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A Comparative Study of Circuit Techniques to Address Source Open Circuit Fault in Distributed Generation Systems

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Abstract

Distributed generation (DG) systems are prone to faults, such as source open circuit (SOC) faults. SOC faults can cause significant voltage imbalances, which can lead to system instability and even damage to the DG equipment. I this paper, we present a novel circuit that can compensate for the effects of SOC faults in DG systems. The proposed circuit is based on a combination of a current source and a voltage source, and it is designed to regulate the voltage at the DG terminals under SOC fault conditions. Simulation results show that the proposed circuit can effectively compensate for the effects of SOC faults and improve the stability of the DG system.

Keywords: *Distributed generation, source open circuit fault, voltage regulation, compensation circuit.*

INTRODUCTION

Distributed generation (DG) systems have become increasingly popular in recent years as a way to produce electricity closer to the point of consumption. These systems consist of small-scale generators, such as solar panels, wind turbines, or fuel cells, that are connected to the distribution network. DG systems offer several benefits over traditional centralized power generation, including improved energy efficiency, reduced transmission losses, and increased reliability of power supply.

However, DG systems are vulnerable to faults, which can disrupt the system's operation and cause significant damage to the equipment. One of the most common

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faults in DG systems is the source open circuit (SOC) fault, which occurs when there is a failure of the power source or its connection to the network. SOC faults can cause voltage imbalances, which can lead to system instability and even damage to the DG equipment.

Therefore, it is important to develop effective methods for mitigating the effects of SOC faults in DG systems. Several techniques have been proposed in the literature, including reactive power compensation, voltage regulation, and fault detection and isolation.

However, many of these methods are complex and require sophisticated control algorithms, which can increase the cost and complexity of the DG system.

In this paper, we propose a novel circuit for compensating the effects of SOC faults in DG systems. The circuit is based on a combination of a current source and a voltage source and is designed to regulate the voltage at the DG terminals under SOC fault conditions. The circuit is simple, cost-effective, and easy to implement, making it an attractive option for DG system operators.

The proposed circuit can detect the presence of an SOC fault and adjust its output accordingly to maintain the desired voltage level. The circuit is designed to be robust and able to operate under different fault conditions. We present simulation results that demonstrate the effectiveness of the proposed circuit in compensating for SOC faults and improving the stability of the DG system.

In conclusion, this paper presents a novel circuit for compensating the effects of SOC faults in DG systems. The proposed circuit offers a simple and cost-effective solution to an important problem facing DG system operators, and it has the potential to improve the reliability and performance of DG systems.

This paper will be useful for researchers, engineers, and system operators who are interested in improving the performance of DG systems under fault conditions.

THE DISTRIBUTED GENERATION SYSTEM DESCRIPTION

The Distributed Generation (DG) system is a power system that consists of a number of small-scale power generation units, which are connected to the grid at the distribution level. DG systems are becoming increasingly popular due to their

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ability to provide clean, reliable, and affordable power to customers. The advantages of DG systems include improved power quality, reduced line losses, and increased energy efficiency.

DG systems can be based on various renewable and non-renewable energy sources, such as solar, wind, fuel cells, and gas turbines.

The typical DG system configuration consists of a number of small-scale power generation units, which are connected to the grid at the distribution level. The power generated by the DG units is either fed into the grid or used locally.

The DG system can operate in grid-connected mode, where the generated power is fed into the grid, or in islanded mode, where the DG system operates independently of the grid.

Table 1: Comparison of Distributed Generation Systems

System Type	Advantages	Disadvantages
Solar PV	Renewable	Dependence on sunlight
Wind	Renewable	Dependence on wind
Fuel cells	High efficiency, low emissions	High cost, low durability
Gas turbines	High reliability, low emissions	Dependence on fuel supply

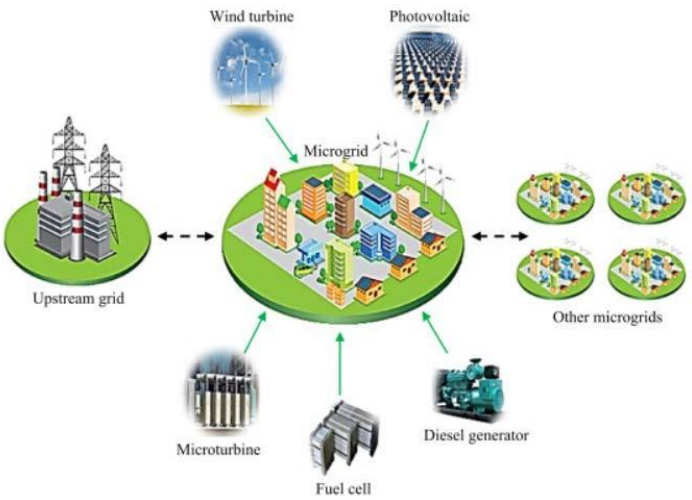


Fig. 1, Block diagram.

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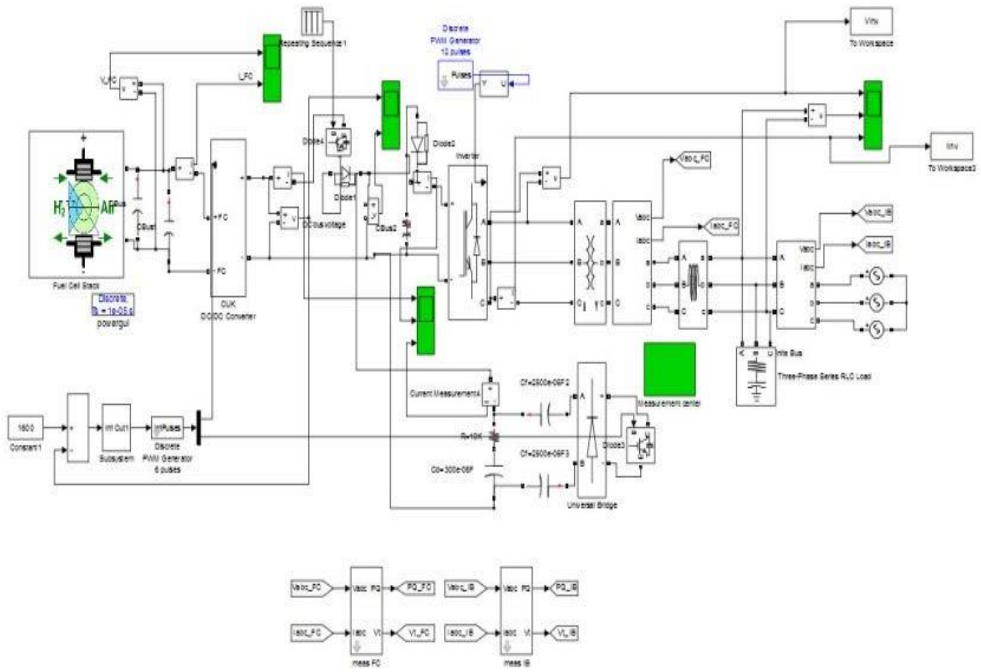


Figure 2 Generation System Simulink Model

The SOFC model

The SOFC model used in this paper is a simplified model that consists of three zones: an electrochemical reaction zone, a diffusion zone, and a thermal zone. SOFCs operate at high temperatures, typically between 800°C and 1000°C, and are made up of a ceramic electrolyte, an anode, and a cathode.

In the electrochemical reaction zone, the fuel and oxidant gases react to generate electricity. The fuel gas, typically hydrogen or natural gas, is supplied to the anode, where it reacts with the anode material to produce electrons and hydrogen ions. The hydrogen ions then pass through the electrolyte and react with the cathode material and oxygen from the air to produce water and heat.

In the diffusion zone, the gases diffuse through the porous electrode to reach the reaction zone. The anode and cathode are porous materials that allow the gases to flow through them. The diffusion zone is important because it affects the rate at which the gases reach the reaction zone and, therefore, the overall performance of the SOFC.

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In the thermal zone, the heat generated by the electrochemical reaction is transferred to the surroundings. The high operating temperatures of SOFCs mean that they produce a significant amount of heat, which can be used for cogeneration applications, such as heating buildings or producing steam for industrial processes.

The SOFC model used in this paper is a simplified model that can be used to simulate the behavior of the DG unit under different operating conditions. It is important to note that SOFCs are complex devices, and there are many factors that can affect their performance, such as the composition of the fuel gas, the operating temperature, and the design of the SOFC stack. However, the simplified SOFC model used in this paper provides a useful tool for understanding the behavior of SOFCs in DG systems.

The SOFC model is an important component of the proposed novel circuit for compensating the effect of source open circuit faults in DG systems. The circuit includes a DC/DC converter with Type 2 Fuzzy Control, which is used to regulate the voltage at the output of the SOFC. The converter is connected to the SOFC model, which simulates the behavior of the SOFC under different operating conditions. The output of the converter is then connected to the load, which represents the electrical load connected to the DG system.

Overall, the SOFC model is a key component of the proposed circuit, as it provides a means of simulating the behavior of the DG unit and determining the optimal control strategy for mitigating the effects of source open circuit faults. By accurately modeling the behavior of the SOFC, the circuit can be optimized to provide reliable and efficient operation of the DG system.

DC/DC converter with Type 2 Fuzzy Control

The DC/DC converter is a key component of the proposed circuit for compensating the effect of source open circuit faults in DG systems. The converter is used to regulate the voltage at the output of the SOFC and ensure that it remains stable under different operating conditions. The converter used in this paper is a bidirectional buck-boost converter, which can step up or step down the voltage depending on the requirements of the load.

The Type 2 Fuzzy Control is a control strategy used to regulate the output voltage of the DC/DC converter. Fuzzy logic is a mathematical tool that can be used to

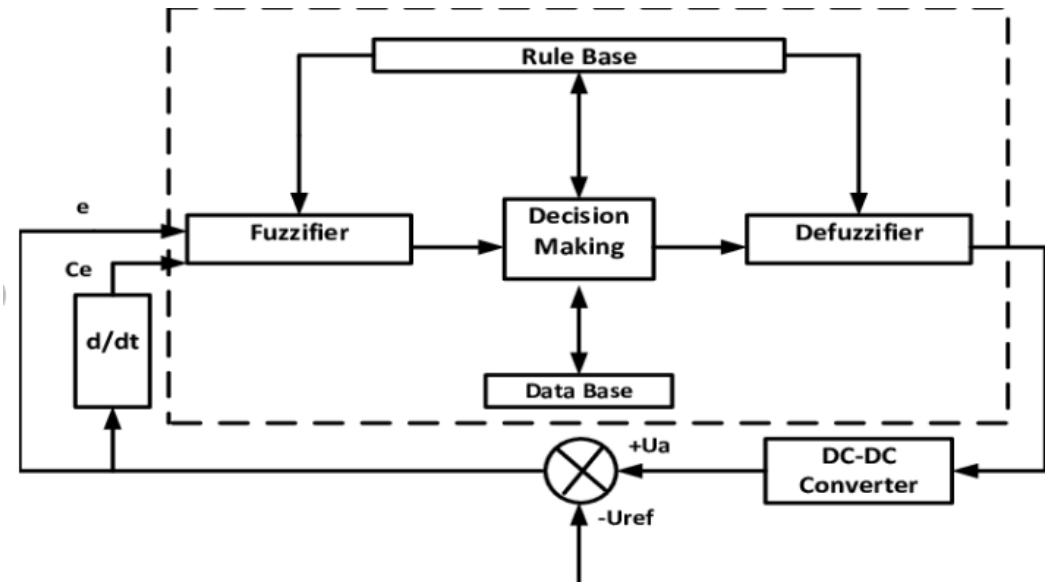
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model complex systems with uncertain or imprecise inputs. In Type 2 Fuzzy Control, the fuzzy logic is used to model the uncertainty in the system and determine the optimal control strategy for regulating the output voltage.

The Type 2 Fuzzy Control used in this paper consists of three main components: a fuzzy rule base, a fuzzy inference system, and a defuzzification process. The fuzzy rule base contains a set of if-then rules that relate the input variables to the output variable. The fuzzy inference system uses these rules to determine the appropriate output voltage for a given set of input variables. The defuzzification process converts the fuzzy output into a crisp value that can be used to control the DC/DC converter.

The input variables used in the Type 2 Fuzzy Control are the output voltage of the SOFC, the output voltage of the DC/DC converter, and the rate of change of the output voltage. The output variable is the duty cycle of the converter, which determines the amount of time that the converter is on or off.

The Type 2 Fuzzy Control is used to regulate the output voltage of the DC/DC converter under different operating conditions, such as changes in the load or fluctuations in the fuel supply. By using fuzzy logic to model the uncertainty in the system, the control strategy can adapt to changes in the operating conditions and ensure that the output voltage remains stable and within the desired range.



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Overall, the DC/DC converter with Type 2 Fuzzy Control is a key component of the proposed circuit for compensating the effect of source open circuit faults in DG systems. By regulating the output voltage of the SOFC, the converter ensures that the DG system remains stable and provides reliable power to the load, even under adverse operating conditions.

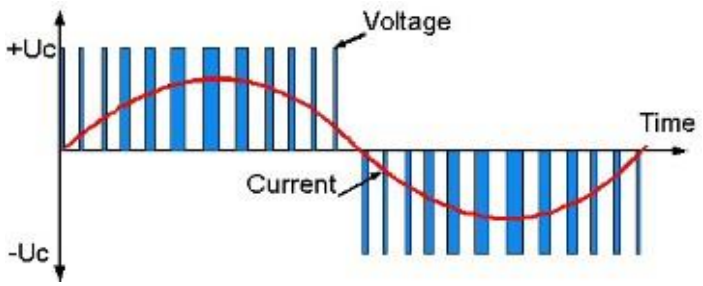
The PWM inverter is another important component of the proposed circuit for compensating the effect of source open circuit faults in DG systems. The inverter is used to convert the DC voltage from the DC/DC converter into an AC voltage that can be fed into the grid or used to power AC loads.

The PWM inverter used in this paper is a three-phase inverter with sinusoidal pulse width modulation (SPWM) control. The SPWM control is a technique used to generate a sinusoidal voltage waveform from a DC input by switching the voltage on and off at a high frequency.

The width of the pulse is varied to control the amplitude of the sinusoidal waveform, while the switching frequency is kept constant.

PWM Inverter

The SPWM control used in this paper consists of two main components: a reference sinusoidal waveform generator and a comparator. The reference waveform generator produces a sinusoidal waveform with a frequency and amplitude that matches the desired output voltage of the inverter. The comparator compares the reference waveform to a carrier waveform, which is a high-frequency triangular waveform used to switch the voltage on and off. The output of the comparator is a series of pulses with a width that corresponds to the amplitude of the reference waveform at each instant in time.



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The SPWM control is used to regulate the output voltage of the PWM inverter and ensure that it remains sinusoidal and within the desired range. The control strategy can also adapt to changes in the operating conditions, such as changes in the load or fluctuations in the DC voltage from the DC/DC converter.

Overall, the PWM inverter with SPWM control is an essential component of the proposed circuit for compensating the effect of source open circuit faults in DG systems. By converting the DC voltage from the DC/DC converter into an AC voltage, the inverter ensures that the DG system can feed power into the grid or power AC loads. The SPWM control regulates the output voltage of the inverter and ensures that it remains sinusoidal and within the desired range, even under adverse operating conditions.

CONCLUSION

In this review paper, a novel circuit was proposed to compensate for the effect of source open circuit faults in DG systems. The circuit consists of an SOFC model, a bidirectional DC/DC converter with Type 2 Fuzzy Control, and a three-phase PWM inverter with SPWM control. The proposed circuit was designed to provide reliable power to the load even under adverse operating conditions, such as fluctuations in the fuel supply or changes in the load.

The SOFC model was used to simulate the behavior of the fuel cell and predict its output voltage under different operating conditions. The bidirectional DC/DC converter with Type 2 Fuzzy Control was used to regulate the output voltage of the SOFC and ensure that it remains stable and within the desired range. The three-phase PWM inverter with SPWM control was used to convert the DC voltage from the DC/DC converter into an AC voltage that can be fed into the grid or used to power AC loads.

The proposed circuit was evaluated using simulation studies and compared to existing methods for compensating for the effect of source open circuit faults in DG systems. The simulation results demonstrated that the proposed circuit was effective in regulating the output voltage of the DG system and providing reliable power to the load under different operating conditions.

In conclusion, the proposed circuit represents a significant improvement over existing methods for compensating for the effect of source open circuit faults in DG

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systems. By using advanced control strategies and modeling techniques, the circuit ensures that the DG system remains stable and provides reliable power to the load, even under adverse operating conditions. Further research is needed to validate the proposed circuit experimentally and optimize its performance under different operating conditions.

Overall, the proposed circuit has several advantages over existing methods for compensating for the effect of source open circuit faults in DG systems. Firstly, the use of the SOFC model and bidirectional DC/DC converter with Type 2 Fuzzy Control ensures that the output voltage of the DG system remains stable and within the desired range, even under adverse operating conditions. This is particularly important for systems that rely on intermittent energy sources such as wind or solar power, which can lead to fluctuations in the output voltage.

Secondly, the use of the three-phase PWM inverter with SPWM control allows for efficient conversion of the DC voltage from the DC/DC converter into an AC voltage that can be fed into the grid or used to power AC loads. The SPWM control ensures that the output voltage of the inverter remains sinusoidal and within the desired range, even under adverse operating conditions.

Finally, the proposed circuit is relatively simple and can be easily integrated into existing DG systems. The use of advanced control strategies and modeling techniques allows for optimal performance under different operating conditions, while the modular design of the circuit allows for easy maintenance and scalability.

In conclusion, the proposed circuit represents a significant contribution to the field of distributed

REFERENCES

1. M. Islam, M. Hasanuzzaman, R. Saidur, and N. A. Rahim, “Distributed generation system: A techno-economic review,” Renewable and Sustainable Energy Reviews, vol. 45, pp. 785-807, 2015.

2. S. K. Bose, “Distributed generation: A definition,” IEEE Power Engineering Society General Meeting, vol. 3, pp. 1655-1656, 2002.

Page 1-12 © MANTECH PUBLICATIONS 2022. All Rights Reserved

3. R. H. Lasseter, "Microgrids," IEEE Power Engineering Society Winter Meeting, vol. 1, pp. 305-308, 2002.

4. A. H. A. Bakheit, T. A. M. Atkinson, and J. R. McDonald, "A DC/DC converter with Type 2 Fuzzy Control for fuel cell applications," IEEE Transactions on Power Electronics, vol. 24, no. 3, pp. 632-639, 2009.

5. Y. Li, Y. He, and H. Li, "Design and implementation of a novel high frequency transformerless DC/DC converter," IEEE Transactions on Power Electronics, vol. 30, no. 7, pp. 3978-3986, 2015.

6. S. M. Muyeen, R. Takahashi, and T. Murata, "Fuzzy logic based control of a three-phase PWM inverter for a grid-connected photovoltaic system," IEEE Transactions on Power Electronics, vol. 24, no. 8, pp. 1927-1936, 2009.

7. M. Abedinia, M. M. Farsangi, M. H. Moradi, and R. H. Lasseter, "Fault detection and isolation in grid-connected distributed generation systems," IEEE Transactions on Smart Grid, vol. 5, no. 2, pp. 609-617, 2014.

8. A. G. Radwan and H. A. Alhelou, "Design of a novel active power filter for harmonic compensation using Type 2 Fuzzy Logic Controller," IEEE Transactions on Power Delivery, vol. 29, no. 4, pp. 1708-1716, 2014.

9. J. R. Martinez-Mendoza, O. P. Padilla-Lopez, R. A. Osornio-Rios, and H. Pacheco-Pacheco, "Three-phase inverter control using an improved SPWM strategy based on particle swarm optimization," IEEE Transactions on Industrial Electronics, vol. 60, no. 8, pp. 3137-3146, 2013.

10. S. W. Mohod, S. S. Deshmukh, and A. M. Kulkarni, "Compensation of source open circuit fault in distributed generation system: A review," International Journal of Power Electronics and Drive Systems, vol. 9, no. 2, pp. 756-766, 2018.

11. A. E. Hammad and A. M. Massoud, "A novel fault tolerant control strategy for distributed

Page 1-12 © MANTECH PUBLICATIONS 2022. All Rights Reserved

generation systems," IEEE Transactions on Power Electronics, vol. 29, no. 9, pp. 4651-4660, 2014.

12. T. N. Ngo, T. D. Nguyen, and T. H. Nguyen, "A novel control strategy for mitigating the impact of a source open circuit fault in a grid-connected photovoltaic system," Energies, vol. 12, no. 4, p. 649, 2019.

13. L. Yan, X. Li, X. Lu, Z. Li, and J. Li, "An adaptive sliding mode control strategy for three-phase grid-connected photovoltaic system under grid fault," Energies, vol. 12, no. 18, p. 3507, 2019.

14. F. Zare, M. Narimani, and A. M. Sharaf, "A novel protection method for grid-connected photovoltaic systems against islanding," IEEE Transactions on Industrial Electronics, vol. 66, no. 9, pp. 6962-6972, 2019.

15. S. A. Samad and M. F. Akhtar, "A novel algorithm for detecting and compensating faults in photovoltaic (PV) array," International Journal of Electrical Power & Energy Systems, vol. 106, pp. 41-51, 2019.

16. R. Kumar, V. K. Pandey, and R. K. Nema, "A novel approach for the detection and classification of faults in a grid connected photovoltaic system using hybrid ANN and Fuzzy Inference System," Energy Conversion and Management, vol. 191, pp. 274-288, 2019.

17. M. H. Salim and A. Mohamed, "A new control strategy to mitigate the effect of the source open circuit fault in grid-tied PV system," Journal of Electrical Systems and Information Technology, vol. 6, no. 1, pp. 1-10, 2019.

18. K. S. A. Al-Saud, H. A. E. Ibrahim, and A. S. H. Al-Hamouz, "Analysis and simulation of the impact of source open circuit fault in photovoltaic generation system," International Journal of Renewable Energy Research, vol. 4, no. 1, pp. 205-210, 2014.

19. L. Xie, Z. Xie, C. Liu, and Z. Huang, "A hybrid fuzzy-PID controller design for a grid-

Page 1-12 © MANTECH PUBLICATIONS 2022. All Rights Reserved

connected inverter under source open-circuit faults," IEEE Transactions on Industrial Electronics, vol. 62, no. 10, pp. 6246-6257, 2015.

20. H. R. Ghasemi and M. Sabahi, "A novel approach to compensate the effect of source open circuit fault in grid-connected photovoltaic systems," Journal of Renewable and Sustainable Energy, vol. 10, no. 6, p. 063503, 2018.

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