Short-Circuit Protection for DC Microgrids and Power Converters

Thesis submitted in partial fulfillment of

the requirements for the degree of

Master of Science

by

Siddhant Kumar

Enrollment No. S18024

under the supervision of

Dr. Bharat Singh Rajpurohit

School of Computing and Electrical Engineering

Indian Institute of Technology Mandi
Kamand, Himachal Pradesh-175075, India

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Dedicated

To My Parents

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Declaration by the Research Scholar

I hereby declare that the entire work embodied in this Thesis is the result of investigations carried out by me at the **School of Computing and Electrical Engineering,** Indian Institute of Technology Mandi, India, under the supervision of **Dr. Bharat Singh Rajpurohit,** and that it has not been submitted elsewhere for any degree or diploma. In keeping with the general practice, due acknowledgements have been made wherever the work described is based on finding of other investigators.

Place: IIT Mandi
Date: 09-Feb-2021

Signature: 
Name: Siddhant Kumar

Declaration by the Research Advisor

I hereby certify that the entire work in this Thesis has been carried out by **Siddhant Kumar,** under my supervision at the **School of Computing and Electrical Engineering**, Indian Institute of Technology Mandi, India, and that no part of it has been submitted elsewhere for any Degree or Diploma.

Signature:
Name of the Guide: Dr. Bharat Singh Rajpurohit

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Siddhant Kumar

ABSTRACT

A DC Microgrid is an interconnection of distributed energy generation sources, energy storage banks, and loads. Usually, interconnection is carried out by DC busses through various power converters. Whereas distributed energy sources are regarded as renewable energy sources such as wind turbines, photovoltaic. In some applications, DC power grids are interconnected to utility or AC grid also. The power electronics interface at each node provides a robust response and additional controllability among the sources and loads. A significant advantage of these converters can be referred at the time of load shedding.

The DC Microgrid fault protection is one of the critical challenges for its widespread adaptation. The short-circuit (SC) faults are frequent faults in the industries and other DC microgrid applications. The SC leads to a current overshoot that damages the circuit components connected through the network. Usually, overshoot fault currents are SC detection parameters whereas, it is observed that variable SC fault current level is one of the critical challenges for its detection. The different conditions and modes (grid-connected or islanded mode) of operation lead to different SC peak fault current levels. Therefore, SC's current limitation and protection are challenging.

In DC systems, there are two basic types of faults reported in the literature. These are—(i) Line-to-Line fault, and (ii) Line-to-Ground Fault. These faults can occur at various nodes and points, therefore, fault at distinct points have a different impact on the system. Thus, while developing the fault protection scheme, it is very important to identify and consider all the fault possibilities and incorporate them into the protection algorithm. Apart from the DC bus faults, literature also reports the faults due to power converter/component failure during mission. The semiconductor components and capacitors are the most fault-prone components. Out of all the circuit components, semiconductor switches are the most fragile in the power converters contributing 30-35% of converter faults. Its failure is random in nature. The converter component fault (open-circuit and short-circuit) interrupts DC bus voltage level. To address this issue, several fault-tolerant converter schemes are proposed in the literature to increase the reliability.

In this research work, SC fault protection and fault-tolerant schemes are reviewed, and new SC fault protection and fault-tolerant approaches are addressed based on the converter output

voltage (bus) characteristics. The proposed approaches are implemented on boost converter. The SC fault protection approach isolates the power source from the voltage source converter connected to the DC bus if SC fault is identified at the DC bus or within the converter. On the other hand, the fault-tolerant approach provides the continuous output power if the switching action (power switch) fails while operating. The proposed SC fault protection and fault-tolerant approaches can find their application at low to medium scale DC microgrids.

Keywords— circuit reconfiguration, DC Microgrids, Faults, Fault-tolerant converter, Open-circuit fault, Protection, Reliability, short-circuit fault, short-circuit current, short-circuit protection.

Table of Contents

Abstract **i**

List of Figures **iv**

List of Tables **vi**

List of Symbols **vii**

List of Abbreviations **viii**

1. Introduction **1**

1.1 DC Microgrid 1

1.2 Types of DC Microgrid 2

1.2.1 Single-bus topology DC Microgrid 2

1.2.2 Multi-bus microgrids 3

1.2.3 Reconfigurable microgrids 4

1.3 Types of Faults and its Impact 5

1.4 DC Microgrid Protections 5

1.5 Objective of Thesis 7

1.6 Thesis Outline and Contribution 9

2. Short-Circuit Protection **10**

2.1 Introduction 10

2.2 Protection Scheme Structure 11

2.3 Computation of SC current limit and isolation time 12

2.3.1 Short-Circuit fault Identification 12

2.3.2 Short-Circuit Fault Detection 14

2.3.3 Short-Circuit Peak Input Current 16

2.4 Simulation Results 17

2.5 Experimental Results 18

2.6 Conclusion 25

3. Power Converter Fault Protection for Continuous Power Supply **26**

3.1 Introduction 26

3.2 Power Converter Reliability 27

3.2.1 Failure Rate 27

3.2.2 Mean Time to Failure 29

3.2.3 Mean Time Between Failure 30

3.3 Fault Tolerant DC-DC Converters 30

3.3.1 Fault Diagnosis 34
3.4 Proposed Switch Fault Protection Scheme 36
3.4.1 Operation of Proposed Scheme 36
3.4.2 Operation Under Normal Condition 38
3.4.3 Operation Under Faulty Condition 39
3.5 Simulation Results 41
3.6 Conclusion 45
4. Conclusion and Future Prospective 46
4.1 Summary & Conclusions 46
4.2 Recommendation for Future Work 47
References 48
List of Publication 51
Curriculum Vitae 52