Dynamic Rating Monitoring Control Communication (DRMCC)

UNITED ENERGY

Project № PJ1413

Project Justification

This document justifies capital expenditure on the United Energy network.

REPEX Road Map

1. Asset replacement – Modelled

a. 6 modelled asset categories

2. Asset replacement – Modelled & Unmodelled

a. Pole top structures + SCADA/protection

3. Other Repex - Unmodelled

a. ZSS Primary Asset Replacement
   - (i) CEES - Capacitor Banks + Earth Grid + Neutral Earthing Resistors
   - (ii) CEES - Buildings

b. Non VBRC Safety Projects
   - (i) Intelligent Secure Substation Asset Management (ISSAM) – UE PL 2401 e.g.CCTV

c. Operational Technology
   - (i) OT Safety
     - Service Mains Deterioration Field Works – PJ1385
     - In Meter Capabilities IMC) – PJ1386
     - Light Detection and Ranging (LiDAR) Asset Management – PJ1400
     - OT Security – PJ1500
     - DNSP Intelligent Network Device – PJ5002
   - (ii) OT Reliability
     - Distribution Fault Anticipation Data Collection and Analytics (DFADCAA) – PJ1599
     - Fault Location Identification and Application Development – PJ1600
   - (iii) OT Other
     - Dynamic Rating Monitoring Control Communication (DRMCC) – PJ1413
     - Test Harness – PJ1398
     - Pilot New and Innovative Technologies – PJ1407

d. Network Reliability Assessment UE PL 2304 – Projects
   - (i) Automatic Circuit Re-closers (ACRs) and Remote Control Gas Switches (RCGSs)
   - (ii) Fuse Savers
   - (iii) Rogue Feeders
   - (iv) Clashing
   - (v) Animal Proofing
   - (vi) Communications Upgrade

e. CEES – Environment

f. CEES – Power Quality Maintained

g. Terminal Station Redevelopment HTS and RTS - UE-DOA-S-17-002 & UEDO-14-003

4. VBRC Projects

a. HV Aerial Bundled Cable Strategic Analysis Plan - UE PL 2053

b. DMA and MTN Zone Substation Rapid Earth Fault Current Limiter (REFCL) Installation

c. Other VBRC projects

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1. EXECUTIVE SUMMARY

Project description

The Dynamic Rating Monitoring Control Communication (DRMCC) system provides a comprehensive transformer monitoring and control solution for medium and large Zone Substation power transformers. The proposed project is to conduct a pilot to assess the benefits of further deployment.

Project Driver

The principal driver for this project is capex efficiency. A secondary driver is the reduced risk of a catastrophic failure of Zone Substation transformers.

Benefits

Dynamic / predictive rating enables controlled emergency loading above the nameplate rating and the conventional static thermal rating, without undue risk. The dynamic rating of a transformer is the maximum load possible without exceeding predefined thermal and current rating limits, based on real time measured ambient and transformer temperatures, cooling system status and load.

The DRMCC system therefore provides the following potential benefits:

- Additional transformer capacity at critical peak times;
- A reduction in the probability of catastrophic failure, especially for transformers with higher than average risk of failure.
- Life extension for transformers that are subject to heavy loading or may be approaching end of life.

Each of these benefits translates to capex efficiency. However, it is important to note that the proposed project is a pilot scheme. The purpose of the pilot is to assess the likely benefits of a wider deployment of the DRMCC system.

Options analysis

The purpose of the pilot scheme is to determine the expected benefits from a wider scale deployment of the DRMCC system. As such, it is not possible to demonstrate unequivocally that the net benefit of the pilot scheme exceeds the status quo ‘reference case’. However, it is possible to determine whether the pilot scheme is likely to provide benefits that exceed the project costs.

The table below presents the alternative options.

Table 1: Option Evaluation ($M, expressed in present value (PV) terms)[1]

Options	PV costs ($M)	PV benefits ($M)	Net Present Value ($M)	PVR (Benefit to Cost Ratio)	Ranking
Reference Case (Status Quo)	0	0	0	0	2
Option 1 - Dynamic Rating Monitoring Control Communication (DRMCC) Pilot Scheme	**1.88**	**See table 2**	**See table 2**	**N/A**	**1** **See Table 2**

As shown in Table 1, the reference case delivers a net benefit of zero. In order for the pilot scheme to be preferred, the likely benefits would need to exceed the project cost of $1.88M in present value terms. Table 2 shows the potential sources of benefit and the required savings in order to justify the pilot scheme.

Table 2: Potential Benefits from Pilot Scheme

Source of benefit	Required benefit to justify pilot scheme	Likelihood of occurrence
Avoidance of transformer augmentation	A typical transformer augmentation has a capital cost of $6M, which is an annualised total capital cost of approximately $500k. To deliver benefits equivalent to the cost of the pilot scheme, a single transformer augmentation would need to be deferred for more than 4 years.	Likely. There is limited transformer augmentation planned in the forthcoming regulatory period. However, further opportunities are likely in future regulatory periods – and the required amount of deferral is modest.
Avoidance of catastrophic failure	The consequential losses of a single occurrence (prolonged outages, equipment damage and fire) would likely exceed the costs of the pilot scheme.	While not likely to occur, the avoidance of catastrophic failure may justify the pilot scheme in order to comply with our obligation to reduce risk to as 'low as reasonably practicable' ALARP.
Transformer life extension	The capital savings from extending a transformer's life by 1 year is approximately $500k per annum. The project is justified if the equivalent of 4 years life extension is achieved across the transformer fleet (expressed in PV terms).	Likely. The amount of life extension required to justify the pilot scheme is relatively modest, given that UE has 112 zone substation transformers.

1 It should be noted that the undiscounted forecast project costs for Option 1 are provided in Table 7 and 8.

Recommendation

It is recommended that the pilot scheme should proceed, as it is likely to provide benefits that exceed the costs. Furthermore, it is prudent to improve the monitoring and control of zone substation transformers, given the critical nature of this asset class.

2. Objectives / Purpose

The objective of this project is to pilot a suitable transformer DRMCC solution for the purpose of delivering capex efficiencies. The DRMCC solution is able to maximise the available transformer capacity, without adversely contributing to transformer aging.

This project is a pilot scheme, which will provide a small scale deployment of the DRMCC solution. The purpose of the pilot scheme is to determine whether a wider scale rollout of the solution is warranted.

3. Strategic Alignment and Benefits

3.1 Asset Management Strategy and Strategic Themes Alignment

This project supports the following strategic themes:

- Maintain network reliability while running transformers outside static limits (i.e. static overload conditions).
- Implement solutions that extend asset lives and defer capex.
- Reduce asset down time.
- Realise and utilise actual zone substation transformer capacity.
- Enable transformer end of life decisions to be made with supporting DRMCC information.

3.2 National Electricity Rules Expenditure Objectives Alignment

This project enables UE to meet its capex objectives prudently and efficiently, in accordance with the requirements of the National Electricity Rules.

4. Alternative Options Considered

4.1 Background and Identified Options

Dynamic / predictive rating enables controlled emergency loading beyond nameplate rating and beyond conventional static thermal rating based on loading guides, without undue risk. The dynamic rating of a transformer is the maximum load possible without exceeding predefined thermal and current rating limits, based on real time measured ambient and transformer temperatures, cooling system status and load.

The monitoring, communication and control features of the DRMCC System provide a complete control solution for medium and large power transformers, including:

- Monitoring of single or three phase amps, volts, watts, vars, frequency, tap position, ambient, oil temperature, winding hot spot, insulation loss-of-life, tap changer status, Load Tap Changer (LTC) diagnostics, and cooler status. The solution provides a forecast for the top oil and hot spot temperature based on the thermal response of that specific transformer, the load on the transformer and the ambient temperature in the Zone Substation.
- Controls are provided for both cooling and LTC operation. Predictive cooling control is generally provided for up to 4 cooling stages. On-load Tap Control includes built-in parallel control with circulating current, master follower, VAR sharing and reverse reactance all included
- Communication features include a variety of interfaces and protocols. Each DRMCC system can be easily interfaced to master DRMCCs and existing SCADA systems for two way communication.

The following options have been evaluated:

Reference Case:	Under the "Reference Case", the status quo is maintained
Option 1:	Implement Transformer DRMCC Pilot Scheme

4.2 Reference Case - Status Quo

The Reference Case will maintain the current processes and no improvements will be made with respect to meeting energy demands beyond the static Zone Substations transformers ratings.

The reference case is acceptable from a compliance perspective.

4.3 Option 1 – Transformer DRMCC Pilot Scheme

The Dynamic Rating Monitoring Control Communication (DRMCC) system provides a comprehensive transformer monitoring and control solution for medium and large Zone Substation power transformers. In particular:

- Monitoring is provided for single or three phase amps and volts, watts, VARs, frequency, tap position, ambient, oil temperature, winding hot spot, tap changer status, LTC diagnostics and cooler status.
- Control is provided for both cooling and LTC operation.
- Cooling control is provided for up to four cooling stages.
- On-load Tap Changer control includes built-in paralleling control with circulating current, master follower, VAR sharing and reverse reactance all included.

The associated interface and communication protocols allow interfaces to Master DRMCCs and existing SCADA systems. The master DRMCCs will hold the individual DRMCCs configurations, measurements, events and controls history with the ability to provide overall analytics, logs and reports.

A number of transformer suppliers and other services providers now include DRMCC as part of their solution set. In the US, Kansas City Board of Public Utilities (BPU) and San Diego Gas & Electric have successfully implemented DRMCC solutions. The successful implementation of DRMCC solutions by other electricity distributors provides the confidence that this pilot and therefore Option 1 will be successful.

4.4 Technical Summary

Table 3: Technical Summary

Alternative	Reference Case (Status Quo)	Option 1 – Transformer DRMCC Pilot Scheme
Technically Viable	Yes	Yes
Address Reliability	No	No
Network Flexibility	No	Yes
Comments	Does not address the identified need for UE's Zone Substation DRMCC solution	Addresses the identified need for UE's Zone Substation DRMCC solution

5. Economic Evaluation

5.1 Evaluation of Options

The table below provides a summary of the costs and benefits of Options 1 relative to the Reference Case. However, the purpose of the pilot scheme is to determine the expected benefits from a wider scale deployment of the DRMCC system. For this reason, the benefits of the pilot scheme are shown as "To be determined".

Table 4: Cost and benefits of Options ($M, expressed in present value (PV) terms) [2]

	"Status Quo" Reference Case	Option 1: Transformer DRMCC Pilot Scheme
Costs: **Project Capex ($)**	$0	$1,878,464
Potential Benefits: **Avoidance of transformer augmentation ($)1**	$0	To be determined
Avoidance of catastrophic failure ($)	$0	To be determined
Transformer life extension		To be determined
Total Benefits ($)	$0	To be determined
Net Present Value ($)	$0	To be determined

While it is not possible to estimate the benefits of the pilot scheme prior to its commencement, we can determine whether the pilot scheme is likely to provide net benefits that exceed the project costs.

Table 5 below sets out this analysis.

Table 5: Potential benefits from Pilot Scheme

Source of benefit	Required benefit to justify pilot scheme	Likelihood of occurrence
Avoidance of transformer augmentation	A typical transformer augmentation has a capital cost of $6M, which is an annualised total capital cost of approximately $500k. To deliver benefits equivalent to the cost of the pilot scheme, a single transformer augmentation would need to be deferred for more than 4 years.	Likely. There is limited transformer augmentation planned in the forthcoming regulatory period. However, further opportunities are likely in future regulatory periods – and the required amount of deferral is modest.

2 It should be noted that the undiscounted forecast project costs for Option 1 are provided in Table 7 and 8.

Source of benefit	Required benefit to justify pilot scheme	Likelihood of occurrence
Avoidance of catastrophic failure	The consequential losses of a single occurrence (prolonged outages, equipment damage and fire) would likely exceed the costs of the pilot scheme.	While not likely to occur, the avoidance of catastrophic failure may justify the pilot scheme in order to comply with our obligation to reduce risk to as 'low as reasonably practicable' ALARP.
Transformer life extension	The capital savings from extending a transformer's life by 1 year is approximately $500k per annum. The project is justified if the equivalent of 4 years life extension is achieved across the transformer fleet (expressed in PV terms).	Likely. The amount of life extension required to justify the pilot scheme is relatively modest, given that UE has 112 zone substation transformers.

Tables 4 and 5 shows that Option 1:

- Is likely to deliver benefits that exceed the costs of the scheme; and
- Is preferred to the Reference Case, which has a net benefit of zero.

5.2 Benefits Summary

The recommended option, Option 1 will provide the following key benefits:

Table 6: Option 1 Benefits Summary

Option 1	Maintain / Improve Quality of Supply	Maintain / Network supply security / Reliability	Extend asset life	Meeting Customer expectation of a safe and secure electricity supply	Mitigate Risk	Reduce costs	Improved asset information history	Improved network and or labour efficiency	Realizing True Capacity	Lower number of planned and unplanned outages	Reduced asset down time
Transformer DRMCC Pilot Scheme	No	✓	✓	Possible	✓	✓	✓	✓	✓	Possible	Possible

The benefits of the DRMCC solution are summarised in the table above. As already noted, the key benefits arise from the real time measurement of operational parameters, which allows the dynamic rating of the transformer to be determined and optimal performance realised.

5.3 Optimum timing and capex profile

The proposed work program for the preferred solution will commence implementation in 2016. The technology will be deployed on transformers that are normally heavily loaded and are likely to exceed static full load limits when load peaks occur. The implementation timetable allows the application of the technology to be refined and enhanced in light of operational experience.

The proposed capital expenditure to implement Option 1 is detailed below.

Table 7: CAPEX for preferred option

CAPEX Forecast ($'000 Real) CAPEX type: Augmentation	2016	2017	2018	2019	2020	Total
Option 1 – Transformer DRMCC Pilot Scheme	646.9	470.1	403.7	471.9	219.3	**2,211.9**

Note: The capex amounts shown in the table above are undiscounted, and are consistent with the present value costs shown for Option 1 in Tables 1 and 4.

6. PROJECT FINANCIALS

The project financials for internal budgeting purposes are detailed below.

The status of the preferred project is detailed below:

Table 8: Project financials - Preferred Option (Option 1)

PROJECT COST	
Year Budgeted	2016 to 2020
Required Service Date	31 Dec 2020
Budgeted Cost ($A excluding GST)	$2,010,800
Business Case Cost ($A excluding GST)	$2,010,800
Business Case Cost + UE overheads ($A excluding GST)	**$2,211,900**

Note: The capex amounts shown in the table above are undiscounted, and are consistent with the present value costs shown for Option 1 in Tables 1 and 4.

7. Recommendation

It is recommended that the pilot scheme should proceed, as it is likely to provide benefits that exceed the costs. Furthermore, it is prudent to improve the monitoring and control of zone substation transformers, given the critical nature of this asset class.

8. APPENDIX A – HIGH LEVEL SCOPE OF WORK

The scope includes:

- Evaluate initial technological and benefits currency, include any new functionality, remove obsolete functionality, prioritise initiatives and produce the associated business case
- After business case approval, initiate project, identify and obtain resources
- Phase 1: Perform the following for the pilot
  - Plan equipment rollout and software changes
  - Purchase equipment and any software required
  - Rollout equipment, configure and implement any software changes
  - Test equipment including hardware and software functionality
  - Commission in to service
  - Modify processes and complete all documentation
  - Monitor performance of the DRMCC pilot system
- Validate the success of the pilot and determine any changes that are required for a wide scale deployment
- Carry out phase 2 if phase 1 is successful
  - Phase 2: Repeat items under Phase 1 to implement the solution until project funding is exhausted
- Closeout project

The DRMCC solutions implemented as part of this pilot will need to cater for following functionality:

- Efficient user Interface with multi-level password control, graphical interface, smart menu buttons, full numerical key pad, weather resistant design, alarm diagnostics, optional remote user display and recommended operator actions
- Self-maintained hardware clock that can be synchronised via NTP, DNP and Modbus
- Multi-Port for a variety of interfaces and input / output modules
- Direct fibre temperature sensing
- Transformer bushing health monitor and electrical partial discharge measurement
- Alarm / status monitoring data storage with at least 12 months history that can be up loaded to master DRMCC systems
- Communication links supporting full IEC 61850, DNP 3.0, Modbus, TCP/IP (SFTP, HTTPS, SSH)
- Communication and Data Security
- A variety of fit for purpose sensors
- Moisture and Thermal Modelling
- Insulation aging for each transformer winding
- Cooling health, efficiency and control

    - The thermal model should adjust the calculated winding temperature hot spot based on the health of the cooling system. The elements of the cooling health should include loss of cooling power, loss of AC control power, contactor failure, oil flow sensors, fan currents and pump currents
    - The predictive top oil temperature is to be compared to the measured top oil temperature to verify that the cooling system is operating correctly and can help identify problems such as:
        - Closed radiator valves or other obstructions to the oil flow
        - Bird nests, tree debris or other external contamination.
    - Predictive Oil Temperature Model
        - Measured load currents and voltage are to be used to calculate relative load losses and no-load losses. By combining this with the ambient temperature, cooling status and cooling system health, an estimated top oil temperature is to be calculated. The predictive oil temperature model can then be used to provide a cross check of the thermal model variables.
- Voltage Control
    - Must be capable of providing primary voltage control or can be used to provide backup voltage control for existing voltage control system
    - Must be capable of voltage adjustment time delays that can be configured by two standard methods:
        - Definite with discrete settings for initial, inter-tap and fast tap time delays
        - Inverse N where time delay used is determined by how far out of tolerance the voltage is.
    - Paralleling functionality utilising any of the following methods (Circulating Current, Master Follower, VAR Sharing, and Reverse Reactance)
    - Operational safety features:
        - Under voltage blocking of raise and lower operations if the control senses a low voltage or no voltage condition
        - Overvoltage blocking of raise operations should the measured voltage exceed the pre-set limit
        - Overcurrent blocking of raise and lower operations if the load current exceeds the rated current of the OLTC
        - Circulating current blocking of tap change operations if the measured circulating current exceeds the pre-set limits
        - Out-of-step blocking to prevent additional tap change operations should the controls get out of sync when using master follower schemes
        - No master and multi-master blocking to ensure one master is present when using master follower schemes.
- Analytics with predictive capability like Dynamic Rating:
    - The dynamic rating is to provide the time remaining at the current state and Maximum Safe Load

        - The time remaining will be the amount of time before the temperature will exceed the maximum thermal limit.

- Provide values for the Maximum Safe Load to indicate the maximum load the transformer can safely carry given the present health of the cooling system and the present environmental and operating conditions of the transformer without pushing the transformer beyond the thermal limit
- “What – If” Rating Calculations:
    - Utilizing the “Predictive Oil Temperature Model” combined with the Dynamic Rating calculation, a “What – If” range of scenarios are to be used to allow additional calculations including:
        - Load for Time: Given an assumed load, how long before the transformer would exceed a specified thermal limit.
        - Time for Load: Given a specific time duration, what is the maximum load the transformer could sustain without exceeding a specified thermal limit.
- Additional strategic asset management decision support software tools that can be centralised and can consolidate and correlate data from multiple DRMCCs to provide full monitoring and control history, dashboards, geospatial representation and reporting
- Master DRMCC Servers must be able to download, upload, stop and start Transformer DRMCC functionality without adversely impacting transformer input / output
- DRMCCs will need to have control enable / disable functionality for all controls available
- Individual transformer DRMCCs will communicate securely to DRMCC master servers located in the data centres. Master DRMCC servers and Transformer DRMCCs will be securely remotely accessible by authorised users utilising TCP/IP communication encapsulated by a suitable encryption method
- The DRMCCs will need to be able to connect to SCADA master station devices, SCADA RTUs and IEDs via a variety of protocols as detailed above and provide DRMCC quantities, statuses and alarms
- Integrated web server pages will need to be provided through a graphical interface
- The DRMCC solution must consolidate control, monitoring, data acquisition and analysis into a single device with multiple communication options
- All functions must be provided in the control cabinet, on the transformer and be capable of being accessed remotely by authorised users only
- The DRMCC design must utilise open architecture
- The DRMCC solution must be easy to configure and maintain.