Distribution Fault Anticipation Data Collection and Analytics (DFADCAA)

UNITED ENERGY

Project № PJ1599

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

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

Project description

This project is called 'Distribution Fault Anticipation Data Collection and Analytics' ('DFADCAA'). It implements disturbance recorder fault devices at critical Zone Substations, where feeders have a high incidence of issues / faults or have the potential to impact the greatest number of customers.

Project Driver

This project contributes to achieving the STPIS target. It is therefore consistent with our regulatory obligation to maintain reliability.

Benefits

This project will capture data that will facilitate the early identification of network issues and equipment deterioration. Our conventional event recorders are unable to provide this information. The superior data and analytics provided by the proposed project will allow UE to identify and proactively address emerging issues before they progress to faults and outages. This delivers a SAIDI benefit of 1.6 minutes, which is a material contribution to achieving the STPIS target. It should be emphasised that this project is not self-financing, as its objective is to achieve (rather than exceed) the STPIS target.

Network investment efficiencies will also be achieved through improved asset management decisions. Better detection of assets in need of replacement ensures that replacement capex is targeted efficiently. In addition, early detection of issues that may lead to asset failure allows us to replace assets prior to failure, resulting in more efficient project delivery and lower costs.

Options analysis

Table 1: Overall Appraisal

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 - Implement decentralised DFADCAA	**3.20**	**6.15**	**2.96**	**1.92**	**1 Recommended**
Option 2 - Implement centralised DFADCAA	7.42	6.15	-1.27	0.83	3
Option 3	This option recognises that alternative capex and opex projects may deliver the same reliability benefits as DFADCAA at a lower present value cost. Chapter 7 of UE's Network Reliability Assessment document ranks alternative reliability projects to identify the portfolio of projects that maximises net benefits.				

Notes:

Net Present Value = present value of benefits minus present value of costs

PVR (Present Value Ratio) = present value of benefits divided by present value of costs. The PVR measures capital efficiency. If the PVR > 1 then the project / option has a net present value (relative to the reference case) greater than zero, and is therefore economic. The greater this ratio the more efficient the capital.

Recommendation

DFADCAA employs new operational technology to identify equipment deterioration and other issues not detected by conventional event recorders, delivering an estimated SAIDI benefit of 1.6 minutes, and facilitating improved capex efficiency.

Option 1 (implementation of decentralised DFADCAA) is the preferred option. It maximises net benefits, with a Net Present Value of $2.96 million. Option 1 also has the highest PVR, at 1.92.

It must be emphasised that this project is not self-financing. It is part of a portfolio of asset replacement plans and reliability programs, which together are forecast to achieve the STPIS target at minimum efficient cost. Option 1 will only proceed if it is ranked ahead of other reliability projects, as detailed in Chapter 7 of UE's Network Reliability Assessment.

2. Objectives / Purpose

The objective of this project is to enable UE to maintain the quality, reliability and security of the supply of standard control services at minimum efficient cost. The projects being considered in this document will contribute to the achievement of this objective by the capture and analysis of data to facilitate the early identification of network issues and equipment deterioration.

3. Strategic Alignment and Benefits

3.1 Asset Management Strategy and Strategic Themes Alignment

This project supports the following key United Energy strategic themes:

- Ensuring ongoing safety, performance, and resilience of the changing and increasingly complex distribution network
- Facilitate effective asset management
- Maintain systems in accordance with industry standards
- Prudent and efficient network investment:
    - Targeted predictive / preventative maintenance programs
    - Targeted network augmentation programs
    - Targeted asset replacement programs (i.e. just in time replacement).

3.2 National Electricity Rules Expenditure Objectives Alignment

This project is aligned to the regulatory objective of maintaining the quality, reliability and security of the supply of standard control services.

To ensure that we achieve this objective, all reliability projects have been ranked to identify the portfolio of projects that meets the STPIS targets at the minimum efficient cost. This ranking process is explained in Chapter 7 of UE's Network Reliability Assessment (document No. UE PL 2304).

4. Alternative Options Considered

4.1 Background and Identified Options

Distribution Fault Anticipation Data Collection and Analytics (CFADCAA) uses new technology to identify emerging issues on the network, thereby enabling a more targeted response and fault avoidance. The technology has been implemented successfully in a number of US Utilities, and the benefits have been highlighted by the IEEE[1]:

> "*Research at Texas A&M University has demonstrated that sophisticated, automated real-time analysis of feeder electrical waveforms can be used to predict failures and assess the health of distribution lines and line apparatus. Reliability can be substantially improved by detecting, locating, and repairing incipient failures before catastrophic failure, often before an outage occurs. Requirements for data and computation are substantially greater than for devices like digital relays and power-quality meters, but feasible with modern electronics. Working in concert with 15 utilities and under the sponsorship of the Electric Power Research Institute, the Power System Automation Laboratory has validated the concept that incipient apparatus and line failures on distribution systems can be detected by sophisticated analysis of waveforms measured through existing current and voltage transformers at the substation bus. The authors have created the most extensive measurement database in existence of recorded electrical waveforms from failing distribution apparatus".*

UE's current technology relies on manual data searches, which cannot match the speed and analytical rigour of the new technology. As a result of the application of DFADCAA, we expect to deliver reliability improvements and deliver capital expenditure efficiencies. DFADCAA will highlight gradual equipment deterioration, and other issues not detected by conventional event recorders. This will allow UE to proactively address emerging issues before they progress to faults and outages. Replacement decisions will be better targeted and savings achieved by replacing assets prior to failure.

DFADCAA will detect and alarm on faults and issues (i.e. failures and problems) including:

- Voltage regulator failure
- LTC controller failure
- Lightning arrestor failure
- Repetitive overcurrent faults
- Line switch / cut-out failure
- In-line splice failure
- Cable failures
- Tree / vegetation contacts with primary and secondary services
- Overhead transformer bushing failure
- Overhead transformer winding failure
- URD pad-mount transformer failure
- Substation bus capacitor bushing failure
- Capacitor problems.

[1] IEEE, Transactions on Smart grid Vol.1 No.1, June 2010 paper titled "Intelligent Systems for Improved Reliability and Failure Diagnosis in Distribution Systems"

As DFADCAA will contribute to a reduction in asset failures, it is also expected to deliver some safety benefits. However, the primary driver for the project is reliability improvement. It must be emphasised that 'reliability improvement' recognises that this project is capable of making a positive contribution to achieving the STPIS target, noting that current performance is well below target. Whether this project should proceed depends on its ranking compared to other feasible reliability projects. This question is addressed in Option 3 below. The following options have been evaluated:

Reference Case:	Under the "Reference Case", the status quo is maintained
Option 1:	Implement decentralised DFADCAA
Option 2:	Implement centralised DFADCAA
Option 3	Implement an alternative project to deliver the target reliability outcome

4.2 Reference Case - Status Quo

Under the Reference Case the current processes would remain unchanged.

Our in-service disturbance recorders currently store short periods of data immediately before and after a fault triggers. These data samples are only available for faults and do not capture other more transient issues. In addition, as already noted, manual data searches are slow and error prone.

4.3 Option 1 – Implement decentralised DFADCAA

Under this option the DFADCAA solution would be implemented by installing disturbance recorder fault devices at critical Zone Substations, where feeders have a high incidence of issues / faults or have the potential to impact the greatest number of customers.

The DFADCAA solution will enable us to monitor three phase voltages from two buses and all feeder currents. Each device will sample data at 1 kHz and will have the capacity to store the 16 channel data for 1 year. The devices capture the network data stream 24/7 at a rate of 20 samples per AC 50 Hz cycle. By utilising predetermined data patterns and analytics, issues can be detected and alarmed very efficiently while removing manual errors.

Each device will store many Giga bytes of data. Therefore, this option will be a decentralised solution to avoid saturation of the communication network while transferring the data to a central server. This decentralised solution will implement one server at each Zone Substation that houses DFADCAA devices. The server will typically look at one month of data at a time from each device and perform analytics to identify and assess a range of issues.

This option delivers a SAIDI benefit of 1.6 minutes, which is a material contribution to the STPIS target. This option will also deliver network investment efficiencies through improved asset management decisions, as follows:

- Better detection of assets in need of replacement ensures that Repex is targeted efficiently.
- Early detection of issues that may lead to asset failure allows us to replace assets prior to failure, resulting in more efficient project delivery and lower costs.

Improved asset management decisions are estimated to avert $200,000 of capex per year starting in 2017.

The overall undiscounted cost of Option 1 is estimated to be $3.94 million. This equates to a present value cost of $3.20 million.

4.4 Option 2 – Implement centralised DFADCAA

Option 2 is the same as Option 1, except that an additional cost will be incurred to implement a centralised analytics solution. The additional cost is estimated at $5 million to:

- allow systems and storage to be established, and centralised analytics software to be developed; and
- to establish associated communication equipment to link to the disturbance recorder fault devices and carry the appropriate data to the centralised servers.

The overall undiscounted cost of Option 2 is estimated to be $8.94 million (equivalent to $7.42 million in present value terms), and will it provide the same effective benefits as Option 1.

4.5 Option 3 – Implement an alternative reliability project

In relation to Option 3, chapter 7 of UE's Network Reliability Assessment (document No. UE PL 2304) ranks alternative reliability projects. Therefore, the preferred DFADCAA solution will be compared against all other feasible options to ensure that the STPIS targets are met at minimum efficient cost.

Option 3 is addressed in chapter 7 of UE's Network Reliability Assessment (document No. UE PL 2304), and is not considered further in this project justification document.

4.6 Technical Summary

Table 2: Technical summary

Alternative	Reference Case -Status Quo	Option 1 – Implement decentralised DFADCAA	Option 2 – Implement centralised DFADCAA
Technically Viable	Yes	Yes	Yes
Addresses Reliability	No	Yes	Yes
Enhances Network Flexibility	No	Yes	Yes
Comments	Technically acceptable but does not enable prediction of future faults so does not contribute to meeting the SAIDI target.	Technically acceptable. Predicts future faults so contributes to meeting the SAIDI target.	Technically acceptable. Predicts future faults so contributes to meeting the SAIDI target.

5. Economic Evaluation

5.1 Costs and benefits of Options

The table below provides a summary of the cost and benefits of Options 1 and 2 relative to the Reference Case.

Table 3: Cost and benefits of Options (in present value terms)

	"Status Quo" Reference Case	Option 1: Implement decentralised DFADCAA	Option 2: Implement centralised DFADCAA
Costs: Project Capex ($)	**0**	**$3,197,194**	**$7,422,417**
Benefits: Reduced capex ($) [1]	0	$2,050,593 [1]	$2,050,593 [1]
Improved reliability ($)	0	$4,102,807 [2]	$4,102,807 [2]
Total Benefits ($)	**0**	**6,153,400**	**6,153,400**
Net Present Value [3] ($)	**0**	**2,956,206**	**-1,269,017**

The notes below apply to Table 3 above:

1. Options 1 and 2 deliver a capital expenditure efficiency of $200,000 per annum. These savings are achieved through the detection of imminent faults, enabling asset replacement to be undertaken on a planned rather than unplanned basis.
2. Similarly, Options 1 and 2 are expected to deliver a SAIDI benefit of 1.6 minutes by anticipating faults and reducing outages.
3. Net Present Value = present value of benefits minus present value of costs.

5.2 Evaluation of Options

Table 4 below shows that Option 1 is the preferred option because:

- it maximises net benefits at $2.96 million; and
- it has the highest PVR, at 1.92.

It must be emphasised that this project is not self-financing. It is part of a portfolio of asset replacement plans and reliability programs, which together are forecast to achieve the STPIS target at minimum efficient cost. Option 1 will only proceed if it is ranked ahead of other reliability projects, as detailed in Chapter 7 of UE's Network Reliability Assessment (document No. UE PL 2304).

Table 4: Economic evaluation of options

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 - Implement decentralised DFADCAA	**3.20**	**6.15**	**2.96**	**1.92**	**1** **Recommended**
Option 2 - Implement centralised DFADCAA	7.42	6.15	-1.27	0.83	3
Option 3	This option recognises that alternative capex and opex projects may deliver the same reliability benefits as DFADCAA at a lower present value cost. Chapter 7 of UE's Network Reliability Assessment document ranks alternative reliability projects to identify the portfolio of projects that maximises net benefits.				

Note: PVR (Present Value Ratio) equals present value of benefits divided by present value of costs. PVR measures capital efficiency:

- If the PVR > 1 then the project / option has a net present value (relative to the reference case) greater than zero, and is therefore economic. The greater this ratio the more efficient the capital expenditure.
- If the PVR = 1 then the project / option has a net present value of zero relative to the reference case. There is no net benefit and no net cost (relative to the reference case) of an option that has a PVR of 1.
- If the PVR < 1 then the project / option is not economic, because it has a negative net present value compared to the reference case.

5.3 Description of Benefits

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

Table 5: Option 1 Benefits

Option 1 Benefits -> Initiatives ↓	Bring STPIS from over target closer to target and lower number of outages and asset down time	Reduce costs and improve efficiency of network investment through improved asset management decisions	Meeting customer expectations of a safe and secure electricity supply	Facilitate effective asset management	Maintain network supply security / reliability	Maintain quality of supply	Prevent / reduce asset failure & extend asset life	Vegetation management	Mitigate risk including bush fire
Option 1 - Implement decentralised DFADCAA)	✓	✓	**possible**	✓	✓	✓	✓	**possible**	**possible**

Option 1 (implement decentralised DFADCAA) will provide the following benefits:

- Assist in maintaining system reliability by delivering a SAIDI benefit of 1.6 minutes. It should be emphasised that this project is not self-financing, as its objective is to achieve (rather than exceed) the STPIS target.
- Facilitate more efficient network investment through targeted predictive / preventative maintenance programs and targeted network asset replacement programs.
- Facilitate effective asset management
- Assist in maintaining steady state voltage closer to the desired target and therefore maintaining power quality
- Analytics will provide insights into trends of asset deterioration that can be used to perform maintenance and thus prevent failures and extend asset life

Table 5 shows that the proposed project will also deliver a number of ‘possible’ benefits, which are incidental or secondary to the primary benefits noted above. These possible benefits are not the key drivers for the project, but provide further reasons to proceed with the preferred option.

.

5.4 Optimum timing and capex profile

The key issue in relation to optimal timing is to adopt an implementation timetable that allows the application of the technology to be refined and enhanced in light of operational experience. The proposed work program for the preferred solution will commence implementation in 2016. The technology will be deployed at critical Zone Substations throughout the forthcoming regulatory period.

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

Table 6: CAPEX for preferred option

CAPEX Forecast ($'000) CAPEX type: Augmentation	2016	2017	2018	2019	2020	EDPR Total
Option 1 – Implement decentralised DFADCAA	536.8	582.6	832.6	1,053.5	933.4	3,938.8

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.

Table 7: Project financials - Preferred Option (Option 1)

PROJECT COST	
Year Budgeted	2016 to 2020
Required Service Date	31 Dec 2020
Budgeted Cost ($A excluding GST)	$3,581,000
Business Case Cost ($A excluding GST)	$3,581,000
Business Case Cost + UE overheads ($A excluding GST)	$3,938,800

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

Option 1 will provide the benefits described in section 5.3, and it is the most economic option because:

- it has the highest net present value of all the options, at $2.96 million; and
- it has the highest PVR of 1.92.

It is therefore recommended that Option 1 (implement decentralised DFADCAA) proceed, subject to the results of the ranking of all alternative reliability projects.

APPENDIX A – HIGH LEVEL SCOPE OF WORK

The scope includes:

- Initiate project, identify and obtain resources
- Perform Activities
  - Perform necessary research to quantify and develop the detailed scope
  - Perform hardware and software design excluding analytics
  - Procure initial equipment and software
  - Develop Issues / Fault Patterns
  - Install Equipment
  - Develop and test Analytics including Alarms / Notifications
  - Add interface to DMS to accept Alarms / Notifications
  - Train NCC and Engineering staff appropriately
  - Optimise solution, procure the remainder of the equipment and software and deploy to other sites
- Install, test and place the equipment and associated analytics into service
  - Install, test and place the equipment and associated analytics into service
  - Modify processes as required
  - Complete documentation and close activity.