

<b>Institution: Glasgow Caledonian University</b>
<b>Unit of Assessment: 15 General Engineering</b>
<b>Title of case study: Improving Asset Management of High Voltage Equipment</b>
<p><b>1. Summary of the impact</b> (indicative maximum 100 words)</p> <p>Condition monitoring instrumentation for high voltage plant has been developed at GCU under contract research for Doble Engineering (Headquarters in MA, USA), a global service provider for the electric power industry. The instruments are an important new line of products for Doble providing increased sales revenue and service provision. The instruments have been widely adopted by Doble's global client base to provide improved asset management. Other beneficiaries of the work include global contract electronic manufacturing companies. In 2012 Doble invested £1.2 million in an Innovation Centre at GCU to support their product development road map.</p>
<p><b>2. Underpinning research</b> (indicative maximum 500 words)</p> <p>An EPSRC funded research project [1] secured by Professor B G Stewart at Glasgow Caledonian University to investigate partial discharge (PD) measurements for electrical testing forms the research work which underpins this case study. The EPSRC project built upon earlier research at GCU by Dr I J Kemp and the University's high voltage research group into the measurement and analysis of PD signals as a diagnostic tool to assess the condition of high voltage insulation. Monitoring the severity of PD in high voltage equipment provides an indication of the insulation condition of the equipment, so that potential failure can be assessed and strategic planned outages undertaken for maintenance.</p> <p>This aim of the EPSRC research grant, titled "A new approach to partial discharge measurements for testing electrical insulation systems", was to investigate, characterize and correlate the relationships between radio frequency (RF) PD emissions and conventional PD IEC60270 Standard apparent charge measurements to enable improved identification and assessment of PD faults.</p> <p>The research focused on investigating and classifying the relationships and correlations between current pulse IEC60270 measurements and RF emissions for a number of well-established and frequently occurring fault geometries within HV insulation systems [e.g. 2-4]. The overall aim was to provide a more fundamental understanding of the physical mechanisms and nature of RF emissions arising from electrical insulation breakdown from fault conditions in order to improve the assessment and reliability of PD fault determination in operational high voltage equipment.</p> <p>The research demonstrated that it was possible to characterize fault types and fault mechanisms using a simultaneous combined IEC60270 apparent charge and RF measurement system. It showed clearly that there were similarities and differences between radiated emission diagnostic patterns and apparent charge diagnostic patterns (e.g. phi-q-n patterns) and that RF emission patterns existed across a wide range of frequency bands. Further, the research also demonstrated that different radiated frequency band characteristics from around 100MHz up to and beyond 1 GHz could be specifically associated with different insulation fault types, and that these distinctive RF broadband frequency bands may change dependent on the fault type and the severity of the discharge activity. The work also led to recommendations to augment the IEC60270 standard to include RF emissions as an additional method for PD assessment [5] and thus improve or supplement the IEC60270 capabilities. The research work also produced a novel severity metric which determines the discharge activity as a function of the apparent charge [6]. The results and knowledge from the research was disseminated through publications in Journals and also flagship industrial conferences on HV insulation.</p> <p>This research provided the background framework to directly inform the design and development of unique PD RF emission measurement instruments, described below, which operate up to 1GHz and which are capable of measuring PD activity and providing PD fault characteristics within HV</p>

environments.

### 3. References to the research (indicative maximum of six references)

- (1) Prof B Stewart, "A new approach to partial discharge measurements for testing electrical insulation systems" EPSRC, 2003. £109,667 (A joint grant with University of Strathclyde, Total £240k)
- (2) A J Reid, M D Judd, B G Stewart and R A Fouracre, "Partial Discharge Current Pulses and the Effect of Superposition of their Radiometric Measurement", J. Phys. D: Appl. Phys. Vol. 39, No. 19, pp. 4167 – 4177, 2006
- (3) A J Reid, M D Judd, R A Fouracre, B G Stewart and D M Hepburn, "Simultaneous Measurement of Partial Discharge using IEC60270 and Radio-Frequency Techniques", IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 18, Issue 2, pp. 444-455, April 2011
- (4) A J Reid, M D Judd, R A Fouracre, B G Stewart and D M Hepburn, "Identification of simultaneously active partial discharge sources using combined radio frequency and IEC60270 measurement", IET Journal of Sci. Meas. and Technol., Vol. 5 (3), pp. 102–108, 2011
- (5) B G Stewart, M D Judd, A J Reid and R A Fouracre, "Suggestions to Augment the IEC60270 Partial Discharge Standard in Relation to Radiated Electromagnetic Energy", Proceedings of the 28<sup>th</sup> Electrical Insulation Conference (EIC2007) and Electrical Manufacturing Expo, pp.112-115, 2007
- (6) B G Stewart, L Yang, M D Judd, A Reed and R A Fouracre, "A Simple Metric for Assessing the Severity of Partial Discharge Activity Based on Time-Sequence-Analysis-Discharge Level Patterns", Transactions on Electrical and Electronic Materials, KIEEME, Vol. 7, No. 6, pp. 313-318, 2006

### 4. Details of the impact (indicative maximum 750 words)

Impact from the Underpinning Research have been achieved through the deliverables of an industrial research and development contract with Doble Engineering [1], a global company that delivers diagnostic test instruments and knowledge services for the electrical power industry. To date, the contract has developed and delivered three new condition monitoring products, the PDS100, which Doble launched in 2010, and the DFA500 and DFA300, launched October 2013 [2].

The research impact has provided 1) increased revenue for Doble through product sales and service provision, 2) improved condition based maintenance for global power utilities resulting in a reduction in operational and safety risk, and 3) increased revenue for contract manufacturing companies based in UK and Norway.

Doble Engineering became aware of the research and the specific knowledge and expertise resulting from the EPSRC project through a technology evaluation of condition monitoring research within UK Universities and companies that was carried out at National Grid. For GCU, Doble Engineering provided an ideal channel to maximise the extent and scope of the research impact due to their global distribution and support service in over 110 countries.

The research and development contract was established with Doble in 2008 with the objective of developing innovative condition monitoring instruments based on the Underpinning Research carried out at GCU. The PDS100, launched 2010, is a handheld surveillance tool for the detection of RF emissions arising from electrical insulation breakdown. The PDS100 provides an easy and

cost effective method to carry out a complete survey of the levels of partial discharge (PD) within a substation and into identify apparatus at risk of failure. The DFA 300 and DFA500 are the world's first portable acoustic analyzers that combine acoustic and RF sensing for Gas Insulated Substations.

The Underpinning Research, described in section 2, provided the knowledge for the design of the hardware platform, the software algorithms, and the application software of the PDS100, DFA500 and DFA300. The signal analysis implemented in the PDS100 resulted in Doble submitting a US patent in 2008 [3] with GCU and Doble as co-inventors.

The main benefit to Doble Engineering from the launch of the instruments has been financial through an increase in revenue from product sales and leasing and increased service provision to clients. Due to commercial confidentiality Doble are not able to provide any financial information relating to the product sales or service provision.

However, the value of the impact to Doble may be demonstrated through their on-going investment in Glasgow Caledonian University and in December 2012 Doble signed a three year strategic research partnership and invested £1.2 million in an Innovation Centre at GCU [4] *"GCU is the key research and development partner in Doble's Innovation Center for On-line Systems (ICOS).... providing key new technologies and know how to Doble that result in state of the art products and solutions reaching customers throughout the global electric power industry."* [5] In addition to the direct investment in GCU, Doble has started recruiting engineers for a new office in Glasgow that will work closely with the Innovation Centre at GCU and support New Product Development and Introduction.

The PDS100 has been widely adopted by the global client base of Doble, examples of whom include National Grid (UK), Polaris Diagnostics & Engineering (UK), ESBI (Ireland), ELIA (Belgium), Shell/Cofely Refinery (Netherlands), Israel Electric Corporation (Israel), Qatalum Aluminium Smeltery (Qatar), ESKOM (South Africa), Fingrid (Finland), NewPower Diagnostics (Australia) [6], Precision Engineering Services (Pakistan), and American Transmission Company (USA). A transformer specialist provided the following statement: *"Use of the PDS100, in partial discharge detection, is a significant development in the diagnostic tool box and provides considerable cost saving in reducing the requirement for system outages and the installation of expensive in-situ sensors."* [7].

In addition to creating impact through new product development, GCU has also worked with Doble in the development of the surveillance methodologies and best working practices disseminated through articles in the international trade press [8], presentations at Doble Client Conferences and a series of international workshops that have trained engineers in power utilities that have been provided by GCU on behalf of Doble.

The research impact has also resulted in significant financial benefits to a number of electronic assembly companies that Doble have used for the outsourced manufacturing of the instruments including Kelvinside Electronics (KEL) [9] in the UK and others in Europe. Due to commercial confidentiality Doble have requested that the financial impact of these contracts remains confidential.

##### 5. Sources to corroborate the impact (indicative maximum of 10 references)

[1] McMeekin S, Nesbitt A, and Stewart B. "Development of HV Condition Monitoring Systems" Doble Engineering, 2008 to 2012. £1.2 million. Funded by Doble TransiNor.

[2] Doble Marketing material for PDS 100 & DFA 500  
[http://www.doble.com/parts/files/PDS100\\_withAccessories\\_Brochure\\_A4\\_LR\(1\).pdf](http://www.doble.com/parts/files/PDS100_withAccessories_Brochure_A4_LR(1).pdf) &  
<http://www.doble.com/products/dfa500.html>

## Impact case study (REF3b)

- [3] "Method and Device for Improved Detection and Analysis of Partial Discharge Activity In and Around High Voltage Electrical Equipment" McMeekin, Scott; Stewart, Brian; Conner, Stephen; Gamio, Carlos; Nesbit, Alan Filing Date 24th March 2010, Application No. WO 2010/111334 A1.
- [4] Press Release for launch of Doble Center for Innovation at CGU,  
[http://www.doble.com/news/pr\\_ext.html/view\\_ext/862/nohead](http://www.doble.com/news/pr_ext.html/view_ext/862/nohead) (accessed 1/11/2013)
- [5] VP Global Engineering & Operations. Doble Engineering Company, Worldwide Headquarters, 85 Walnut Street, Watertown, MA 02472 USA, Tel: +1 617 393 2915
- [6] NewPower Diagnostics Services, On Line Services Brochure:  
<http://www.newpowerdiagnostics.com.au/sites/default/files/Online%20scanning%20brochure.pdf>
- [7] Technical Director, Polaris Diagnostics & Engineering, 6 Tain Terrace, West Craigs, Glasgow, G72 0GD. Tel: 07530 827912
- [8] "Partial discharge detection using RFI measurements", Kamendren Govender, Luwendran Moodley (Doble) and Alan Nesbitt (GCU). Energize, South Africa, April 2010 pg 26-28.  
([http://eepublishers.co.za/images/upload/Energize%20%202010/01\\_TT\\_01\\_PartialDischarge.pdf](http://eepublishers.co.za/images/upload/Energize%20%202010/01_TT_01_PartialDischarge.pdf))
- [9] Sales Manager, Kelvininside Electronics Ltd. 2 Gavell Road, Kilsyth, Glasgow, G65 9BS, Tel: 01236-824433.