Digitisation revolutionised intelligent gate drives for power semiconductor devices

Highlights

- Extending the longevity and improving the efficiency of high voltage power IGBT modules by suppressing their catastrophic failures
- Devising and implementing intelligent gate drive to enable smart grid-connected power converter
- Determining the underlying relationship between common wear-out failures and the strength reduction of power semiconductor modules

Overview

The global energy demand is growing rapidly and due to the continuous urbanization large distances must be bridged to ensure a supply of electricity from sources that are normally located in remote and resource-abundant areas. High Voltage Direct Current Transmission (HVDC) has superior energy efficiency over Alternating Current overhead lines given the same width of the cable run. The power and energy flow through HVDC systems can be flexibly and accurately controlled thanks to the ever-advanced power semiconductor devices, which are the key components in power converters. The High-Voltage (HV) Insulated Gate Bipolar Transistors (IGBTs) are typical power devices used for HVDC carrying superior characteristics and high power handling capability. This PhD research is concerned with the Advanced Gate Drives (AGDs) of IGBT modules ensuring improvements of performance and reliability under both healthy and accelerated aged conditions. This will enable reliable, cheap and clean energy and power transmission systems to address the global energy challenge.

AGDs are a convergence of sensors, processors, and software to improve efficiency, safety and ultimately deliver software-defined power processing capability. Most of conventional gate drives (CGDs) today use elementary protection functions to ensure the field robustness of an IGBT that have already made measurable impact. Still, large amount of IGBT field failures are reported whose gate drives are accused of ineffectiveness of protection. Moreover, CGDs are constrained to control freedom which prevent the potential of IGBT being fully released.

The overall objective of this research to extend the longevity and improve efficiency of an IGBT power modules by suppressing their catastrophic failures and improving through-life resilience using AGDs featuring reinforced signal processing, adaptive control and connectivity. AGDs can regulate the loading/stress conditions of the IGBT operating in a different load points in a HVDC converter, as shown in Figure (a) that is captured from a power semiconductor test rig (Figure (b)). Power semiconductor modules normally comprise multiple functionally identical dies in parallel.
which are subject to uneven stresses in practice. Commonly observed wear-out failures such as bond wire lift-off, solder layer fatigue, oxide degradation, dielectric failure of silicone gel, etc degrade their performance in both functional characteristics and robustness. The exaggerated local stress, especially under extreme conditions such as short-circuit will lead to abrupt failures. Results shown in Figure (c), (d) and (e) indicate that inhomogeneous stress continue to aggravate along with the evolution of bond wire aging. This research aims to contribute to the existing ‘Press-Pack China-UK’ industrial project jointly undertaken with Dalian University of Technology (China). The PhD research derives from the supervisors’ completed/existing projects including EPSRC feasibility study project and KTP project with Alstom Grid (Now GE), which was fueled by the cohesive academia-industry partnership as reported by “The Journal”, 2020 Vision.

Methodology

The overarching aim of the PhD research project is to devise a health status tracking method and an adaptive health management system that can be integrated in the active gate drivers. The proposed research comprises of five main activities as detailed below:

- Constructing knowledge base regarding the IGBTs and their control fundamentals in a HVDC application.
- To design a non-destructive test circuit for the evaluation of device switching performance under nominal and extreme conditions.
- Generate specified wear-out failures using accelerated aging test in order to understand the safe operating area implications.
- To identify the AGD response to post-aging conditions and evaluate control algorithms to address safety margin reduction at the presence of wear-out failures
- Devise the condition monitoring method and a health status tracking system that can be integrated in the active gate drivers.

Further Reading

Funding

This research project is one of a number of projects in the Department. It is in competition for funding with one or more of these projects. Usually the project which receives the best applicant will be awarded the funding.

Home/EU Applicants
This project is eligible for a fully funded College of Science and Engineering studentship which includes:

- A full UK/EU fee waiver for 3.5 years
- An annual tax free stipend of £14,777 (2018/19)
- Research Training Support Grant (RTSG)

International Applicants
This project is eligible for a fully funded College of Science and Engineering studentship which includes:

- A full international fee waiver for 3.5 years
- Research Training Support Grant (RTSG)

Application Instructions

The online application and supporting documents are due by Monday 21st January 2019.

Any applications submitted after the deadline will not be accepted for the studentship scheme.

References should arrive no later than Monday 28th January 2019.

Applicants are advised to apply well in advance of the deadline, so that we can let you know if anything is missing from your application.

Required Materials

1. Online application form
2. Two academic references
3. Transcripts
4. Degree certificate/s (if awarded)
5. Curriculum Vitae
6. CSE Studentship Form
7. English language qualification

Applications which are not complete by the deadline will not be considered for the studentship scheme. It is the responsibility of the applicant to ensure the application form and documents are received by the relevant deadlines.

All applications must be submitted online, along with the supporting documents as per the instructions on the website.

Please ensure that all email addresses, for yourself and your referees, are correct on the application form.
For more information, please visit our website at:
https://www2.le.ac.uk/colleges/scien/research/postgraduate-opportunities/cse-2019/instructions