Adaptive Network Control Functional Design Specification

Capacity to Customers (C_2C) Project

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1. INTRODUCTION

Current Electricity North West Limited EHV and HV electricity distribution networks use redundancy to achieve security of supply standards, and often are interconnected by a normal open point (NOP) which is only utilized in the event of a network fault or planned outage. It is of note that nearly half of the circuits do not suffer faults and one third experience faults lasting 1 - 2 hours every 5 years. Under such conditions, closing the NOP allows all customers affected by a fault to be re-supplied from the alternative circuit. This means that circuits typically operate at only 50-60% of their rated capacity; it is this inherent capacity that the Capacity to Customers (C_2C) method seeks to release for use by customers for the connection of new loads and generation. New and existing Industrial and commercial customers on circuits used in this trial scheme are to be offered C_2C contracts, the customers that take up this type of C_2C contract are referred to as Managed Customers in this document.

The purpose of this document is to describe the design for the implementation of the adaptive network control functionality required to release this capacity.

The document has been written by Electricity North West with contribution from IGE Energy Systems (UK) limited.

2. SCOPE

The C_2C IT project scope is limited to the aspects of the Electricity North West Control Room Management System (CRMS) and IGE Energy Services (UK) Ltd PowerOn^{Fusion} (POF) system required to achieve its outcomes.

The proposed solution architecture is largely based on functionality within the existing POF and CRMS products with additional developments to facilitate the full solution. Interfaces are used to allow communication between the CRMS system and the POF system. The subsystems directly involved for each system are documented in the System Architecture Overview section below.

3. SYSTEM ARCHITECURE OVERVIEW

The conceptual design of the C_2C system treats both the POF and CRMS systems effectively as black boxes, with the new or changed functionality as defined in the facilities provided section. The remainder of the functionality of both systems are as per the current product, and hence not reiterated here.

The system interfaces are based on the Simple Object Access Protocol (SOAP) and the Common Information Model (CIM) to ensure these are standards based interfaces with transferable technology implementations.

The system is designed such that customers that are not managed are restored using the CRMS Automatic Restoration Sequence (ARS) without interaction with the POF system, hence a high availability design is not necessary for the trial implementation. Redundancy in the design is limited to mirroring on the POF servers.

Detailed below are the process and data flows between each system at a high level.

3.1 CRMS Process

CIM Export	Inhibits	Plant COS	Advised Restoration	Managed Customer Details	Measurements	Periodic Load Flow Results

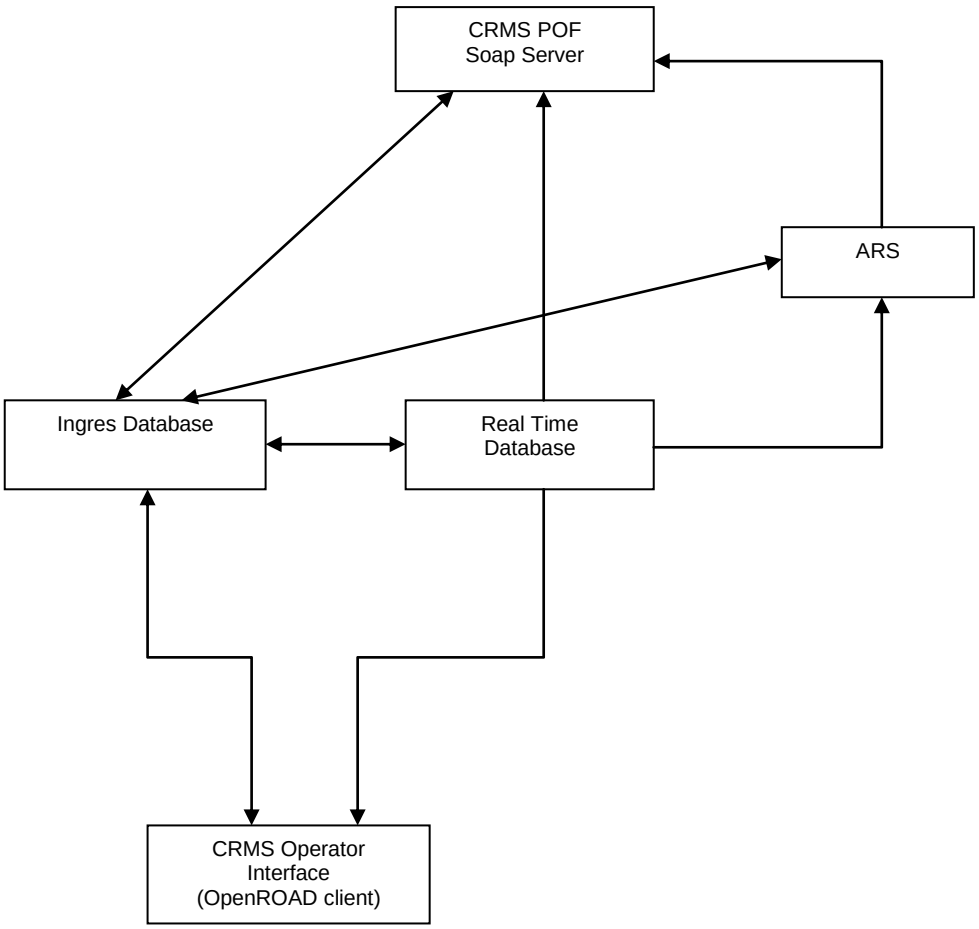

Figure 1: CRMS Processes

Operator Interface

The CRMS interface for the users to interact with the C_2C system is via OpenROAD client – This is a Linux client application which resides on the client machine. It provides users with the ability to visualise the network, perform manual switching operations and manage documents.

Ingres Database

This is a replicated server database that contains the network model, configuration parameters and documents.

Real Time Database

This is a memory resident copy of a subset of the Ingres database to provide a source for all the analogue, state and status updates to be passed across the SOAP interface into the POF system.

ARS (Automated Restoration Sequence)

This is the system module which automatically restores customers after a fault.

Load Allocation

This is the data source for the historical load breakdown for each load point on the network, together with the estimated future load for the next 12 months.

CRMS POF SOAP Server

This process communicates with the POF Server via SOAP interfaces. It provides functionality to send plant COS (Change of State) changes and analogues from CRMS to the POF Server, receive restoration schedules from the POF server after an ARS restoration and store them in the CRMS database for users to view via the CRMS client.

It also receives DPF results for display on CRMS and triggers requests from CRMS for POF Servers such as DPF.

CIM/GML Model Export

The processes to generate an offline CIM (Common information Model) file to contain all the network connectivity and plant mappings, together with a GML (Geographic Markup Language) file following the GE designated format. This is used to create the network model in the POF system. The initial approach is to have a weekly reload of the database (this is sufficient for the trial

implementation), however an incremental update process is to be investigated, and subject to cost and timescale may be implemented.

3.2 PowerOn*Fusion* (POF)

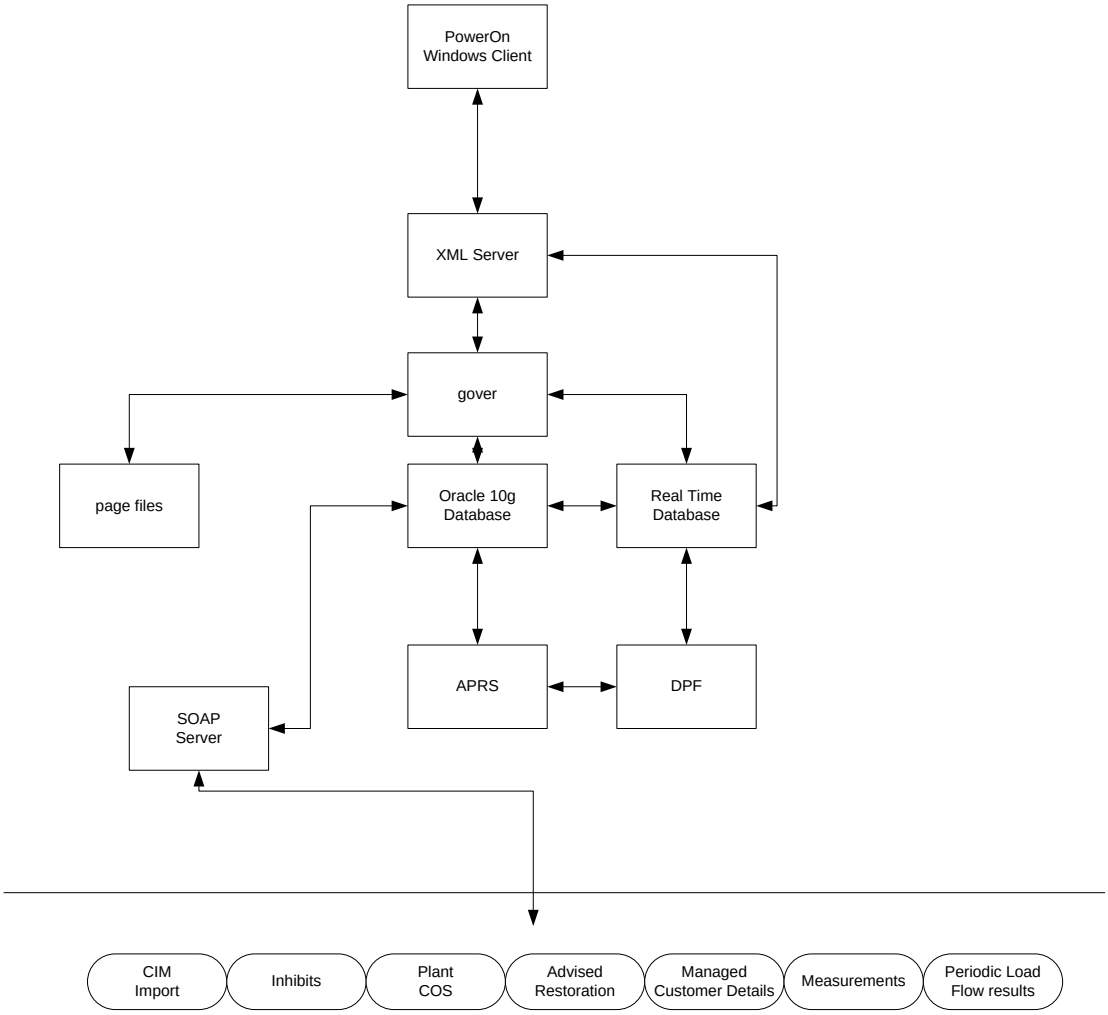

Figure 2: POF Processes

POF Windows.Net Client

This is a Microsoft .Net based windows client application which resides on the Client machine, it provides users with the ability to visualise the network model and search information as required.

Xml Server

This is the server side process that communicates with the POF Client, updating it with encrypted messages.

Oracle 10g Database

This is the server database that retains the plant model and configuration parameters

Gover

This is the process responsible for updating the page files with plant dressings, documents etc and passing the diagram to the client.

Pages files

These are the collection of the graphical primitive files used to display the electrical model graphically and their links to the Oracle/RT databases.

Real Time Database

This is the in-memory Real Time database used for the POF Application

Automated Power Restoration System (APRS) engine

This is the engine that analyses the state of the network and proposes the switching changes needed to restore as much of the network as possible.

DPF server

This is the unbalanced 3 phase power analysis engine used to provide load flow studies based on the current state of the network or analyse the proposed switching actions sent from the APRS engine.

3.3 Security Setup (Test/Development Phase)

All parts of the system undergo system hardening, following which all services and ports that are not required are closed. Unused system processes and applications are also removed from the system components.

The POF system resides in a separate security zone within the Electricity Control Systems (ECS) test infrastructure. Rules for access are limited to those necessary for the interfaces and the 3rd party access.

The firewall rules and ports are defined in a separate 'internal use only' document.

In addition the POF server is clustered with a virtual image hosted at Livingston, to allow the two systems to remain in step, hence enabling the development of the new processes at both Livingston and Manchester to use the same datasets. These systems are connected via an IP connection on a business to business (B2B) type connection. The link is at least a 10Mb/s. The individual parties are responsible for protecting their own networks from any threats through the link being compromised.

3.3.1 3rd Party Access

Support facilities in the production system are provided via the B2B link, through to a hardened staging box within the Control infrastructure. This allows a user to gain access to a desktop session on the POF Servers only. The access agreement is covered by the 3rd party access procedure.

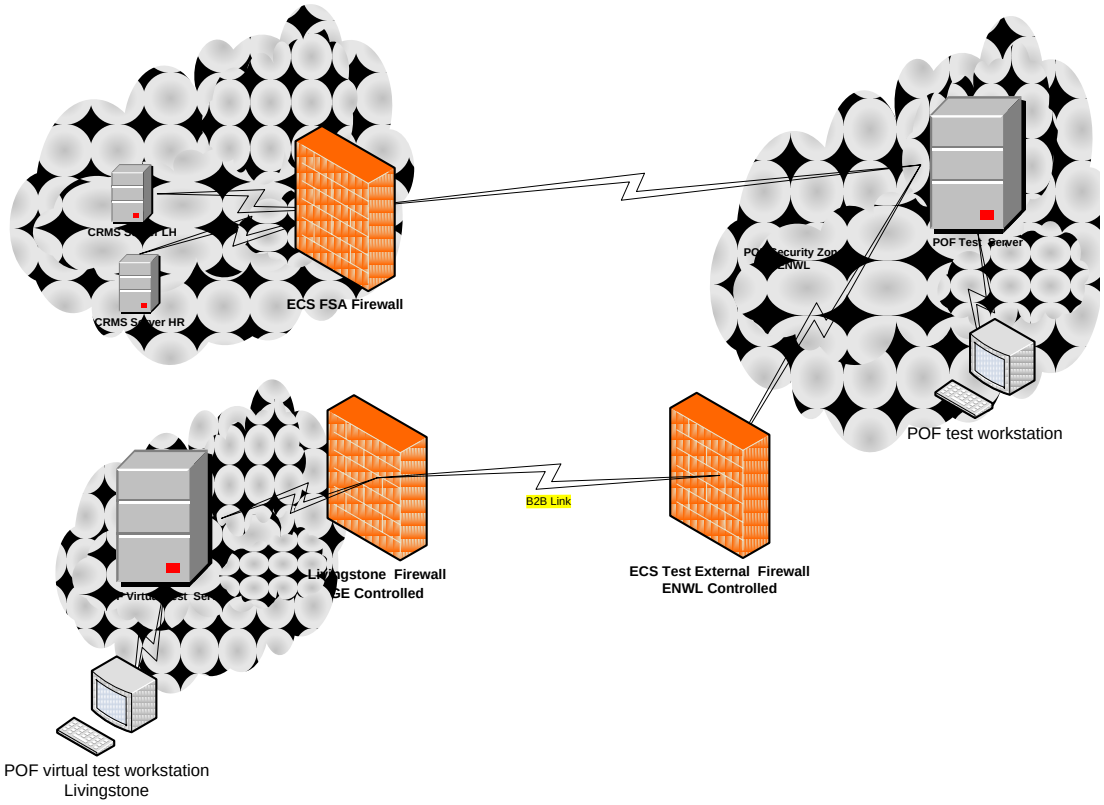

Figure 3: Security setup (Test/Development phase)

3.4 Security Setup (Live Trial Phase)

All parts of the system undergo system hardening, following which all services and ports that are not required are closed. Unused system processes and applications are also removed from the system components.

The POF system resides in a separate security zone within the Electricity Control Systems (ECS) infrastructure. Rules for access are limited to those necessary for the interfaces and the 3rd party access.

The firewall rules and ports are defined in a separate 'internal use only' document.

3.4.1 3rd Party Access

Support facilities in the production system are provided via a 2 factor authenticated VPN, linking through to a hardened staging box within the Control infrastructure. This allows a user to gain access to a desktop session on the Server only. The access agreement is covered by the 3rd party access procedure.

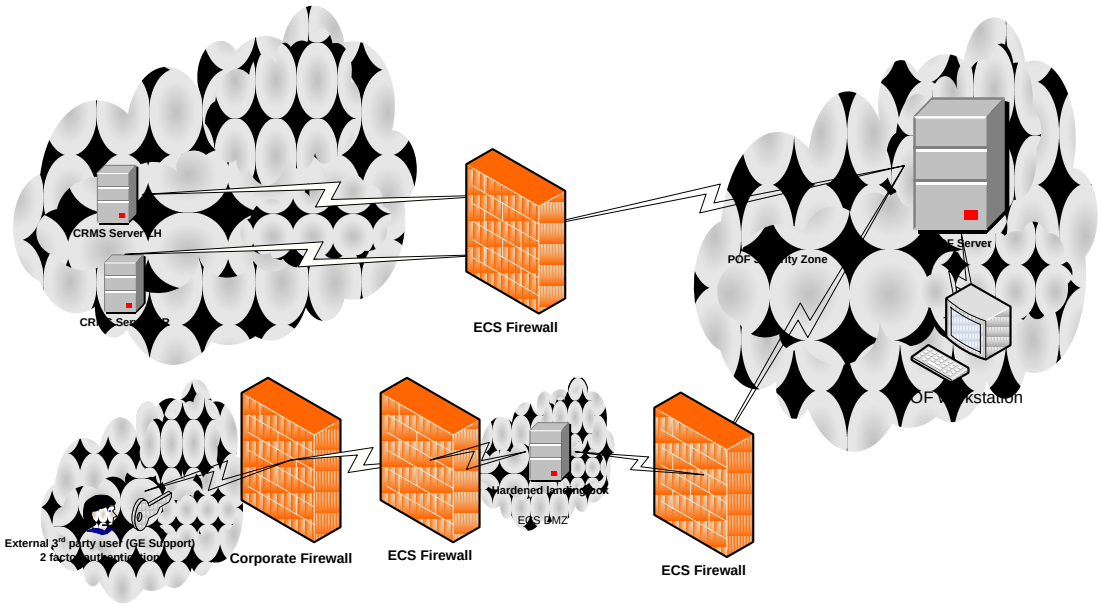

Figure 4: Security setup (Live Trial phase)

3.5 SOAP

POF provides a Simple Object Access Protocol (SOAP) interface to allow data to pass into and out of the system. SOAP has been chosen because it is a standard, open protocol and also eases debugging due to the readable nature of the messages themselves. CRMS also has a SOAP interface available to pass data in and out. The use of a SOAP interface ensures transferability of the technology to other Distribution Network Operators.

The interface provides both client and server behaviour. SOAP messages can be sent to the interface on a defined port in a defined format. The interface interprets the message, executes the required code or transactions and returns any expected results in the form of a SOAP message. It is also capable of sending messages originated from within POF.

The POF interface operates over HTTP/HTTPs with support for WSDL v1.1 and follows the guidelines as specified by Web Services Interoperability (WS-I) Basic Profile 1.1.

This interface is used to integrate with the existing CRMS systems.

4. Facilities Provided

4.1 C_2C Managed Customers

New and existing Industrial and Commercial customers on the circuits used in this trial scheme are to be offered contracts allowing all or part of their supply to be interrupted under various circumstances.

These contracts may stipulate inter alia:

- Times when interruptions are allowed
- Days when interruptions are allowed
- Seasons when interruptions are allowed
- One off events when interruptions are not allowed
- Number of interruptions in a specified period
- Interruption duration
- Accumulated interruption durations in a defined period e.g. a year.

The details of these contracts are held on the POF system. There is an initial manual load of this data into POF at the start of the pilot trial. Any changes to this data during the pilot are to be added manually to the POF system using manual data entering facilities provided to Electricity North West via POF.

The CRMS system shows an indication on the network diagram where a load or generator is on a Managed contract. To ensure that the CRMS diagram represents the Managed Customers held by the POF system the SOAP interface between the systems allows CRMS to request a list of all Managed Customers.

For a Managed Customer the CRMS system can present details of the contract covering that load/generation and the current values of number of interruptions etc. This data is obtained from the POF system as required and used for planning purposes by the Control Engineers. There is no facility on the CRMS system to amend any of this data.

4.2 Control Engineer

The changes to the CRMS system are implemented such that the impact on control room staff is minimized (i.e. screen layout changes and work flows). The changes for the pilot implementation, as seen by a Control Engineer are as follows:

a) Diagram – the Managed Customers are indicated on the diagram by a new distinct symbol

b) ARS information – the disconnection of Managed Customers is logged using the existing ARS logging

c) ARS customer counts – the existing customer counts for ARS restorations remain as they are. Any corrections due to Managed Customers are made manually; this is required due to the possible complexities as to when Managed Customers are counted in the statistics.

d) Results read – following an ARS restoration involving Managed Customers, the POF system generates a set of suggested switching operations to restore interrupted customers. This suggested list can be brought to display on any CRMS workstation.

e) Study initiation – Should a HV circuit approach its capacity limit and demand Managed Customers have been disconnected; the Control Engineer can request a study and obtain suggested switching operations. The circuit is selected from the CRMS diagram. The results are displayed as per the switching suggestions following an ARS restoration.

f) Contracts – details on individual Managed Customers contracts and current status are able to be called to a CRMS workstation. The screen displays for this functionality are new and are read only.

g) Report – A report is available showing all disconnected Managed Customers. The report is available from the CRMS reports facility.

h) Faults – When ARS switches to disconnect a Managed Customer it creates a switching fault entry for that operation. This ensures that a disconnected customer is not left disconnected.

4.3 Network Model Synchronisation

POF system is kept in step with the CRMS system to allow accurate DPF analysis and to allow the POF system to produce a feasible switching plan for restoration of Managed Customers when invoked. The system consists of static data and dynamic data which are kept consistent. This is shown in Figure 5 with each of the components in the diagram outlined in the following sections.

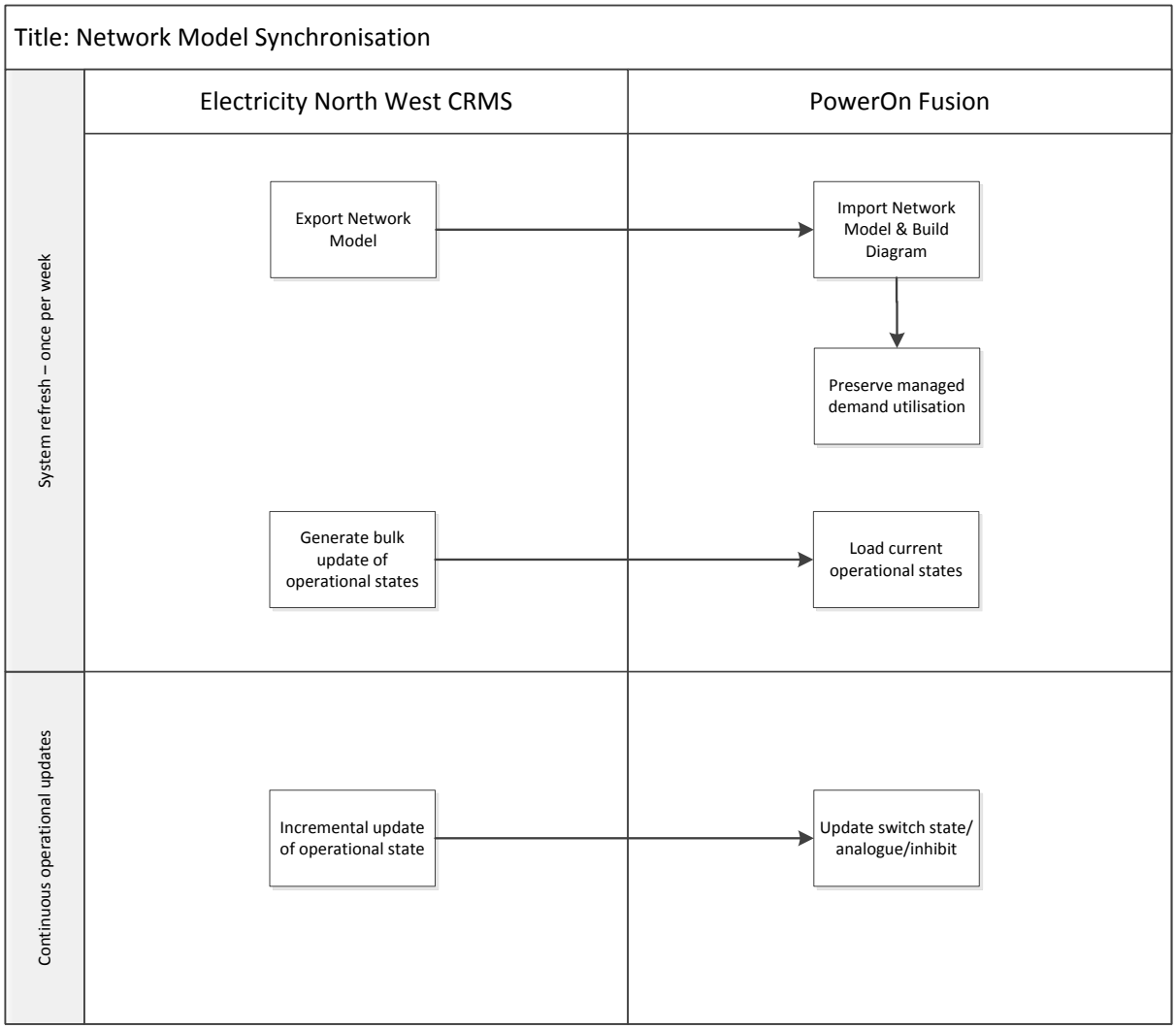

Figure 5: Network Model Synchronisation

4.4 Connectivity Model Population and Maintenance

The CRMS network model is exported in a CIM conformant form. The export includes all relevant assets and associated meta-data.

At this stage it is assumed that LV assets are not required in the export, unless the Managed Customer is connected at LV in which case the specific LV assets related to that customer will be exported. Also, certain other plant types may not be necessary if they are not relevant to the electrical model. A full list of required plant is determined during the build phase.

The CRMS network model export is then loaded into the POF system using the CIM interface which provides a network diagram in POF.

The POF copy of the CRMS network model is to be kept up to date as the network topology changes due to diagram amendments. There are a number of options for

doing this. The complexity and practicality of these options is to be considered and a viable method to be converged upon as part of the build phase.

The options considered are detailed below.

4.4.1 Option 1: Full system refresh

With the full system refresh option, the POF model is refreshed once a week from the CRMS system. There are no updates between the full system refreshes. The implication of this weekly refresh is that the connectivity model diverges from the actual state over the course of the week and the POF system would be making switching recommendations based on an inaccurate network representation. Given that the pilot is on a test area of around 200 circuits that represents approximately 10% of Electricity North West network, this divergence is not believed to be an issue. As the switching is being provided purely as a set of recommendations, the Control Engineer can use his knowledge of the network and choose to ignore the recommendations as he sees fit. In the initial pilot there is no automatic control of the electrical network from the POF system.

As part of this weekly system refresh, POF would preserve any data relating to customer minutes lost for managed customers so that demand utilization can be tracked.

4.4.2 Option 2: CIM incremental updates

Each time a network change is commissioned by a Control Engineer, the CRMS system produces a CIM compliant incremental update in the form of xml and gml files. This is passed to the POF system where it is processed and the network diagram updated. Using this option, the connectivity model would remain in approximate step between the two systems. Any real time data changes are queued by CRMS during the update.

4.4.3 Option 3: Manual updates using POF tools

With this option the diagrams would be parallel maintained using the editing tools within the POF software. This option requires an initial data load as per option 4.4.1 with subsequent changes being performed manually.

4.5 Complete Network States

The export of the connectivity model from CRMS provides the normal state of the network therefore the operational state of the POF copy of the network is initialized to reflect the current state. This initialization includes

- abnormal switch states (open/close),
- all SCADA analogue values
- plant inhibits
- tap positions

- load estimation data

As a minimum the state transfer is required on the initial system build. If it is decided to keep the systems in synchronism by a complete refresh of the network connectivity, the state initialization happens after each synchronization.

The other scenario where we may need to reinitialise the system is if the POF system or the network link between the systems has been unavailable for a period of time and POF has become out of step with the operational state of the network.

There are several ways of dealing with this scenario:

a) The CRMS system queues all outbound messages until the POF system is available again and the messages are sent at this point, bringing the system back up to date. This is inefficient as values can change many times during an outage.

b) The CRMS system does not queue outbound messages and they are discarded. When the connectivity between the systems is reinstated, the POF is initialised as above with switch states, SCADA analogues values and inhibits being passed from CRMS system. In this case, all switch states would be required not just abnormal switch states.

c) The CRMS system queues outbound messages until a number or time limit is reached. On reaching the limit the messages are discarded and an initialization is required.

The full mechanism for doing this is decided upon during the build phase.

To ensure that no telemetered data changes are lost, the complete network state transfer must remove any queued state transfers, store any state changes and transfer them after the complete network state transfer has completed.

4.6 Real time updates

The real time updates come from SCADA data collection and from manually dressing the network diagram. This data is passed from CRMS to POF. The data passed falls into the following categories:

- switch states (open/close),
- all SCADA analogue values
- plant inhibits
- tap positions

As noted above, a method of recovering from loss of synchronization is to be developed during the build phase.

4.6.1 Switch States

CRMS uses a 7 state switch model. CRMS translates its model into: close maps to ‘close’, everything else maps to ‘open’ for use in the POF model.
CRMS allows previewing of future diagram changes. This feature is used during commissioning plant. As a result state changes can be received for plant that is not known to POF. When this happens POF should simply log the message but otherwise ignore the state change.

4.6.2 Analogue Values

Analogue values change frequently by small amounts. Only the most recent value is of use. Should the CRMS and POF lose connection for an appreciable length of time, it may be more efficient to perform a full state download to transfer the most recent analogue values – the decision on whether to queue or refresh the values is dependent on the performance of the update interface and taken after prototyping during the build phase.

In addition to the actual engineering value,status information is passed.

4.6.3 Plant Inhibits

There are two forms of plant inhibit, those that inhibit operation of a single plant item and those that inhibit all operation on any device on a feeder.
Any CRMS state other than open and close causes the plant item to be inhibited. These other states correspond to isolation states in the CRMS state model.

Any plant quoted as a point of isolation on a safety document. These are the boundary items of the safety zone.

Any plant where telemetry of data is not available for any reason. For these items the current state may not be known.

Any plant whose operation is covered by an operational restriction prohibiting automatic operation.

Any switch which is thought to bound a faulted network section.

4.6.4 Tap Positions

These are transferred to allow load flow calculations. Where the value is not known a default can be assumed (ie. 1.02 per unit boost).

4.7 Distribution Power Flow

The existing Electricity North West ARS facilities are utilised and ARS software is appropriately modified to make use of the calculated real-time loadings which are to be provided by POF for each distribution load point.

The POF system periodically calculates loading across the network using the latest SCADA measurements, and as described in the POF Configuration Guide (Power Analysis DPF Data Requirements GO21-03-04-02-01 v1.2 Release 5), supported by real time SCADA data along with load-allocation techniques to obtain the loadings. Whether load profiles or pseudo analogues are used is to be finalized during the build phase. Figure 6 indicates the logical flow of data to deliver this functionality.

The CRMS system is able to request the results of these studies via a SOAP interface.

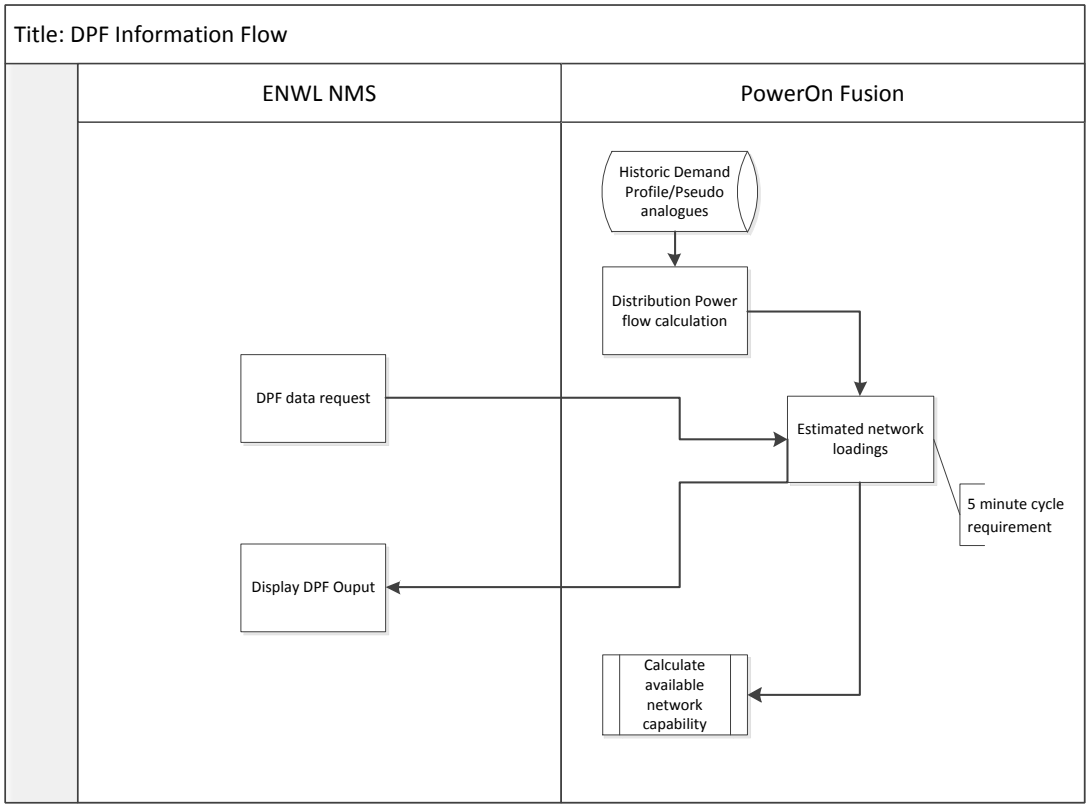

Figure 6: Distribution Power Flow

4.8 Load allocation Data

The CRMS model contains load allocation data which represents expected load at distribution transformers and HV consumer connections to the HV network. The data is for each half hour (48 per day), for each transformer (approx 45000), for each day. This is a large amount of data and should be transferred weekly irrespective of the update mechanism for network diagram connectivity changes.

The POF system will perform a periodic load flow study across the network. The load flow study will use the feeder current supplied by CRMS, electrical connectivity model and load information performing load allocation to predict power usage across the secondary network.

The load allocation strategy works by taking all feeds into and out of a section of network as well as losses due to equipment. It then uses load information data supplied by Electricity North West and a load confidence factor (in case some loads are better known than others) allocates the consumption on each of the secondary load points in the section. The DPF engine then computes the rest of the electrical parameters of the network based on load and equipment properties.

This periodic study results will feed into the APRS algorithm as a starting point for APRS proposed restoration studies, namely the estimated transfer capacity from adjacent circuits and peak load allocation used to validate any proposed switching recommendations against equipment ratings.

4.9 CRMS Automatic Restoration Sequence (ARS)

A request for a demand restoration sequence comes from CRMS either as a result of a fault, or as a result of a capacity constraint (i.e. not as a result of a circuit breaker trip). Figure 7 provides an overview of the flow of information between the 2 systems when a fault occurs.

The CRMS ARS monitors possible fault conditions on the 11 / 6.6kV network and attempts to restore customer supplies within 3 minutes of a fault outage being detected.

ARS is modified to recognise C_2C circuits so it can carry out the following actions in event of a fault on a C_2C circuit that operates main line tripping devices :-

a) Open the closed remote controllable NOP to split ring in to two radial feeders – feeder 1 and feeder 2.

b) Open the remote controllable dedicated feeding device for all Managed Customers on the feeders so these supplies are not restored during ARS.

c) Reclose tripped device on feeder 1

   i. If device trips – Reclose tripped device on feeder 2, Commence normal ARS on feeder 1.

   ii. Restores feeder 1 – Commence normal ARS on feeder 2.

Once this has been completed, the CRMS system sends details of the circuit breakers that have tripped to the POF system via a SOAP interface. Details of inhibits on the faulted section have already been sent as part of the operational updates – the POF system is aware of these inhibits in order to avoid attempting to restore the faulted section.

On receiving the request from CRMS, the POF system, using APRS and DPF loadings, identifies any additional load that can be switched back on via telemetry. This includes any non-Managed Customers as a priority, followed by any Managed Customers. APRS works by looking to see if load can be picked up on the circuit where the outage is located. If this is not possible it accesses adjacent circuits for

their capacity and may select one or more circuits to pick up load from. If it is not possible to pick up load from existing capacity then APRS is to be extended to look at using capacity from Managed Customers, to shed load allowing other customers to be restored.

Based on the outcome of its analysis, the POF system sends a set of switching recommendations back to the CRMS system via a SOAP message. There is no direct control of the CRMS system in the trial phase – the recommendations are sent as a series of switching steps that the Control Engineer can action as they see fit.

The second stage of the restoration is manually initiated by CRMS after some switching on the network. The information sent is as per the first request (i.e. the tripped circuited breakers). The POF system re-analyses the same section of network and provides another set of switching recommendations, this time including manual switching steps to restore as much demand as possible.

If the supply is removed from Managed Customers, the POF system tracks the customer minutes lost (CML) for that customer against the customer specific contract requirements. C2C Managed Customer CMLs are only to be counted for these customers when the feed in to the customer is live but they are still off supply i.e. if the switch is dead on both sides, it is assumed that the customer is off due to a fault rather than a deliberate action and the CMLs are not counted, for the purpose of the Managed Customer contract.

If there are 2 Managed Customers off supply and there is only capacity to restore one of those Managed Customers, the POF system makes a decision based on predefined rules, for example taking into account whether there is embedded generation, or whether one of those 2 customers has been off more recently than the other.

Supplies are not removed from Managed Customers in order to restore other Managed Customers.

Enabling the Managed Customer functionality for ARS is via the existing configuration screens on CRMS.

The existing ARS logging is enhanced to show the identification and removal of supplies to Managed Customers.

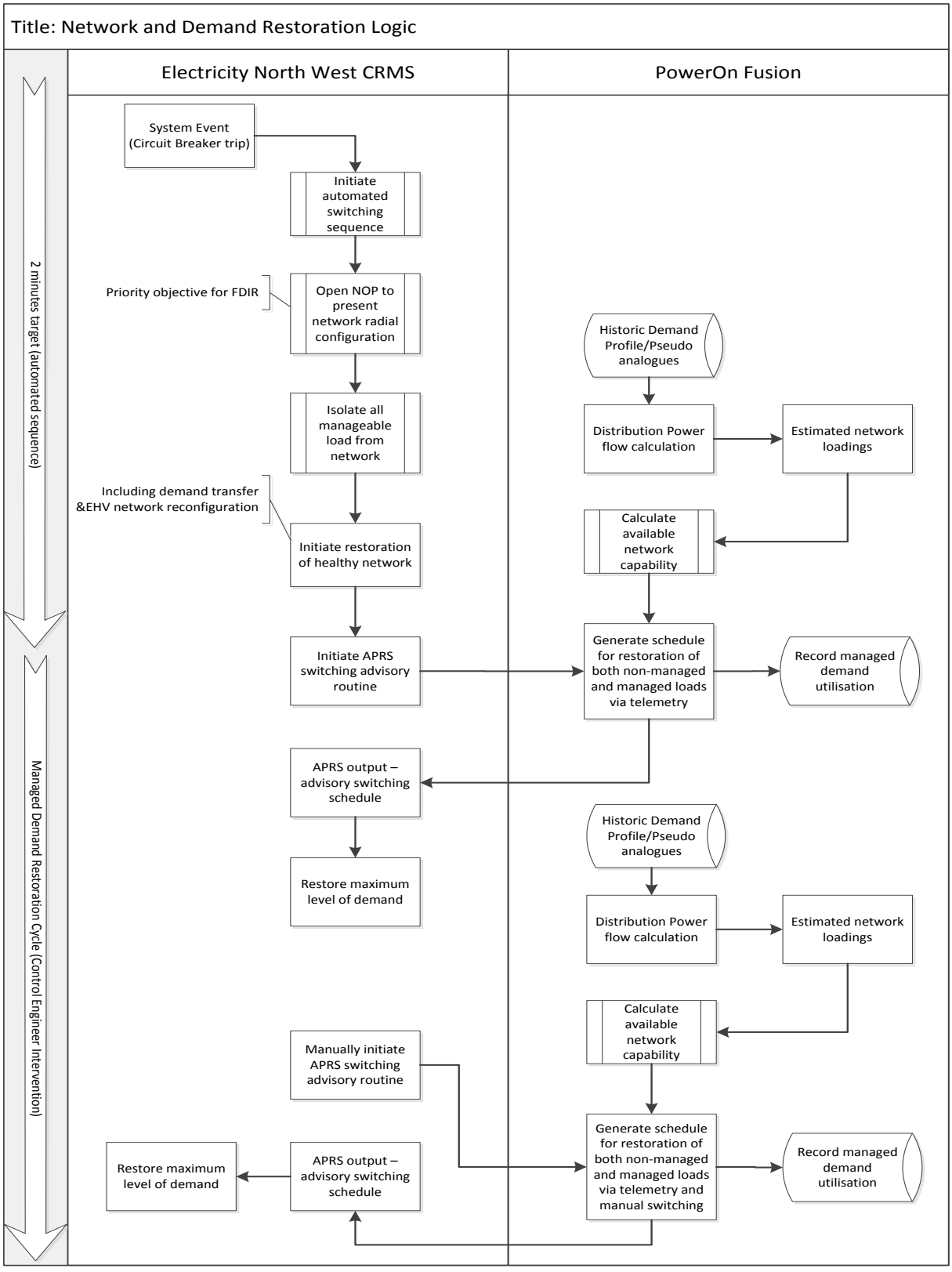

Figure 7: Network and Demand Restoration Logic

4.10 Reporting

4.10.1 Capture of fault data

For the trial phase, as much data as possible is captured for each ARS fault restoration. Each set of data is examined by control staff to verify correct operation of the system (this covers both circuits in the trial and those not in the trial). The data is available using a combination of the CRMS screens and system level logging files.

4.10.2 Control Engineer Reports

For presentation to Control Engineers of data on restorations involving Managed Customers a combination of CRMS Reports, existing ARS screens and new study screens is used. These are detailed later in this document.

4.10.3 Interface Message Monitoring

All messages across the SOAP interfaces are monitored for errors, bad status returns, and lost messages. A report of these messages is available.

All messages to response times are measured and a report of these times is available.

5. AUTOMATIC EXTERNAL INTERFACES

For the trial phase the CRMS and POF systems are not tightly integrated, instead they retain their identities and pass messages between the systems using a SOAP interface. An overview of each of the interfaces between the systems is given below including a description of the interface, the triggering events for data transfer, minimum requirements for data that needs to be passed between the two systems, and the expected response.

5.1 CIM Interface

The purpose of the CIM Interface is to provide a mechanism for transferring the full network diagram and subsequently incrementally updating the CRMS network model in POF. For incremental changes the CRMS system requests the model to be updated and POF processes the request and sends a response. The SOAP interface is a two way interface with information being returned to the CRMS system about the acceptance/rejection of a network model change.

5.1.1 Triggering events

The full network model download is requested manually from CRMS using operating system level facilities.

Incremental changes are transferred automatically once a Control Engineer commissions a diagram amendment on CRMS.

5.1.2 Data transferred

For the initial network load and subsequent incremental changes, the interface transfers a pair of CIM compliant XML and GML files.

5.1.3 Response/Results

A response is sent from POF once it has secured the model for processing (i.e. has downloaded all the CIM/GML files and stored them for processing)

- 0 is a success
- non 0 is an error of some description

The acceptance/rejection of the change is sent by a separate message. While the acceptance/rejection is outstanding, the real time data flows are held by CRMS, this ensures consistency in the two systems.

5.1.4 Errors

Errors may include, but are not limited to:

- The message structure is invalid

- The message structure is valid but the data specified in the message is not valid

- The application or the network is unavailable resulting in non-delivery of the message

The error responses for invalid data require a full network model download from CRMS. This download is initiated manually after investigation of the error condition.

For errors involving the non-delivery of the message an automatic retry mechanism is used for recovery.

5.2 Measurements and SCADA Quality Interface

The purpose of the Measurements and SCADA Quality Interface is to provide a mechanism to send both analogue scaled values and the digital quality information from telemetred devices to POF from the CRMS system. There is no requirement for the interface to transfer measurement data to CRMS from POF.

Following a full network download, all dynamic data is in its default state. Consequently data on all non-default values is transferred following the network download. To ensure consistency all messages are delivered in order of creation.

5.2.1 Triggering events

Each change to a SCADA analogue value causes a message to be generated.

Each change to SCADA quality and telemetry status causes a message to be generated.

A full network download requires all Measurements and SCADA Quality data to be sent.

5.2.2 Data transferred

The data sent over the interface includes but is not limited to:

- Electricity North West unique plant reference

- Attribute Name

- Value

- Quality

- Timestamp

5.2.3 Response

A response is sent back to the CRMS system containing the status of the request:

- 0 is a success
- non 0 is an error

5.2.4 Errors

Errors may include, but are not limited to:

- The message structure is invalid
- The message structure is valid but the data specified in the message is not valid
- The application or the network is unavailable resulting in non-delivery of the message

Invalid messages cannot be repeated (presumably they would still be invalid). For such messages manual intervention is required to correct the situation.

Messages for non existent plant items should be logged. Due to commissioning work there may be data on devices that are not currently part of the CRMS network diagram.

For non-delivery of messages, the message is queued and a retry attempted.

5.3 Inhibits Interface

The purpose of the Inhibits Interface is to provide the ability to dress inhibits on certain pieces of plant so as to tell the POF system that they cannot be operated as part of an APRS restoration sequence. There are two distinct types of inhibits –

- operation inhibit is a complete ban on operation of an individual plant item
- automation inhibit is a complete ban on operating any device on an entire feeder.

The interface also provides a mechanism for removing these inhibits when they are no longer present on the CRMS system. The interface transfers inhibits from CRMS to POF system only.

5.3.1 Triggering events

Any item placed on a Safety document to mark the safety zone boundaries is marked as inhibited and generates a message for the Inhibits Interface.

Any item placed on an Operational Restriction document to prevent automatic operation is marked as inhibited and generates a message for the Inhibits Interface.

Items where telemetry is not available for any reason are marked as inhibited.

Following an ARS restoration a faulted section of network may be identified. This faulted section should not be energized and so the surrounding switches are marked as inhibited. Any subsequent manual operation of the devices remove inhibits.

Any switch item that is manually operated to be not in Open or Closed states is isolated and as such is not available for restoration use. Such manual operations generate a message for the Inhibits Interface.

A full network download requires all inhibits to be sent. The default state for all plant is that it is not inhibited.

5.3.2 Data transferred

The data transferred from CRMS is to include but not be limited to:

- Electricity North West unique plant reference
- Inhibit type (operation/automation)
- Add/remove
- Timestamp
- Responsible Engineer
- Comment

Note that a piece of plant may have both control and automation inhibits applied at the same time and that some plant may have multiple inhibit reasons.

5.3.3 Response

A response is sent back to the CRMS system containing the status of the request

- 0 is a success,
- non 0 is an error or informative information. The status may indicate that the inhibit is already present on the item of plant – this is not regarded as an error.

5.3.4 Errors

Errors may include, but are not limited to:

- The message structure is invalid

- The message structure is valid but the data specified in the message is not valid

- The application or the network is unavailable resulting in non-delivery of the message

Invalid messages cannot be repeated (presumably they would still be invalid). For such messages manual intervention is required to correct the situation.

For non-delivery of messages, the message is queued and a redelivery attempted.

5.4 Plant Change of State Interface

The purpose of the Plant Change of State Interface is to keep the plant state representations in step between CRMS and the POF systems.

The Plant Change of State interface transfers state information from CRMS to POF only.

5.4.1 Triggering events

As a switch device state changes to/from either open or closed an interface message is generated. This change of state can be either via telemetry or via manual dressing.

A full network download requires all non-normal states to be sent via the Plant Change of State Interface.

5.4.2 Data transferred

The data sent from CRMS includes but is not limited to:

- Electricity North West unique plant reference

- Old State

- New State

- Reason (manual/telemetry/automatic)

- Time of operation

5.4.3 Response

A response for the Plant Change of State message is sent back to the CRMS system containing the status of the request

- 0 is a success,

- non 0 is an error of some description (but could indicate a same state change).

5.4.4 Errors

Errors may include, but are not limited to:

- The message structure is invalid
- The message structure is valid but the data specified in the message is not valid
- The application or the network is unavailable resulting in non-delivery of the message

Invalid messages cannot be repeated (presumably they would still be invalid). For such messages manual intervention is required to correct the situation.

For non-delivery of messages, the message is queued and a redelivery attempted.

5.5 Periodic Load Flow Results Interface

The purpose of the Periodic Load Flow Results Interface is to allow the CRMS system to submit a request to the POF system for load information for each load point. The results are returned to the CRMS system.

The SOAP interface is a two way interface.

5.5.1 Triggering events

Manual – Control Engineer initiates a request for load flow results on a circuit.

5.5.2 Data transferred

The data sent to the POF system includes:

- Electricity North West unique plant reference

5.5.3 Response/Results

A response is sent back to the CRMS system containing the status of the request

- 0 is a success
- non 0 is an error of some description

The results returned to the CRMS system includes:

- Electricity North West unique plant reference
- Loading information

5.5.4 Errors

Errors may include (for both sides of the interface), but are not limited to:

- The message structure is invalid
- The message structure is valid but the data specified in the message is not valid
- The application or the network is unavailable resulting in non-delivery of the message

No recovery mechanism is provided for these errors. The control engineer may request subsequent load information.

5.6 Advised Restoration Interface

The purpose of the Advised Restoration Interface is to allow the CRMS system to call upon the POF system to advise a restoration sequence.

Results from the Advised Restoration study are returned to the CRMS system as a SOAP message and are used to provide the control engineer with switching advice.

The SOAP interface is a two way interface.

5.6.1 Triggering events

Automated – ARS sends request at the end of a restoration

Manual – Control Engineer initiates request for switching recommendations

5.6.2 Data transferred

The data sent to the POF system includes:

- Identity of the tripped circuit breaker
- Time duration for which the proposed solution does not stress any plant
- Equipment rating percentage that should not be exceeded

- Flag to indicate whether it is an automatic or manual restoration that is required

5.6.3 Response/Results

A response is sent back to the CRMS system containing the status of the request

- 0 is a success
- non 0 is an error of some description

The results returned to the CRMS system include, for each piece of plant to be operated:

- Electricity North West unique plant references
- Sequence of actions (telecontrol open/telecontrol close/manual open/manual close)
- Details of customers affected

5.6.4 Errors

Errors may include (for both sides of the interface):

- The message structure is invalid
- The message structure is valid but the data specified in the message is not valid
- The application or the network is unavailable resulting in non-delivery of the message
- No usable recommendations can be made due to bad data

No recovery mechanism is provided for these errors. The control engineer may request another Advised Restoration.

5.7 C_2C Managed Customer Details Interface

The C_2C Managed Customer Details Interface allows a user on the CRMS system to request details of a customer contract from the POF system and for those results to be returned and displayed to the user.

The SOAP interface used is bidirectional.

5.7.1 Triggering events

A CRMS user initiates request for information about a Managed Customer.

5.7.2 Data transferred

The data sent to the POF system may include but not be limited to:

- Electricity North West unique plant reference

5.7.3 Response/Results

A response is sent back to the CRMS system containing the status of the request

- 0 is a success,
- non 0 is an error of some description.

The results returned to the CRMS system may include but not be limited to:

- Customer and load name
- Contact details
- Contract details for managed interruption times and durations
- Outage history

5.7.4 Errors

Errors may include (for both sides of the interface), but are not limited to:

- The message structure is invalid
- The message structure is valid but the data specified in the message is not valid (eg. Load details not found)
- The application or the network is unavailable resulting in non-delivery of the message

As the interface supports a non automatic interface, there is no recovery mechanism. The user is informed that there was an error in obtaining the data.

6. OPERATOR INTERFACES

The general principle for the operator interface is that it should have as small an impact on existing working practices as possible while ensuring that all loads are restored.

6.1 ARS

6.1.1 ARS Detail Screen

The existing ARS Detail screen shows all operations carried out during a restoration sequence. The operations that disconnect Managed Customers are shown on that screen and marked as a disconnection.

For operations involving the disconnection of Managed Customers it is possible to show the contract details for the contract covering the load. This feature is to aid in restoration following the ARS switching.

6.1.2 ARS Configuration Screen

The ARS configuration screen has an enable/disable parameter for Managed Customers.

- The disable value causes the functionality to be as at present.
- The enable value causes Managed Customers to be disconnected and the POF study to be performed automatically at the end of the restoration switching for circuits in the pilot trial.

6.1.3 Other ARS Screens

ARS screens showing customer interruptions and minutes saved are not being changed to allow for Managed Customers. Any change to the reported figures is made by hand after the various contract details have been examined.

6.2 Reports

Reports are generated using the existing CRMS reports facility. Should they prove useful extra reports can be added in future. At present it is envisioned that the following report is required-

- A report showing all disconnected Managed Customers. This report can be used as a confirmation that all Managed Customers have been restored.

6.3 Study

A Control Engineer can request a POF study be performed on a circuit and any switching actions recommended be displayed. There is no automated switching for this functionality; all switching must be performed manually by the Control Engineer.

ARS initiates a study automatically following restorations on any of the pilot trial circuits. Studies initiated automatically by ARS are given a suitable name based on ‘ARS’ and the circuit that tripped.

6.3.1 Study initiation

For manually initiated studies, the Study Initiation screen captures the name and circuit from the Control Engineer. The screen initiates the study and when the results are received cause them to be displayed.

6.3.2 Study results

The study results consist of suggested switching operations and item loadings. With the limited usefulness of the item loadings, only the highest loaded items are displayed. All suggested switching operations are shown. Any actual switching is by the Control Engineer using existing facilities. Other than scrolling through the lists and exiting the screen, there are no user operations from this screen.

6.3.3 Study directory

A directory of all studies is available with the most recent shown first. Studies are identified by their name and time/date stamp.

Selecting a study from the directory causes its results to be displayed.

The study directory periodically refreshes so that automatically requested studies can be waited for.

6.4 Contracts

There is no existing CRMS functionality covering Managed Customer contracts. Consequently all operator interfaces in this area are new functionality. The interfaces are:

6.4.1 Directory

A directory of all Managed Customers is available. The directory is filtered by district and sorted alphabetically on the load's name. Individual entries can be selected and further details obtained for the contract involved.

Loads shown in the directory that are currently disconnected are marked as off-supply.

6.4.2 Details

The details on a particular Managed Customer contract can be viewed. As well as the fixed data (Name, dates, interruption limits, etc) the current interruptions with duration are listed along with total interruption count and time. The statistics are not reset during the pilot project trials.

The details can be called to display from:

- The directory of all Managed Customers

- The diagram load symbol showing a Managed Customer
- The ARS switching actions showing a disconnection of a Managed Customer
- The recommended switching actions showing a reconnection of a Managed Customer.

6.4.3 Diagram

Each Managed Customer has a symbol shown on the CRMS diagram. Selecting the symbol allows a display of the load contract details. The creation and placement of the symbols on the CRMS network diagram is a manual operation.

6.5 Logging

For the trial a great deal of data is collected and logged. Unless specifically stated, none of the data is shown via the CRMS workstation interface. Full access to the logging information is at operating system level.

7. ERROR REPORTING

Error reporting of each interface is covered in the Automatic Interfaces section above.

All errors are logged to an error logging file. Any significant system errors cause a system event to be raised that is logged in the CRMS system event log.

Any change of state in the link between the CRMS and POF systems raises an alarm that is displayed on the system event banner as well as being logged in the system event log.

8. SYSTEM SIZING

8.1 CRMS sizing

The complete CIM data model export is carried out on a weekly basis. The CRMS system has suitable capacity to carry this out in all but extreme system conditions. The full system model export is manually invoked; hence its impact is managed.

The SOAP interfaces for status updates including analogues, states, statuses are using a slave copy of the CRMS Real Time Database, and hence do not impact the CRMS system. This is executing on separate hardware to the main CRMS system, hence does not directly impact the real time monitoring and control capabilities of the CRMS and SCADA systems. The CRMS system currently has the capability for attribute and point growth of in excess of thirty percent, and hence can accommodate the additional parameters and network components required to service the data required by the power flow aspects of POF.

8.1.1 Network Sizing

The current sizing and segmentation of the ECS Ethernet network is suitably sized to absorb the additional load associated with the CIM model and the pseudo real time updates.

8.1.2 Hardware

The additional CRMS hardware is limited to a Linux rack mounted workstation that is used to host a RTDB client copy, and RDB connection for data export.

8.1.3 POF Sizing

The following system specification was defined by IGE Energy Systems (UK) Ltd as applicable for the Electricity North West C_2C project containing a CIM loaded model of the distribution system for load flow and APRS functionality, based on the network size of the Electricity North West electrical network of circa 45000 substations.

When sizing POF server these three areas were taken into consideration:

a) The size and complexity of the network being modelled based on a 45,000 substation model for Electricity North West.

b) The number or range of POF products in use on the server.

   The C_2C project only uses a small subset of POF features; the Outage Management functionality for example is not used. However the CIM loading and DPF modules are expected to require the available system resources.

c) The number of concurrent users logged into the system

   Electricity North West has only two clients logged into the server, typically POF Servers run operationally with hundreds or users logged in so it's not envisaged this would have an impact on system performance.

8.1.4 Hardware

An HP DL 380 G7 server with the following specification, a single socket Intel Xeon X5690 with a clock speed of 3.46GHz and 6 cores, 32GB of RAM and 16 SAS hard disks 146GB in size operating at 15K rpm. These disks are connected via a raid card with 1GB Flash backed Cache.

The sizing of the system is as follows.

a) The CPU choice was based on the knowledge that similar sized systems run on fewer cores and that moving to a second socket would have resulted in an increased Oracle licensing cost.

b) The RAM supplied is double the typical usage of a similar size of system giving a capacity for system growth, and also additional capability for managing the high throughput of the CIM data model import and conversion into POF.

c) The RAID cards/ hard disk combinations were chosen as they represented the best mix of performance and durability. They intention is to stripe raid them providing 1168GB capacity while distributing the CIM Import disk load across a number of spindles. They represents 8 times the capacity required for a similar sized system, the decision to avoid external disk trays was to reduce latency and racking space needed. The disk subsystem includes redundancy to protect against disk failure.

d) POF can also be implemented in a distributed architecture, moving the Database, applications etc to separate machines, this can be helpful in distributing load but adds latency, rack space and networking issues. It was determined that this was unnecessary for the performance and level of resilience required for C_2C. However this remains an option in the event that system resilience is required if the trial is subsequently adopted as a full production system, without significant abortive costs.

e) The POF application is used only as a supporting process to CRMS, hence the need for a multi-server, multi-site redundant architecture was deemed unnecessary.

8.2 Security system sizing

The firewalls on the production system are suitably sized to cope with the additional security zones in the current setup. When the security zones are restructured as part of our security project, these are upgraded to support the additional throughput and additional protection that is required.

On the test system it is proposed to use Juniper SSG5 firewalls as point solutions for protecting the B2B link and isolating the POF security zone.

9. CONFIGURATION

Standard product configurations for POF are utilised.

Additional parameters added within CRMS to allow the use of the Managed Customers functionality within ARS.

There is a POF interface enable/disable configuration parameter within CRMS.

There is a POF DPF enable/disable configuration parameter within CRMS.

10. Appendix A - Acronyms

The following is a list of abbreviations used in the document; the description also shows who owns particular IT systems where applicable.

Acronym	Description
APRS	Automatic Power Restoration System (IGE Energy Systems (UK) Ltd)
ARS	Automatic Restoration Sequence (Electricity North West Ltd)
B2B	Business to Business
C_2C	Capacity to Customers
CIM	Common Information Model
CI	Customer Interruption
CML	Customer Minute Lost
COS	Change of State
CRMS	Control Room Management System (Electricity North West Ltd)
DPF	Distribution Power Flow (IGE Energy Systems (UK) Ltd)
ECS	Electricity Control Systems (Electricity North West Ltd)
EHV	Extra High Voltage
ENWL	Electricity North West Ltd
GE	IGE Energy Systems (UK) Ltd
GML	Geography Markup Language
HV	High Voltage
LV	Low Voltage
NOP	Normal Open Point
POF	PowerOn*Fusion* (IGE Energy Systems (UK) Ltd)
SCADA	Supervisory Control and Data Acquisition
SOAP	Simple Object Access Protocol
VPN	Virtual Private Network
WSI	Web Services Interoperability
XML	Extensible Markup Language