A mechanism for collaboration between industry and academia in the UK, exemplified by project SYNAPS

Simon Le Blond and Vančo Litovski

Invited paper

Abstract – Whilst often working in separate silos, there are huge rewards in effective collaboration between industry and academia. Complex modern engineering challenges also necessitate working within a team of teams – *meta-team-working*. We exemplify how academic and industrial collaboration combined with *meta-team-working* may be leveraged through the Innovate UK Energy Catalyst funding mechanism, specifically project SYNAPS, a technically challenging project focussed with smart low-voltage power distribution networks with a heavy simulation component.

Keywords – Research funding, collaboration, power network simulation.

I. Introduction

Within the engineering world, the path of least resistance is for industry and academia to operate in very separate silos. Often this is down to conflicting goals: the key performance metric for academic career progression is to disseminate new knowledge through publication, whereas industry must protect and monetise intellectual property. For these reasons among others, academics and industrialists can have very different mind-sets, attitudes and beliefs that can make collaboration problematic.

However, there are potentially huge rewards from close collaboration. Deep specific, fundamental and focussed knowledge in a particular field can be transferred, applied and commercialised through the right partnership. Moreover specialist *real world* knowledge, for example that which is commercial and regulatory as well as technical can inform and direct fundamental research. So the best functioning partnerships therefore become mutually beneficial and symbiotic.

It is a truism to say that well into the twenty first century much of the easy advances - the *low hanging fruit,* in science and engineering has already been picked. One just has to look at increasing trend in numbers of authors on scientific publications to conclude that even incremental breakthroughs require large collaborations of many researchers from a range of disciplines. A recent paper from CERN regarding the Higgs Boson set the record at over 5000 authors [1]! In the information age, our complex modern world relies as much on the division of expert knowledge as the production lines that drove the industrial revolution relied on the division of labour. Complex modern engineering problems often require *Big Engineering.* This is the harmonious, channelled application of knowledge and expertise from a number of specialist entities to achieve a specific outcome or set of interrelated outcomes. This structured meta-team working is contrary to the pressure to appoint and retain "research stars" in academia; well known personalities that give kudos to an institution, helping to accrete funding and students. However it is also true that the contribution from one particular individual can far outstrip the combined contributions of many, particularly in innovation: a study [2] concluded there was an approximate variation in productivity in programmers of 20:1. Going further, Bill Gates is, (perhaps apocryphally) accredited for asserting "A great lathe operator commands several times the wage of an average lathe operator, but a great writer of software code is worth 10,000 times the price of an average software writer." So star individuals can play a role in providing a step change if they are lucky enough to occupy the tail end of the Boltzmann-like distribution of ability: they achieve the escape velocity necessary in the way that the combined efforts of others will not.

In academia the analogy can be thought of like a theatre *company* where the stars are equally important, if not more so, than those doing the directing and producing. In this paradigm those off stage cannot necessarily do the job of the actors, in the same way that a research manager may not have the expertise to conduct the work of the researchers (s)he is supervising. In engineering industry the structure is much more hierarchical such that those at higher levels normally have the skills and knowledge to do the work of those below them. They are therefore given greater responsibility (and remuneration) and solve complex outcomes through divide and conquer – breaking up small parts of the problem onto complex Gantt charts and allocating the human resource appropriately. Since there are advantages to both paradigms, their hybridisation when academia and industry meet can be very effective and also lead to better understanding and new ways of operating for both parties. For the very same reasons, these two world views can lead to tensions particularly between researchers and industry executives who at first have little mutual empathy due a lack of understanding about the pressures they face.

Simon Le Blond and Vanco Litovski are with the Department of Electronics and Electrical Engineering, University of Bath UK, s.p.leblond@bath.ac.uk

This paper presents a high level discussion of the Innovate UK / EPRSC mechanism for collaboration in the hope that it will provide a useful template at various levels of scale for those faced with catalysing a functional symbiosis between industry and academia.

The SYNAPS (Synchronous Analysis and Protection System) project is an Energy Catalyst Mid-Stage Innovate UK/EPSRC project aiming to developing smart grid technologies to the low voltage power distribution network. Within SYNAPS the authors are responsible for delivering a work package with a heavy power system simulation component. We use the SYNAPS project to exemplify how academic-industrial collaboration may be orchestrated. In particular we examine the key players in the UK power industry, those at the vanguard of the smart grid, both external and within the consortium and how good working relationships can be forged amongst these entities.

The rest of the paper is organised as follows. In section 2 we discuss the general funding ecosystem going into more detail over SYNAPS funders, Innovate UK and EPSRC. In section 3 we examine the UK power industry. In section 4 we introduce the SYNAPS project with a brief technical overview, and in section 5 discuss how collaboration inside and outside can achieve the ambitious technical goals by meta-teamwork. Finally we draw some general conclusions.

II. UK Research Funding Ecosystem

A. General Overview

In the UK, funding for research innovation comes from many sources, although this section is written from the perspective of the authors, academics in electronic and electrical engineering. With this in mind, our main funding sources are:

- Research Councils UK [3]:
An umbrella organisation for 7 broad discipline focussed UK academic research councils, with those particularly relevant to electrical engineering being EPSRC, (Engineering and Physical Sciences Research Council) NERC (National Environment Research Council and STFC (Science and Technology Facilities Research Council). These bodies use specifically scoped calls alongside standard "responsive mode" with open scope, both awarded through a rigorous peer review process, usually including a panel stage.
- European Research Council (ERC) [4]:
European Union Funding, currently migrating from Framework Programme 7 to Horizon 2020 [reference website]. European funding rules often necessitate consortia of many partners both academic and industrial across at least 3 EU countries so rely on large critical mass to be viable.
- Direct Funding from the UK Government:
Various government departments may commission targeted research calls.
- Innovate UK [5]:
An executive non-departmental public body sponsored by the government department for Skills Business and Innovation set up to de-risk research and development.
- Collaborations with various partner research councils across the globe, usually focussing on mobility and seed funding.
- Finally an industrial partner may outsource research to an academic institution if they are unable to undertake it internally.

With the exception of the international and private sources, the UK Government pays into these expert bodies to distribute money as they see most appropriate, so in some sense, the UK Tax Payer is the ultimate source of most research funding. Clearly public money must be used responsibly and thus the research from these areas is subject to the highest levels of scrutiny: both auditing, monitoring and reporting throughout the grant lifecycle to ensure the funding is being used effectively.

The particular funder that one targets for a grant proposal is highly dependent on the type of work, the research outcomes and the parties required to achieve these, in addition to the stage of career of the principal investigator. A pure research project in engineering may be most directly suited to EPSRC funding, whilst one closer to commercial application would be more relevant to either Innovate UK or ERC. Moreover it is unlikely that grant reviewers will entrust large sums of money to early stage career researchers without an established track record, regardless of the merit in their idea.

B. EPSRC

EPRSC (Engineering and Physical Sciences Research Council) is the UK's main agency for funding research in engineering and the physical sciences, investing up to £800M p.a. in research and postgraduate training [6]. It is the primary source of funding for pure physical sciences research more blue sky "engineering research" and is thus the first stop for academics who wish to fund a research project confined within their own institution or with one or more academic partner institutions. EPSRC's strategic plan [7] informs on "grow" "maintain" and "reduce" subject areas within the portfolio and thus the case for supporting a particular grant can be enhanced if it aligns with EPSRC's overall strategy.

C. Innovate UK

According to their Website, Innovate UK is "the UK's Innovation Agency" [5]. Their remit is to

- determine which science and technology developments will drive future economic growth.
- meet UK innovators with great ideas in the fields Innovate UK are focused on.
- fund the strongest opportunities.
- connect innovators with the right partners they

need to succeed.
- help innovators launch, build and grow successful businesses.

D. Energy Catalyst

Energy globally is regarded as a major societal challenge – the compounding problems of climate change, limited fuel resources (and their increasingly uncertain supply chains) increasing population, global industrialization and the accompanying load growth combine to form an “energy crisis” that is one of the greatest existential threats to human civilization. On the other hand, the UK government recognizes that there is huge global commercial opportunity for UK plc in meeting this challenge.

The Energy Catalyst is a rolling funding scheme overseen by Innovate UK to support technology projects addressing all three corners the “Energy Trilemma”: the competing need to reduce emissions, improve security of supply and reduce costs (see Fig .1.) There are three tiers of funding awards: early stage, mid stage and late stage with funding capped at £300 K for early feasibility studies, £3 M for mid-stage technology development and £10 M for pre-commercial technology validation respectively. Mid stage and late stage must be business led and collaborative but may involve academic partners or any other research organisation who are permitted to absorb up to 30% of total project allocation. Crucially, the funding for academic partners comes from EPSRC and is funded at 80% Full Economic Costs (which in the author’s world is synonymous with “fully funded” due to the complex array of overheads that RCUK are willing to fund and those that they are not). Innovate UK defines the separate players in this ecosystem as 1. Research institution, 2. Small/micro SME (Small Medium Enterprise) 3. Medium SME and 4. Large Business. This demarcation points are summarized in table 1 which also shows the level of match-funding that each entity must contribute themselves.

It is worth explicitly noting, with reference to table 1, that with these carefully graded funding rules, the industrial partner must match fund a portion of their own project costs with a higher percentage investment the closer they are to commercial readiness, such as to drive the eventual commercial exploitation of the project IP. Also, since the research institution is not expected to commercialise their IP they are not asked to risk the match funding. The negotiation of Collaboration Agreements between all partners is necessarily complicated as it must allow for the free flow of information between the partners to collaborate in the project, but also simultaneously protect the commercial interests of the industrial partners and the academic partner’s remit to disseminate research outcomes. Innovate UK therefore supplies a template Collaboration Agreement to assist SMEs that may not have access to, or the resource, to outsource legal assistance. In addition it is vital all partners must be under NDA (Non-Disclosure Agreement) in order to even begin working on the proposal, let alone the project itself. Despite these safeguards, all partners, particularly the SMEs are exposed to a high level of commercial risk through leaked IP, whether by design or by accident. It is therefore imperative that partners behave with impeccable business ethics and build up mutual trust at the consortium building stage before embarking on a project.

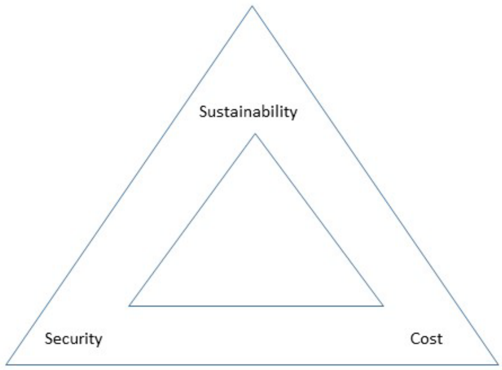

Fig. 1. The “energy trilemma” illustrating the competing needs in the energy crisis to reduce emissions, improve security of supply and reduce costs. It is very difficult to meet one or two of these without compromising heavily on the third.

III. UK Power Industry

Before discussing Project SYNAPS it is necessary to briefly summarise the UK Electrical Power Industry. The UK power industry was globally one of the first utilities to be privatised in 1990. Since then, the national transmission grid, the supply side and the regional distribution networks have all been operated and owned by private entities.

TABLE I
ENERGY CATALYST FUNDING TIERS

Scheme	Total funding available	Research Institution	Small SME <50 people, turnover £10 M	Medium SME < 250 people, turnover £50 M	Business
Early Stage	£300 k	80% FEC <50% total project cost	70%	60%	50 %
Mid Stage	£3 M	80% FEC <30% total project cost	70%	60%	50 %
Late Stage	£10 M	80% FEC <30% total project cost	45%	35%	25 %

The UK government recognizes that the overseers of generation, transmission and distribution necessarily hold natural monopolies and thus appoints a regulator - *Ofgem* - to protect consumers. Businesses can be liable for heavy financial penalties for any breach of contract or exploiting their monopoly.

Suppliers or retailers are companies that purchase electricity on the wholesale markets from generators and then sell it to customers – commerce, industry and domestic alike. Most UK consumers have a vague notion that retailers are those responsible for getting electricity to their power sockets. However this role is fulfilled at a national level by National Grid, the Transmission System Operator (TSO) and then at a regional level by the eight Distribution Network Operators DNOs, who are collectively responsible for the operation and maintenance of the electrical power network infrastructure. Electrons are not so discerning of these arbitrary boundaries so power flows at light speed down wires using alternating current at a system-wide nominal frequency of 50 Hz. The High Voltage Transmission Network and can be thought of the highways whilst the distribution network at lower voltages are the trunk roads all the way down to individual driveways. There is presently a trend towards decentralization of energy infrastructure to better facilitate low carbon economy. Historically, the system was designed around large centralized thermal based power plant. Many cleaner energy sources and energy storage technologies suit connection at lower voltage levels and therefore the distribution networks are becoming more active with bi-directional power flows, with micro-generators selling their power back to the grid as well as consuming it. Contrary to this drive, ageing infrastructure is being pushed well beyond its expected lifetime leading to a huge asset management problem, particularly within the oldest parts of the network: the low voltage (LV) distribution network. This puts two fold pressure on the LV voltage network – the requirement to modernize the aging assets and the requirement to modernize into a "smart grid" to accommodate connection of new energy technologies. This also creates a massive business opportunity in LV networks.

IV. Project SYNAPS – Technical Overview

Project SYNAPS (SYNchronous Analysis and Protection System) is a £1.7 M Innovate UK energy catalyst mid-stage project currently underway, addressing the problem of LV network modernisation directly by developing an array of inter-related Smart Grid LV network technologies. In this section we will give an overview of its technical themes.

A. Higher network visibility

Essentially the core SYNAPS technology will be a way of monitoring network conditions at extremely high granularity. This involves measuring the physical quantities of voltage and current waveforms in the 415 V three phase network at high sample rates (~200 kHz) and then inferring knowledge about the network in real time or near real time. This unlocks a whole host of new functionality. For example, a big issue for network operators is knowing the topology of the LV network itself. Like capillary level blood vessels in the human body, the LV network is vast and sprawling and often "multiply patched" since over time it has grown sub-optimally and organically, following the incremental growth of the built environment. DNOs therefore often have poor historical records of exactly what assets they have at LV. SYNAPS will develop a monitoring platform able to infer network topology.

B. Pro-active Maintenance

A particular problem is progressive water ingress into cable insulation causing arcing short circuit faults. This often initially causes an intermittent fault that does not always melt the protective fuse but nonetheless risks damage to connected equipment. The DNO only has knowledge about this problem when the fuse eventually does operate, and customers call in to complain they have lost supply. The DNO responds by physically sending maintenance personnel out to replace the fuse. If the fault persists the fuse will then operate again necessitating digging the cable up and replacing it. This cumbersome process leads to many customer minutes off supply and large financial penalties to the DNO from the regulator. SYNAPS will be able to use pattern recognition techniques to detect early when an intermittent fault will occur and thus maintenance can be proactively organised to avoid customer minutes lost.

B. Protection and reconfiguration

The protective fuse is itself a very crude device. It only operates once before requiring replacement and its operating characteristic is limited to an inverse time-overcurrent. At higher voltage levels the network is protected by circuit breakers that use sophisticated fast digital relaying algorithms to operate in milliseconds following a fault, overseen by carefully coordinated settings of the overall protection system. This approach keeps as much of the healthy system live whilst isolating the faulted part. SYNAPS will apply this paradigm to the LV network.

With a partially meshed or fully meshed network, there is the possibility of routing power from a different source and thus bringing customers back on supply before a permanent fault can be fixed. There are complex safety and technical implications that must be considered before doing this. With regard to the technical, low carbon stresses such as micro generation and electric vehicles will make the situation more complex: for example if they remain connected under faults they can potentially create an unintentional islanded network. SYNAPS will consider these aspects and develop new reconfiguration algorithms for the LV network.

C. Solid state switchgear

An important gateway technology at LV would thus be replacement for the fuse: a switch that can be tele-operated and that can interrupt heavy short circuit currents that arise under fault conditions. SYNAPS is thus researching and developing solid-state switchgear than can operate much faster than electromechanical devices by using power electronics. Regardless of the final choice of technology, the ability to tele-operate SYNAPS switchgear will unlock much more sophisticated protection and reconfiguration algorithms.

D. Network Simulation

Real world fault data on actual systems is scarce because these systems are not monitored and live tests are expensive, disruptive and dangerous. Therefore in achieving the SYNAPS outcomes there is an overarching requirement to simulate various fault scenarios in the LV network in high levels of detail. The authors are thus tasked with time domain simulation of various LV network topologies. In the first stage this involves simulating fault waveforms “offline” with tools such as SPICE and ATP-draw (the modern graphical version of EMTP) to conduct electromagnetic transient simulation, to create waveform data that can be fed into to machine learning inference engines. In the second stage the simulations must be in real time such that the developed SYNAPS platform can be tested and validated.

The RTDS is a power network simulation hardware tool that allows any power system to be digitally simulated in real time at a base time step of 50 μs, confined only by the amount of modular processing power available [8]. See figure (2). The RTDS has the very powerful feature of putting hardware into a closed loop in the simulation through various I/O ports. In more detail the RTDS can simulate the power system, synthesising real voltages and currents as they vary with time using digital to analogue conversion and then send these signals to outboard equipment – in this case, the SYNAPS platform. The SYNAPS equipment can do the required processing and then send analogue or digital signals back to the RTDS, automating network tasks. This could be opening or closing a switch following a fault, for example. Due to the aforementioned difficulties in real world testing, this step is a vital test and validation task before utilities are comfortable deploying SYNAPS on a real power network.

An interesting technical challenge in SYNAPS is digitally simulating the electrical fault arc – the high channel of ionised plasma when an insulating medium breaks down - which is a complex physical phenomenon [9]. This involves computing the time varying arc conductance in every timestep using differential equations. Interested parties are referred to the paper in the SSSS conference proceedings by the same authors confined to this very subject that develops a new model specifically for arcs propagating through cable insulation [10].

V. PROJECT SYNAPS – THE CONSORTIUM

A technically ambitious and complex project such as SYNAPS requires an array of various specialisms to be channelled and focussed into a concerted harmonious

Fig. 2. The RTDS (Real Time Digital Simulator) allows real time simulation of Power networks and can connect hardware in the loop.

effort. This is a kind of *meta-teamwork* in as much as it requires a team of teams. Within the consortium we therefore have assembled three companies, classified under Innovate UK as micro-SMEs, and two partner universities. In addition a large established micro-processor manufacturer is offering contribution in kind with chip development platforms in line with a strategic view onto the smart grid market.

The industrial project partners are:

- Power Line Technologies (Project leaders)

PLT designs, manufactures and markets solutions in the smart grid and communications market place. The Company has expertise in LV & MV smart grid, telecommunications, powerline communications and network management. It has already established relationships with distribution and transmission network operators for its solutions.

- Akya Ltd

Akya Ltd are responsible for developing the chips that will process the SYNAPS data. Akya specialises in the development of advanced bespoke digital signal processing solutions for high performance and / or low power devices. Akya's ART technology is capable of providing highly-optimised, application-specific, fully programmable DSP cores with a power/performance far better than that which can be achieved by conventional general-purpose DSP designs.

- Techna Ltd

Techna are producing the SYNAPS LV switch gear. With over seventy years of electrical engineering experience Techna are specialists in advanced circuit protection products.

The academic partners are:

- University College London (Department of Mathematics and Statistics) are developing the machine learning algorithms that will take LV network data and infer information about the network.
- University of Bath, Centre for Sustainable Power Distribution (CSPD) is contributing its expertise in real time digital simulation and transient based protection to generate fault data to validate the SYNAPS platform. (The authors of are from the University of Bath.)

Since SYNAPS is a truly collaborative project, there is necessarily much interdependency between the partner work packages. For example it is important that the simulation data is supplied on time, and that developed software algorithms can be delivered in a form to run on the SYNAPS hardware. All deliverables are therefore synched to a common time grid of quarterly milestones over the 2 year project lifespan.

It is also vital therefore to establish good working relationships, clear channels of communication and regular reporting between the partners. In addition due to the modest size of the industrial partners, many of those involved must fulfil both a high level executive role and a detailed technical engineering role.

Formal project meetings may therefore become too large and unwieldy for detailed intimate technical discussions that concern only two or three partners. Therefore to facilitate cross-partner technical work there are three technical coordination groups (TCGs) with a different focus and combination of membership of the relevant project partners. The TCGS favour small and agile working between technical personnel (or those fulfilling their technical role) within different partner entities. To facilitate this inter-partner collaborative working various web based software tools are invaluable. For example Skype is ubiquitous free software for VoIP conference calls. However Cisco's WebEx also allows screen sharing and meeting recording across multiple remote guests and user. The Confluence software by Atlassian allows a web based focal project repository of documents, media and meeting minutes to be shared and edited collaboratively. However none of these can currently replace the nuances of a physical face to face meeting, so often it is necessary to travel and it is important partners distribute the burden of travel and hosting fairly across the consortium. All other things being equal, it is perhaps therefore better to choose partners that is within a reasonable distance. Face to face meetings are a great opportunity to conduct partner site visits and socialise (with the help of appropriate choice food and beverage of course to lubricate and celebrate progress).

SYNAPS brings together engineers from different disciplines that have a slightly different technical vocabulary. Computer science (hardware and software), electronics engineers, mathematicians and electrical engineers have a lot of overlapping knowledge but the Venn intersection clearly does not cover the specialist knowledge within each discipline. (If it did there would be no added value in *meta-team work*…) It is therefore vital that the partners have empathy for different levels of technical knowledge and understanding within the consortium, and tread the fine line between informing and condescension when explaining concepts to non-expert-colleagues. However this is also a great opportunity, not just acquiring complementary knowledge from a different discipline but also enhancing understanding of one's own. In academia the symbiosis between the pillars of teaching and research is mutually reinforcing because being able to teach and explain a high level concept necessities the highest form of understanding in the teacher. Like students, colleagues from different disciplines can often ask uncomfortable fundamental questions that can helpfully critique an idea for feasibility and robustness; a question that might not occur to an expert peer in the same area due to mutual assumed knowledge.

In order to succeed the SYNAPS consortium must interface with various external power industry organisations. In particular, close working with DNOs (Distribution Network Operators) is necessary to acquire technical data and also scope market requirements since the DNOs will be the main customers of any commercial offering. Here too empathy and emotional intelligence is required. Utilities have a huge challenge maintaining and operating the network within regulatory limits with limited human technical and financial resources. Therefore in acting responsibly they are understandably wary of any new technology due associated risk and large learning curve. This results in an extremely conservative industry, where simple elegant design is preferred over feature laden sophistication. Whilst power systems technology may appear to evolve at a glacial pace to engineers with an ICT background, it is important to remember the utilities must maintain a complex interconnected system with 100% reliability and safety. The consequences of a smart phone widget failing are rather less drastic than a transformer protection relay failure. One leads to an angry customer review whilst the other leads to a substation explosion, customers without power and potential loss of life. The DNOs have unequalled intimate knowledge of the interrelatedness of their networks and the resulting design philosophy which should be respected all costs. It is therefore necessary for SYNAPS to engage with utilities early establishing rapport for functional partnerships founded on mutual respect and empathy. This of course extends to any technology project where the end users are not within the consortium: regular engagement with the customers from the start is vital.

CONCLUSION

This paper has discussed the merits of collaboration between academia and industry and coined a new expression *meta-team-working* – working in a team of teams. Interdisciplinary *meta-team-working* is needed to solve complex modern engineering challenges. For successful *meta-team-working* the ways of operating, cultures and vocabulary must be respected and understood. The very same challenges also bring great opportunity for widening the horizons for all those involved.

We have exemplified this thesis though the innovation funding ecosystem in the UK and in particular the Innovate UK Energy Catalyst project SYNAPS which is developing smart grid technology in LV power networks. Here as with all such projects there is need for effective communication, empathy and mutual respect, in all directions within the organisational model.

ACKNOWLEDGEMENT

This work is funded by EPSRC under the Innovate UK Energy Catalyst project, SYNAPS (SYNchronous Analysis and Protection System). The authors gratefully acknowledge the joint financial support of EPSRC and Innovate UK and use of facilities and services at the University of Bath, UK.

REFERENCES

[1] A. Collaboration, C. M. S. Collaboration, G. Aad, B. Abbott, J. Abdallah, O. Abdinov*, et al.*, "Combined Measurement of the Higgs Boson Mass in pp Collisions at $\sqrt{s}=7$ and 8 TeV with the ATLAS and CMS Experiments," *Physical Review Letters,* vol. 114, p. 191803, 05/14/ 2015.
[2] B. Curtis, "Substantiating programmer variability," *Proceedings of the IEEE,* vol. 69, pp. 846-846, 1981.
[3] Research Councils UK website http://www.rcuk.ac.uk/ (last accessed December 2015)
[4] Eurpean Research Council https://erc.europa.eu/ (last accessed December 2015)
[5] Innovate UK website https://www.gov.uk/government/organisations/innovate-uk/about (last accessed December 2015)
[6] EPSRC Engineering and Physical Sciences Rearch Council https://www.epsrc.ac.uk/ (last accessed December 2015)
[7] EPSRC Engineering and Physical Sciences Rearch Council https://www.epsrc.ac.uk/about/plans/strategicplan/ (last accessed December 2015)
[8] P.A. Forsyth, D. Shearer, D. Rydmell, "Testing Firing Pulse Controls for a VSC-based HVDC Scheme with a Real Time Timestep < 3 μs," presented at the IPST, 2009.
[9] H. A. Darwish and N. I. Elkalashy, "Universal arc representation using EMTP," *Ieee Transactions on Power Delivery,* vol. 20, pp. 772-779, Apr 2005.
[10] Our paper?