LCNF Tier 1 Close-Down Report

Digital Substation Platform

SSET1011

Prepared By

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Glossary

ANM	Active Network Management
AVC	Automatic Voltage Control
CCU	Central Control Unit
DSP	Digital Substation Platform
ESQCR	Electricity Safety, Quality and Continuity Regulations
FAT	Factory Acceptance Test
IED	Intelligent Electronic Device
PNDC	Power Networks Demonstration Centre
RTDS	Real Time Digital simulator
SHEPD	Scottish Hydro Electric Power Distribution
SGS	Smarter Grid Solutions
TOTEX	Total Expenditure
TRL	Technology Readiness Level

Executive summary

Project scope

In the event of a short circuit fault from phase to earth, or from phase to phase, the current flow is interrupted by circuit breaker with insulation and arc breaking capability provided by SF6, air, oil or vacuum. Protection relays are installed on each circuit to monitor and detect the network failure and send a trip signal to operate the circuit breaker and disconnect the faulty section. These protection relays were traditionally electro-mechanical and evolved into electronic and then microelectronic versions. More recent developments have seen the emergence of Intelligent Electronic Devices (IED) to provide protection relay functionality. All of these Protection devices are task specific, with configuration and functionality set prior to installation, and a change in requirements would need a replacement IED or additional units to be fitted.

The increasing spread of newer technology into the electricity networks has provided for the digital control of the protection functions within primary sub stations. SHEPD is currently running a NIA funded project, NIA_SSEPD_0002 SA*Sensor* HMV Primary Substation Provider, which has installed a Locamation protection system in the primary substation at Caputh, Perthshire. This protection system is running in open loop mode, where it is mirroring the traditional protection devices.

The growth of renewable forms of generation, and their variability of generation, particularly wind and solar, has presented DNOs with the challenge of managing the new connections of renewable forms of generation within the constraints of the capacity of the distribution network, as well as the variability of demand. Software algorithms that can monitor and apply generation constraints where necessary to prevent networks from exceeding their design limitations are starting to become more readily available.

The need for network protection from faults and unconstrained generation would indicate that primary substations may require a number of digital devices installed to cover both eventualities. This could mean that provision has to be made in the design of new sub stations to fit these devices, and that space has to be found in current sub stations to accommodate the devices. To reduce the physical space required, a solution where the functionality of several types of digital device resides on a single physical system is needed.

The project will be looking at the feasibility of running an ANM control system, currently coded for a Linux operating system server platform, on an industrial hardware platform that uses a proprietary operating system intended for use as a substation protection system. The project will not produce a fully functional system, but rather confirm the possibility of the 2 systems working as an integrated system, and assess the potential business benefits.

Executive Summary (contd.)

Aims

The aim of the project is to prove that software developed for a standalone platform can be re-coded for another platform, and maintain its integrity and functionality, without causing any adverse effects on the new host platform.

Activities

Locamation have a hardware platform which is able to be fitted with voltage and current sensors, and can run algorithms that detects faults and issue trip signals to circuit breakers. Smarter Grid Solutions, (SGS), have developed an Active Network Management (ANM) system that runs on a Real Time enabled Linux platform. These 2 companies worked together to port the ANM system from Real Time Linux to the proprietary Locamation platform, and then carried out development work on both systems to integrate them into a common system that can provide both active network management and protection. They used the simulation facilities at the Power Network Demonstration Centre (PNDC) in Cumbernauld to test the integrated system, by installing a Locamation platform with the ANM software installed on it. Testing was carried out, firstly by using a standalone ANM system to show that the ANM core software performs as expected using the simulated network. Secondly, the Locamation protection was tested as a stand alone system, (ANM software disabled). Finally the ANM software on the Locamation platform was enabled, and the integrated system was tested. The integrated system tests included tests to prove that the ANM could successfully control generators in the same way as the standalone system did; tests to prove that the protection system still worked as it did when the ANM software was disabled; and the integrated system was tested to show that when the system was actively controlling a generator, the protection system took priority and operated to protect the network when fault current was detected.

Outcomes of the project and key learning

The outcomes and key learning from the project are:

1. Demonstration of the protection of High Voltage network assets using SA*Sensor*'s suite of protection algorithms;
2. Simulated control of a generator to allow for the management of voltage on the network;
3. Demonstration of data integration and interfacing between the two platforms
4. Definition of a methodology for deeper integration in Phase 2.

Development of a business case shows that the integrated system is only likely to be of use where there is an ANM system, so the deployment of the integrated ANM and Protection scheme is limited to the proposed ANM schemes in the SHEPD licence areas. This means that the business case for the continuation of the project at this time is not made.

Executive Summary (contd.)

Conclusions and future work

The project was successful in as much as it achieved the aims stated above. It was not without issues though. The original intention was to use the live network at PNDC to install the equipment under test, and then control the network using the installed equipment. Due to constraints on the PNDC live network this was not possible in the timeframe of the project.

Should the project idea be taken forward, the first stage would be to repeat the testing done under this project, using the live network at PNDC, instead of the simulated network provided by the PNDC Real Time Digital Simulator.

The results from this testing, along with any changes made to the integration software, following discussions with protection and commissioning engineers, will be able to drive an installation onto a SHEPD live substation, so that the system can be monitored in its responses to real world events, mirroring the existing protection devices, by operating in an open loop mode whereby the system generates protection and control signals, but only writes them to a log, and does not send them to the protection devices.

1 Project background

Previously SHEPD has worked with Smarter Grid Solutions (SGS) and Locamation separately on a number of different projects. These include the development and deployment of an upgrade to the UK's first Active Network Management (ANM) system by SGS, to allow the use of commercial off the shelf servers, running Real Time Java on a Linux operating system to provide the necessary deterministic processing, so that scalability was improved, under an IFI project 2012_09 Real Time Java. The use of an ANM system deferred the reinforcement of the Orkney Distribution Network by using a real time monitoring and control system to better utilise the existing network capacity. SHEPD have also worked with Locamation on an IFI project to determine if a server based protection system would provide any benefits over the traditional relay based systems, IFI 2012_13 SA*Sensor* HMV Primary Substation Provider, and now NIA SHEPD 0002 SASensor HMV Primary Substation Provider.

This project is aimed principally at determining the feasibility of combining the ANM and the protection systems together to simplify the IT architecture and minimise costs by rationalising both hardware and software whilst retaining the benefits and performance of both systems.

SHEPD will establish a collaboration agreement with both parties and use a phased approach for project delivery. This will allow the project to be ended early if the anticipated benefits don't materialise.

If appropriate then Phases 2 and 3 will be separate follow on projects and will be registered under NIA governance.

2 Scope and objectives

The scope of this project is to deploy a trial system with protection and ANM functionality together on the same hardware platform in a test environment i.e. the Power Network Demonstration Centre (PNDC).

<u>Objectives:</u>
1 - Demonstration of data integration and interfacing between the two platforms;
2 - Simulated control of a generator to allow the management of voltage on the network;
3 - Protection of primary assets using Locamation's suite of protection algorithms;
4 - Definition of a methodology for deeper integration in Phase 2

<u>Potential benefits:</u> A reduction in the cost of hardware and software resource requirements for a typical primary substation installation.

3 Success criteria

If the project produces a draft cost benefits analysis and a set of requirements for the next phase for effective integration of the two systems then the project will be a success.

4 Details of the work carried out

This project has been completed in two stages. In the first stage software developers from Locamation and SGS worked together to develop the data communications between the Locamation SA*Sensor* and the SGS SGComms Hub so that the two devices would be able to communicate with each other seamlessly. Tests then showed that the SA*Sensor* could pass measurements taken by the Voltage Interface Module (VIM) to the SGComms Hub which would then pass them to the SGCore so that the constraint management could be calculated and outputs to control the generator voltage could be sent to the SGConnect. In the second stage the SGConnect is replaced with a virtual version running completely in software, which is installed onto the Locamation Central Control Unit (CCU). Testing showed that the ANM system was able to control the AVC by applying constraints through the Locamation CCU. This allows for a reduction in hardware costs, as the second SGConnect is not required.

The physical integration of the platforms in this project, contributes to understanding of the business benefits that could be realised by the Digital Substation Platform.

4.1 Method trialled

4.1.1 Phase 1 Stage 1

In this phase the aim was to successfully integrate data communications between the SA*Sensor* and **sgs comms hub** devices. This allows the SGS ANM system to utilise measurements from the SA*Sensor* system and to control the target set points of the AVC and generator output through interfacing with **sgs connect** devices. This is illustrated in *Figure 1.*

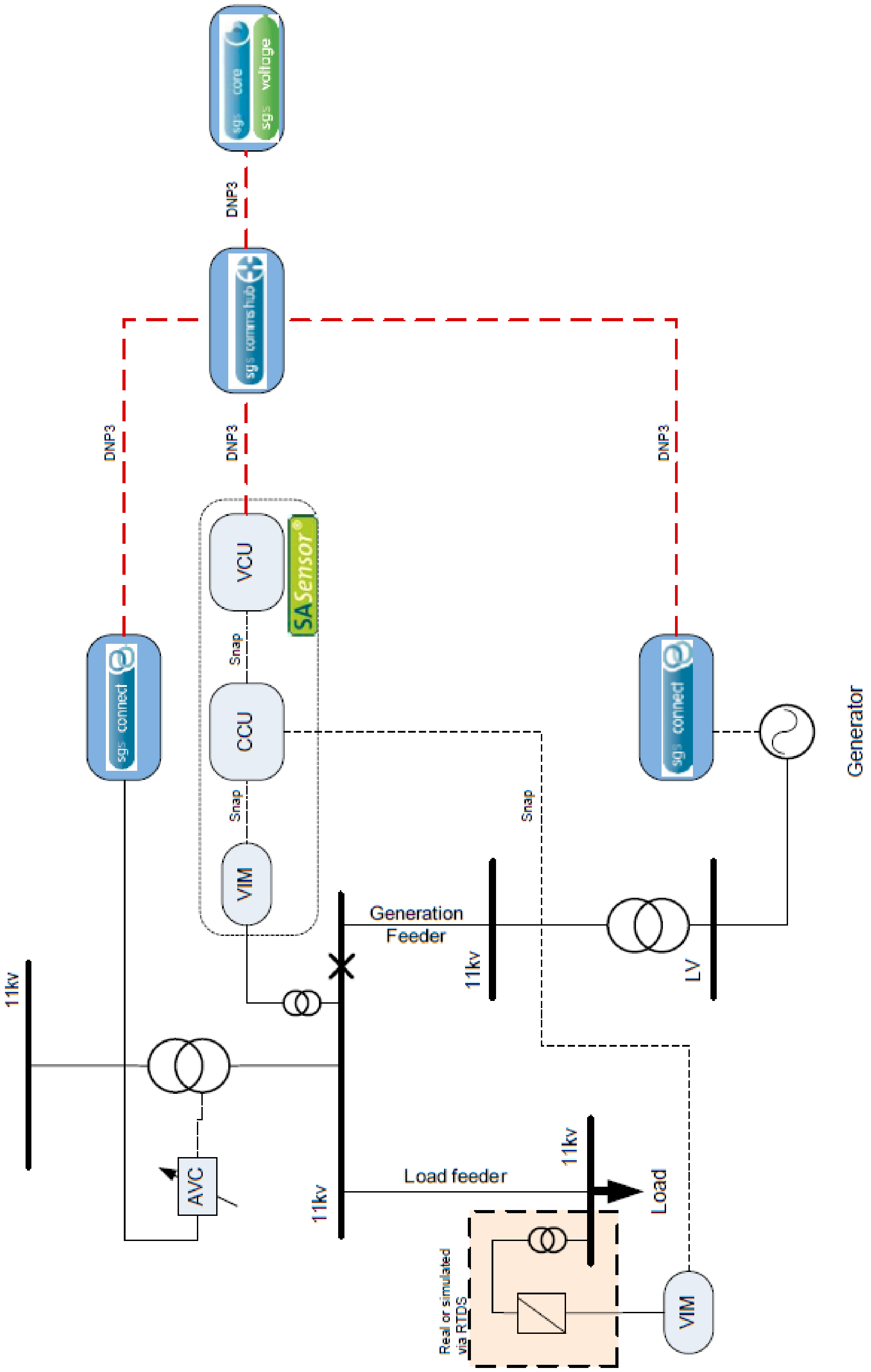

Figure 1: Phase 1 Stage 1 test case scenario and configuration

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4.1.2 Phase 1 Stage 2

In this stage the **sgs connect** for AVC is housed on the SA*Sensor* CCU, which facilitates a reduction in the hardware required in the substation. In this configuration the network's measurements are received by the CCU and fed to the **sgs comms hub.** The **sgs connect** for AVC algorithm is in place to operate and control the target set points of the AVC, and the ANM system can control the output of the generator as required. This is illustrated in *Figure 2.*

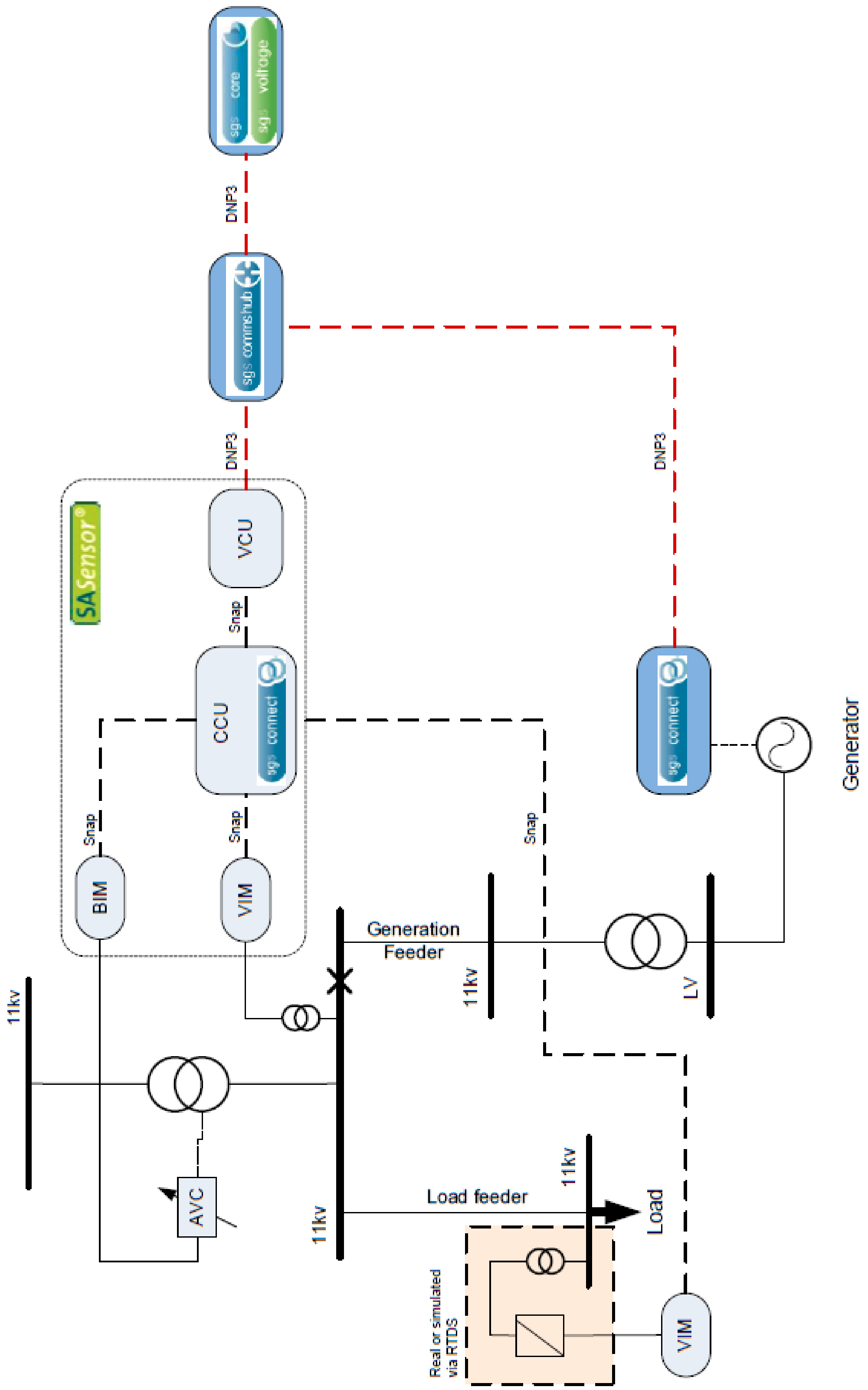

Figure 2: Phase 1 Stage 2 test case scenario and configuration

4.2 Trialling Methodology

4.2.1 Digital Substation Platform Testing

A number of tests were conducted on the Digital Substation Platform to prove the functionality of integrated systems, and to prove that Locamation's protection operations are not compromised by housing an SGS application on the CCU.

Testing of the Locamation SA*Sensor* equipment demonstrated measurement of key network parameters, digital fault recording and overcurrent protection. Through this, it was established that the protection functionality is not compromised by the SGS application, however further testing of this will be done in Phase 2 of the project. The operation of the overcurrent protection is illustrated in Figure 3. The increase in current can be seen in the top graph, occurring after 50 ms, and continues until after 1100 ms. The middle graph shows the voltage of the busbar, and the bottom graph shows the digital signal for the overcurrent protection to operate.

Testing of the ANM system demonstrated that the **sgs voltage** application controlled the generator's real and reactive power to keep network voltages within limits. Network voltages were then kept within limits through control of the AVC which changed the transformer's tap settings to release capacity to the generator.

The data integration between the two platforms was then demonstrated. The two platforms communicate through DNP3.0 communications and voltage measurements were shared between them. The tests conducted on the ANM system were repeated with the AVC control functionality within the Locamation CCU to demonstrate the functional integration of the platforms.

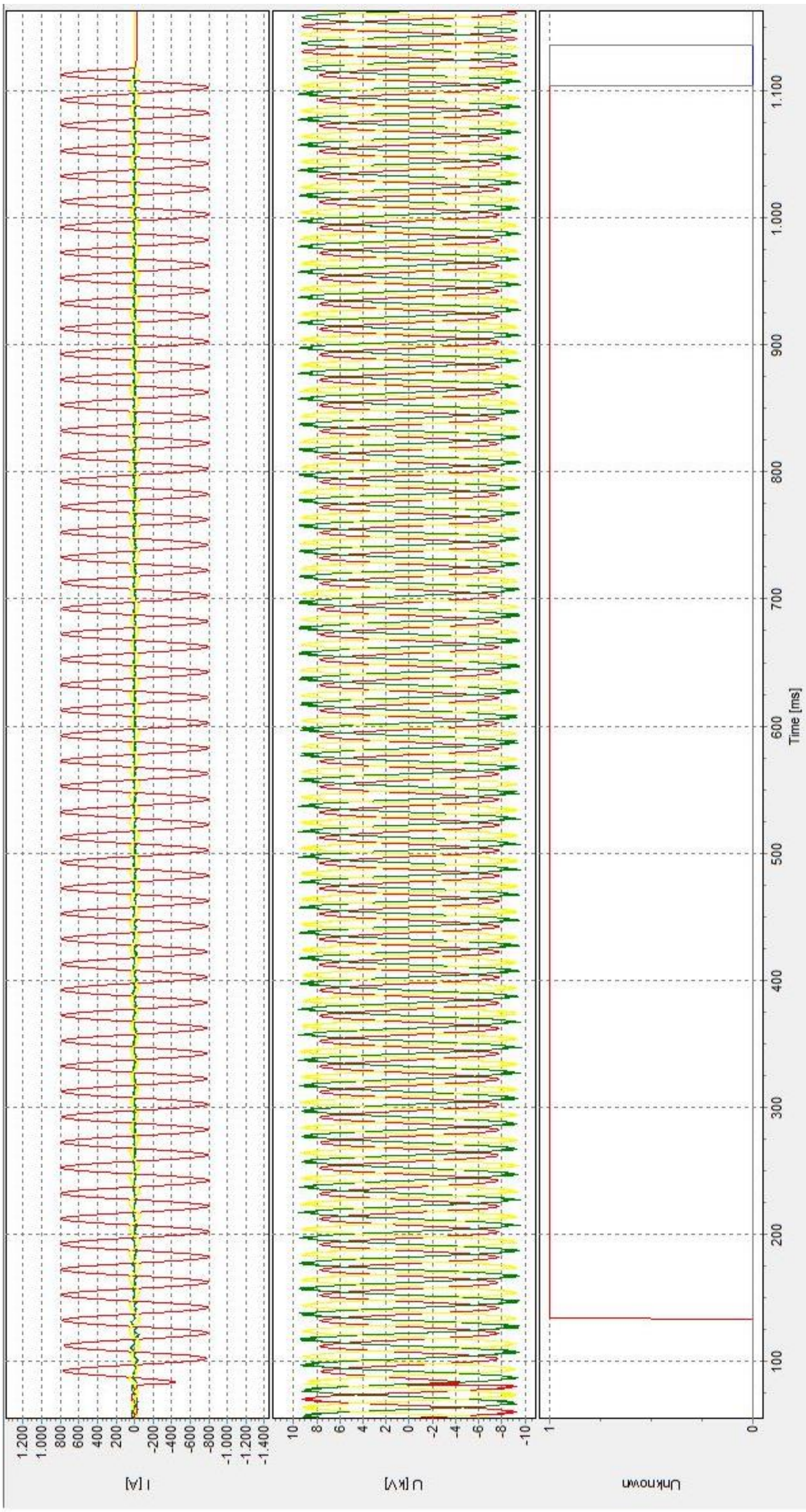

Figure 3: Fault current (top), busbar voltage (middle), protection operation signal (bottom)

4.2.2 Workshops: Aims and outcomes.

SGS and Locamation delivered workshops in parallel with the integration of the two systems to facilitate sharing of knowledge, discussion of key issues and to determine the requirements for Phase 2 of the project. They also took part in a workshop with SHEPD staff. The objectives and outcomes of this workshop are detailed in this section.

4.2.2.1 Workshop 1: 26th February 2015

This workshop aimed to provide an overview of the Digital Substation project as a whole with reference to both the project and business case objectives. Discussion around issues and concerns for progression to Phase 2 was encouraged, which included possible approaches for Phase 2. The main objective of the workshop was to consider the transition towards a business-as-usual roll-out for the Digital Substation project.

The attendees at this workshop are outlined in Table 1.

Table 1: Workshop 1 attendees

Organisation	Attendee
SHEPD	Bill Barrett Andrew Urquhart John Robertson Ian Strachan Andrew Martin Iain Bremner
Locamation	Rene Wassink Russell Clayman
SGS	Euan Davidson Tom Leonard

The participants in the workshop concluded that Phase 1 of the project was progressing as planned. One of the key points arising from the workshop was the importance of suitable communications links.

It has been agreed that a proposal will be drafted for Phase 2, which will be considered for putting forward as a NIA governance project. Highlights from the discussion on Phase 2 include:

- Deeper integration of the SGS and Locamation platforms such that hardware costs are reduced. To achieve this further analysis will be required, and protection must be the priority system that cannot be compromised.
- The issue of cyber security is of significant importance. It has been suggested that a Threat Analysis should be conducted as part of Phase 2, and that the Digital Substation solution should investigate interaction with appropriate security systems.

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- Penetration and fuzz testing will be required, however as SHEPD currently have no benchmark for this, success criteria could be outlined in Phase 2. Fuzz testing is the bombardment of the inputs to a software application with a stream of random data, in order to provoke errors, crashes, and expose vulnerabilities. These vulnerabilities could allow cyber attacks to be successful, so fuzz testing improves the security of the software.
- The cost benefit analysis should progress beyond that in Phase 1. It should use more tightly defined commercial values and include the cost associated with environmental protection and for SHEPD supporting the Digital Substation solution. Also, a cost benefit analysis for cyber security should be conducted as complex security systems can be expensive. The quantification of threats, and the appropriate response should be defined for the move towards business-as-usual rollout.
- As the transition to a business-as-usual rollout is a key, overall outcome from this project, it was identified that appropriate SHEPD resources would be involved to ensure that progression of the Digital Substation solution considers SHEPD procedures and processes.

5 The outcomes of the project

There are four key learning outcomes for this project, which are:

a) Protection of primary assets using SA*Sensor*'s suite of protection algorithms;

b) Simulated control of a generator to allow for the management of voltage on the network;

c) Demonstration of data integration and interfacing between the two platforms

d) Definition of a methodology for deeper integration in Phase 2.

5.1 Protection of primary assets using SA*Sensor*'s suite of protection algorithms

The protection functionality of the Locamation SA*Sensor* was demonstrated as part of the Acceptance Tests carried out at PNDC. All faults applied through the simulated network produced the intended outputs.

5.2 Simulated control of a generator to allow for the management of voltage on the network

The Generator control simulation was proved during the ANM Testing part of the Acceptance Tests at PNDC, and showed that voltage management was possible for both Real and Reactive power using generation control.

5.3 Demonstration of data integration and interfacing between the two platforms

The integration of data between the 2 platforms was demonstrated during the Data Integration tests carried out as part of the Acceptance Tests at PNDC. The tests also proved the primacy of the protection system ahead of the generation management control.

5.4 Definition of a methodology for deeper integration in Phase 2.

5.4.1 A key outcome of the workshops held between SHEPD, Locamation and SGS, was the requirement for the following in Phase 2:

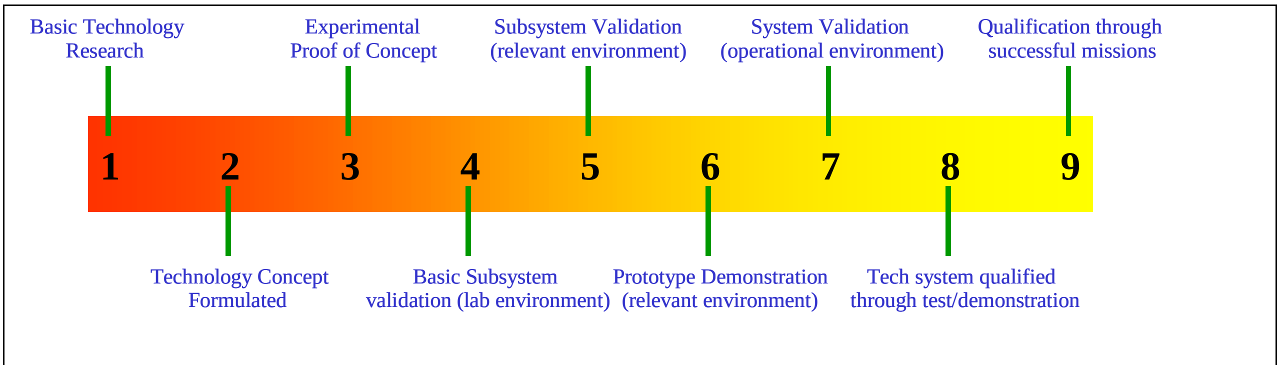
- A methodology for determining that protection functions running on the SA*Sensor* platform remain unaffected by the addition of ANM functions and other functions that SHEPD may wish to deploy. Whilst SHEPD seeks a solution that is flexible, extensible, and scalable, certainty of the primacy of the protection functionality must be demonstrated;
- Testing at PNDC on the 11 kV network rather than simulation with representative generation plant used to feed into the test network; and

- Investigation into a structured approach to cyber-security, informed by threat modelling and potentially penetration testing.
- A detailed cost benefit analysis with tightly defined commercial figures is required.

5.4.2 Based on the requirements above, the following methodology is proposed for Phase 2:

1. Injection testing of the SA*Sensor* systems at PNDC. To provide evidence that the protection functions are not affected by adding additional functionality, SGS and Locamation proposed an approach whereby the performance of the required protection functions are baselined using injection testing. By running a large number of injection tests, baseline probability distributions for the performance of the protection function for each test will be obtained. These tests can then be repeated with ANM functionality, or any other functionality, running alongside or within the SA*Sensor* platform. Comparison of these tests with the results of the baseline tests will then be used to show no effect on protection scheme performance.
2. Replication of Phase 1 Stage 1 and 2 tests at PNDC on the 11 kV test network:
    a. Design and development of the live system experimental set-up by staff at PNDC. Discussions during Phase 1 highlighted the challenges in running a set of experiments on the 11 kV network at PNDC. PNDC will be required to design an appropriate experimental set-up within the facility. This is a non-trivial task; and
    b. Based on PNDC's experimental design, repeat Phase 1 Stage 1 and 2 tests on the 11 kV network using representative generation plant and throwing faults to exercise the protection functions.
3. Migration of further ANM functionality to the Digital Substation Platform. This should include:
    a. Running Locamation's AVC function on the Digital Substation Platform rather than having an additional AVC relay in situ; and
    b. Further integration of ANM functionality within the Digital Substation Platform.
4. Testing of the Phase 2 solution within the 11 kV test environment at PNDC, as per an experimental design produced by PNDC; and
5. Investigation of an appropriate approach to cyber security threat modelling and penetration testing with SHEPD.
6. Detailed cost benefit analysis which will consider TOTEX in detail as well as consider any environmental protection that may be required and for SHEPD supporting the solution.

5.5 Technology Readiness Level (TRL)



1	2	3	4	5	6	7	8	9
				OUTSET	**END**			

Figure 4: Start and End TRL for project.

The start TRL of 5 is due to both of the component parts being readily available for procurement in the commercial world, and installed in several locations in the UK, but not having been used together prior to this project, so the subsystems can be regarded as validated technologies. The project has moved the technology of the combined on to a demonstration of the prototype combined system in a relevant test environment. Due to the constraints placed on the testing by the test environment at the PNDC, the next phase of the project would still start at TRL 6. The testing already undertaken would have to be repeated using an energised network; to confirm the findings from using a simulated network; prior to further development work on closer integration between the 2 systems being carried out.

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6 Performance compared to original project aims, objectives and success criteria

The project has achieved the project aim by showing that the integration of software from a third party onto a recognised protection platform is feasible, and that the separate functions of the two algorithms tested do not conflict with each other.

Table 2 - Extent to which objectives have been met

Objective	Met?	Commentary
Protection of primary assets using SA*Sensor*'s suite of protection algorithms.	✓	A series of short circuit tests on the PNDC network was simulated in the RTDS with Omicron Test Sets being used to injection test the partially integrated system with Locamation's suite of protection algorithms. Successful testing was witnessed by SHEPD on the 12th of March 2015.
Simulation of control of a generator to allow for the management of voltage on a network.	✓	A model of the 11 kV overhead line network at PNDC was created in RSCAD, the modelling tool for the Real Time Digital Simulator (RTDS). This included a 500 kW wind turbine connected at the end of the overhead line. The simulated generator was sized such that voltage rise limits the permissible export of the machine when the network is lightly loaded. SGS's ANM system was used to release additional capacity to the generator through the following control measures: - Management of the AVC set-point to lower the voltage along the feeder whilst maintaining voltage at all buses within Electricity Safety, Quality and Continuity Regulation (ESQCR) limits; - The use of the wind turbine's own reactive power capabilities to absorb reactive power and reduce voltage rise at key constraint locations; and - The use of real power curtailment to mitigate voltage rise at key constraint locations. SGS's ANM system was interfaced to the RTDS via a DNP3.0 connection and also to the Locamation System. The real time simulation test environment was used to demonstrate the functionality above. Testing was successfully completed at the PNDC on the 12th of March 2015 and witnessed by SHEPD.
Demonstration of data integration and interfacing between the two platforms.	✓	Data integration via a DNP3.0 link between SGS's ANM platform and Locamation's SA*Sensor* platform was demonstrated at the Power Networks Demonstration Centre (PNDC). Both systems were run

		alongside one another and their joint performance as a protection system (Locamation's SA*Sensor* system) and an ANM system (SGS's ANM50 system) were baselined. Part of the ANM system functionality was then ported to run on Locamation's platform. Baseline tests were repeated and the performance of the partially integrated systems was validated against the results of the baseline testing.
Definition of a methodology for deeper integration.	✓	Based on the results of testing at PNDC and the outcome of a series of workshops, SGS and Locamation have defined a methodology for deeper integration between the previously distinct systems, running ANM algorithms alongside protection functions provided by Locamation.

Table 3 - Extent to which success criteria have been met

Objective	Met?	Commentary
Produce requirements for the next phase of integration of the two systems	✓	Workshops were held between SHEPD, SGS and Locamation to assist in the definition of the requirements for the next phase of integration. The workshops covered key functional and non-functional requirements for any further development of the Digital Substation concept. The requirements for the next phase of the project focus not only on the functionality of the Digital Substation solution, but also on flexibility, extensibility and scalability for other test networks. Security of the platform is a key area requiring investigation to ensure that a deployed Digital Substation solution would be secure against cyber-attack.
Develop a draft Cost Benefit Analysis to indicate business benefit of using the combined system	✓	The draft cost benefit analysis is included as Appendix 1.

7 Required modifications to the planned approach during the course of the project

The test facility chosen to provide a test and demonstration facility was the Power Network Demonstration Centre (PNDC) at Cumbernauld. These facilities included the ability to fit the Locamation hardware with both Locamation protection software, and the SGS ANM control software installed, into a live network sub station. Following discussions with the staff at PNDC it was obvious that the proposed tests could not take place on the PNDC live network, as they were not able to provide a controllable source of generation within the timeframe needed.

The alternative of creating a test network on the PNDC Real Time Digital Simulator, which would mimic the responses of a real network to the protection and control signals produced by the integrated platform, was considered to be a valid way forward. All tests were carried out using this simulated network.

8 Significant variance in expected costs and benefits

The project used the combined skills of Locamation and Smarter Grid Solutions. The 2 companies were required to work together as equal partners, without a primary contractor. Each of the companies assigned a project manager to the project, and they held regular weekly meetings with the SHEPD project manager. As a research and development project, the forecast analysis and ICT design costs were estimates, and came in under the forecast. Most project meetings were held using conference calls, which reduced travel needs and saved time allocated to the project. The Overall time and financial budgets were close to forecast.

Table 4 - Project costs

Item	Forecast	Actual	Variance (£k)	Variance (%)
Project Management	£40k	£38,044	-£1956	-4.89
Analysis	£80k	£77,125	-£2875	-3.59
Tender Process	£10k	£10k	0	0
Contract Creation	£6k	£6k	0	0
ICT Design	£51,300	£49,300	-£2000	-3.90
PNDC Testing	£32k	£32108	£108	0.33
Contractor (service)	£6.5k	£6.5k	0	0
Equipment	£22.5k	£22.5k	0	0
Total	£248,300	£241,577	-£6723	-2.71

The aim of the project was to prove that the concept of installing one vendor's software on another vendor's hardware platform was feasible. The Locamation hardware platform uses a proprietary operating system that Locamation have developed over a number of years, and allow third party developers access to the system in order to provide additional functionality to the base system. SGS already had a proven ANM system that ran on a Real Time enabled version of Linux. This project required that the 2 companies worked together to port the SGS software to work on the Locamation hardware, in such a way that the full functionality of both systems was available to the DNO, and that the protection system provided by the Locamation hardware was not compromised by the SGS software. The initial testing carried out at the PNDC has shown that this is the case, with the protection taking the highest priority and operating even when the ANM software is carrying out constraint management.

Further testing and development work is needed to confirm that the system will operate as intended in the real world, when installed in a substation; but this preliminary project would indicate that by using the Locamation platform, there is no requirement to procure additional standardised server hardware

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to run the ANM system software on. A standalone ANM system uses 2 standardised servers, one for managing communications between the system and the Generators, and the second to carry out the processing and calculate the constraints to be placed on each generator. The current cost of these servers is approximately £7.5k each, so as a minimum a hardware saving of £15k per substation should be possible.

9 Lessons learnt for future projects

The project has shown that it is possible to port advanced software from one operating system and hardware platform to another, from a commercial open source base to a proprietary closed base, which is available for external developers to use.

9.1 Test constraints

The test facilities at PNDC were shown to be able to allow the developments to be fully functionally tested in a RTDS. However, it would have been beneficial to have been able to install the Locamation hardware on the Live test network at PNDC, to give a 'real world' sense of the success of the testing. This was not possible in the timeframe that the project worked under, and the decision was taken to use the onsite Real Time Digital Simulator (RTDS) instead. The RTDS has been used by PNDC for many other initial development testing scenarios, for SHEPD and other DNOs, and equipment manufacturers, so the decision was taken in the knowledge of previously successful test regimes.
A DNO that wished to replicate the project would be advised to find a Live test network that could be used to carry out the integration and functional tests, so that they would have the benefit of knowing how the integrated system is likely to operate once installed on their distribution network.

9.2 Cyber security

For this phase of the project Cyber Security was not considered to be an issue, as the systems were not going to be connected to external networks. The requirement for cyber security was stressed at the project start up meeting, and again at the workshop held with SHEPD staff. Both of the vendors are fully committed to providing cyber security built in to the final product, and have planned for this as part of the development tasks.

9.3 Future trialling required

The next phase of the project will be to take the development forward to having a trial system installed at a SHEPD primary substation.
This will require the system developed as is to be tested again at PNDC, connected to a substation on their 11KV test network.
Following successful completion of the test schedule, SHEPD will then have to decide on a suitable location to install the integrated system. The location will require the need to have control of distributed generation, as well as require an update to the installed protection systems.
The decision will have major consequences across the Distribution network, so will have several dependencies to meet. These are:

1) The IFI funded project, 2012_03 SA*Sensor* HMV Primary Substation Provider, which has now transferred into NIA funding as NIA SHEPD 0002 SA*Sensor* HMV Primary Substation

Provider, will have to produce a successful outcome with a recommendation to transfer into BAU agreed with SHEPD Protection Engineering,

2) SHEPD Policy department will have to fully approve the installation, and
3) SHEPD Planning will have to identify a suitable site,
4) Data communications to the substation will either have to be in place already, or installed as part of the project. There is a need for 2 data paths, one which will feed directly into the SHEPD Power On SCADA system, and the other to allow remote access to the Locamation system. These paths will need to be security hardened as appropriate to their use and approval gained from SSE's IT department.

The learning produced by NIA SHEPD 0002 project above, will be valuable in producing understanding of the installation of the Locamation system, and the day to day operation of the system.

The trial will have to be carried out over a period of 18 months in order to capture as much learning as possible covering as much of the normal and abnormal operating conditions that occur on the distribution network attached to the sub station.

10 Planned implementation

This project was not intended to produce a system that could be passed into BAU. The project is a proof of concept, looking at whether or not it is feasible to combine two different network management functions into one set of hardware.

The extra work needed to produce an installable system is:

1) Carry out full functionality testing on a live network (PNDC Test Network)
2) Decide on the protection functionality that is required in a live substation environment. The protection modules available from Locamation are listed in table 5 below.
3) Install the system in a primary substation and use it to monitor the existing protection system, checking to see that the new system produces the same actions as an existing system does.
4) Assess the results of the monitoring in an operational environment, and then decide on suitability for BAU.

Table 5: SASensor protection operations

Protection Operation
Overcurrent Protection
Breaker Failure Protection
Over/Undervoltage Protection
Neutral Overvoltage Protection
Directional Earthfault Protection
Arcing Earthfault Protection

11 Project replication and intellectual property

The following tables list all physical components and knowledge required to replicate the outcomes of this project, showing how the required IP can be accessed by other GB DNOs. Further detail relating to any knowledge item is available from SHEPD on request through futurenetworks@sse.com.

Table 6 - Components required for project replication

Component	Products used in project or commercially available equivalents
Locamation hardware	1. 1x CCU (Central Control Unit) 2. 1x VCU106 (Versatile Communications Unit) 3. 1x BIM641 (Breaker Interface Module) 4. 2x VIM622 (Voltage Interface Module) 5. 1x CIM631 (Current Interface Module) 6. 1x MP/Pentium 7. 1x MP601
Locamation software	1. Standard Locamation platform consisting of ARTOS operating system and modules for fault recording, power quality, transformer tap change control, directional over current protection, Modbus data communication and the graphical programming interface
SGS hardware	1. 2 x Amplicon E72 Industrial PC 2. 2 x Brodersen RTU32
SGS software	1. SGS standard ANM modules, SGS Core, SGS Comms Hub, and SGS Connect; with the addition of SGS Voltage for voltage control.
PNDC	1. Real Time Digital Simulator.

Table 7 - Knowledge products required for project replication

Knowledge item	Application	IP ownership and availability
Initial project design Testing	Design of the integration of SGS Software on to the Locamation platform. Test schedule for testing at PNDC	SHEPD Available through project contacts.

12 Project contacts

SHEPD	futurenetworks@sse.com.
Locamation	rene.wassink@locamation.nl
SGS	a.smith@smartergridsolutions.com

13 Appendix 1 Draft Cost Benefit Analysis

The outcome of phase 1 of the project was that it was feasible to interface the Locamation SA*Sensor* and SGS ANM systems. The SGS Connect was coded for use on the SA*Sensor* platform and the main ANM scheme was running on a Linux platform communicating with SA*Sensor* over DNP3. This enabled SGS to manage the algorithms as part of a roll out within their standard processes. The next phase for the project would be to investigate methods to combine the operation of both systems onto suitable hardware for substation deployment.

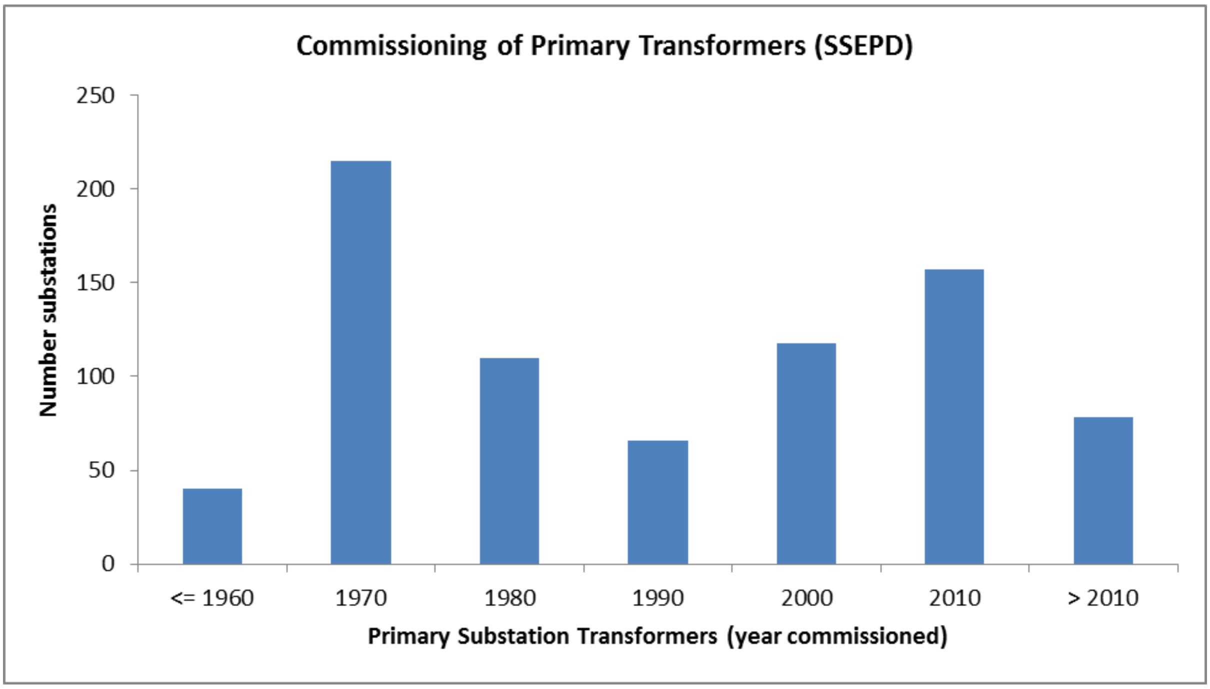
Through rationalisation of the two systems there was the elimination of some components; however should the project move to the next phase there would be potentially further rationalisation. However, this assumes that there is a business need to deploy both the ANM system and Locamation SA*Sensor*.

Savings identified from phase 1 due to elimination of components used at present:

Item	Saving
SGS connect (Brodersen RTU32) including installation	£10,000
Tap change control	£9,000
TOTAL	**£19,000**

The average cost of an ANM deployment from Work Stream 3 is £360,000 across different voltages. An individual installation of a typical 12 panel switchboard Locamation SA*Sensor* system would be in the order of £55,000. Following further integration of the two systems, rollout of the Locamation hardware will allow DNOs to ANM-enable their substations while benefiting from the existing advantages of the SA*Sensor* platform. The commercial model for such a roll out is not yet defined but a small incremental price to provide a SA*Sensor* that is 'ANM-enabled' is likely to reduce the overall costs for ANM by more than the individual hardware costs and, across a small number of substations, will provide significant savings.

The graph below shows the relative age of primary substation transformers and there will be an increasing need to consider replacing the existing protection equipment. There are more than 200 substations where the transformers were commission more than 45 years ago and therefore their protection equipment may require replacement. It has been estimated that replacing the existing protection with the Locamation SA*Sensor* system could provide a cost benefit of £5,000 per substation (based upon a 12 panel switchboard).



Therefore, if that substation was also deemed to be appropriate for ANM deployment there would be potential benefits in excess of £24,000. As a result the benefit case is driven heavily firstly by the protection systems installed in a particular substation and secondly the need for an ANM system.

A further consideration in 'ANM enabling' primary substations ahead of need is the on-going obsolescence and maintenance overhead alongside any software licencing costs. The specifics of the commercial arrangements in place are therefore paramount to the benefit case in this scenario.