ratings.

Table no 2: Presents the specifications of the transformers used in the proposed microgrid system. Three transformers, T1, T2, and T3, are connected to DG-1, DG-2, and DG-3 respectively. Transformer T1 has a rated capacity of 10 MVA, while T2 and T3 each have a capacity of 2.5 MVA. All transformers operate at a primary and secondary voltage of 11 kV, indicating no voltage level change but providing electrical isolation and system stability. Each transformer is designed with a percentage impedance of 10%, which plays a crucial role in limiting fault currents and ensuring proper load sharing among generators. This configuration supports reliable and efficient operation of the microgrid.

Transformer No.	Rated Capacity (MVA)	Primary Voltage (kV)	Secondary Voltage (kV)	Percentage Impedance (%)
T1 (DG-1)	10	11	11	10
T2 (DG-2)	2.5	11	11	10
T3 (DG-3)	2.5	11	11	10

Table no2: Transformer Ratings and Specifications.

Table no3**:** Shows the load details of the proposed microgrid system. The system consists of an institutional load with an active power demand of 3.2 MW and a reactive power requirement of 2.4 MVAr, resulting in a total apparent power of 4.0 MVA. The load represents typical institutional consumption, including lighting, laboratory equipment, and other electrical appliances. The combination of active and reactive power reflects realistic operating conditions, which is essential for accurate load flow and system performance analysis. This load configuration is used to evaluate the capability of the microgrid to maintain stable voltage, ensure proper power distribution, and support reliable operation under varying conditions.

Load Type	Active Power (MW)	Reactive Power (MVAr)	Apparent Power (MVA)	Load Type
Institutional Load	3.2	2.4	4.0	Institutional Load

Table no 3: Load Details of the Proposed Microgrid

Table 4 presents the bus voltage profile of the proposed microgrid system obtained from load flow analysis. The source bus maintains a voltage of 1.00 p.u. (100%), indicating stable generation conditions. As the distance from the source increases, a gradual voltage drop is observed due to line impedance and load consumption, with Bus–10 and Bus–25 showing voltages of 0.98 p.u. (98%) and 0.96 p.u. (96%), respectively. The minimum voltage is recorded at Bus–54 as 0.9481 p.u. (94.81%), which lies within acceptable operating limits. The results indicate that the system maintains a stable voltage profile without any violations, confirming reliable operation of the microgrid under normal conditions.

Bus No.	Voltage (p.u.)	Voltage (%)	Bus No.	Voltage (p.u.)
Source Bus	1.00	100	Source Bus	1.00
Bus – 10	0.98	98	Bus – 10	0.98
Bus – 25	0.96	96	Bus – 25	0.96
Bus – 54	0.9481	94.81	Bus – 54	0.9481

Table no 4: Bus Voltage Profile Under Load Flow Analysis

Image of Load Flow Analysis Report

Project:		Page:	1
Location:	ETAP 12.6.5E	Date:	08-12-2008
Contract:		SN:	GPULLARED
Engineer:	Study Case: LF	Revision:	Base
Filename: srinivas246		Config.:	Normal

LOAD FLOW REPORT

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
*Bus1	33.000	100.000	0.0	3.426	2.198	0	0	Bus2	3.426	2.198	71.2	84.2	
Bus2	33.000	100.000	0.0	0	0	0	0	Bus3	3.426	2.198	71.2	84.2	
								Bus1	-3.426	-2.198	71.2	84.2	
Bus3	11.000	97.943	-1.7	0	0	0	0	Bus4	3.417	2.055	213.7	85.7	
								Bus2	-3.417	-2.055	213.7	85.7	
Bus4	11.000	97.764	-1.6	0	0	0	0	Bus3	-3.409	-2.053	213.7	85.7	
								Bus5	0.000	0.000	0.0	0.0	
								Bus22	0.000	0.000	0.0	0.0	
								Bus51	0.000	0.000	0.0	0.0	
								Bus53	3.409	2.053	213.7	85.7	
								Bus56	0.000	0.000	0.0	0.0	
Bus5	11.000	97.764	-1.6	0	0	0	0	Bus4	0.000	0.000	0.0	0.0	
								Bus6	0.000	0.000	0.0	0.0	
Bus6	11.000	97.764	-1.6	0	0	0	0	Bus5	0.000	0.000	0.0	0.0	
Bus22	11.000	97.764	-1.6	0	0	0	0	Bus4	0.000	0.000	0.0	0.0	
								Bus23	0.000	0.000	0.0	0.0	
Bus23	11.000	97.764	-1.6	0	0	0	0	Bus22	0.000	0.000	0.0	0.0	
Bus51	11.000	97.764	-1.6	0	0	0	0	Bus4	0.000	0.000	0.0	0.0	
								Bus52	0.000	0.000	0.0	0.0	
Bus52	11.000	97.764	-1.6	0	0	0	0	Bus51	0.000	0.000	0.0	0.0	
Bus53	11.000	97.586	-1.6	0	0	0	0	Bus4	-3.402	-2.052	213.7	85.6	
								Bus54	3.402	2.052	213.7	85.6	
Bus54	0.415	94.807	-4.0	0	0	3.385	1.853	Bus53	-3.385	-1.853	5663.4	87.7	
Bus56	11.000	97.764	-1.6	0	0	0	0	Bus4	0.000	0.000	0.0	0.0	
								Bus57	0.000	0.000	0.0	0.0	
Bus57	11.000	97.764	-1.6	0	0	0	0	Bus56	0.000	0.000	0.0	0.0	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

\# Indicates a bus with a load mismatch of more than 0.1 MVA

The load flow analysis of the proposed standalone microgrid was carried out using the Newton–Raphson method in ETAP to determine the steady-state operating condition of the system. The analysis confirms that the total generation from the three diesel generators (8 MW, 2 MW, and 2 MW) is sufficient to meet the connected institutional load of approximately 4 MVA. The generators operate in coordinated mode, where DG-1 acts as the swing bus maintaining system voltage and power balance, while DG-2 and DG-3 operate in PQ mode contributing specified active and reactive power. The results indicate effective load sharing among the generators proportional to their ratings, ensuring stable parallel operation. The bus voltage profile across the network remains within acceptable limits. The source bus maintains a voltage of 1.0 p.u. (100%), while a gradual voltage drop is observed towards the load buses due to line impedance and load demand. Bus–10 and Bus–25 show voltage levels of 0.98 p.u. (98%) and 0.96 p.u. (96%) respectively, and the minimum voltage recorded is 0.9481 p.u. (94.81%) at Bus–54. This voltage level lies within the permissible range, confirming that the system maintains acceptable voltage regulation. The analysis also shows no overloading of generators or feeders, and both real and reactive power flows are properly distributed.

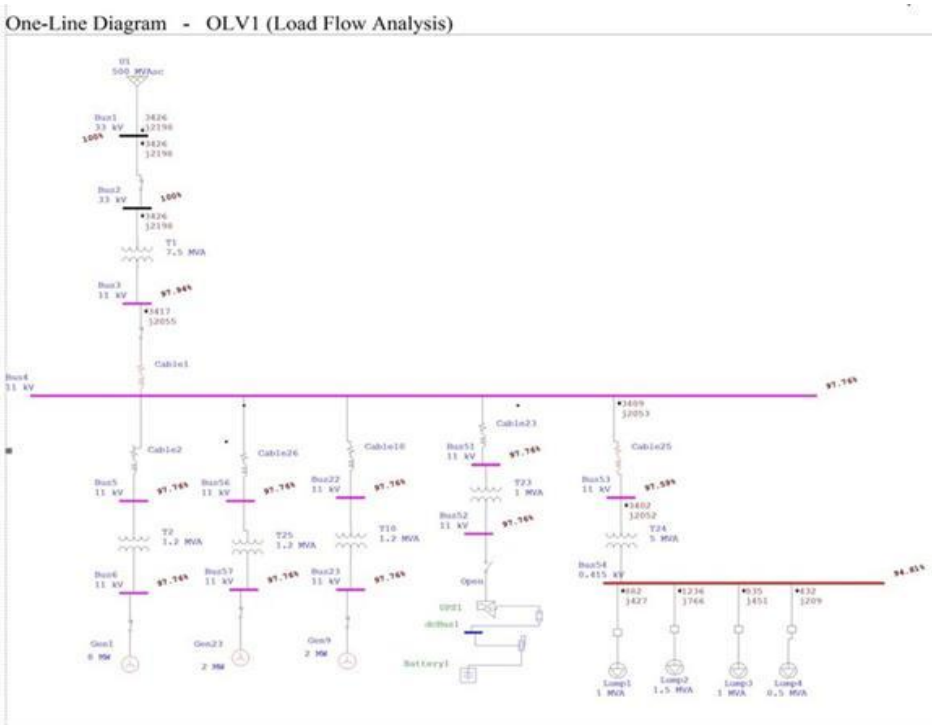


Table no 5 Shows the short circuit analysis results of the proposed microgrid system. A three-phase fault, which is considered the most severe fault condition, is applied at Bus–3. The maximum fault current observed is 7.094 kA. This value represents the worst- case scenario in the system and is critical for the selection of protective devices such as circuit breakers. The repeated values indicate consistent simulation results under identical fault conditions. The analysis confirms that the system can withstand fault conditions safely when appropriate protection mechanisms are implemented.

Fault Type	Bus Location	Fault Current (kA)	Fault Type	Bus Location	Fault Current (kA)	Fault Type
Three-phase fault	Bus – 3	7.094	Three-phase fault	Bus – 3	7.094	Three-phase fault

Table no 5: Shows the Short Circuit at Critical Bus

Image of Short Circuit Analysis Report

Project: | ETAP 12.6.5E | Page: 1
Location: | | Date: 08-12-2008
Contract: | | SN: GPULLARED
Engineer: | Study Case: SC | Revision: Base
Filename: srinivas246 | | Config.: Normal

SHORT-CIRCUIT REPORT

3-phase fault at bus: **Bus3**

Prefault voltage = 11.000 = 100.00 % of nominal bus kV (11.000 kV)
= 100.00 % of base (11.000 kV)

Contribution		1/2 Cycle					1.5 to 4 Cycle				
From Bus ID	To Bus ID	% V From Bus	kA Real	kA Imaginary	Imag. /Real	kA Symm. Magnitude	% V From Bus	kA Real	kA Imaginary	Imag. /Real	kA Symm. Magnitude
Bus3	Total	0.00	0.739	-7.056	9.5	7.094	0.00	0.616	-6.744	10.9	6.772
Bus4	Bus3	1.91	0.397	-2.147	5.4	2.183	1.63	0.274	-1.835	6.7	1.856
Bus2	Bus3	81.25	0.343	-4.909	14.3	4.921	81.25	0.343	-4.909	14.3	4.921
* Bus1	Bus2	81.25	0.114	-1.636	14.3	1.640	81.25	0.114	-1.636	14.3	1.640

NACD Ratio = 0.88

\# Indicates a fault current contribution from a three-winding transformer
* Indicates a fault current through a tie circuit breaker
If faulted bus is involved in loops formed by protection devices, the short-circuit contributions through these PDs will not be reported.

Short circuit analysis was performed to evaluate the system's response under fault conditions and to determine the maximum fault current levels for protection design. A three-phase fault was applied at Bus–3, which is identified as a critical bus due to its proximity to generation sources and lower system impedance. A three-phase fault represents the most severe fault condition and produces the highest fault current in the system. The analysis results show that the maximum fault current at Bus–3 is 7.094 kA. This value is the combined contribution of all three diesel generators through the network and transformer impedances. The magnitude of fault current is influenced by generator ratings, transformer impedance (10%), and network configuration. The obtained fault current value is crucial for selecting appropriate protective devices such as circuit breakers and relays with adequate interrupting capacity. The results confirm that the system can be safely protected by using devices rated above the calculated fault current. Additionally, the analysis ensures that system components are capable of withstanding fault conditions without thermal or mechanical damage. Thus, the short circuit analysis validates the safety and protection capability of the proposed microgrid under abnormal operating conditions.

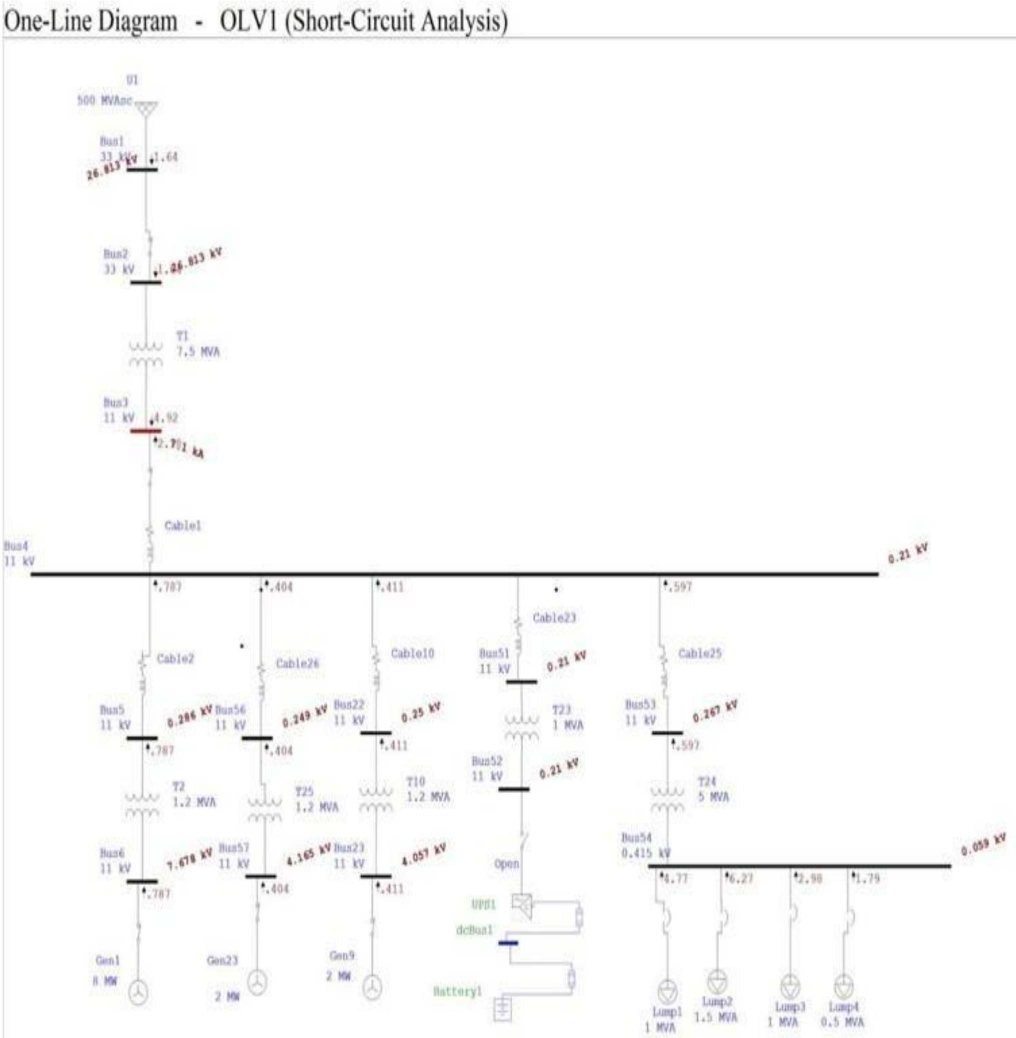


Table 6 presents the comparison of minimum bus voltage obtained from Load Flow Analysis and Optimal Power Flow (OPF) Analysis. Under load flow conditions, the minimum bus voltage is observed to be 94.81%, indicating acceptable but slightly lower voltage levels at the weakest bus. After applying OPF, the minimum bus voltage improves to 97.16%, demonstrating enhanced voltage regulation and reduced voltage deviation across the system. This improvement highlights the effectiveness of OPF in optimizing generator outputs and improving overall system performance and stability.

Condition	Minimum Bus Voltage (%)
Load Flow Analysis	94.81
Optimal Power Flow	97.16

Table no 6: Comparison of Load Flow and OPF Voltage Results

Image of Optimal Power Flow (OPF) Analysis Report

Project:	**ETAP**	Page: 1
Location:	12.6.5E	Date: 08-14-2008
Contract:		SN: GPULLARED
Engineer:		Revision: Base
Filename: srinivas246	Study Case: OPF	Config.: Normal

Optimal Settings

Generator/Power Grid

ID	%Voltage	Operating MW	Operating Mvar	Delta MW	Delta Mvar
Gen1	100.09	0.000	0.000	0.000	0.000
Gen9	100.09	0.000	0.000	0.000	0.000
Gen23	100.09	0.000	0.000	0.000	0.000
U1	102.38	3.594	2.303	3.594	2.303

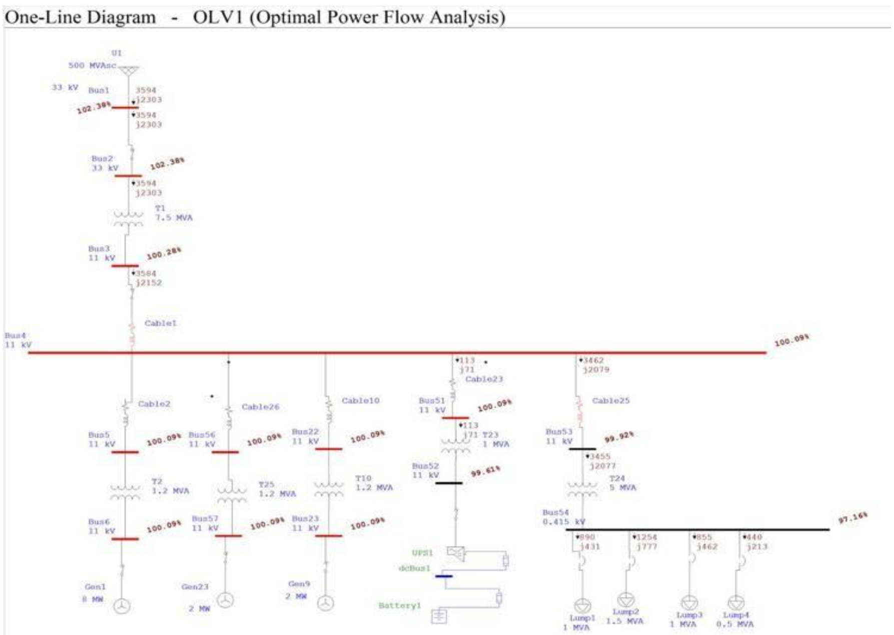
LTC (Load Tap Changer)

Transformer ID	Tap Initial	Tap Final	Tap Delta

Shunt Capacitor/SVC

Device ID	Mvar Initial	Mvar Final	Mvar Delta

Optimal Power Flow (OPF) analysis was carried out to enhance the performance of the microgrid by optimizing generator outputs while satisfying system constraints such as voltage limits and power balance. Unlike conventional load flow analysis, OPF aims to improve system efficiency and voltage profile without altering the physical configuration of the network. The OPF results demonstrate a significant improvement in the voltage profile of the system. Under load flow conditions, the minimum bus voltage was observed to be 94.81% at Bus–54, indicating a noticeable voltage drop at the weakest bus. After applying OPF, the minimum bus voltage improved to 97.16%, reflecting enhanced voltage regulation and reduced voltage deviation across the network. This improvement is achieved by optimally adjusting the power output of generators, ensuring better load sharing and efficient utilization of available generation resources. The OPF analysis reduces stress on the system, improves voltage stability at weaker buses, and enhances overall operational performance. In comparison, while load flow analysis provides the basic operating condition of the system, OPF offers an optimized solution that improves voltage levels and system efficiency. The increase in minimum voltage from 94.81% to 97.16% clearly demonstrates the effectiveness of OPF in enhancing microgrid performance. Therefore, OPF plays a critical role in achieving a more stable, efficient, and reliable operation of the microgrid system, making it an essential tool for advanced power system analysis.



IV. DISCUSSION

Reliable and efficient power supply is a critical requirement for modern electrical systems, especially in institutional and isolated environments. Conventional centralized power systems often face challenges such as transmission losses, voltage instability, and limited reliability. Microgrids have emerged as an effective solution to overcome these limitations by enabling localized generation, improved voltage regulation, and enhanced system flexibility. In particular, standalone microgrids play a vital role in ensuring uninterrupted power supply in areas where grid connectivity is weak or unavailable.

In the present study, a standalone microgrid system consisting of multiple diesel generators was designed and analyzed using ETAP software. The system was evaluated using load flow, short circuit, and optimal power flow analyses to assess its performance under different operating conditions. The load flow analysis results indicate that the system maintains stable voltage levels across all buses, with the minimum voltage recorded as 94.81%, which lies within acceptable limits. This demonstrates that the microgrid is capable of supplying power reliably without significant voltage violations.

The study also shows that effective load sharing is achieved among the diesel generators operating in parallel. The use of a swing generator along with PQ-controlled generators ensures proper power balance and stable system operation. These findings confirm that the proposed configuration supports reliable and efficient distribution of power within the microgrid.

Short circuit analysis plays an important role in evaluating system safety under fault conditions. In this study, the maximum fault current observed was 7.094 kA under a three-phase fault condition at a critical bus. This result highlights the importance of selecting appropriate protective devices to ensure system safety. The calculated fault current values are within manageable limits, indicating that the system can withstand fault conditions without causing damage to equipment.

Optimal Power Flow (OPF) analysis further enhances system performance by optimizing generator outputs. The results show that the minimum bus voltage improves from 94.81% under load flow conditions to 97.16% after applying OPF. This improvement demonstrates better voltage regulation and reduced voltage deviation across the network. In comparison to conventional load flow analysis, OPF provides a more efficient and optimized operating condition by improving voltage stability without altering the physical configuration of the system.

Overall, the results of this study confirm that the proposed multi-diesel generator microgrid is technically feasible, reliable, and capable of maintaining stable operation under both normal and fault conditions. The findings also highlight the significance of optimization techniques such as OPF in enhancing system performance. This study provides a strong foundation for future work involving integration of renewable energy sources and advanced energy management strategies to further improve microgrid efficiency and sustainability.

V. CONCLUSION

This paper presented the design and detailed analysis of a standalone microgrid using ETAP software. The load flow analysis confirmed stable system operation, with bus voltages maintained within acceptable limits, ranging from 100% at the source bus to a minimum of 94.81% at the weakest bus (Bus–54). Effective load sharing among the diesel generators (8 MW, 2 MW, and 2 MW) was achieved without any overloading, ensuring reliable power distribution.

Short circuit analysis revealed that the maximum fault current under a three-phase fault condition at Bus–3 was 7.094 kA, which represents the worst-case scenario. This value is within manageable limits and provides a basis for selecting appropriate protective devices to ensure system safety.

Optimal Power Flow (OPF) analysis significantly improved system performance by enhancing voltage regulation. The minimum bus voltage increased from 94.81% to 97.16%, indicating reduced voltage deviation and better utilization of generation resources.

Overall, the results demonstrate that the proposed microgrid system is technically feasible, stable, and reliable for standalone operation. The study highlights the effectiveness of ETAP-based analysis and optimization techniques in improving system performance, and it provides a strong foundation for future integration of renewable energy sources and advanced energy management strategies.

References

1. A. G. Tsikalakis and N. D. Hatziargyriou, “Centralized control for optimizing microgrids operation,” IEEE Transactions on Energy Conversion, vol. 23, no. 1, pp. 241–248, Mar. 2008.
2. N. Hatziargyriou, H. Asano, R. Iravani, and C. Marnay, “Microgrids,” IEEE Power and Energy Magazine, vol. 5, no. 4, pp. 78–94, Jul.–Aug. 2007.
3. R. H. Lasseter, “Microgrids,” in Proc. IEEE Power Engineering Society Winter Meeting, New York, USA, 2002, pp. 305–308.
4. P. Kundur, Power System Stability and Control. New York, NY, USA: McGraw-Hill, 1994.
5. N. D. Kaushika and N. K. Gautam, “Energy yield simulations of interconnected sola PV arrays,” IEEE Trans. Energy Convers., vol. 18, no. 1, pp. 127– 134, Mar. 2003
6. J. Grainger and W. D. Stevenson Jr., Power System Analysis. New York, NY, USA: McGraw-Hill, 1994.
7. ETAP, ETAP Power System Analysis Software – User Guide. Operation Technology Inc., Irvine, CA, USA.
8. A. Wood and B. Wollenberg, Power Generation, Operation, and Control, 2nd ed. New York, NY, USA: Wiley, 1996.