Institution: University of East London

Unit of Assessment: 15

Title of case study: Enhanced Performance of Permanent Magnet Synchronous Motors, Reduced Manufacturing Material and Time to Production

1. Summary of the impact

Research conducted since July 2008 by the University of East London in collaboration with Control Techniques Dynamics (CTD), a leading manufacturer of Permanent Magnet Synchronous Motors (PMSMs), has led to the development of a software tool called the PMSM analyser. This tool has helped CTD to improve its motor design methodology by incorporating electromagnetic, thermal and cost models, together with genetic algorithms. In turn, the design optimisation allowed CTD to enhance motor performance and reduce manufacturing time by 30-40%, leading to an increase of 20% in company sales between 2008 and 2013. During the same period the company was able to cut materials usage by 15%.

2. Underpinning research

Research underpinning the impacts described here was conducted in two phases between 2008 and 2013 by academic staff at the University of East London, working in collaboration with researchers from Control Techniques Dynamics (CTD). Based in Andover, Hampshire, CTD is a leading manufacturer of permanent magnet synchronous motors (PMSMs) and a division of Emerson Industrial Automation, USA.

The research conducted with CTD focussed on the development of a multi-criteria PMSM design optimisation technique. To that end, an employee of CTD, Gunaratnam Sooriyakumar, worked between 2008 and 2010 with Roy Perryman (Ford Professor at UEL between 1995 and 2012 and expert on design of electric machines) and Stephen Dodds (Emeritus Professor of Control Engineering, member of UEL staff since 1986 and expert on control technique of electric drives) within UEL's Communications, Control and Electrical Power research group to improve the design of Permanent Magnet Synchronous Motors (PMSMs). The research problem was identified through discussions between the three researchers during the 42nd International Universities Power Engineering Conference in Brighton, UK in 2007.

This research on PMSMs, which began in 2008, culminated in the development of a new and more efficient design methodology for the specification and development of high torque to inertia (and thereby high acceleration and deceleration) criteria. In 2009 the software tool PMSM analyser was developed by the UEL/CTD research team to enhance the motor design methodology by integrating and interfacing genetic optimisation algorithms and the electromagnetic, thermal and cost models.

This resulted in an optimisation rate of stall torque per unit cost of 7% in comparison with standard designs, allowing a reduction of around 15% in materials usage. In addition, a new position controller for vector controlled electric drives employing permanent magnet synchronous motors (PMSM) was developed, achieving approximately 27% less frictional energy loss than a conventional controller adjusted to give the same manoeuvre time for the same initial and final positions. These outcomes were published in [1] and [2]. A major advantage of the new methodology is that it not only reduces the time taken to complete a

design by 30-40%, but also achieves a much better design.

The collaboration between UEL and CTD continued in 2009, when Perryman and Dodds were joined by Dr Wada Hosny (Principal Lecturer, at UEL since 1985) and Helder Da Silva (CTD) on an EPSRC/Case award supported project. This aimed to add a new feature to the optimised design to further enhance the performance of the PMSM (torque and efficiency per unit cost ratio) by incorporating segmented stator core structure and concentrated winding with novel wall insulating material for a range of 1.7 kW-2.5 kW PMSM motors. Operating these motors over continuous periods requires efficient thermal distribution of heat both within and away from the motor to ensure that their stator windings run at cooler temperatures than 130 ^{0}C to provide optimum overall performance and better operating characteristics (5-8% stall torque improvement in comparison with a standard design).

The results of this part of the research were published in [3]. The process of developing the company's products is a continuously evolving process with further improvements anticipated.

3. References to the research

1. Perryman,R. Sooriyakumar,G., Dodds,S.J. (2008, February): Thermal Modelling for PMSM, 3rd IASE/WASEAS International Conference on Energy and Environment, Cambridge, pp. 379-385. doi:10.1109/upec.2007.4468945

2. Dodds, S. J., Sooriyakumar, G., Perryman, R. (2008, April): A Robust Forced Dynamic Sliding Mode Minimum Energy Position Controller for PMSM Drives, WSEAS Transactions on Systems and Control, Vol.3, issue 4, pp. 299-309. ISSN: 2224-2856. Available on request.

3. Influence of Wall Insulation Material in BPM Synchronous Servomotor (2013, September), Helder Da Silva, W M Hosny, S J Dodds, D A Staton, UPEC2014, 48th International Conference, Dublin.

4. Details of the impact

The research described above yielded a unique optimisation technique for the design of permanent magnet synchronous motors (PMSMs), using genetic algorithms to handle multiple design parameter constraints and achieve global optimisation. Since 2008, that **improved technique has been adopted and put into use by Control Techniques Dynamics** (CTD), where it has dramatically **transformed the design process and construction of PMSMs**, with significant and sustained benefits to the company. These developments have supported efficient design methodology for PMSMs, as well a reduction in the materials usage during the manufacturing process. As a result, the company has been able to **provide improved products in a reduced manufacturing time and at a reduced cost**. Furthermore, these manufacturing efficiencies have delivered environmental, as well as commercial, benefits.

More specifically, the software tool developed by the research team in 2009 has decreased the lead time to manufacture PMSMs by 30-40%; reduced materials usage by some 15%, enabling a new range of servo motors to be developed; and enhanced CTD's company sales by 20% since 2009 **[a]**.

The second phase of the research has resulted in improved thermal management and thus enhanced stall torque per unit cost ratio by about 7% **[a]**; in combination with phase one of the research, this allowed CTD to develop its High Dynamic servo motor range, Unimotor hd. First brought to market in March 2009, Unimotor hd is a range of high dynamic, low inertia brushless AC servo motors (0.72-85 Nm, rated speed 2000,3000,4000,6000 rpm), designed to enhance the production efficiency and throughput of automation applications requiring hard acceleration and deceleration, such as flying shear, pick and place and cut to length. The range provides high torque servo drives, providing up to 300% peak overload for maximum dynamic performance **[b]**. At the same time, it is exceptionally compact and uses less material than equivalent power servomotors made by CTD's competitors. The changes introduced in this new range in response to the findings of the research outlined above have resulted in a 10% improvement in CTD's commercial performance between 2009-2013 **[a]**.

These changes and improvements in both the manufacturing processes and the quality of their eventual products have allowed CTD to maintain and even grow its share in a difficult market and to maintain higher profitability than most of its competitors who, over the same period, have typically made well below 10% operational profits. As such, our research has supported the commercial activity and profitability of a UK-based company during a difficult economic period and so contributed to the recovery of the UK economy as a whole.

Control Techniques Dynamics is a global player, with manufacturing, engineering and design facilities in Europe, USA and Asia. It has 94 subsidiary Drive Centres in 70 countries offering customers local technical sales, service and design expertise, many offering comprehensive system design and build services. The parent company Emerson has approximately 127,700 employees and 240 manufacturing locations worldwide with revenues amounting to over $21 billion. It should be emphasised that the development of these new and improved products has not only delivered commercial benefits to CTD itself but has also provided significant benefits to the company's many international clients and customers. In particular, it has supported the development of enhanced and improved automation applications from the manufacture of precision machines to high performance elevators, cranes and fans. In all such products, the research has contributed to enhancing motors stall torque per unit cost (particularly using the innovative thermal management technique developed in the second phase of the research) and increased productivity, whilst reducing energy consumption and material usage.

By supporting reductions in both material waste and energy consumption among CTD and its many clients, the research has also contributed to a more widespread reduction of energy consumption in the UK for automation applications and thereby contributed to the reduction of environmental pollution from this particular manufacturing sector.

5. Sources to corroborate the impact

[a] Written testimonial from the Technical Director, Control Techniques Dynamics corroborating the impact of UEL's research on CTD. Available on request.

[b] For a description of the benefits of the Unimotor hd, developed as a result of UEL research, see: http://www.emersonindustrial.com/en-EN/controltechniques/products/servodrives/unimotorhd/Pages/unimotor-hd.aspx