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FACULTY OF ENGINEERING
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ICT Practices in New Zealand Distribution Utilities

Discussion paper on Smart meters, Communication technologies & Ripple control

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Notice

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Abstract

New Zealand (NZ) electricity distribution sector is experiencing changes in terms of deployment of new technologies and processes to interact with consumers and also manage the network better. This report addresses the practices followed by 29 NZ distribution companies for their Smart / advanced metering implementation, communication technologies used and the existing ripple control infrastructure. This discussion document also identifies the relevant NZ Smart metering regulations together with concurrent International practices and implementation.

This discussion document will help form the basis of a coordinated approach by NZ distribution companies for utilizing their existing Information and Communication Technologies (ICT) plans and implementation in future. During the GREEN Grid 2014 annual conference in November 2014, we will solicit opinions from participating utilities for their viewpoint on the current state of affairs of ICT as identified in this discussion paper. This will thus help GREEN Grid to publish a practical NZ ICT Distribution Network Operator (DNO) roadmap for monitoring, protection and control of the network and offer services that are better informed by industry stakeholder engagement and extract maximum benefit to all consumers.

Key words: Smart Meters, Information and Communication Technologies (ICT), Ripple Control

Acronyms

AMI	Advanced Metering Infrastructure
AMS	Advanced Metering Services
BAN	Business Area Network
CDMA	Code Division Multiple Access
CPE	Customer Premises Equipment
DLC	Direct Load Control
DNO	Distribution Network Operator
DR	Demand Response
DSL	Digital Subscriber Line
EA	Electricity Authority
ESME	Electricity Smart Metering Equipment
G2V	Grid to Vehicle
GPRS	General Packet Radio Service
GPS	Global Positioning System
GWh	Giga Watt Hour
GXP	Grid Exit Point
HAN	Home Area Network
Hz	Hertz
IAN	Industrial Area Network
ICT	Information and Communication Technology
IED	Intelligent Electronic Device
IP	Internet Protocol
kHz	kilo Hertz
km	kilo meter
kV	kilo Volt
kVA	kilo Volt Ampere
MAN	Metropolitan Area Network
MHz	Mega Hertz
MW	Mega Watt
NZ	New Zealand
PLC	Power Line Communications
PMU	Phasor Measurement Units
PSG	Power System Group
RMS	Root Mean Square
RTU	Remote Terminal Unit
SCADA	Supervisory Control And Data Acquisition
T & D	Transmission & Distribution
TCP	Transmission Control Protocol
UHF	Ultra High Frequency
UK	United Kingdom

UoA	University of Auckland
US	United States
V2G	Vehicle to Grid
V2H	Vehicle to Home
VHF	Very High Frequency
VPP	Virtual Power Plant
WAN	Wide Area Network
WEMS	Wind Energy Management Systems
WFDAMS	Wind Farm Data Acquisition and Management Systems
WIMAX	Worldwide Interoperability for Microwave Access Technology

Executive Summary

The electricity distribution utilities are facing increased expectation from variety of stakeholders to help support national energy efficiency and climate change policy targets. Grid technology and available communication devices are being actively explored for enabling the electricity network to meet these goals. In this context the advancement or up-gradation of their existing Information and Communication Technology (ICT) will need to be fully understood.

Compared to international practices (details in first ICT GREEN Grid Report), New Zealand is also progressing towards installing Smart Grid infrastructure. To assess energy efficiency measures and enable existing network develop smarter operation, adequate information flow between all participating entities is required. This necessitates the usage of the advanced information and communication technologies. The main objective of this report is to address the existing ICT practices followed by all the distribution utilities in New Zealand and summarize their plans and ongoing trials. The New Zealand distribution companies are currently witnessing new ICT deployments mainly in the following areas:

i. **Metering:**

Majority of the electricity meters installed at consumer location in NZ are owned by the retailers. As per the Electricity Industry Participation Code 2012, it is mandatory for all the household electricity meters to get certified that they measure consumption accurately. Most of the residential meters have certification which is valid till 1st April 2015. In addition, most existing meters are traditional analogue meters that do not allow information exchange which is the basic requirement for achieving Smart Grid vision. Hence, many retailers are using this as an opportunity to upgrade their metering technology in place of recertifying their existing traditional meters. The Electricity Authority has voluntary industry guidelines for the use of smart meters. It is stated that the Advanced Metering Guidelines given by the Electricity Authority are not legally binding; rather the guidelines are intended to be advisory.

The smart meters that are being installed in New Zealand have many features like remote meter reading, interfacing with Home Area Networks (HAN), Load control applications, real time energy flow data, measurement of two way power flow, measurement of power quality, voltage level, providing electricity costs and usage information to consumers.

Media release of Electricity Authority (EA) record that around 1,001,475 of the 2,066,827 connection points in New Zealand have smart meters installed (as on 31st December 2013). It is estimated that there will be more than 1.2 million smart meters in New Zealand by April 2015, with over 800,000 of the traditional meters remaining. Some distribution utilities have already initiated their rollout whereas others are still actively investigating their deployment pathway and assessing implication. This discussion paper addresses the current metering practices pursued by different distribution companies and their future plan.

ii. Communication:

The information exchange between the different stakeholders in the electricity network and the consumers requires robust communication channel. The existing installed traditional meters do not always allow seamless information exchange. However newer smart meters that are being installed communicate with retailers or with the distribution companies using either GPRS or Radio Mesh networks. Further, this would also enable the interfacing with HAN.

In addition the protection, automation and control would also require backbone communication channels realized through Very High Frequency radio, UHF radio links, microwave, copper communication cables and optical fibre. This document covers current communication technologies of the distribution utilities and highlights some of their future plans.

iii. Ripple Control:

There are several ways for managing loads to achieve peak load reduction in utility infrastructure at specified times and situation. Ripple control is one that NZ utilities have been using as control mechanism to shed household hot water heating load for several decades now. For several utilities their control systems are dated and needs either replacement or sustained maintenance. At the same time, smart meters are being rolled out through which load could also be managed if consistent and grid visible wide-area control be realized. Several distribution companies are upgrading their load management system and investigating if smart meters can add further value. Details of these are addressed in the main body of this discussion paper.

To summarize, this discussion document covers the ICT practices (in terms of Smart metering, Communication and Ripple Control) pursued by all NZ distribution utilities. It has to be noted that the guidelines for advanced metering by NZ Electricity Authority (EA) are not mandatory and treated only as advisory. The international trend of developing separate grid codes to harmonize and address several ICT implementation issues might become necessary for New Zealand. This discussion document and responses from utilities will help achieve consensus and help drive informed rollouts that is efficient and effective.

Contents

Table of Figures

1. Introduction

The electrical grid refers to the interconnected power system network, which transfers power from all participating generators to consumers spread throughout. It has undergone several changes since its inception. The electrical grid is getting smarter and in future electrical grid is expected to make use of the advanced technologies from Information and Communication Technology (ICT) to gather the information from across its various participants. The information gathered from different stakeholders would be used to control and monitor in order to improve the efficiency, reliability, flexibility and for economic benefits.

Traditional energy sector value chain is pictorially represented in Figure *1*. In spite of technological advancements in electricity sector, still there is information gap. There has to be a real-time coordination between the stakeholders in the electricity sector, which could be achieved by properly using the ICTs in the smarter grid[1].

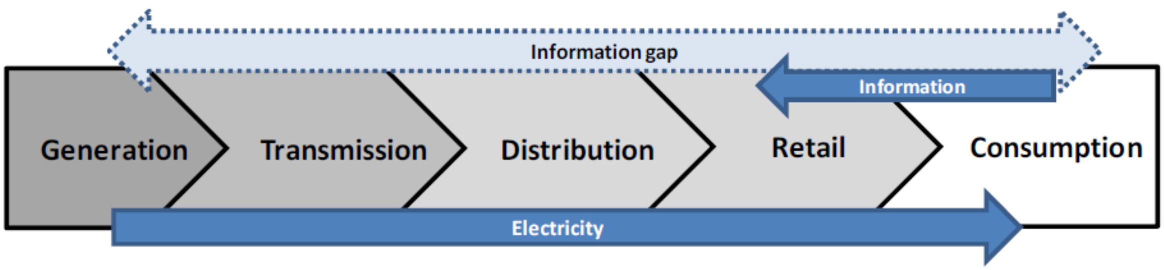

Figure 1: Traditional Energy Sector Value Chain[1]

In addition to the information gap, other challenges faced by the electricity sector globally are,

I. **Generation:** LargeScale Renewable Energy integration, Distributed small scale generation

II. **T & D:** T & D Grid management, Real-time coordination between retailers and distribution companies, Load management, Power Quality issues etc.

III. **Storage :** Data management and storage challenges

IV. **Retail:** Dynamic & Real-time pricing for electricity consumption and distributed generation, Coordination with distribution companies

V. **Consumption :** Electricity conservation and energy efficiency, Remote demand management, Integration of electric vehicles and in house solar generation

The development happening in ICT to come up with cheaper solutions would address these challenges faced by the electricity sector globally and would help in developing smarter grid.

2. Objectives and Organization

Internationally, countries are working or planning to implement advanced ICTs in their electrical power system infrastructure. New Zealand is one that have already started implementing the advanced ICTs in their network operation. The main objective of this report is to address the ICT practice followed by the different distribution companies in New Zealand. The literature survey has been carried out for all the 29 distribution companies in New Zealand addressing the key factors in ICTs like:

(i) Smart or Advanced metering and its communication,

(ii) Communication used for SCADA and

(iii) Load management (ripple control) systems

This report would address all three factors for all NZ distribution network utility, which is a comprehensive objective to base future actions. This document is organized as follows:

Section 3: addresses the conceptual network architecture for the smart grid like Premises Network, Neighborhood area network and Wide Area Network. A brief overview of communication solutions such as WIMAX, ZigBee, Z-wave, cellular technologies, PLCs etc. is also discussed. It also addresses the ICT applications in power sector.

Section 4: details the ICTs used in all the 29 distribution companies comprehensively. For all the distribution companies Metering (Smart meter implementation OR plan), Communication and Load management (ripple control) are addressed.

Section 5: presents the analysis of ICT practices in NZ distribution utilities.

Section 6: Discusses the points covered and invites the opinion of stakeholders.

Annexure A addresses the metering and regulations in New Zealand. The recommended advanced meter infrastructure system minimum attributes list as per the EA AMI guidelines is given for information.

Annexure B presents the practices followed in other countries. (UK is considered as an example and the practice followed in UK is presented).

Annexure C highlights the Smart grid infrastructure implementation status / target for other parts in the world.

Annexure D presents the Format for submission

Annexure E presents the summary of ICT practices in New Zealand Distribution Utilities as elaborated in Section 4 of this discussion document.

3. Introduction to ICTs

As explained in the earlier part of this report, the electrical power grid is going through a substantial evolution to become an intelligent, reliable and automated grid. To work smarter, smart grid is expected to have a robust communication network. These communication networks would help in exchanging the information from end-to-end, thereby helping the different stakeholders to operate the grid reliably. The University of Auckland has already released a white paper on ICT[2] and the highlights there are briefly repeated in this section.

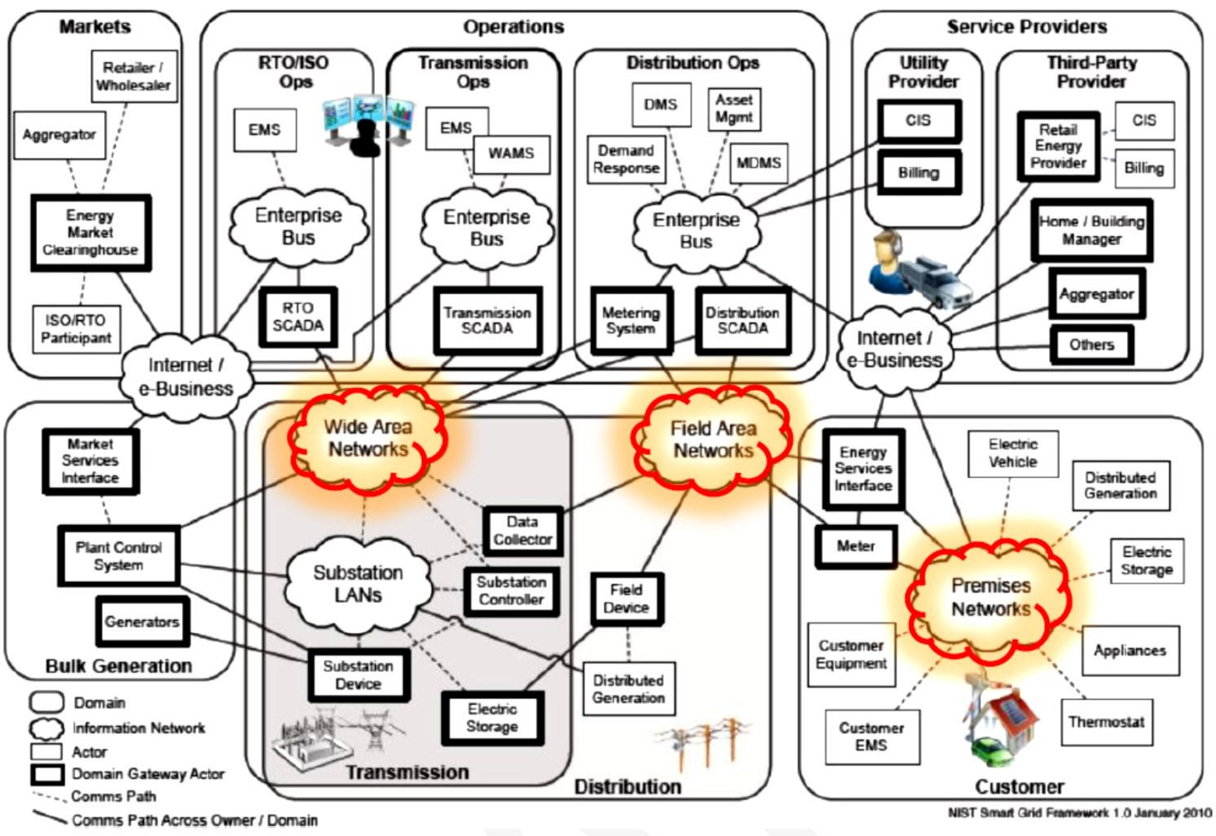

Figure 2: Communication Network Architecture[3]

The Communication Network Architecture is pictorially represented in Figure 2. The overall communication network is divided into three parts as Premises Network, Field Area Networks / Neighborhood Area Network and Wide Area Network.

Premises Network is conceptualized to form communication access for consumer devices such as electric vehicles, appliances, automated lightning etc. which will enable them to interface with smart grid. Premises Network is further divided into Home Area Network (HAN), Business Area Network (BAN) and Industrial Area Network (IAN).

Neighborhood Area Network would cater the communication link between Smart or Advanced meters at a neighborhood level or devices like IEDs and field level.

The Wide Area Network (WAN) is the final stage of the network architecture that connects Neighborhood Area Network to the utility. The Wide Area Network has three main sub-networks such as Backbone Network, Metropolitan Area Network (MAN) and the Backhaul Network.

Similar to Network Architecture, Communication can be classified as Wireless Communication and Wireline Communication. The potential Wireless Communication solutions in smart grid are WIMAX (IEEE802.16), ZigBee (IEEE802.15.4), Z-wave and Cellular (3G and LTE) technologies.

Power Line Communications (PLC), Digital Subscriber Line (DSL) and Optical fibre are the solutions available under wireline communication.

The network architecture and communication is explained in detail with example in the earlier white paper. For detailed information, one s recommended to refer “Smart Grid Communication Infrastructure” released by PSG through GREEN Grid in October 2013.

3.1 ICT Application in Power system

Implementation of advanced ICTs in electricity networks will help enable the system operator to solve common challenges faced in power sector. The application part of the ICTs in different sectors of power system is pictorially represented in Figure *3*. As can be seen from the figure, all power systems stakeholders will benefit by implementing the ICTs and provides a pathway for policy targets like reducing the greenhouse gas emission. This section of the report would address the application side of ICTs in power sector.

3.1.1 Generation

To address the climate change issues, the generation sector across the world is looking at the renewable energy resources like wind, solar etc. Hence renewable energy sector plays a crucial role in future power scenarios[1]. However, the transition from existing energy sources to renewable energy will take time and effort during the transition phase.

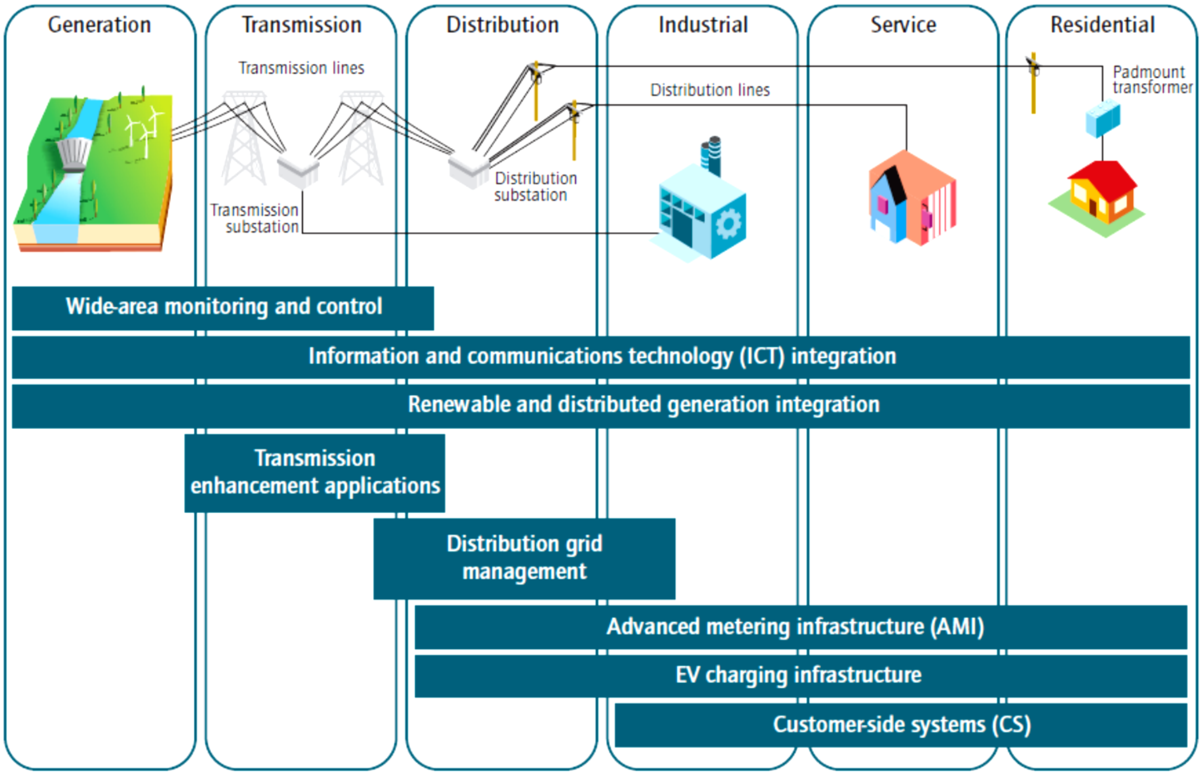

Figure 3: ICT Application domains in Smart Grid

Source: OECD 2012

Electricity generation by fuel as per New Zealand's Energy outlook 2010 is pictorially presented in Figure *4*.

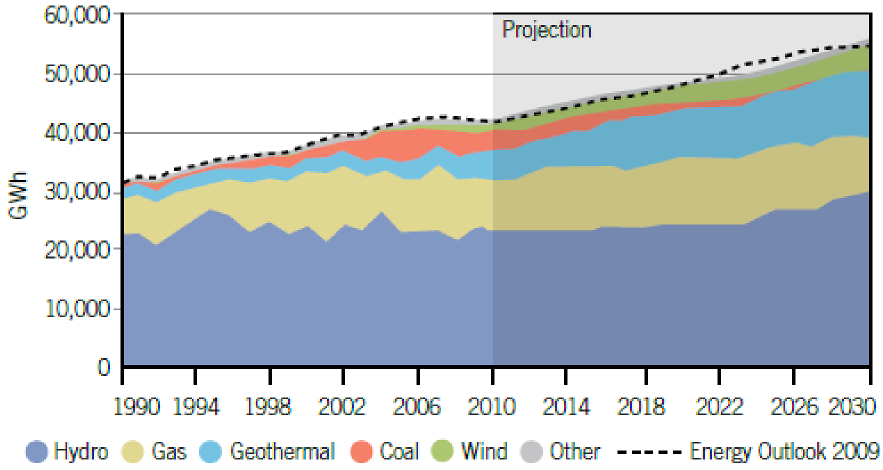

Figure 4 : Electricity generation by fuel

Source: New Zealand Energy Strategy 2011-2021, Ministry of Economic Department

It is clear from Figure 4 that in future large scale renewable energy integration to electricity grid is expected and it will play a vital role. However, the renewable energy sources are intermittent and at times unpredictable. Further, the penetration of these power resources into the grid can be better managed when there is lower demand in the grid. The system operation is trying to address this using ICTs which enables the operator to predict the wind generation as accurately as possible well in advance (using tools like WEMS and WFDAMS in wind farms, which provides the predicted wind power generation which provides means to better schedule other generators during wind peaks, to make sure renewable resources are fully utilized).

A case study for North Carolina (US) suggests that over 70% of load which includes base load and peak load can be provided from the renewable energy sources provided that the ICTs are used for electricity storage, wider geographic scopes of the grid, effective demand management and dynamic pricing[1].

The trend of decentralized power generation is also rapidly growing. The electricity authorities are making policies for distributed generations like in-house solar and other small scale generation. ICTs will help the operator for developing Virtual Power Plants (VPP) which will facilitate the expansion of installed capacity from micro generation. VPP is the aggregation of several hundreds or even thousands of small generating units into a single unit which has real-time communication with downward links from each generating unit. This enables greater predictability of overall power supply from the VPP[1].

3.1.2 Transmission and Distribution

ICT based applications are being extensively used in transmission and distribution utilities. The commonly used ICTs are Intelligent Electronic Devices (IEDs), Phasor Measurement Units (PMUs) and Supervisory Control and Data Acquisition (SCADA). The existing technologies of communication in these devices are being replaced with the latest communication technologies.

Sensors which are installed across the network would help in measuring the various characteristics such as voltage, temperature etc[1]. This improved monitoring gives also a better visibility of real-time power quality that is being delivered to consumers. The smart meters are able to calculate the average value of RMS voltage over a period which can be configured, can record the value calculated, be able to detect when the value calculated is above or below the threshold values and send an alert signal to HAN interface[103]. Based on the local voltage deviation detections, smart meters can trigger events to alert the local grid operator. These events could either generate a request to automatically increase the sampling rate in the affected area or be forwarded to a grid operator for manual decision making. Thereby ICTs can not only help in improving the quality of power being supplied, it also offers greater potential for early problem identification and preventive maintenance**.

The distribution companies can effectively utilize ICTs to manage their system loads. An Advanced Metering Infrastructure (AMI) coupled with dynamic pricing and connection to smart appliances at consumer location would help in shifting the timing of certain consumption of consumers. In addition to this, AMI can also feature the ripple control receivers which would help the distribution company to cut off certain loads like hot water connection, street lights etc. AMI would also allow remote meter reading. If properly utilized, ICTs could be a demand management tool for any distribution company[1].

3.1.3 Electricity Storage

Due to large scale renewable energy integration into the grid, electrical storage becomes important when the renewable generation is at its peak whereas the demand is low. ICT would play a vital role here in managing the power flow between grid and electric car. The schemes like G2V (Grid to Vehicle), V2G (Vehicle to Grid) and V2H (Vehicle to Home) rely on ICT for managing and controlling the power flow. These schemes also require an end user interface (at consumer location), through which the system operator can give signals to vehicles (consumers) to absorb the power when the system generation is high (renewable energy penetration is more). Smart meters becomes important here to send / receive signals (between grid and vehicle), monitoring the power flow direction and for metering[1].

3.1.4 Energy conservation and Energy efficiency

The electricity is finally consumed at the service end point i.e. consumers. The provision of ICT at consumer location becomes important in reducing the overall energy used by the consumers and also for managing peak usage. The Advanced Metering Infrastructure (AMI) at consumer locations would enable the data transfer between the utility and the consumers. This would give the dynamic and real-time prices which can help the consumers to choose the conservation options available or the option of feeding electricity back into the grid. Further the AMI allows the programing of automated response to system peak demand and necessary response which can include control of specific electric device under that scenario[1].

4. ICTs in New Zealand Distribution Utilities

New Zealand distribution companies are serving electricity to approximately 1.7 Million of residential consumers, 165,000 of commercial consumers, 70,000 of agriculture, forestry & fishing consumers and around 40,000 of Industrial consumers. Over 150,000 km of distribution network lines passing through 29 distribution companies are linking the different types of consumers with the national grid. The geographical spread of all the distribution companies is pictorially represented in Figure 5[4].

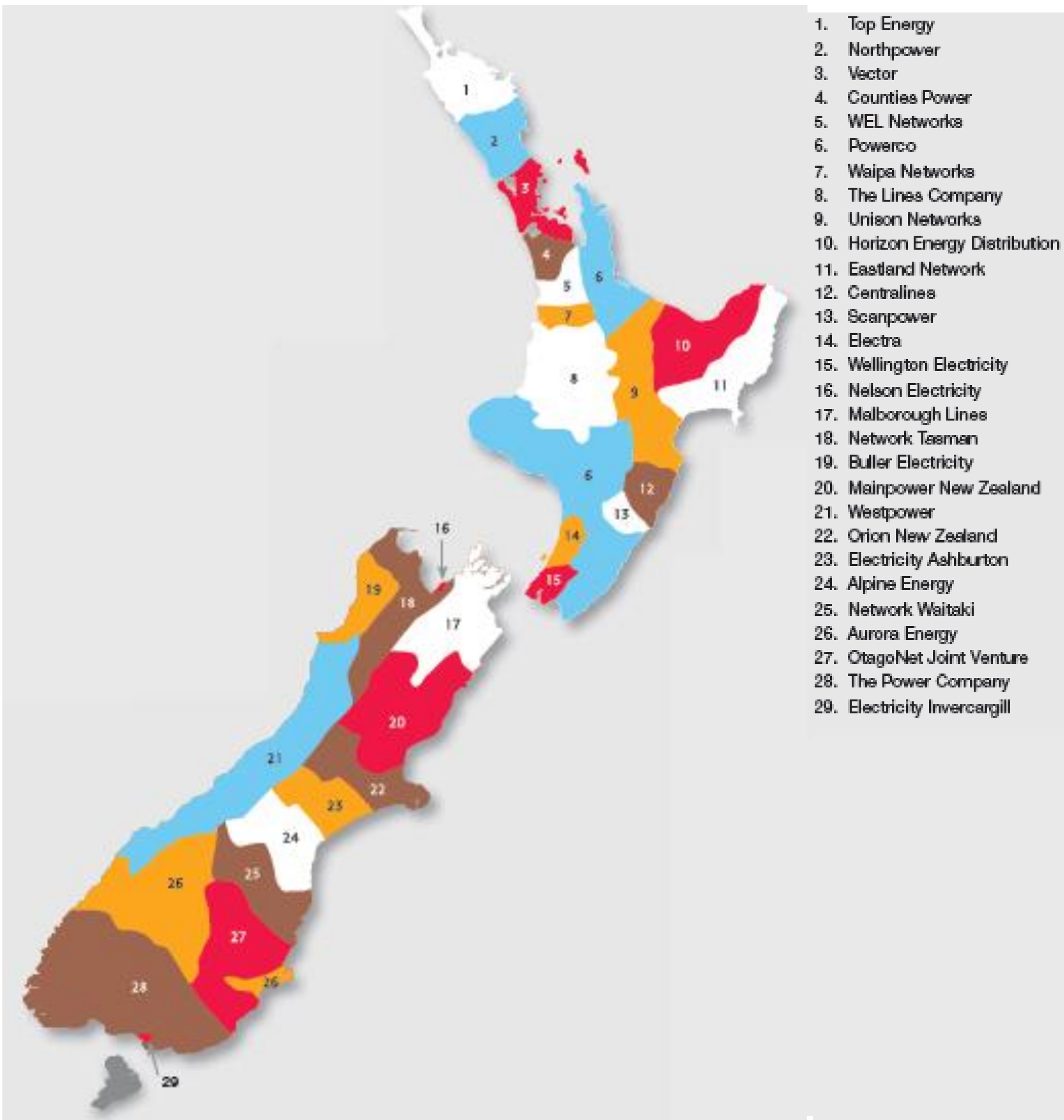

Figure 5 : NZ Distribution Companies – geographical representation[4]

These distribution companies transport power to consumers. Presently lots of effort is being carried out by distribution companies along with retailers to upgrade their system. This section of the document mainly addresses the metering, communication technologies and ripple control practices followed by distribution companies in New Zealand.

Metering:

The Electricity Industry Participation Code 2012 (Code) requires household electricity meters to be certified that they accurately measure electricity consumption. Most residential meters have certification that expires on 1 April 2015. To ensure that they operate accurately, all these meters need to be recertified before that date. Many retailers are using this as an opportunity to update metering technology, rather than having existing meters recertified[5]. As on 31st December 2013 around 1,001,475 of the 2,066,827 connection points in New Zealand were recorded as having smart meters installed. By April 2015, it is estimated that there will be more than 1.2 million smart meters in New Zealand with over 800,000 of the traditional meter remaining[6].

The latter part of this document will address the implementation of Smart meter infrastructure program under the jurisdiction of different distribution companies.

Communication:

The smart meters installed would communicate with retailers or with the distribution companies using either:

General Packet Radio Service (GPRS): Cellular transmission in 900MHz or 1800MHz frequency bands. It is a point-to-point communication from the smart meter to a cell phone tower, OR,

Radio Mesh: radio transmission in the 900MHz frequency band – a point-to-many communication. These systems are relatively low power with a short range of a few kilometers. Information is collected into data concentration points and relayed[6].

The latter part of this document will address the communication technology used by different service providers along with the communications used in SCADA.

Ripple Control:

The term Demand Response can be defined as “Changes in electric usage by demand-side resources from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized”[7]. There are many ways to manage the loads and ripple control is one among them.

Ripple control to shed household hot water heating load has been in use for many decades in New Zealand to very successfully improve the utilization of generation, transmission, and distribution assets. It is a form of incentive based DR known as Direct Load Control (DLC)[8]. Ripple control approach implemented by different distribution companies in New Zealand is discussed in detail in the sub-sequent sections.

4.1 Top Energy

Top energy Limited, formerly Bay of Islands Electric Power Trust is owned by Top Energy Consumer Trust. The Company serves an area of 6800 square kilometers in the mid and far north of New Zealand’s north island to approximately 30,000 electricity consumers[9] [10].

4.1.1 Metering

Top Energy Limited and WEL Networks have agreed a contract for installation of Smart boxes and Radio Frequency (RF) Mesh network required to facilitate the necessary communication network required for smart meters[11]. The rollout will include the installation of 25,500 smart boxes in the homes and businesses of Top Energy customers. The meters will be owned by WEL, replacing meters currently owned by Contact Energy. Top Energy will be subcontracted by WEL to install the RF communication mesh, the framework of multiple radio links between devices on which smart meters communicate[12]

4.1.2 Communication

Top Energy Networks (TEN) existing SCADA system architecture consists of distributed data collection and operation via an Ethernet Wide Area Network (WAN). The SCADA system communicates with various relays, protection and measurement transducers in zone substations, and high voltage switching device locations either using the Abbey base station or by directly communicating to the devices using various communication drivers available within the system.

TEN uses multiple communication protocols which includes its own VHF network and a leased UHF broadband network. TEN’s existing communications system is reaching the end of its useful life and is not capable of providing protection signaling which is required by the network. Fibre-optic cables, which are capable of providing signaling required for networks by differential protection schemes, are progressively replacing the existing communications links [11].

4.1.3 Ripple Control

TEN controls water heating load through its ripple frequency controlled load management system. TEN's static ripple control plants are operated via its SCADA system and injection onto its 33kV sub transmission system is made at 317Hz. The Control plants are located at TEN's Kaikohe and Okahu road substations and a standby plant is located at Waipapa substation. It is estimated that such system currently reduces the actual peak demand on network by 10MW[11].

4.2 North Power

Northpower is one of the distribution companies in New Zealand which is owned by the Northpower Electric Power Trust (NEPT). The company has two divisions - Northpower Network providing electricity and fibre infrastructure to Whangarei and Kaipara, and Northpower Contracting, operating throughout the North Island of New Zealand and in Perth and Melbourne in Australia. North Power distributes electricity to approximately 50,000 consumers and over 54,900 ICPs connected to its network with an area of 5,700 square kilometers across Whangarei and Kaipara districts in Northland[13].

4.2.1 Metering

Northpower owns most of the metering at the properties that are connected to its network. Energy retailers are currently planning to replace Northpower meters with smart meters that can provide them remote meter reading[14]. Over 6,000 Northpower meters have been replaced by Genesis Energy smart meters[15]. North Power is closely monitoring the developments in the field of smart metering / smart grid technology which are expected to have a fairly significant impact on the manner in which networks are managed. Initiatives in this sphere could possibly reduce peak demand growth to some extent and so tend to offset the effect of increasing installed load but any impact is difficult to predict at this time[16].

4.2.2 Communication

Nothpower's communications network uses microwave, UHF and VHF radio links, as well as copper and optical fibre cable links. Due to the aging nature of the analogue based radio systems and copper based communications systems and the advent of modern communications technologies such as fibre / microwave, Northpower has been upgrading the existing communications network infrastructure. Further advances in technology now provide the ability for Ethernet communications over microwave or Fibre-optic cabling. This technology has been adopted by Northpower and migration to these systems along with digital UHF is being carried out over the period.[16]

4.2.3 Ripple control

Northpower owns six ripple signal generation plants located at Maungatapere, Tikipunga, Bream Bay, Maungaturoto, Dargaville and Ruakaka. These plants generate a 283Hz signal. Out of six plants, three plants inject into the 33kV network and other three inject into the 11kV network. The injected signal activates ripple receivers installed in the low voltage system of the network through which load such as water heating and streetlights are controlled. The ripple system in the Northland Regional Council can also be used as Tsunami warning system[16].

4.3 Vector

Vector is one of the distribution companies in New Zealand which owns and operates the electricity distribution network in the greater Auckland region. Vector has more than 543,000 homes and business units connected to its network[17]. Vector established a joint venture with Siemens NZ to deliver the advanced metering technology services and later Vector has purchased Siemen's shareholding completely. At present, Vector operates two metering business i.e. Advanced Metering Services (AMS) and Advanced Metering Assets. These business units own and operate meter and metering services throughout New Zealand.

4.3.1 Metering

Since Vector owns AMS, the electrical meters coming under Vector service area are also being replaced with Smart meters. Smart meters installed by Vector (through AMS) have many features including[18]:

- Load control applications using conventional ripple control, radio-based, GPRS-based or fibre-optic based means of communication
- Interface to Home Area Networks (HAN), supporting customer-based load control or energy-saving applications
- Signalling electricity costs and usage rates to customers
- Providing real-time energy flow data to be used in smart network applications
- Measurement of two-way power-flow – accommodating distributed generation sources
- Measuring power quality and voltage level and
- Providing an exact location and record of power outages

As per the operating statistics of Vector, out of 893,919 electricity meters, approximately 675,555 meters are smart meters, 202,561 are of legacy meters, 4,527 are of prepay meters and 11,276 are of time-of-use meters[19]. Further, AMS has an agreement with Smartco (A consortium of electrical distribution companies including Alpine Energy, Counties Power, Electricity Invercargill, Network Tasman, Network Waitaki, The Power Company and WEL Networks) and a significant portion of the meters to be rolled out in 2015 which will be owned and funded by Smartco. These meters communicate through GPRS.

4.3.2 Communication

The communications network is used for protection signaling, SCADA communications, operational telephony, access security, metering, remote equipment monitoring and automation. Vector's Wide Area Network (WAN) infrastructure which began in 2002, consists of the optical fibre infrastructure, digital communication over Vector's copper pilot cables, Vector's owned digital microwave radio links and third party IP network, including wireless GPRS/3G GSM standard based networks[18].

4.3.3 Ripple Control

Vector's Load control system consists of audio frequency ripple, pilot wire and cyclo control types. These load control equipment use older technologies and most of which are approaching the end of their life. As Vector is working towards smarter network by implementing smart meters and new communication technologies, alternative means of load control would be possible. Hence, it is anticipated that the existing load control systems would be phased out and Vector is working on the strategies for this transition[18].

4.4 Counties Power

Counties Power Ltd, formerly the Franklin Electric Power Board, is owned by the Counties Power Consumer Trust. The company serves an area situated on the southern edge of Greater Auckland and delivers electricity through 3400 km of network lines to approximately 35,000 customers[20].

4.4.1 Metering

Counties power is one of the members of Smartco. At present, the consumers connected to Counties Power network have conventional analog meters. Counties Power would like to replace the conventional meters with smart meters. Mighty River Power's metering business, Metrix, and Counties Power have signed an agreement to roll out smart electricity meters to all homes and businesses on the Counties Power network, which covers the area between Papakura and Mercer.

The new Counties Power owned smart meters are ZigBee enabled and will replace the existing manually read electro-mechanical meters. These meters will enable remote reading of electricity consumption and analytical information for network management. The meters will also enable future capabilities such as outage alerts, and remote load control. The meters can communicate with each other and with 220 relays to form a radio meshed communication network. This mesh configuration ensures no single fault will disrupt the meter communications. The communication equipment is provided by Silver Spring Networks, with the accompanying software being managed by Metrix[21].

The Company has commenced the deployment of smart meters, aiming to connect 95% of the customers by June 2015. It is reported that the company is on track in implementing[22].

4.4.2 Communication

The communications system is in use for provision of voice communications (VHF analogue) between vehicles and the control room, remote control of equipment at zone substations, control and indication of field equipment (reclosers, sectionalizers, switches and fault indicators), and protection and metering links (UHF analogue) [23].

Communication to all substations is achieved by UHF radio except Bombay, Opaheke, Pukekohe and Ramarama, where optical fibre links have been deployed. Communication between the Transpower Glenbrook substation and the Glenbrook Load Control Plant also uses a fibre link[23].

4.4.3 Ripple Control

Counties Power ripple control scheme operates at a frequency of 317 Hz. It is estimated to be around 6000 water heaters supplied by the Counties Network, in which after diversity maximum demand of 9 MW is controlled via Bombay GXP and another 2.2 MW via Glenbrook GXP[23].

The Smart network program would also address remote load control. This internal load control operation will be a hybrid of control via internal meter timer decabit ripple control and UIQ broadcast[23].

4.5 WEL Networks

WEL Networks provides electricity supply to the consumers located in Waikato region. WEL network has over 5,200 kilometres of electricity lines connecting approximately 85,000 consumers from Maramarua in the north and across to the west coast, incorporating Huntly, Raglan, Te Kauwhata, Hamilton and Ngaruawahia[24].

4.5.1 Metering

WEL Networks has been investing on “Smart Network” for serving energy efficiently. WEL networks also owns 15% of Smartco limited which is a joint venture company set up to contract with supplier and electricity retailer to rollout advanced electronic meters across its shareholder networks. As part of WEL Networks “Smart Network” program, over 35,000 of smart boxes have been installed and has an aim to achieve further 25,000 smart boxes by March 2015. The rollout in WEL’s rural northern and western areas has now been completed and installations continue at an average of 2,500 per month in the greater Hamilton area. This will also include RF communication mesh[25].

4.5.2 Communication

Protection signalling, SCADA and remote control communications are transmitted through comprehensive radio network. This is being progressively extended to improve communication dependability by a Fibre-optic cable network. Copper pilot network is still in use in the CBD[26].

4.5.3 Ripple Control

Hot water and streetlight load control is managed with 283Hz and 500Hz mains borne ripple signals. Most of WEL’s customers have ripple control relays while a small proportion of customers in some parts of the city are controlled via hard-wired pilot cables. As part of “Smart Network” project, WEL network is installing smart metering devices (Smart boxes) and associated mesh radio communications infrastructure across the whole network. Integrated ripple devices within the deployed Smart Boxes are progressively replacing old separate ripple relays[26].

4.6 Powerco

Powerco electricity networks distribute electricity to 320,000 urban and rural households, businesses and major industrial and commercial sites in New Zealand's North Island. Powerco's electricity networks are in the Taranaki, Wanganui, Rangitikei, Manawatu and Wairarapa regions, including the urban centres of New Plymouth, Wanganui, Palmerston North and

Masterton, as well as Tauranga and the surrounding rural areas and the eastern and southern Waikato, Thames and Coromandel regions. Powerco has 30,000 km of overhead and underground electricity lines[27].

4.6.1 Metering

Retailers have started installing smart meters to the consumers coming under Powerco network since 2011[28]. Powerco will also investigate the installing of smart meters in their inner city distribution substations to get accurate information on load usage for network management and pricing purposes. Radio Frequency mesh is considered for the purposes of obtaining smart meter data[29].

4.6.2 Communication

Powerco's communication system consists of

- VHF, UHF or Microwave radio circuits
- Optical fibre
- Telstra Clear/Telecom leased circuits
- CDMA and GPRS private IP networks and
- Powerco-owned copper and Fibre-optic cable communication circuits

A SCADA replacement project is proposed, which will replace the Abbey Systems Western SCADA master station and load-control systems with OSI Monarch to provide a common interface across Powerco. Powerco is also re-establishing and enhancing its own VHF Voice Radio network to remove reliance on the current Fleet link trunked radio system[29].

4.6.3 Ripple Control

Powerco has already an extensive ripple control system installed, primarily to provide DSM of water storage cylinders, but with an historical focus on managing transmission constraints. At present, the ripple injection is used more for the time shift of load for retailers and generators, but any use of the ripple system essentially results in lower total generation and network losses. Powerco have been reviewing the nature and ownership of current technology, and is considering options to optimize the cost efficiency and long-term viability of load control technology. Powerco is also focusing its demand-side management initiatives, in the form of smart meters and possible energy storage systems, in the Tauranga area[29].

4.7 Waipa Networks

Waipa Networks Limited is one among the 29 distribution companies in New Zealand which is owned by the Waipa Networks Trust. Waipa Networks' Electricity distribution network serves customers throughout the Waipa area, Te Awamutu, Cambridge and surrounding areas[30].

4.7.1 Metering

Consumers connected to Waipa networks are mostly having Time of use meters. Waipa Network considers that once the installation of smart meters is done by retailers, it can be used for load control[31].

4.7.2 Communication

Waipa owns separate VHF voice and data communication networks which comprises of Radio repeater sites located at Pukekura, Te Rauamoa, Wharepuhunga and Mount Oue. Base stations are located at the Te Awamutu Company's Control Room. Vehicle mounted radios and hand held units are used by the Company's field crews for communication. Waipa has separated out voice and SCADA data radio channels to ensure the integrity of operational commands, voice traffic and the safety of field crews[31].

4.7.3 Ripple Control

Waipa Network owns two ripple injection plants located at Cambridge GXP and Te Awamutu GXP, respectively. Ripple injection signals are initiated by the SCADA system via these plants to control load, street lighting and metering tariffs. The Company also owns the receiving relays in consumers' installations. The ripple control system controls 10MW of connected load in Cambridge and 12MW of connected load in Te Awamutu over peak periods. Ripple Injection Plant at Cambridge is 283Hz Enermet static plant. Ripple Injection Plant at Te Awamutu has a legacy 297Hz ripple injection frequency. The 297Hz signal propagation is expected to progressively deteriorate as the load increases. Waipa has installed a new Enermet static ripple injection transmitter at Te Awamutu which can drive a 297Hz coupling cell and a 283Hz coupling cell. Waipa has planned to progressively change to new 283Hz ripple relays over the period 2008-2015[31].

4.8 The Lines Company

The Lines Company (TLC) owns and operates the electricity distribution network that provides power for the people of the King Country region of the central North Island. The company's distribution network is 4,500 kilometers long[32]. It supplies over 24,000 customers. The company's distribution area covers 13,700 km^2 and is the largest network area in New Zealand with no major urban centre[33].

4.8.1 Metering

The Lines Company is replacing the old meters with new ones. The new meter is an advanced meter. Initially the new meters will not have active communications. Once the communication system is in place the meter will be able to be read remotely and then it becomes a smart meter. The meters that have been installed between September 2013 and May 2014 are likely to have communications enabled by 1st October 2014. The options for communications are either radio mesh or GPRS (cell phone signal). Mangakino and Otorohanga will start the roll-out at the end of September with other areas starting to roll out meters soon after[34].

TLC has developed advanced meter software including an in home display that aligns to its pricing. This software and the in home display have been trialed and will be developed as soon as this work is completed. Advanced meter firmware has now been developed to the point that it will read both retailer and TLC demand based charging data and includes the capabilities for future communications and in-home displays[35].

4.8.2 Communication

TLC operates a network of six E-Bands (150 – 155 MHz), radio repeaters providing voice communication throughout the operational area. Eight further repeaters divided across three sub communication networks provide a complimentary low speed (1200bps) SCADA transmission platform to access 100 plus remote terminal units. The communications system is low speed, but robust and relatively low cost. The installation of additional links to provide diversity is part of proposal for long-term development of the system. The plan is to systematically connect the voice then the data system to 12.5 kHz band width digital systems[35].

4.8.3 Ripple Control

TLC operates two generations of ripple systems, one in the southern part of the network and a combination of new and old in the north. Both systems share the same controller, which is integrated into the Lester Abbey SCADA system. The controller decides on the need to shed and restore load. Telegrams are generated at the plant controller level. The high frequency (725Hz) and relatively low power output of the 11kV Landis and Gyr legacy plants results in marginal to no signal being available for about 300 customers at Hangatiki and 500 customers at Marotiri. To overcome this problem, two new 317Hz 33kV plants were commissioned in 2010.

The advanced meters that are being installed also include load control relays. The old Landis and Gyr plants can be decommissioned once the advanced meters have been installed[35].

4.9 Unison Networks

Unison Networks is owned by the Hawke's Bay Power Consumers' Trust (HBPCT). Unison Network's distribution network supplies approximately 1,678 GWh of electricity per annum to over 110,000 customers. Company's network spans over 9,000 km, distributing electricity across an area of over 12,000 square km in areas of Napier, Hastings, Havelock North, Rotorua and Taupo[36].

4.9.1 Metering

Unison Networks are in the process of implementing smart grid strategy which includes smart network technologies and advanced metering infrastructure (AMI). Unison has decided to be collaborated with Energy Retailers to deploy smart meters. Unison has partnered with Silver Spring for distribution automation, smart metering and demand response. The Silver Spring Networks platform enables two-way communication on Unison's network. This network is used to communicate to devices such as Unison's smart transformers and in the future will be used to talk to smart devices at customers' home. Smart meters will enable the customers a better energy management by giving them real time access to the meter data. Currently only a small portion of customers on Unison Network are using smart meters[37] [38] [39].

4.9.2 Communication

Unison's communication system includes UHF telemetry links, VHF radio links, fibre network, Copper Telcon cables, meshed radio links, leased IP links and GPRS links. Unison's Smart grid encompasses the installation of substations, transformers, and switches which will be communicated with other services and can be remotely operated via fibre network or wireless radios. Unison uses Silver Spring's networking technology which enables real-time communication with network devices and real-time monitoring of the status and quality of customer supply. Silver Spring's latest generation of IP mesh radios facilitate better data transfer between Network devices and Control room. This provides better data rates hence enhancing the reliability of supply and reducing outages for the customers through faster and more reliable communication [38] [39].

4.9.3 Ripple Control

Unison owns ripple injection systems operating at relatively high ripple frequencies of 500Hz and 725Hz at Rotorua (500 Hz) and Taupo region (725 Hz). Unison does not own any ripple control receivers at customer premises. As a consequence of high frequency ripple plants and absence of ripple receivers, Unison's ability to control hot water load has been reducing. Unison is planning to change its existing ripple control systems to 317 Hz devices. Also the installation of smart meters may provide possible alternative or additional forms of load control, not only of hot water load but also for other household appliances[39].

4.10 Horizon Energy

Horizon Energy Limited's distribution network serves an area of approximately 8,400 square km in the Eastern Bay of Plenty. Horizon Energy's network serves around 23,000 customers with a maximum demand of 90MW. The Eastern Bay Energy Trust with 77.29% of shares is the largest shareholder of Horizon Energy[40] [41].

4.10.1 Metering

Horizon Energy is investigating on the option of replacement of existing meters with smart meters. The company is actively investigating option of using smart meters as an alternative to traditional ripple plants for load control[42].

4.10.2 Communication

Horizon Energy's communication system consists of UHF and VHF Radio communications. The communication system provides communication to pole-top circuit breakers and switches and high speed radio communication to zone substations. Radial links exist to Galatea, Kaingaroa, Ohope, Waiotahi and Te Kaha. A Spur line Tait E band VHF repeater located at Cape Runway provides voice and data communication to the coast region north east of Te Kaha.

The system is configured with a high speed back-bone loop with microwave radio from Plains, Pukehoko, Putauaki, and Commerce Street and a leased fibre-optic circuit completing the loop from Commerce Street, Kope, Station Road, Te Rahu, East Bank, and Plains substations.

Horizon Energy is also considering the option of IEC61850 communications protocol for substation communication. The protocol is currently implemented at the Galatea and Kopeopeo substations [42].

4.10.3 Ripple Control

Horizon Energy's ripple control systems operate at 750 Hz present at Galatea and Waiotahi regions. However the signal propagation at 750Hz is poor and there is no guarantee of proper receiver operation. Also the 750Hz Ripple systems cannot be used for 33kV network. Horizon Energy is planning to upgrade its existing network to 33kV network. Because of the network up-gradation, Horizon energy has decided to replace the existing 750Hz ripple systems with 317Hz systems. The replacement of ripple systems are planned prior to network up-gradation, so that the new ripple plant is not a dual frequency plant[42].

4.11 Eastland network

The Eastland Company covers an area of approximately 12,000 sq. kilometres, which is spread across Gisborne, East Coast and Wairoa regions. There are nearly 25,500 connection points to which Eastland network is serving the electricity. The majority of the network is comprised of 3,280 kilometres of overhead reticulation, with a further 380 kilometers underground reticulation installed mainly in the urban areas of Gisborne and Wairoa[43].

4.11.1 Metering

Some of the energy retailers are actively progressing in implementing the smart meters in Eastland network area. The smart meter implementation program is part of metering upgrade program which is being commenced in 2014-15[44].

4.11.2 Communication

Eastland network has its SCADA master station located at the head office which comprises of an Abbey Systems dual master / backup master station configuration. There are 14 Abbey Systems; Full RTU installations located at each of Eastland's major substations and 147 Abbey Systems Topcat installations at remote control switches or monitoring and control sites. The communication media used to provide voice and data information include VHF Radio, UHF Radio and Copper or fibre cables[44].

4.11.3 Ripple Control

Eastland network currently owns and operates three load control transmitter facilities to control the ripple relays. The transmitters are as following:

- Valley Road –11kV injection at 315 Hz (not in service)
- Makaraka – 50kV injection at 315Hz
- Wairoa – 11kV injection at 1,250Hz

The majority of controllable loads in the urban Gisborne area were already controlled by a cascade pilot wire network which was consisting of 10 pilot feeders. Due to issues related to the pilot systems functional inflexibility, reliability and expense, in 1992 a ripple load control system was installed on the Gisborne network. The pilot and ripple systems were operated in tandem. Considering the reliability due to age deterioration of the pilot assets, Eastland has phased out the existing Gisborne city overhead pilot system in favour of ripple relays installed at customer's premises which was achieved during 2002 to 2008. The opportunity of replacing some of the pilot system with ripple receivers in conjunction with an energy retailer smart metering program is currently being considered[44].

4.12 Centralines limited

Centralines limited is one of the distribution companies in New Zealand which owns and manages the electricity distribution network in the Central Hawke's Bay region. Centralines distributes electricity to approximately 8285 connected consumers[45].

4.12.1 Metering

The implementation of smart meters was initially took place in Centralines service area. During 2006-08 Arc Innovations undertook a major meter replacement program and a modern smart meter system was installed into the Centralines network[45].

4.12.2 Communication

The communication system at Centralines primarily comprise of an Abbey Systems computer application with connection through 2 x VHF channels to equipment and devices connected throughout the network. Further, this is connected to a "Real Flex" computer application which is utilized by the Unison Control Room based in Hastings which has a mimic of the Centralines system in its database. The communication system used by Centralines for the network control includes:

- *Leased radio link:* Zone Substation and field mounted equipment to the Abbey System Master PC
- *Leased data circuit:* Abbey System link to Real flex
- *Leased wireless circuit:* Abbey System link to Real flex

Further, communication to RTU and Unison's control room in Hastings is established through a fibre-optic cable, a wireless link and a radio network[45].

4.12.3 Ripple Control

For load management, Centralines has purchased its ripple injection plant from the retailer (Meridian). The ripple plant provides Centralines with the capability to manage controlled load within the network. The load control scheme operates at a frequency of 475Hz. It is estimated to be around 6,000 water heaters supplied by Centralines' network. The after diversity demand of these heaters in Centralines' network is estimated to total 1.5MW at the time of the co-incident peak on a cold winter afternoon[45].

4.13 Scan Power

Scan Power's electricity distribution network serves an area of 2100 square km reaching around 6,800 customer installations in the Tararua region, including Dannevirke, Woodville, Norsewood and the outlying rural areas[46] [47].

4.13.1 Metering

Installation of smart metering at key network nodes and an enhanced Load Management System on Scanpower's SCADA are priority objectives for developments of companies AMIS. Scan power plans to use smart metering which may provide an alternative to fault indicators. Scan power is planning to implement the approach which would be greatly enabled by smart grid application of the Advanced Metering Infrastructures (AMI – smart meters). It is expected to be deployed over the next 3-5 years[48].

4.13.2 Communication

Scan Power has installed its own private radio network during 2005/06. Scan Power uses VHF mobile communication for Vehicle radio communication and UHF radio links for SCADA and ripple communication. Scan Power may move to communication platforms created by others for smart metering as an alternative to running a private radio network.[48]

4.13.3 Ripple control

In 2006, Scanpower installed and commissioned a 283Hz Enermet ripple injection plant at the Dannevirke substation to replace the Zellweger static plant. Correspondingly, all ripple relay receivers at customer premises have now been upgraded to operate from this system. In 2010 the existing plant at Woodville was replaced with a 283 Hz and all relays were changed[48].

4.14 Electra

Electra is one of the distribution companies in New Zealand which is spread over the Horowhenua and Kapiti districts on the narrow strip of land located between the Tasman Sea and the Tararua Ranges, reaching from Foxton and Tokomaru in the north to Paekakariki in the south and covering an area of 1,628 square kilometers. Electra serves electricity to approximately 43,000 consumers[49].

4.14.1 Metering

The existing meters at consumer locations will be replaced with smart meters and this smart meter rollout is expected to be in place over a time[50].

4.14.2 Communication

Electra has SCADA master station in the Levin west zone substation. SCADA information is further broadcasted to the main Electra office. At the Levin west zone substation, an emergency control centre exists as a backup to the main one. This information is being communicated using radio, microwave links and Fibre-optic cable[49].

4.14.3 Ripple Control

Electra has ripple injection plants and these ripple injection plants are used to control water-heating load, other storage heating loads, and street-lighting. Injection from each plant is into the Electra 33 kV sub-transmission system at 283Hz. The majority of the individual ripple control receivers are owned by energy retailers with the exception of approximately 2,500 mounted in distribution transformers and on poles to control the streetlights under veranda lighting and controlled load pilot systems which are owned by Electra[49].

4.15 Wellington Electricity Lines Limited

Wellington Electricity lines limited supplies electricity to approximately 160,000 distribution customers in Wellington, and to the Porirua and Hutt Valley regions of New Zealand. The company's primary role is to manage the largely underground network, which spans around 4,500 kilometers and delivers service to business and residential customers coming under the service area[51].

4.15.1 Metering

Wellington electricity is not actively pursuing smart grid projects or trials. The Wellington Electricity network has a number of features that may be considered to be part of a "smart network". These may include closed ring feeders with differential protection zones that trip out leaving healthy sections in service, on demand load control via the existing ripple control system, and extensive use of SCADA with over 230 sites offering remote control and indication[52]. However as per the information available, the retailers are replacing the existing meters with smart meters.

4.15.2 Communication

The Communication technology used in Wellington Electricity is mainly copper pilot cable with a small amount of fibre-optic and UHF radio infrastructure which is owned by Wellington Electricity. Communication links leased from other service providers are either fibre-optic or radio links[52].

4.15.3 Ripple Control

Wellington Electricity uses a ripple injection load control system to control selected loads such as water heating and storage heaters within consumers' premises, to control street lighting and to provide tariff signaling as required by retailers using the network. Wellington Electricity owns ripple injection equipment at a number of its zone substations, connected at 33kV in Wellington, and at 11kV in the Hutt Valley. The ripple injection equipment sends coded signals over the power lines, which are detected by control relays at the point of control. The signals are sent at 475 Hz and 1050 Hz. Since April 2012, Wellington Electricity has offered a controlled rate tariff intended primarily for electric vehicle (EV) charging. This load is controlled using conventional ripple signals through the addition of an EV channel[52].

4.16 Nelson Electricity Limited

Nelson Electricity limited network comprises of approximately 9,100 connections which is concentrated in the area of 24 square kilometers. The area is of central Nelson city and includes most of the Port area, Port Hills, Victory Square, Hospital, Brook, Wood, Nelson East, Nelson South and the central business district. The network has approximately 318 kilometers of circuits[53].

4.16.1 Metering

The smart meters would be installed in Nelson network area in coming years.

4.16.2 Communication

Nelson Electricity has a fibre link between its Zone Substation and Transpower's Grid Exit Point at Stoke for the purpose of monitoring load pulses and for 33kV feeder protection. The load pulse system is backed up by a radio communication link. Nelson Electricity's pilot cable network has been superseded by simplex radio communication between the Zone Substation and major 11kV switching stations[53].

4.16.3 Ripple Control

Nelson Electricity controls the load automatically using SCADA via a ripple injection system. Nelson Electricity has two ripple generators, each injecting a signal into the opposite side of the 11kV bus. Nelson Electricity operates a 725Hz ripple control system on its distribution network. Currently the assessed benefit of load control is 3MW which is approximately 10% of total maximum demand[53].

4.17 Marlborough Lines

Marlborough Lines Limited (MLL) is the distribution company which is owned by Marlborough Electric Power Trust. MLL's electricity network delivers electricity to around 24,000 customers in Marlborough Sounds, Molesworth Station and the rugged southern Marlborough coast areas[54].

4.17.1 Metering

MLL's intention is that the investments undertaken within the SCADA system to not only enhance reliability but to maximize the efficiency of investment within the network. MLL would concentrate more on achieving success and greater benefit in this area rather than pursuing installation of smart meters at customer locations. MLL's customers' electricity meters are owned by various electricity retailers. MLL has also noticed that in many instances where smart meters have been installed, their utilization has typically been limited to remote disconnection reconnection and reading. Due to this reason MLL has decided not to pursue the installation of smart meters at customer premises as it makes no economic sense for MLL[55].

4.17.2 Communication

MLL's communication network consists of dedicated radio equipment and cell phones for SCADA communication. MLL uses a Voice Radio network for operation control of the whole network. MLL owns a UHF linked VHF radio voice communication system, which is used for switching and operational control of the Network. Seven repeaters located on various hill tops use one of the five VHF E-band frequencies for broadcasting. A UHF link is used to link all the seven repeaters. MLLL has decided to change from 25 kHz gap to 12.5 kHz gap in VHF frequencies starting November 2015[56].

4.17.3 Ripple Control

MLL ripple injection system operates at 217Hz and 1050 Hz. Ripple injection equipment is installed at the Spring lands substation site which injects via 33kV coupling cells. All ripple relays are owned by the energy retailers. The 1050 Hz ripple systems were installed in 1967. The existing load control system uses Zellweger decabit telegrams. The company has decided to introduce a new frequency of 217Hz for ripple control, since 1050 Hz ripple systems gives rise to various problems. The 1050 ripple systems can cause signal amplification due to impedance and loading of system, which can interfere with operation of electronic equipment and manifest itself as noise in sound equipment. It is to be noted that 1050Hz and 217Hz relays are owned by the energy retailers and accordingly MLL has no control over when this signal can be phased out[56].

4.18 Network Tasman

Network Tasman Limited (NTL) is owned by The Network Tasman Trust. The company's electricity distribution network serves an area of 10,800 square km in the Northwestern corner of South Island reaching approximately 37,500 Customers. Total electricity distributed through its network is 781 GWh, with a peak load of 150 MW[57].

4.18.1 Metering

Network Tasman has agreed to invest in SmartCo, a joint venture company for the deployment of advanced meters to around 250,000 consumers across New Zealand. Such advanced meters will be able to send monthly usage information to the retailers. Radio signals are used for transmission of usage of information. The meter can also send other information related to state of the network which helps in identifying problems developed in the network. Installation of advanced meter is expected to commence in late 2014[57] [58].

4.18.2 Communication

Network Tasman's Communication Network compromises of SCADA fibre communication network and the VHF voice mobile communication network. The SCADA fibre communication network comprises of fibre-optic links which connects zone substations and ripple injection plants to the control centre at Hope. The voice mobile system comprises four E-band FM 12.5 kHz half duplex repeater channels that allow coverage from the Richmond control centre to all points in the distribution network. SCADA communications between control centre and field auto reclosers are achieved using three additional E-band data channel repeaters[59].

4.18.3 Ripple Control

Ripple control systems are used to reduce the overall peak demand on the transmission and distribution networks by utilizing the storage available in some types of loads. Ripple control systems take control of loads and turns off the supply when the uncontrollable loads are at their greatest. According to NTL's policy it is mandatory for domestic storage water heaters to be connected through an NTL approved ripple control receiver. NTL network has five ripple control transmitter each operating in bulk supply areas. Ripple injection frequencies are 475 Hz and 233 Hz. Ripple control plants at Stoke, Motueka and Golden Bay areas are static frequency generator plants. The Kikiwa and Murchison ripple control plants are motor generator sets. Contact Energy is the owner of the ripple receivers in Kikiwa and Murchison areas and has replaced all of the receivers in the area. NTL is replacing the ripple injection transmitters at both sites and upgrading the Kikiwa site to remote SCADA based control. This project is underway and completion is expected during 2014[59].

4.19 Buller Electricity

Buller Electricity Limited (BEL) was established in 1947 and is owned by Buller Electric Power Trust. The company serves an area situated on the West Coast of the South Island of New Zealand and delivers electricity across 4,345 square km of network area to approximately 4,700 electricity customers[60].

4.19.1 Metering

BEL management has identified the need for a separate long term strategic planning document (Vision 2030). The points of interest include the identification of new and future trends in electrical industry such as smart metering, smart grids, electric vehicles, energy storage etc. BEL will continue to monitor and improve its service by developing a smart grid philosophy, firstly with HV assets and then progressing to LV including metering if found effective and efficient. Further, BEL is installing 50 smart meters to assist in determining the line losses in different areas[61].

4.19.2 Communication

BEL uses a mix of UHF and VHF radio networks for voice, data and SCADA communications. In addition to this, it uses a short 12 pair fibre cable for communication between BEL offices and control room located at Robertson Street[61].

BEL has three main repeater sites located at Cape Foulwind, Millerton and Karamea. These zone substations have their individual radio networks for Voice and SCADA communications. A separate network using MimoMax digital radios connects to all zone substations[61].

4.19.3 Ripple Control

BEL owns a ripple control system consisting of an 11kV static indoor ripple injection plant located at the Robertson GXP which operates at 317 Hz. This system is used to manage its maximum demand at the GXPs. BEL does not own ripple control receivers at the customer's premises. BEL owns only some ripple signal receivers which are used to provide feedback to the SCADA load management system[61].

4.20 Main Power

Main Power is one of the distribution companies in New Zealand. The Main Power Trust holds the shares in Main Power on behalf of MainPower's customers. The company serves to approximately 34,000 customers in the community of North Canterbury and Kaikoura[62].

4.20.1 Metering

The majority of meters in Main Power's region are owned by Contact Energy. These meters are non-compliant and will require replacement by 1st April 2015. Main Power has signaled its desire to own the replacement of smart meters as part of its smart grid objective. Main Power comes under "SmartCo" electricity distribution area. A business case for both meter ownership and the region wide communications infrastructure specific to Main Power's requirements is currently being developed[63].

Network Tasman has entered into a joint venture with Alpine Energy Limited to deploy advanced meters on the Main Power network. Current plans are for the first advanced meters to be installed on both the Network Tasman and Main Power networks in the second quarter of the 2014/15 financial year[64].

4.20.2 Communication

Main Power's communication network consists of digital data radio network. This system is capable of supporting DNP3 and Modbus protocols. It is a full duplex hot carrier backbone network which provides data gateways at Mt Cass, Beltana and Kaikoura, communicating with the SCADA network hosted in Rangiora[65].

Fibre-optic cables are used for communication between Culverden GXP and Mouse Point substation to interface with the GXP metering. The Kaikoura GXP and Ludstone substation, Kaiapoi GXP and the Kaiapoi load control building are also connected via fibre-optic cables.

Fibre-optic cables connect the Rangiora West switching station to Southbrook for protection and SCADA functions. Similar links are also being incorporated with the Kaiapoi North, Pegasus, and Percival St switching station. Mt Grey and Wallace Peak are connected via a data radio link[65].

4.20.3 Ripple control

Main Power's ripple injection plants are located in Transpower GXPs at Waipara, Mouse Point, Kaikoura, Southbook and Kaiapoi. These plants operate at an injection frequency of 283Hz and all the plants are GPS synchronized. Ripple Control plants are used to manage peak demand, to maintain acceptable voltage, to alleviate network constraints, to defer capital investment and to reduce transmission charges. Main Power's ripple control plants can also be used to control irrigation loads during emergencies or at times of system constraints. Main Power has employed Landis & Gyr SFU-G and SFU-K ripple injection plant using decabit code for load control and tariff switching[65].

4.21 West Power

West Power is owned by the West Coast Electric Power Trust. WestPower's distribution network covers an area of 18,017 square km on the West Coast of New Zealand's South Island reaching over 13,000 consumers. The network has over 2000 kms of power lines[66] [67].

4.21.1 Metering

Not much of details about smart metering are available. However in the pricing methodology (2014) it is mentioned that, with the introduction of smart meters, West power intends to take a circumspect approach to developing and implementing TOU tariffs.

4.21.2 Communication

West Power's communication network is a mix of fibre, analogue radio and digital radio. A fibre-optic cable from the server room in the Tainui St building to the Greymouth substation is used for speech, SCADA and surveillance monitoring of the Greymouth substation. A second fibre cable from the server room to Chapel St is used for SCADA and offsite computer backups. Digital radio links provide Transmission Control Protocol and Internet Protocol (TCP/ IP) and where required, serial and voice channels to all major WestPower substations. The VHF speech is extensively used by WestPower[68].

4.21.3 Ripple Control

Westpower owns five ripple injection plants located at Reefton, Greymouth, Hokitika, Dobson and Wahapo. These plants are used for load control purposes as well as providing tariff-switching signals for use by retailers. Hokitika and Greymouth have Enermet SFU-K303 series 120 kVA injection plants installed, while Dobson and Reefton have Enermet SFU-K 203 series 80 kVA plants. All plants are controlled remotely by the SCADA load management system and locally via Abbey Powerlink injection controllers. Four of the five on-line plants run synchronously with the help of GPS technology. These plants are able to inject the identical ripple waveform at each of the four sites at the same time. Ripple plant installed at Wahapo zone substation is a standalone plant and is used to provide ripple control to South Westland area when Wahapo generation is running islanded from the remainder of Westpower's network[68].

4.22 Orion group

Orion New Zealand Limited (Orion) owns and operates the electricity network in central Canterbury between the Waimakariri and Rakaia rivers, and from the Canterbury coast to Arthur's Pass. Orion network covers 8,000 square kilometres of diverse geography, including Christchurch city, Banks Peninsula, farming communities and high country regions. Orion receives electricity from Transpower through GXPs located at nine different locations and distribute electricity to more than 192,000 homes and businesses[69].

4.22.1 Metering

Orion network is one among the distribution companies who has actively participated in replacing the traditional or analogue meters with smart meters. The metering owners have installed approximately 110,000 smart meters on the Orion network[70]. Now the Smart meters installed under Orion network has flexible communications capability, seamlessly mixing RF mesh, GPRS and satellite technologies to provide AMI service to almost any location[71].

4.22.2 Communication

Orion network has both data and voice communication systems. The voice communication system uses VHF radio links as well as private and public telephone, cellular and paging networks. The data communication system uses various technologies running over UHF radio, copper communication cables and fibre and is used for SCADA RTU links to provide access to substation engineering data. The cable communication system is mainly in the Christchurch urban area, and is used to link the SCADA master station with the RTUs and for unit protection at urban zone and network substations. Where there are gaps in radio network, cellular data modems are used. These systems will be replaced as the new IP radio system expands[72].

SCADA cable link is comprised on three communication cable technologies.

i. Audio Frequency Shift Keying (AFSK) modem technology
ii. Low frequency modem communication
iii. High bit-rate Digital Subscriber Line (HDSL) modem communications

4.22.3 Ripple control

Orion network has approximately 110,000 smart meters installed at consumer locations, most of which contain inbuilt ripple receivers and the remainder of around 190,000 network connections have standalone ripple receivers[70].

Orion operates two ripple coding systems:

i. Telenerg, based on 11kV injectors using a 175Hz carrier frequency which operates mainly in the urban Christchurch and Lyttelton areas, and
ii. Decabit, based mainly on 33kV injectors using a 317Hz carrier frequency which operates in the rural Canterbury and Banks Peninsula.

Orion does not provide ripple injection signalling in three remote network areas, Arthur's Pass, Castle Hill and Coleridge. For these areas, it is recommend that to use smart meters or time clock switches for the purpose of switching meter registers and loads[73]. The use of ripple control allows 5-10% reduction of peak demand corresponding to 30-60 MW[70].

4.23 Electricity Ashburton

Electricity Ashburton owns, operates and manages nearly 3,000km of electricity lines across the Mid-Canterbury district. Electricity Ashburton serves electricity to approximately 19,000 consumers[74 75].

4.23.1 Communication

Electricity Ashburton uses extensive fibre-optic which now links its three zone substations. All fibre links are duplicated with very few common paths. Even the primary radio repeater site is serviced by fibre with a microwave backup. Further, the VHF speech network is a repeater system used exclusively by the Network and Contracting divisions. The UHF network has equipment dating back to the mid 1980's and is being withdrawn from service with the exception of the backup Microwave link to hill top repeater site. There is a plan to replace the existing VHF voice network to a new digital platform over the next two years[75].

4.23.2 Ripple Control

Electricity Ashburton uses ripple control as the only form of direct demand management to control hot water and night storage heating facilities. The ripple injection frequency used by Electricity Ashburton is 283 Hz. Electricity Ashburton is actively investigating the suitability of alternative signalling technologies which are available[75].

4.24 Alpine Energy

Alpine Energy is completely owned by the South Canterbury Community. Alpine Energy's electricity distribution network connects approximately 30,000 customers in South Canterbury[76].

4.24.1 Metering

Currently the consumers connected to Alpine Energy Networks have Legacy meters owned by Alpine Energy. Being a member of Smartco, Alpine Energy signs an agreement to roll out advanced meters across Alpine Energy's electricity distribution Network. Deployment of Advanced meters has started in first quarter of 2014 and is expected to be completed by 2016. Deployment of advanced meters is prioritized in Albury area and the Twizel area. Alpine Energy is also planning to deploy Silver Spring RF mesh communication network which is required for advanced meters to communicate[77] [78].

Alpine Energy is planning to use advanced meters for demand management and load control within its electricity distribution network. Advance meters can be used in place of traditional ripple relays and this provides savings in capital expenditure for Alpine Energy[78].

4.24.2 Communication

Alpine Energy's communication system includes two UHF FM tone modulated, 1200 baud rate, Conitel protocol paths, one hired microwave broadband TCP/IP link, DNP3 protocol path and two land lines as communication paths. As part of communication upgrade project, the new communication system uses a 5 GHz digital radio network backbone supplemented by a fibre-optic network. These modern substations contain microprocessor based protection and control equipment that use the DNP3 protocol and require modern communications[78].

4.24.3 Ripple Control

Alpine Energy performs load control of energy storage devices like hot water cylinders via operation of ripple injection plants located at Timaru, Studholme, Temuka, Albury, Bell's Pond, and Tekapo. The ripple control scheme operates at a frequency of 317Hz. Once smart meters are rolled–out, Alpine Energy has plans to use smart meters as a means of demand management and load control within the network. This avoids the need to install more expensive load control equipment on the network. However they would still require the substation ripple injection plants to send the load control signals to the new smart meters[78].

4.25 Network Waitaki

Network Waitaki Limited (NWL) is one of the distribution line companies which supplies electricity to the area extends from the Waitaki River to Shag Point, up the Waitaki Valley as far as Ohau and the Hakataramea Valley. Network Waitaki limited has approximately 1,800 kilometer of lines to serve electricity to approximately 12,000 consumer connections. Network Waitaki limited also offers a metering service to electricity retailers[79].

4.25.1 Metering

Network Waitaki limited owns majority of electricity metering in the area it serves. The company is a member of SmartCo along with other electricity network companies who, together, are working with retailers to build the smarter network. Network Waitaki limited has invested in smart meters representing the replacement of all old technology electricity meters throughout the Network[80] [81].

4.25.2 Communication

Network Waitaki's SCADA master station is located at its main office. It can be remotely accessed over the PC LAN and via the remote modem access. Network Waitaki's SCADA system uses UHF radio data communications provided by NWL's 3 repeater radio network. Repeaters are shared by the VHF Radio Telephone system NWL used for operational voice communications between the Control Room and field operators.

Further, Network Waitaki owns a section of trunk fibre. The project involves rolling out fibre to Weston, Chelmer, Redcastle, Pukeuri, Papakaio, and Hampden substations over a two year period. This project will enable an alternative communication path for substation remote control and data monitoring, as a back haul communication path for smart meters, also as a communication path for future intelligent devices[82].

4.25.3 Ripple Control

Network Waitaki limited owns and operates Enermet solid state 33kV ripple injection plants at both the Oamaru and Twizel GXP's. Further, Network Waitaki limited has installed ripple relays on irrigation pump loads greater than 30 kVA to enable irrigation load to be shed when the capacity at the Oamaru GXP is exceeded. The company sees this as a short term project to provide security to the load supplied from this GXP, until the transmission capacity issues are resolved[82].

4.26 Aurora Energy

Aurora Energy Limited (AEL) is New Zealand's sixth-largest electricity distributor, delivering annual electricity of about 1,300 GWh to over 83,000 homes and businesses in Dunedin and Central Otago[83].

4.26.1 Metering

Implementation of smart meters is under the control of electricity retailers and metering service providers. Hence, Aurora Energy limited is assessing using the smart meter technology that can encourage its customers to reduce their demand during faults on Aurora Network which can help Aurora to defer some network upgrades[84].

4.26.2 Communication

AEL's communication system in Dunedin consists of mixture of copper pilots, fibre-optic cables, and UHF radio. Communication with twelve of eighteen zone substations is via pilot cable network installed with 33 kV cables. The SCADA communications are done via copper pilots using the Conitel protocol. SCADA Communications to Mosgiel, East Taieri, Outram and Berwick Substations are via UHF radio repeater. Communications to Central Otago are mainly via VHF and UHF[84].

4.26.3 Ripple Control

Aurora's ripple signal injection devices are located at key substations. Ripple signal frequencies for Aurora's network is 1050 Hz and 317 Hz.1050 Hz ripple signal is injected into the 6.6kV and 11kV distribution lines and cables, and 317Hz signal is injected into the 33kV distribution lines. Aurora is progressively replacing the 1050 Hz ripple systems with 317 Hz ripple systems. Ripple control systems are mainly used to send signals through network to control hot water cylinders. AEL's ripple control system has resulted in a reduction of 38MW power between estimated peak demand and actual peak demand[84 85].

4.27 OtagoNet

OtagoNet is the major service provider for most of the Otago. The company owns approximately 4,391 kilometers of lines used for serving electricity to approximately 14,700 numbers of consumers. PowerNet was contracted to manage the electricity network assets on behalf of Otagonet.[86]

4.27.1 Metering

All the domestic consumer meters coming under Otagonet area are owned by the retailers which include smart meters if any. Only a very few number of smart meters have been installed by the retailer as a result of this OtagoNet is unable to access potentially useful information like LV voltage levels. In view of this, OtagoNet is planning to install its own smart meters to some of its larger distribution transformer sites which will enable Otagonet to gather necessary information on its service quality.[87]

4.27.2 Communication

OtagoNet has its SCADA master station located in the PowerNet office with a link to the PowerNet system control. The master system communicates to 44 remote terminal units. Otagonet uses VHF and UHF links for communication.[87]

4.27.3 Ripple Control

OtagoNet uses ripple control for controlling the hot water loads, switch day/night load tariffs and also to switch street light using the following load control transmitter facilities for controlling the ripple relays which are owned by OtagoNet.[87]

- Three 33 kV 492 Hz 100 kVA injection plants at Naseby, Palmerston and Balclutha points of supply.
- One new 33 kV 317 Hz 100 kVA injection plant at Balclutha point of supply which will gradually take over from the 492 Hz plant as relays are replaced.

4.28 The Power Company Limited

The Power Company Limited is an electricity network asset company which owns the electricity network assets in the Southland area, excluding parts of Invercargill City and the Bluff township area. The Power Company limited network length is approximately 8,691 kilometers which is used to serve electricity to approximately 34,602 consumers connected in the service area. PowerNet manages the assets of The Power Company limited on its behalf[88].

4.28.1 Metering

The Power Company Limited is part of Smartco which is installing smart meters across 10 networks in New Zealand. The smart meters will be installed in the Power Company Limited's area starting from April 2014. The smart meters would replace other meters and thereby reducing the number of meters across the local network. The smart meters use a radio frequency mesh network to communicate with a central control centre[88].

4.28.2 Communication

The Power Company Limited has its SCADA master station located at the companies system control centre. Further, TPCL owns and operates following communication links[89].

- Three microwave links
- Twenty eight UHF links
- Seven Data radio UHF channels (one shared with Electricity Invercargill)
- One low power unlicensed link
- Five VHF Land Mobile channels (one shared with Electricity Invercargill)

4.28.3 Ripple Control

The Power Company Limited currently owns and operates the following load control transmitter facilities to control the ripple relays[89].

- Four main 33kV 216⅔Hz 125kVA injection plants at Invercargill, North Makarewa, Gore and Edendale.
- One backup 66kV 216⅔Hz 125kVA injection plant at Winton.

4.29 Electricity Invercargill

Electricity Invercargill is an electricity network asset company which has its network assets in Invercargill city and the Bluff township area. The total network length is 658 km. Approximately 17,200 consumers are connected to the Electricity Invercargill network. PowerNet manages the Electricity Invercargill's network on its behalf [90] [91].

4.29.1 Metering

Electricity Invercargill is part of Smartco. The smart meters will be installed in Electricity Invercargill's area starting from 2014 and would replace other meters. The smart meters use a radio frequency mesh network to communicate with a central control centre[91].

4.29.2 Communication

Electricity Invercargill's SCADA master station is located at PowerNet's System control centre. Further, Electricity Invercargill owns and operates following communication links[92].

- Multicore network between zone substations and CBD distribution sites and the Control room
- Data radio links to the Control room

4.29.3 Ripple Control

Electricity Invercargill currently owns and operates one main 33kV 216⅔Hz 125kVA injection plant at Invercargill, with backup provided from the adjacent TPCL plant for controlling the ripple relays. This would be redundant with the roll out of smart meters which is expected in next few years[92].

5. Inference

The ICTs used in different distribution companies of New Zealand have been comprehensively addressed in Section 4 of this document. A tabular summary of these CT Practices amongst New Zealand distribution companies has been compiled in Annexure D. This section address the inferences gained based on this assessment of ICT practices of NZ distribution companies.

5.1 Metering

As discussed, most of the distribution companies in NZ are actively involved towards replacing existing meters with smart meters. There are over 2 million electricity consumers and it is estimated that over 1.2 million smart meters will be installed by April 2015 leaving over 800,000 traditional meters remaining. This means that an estimated ***60%*** of electricity meters in NZ will be smart meters after April 2015. Further, the implementation of smart meters in distribution companies is analyzed using their actual status and is given in Table *1*.

Table 1: Status of smart meter implementation

Status of Smart meter implementation	No. of Companies	% of Consumer connections under this status
Initiated / will be initiated shortly	10	15.80%
Installing	9	40.57%
Installed in most part of the network	4	38.67%
Planning and deployment in coming years	6	4.95%

It is to be noted that the percentage shown in Table 1 represents ratio of the total number of consumer connections under the distribution companies for that particular cluster to the total number of connections in NZ.

The distribution company status of smart meter implementation is graphically represented in Figure *6*. The percentage values shown in Figure *6* represent the ratio of number of distribution companies coming under particular category to the total number of distribution companies in NZ. It can be observed that around 14% of distribution companies have smart meters installed in most part of their network. Smart meter is being rolled out in approximately 31% of distribution company's networks. The roll out initiated or in the process of initiation is approximately 4% of the utilities whereas deployment expected in coming years is for approximately 21% utilities.

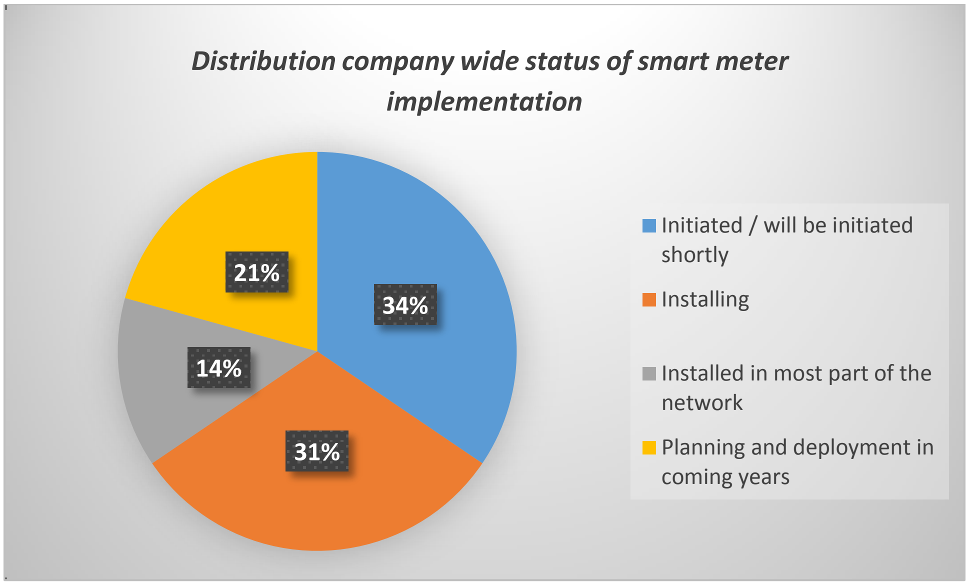

Figure 6 : Status of smart meter implementation

5.2 Communication

There are many different communication mediums that are being currently used in NZ distribution companies. It is observed that,

- More than 80% of the distribution companies in NZ use VHF and UHF radio links.
- Microwave radio links have been used by around 6 distribution companies (around 21% of total companies).
- Around 9 distribution companies are using copper cables (around 31% of total companies)
- Around 21 distribution companies are using optical fibre infrastructure (around 72% of total companies)
- A few distribution companies are also using Cellular data modems.

It is to be noted that the distribution companies are not relying on any single communication mode. They are using different available technologies for communication.

5.3 Ripple Control

Ripple control system has been extensively used by all the distribution companies. The different frequencies used by distribution companies are 175 Hz, 216⅔ Hz, 217 Hz, 233 Hz, 283 Hz, 297 Hz, 315 Hz, 317 Hz, 475 Hz, 492 Hz, 500 Hz, 725 Hz, 750 Hz, 1050 Hz and 1250 Hz. Since smart meters are being rolled out throughout New Zealand, it is anticipated that the existing load control system would be phased out eventually.

6. Discussion

a. A white paper on "Smart Grid Communications Infrastructure" was published as part of Green Grid project during October 2013.The different technologies and opportunities of communications infrastructure were discussed in detail. Main focus was the types of communication network which could be classified into Premises Network, Field Area Network and Wide Area Network. It also focussed on Wireless Communication solutions in Smart Grid such as WIMAX (IEEE802.16), ZigBee (IEEE802.15.4), Z-wave & Cellular (3G and LTE) technologies and wireline communications such as Power Line Communications (PLC), Digital Subscriber Line (DSL) and Optical fibre. The network architecture and communication infrastructure was explained in detail with international exemplars.

b. The previously published white paper expands on the different technologies available and those being used in different parts of the world. Based on feedback from companies, this discussion document was put together to summarize the ICT practices followed in New Zealand distribution companies and compare it with standard practices / requirements. The PSG researchers have gathered all the information to understand the current status of ICT implementation in New Zealand distribution companies. The assessment was mainly focused on the current state of technologies being used and future plans for implementing ICTs. This work has also covered the type of communications and ripple control systems used in the distribution companies. It has been signalled that over 60% of meters in New Zealand would be smart meters by April 2015. With this background, detailed analysis could be done considering the technologies used and providing a practical pathway to different distribution companies.

c. From the information gathered, the current practices followed by line companies are summarized. To differentiate the practices followed, it is necessary to segregate the line companies on some basis. This could be achieved using several ways. One way of doing that is based on the technologies used. Distribution companies have signed agreement with different MEPs and stakeholders to implement smart meters. The clustering based on the technologies would help to analyze and compare the different features available and improvements possible if any.

d. Clustering can also be done based on the loads served by different companies. It was noticed that, some of the distribution companies serve limited number of consumers. Implementing the smart meter and advanced ICTs within stipulated timeframe may have neutral or negative impact for such utilities. Hence, for such companies, Cost Benefit Analysis may be required. Clustering based on loads (or number of consumers) would be helpful in this regard.

e. One more possible clustering classification can be based on Grid exit points. Analysis could be done based on the power handling capacity of the GXPs and if they fall under conforming or non-conforming load classification of Transpower.

Q1: What is the technology used for Advanced Metering Infrastructure?

f. In addition to the smart meter implementation, the establishment of communication medium is also important to enable the information exchange between the utility and the consumer. For some utilities, it is observed that, the smart meters would be installed initially and the communication would be established after some years.

Q2: Are Smart meter roll-out and establishment of communication medium, going on simultaneously?

If the answer is 'No', then what is the anticipated time for the establishment of communication medium?

g. The Advanced Metering Infrastructure coupled with dynamic pricing may help in shifting the timing of certain activities of the consumers thereby reducing the demand during peak load.

Q3: Do you agree that the peak consumption timing of consumers will change with smart meter enabled dynamic pricing?

Q4: To achieve discussion point "g", it may be necessary to integrate the smart meters with Home Energy Management Systems (HEMS). Do you have any plans in this regard?

Q5: Do you have any plans to install *In-Home Displays* OR similar arrangements at consumer locations?

h. The distribution companies are using different communication technologies for reliable operation of the system. The technologies used includes VHF, UHF, Microwave radio links, Copper cables, Optical fibre infrastructure and cellular data modems.

Q6: If the existing communication links are old and needs replacement, then what is the alternative technology planned for implementation?

i. Gathering the information from distribution transformer sites would help in understanding and improving the quality of the power being supplied. Meter installed at distribution transformer sites is the readily available equipment, which could be used for this purpose.

Q7: What types of meters are installed at distribution transformer sites? If not, do you have plans to install smart meter OR any other monitoring technology at distribution transformer sites?

j. Ripple control has been used in New Zealand for many decades and still it is effectively being used. It is a form of incentive based Demand Response (DR) and it remains as the principal DR tool used by distribution companies. The implementation of smart meters at consumer's premises may lead to significant adoption of price based DR, such as initiatives to introduce time of use and peak pricing to domestic users*.

Q8: Are you planning to use smart meters as an alternative to ripple control?
If YES then, what is timeline estimated for this change-over?

* "Systems to Implement Demand Response in New Zealand", Allan Miller, EEA Conference & Exhibition 2014, 18 - 20 June, Auckland

Q9: It is anticipated that the smart meter roll out would lead to significant adoption of price based DR. What is your view on this?

k. The Electricity Authority has voluntary industry guidelines for the use of smart meters. It is stated that The Advanced Metering Guidelines given by the Electricity Authority are not legally binding, rather the guidelines are intended to be advisory. Since this roll out would be a long term investment, it may be necessary to stick to a common platform for the roll out rather than limiting it to some specific applications.

l. As per new regulations of the Victorian Government (Australia), if an electricity distributor has not attempted to install a smart meter in a Victorian home or small business by 30 June 2014, the customer at that premise will be entitled to a rebate (provided the customer has not refused the installation of a smart meter).

m. From 1 April 2015, for the small number of customers who continue to refuse a smart meter, electricity distributors will be able to recover the costs associated with running a separate meter reading service from those customers.

Q10: What is your opinion on having a common platform for the AMI implementation?

Q11: What if the regulations similar to Victorian government is implemented in New Zealand? What is your view?

7. Conclusion

The main objective of this report was to assess the ICT practices in New Zealand. Initially, the communication network architecture and different communication technologies available are discussed. With that background, the ICT practices followed by all the 29 distribution utilities in New Zealand are comprehensively discussed. The ICT practices considered for this discussion document are metering, communication and ripple control and it is noted that:

- ❖ As stated in media release of Electricity Authority (EA), around 1,001,475 of the 2,066,827 connection points in New Zealand were recorded as having smart meters installed (as on 31st December 2013). It is estimated that there will be more than 1.2 million smart meters in New Zealand by April 2015, with over 800,000 of the traditional meter remaining. Some of the distribution network organizations have already initiated the rollout while some others are actively investigating on implementation.
- ❖ The information exchange between the different stakeholders in the electricity network and the consumers requires appropriate communication channel. The traditional meters installed earlier, does not allow seamless and timely information exchange. However the new smart meters that are being installed can communicate with retailers or with the distribution companies using either GPRS or radio mesh networks. Further, this would also enable the interfacing with HAN. In addition, the protection, automation and control functionalities for Smart Grid operation would also require communication channel using the available options i.e. Very High Frequency radio, UHF radio links, microwave links, copper communication cables and Optical fibre.
- ❖ There are many ways to manage the loads and thereby reductions in the peak load of the system with ripple control being traditionally available as an option. New Zealand has been successfully using ripple control mechanism to shed the household hot water heating load and has been in use for many decades. Most of the elements used for this needs replacement or maintenance. At the same time, smart meters are being rolled out in NZ through which load could be potentially managed. Hence, many distribution companies are using this as an opportunity to upgrade their load management system with smart meters and some of the distribution companies are seriously contemplating.

Further, it is noted that the guidelines for advanced metering infrastructure by EA is not mandatory and is to be treated as advisory. Since separate grid codes are being developed to address these issues in other countries, it may be necessary to have a common platform for this rollout in New Zealand.

Annexure A: History of Metering and Regulations in New Zealand

A.1 Overview of Electricity sector in New Zealand

The key players in New Zealand electricity sectors are (i) Generation (ii) Transmission (iii) Distribution (iv) Retailers (v) Consumers (vi) Metering Equipment Providers and (vii) Regulation.

- **(i)** **Generators:** Generators produce electricity. The Owners / Operators in New Zealand which are into power generation are Genesis Energy, Contact Energy, Mighty River Power, Top Energy, Meridian Energy, Trust power, Todd Energy, Norske Skog Tasman and Alinta ENZ[93].
- **(ii)** **Transmission:** Transpower operates the New Zealand national grid which has approximately 12,000 km of High Voltage transmission lines. The national grid transports electricity from over 50 power stations, and connects with distribution networks or major industrial users at around 200 grid exit points (GXPs) around New Zealand[93].
- **(iii)** **Distribution:** Distribution networks transport power to consumers through a network of overhead wires and underground cables. In total, there are over 150,000 km of distribution lines in New Zealand. There are 29 such distribution companies in New Zealand[93].
- **(iv)** **Retailers:** The retailers purchase electricity from the generators and sell it to the consumers. The retailer is responsible for the installation of appropriate metering, meter reading, billing and payment collection[93].
- **(v)** **Consumers:** Electricity consumers range from large industrial sites down to individual households[93].
- **(vi)** **Metering Equipment Providers:** The metering equipment providers supply, maintain and lease metering equipment to the retailers. The metering equipment is used to measure the amount of energy consumed at the installation control point (ICP) so that the retailer can bill the consumer for the electricity they have used[94].
- **(vii)** **Regulation:** The New Zealand “Electricity Authority” is responsible for management of electricity industry. However, the policies and governance are managed by bodies like “Ministry of Business, Innovation and Employment” and “Energy Efficiency and Conservation Authority”.

A.2 Evolution of Electricity Meters

The electricity has been measured and recorded using conventional electro-mechanical meters. The meter reading period has also been varied from one to four months even though the consumers have been invoiced on monthly basis. In the 1980s, more frequent recording using electronic data loggers became available. The advent of modems meant that these data loggers could, at significant cost, be read remotely via telecommunication land lines. In the early 1990s, advances in electronics reduced data logger costs sufficiently so that data loggers could be used in conjunction with the electro-mechanical meters for mass-market purposes. By the late 1990s, electronic meters and reliable data loggers began to replace mass-market electro-mechanical meters. In some instances, communication devices were installed at the meter and data logger, enabling remote reads by using technologies like landline, Cellular telecommunications radio etc.[95].

In September 2005, the first Smart (Advanced) electricity meters were installed into homes in Central Hawkes Bay by Meridian Energy. Since that time, smart meters have been rolled out in Auckland, Christchurch and Hawkes Bay with other cities set to get them over the coming year[96].

A.3 Metering Regulations in New Zealand

The Electricity Industry Participation Code 2012 (Code) requires household electricity meters to be certified that they accurately measure electricity consumption. Most residential meters have certification that expires on 1 April 2015. To ensure that they operate accurately, all these meters need to be recertified before that date. Many retailers are using this as an opportunity to update metering technology, rather than having existing meters recertified. There is no regulatory requirement for parties to install or use smart meters in New Zealand[97].

Part 10 of the Code addresses certain obligations of participants in relations to metering, including processes and responsibilities for testing, calibrating and certifying metering installations. However, Part 10 does not regulate the rollout of smart meters. This is being undertaken on a commercial basis by retailers and in some cases distributors[97].

However, the Authority is monitoring the roll-out of smart meters and use of information closely and will intervene if practices develop that impede the advancement of competition, reliability or efficiency for the long-term benefit of consumers[97].

The Authority has voluntary industry guidelines for the use of smart meters. It is stated that The Advanced Metering Guidelines given by the Electricity Authority are not legally binding; rather the guidelines are intended to be advisory. This section of the report would present the minimum requirements for AMI systems established in New Zealand as per the EA AMI guidelines[98].

i. The metrology section may offer several different metering elements to allow simultaneous measurement on separate circuits, but the Authority's view is that the minimum requirement should be only for one element.
ii. The meter should record half-hourly consumption or generation information.
iii. One master accumulation (MA) register for all units consumed on site which is never reset and is read as part of a meter reading sequence.
iv. A minimum of six general accumulation (GA) registers which may start and stop their accumulation at programmable times to at least 30 minute resolution and coincident with the half-hour meter data logging boundaries. This functionality may be provided within the meter's CPE or at another location (such as the back-office system) within the AMI system.
v. Ability to securely store, transport and process metering and other data relevant to services offered, and in accordance with the Code where it applies.
vi. A means of controlling the existing hot water cylinder load currently (or previously) attached to a ripple control relay or similar load control device in the premises.
vii. Provide a services access interface for users to receive from, and send communication into, the AMI system. This communication should use either formats required under the Code, or Electricity Information Exchange Protocols, or should these not be available, commonly used industry protocols (such as XML, or already existing data swapping file formats) through which all authorized service users can access the services provided via the AMI system on equal terms.
viii. Services access should be secure to ensure that unauthorized access to both the system, and to files transmitted from the AMI system to users, is prevented. Transmission of information between AMI system owners, and between an AMI system owner and a user of the AMI system, should use an industry standard secure communication methodology.
ix. Maintain a time-stamped event log, available to both service users and system auditors as appropriate, to capture critical AMI system parameters or state changes that could

impact, directly or indirectly, on metering data or financial accounting accuracy, as well as outage and power quality information.

x. Provide ability to meter both import and export of power on sites where this is formally contracted between the energy retailer and their customer.

xi. Sufficient memory, processing and communication capability to ensure that the devices can be remotely reprogrammed to handle future applications, without requiring replacement of the meter during its financial or technical life cycle, and

xii. Interoperability with other utilities advanced meters that may wish to share the infrastructure, e.g. water and gas traders.

The recommended advanced meter infrastructure system minimum attributes list as per the EA AMI guidelines are given below[98].

Area	Function	Recommendation
Back-office	1. Time correction records.	Essential. Track in event log (also see 52).
	2. Meter event logs.	Essential. Track in event log (also see 46 and 53).
	3. Power loss and restore logs.	Essential. Track in event log (also see 23).
	4. Collection of raw meter data in accordance with the Code.	Essential.
	5. Code certification as half-hourly (HH) or non-half-hourly data aggregator (NHHDA) as applicable to metering information.	Essential.
Installation	6. Installed and certified by an approved test house.	Essential. No change to metrology section without re-certification (also see 49).
	7. Dust proof.	Essential. Compliant with relevant IEC standards.
	8. Installed in a dry situation.	Essential. Follow good industry installation practices.
	9. Complies with Part 10 of the Code.	Essential.
	10. Assess wiring condition before installing.	Essential. Notify premises owner of options.
	11. Ensure load control contacts are capacity and short circuit protected.	Essential. Compliant with relevant IEC standards.
Data retention	12. Data can be moved securely from CPE to the back-office system in accordance with the Code.	Essential.
	13. CPE to have non-volatile memory or battery backup + management plan.	Essential.
	14. System as a whole must comply with metrology, data handling, and data retention requirements in the Code.	Essential.
	15. Sufficient capacity to include the addition of future services such as shared infrastructure with other utilities.	Essential.
	16. Remote total disconnection.	Optional. Case-by-case specific.
	17. Disconnection devices must not disconnect the neutral.	Essential. Disconnecting meter neutral has safety concerns and is not acceptable.

Area	Function	Recommendation
Load control	18. Lifeline disconnection.	Essential. AMI system must support industry processes.
	19. Capacity control capability.	Highly desirable.
	20. User programming of capacity control via internal display.	Optional.
	21. Confirmation of main and discretionary load control switches.	Essential where these are fitted. Note that main disconnection contacts should use an acknowledgment process prior to disconnecting.
	22. Remote connect/disconnect with push button consumer final connect.	Optional.
	23. Automatic under frequency load control.	Optional. Desirable where cost effective.
Detection	24. Real time outage detection.	Optional (also see 3).
	25. Tamper detection, phase neutral imbalance, meter open etc.	Essential.
Volume registers	26. Programmable number of accumulating registers.	Essential. Minimum of six recommended.
	27. Half-hour consumption information.	Essential.
	28. Hosting of read output of other metering devices.	Essential where these are used as shared infrastructure.
	29. Remote display of accumulating registers used in settlement.	Optional.
	30. Meter display of accumulating registers used in settlement.	Essential. Total units used in settlement period should be displayed. Further breakdown optional.
	31. Import/export measurement functionality.	Optional. Case-by-case specific.
	32. Reverse power (export) indication.	Essential
Remote display	33. Ability to set user programmable automatic price rate, budget $, or capacity business rules to allow the meter to control load.	Optional. AMI system should have capability to support introduction of such customer applications over time.
	34. Manual over-ride of user programmable automatic price or capacity business rules.	Optional.
	35. Display of peak, average use, current use for the day in consumed $ and kWh.	Optional.
	36. Ability to show consumption trends either via the display or internet.	Optional. AMI system should have capability to support introduction of such customer applications over time.
	37. Show current retailer's phone number.	Optional.
Price registers	38. Remotely programmable price information/registers.	Essential for prepay, otherwise optional.
	39. Remote display of pricing registers.	Optional.
	40. Meter display of pricing registers.	Optional.
	41. Remote pricing plan management.	Optional.
	42. Display of consumption value in $.	Optional. However, encouraged as useful for assisting customer understanding.
	43. Display of price specials.	Optional.
Meter reading	44. Routine read (scheduled).	Essential. In accordance with Part 15 of the Code.
	45. Back-office triggers a special read (unscheduled).	Essential. Available without undue delay.
	46. Precision of reads.	Essential. In accordance with relevant provisions

Area	Function	Recommendation
		of the Code.
	47. Meter event triggers a special read	Essential for the agreed functionality and may include events such as tamper, or preset thresholds for instantaneous event log events such as low voltage or high current.
Operation	48. Power off/restore flag.	Essential. Track in a CPE event log (also see 3).
	49. Supply capacity control.	Optional. Case-by-case specific.
	50. External load control capability.	Essential. Must ensure site has active control of existing hot water load. Control of other loads desirable but optional.
	51. Programming for measurement within the meter separated from the programming ability for cumulative registers and other load control or added value functionality.	Essential. No change to metrology section without re-certification. Changes to non-metrology sections may be permitted after sample CPE devices recertified and with suitable control processes in place, incl. rollback (also see 6). Results subject to audit (also see 58).
	52. Low frequency load shed capability.	Optional. Desirable where cost effective.
	53. Sufficient memory and processing capability to allow the addition of future services including power quality monitoring and reporting, capacity control, and home area networks.	Essential (see also 15) without requiring meter replacement.
Prepay/Post-pay	54. Remote switch from prepayment/post payment capable.	Optional. Local management of customer account on case-by-case basis should be possible after enabling (or adding) suitable application code in CPE.
Operation	55. Time synchronization from back-office software in accordance with the Code.	Essential (also see 1).
	56. Non remote programmable multipliers.	Essential. Meter multipliers can be located anywhere within AMI system provided robust change management processes are implemented and results are logged for audit purposes. Multiplier values should be available via Services Access Interface.
	57. Common protocol with other meters.	Essential. AMI system will be open, but not necessarily at CPE. All service users have access to AMI system features on equal terms. AMI systems owners to ensure data exchange protocols are not a barrier to using their AMI system (also see 60).
Technical	58. Available as 1, 2 or 3 phase direct connected.	Essential. Tailored to premises.
	59. Available as current transformer connected.	Optional. Case-by-case basis.
	60. Internal watch dog on critical components.	Essential. System design should follow established electronic design best practice.
	61. On site connectable/programmable.	Essential. On site reprogammability feature optional. Same recertification procedures will apply whether remotely or locally reprogrammed (also see 48).
	62. Password protected in accordance with Schedule 10.2 security requirements for inbound communications.	Essential. Data security requirements in accordance with Code.

Area	Function	Recommendation
	63. Common data read protocol.	Desirable. AMI systems owners need to ensure data access is not a barrier to use (also see 54).
Connections to other devices	64. Home Area Network (HAN)	Optional. However, ability to add and support a suitable HAN interface is required without requiring a meter change.
	65. Remote control manual override.	Optional.
	66. Connectability to external controllers.	Desirable. Essential for hot water control.
	67. Connectability to/from other meters.	Essential. This is the capability to provide shared infrastructure for other utility providers.

Annexure B: Smart Meter Implementation – UK Practice

An effort has been made to understand the Smart meter implementation in other countries. This section of the report addresses the Smart meter infrastructure which is being implemented in United Kingdom.

B1: Governing bodies of Smart metering program and Plan

The Government has played a central role during the foundation stage, which began in 2011, by establishing the policy, regulatory and commercial framework that will underpin and drive the roll-out of smart metering. Energy suppliers are responsible for planning and delivering the roll-out on the ground, working within the framework DECC has established. The Department of Energy and Climate Change (DECC) has set up a number of working groups to enable representatives from industry, consumer organizations and other bodies to provide advice and expertise on a range of key issues in the field of Smart metering. The Data and Communications Company (DCC) has been established which is responsible for linking meters in homes and non-domestic sites with the systems of energy suppliers and networks and energy service companies. Smart Energy Code (SEC) came into existence which is the legal framework that governs the relationship between the DCC and its users. The Government has a critical role to play in monitoring and evaluating the roll-out of smart meters, both during the foundation stage and during the period from autumn 2015 to 2020, to ensure that the enabling framework remains fit to the purpose of driving benefits realization. It is planned to install around 53 million meters in households and at smaller non-domestic premises by 2020 under Smart Metering Program[99].

B2: The Smart meter System

The main parts of the smart metering system including the equipment and communications within the premises, the organizations that will use the information provided by smart meters (DCC Service users), and the systems provided by the DCC that will link these organizations with smart meters is pictorially represented in Figure B1. This Smart metering system is expected to work from late-2015, when a new shared smart metering national infrastructure would be in place[99].

The equipment installed by suppliers will normally consist of a smart electricity meter, a smart gas meter (where required) and a communications hub (which may be integrated in the meter).

Energy suppliers will offer domestic customers a free in-home display as part of the installation process. The in-home display allows consumers to see what energy they are using and how much it is costing in near-real-time. The display can also show information about the amount of energy used in the past day, week, month and year[99].

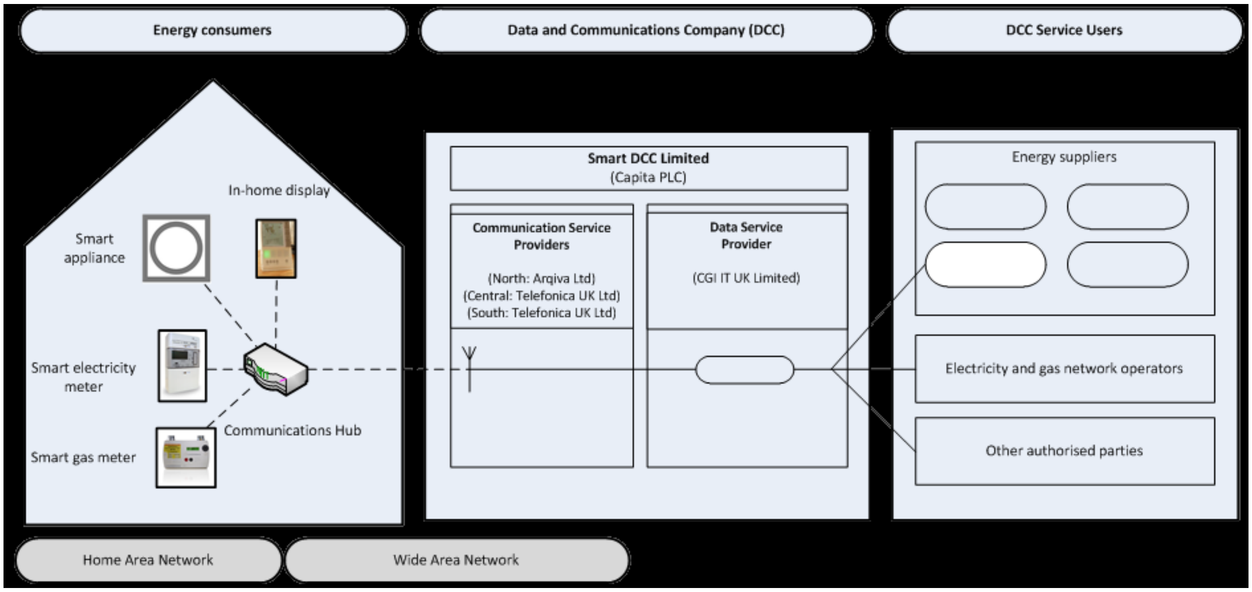

Figure B1: The main parts of Smart metering systems in UK [99]

DCC Service Users: The Organizations which will use the information provided by smart meters (DCC Service Users) are:

Energy Suppliers: Energy suppliers are responsible for planning and delivering the installation of smart meters for their customers. Suppliers need to adapt their businesses to prepare for the smart meter roll-out, including upgrading their internal systems to handle smart meter data, procuring equipment (especially smart meters and IHDs), recruiting and training staff (such as meter-installers) and developing the customer installation journey. A consumer's energy supplier will communicate remotely with smart metering equipment to take meter readings, update price information on the in-home display and take readings on change of supplier or change of tenancy [99].

Energy Networks: Energy network companies will be able to access data to help them understand the loads on their network at the local level and to respond faster to loss of supply. Networks will have better information upon which to manage and plan current activities and move towards smart grids, which support sustainable energy supply [99].

Organizations offering services: Consumers can allow other organizations to have access to the data from their smart meter. For example, switching sites could use accurate information about the amount of energy used to advise consumers on suppliers and tariffs. As the roll-out proceeds, more devices should become available to help consumers manage their energy usage, including smart appliances that can operate automatically when electricity is cheaper [99]. The Data and Communications Company will put in place communications across Great Britain to send and receive information from smart meters to energy suppliers, energy network operators, and energy service companies using the Wide Area Network [99].

Communication Hub: The communications hub has two functions: (i) it allows the smart meters and in-home display to communicate with each other over a Home Area Network and (ii) it provides a link to the Wide Area Network, which allows information to be sent to and from meters by suppliers, network operators and energy service companies[99].

Communication Specifications of the Smart Meter:

Further as per the specifications, the Communications Hub Physical Interface shall as a minimum, include a physical interface that meets the requirements defined by the Data and Communications Company at the time of installation and includes provision for a DC power supply to the Communications Hub. Electricity Smart Metering Equipment (ESME) shall be capable of automatically resuming operation after a power failure in its operating state prior to such failure[100].

The HAN Interface of ESME shall be capable of joining a ZigBee SEP v1.2 Smart Metering Home Area Network which:

i. Operates within the 2400 – 2483.5 MHz harmonized frequency band and
ii. Supports the Communications Links for the devices

Voltage Quality measurements:

Further DECC sets specifications for voltage quality measurements and explains the requirements for the calculation of *Average RMS voltage*, RMS extreme over voltage detection, RMS extreme under voltage detection, RMS voltage sag detection, RMS voltage swell detection and Supply outage reporting. It can also send alert signal to HAN interface[100].

Annexure C: Smart Meter Implementation World wide

Most of the countries have already started or planning to implement the smart meters for their smarter network. This section of the report addresses the smart meter roll-out in different parts of the world.

Europe

Great Britain's smart metering roll-out is being carried out under powers included in the Energy Act 2008[101]. The EU has subsequently set rules in this area. The Third Package[102] requires Member States to roll out intelligent metering systems, although a decision to proceed with a roll-out may be subject to a cost/benefit analysis. Where metering systems are rolled out, Member States must ensure that at least 80% of consumers have intelligent electricity metering systems by 2020. Member states are required to prepare a timetable for installation of intelligent gas metering systems, but the directive does not set a completion date. 16 Member States (Austria, Denmark, Estonia, Finland, France, Greece, Ireland, Italy, Luxemburg, Malta, Netherlands, Poland, Romania, Spain, Sweden and UK) have decided in favour of a wide-scale roll-out of smart electricity metering by 2020 or earlier[103].

Denmark

As per the announcement of Danish Energy Agency, all the electricity meters must be remotely read by the end of 2020 which will allow consumers to track their consumption hour by hour. The announcement and ensuing rollout of smart meters for the MV group are the manifestation of Danish government's progressive smart grid strategy which aims to build the intelligent grid and ready for the green transition[104].

Approximately half of all the Danish homes already have a smart meter, having had one installed before the announcement of a mandated roll-out. The roll-out of smart meter is expected to increase the competition in the electricity market which is the major motive. The Danish Ministry of Climate and Energy anticipates a 2% reduction in electricity consumption per year for an average homeowner as a result of the roll-out[103].

France

France's energy regulator (CRE) has announced that the government is targeting the deployment of smart meters across 95% of the country or 35 million units by 2020. The Prime minister of France has announced go-ahead of country's smart electricity metering rollout in 2013, with an aim of deploying 3 million of smart meters in its first phase by 2016. The national wide roll-out of 35 million smart meters is expected to be completed by 2020 with an investment of € 5 billion[105].

A large (250,000 installations) year-long pilot project, completed in March 2011, tested the installation process, the communications system and meter interoperability[103]. It is stated that the Linky smart meters helps in significant 5 to 15% energy savings in the region, and for an average annual bill of €400 per household, saving of €50 per annum could be achieved[106].

Germany

A study has been carried out by Ernst & Young on behalf of ministry about the smart meter roll-out. The study concludes that smart meters in particular for small consumers are not cost efficient, as the potential savings would be below actual costs of smart meters and their operation[107]. Hence mass roll-out of smart metering before 2020 would have a negative economic impact. Therefore, smart meters are only rolled out on a voluntary basis - often when an old or non-functioning meter needs to be replaced and when buildings are refurbished. This approach has not resulted in the deployment of significant numbers of smart meters to date. There has been considerable hesitation by consumers over installation owing to substantially higher fees for smart meters covering both the cost of the meter and the installation[103].

Republic of Ireland

The smart metering trials took place during 2009 and 2010 with over 5,000 Irish homes and business units. This trial was carried out by Electric Ireland and SEAI with the Commission for Energy Regulation (CER) and the Department of Communications, Energy and Natural Resources (DCENR). The trial was aiming to assess the performance of Smart meters, their impact on customer's electricity consumption and the economic case for wider national rollout. The results of smart meter trial published by CER indicated that the Irish customers responded very positively to smart meters by reducing their electricity consumption and bills[108].

Now, the Republic of Ireland aims to roll out 2.2 million smart electricity and 600,000 smart gas meters to all domestic properties and a large number of businesses by 2019. The Irish Government has decided to roll out smart meters after the positive results of comprehensive electricity and gas smart metering trials and associated cost/benefit analysis[103].

Italy

Italy was the first EU member state to opt for a large-scale smart metering roll-out and the roll-out decision was made by the major electricity company Enel[103]. Enel was the first company in the world that replaced old electromechanical meters with electronic meters. The company has installed 32 million of such meters in five years. With over 99% of electricity meters already installed, Enel is well ahead of the deadline set by the authorities. The project began in 2001 and is called as Telegestore which represents the most widespread remote management infrastructure in the world. Telegestore consists of an electronic meter, a concentrator (installed in medium to low voltage substations to gather the data recorded by the connected meters) and a central system for remote management of meters, processing billing information and to monitor the quality of service[109].

Netherlands

Smart meter trial has been carried out during 2012, in which the country has deployed over 600,000 smart meters[110]. After the successful smart meter pilot project, Netherland aims to reach 7.6 million domestic and small business users, with a large part of the roll-out completed by 2015. The Government's aim is that all households to be offered a smart meter by 2020. The objectives of the Dutch program include enabling greater energy market competition through easier switching for customers, improving operational efficiency and supporting energy savings[103].

Spain

The Spanish program aims to roll out 26 million smart electricity meters to domestic customers by the end of December 2018. The Government and energy suppliers identified the main benefit of the roll-out as the ability remotely to change the limits on the amount of energy that the household can draw upon. In 2006, Spain introduced a law to ensure that all meters installed in new homes from July 2007 would have time-of-use functionality and remote management capability[103].

Sweden

Sweden has initiated the smart meter pilot project in 2001. Sweden was the first country to install smart meters to all its consumers by July 2009. EU targets for smart meter roll-out, in addition to the decision to require monthly meter readings – spurred the deployment of the technology. The Swedish system uses power lines to transmit readings and the transmission of meter data is delayed by between one and two hours. As a result real-time information is not available to electricity customers. Sweden is currently undertaking pilot projects to evaluate the potential of time-of-use tariffs and other new services[103].

India

Ministry of Power has shortlisted 14 smart grid pilot projects to be implemented by state owned distribution utilities. In India, smart meters are seen as a means of increasing the *System* *reliability* (identify and automatically respond to electric demand which minimizes power outages), *Energy costs* (increased reliability, functionality, reduced power outages and streamlined billing will cut costs) and *Electricity theft* (AMI system will help in monitoring power in real time thus increased system transparency)[111]. India plans to roll out 150 million smart electricity meters across five regions between 2013 and 2025[103].

USA

There has been significant smart metering activity in the US. AMI and customer system projects are funded through the Recovery Act Smart Grid Investment Grant (SGIG) program[112]. Almost 40 per cent of households in the United States now have smart meters with over 45.8 million smart meters having been deployed through to July 2013. For example, the state of Maine has rolled out 625,000 smart electricity meters to domestic customers and a range of small to large non-domestic customers within a two year period. The success of the roll-out program was enabled by early testing and trialing of equipment, consumer engagement to ensure approvals and customer acceptance and the communications network being made available before the roll-out began[103].

Victoria, Australia

After an extensive review of smart meter program during 2011, the Victorian government has decided to continue with an improved rollout which ensures the consumer receives the benefits. The roll out of smart meters in Victoria is now effectively completed with almost 2.8 million of smart meters installed. The government policy is that the smart meters are and will be the standard meters for the state. As per new regulations of the Victorian Government, if an electricity distributor has not attempted to install a smart meter in a Victorian home or small business by 30 June 2014, the customer at that premise will be entitled to a rebate (provided the customer has not refused the installation of a smart meter). From 1 April 2015, for the small number of customers who continue to refuse a smart meter, electricity distributors will be able to recover the costs associated with running a separate meter reading service from those customers[113].

Annexure D: Recommended Format for Submission

Please email your submission to Dr. Momen Bahadornejad (m.bahadornejad@auckland.ac.nz)

Recommended Format for Submission

Question	Response
Q1: What is the technology used for Advanced Metering Infrastructure?	
Q2: Are Smart meters roll-out and establishment of communication medium going on simultaneously? If the answer is 'No', then what is the anticipated time for the establishment of communication medium?	
Q3: Do you agree that peak consumption timing for consumers will change after arming smart meter with dynamic pricing?	
Q4: To achieve discussion point (item g), it may be necessary to integrate the smart meters with Home Energy Management Systems (HEMS). Do you have any plans in this regard?	
Q5: Do you have any plans to install *In-Home Displays* OR similar arrangements at consumer premises?	

Question	Response
Q6: If the existing communication links are old and needs replacement, then what is the alternative technology planned for implementation?	
Q7: What types of meters are installed at distribution transformer sites? If not, do you have plans to install smart meter OR any other monitoring technology at distribution transformer sites?	
Q8: Are you planning to use smart meters as an alternative to ripple control? If YES then, what is timeline anticipated for the change-over?	
Q9: It is anticipated that the smart meter roll out would lead to significant adoption of price based DR. What are your views on this?	
Q10: What is your opinion on having a NZ common platform for the AMI implementation?	
Q11: If regulations similar to Victorian government are implemented across New Zealand, What is your opinion?	

Annexure E: Summary of ICT practices in NZ distribution utilities

Summary of ICT Practices in New Zealand Distribution Utilities

	Power Lines Company	Area	No. of Consumers	% of Total	Metering	Communication	Ripple control
1	**Vector**	Greater Auckland region	543,000	26.98	Vector owns AMS. Out of 893,919 electricity meters, approximately 675,555 meters are smart meters, 202,561 are of legacy meters, 4,527 are of prepay meters and 11,276 are of time-of-use meters; These smart meters communicate through GPRS.	Optical fibre infrastructure, digital communication over Vector's copper pilot cables, Vector's owned digital microwave radio links and third party IP network, including wireless GPRS/3G GSM standard based networks.	Consists of audio frequency ripple, pilot wire and cycle control types. It is anticipated that the existing load control systems would be phased out and Vector is working on the strategies for this transition.
2	**PowerCo**	New Zealand's North Island	320,000	15.90	Retailers have started installing smart meters; Radio Frequency mesh is used for smart meter communication.	VHF, UHF or Microwave radio circuits, Optical fibre, Telstra Clear/Telecom leased circuits, CDMA and GPRS private IP networks & PowerCo owned copper and fibre-optic cables.	An extensive ripple control system installed, primarily to provide DSM of water storage cylinders. Focusing its DSM initiatives, in the form of smart meters & possible energy storage systems, in the Tauranga area
3	**Orion Group**	Central Canterbury between the Waimakariri and Rakaia rivers and from the Canterbury coast to Arthur's Pass	192,000	9.54	Metering owners have installed approximately 110,000 smart meters on the Orion network. Smart meters installed under Orion network has flexible communications capability, seamlessly mixing RF mesh, GPRS and satellite technologies to provide AMI service to almost any location.	Uses VHF, UHF, copper communication cables and fibre. Where there are gaps in radio network cellular data modems are used. These systems will be replaced as the new IP radio system expands.	110,000 smart meters installed contain inbuilt ripple receivers and the remainders of around 190,000 network connections have standalone ripple receivers. Orion ripple control operates at 175 Hz on 11 kV and 317 Hz on 33 kV.
4	**Wellington Electricity Lines Limited**	Wellington and to the Porirua and Hutt Valley	160,000	7.95	Not actively pursuing smart grid projects or trials. However, retailers are replacing the existing meters with smart meters.	Copper pilot cable with a small amount of fibre-optic and UHF radio infrastructure.	Owns ripple injection equipment at a number of its zone substations, connected at 33kV in Wellington, and at 11kV in the Hutt Valley. The signals are sent at 475 Hz and 1050 Hz. Since April 2012, Wellington Electricity has offered a controlled rate tariff intended primarily for electric vehicle (EV) charging. This load is controlled using conventional ripple signals through the addition of an EV channel.
5	**Unison Network**	Napier, Hastings, Havelock North, Rotorua and Taupo	110,000	5.47	In the process of implementing smart grid strategy. Collaborated with Energy Retailers to deploy smart meters. Partnered with Silver Spring for distribution automation, smart metering and demand response. Currently only a small portion of customers are using smart meters.	UHF telemetry links, VHF radio links, fibre network, Copper Telcon cables, meshed radio links, leased IP links and GPRS links.	Owns Ripple injection systems operating at relatively high ripple frequencies of 500Hz and 725Hz. Planning to change its existing Ripple control systems to 317 Hz devices.
6	**WEL networks**	Waikato region	85,000	4.22	Owns 15% of Smartco limited. As part of "Smart Network" program, over 35,000 of smart boxes have been installed and has an aim to achieve further 25,000 smart boxes by March 2015. RF mesh is used for communication.	Radio network, a fibre-optic cable network and Copper pilot network.	Uses 283 Hz and 500 Hz signals. Integrated ripple devices within the deployed Smart Boxes are progressively replacing old separate ripple relays.
7	**Aurora Energy**	Dunedin and Central Otago	83,000	4.12	Implementation of Smart meters is under the control of retailers and Metering service providers.	Communication system in Dunedin consists of mixture of copper pilots, fibre-optic cables, and UHF radio; Communications to Central Otago are mainly via VHF and UHF.	Ripple signal frequencies for Aurora's network is 1050 Hz (6.6 kV and 11 kV) and 317 Hz (33 kV). Progressively replacing the 1050 Hz ripple systems with 317 Hz ripple systems.
8	**North Power**	Whangarei and Kaipara districts in Northland	50,000	2.48	Over 6,000 North power meters have been replaced by Genesis Energy smart meters.	Uses microwave, UHF and VHF radio links, as well as copper and optical fibre cable links.	Owns six ripple signal generation plants, generates a 283 Hz signal. Three plants injects into 33 kV and 3 plants to 11 kV network.

	Power Lines Company	Area	No. of Consumers	% of Total	Metering	Communication	Ripple control
9	**Electra**	Horowhenua and Kapiti districts	43,000	2.14	The existing meters at consumers' locations would be replaced with Smart meters and this smart meter rollout is expected to be in place over a time.	Uses radio, microwave links and fibre-optic cables.	Injection from each plant into the Electra 33 kV sub-transmission system at 283Hz.
10	**Network Tasman**	Northwestern corner of South Island	37,500	1.86	Member of Smartco; Installation of advanced meter is expected to commence in late 2014.	Uses VHF and fibre-optic links.	NTL network has five ripple control transmitter each operating in bulk supply areas. Ripple Injection frequencies are 475 Hz and 233 Hz.
11	**Counties Power**	Southern edge of Greater Auckland	35,000	1.74	Member of Smartco; Commenced the deployment of smart meters, aiming to connect 95% of the customers by June 2015 and is on track. Meters are ZigBee enabled.	VHF, UHF and optical fibre links.	Ripple control scheme operates at a frequency of 317 Hz.
12	**The Power Company Limited**	Southland area, excluding parts of Invercargill City and the Bluff township area	34,602	1.72	Member of SmartCo; Smart meters will be installed in The Power Company Limited's area starting from April 2014. Smart meters use a radio frequency mesh network.	Owns and operates microwave links, UHF links, data radio UHF channels and VHF land mobile channels.	Owns and operates ripple plants. Frequency injected is 216⅔Hz.
13	**Main Power**	North Canterbury and Kaikoura	34,000	1.69	Majority of meters in Main Power's region are owned by Contact Energy and requires replacement by 1st April 2015. Network Tasman has entered into a joint venture with Alpine Energy Limited to deploy advanced meters on the MainPower network and first phase implementation is in the second quarter of the 2014/15 financial year.	Consists of digital radio network and fibre-optic cables.	Ripple injection plants operates at an injection frequency of 283Hz and all the plants are GPS synchronized.
14	**Top Energy**	Mid and far north of New Zealand's north island	30,000	1.49	Current meters would be replaced by Smart boxes. Rollout includes installation of 25,500 smart boxes. Smart boxes would communicate using RF mesh network.	Owns VHF, leased UHF broadband, fibre-optic cables.	Injection to 33 kV network is made at 317 Hz.
15	**Alpine Energy**	South Canterbury	30,000	1.49	Member of SmartCo. Deployment of Advanced meter has started in First quarter of 2014 and is expected to complete by 2016. Planning to deploy Silver Spring RF mesh Communications Network which is required for advanced meters to communicate.	Uses 2 UHF FM tone modulated, 1200 baud rate, Conitel protocol paths, one hired microwave broadband TCP/IP link, DNP3 protocol path and two land lines as communication paths. The new communication system uses a 5 GHz digital radio network backbone with supplemented with a fibre-optic network.	The Ripple control scheme operates at a frequency of 317Hz. Once smart meters are rolled– out, Alpine Energy has plans to use smart meters as a means of demand management and load control within the network.
16	**Eastland Network**	Gisborne, East Coast and Wairoa regions	25,500	1.27	Some of the energy retailers are actively progressing in implementing the smart meters in Eastland network area.	VHF Radio, UHF Radio and Copper or fibre cables.	Owns and operates three load control transmitter facilities for control of ripple relays. Signals are sent at 315 Hz and 1250 Hz.
17	**Waipa Networks**	Waipa area, Te Awamutu, Cambridge and surrounding areas	24,040	1.19	Consumers are mostly having Time of use meters. However, retailers are replacing the existing meters with smart meters.	Owns separate VHF voice and data communication networks comprises of Radio repeater sites.	Owns two ripple injection plants. Company also owns the receiving relays in consumers installations. Uses 283 Hz and 297 Hz signals. Has plans to change from 297 Hz to 283 Hz before 2015.

	Power Lines Company	Area	No. of Consumers	% of Total	Metering	Communication	Ripple control
18	**The Lines Company**	King Country region of the central North Island	24,000	1.19	Replacing the old meters with advanced meters; Initially new meters will not have active communications; options for communications are either radio mesh or GPRS. TLC has developed advanced meter software including an in home 20display that aligns to its pricing.	Operates a network of 6 E-band (150 – 155 MHz), radio repeaters providing voice communication throughout the operational area; 8 further repeaters divided across 3 sub communication networks provide a complimentary low speed (1200bps) SCADA transmission platform to access 100 plus remote terminal units.	Operates two generations of ripple systems; Generates signals at 317 Hz at 33 kV network. Old system would be replaced, once the advanced meters have been installed.
19	**Marlborough Lines**	Marlborough Sounds, Molesworth Station and the rugged southern Marlborough coast areas	24,000	1.19	MLL's customers' electricity meters are owned by various electricity retailers. MLL has noticed that in many instances where smart meters have been installed, their utilization has typically been limited to remote disconnection reconnection and reading. Due to this reason, MLL has decided not to pursue the installation of smart meters at customer premises	Uses, VHF and UHF radio links; Decided to change from 25 kHz gap to 12.5 kHz gap in VHF frequencies starting November 2015	Ripple Injection system operates at 217Hz and 1050 Hz; The company has decided to introduce a new frequency of 217Hz for ripple control, since 1050 Hz ripple systems gives rise to various problems.
20	**Horizon Energy**	Eastern Bay of Plenty	23,000	1.14	Investigating the option of replacement of existing meters with Smart meters.	UHF and VHF radio communications.	Operates at 750 Hz. Decided to replace the existing 750Hz Ripple systems with 317Hz Ripple systems.
21	**Electricity Ashburton**	Mid-Canterbury district	19,000	0.94	As per the information available, retailer would replace the existing meters with advanced meters.	Uses extensive fibre-optic, also uses VHF and UHF networks; Plan to replace the existing VHF voice network to a new digital platform over the next two years.	The ripple injection frequency used by Electricity Ashburton is 283 Hz. Electricity Ashburton is actively investigating the suitability of alternative signalling technologies which is available.
22	**Electricity Invercargill**	Invercargill city and the Bluff township area	17,200	0.85	Member of SmartCo; Smart meters will be installed in Electricity Invercargill's area starting from 2014; Smart meters use a radio frequency mesh network.	Data radio links and multicore networks.	Owns and operates one main 33kV 216⅔Hz 125kVA injection plant at Invercargill, with backup provided from the adjacent TPCL plant for control of ripple relays. Would be redundant with the roll out of smart meters which is expected in next few years.
23	**Otagonet**	Otago	14,700	0.73	Only a very few number of smart meters have been installed by the retailers. OtagoNet is planning to install its own smart meters to some of its larger distribution transformer sites which will enable Otagonet to gather necessary information on its service quality.	Uses VHF and UHF links for communication.	Ripple signal frequencies are 492 Hz and 317 Hz.
24	**West Power**	West Coast of New Zealand's South Island	13,000	0.64	Not much of details about smart metering is available. However it is mentioned that, with the introduction of smart meters, West power intends to take a circumspect approach to developing and implementing TOU tariffs.	A mix of Fibre-optic, analogue radio and digital radio; VHF speech is extensively used by WestPower.	Owns five ripple injection plants. Four of the five on-line plants run synchronously with the help of GPS technology. These plants are able to inject the identical ripple waveform at each of the four sites at the same time.
25	**Network Waitaki**	Area extends from the Waitaki River to Shag Point, up the Waitaki Valley as far as Ohau and the Hakataramea Valley	12,000	0.60	Owns majority of electricity metering in the area it serves. Member of SmartCo. Has invested in Smart meters representing the replacement of all old technology electricity meters throughout the Network	Uses UHF, VHF and a section of trunk fibre.	Owns and operates Enermet solid state 33kV Ripple Injection Plants. Also installed ripple relays on irrigation pump loads greater than 30 kVA to enable irrigation load to be shed when the capacity at the Oamaru GXP is exceeded.

	Power Lines Company	Area	No. of Consumers	% of Total	Metering	Communication	Ripple control
26	**Nelson Electricity Limited**	Central Nelson city and includes most of the Port area, Port Hills, Victory Square, Hospital, Brook, Wood, Nelson East, Nelson South and the central business district	9,100	0.45	Smart meters would be installed in Nelson network area in coming years.	Has a fibre link. The load pulse system is backed up by a radio communication link. Pilot cable network has been superseded by simplex radio communication.	Nelson Electricity has two ripple generators, each injecting a signal into the opposite side of the 11kV bus. Nelson Electricity Ltd operates a 725Hz ripple control system on its distribution Network.
27	**Centralines Limited**	Central Hawke's Bay region	8,285	0.41	Implementation of smart meters was initially took place in Centralines service area. During 2006/08 Arc Innovations installed a modern smart meter system into the Centralines network.	Leased radio link, leased data circuit, leased wireless circuit and fibre-optic cable.	The load control scheme operates at a frequency of 475Hz.
28	**Scan Power**	Tararua region, including Dannevirke, Woodville, Norsewood and the outlying rural areas	6,800	0.33	Installation of smart metering at key network nodes and an enhanced Load Management System on Scanpower's SCADA are priority objectives for developments of its AMIS. It is expected to be deployed over the next 3-5 years.	Uses VHF and UHF radio links. May move to communication platforms created by others for smart metering as an alternative to running a private radio network.	Installed and commissioned a 283Hz Enermet ripple injection plant at the Dannevirke substation to replace the Zellweger static plant.
29	**Buller Electricity**	West Coast of the South Island	4,700	0.23	BEL will continue to monitor and improve its service by developing a smart grid philosophy, firstly with HV assets and progressing to LV including metering if found effective and efficient. BEL is installing 50 smart meters to assist in determining the line losses in different areas.	uses a mix of UHF and VHF radio networks and a short 12 pair fibre cable.	Owns a 11kV static indoor ripple injection plant operates at 317 Hz.

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