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DESIGNING OF CONTROL AND ADAPTIVE PROTECTION ARCHITECTURE FOR MICROGRID CLUSTERING IN A RING-CONNECTED DISTRIBUTION FEEDER

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Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree
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DECLARATION

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 23/01/2026

The above candidate has carried out research for the PhD thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Prof. L. N. W. Arachchige

Signature of the Supervisor: Date: 23/01/2026

DEDICATION

This thesis is dedicated to my mother, and my father for their endless love and support

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ABSTRACT

A ring-connected microgrid cluster can increase the reliability in operation and effectively reduce the problems in the distribution network such as voltage rise, harmonics, and poor power factor. This research is focused on addressing the inherent challenges associated with ring-connected microgrid clusters with several grid in-feeders. Challenges include, the complex protection design requirements and energy management with possible system topology changes under contingencies, and synchronization with several grid in-feeders. In this thesis, a ring-connected microgrid cluster with four microgrids is derived based on a real distribution feeder model in Sri Lanka to improve resilience and reliability. A two-level energy management system (EMS) is designed to harness maximum renewable energy generation, maintenance of the state of charge (SOC) levels at effective levels, and minimize the usage of diesel engines. A coordinated control algorithm is used to maintain the stable operation of the system. A local synchronization algorithm is proposed for each microgrid to transit from islanded operation to grid-connected operation. The behavior of the proposed system under different contingencies are analyzed. Thesis contributes by designing a reliable protection scheme integrating an intelligent fault detection and localizing scheme based on pattern classification of transient characteristics of current and voltage signals. Simulation-based case studies assert that ring operation increases the utilization of renewable power generation while reducing the operation of diesel generators. Analysis confirms ring networked operation maintains the voltage and frequency profile of microgrids within limits specified in IEEE 1547-2018 as designed, while improving the resilience and reliability level compared to the radial operation. The proposed protection technique has accurate, fast, and intelligent fault detection capability compared to the existing protection schemes applied in microgrid clusters. Possible improvements to the current control and protection technologies and future directions for research, which could enhance the protection of ring-connected microgrid clusters, are also outlined in this thesis.

Keywords: energy management, microgrid cluster, protection, reliability, solar PV

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LIST OF ABBREVIATIONS

Abbreviation	Description
MG	Microgrid
SW	Power electronic switch
DG	Distributed generation
RES	Renewable energy source
PV	Photovoltaic
EV	Electric vehicle
ESS	Energy storage system
DWT	Discrete wavelet transform
ANN	Artificial neural network
CNN	Convolution neural network
CB	Circuit breaker
FTT	Fast fourier transform
STFT	Short time fourier transform
WT	Wavelet transform
SVM	Support vector machine
MMC	Modular multilevel converter
NASA	National Aeronautics and Space Administration
RMS	Root mean square
EMT	Electromagnetic transient
VRT	Voltage ride through
LVRT	Low voltage ride through
J	Moment of inertia
DP	Damping factor
EMT	Electromagnetic transient
FCL	Fault current limiter
SSCB	Solid state circuit breaker
VSC	Voltage source converter

MPPT	Maximum power point tracker
SOC	State of charge
BEMS	Battery management system
WE	Wavelet energy

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