LETTERS

HAVE SOMETHING TO SAY?
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ASSURING SAFETY AND SECURITY IN RAS

Professor David Lane CBE FREng makes a powerful case for the UK to seize the opportunities offered by robotics and autonomous systems (RAS) and he rightly emphasises the need to build public trust in these systems ('Robotics and autonomous systems – affecting everything that moves', *Ingenia* 67).

To be trustworthy, RAS must of course be safe and secure. However, demonstrating this is harder than it may seem because software is at the heart of RAS and programmers are at risk of making lots of mistakes: it is an unusually talented programmer who only introduces one defect in every 1,000 lines of software program that he or she writes (defect rates typically lie in the range between 5 and 30 defects per 1,000 lines). Many of these errors remain undetected because programmers rely on testing to find their mistakes, and computer scientists and software engineers have known for at least 40 years that testing can only show that faults exist rather than that the software is safe or secure. Running a series of tests may show that the specific tests work, but even a small change to the test conditions will put the software in a different, untested state that may fail. In general, it is not valid to extrapolate from test results or to interpolate between tested conditions. So if strong evidence is needed that software is safe and secure, testing is simply the wrong approach; strong evidence can only be provided by rigorous analysis, such as using model checking or theorem provers.

If the UK is to take, and maintain, leadership in RAS, the software must be built to professional engineering standards, with evidence that it is safe and secure. That requires a mathematically rigorous specification of the safety and security requirements followed by rigorous evidence that the software has the specified properties. This is skilled work but it has been shown to be practical and cost effective, using engineering tools and methods such as Z and SPARK, for example. Z is a mathematically formal specification method and SPARK is a software development technology specifically designed for engineering high-reliability applications. SPARK comprises a programming language, a verification toolset and a design method which, taken together, ensure that ultra-low-defect software can be deployed in application domains where high reliability must be assured, for example where safety and security are key requirements.

The software industry has resisted the adoption of professional engineering methods for far too long; programmers often have little education or training in the necessary mathematics and the most commonly used programming languages (for example, C and C++) were not designed to support rigorous analysis. Software companies have focused on getting new products into the market as quickly as possible rather than on making their software highly reliable or secure, as this is what most customers seem to want. One consequence is that we now face a cybersecurity crisis because most software contains many errors and a proportion of these errors can be exploited to force failures or to make the software misbehave. The world cannot afford a RAS industry that makes the same mistakes.

The UK has the universities and the software companies that could deliver the safe and secure systems that the world needs. We should follow Professor Lane's call to work together in industry, government and academia to win a large share of the global markets for RAS.

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THE FUTURE OF ENERGY STORAGE

In his June editorial 'What's in store for energy' (*Ingenia* 67), Dr Scott Steedman rightly announced the coming of storage and there is no doubt that electricity storage, in the form of batteries, is enjoying long overdue recognition as a robust proven technology that can support our electricity networks. While internationally, particularly in the Americas, batteries have been deployed routinely to provide a variety of system support services, it wasn't until Tesla announced in early 2015 that its Powerwall would be available in the UK that local interest was piqued. However, Tesla is not the only show in town and there are many innovative UK companies that have batteries for the domestic behind-the-meter market.

As Dr Steedman states, this market is challenging to promote to a domestic consumer on economics alone. Some systems cost £6,000 to £8,000 to install and have a payback of 16 to 24 years, even coupled with rooftop solar generation. One way to reduce the payback period is to also provide flexibility services to the system operator and Moixa Technologies offers this model to its customers by aggregating many small domestic batteries together to offer them as a larger asset to National Grid, allowing additional income to be earned, as well as avoiding the cost of importing electricity.

Behind the meter in industrial and commercial companies, energy storage does make absolute sense now. Companies that see half-hourly use-of-system charges can use storage to avoid peak charges while maintaining business operations. Storage at this larger scale is also easier to offer as a service to support the system operator and this is a key growth area that has yet to be fully exploited.

However, Dr Steedman missed one of the key opportunities for storage and that is energy storage and not electricity storage. Batteries can only store electricity, and often 'energy storage' is used loosely to describe the specific storage of electricity but, of course, batteries are not the only approach to storing electricity. It is important to remember that of the energy we use in our homes, up to 80% of the cost can be on space and water heating. Even in businesses, heating and cooling represent 50% to 70% of the energy costs. While we focus on batteries and storing electricity, we miss the crucial aspect of storing heat (or cold).

Hot water tanks are an endangered species in the home as we change technologies and while batteries may not be economic behind the meter, storing heat is. It is estimated that in the UK, all-electric heating systems could provide 30 GWh (Gigawatt-hours) of flexibility and this ignores the additional gas/oil systems that also have immersion heaters, homes with storage heaters and exciting new phase-change thermal storage, such as that offered by Sunamp. National Grid has a new 'demand turn-up' service that rewards providing load when required. Recent figures indicate that there have been over 80 half-hour settlements periods in 2016 with negative wholesale electricity prices. If demand turn-up was used to 'mop up' excess generation, 30 GWh of flexibility could earn more than £100 million per year, with not a battery in sight.

Dr Steedman also points out that building regulations play an important part in delivering a new flexible system, but those regulations should focus on much more than micro-generation and batteries. Energy efficiency should be at the heart of any new regulations because if heat is not lost, there is no need to use energy to make more heat, which reduces emissions and critically reduces energy costs to the consumer. Until housing is viewed as an important solution in delivering climate targets, the government will continue to focus on the delivery of expensive, large energy infrastructure projects, such as the proposed Hinkley Point C, rather than moving forward with the decentralised energy revolution.

There is no doubt that electricity storage has much to offer the UK's electricity system at the utility scale, and behind the meter at the commercial and industrial scale. National Grid's recent new enhanced frequency response service attracted huge interest, with 7.5 GW offered and 1 GW bid for 200 MW of required service. Electricity storage can respond rapidly, with simultaneous multiple services, as either load or export (which is not something thermal storage can do), to keep our system stable. It is clear that an electricity system that incorporates electricity and energy storage can allow the integration of greater amounts of low carbon generation and maintain system security, while doing so in the most efficient and lowest-cost way to consumers. To maximise the benefits of electricity storage, we need to act quickly, at utility scale and behind the meter, and use all types of technologies. There is significant understanding of what has to change in the commercial and regulatory frameworks to facilitate the deployment of storage, but we have yet to take the necessary actions to deliver the low carbon, low cost and secure system of the future and we will all need to actively participate in understanding and managing our demand to ensure a sustainable future.

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