International Journal of Scientific Research and Engineering Development-– Volume 8 Issue 3, May-June 2025

Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Analysis and Control of DC Microgrid Using Quadratic Boost Converter with Intelligent Controllers

K R Sridhar *, Dr. N. Ashok Kumar **, Dr. R. Malathi ***

* PG Scholar, Department of EEE, SCSVMV University, Enathur, Kanchipuram, Tamilnadu
** Assistant Professor, Department of EEE, SCSVMV University, Enathur, Kanchipuram, Tamilnadu
*** Associate Professor, Department of EEE, SCSVMV University, Enathur, Kanchipuram, Tamilnadu

--************************------------------------------------

Abstract:

This paper presents the modeling, simulation, and comparative analysis of a DC microgrid system under healthy and faulty conditions. The system incorporates renewable energy sources such as PV, wind, fuel cells, and battery storage, regulated through a Quadratic Boost Converter (QBC). Faults including shorted switch, line-to-line, and line-to-ground conditions are analyzed through MATLAB/Simulink simulations. Control strategies including Proportional-Integral (PI), Fractional Order PID (FOPID), and Fuzzy Logic (FL) controllers are implemented to regulate output parameters. The FOPID and FL controllers showed improved transient response compared to conventional PI control. Results demonstrate the superiority of FL controllers in minimizing rise time, peak time, settling time, and steady-state error.

Keywords — **DC Microgrid, Quadratic Boost Converter, PI Controller, FOPID, Fuzzy Logic Controller, Fault Analysis, THD, MATLAB/Simulink.**

--************************------------------------------------

I. INTRODUCTION

Microgrids have emerged as a promising solution for decentralized energy systems, offering enhanced reliability, efficiency, and integration of renewable sources. They operate in grid-connected or standalone modes, supporting AC or DC distribution systems. DC microgrids are especially advantageous when interfacing with DC output sources like PV, fuel cells, and energy storage systems. However, challenges in fault detection and control stability remain significant.

This work proposes a DC microgrid architecture using a Quadratic Boost Converter (QBC) and evaluates system performance under various fault conditions. Furthermore, advanced control strategies including PI, FOPID, and FL controllers are employed to enhance output regulation and robustness against disturbances.

II. SYSTEM ARCHITECTURE AND METHODOLOGY

The proposed DC microgrid includes interconnected sources—PV, wind turbines, batteries, and fuel cells—coupled through a QBC. MATLAB/Simulink is used to simulate both healthy and faulty conditions, and controllers are applied in closed-loop configurations to regulate the output.

A. Fault Conditions

- Shorted Switch Fault: Reduced output voltage and power observed (20V, 8W) compared to the healthy system (67V, 90W).
- Line-to-Ground Fault: Induced 47.95% Total Harmonic Distortion (THD) in source current.
- Line-to-Line Fault: Reduced THD to 39.18%, indicating improved current quality.

B. Control Approaches

- PI Controller: Conventional method with notable steady-state error.
- FOPID Controller: Improves rise time (0.66s) and settling time (0.96s) over PI.
- Fuzzy Logic Controller: Best performance with rise time of 0.18s and steady-state error of 0.35V.

III. DC MICROGRID IN HEALTHY CONDITION AND SHORT-CIRCUITED SWITCH FAULT

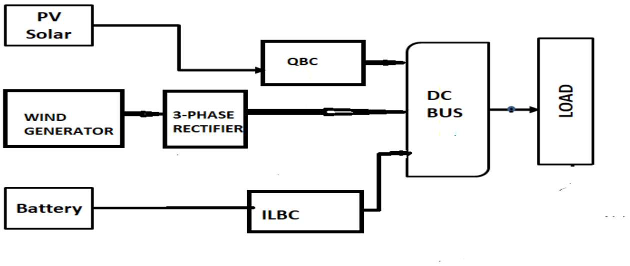

Fig.1. Modified block diagram

Simulation Results: DC Microgrid in healthy condition is presented in Fig.2. Voltage across PV is presented in Fig.3 and its value is 16V. Voltage across battery is presented in Fig.4 and its value is 15V. Voltage across R load is presented in Fig.5 and its value is 68V. Current through R load is presented in Fig.6 and its value is 1.4A. Output Power is presented in Fig.7 and its value is 90W.

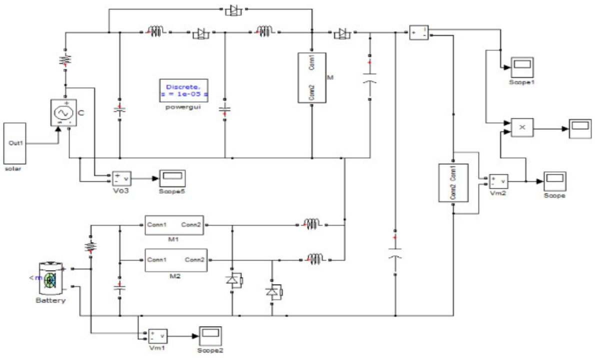

Fig.2 DC Microgrid in healthy condition

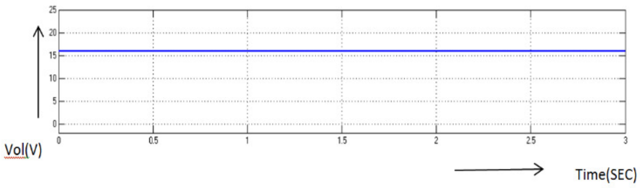

Fig.3 Voltage across PV

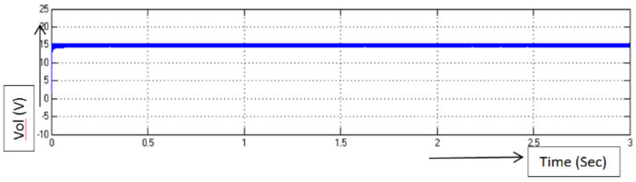

Fig.4 Voltage across battery

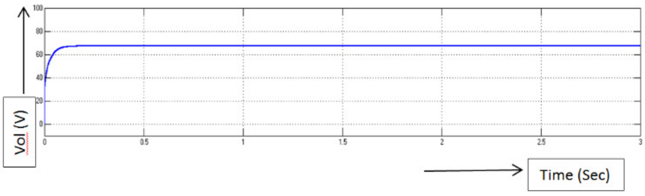

Fig.5 Voltage across R load

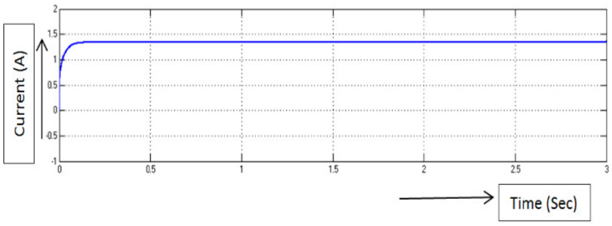

Fig.6 Current through R load

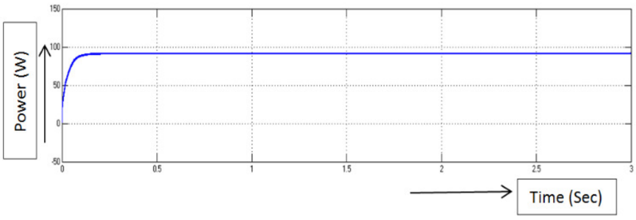

Fig.7 Output Power

IV. DC MICROGRID WITH LINE TO GROUND FAULT AND DC MICROGRID WITH LINE TO LINE FAULT

Simulation Results: DC Microgrid with line to ground fault is presented in Fig 8. Current of wind generator is presented I n Fig 9 & its value is 34A. Input current THD is presented in Fig 10 &its value is 47.95%.

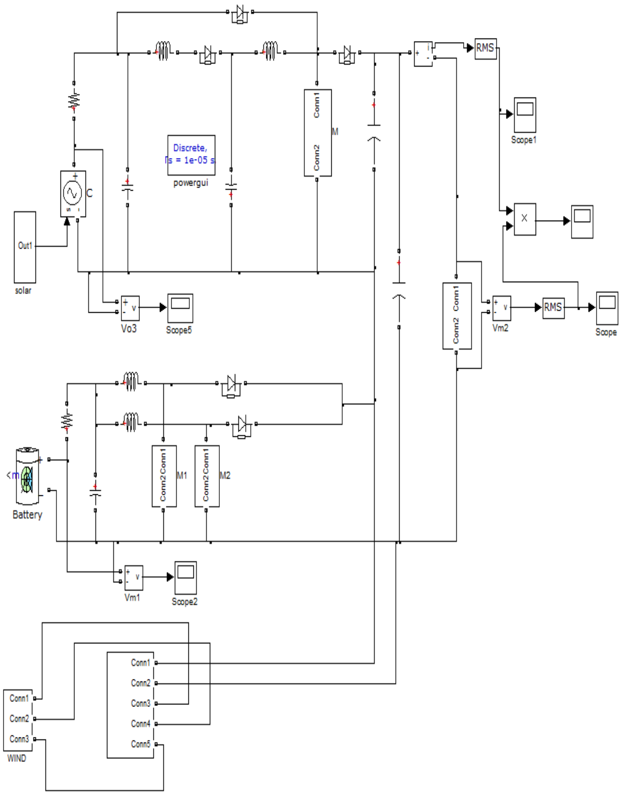

Fig.8 DC Microgrid with line to ground fault

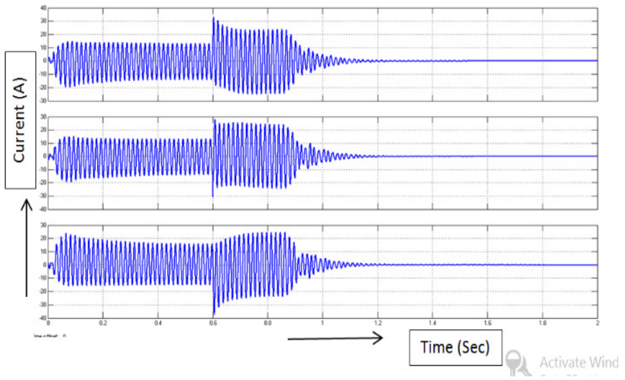

Fig.9 Current of wind generator

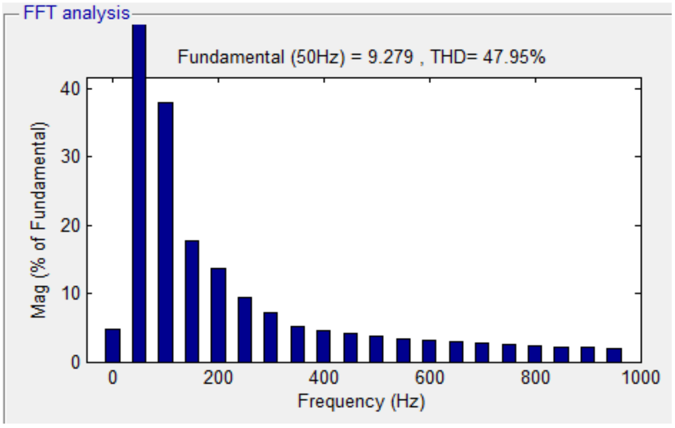

Fig.10 Input current THD

V. PI AND FOPID CLOSED LOOP DC MICRO-GRID

Simulation Result: Open loop DC micro-grid with source disturbance is delineated in fig.11. Input voltage with disturbance is delineated in fig. 12 and its value is 23V. Voltage across R-load with disturbance is delineated in fig.13 and its value is 118V.Current through R-load with disturbance is delineated in fig.14 and its value is 2.3A. Output power with disturbance is delineated in fig.15 and its value is 270W.

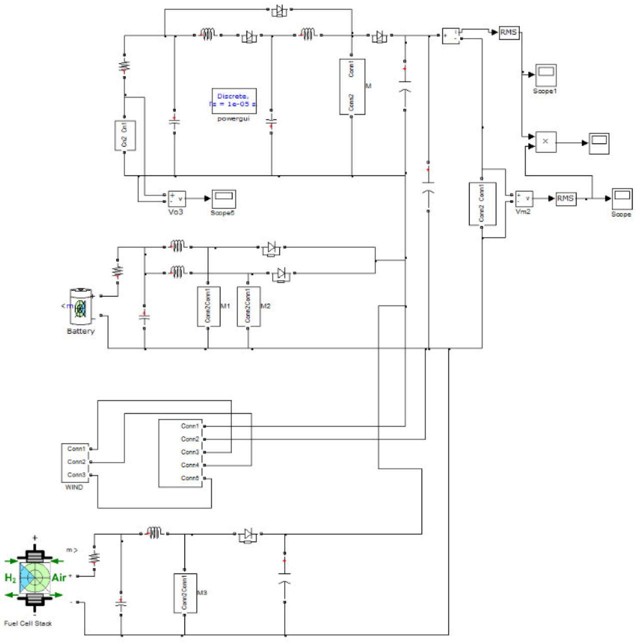

Fig.11 Open loop DC micro-grid with source disturbance

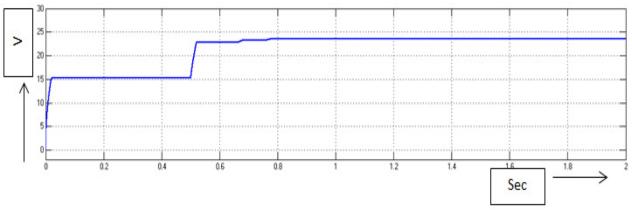

Fig.12 Input voltage with disturbance

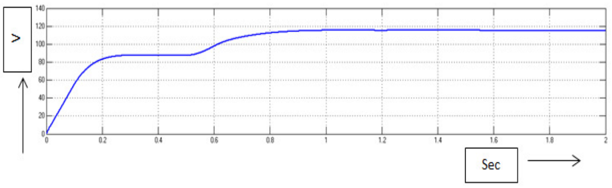

Fig.13 Voltage across R-load with disturbance

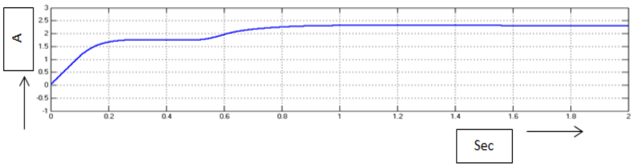

Fig14 Current through R-load with disturbance

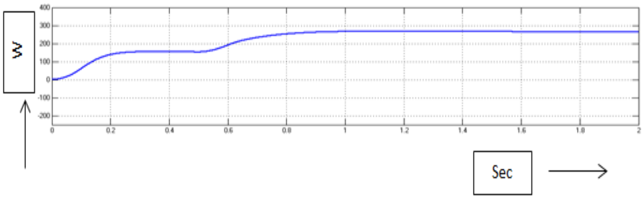

Fig.15 Output power with disturbance

VI. FLC CONTROLLED CLOSED LOOP DC MICRO-GRID

Simulation Results: Closed loop DC micro-grid with FL controller is delineated in Fig. 16 Voltage across R-load with FL controller is delineated in Fig 17 and its value is 90V. Current through R-load with FL controller is delineated in Fig 18 and its value is 1.9A. Output power with FL controller is delineated in Fig 19 and its value is 160W. From the simulation results, it can be seen that the output voltage, current and power are regulated and the closed loop system rejects the change in input voltage.

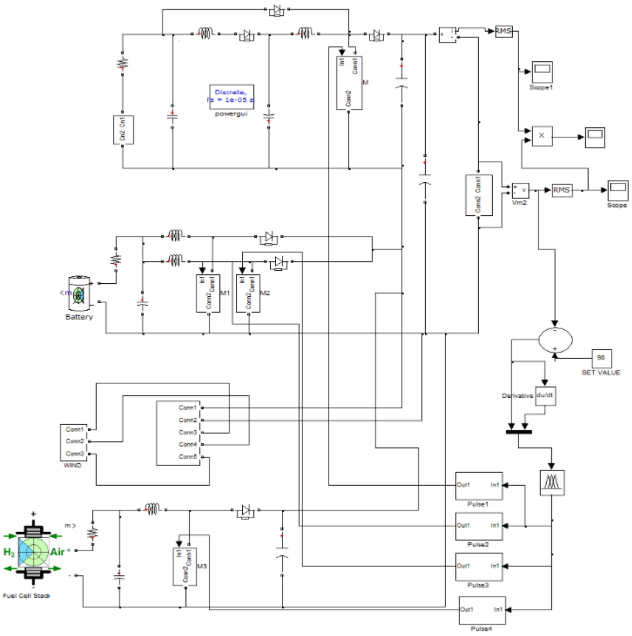

Fig.16 Closed loop DC micro-grid with Fuzzy Logic controller

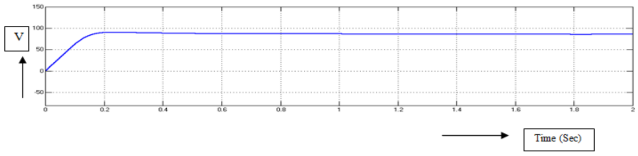

Fig.17 Voltage across R-load with Fuzzy Logic controller

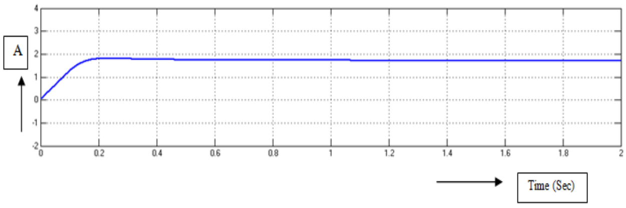

Fig.18 Current through R-load with Fuzzy Logic controller

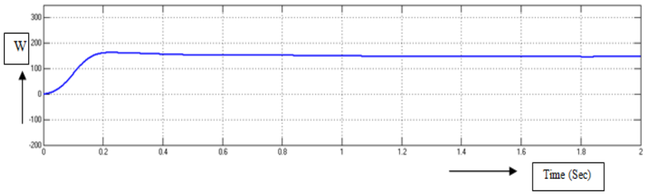

Fig.19 Output power with Fuzzy Logic controller

Comparison of Time Domain Parameters is delineated in Table 1. By using FL controller, rise time is reduced from 0.66 Sec to 0.18 Sec; peak time is reduced from 0.76 Sec to 0.22Sec; settling time is reduced from 0.96 Sec to 0.55 Sec; steady state error is reduced from1.23V to 0.35V. Bar chart comparison of Time Domain Parameters is delineated in Fig. 20.

TABLE I
Comparison of Time Domain Parameters

Controller	**Tr**	**Ts**	**Tp**	**Ess**
FOPID	0.66	0.96	0.76	1.23
FLC	0.18	0.55	0.22	0.35
Controller	Tr	Ts	Tp	Ess

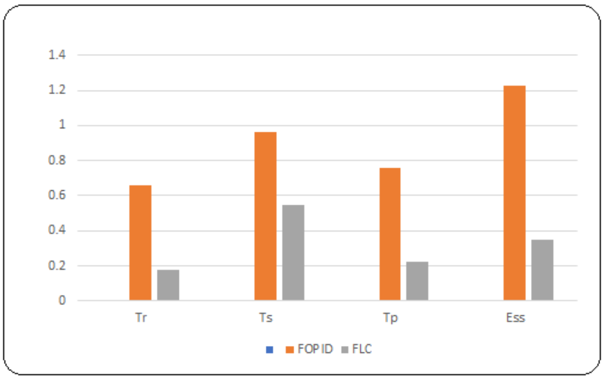

Fig.20 Bar chart comparison of Time Domain Parameters

VII. CONCLUSION

This work mainly deals with the design, plan and comparison of DC micro grid in healthy condition and DC microgrid in short circuited switch fault. The outcomes are compared in terms of output voltage, output current and output power. In faulty condition, output voltage, output current and output power are reduced.

This work also presents the design, plan and comparison of DC microgrid with line to ground fault and DC microgrid with line to line fault . The outcomes are compared in terms of Current THD. With Line to line fault, current THD is 47.95% and with Line to ground fault, current THD is 39.18%. Hence, the outcomes represents that the DC Microgrid with line to line fault produces higher THD when compared to DC Microgrid with line to ground fault.

Simulation results with shorted fault in boost converter indicate fall in grid voltage and output power. Open loop and closed loop QBC with PV, wind, battery and Fuel cell with PI/ FOPID controller are analyzed and simulated. By using FOPID controller, rise time is reduced from 0.75 Sec to 0.66Sec; peak time is reduced from 0.83 Sec to 0.76Sec; settling time is reduced from 1.20 Sec to 0.96 Sec; steady state error is reduced from 1.78V to 1.23V. Hence, the outcome represents that closed loop DC micro-grid with FOPID controller is superior to closed loop DC micro-grid with PI controller.

Closed loop DC microgrid with FOPID/FLC controller are analyzed and simulated. By using-FL controller, rise time is reduced from 0.66Sec to 0.18 Sec; peak time is reduced from 0.76 Sec to 0.22 Sec; settling time is reduced from 0.96 Sec to 0.55 Sec; steady state error is reduced from 1.23V to 0.35V. Hence, the outcome represents that closed loop DCMGS with FL controller is superior to closed loop DCMGS with FOPID.

REFERENCES

[1] Liang Che; Mohammad Shahidehpour; Ahmed Alabdul wahab; Yusuf Al-TurkiHierarchical Coordination of a Community Microgrid With AC and DC MicrogridsIEEE Transactions on Smart Grid Year: 2015 | Volume: 6, Issue: 6 | Journal Article | Publisher: IEEE.

[2] HongjieJia;QianXiao;Jinwei HeAn Improved Grid Current and DC Capacitor Voltage Balancing Method for Three-Terminal Hybrid AC/DC MicrogridIEEE Transactions on Smart Grid Year: 2019 | Volume: 10, Issue: 6 | Journal Article | Publisher: IEEE.

[3] XiangkeLi;WentaoJiang;JunjunWang;PengWang;Xiaohua WuAn Autonomous Control Scheme of Global Smooth Transitions for Bidirectional DC-DC Converter in DC MicrogridIEEE Transactions on Energy Conversion Year: 2021 | Volume: 36, Issue: 2 | Journal Article | Publisher: IEEE.

[4] PrajofPrabhakaran;VivekAgarwalNovel Boost-SEPIC Type Interleaved DC–DC Converter for Mitigation of Voltage Imbalance in a Low-Voltage Bipolar DC MicrogridIEEE Transactions on Industrial Electronics Year: 2020 | Volume: 67, Issue: 8 | Journal Article | Publisher: IEEE.

[5] XinanZhang;BenfeiWang;UjjalManandhar;HoayBengGooi;Gilbert FooA Model Predictive Current Controlled Bidirectional Three-Level DC/DC Converter for Hybrid Energy Storage System in DC MicrogridsIEEE Transactions on Power Electronics Year: 2019 | Volume: 34, Issue: 5 | Journal Article | Publisher: IEEE.

[6] M. Lakshmi;S. HemamaliniNonisolated High Gain DC–DC Converter for DC MicrogridsIEEE Transactions on Industrial Electronics Year: 2018 | Volume: 65, Issue: 2 | Journal Article | Publisher: IEEE.

[7] NieHou;LiDing;PasanGunawardena;TianHongWang;YueZhang;Yun Wei LiA Partial Power Processing Structure Embedding Renewable Energy Source and Energy Storage Element for Islanded DC MicrogridIEEE Transactions on Power Electronics Year: 2023 | Volume: 38, Issue: 3 | Journal Article | Publisher: IEEE.

[8] Mustafa Alrayah Hassan; Chun-Lien Su;Josep Pou; Dhafer Almakhles; Tung-Sheng Zhan;Kuo-Yuan LoRobust Passivity-Based Control for Interleaved Bidirectional DC–DC Power Converter With Constant Power Loads in DC Shipboard MicrogridIEEETransactions on Transportation Electrification Year: 2024 | Volume: 10, Issue: 2 | Journal Article | Publisher: IEEE.

[9] HaoTian;Yunwei LiVirtual Resistor Based Second-Order Ripple Sharing Control for Distributed Bidirectional DC–DC Converters in Hybrid AC–DC MicrogridIEEE Transactions on Power Electronics Year: 2021 | Volume: 36, Issue: 2 | Journal Article | Publisher: IEEE

[10] V. FernãoPires;ArmandoCordeiro;DanielFoito;J. Fernando A. SilvaDual Output and High Voltage Gain DC-DC Converter for PV and Fuel Cell Generators Connected to DC Bipolar MicrogridsIEEE Access Year: 2021 | Volume: 9 | Journal Article | Publisher: IEEE.

[11] NieHou;Yunwei LiCommunication-Free Power Management Strategy for the Multiple DAB-Based Energy Storage System in Islanded DC MicrogridIEEE Transactions on Power Electronics Year: 2021 | Volume: 36, Issue: 4 | Journal Article | Publisher: IEEE.

[12] Ahmed AmrSaafan;VinodKhadkikar;MohamedShawky El Moursi;Hatem H. ZeineldinA New Multiport DC-DC Converter for DC Microgrid ApplicationsIEEE Transactions on Industry Applications Year: 2023 | Volume: 59, Issue: 1 | Journal Article | Publisher: IEEE.

[13] Saman A. Gorji Reconfigurable Quadratic Converters for Electrolyzers Utilized in DC MicrogridsIEEE Access Year: 2022 | Volume: 10 | Journal Article | Publisher: IEEE.

[14] PrajofPrabhakaran;VivekAgarwalNovel Four-Port DC–DC Converter for Interfacing Solar PV–Fuel Cell Hybrid Sources With Low-Voltage Bipolar DC MicrogridsIEEE Journal of Emerging and Selected Topics in Power Electronics Year: 2020 | Volume: 8, Issue: 2 | Journal Article | Publisher: IEEE.

[15] Gang Lin;Junjie Ma; Yong Li; Christian Rehtanz; Jiayan Liu; Ziya Wang; PengchengWang;Fengjian SheA Virtual Inertia and Damping Control to Suppress Voltage Oscillation in Islanded DC MicrogridIEEE Transactions on Energy Conversion Year: 2021 | Volume: 36, Issue: 3 | Journal Article | Publisher: IEEE.

[16] Xialin Li;Li Guo; Shaohui Zhang; Chengshan Wang; Yun Wei Li;Anwei Chen;Yibin FengObserver-Based DC Voltage Droop and Current Feed-Forward Control of a DC MicrogridIEEE Transactions on Smart Grid Year: 2018 | Volume: 9, Issue: 5 | Journal Article | Publisher: IEEE.

[17] ZulfiqarAli;YacineTerriche;LeQuangNhatHoang;SyedZagamAbbas;MustafaAlrayahHassan;MuhammadSadiq;Chun-LienSu;Josep M. GuerreroFault Management in DC Microgrids: A Review of Challenges, Countermeasures, and Future Research TrendsIEEE Access Year: 2021 | Volume: 9 | Journal Article | Publisher: IEEE.

[18] SenTan;PeilinXie;Josep M. Guerrero;Juan C. Vasquez;JoseMatasAlcala;Jorge El MariachetCarreño;Manel Guerrero-ZapataLyapunov-Based Resilient Cooperative Control for DC Microgrid Clusters Against False Data Injection Cyber-AttacksIEEE Transactions on Smart Grid Year: 2024 | Volume: 15, Issue: 3 | Journal Article | Publisher: IEEE.

[19] Ajay Gupta;SuryanarayanaDoolla;KishoreChatterjeeHybrid AC–DC Microgrid: Systematic Evaluation of Control StrategiesIEEE Transactions on Smart Grid Year: 2018 | Volume: 9, Issue: 4 | Journal Article | Publisher: IEEE.

[20] XialinLi;PengfeiLi;LeijiaoGe;XunyangWang;ZhiwangLi;LinZhu;LiGuo;Chengshan Wang A Unified Control of Super-capacitor System Based on Bi-directional DC-DC Converter for Power Smoothing in DC MicrogridJournal of Modern Power Systems and Clean Energy Year: 2023 | Volume: 11, Issue: 3 | Journal Article | Publisher: SGEPRI.

[21] Umamaheswararao Vuyyuru; Suman Maiti; Chandan Chakraborty; Efstratios I. BatzelisUniversal Active Power Control Converter for DC-Microgrids With Common Energy StorageIEEE Open Journal of Industry Applications Year: 2021 | Volume: 2 | Journal Article | Publisher: IEEE.

[22] UjjalManandhar;BenfeiWang;XinanZhang;GooiHoayBeng;YitaoLiu;AbhisekUkil, Joint Control of Three-Level DC–DC Converter Interfaced Hybrid Energy Storage System in DC MicrogridsIEEE Transactions on Energy Conversion Year: 2019 | Volume: 34, Issue: 4 | Journal Article | Publisher: IEEE.

[23] Na Zhi;KeDing;LiangDu;Hui ZhangAn SOC-Based Virtual DC Machine Control for Distributed Storage Systems in DC MicrogridsIEEE Transactions on Energy Conversion Year: 2020 | Volume: 35, Issue: 3 | Journal Article | Publisher: IEEE

[24] FahadSaleh Al-Ismail DC Microgrid Planning, Operation, and Control: A Comprehensive Review IEEE Access Year: 2021 | Volume: 9 | Journal Article | Publisher: IEEE.

[25] ErnauliAprilia;KeMeng;Mohamed Al Hosani;Hatem H. Zeineldin;Zhao Yang DongUnified Power Flow Algorithm for Standalone AC/DC Hybrid MicrogridsIEEE Transactions on Smart Grid Year: 2019 | Volume: 10, Issue: 1 | Journal Article | Publisher: IEEE.

[26] JavadKhodabakhsh;GerryMoschopoulosSimplified Hybrid AC–DC Microgrid With a Novel Interlinking ConverterIEEE Transactions on Industry Applications Year: 2020 | Volume: 56, Issue: 5 | Journal Article | Publisher: IEEE.

[27] Liang Kong;HengNianTransient Modeling Method for Faulty DC Microgrid Considering Control Effect of DC/AC and DC/DC ConvertersIEEE Access Year: 2020 | Volume: 8 | Journal Article | Publisher: IEEE.

[28] Tian Long Zhang;QianZhou;ShuaiMu;HaoLi;You Jin Li;Jian WangVoltage-Based Segmented Control of Superconducting Magnetic Energy Storage for Transient Power Fluctuation Suppression in Island DC MicrogridIEEE Transactions on Applied Superconductivity Year: 2021 | Volume: 31, Issue: 8 | Journal Article | Publisher: IEEE.

[29] Mahdi Zolfaghari;MehrdadAbedi;Gevork B. GharehpetianPower Flow Control of Interconnected AC–DC Microgrids in Grid-Connected Hybrid Microgrids Using Modified UIPCIEEE Transactions on Smart Grid Year: 2019 | Volume: 10, Issue: 6 | Journal Article | Publisher: IEEE.

[30] SatyajitHemantChincholkar;Chok-You ChanDesign of Fixed-Frequency Pulsewidth-Modulation-Based Sliding-Mode Controllers for the Quadratic Boost ConverterIEEE Transactions on Circuits and Systems II: Express Briefs Year: 2017 | Volume: 64, Issue: 1 | Journal Article | Publisher: IEEE.

[31] Hwa-Dong Liu;AnindyaSundarJana;Chang-Hua LinAn Improved High Gain Continuous Input Current Quadratic Boost Converter for Next–Generation Sustainable Energy ApplicationIEEE Transactions on Circuits and Systems II: Express Briefs Year: 2024 | Volume: 71, Issue: 5 | Journal Article | Publisher: IEEE.

[32] Chok-You Chan An Improved Voltage-Mode Controller for the Quadratic Boost Converter IEEE Transactions on Circuits and Systems II: Express Briefs Year: 2022 | Volume: 69, Issue: 2 | Journal Article | Publisher: IEEE.

[33] Sin-Woo Lee;Hyun-Lark DoQuadratic Boost DC–DC Converter With High Voltage Gain and Reduced Voltage Stresses IEEE Transactions on Power Electronics Year: 2019 | Volume: 34, Issue: 3 | Journal Article | Publisher: IEEE

[34] Chok-You Chan;SatyajitChincholkar;Wentao JiangA Modified Fixed Current-Mode Controller for Improved Performance in Quadratic Boost ConvertersIEEE Transactions on Circuits and Systems II: Express Briefs Year: 2020 | Volume: 67, Issue: 10 | Journal Article | Publisher: IEEE.

[35] OswaldoLópez-Santos;NicolásLópezVarón;Julio C. Rosas-Caro;Jonathan C. Mayo-Maldonado;Jesús E. Valdez-ReséndizDetailed Modeling of the Low Energy Storage Quadratic Boost ConverterIEEE Transactions on Power Electronics Year: 2022 | Volume: 37, Issue: 2 | Journal Article | Publisher: IEEE.

GuanlinLi;XinJin;XiyouChen;XianminMuA novel quadratic boost converter with low inductor currentsCPSS Transactions on Power Electronics and Applications Year: 2020 | Volume: 5, Issue: 1 | Journal Article | Publisher: CPSS.