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Distributed Generation on Rural Electricity Networks – A lines company perspective

A thesis presented in partial fulfillment of the
requirements for the degree of

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ABSTRACT

A number of electricity assets used in rural New Zealand yield a very low return on investment. According to the provisions of the Electricity Act 1992, after 01 April 2013, lines companies may terminate supply to any customer to whom they cannot provide electricity lines services profitably.

This research was undertaken to assist the policy makers, lines companies, rural investors on the viability of distributed generation in a rural setting from the point of view of the lines company and the investor as well as to provide recommendations to the problem areas.

A dynamic distributed generation model was developed to simulate critical distributed generation scenarios relevant to New Zealand, such as diverse metering arrangements, time dependent electricity prices, peak shaving by load control, peak lopping by dispatchable distributed generation and state subsides, which are not addressed in commercial software.

Data required to run the model was collected from a small rural North Island sheep and beef farming community situated at the end of a 26km long radial distribution feeder. Additional operational data were also collected from the community on distributed resources such as solar hot water systems.

A number of optimum distributed generation combinations involving a range of technologies under different metering arrangements and price signals were identified for the small and the medium investor. The effect of influencing factors, such as state initiatives and technological growth, on the investor and the lines companies were discussed. Recommendations for future implementation in order to integrate distributed generation on to rural networks were also given.

Several key research areas were identified and discussed including low cost micro hydro, wind resource assessment, diversification of the use of the induction generators, voltage flicker and dynamic distributed generation techno-economic forecasting tools.

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Nihal Jayamaha
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Table of Contents

Page

Executive Summary xix

1 INTRODUCTION 1

1.1 ELECTRICITY IN NEW ZEALAND 1

1.2 AN OVERVIEW OF THE ELECTRICITY INDUSTRY TODAY 2

1.2.1 Issues pertaining to distribution companies in New Zealand's deregulated electricity industry 3

1.2.2 Possible considerations for issues faced by distribution companies 4

1.3 THE HISTORICAL BACKGROUND 4

1.4 KEY DEVELOPMENTS INCLUDING FORMATION OF ACTS AND REGULATIONS 5

1.5 PROBLEM IDENTIFICATION 7

1.6 OBJECTIVES 8

1.7 THE STRUCTURE OF THE THESIS 9

2 LITERATURE REVIEW 11

2.1 THE TRADITIONAL OUTLOOK OF ELECTRICITY GENERATION, TRANSMISSION AND DISTRIBUTION 11

2.2 DEFINITION OF DISTRIBUTED ENERGY SYSTEMS 12

2.2.1 Definition of distributed resources 12

2.2.2 Definition of distributed generation 12

2.3 THE POSITION OF DISTRIBUTION GENERATION IN THE POWER SYSTEM ARCHITECTURE 12

2.4 ECONOMICS OF DG 14

2.5 PRICE OF GRID CONNECTED ELECTRICITY 15

2.5.1 The wholesale price of electricity 15

2.5.2 The retailer's cost structure and the required rate of return 19

2.5.3 The pricing methodology of the network operators 21

2.5.3.1 The general approach and governing rules **21**

2.5.3.2 Transpower's pricing methodology **23**

2.5.3.3 Lines company pricing methodology **25**

2.6 **LOAD MANAGEMENT AS A DSM RESPONSE** **27**

2.6.1 Peak lopping **28**

2.6.1.1 Modern energy storage technologies for power system applications involving distributed resources **30**

2.6.1.1.1 Power quality/voltage support **30**

2.6.1.1.2 Load factor increase/distribution capacity deferral **30**

2.6.1.1.3 Tariff trading **31**

2.6.1.1.4 Renewable support **31**

2.6.1.2 Use of standby generators for peak lopping **32**

2.6.2 Peak shaving by load curtailment **33**

2.7 **THE SIGNIFICANCE OF DG AND BARRIERS TO THE UPTAKE OF DG** **35**

2.7.1 Technical requirements for interconnection **36**

2.7.2 Business practice and contractual requirements **37**

2.7.3 Tariffs and metering **38**

2.8 **USE OF DISTRIBUTED RESOURCES IN NEW ZEALAND** **41**

2.8.1 Distributed Generation in New Zealand **41**

2.8.2 Application of other distributed energy systems in New Zealand **43**

2.9 **SOME RELATED NEW ZEALAND RESEARCH** **44**

3 **TECHNOLOGICAL AND ECONOMIC ASPECTS OF DISTRIBUTED ENERGY SYSTEMS** **47**

3.1 **PHOTOVOLTAIC (PV) MODULES** **47**

3.1.1 PV Performance **47**

3.1.2 Economics of PV Technology **50**

3.2 **WIND TURBINE GENERATORS (WTG)** **51**

3.2.1 WTG Performance 51
3.2.2 Environmental Issues Related to Wind Turbine Generators 57
3.2.3 WTG Economics 57
3.3 MICRO-HYDRO SYSTEMS 58
3.3.1 Micro-Hydro Performance 58
3.3.2 The Economics of Micro-Hydro 62
3.3.3 Environmental Issues Related to Micro-Hydro 62
3.4 LOW COST PUMPED HYDRO SYSTEMS 63
3.5 FUELLED GENERATING SETS 65
3.5.1 Reciprocating Engines 66
3.5.2 Fuel cells 68
3.6 LEAD-ACID STORAGE BATTERIES 70
3.7 DOMESTIC SOLAR HOT WATER SYSTEMS 73

4 LOAD PROFILING AND SYNTHESIS OF LOAD DATA 75

4.1 'LOAD' AND THE TIME DOMAIN USED FOR AVERAGING 75
4.2 LOAD PROFILING 76
4.2.1 Load Profiling Applications 76
4.2.2 Load Profiling Methods 77
4.2.3 Static Load Profiling 77
4.3 ESTIMATING THE REAL TIME LOAD OF ANY ONE SINGLE CLASS OF CUSTOMERS 81
4.4 ESTIMATING THE REAL TIME LOAD OF A COMMUNITY 83
4.5 AVAILABLE DATA SOURCES FOR ESTIMATING THE REAL TIME LOAD OF A COMMUNITY 85
4.6 LOAD RESEARCH ON RURAL AGRICULTURAL COMMUNITIES AND THE IMPACT OF NEW TECHNOLOGY ON LOAD PROFILES 89

5 RESEARCH DESIGN 91

5.1 RESEARCH DESIGN CONSIDERATIONS 91

5.2 SAMPLE SELECTION 91

5.3 DESCRIPTION OF THE CASE STUDY COMMUNITY 93

5.4 PREVIOUS PROGRESS 95

5.5 TECHNOLOGICAL AND ECONOMIC CONSIDERATIONS 96

5.5.1 Setting objective criteria for utilisation of distributed generation systems **96**

5.5.2 Analysis of electrical distribution system **99**

5.2.2.1 Aggregating loads at the transformer secondary level **100**

5.2.2.2 Aggregating loads at the community level **101**

5.6 FINALISATION OF THE LOAD METERING ARRANGEMENTS 102

5.7 IDENTIFICATION OF KEY DATA COLLECTION REQUIREMENTS 102

5.8 DETAILS OF ACTUAL DATA COLLECTION 104

5.8.1 Load monitoring system of Zone A **104**

5.8.2 Electricity Price Data **106**

5.8.3 Distributed energy system performance monitoring for Zone A **107**

5.8.3.1 The solar hot water system **107**

5.8.3.2 The 100Wp PV modules **109**

5.9 ELECTRONIC FILES CONTAINING RAW DATA 110

6 MODELLING OF DISTRIBUTED ENERGY SYSTEMS 111

6.1 KEY DESIGN CONSIDERATIONS 111

6.1.1 A distributed energy resource system as a physical system **111**

6.1.2 Energy matching interval **113**

6.1.3 The suitable application software platform **115**

6.2 THE COMPUTER PROGRAM 115

6.2.1 The structure of the program **116**

6.2.1.1 Input data **116**

6.2.1.2 Derived data **118**

6.2.1.3 The control philosophy **118**

6.2.1.4 Timing of events simulated **121**

6.2.2 The *load worksheet* **122**

6.2.2.1 Synthesis of time series customer load data **122**

6.2.2.2 Packaging load data of energy storage devices **126**

6.2.3 The *wind worksheet* **126**

6.2.4 The *solar worksheet* **128**

6.2.5 The *hydro worksheet* **129**

6.2.6 The *electricity pricing worksheet* **130**

6.2.6.1 Assumptions and definitions **131**

6.2.7 The *central worksheet* **136**

6.2.7.1 Inputting data **137**

6.2.7.2 The data processing **139**

6.2.7.3 Output data **140**

6.2.8 The *final calculations worksheet* **140**

6.2.8.1 DG project investment appraisal **141**

6.2.8.2 Foregone revenue to the lines company **142**

6.2.8.3 Algorithms used **142**

6.2.9 The *summary performance and economics worksheet* **146**

6.3 APPLICATION OF THE MODEL TO "TOTARA VALLEY" 147

6.3.1 Filling of input data gaps **147**

6.3.2 DG combinations and metering schemes considered **148**

6.3.2.1 Zone A (i.e. a single farm application on Totara road) **148**

6.3.2.2 Zone B (i.e. a small scale centralised community application) **149**

6.3.2.3 Zone C (i.e. a medium scale centralised community application) **150**

6.3.3 Calculation of the annuity ScanPower could pay to DG owners for peak lopping, in the event of country feeder overload 150

6.3.3.1 Estimation of SacnPower's short run marginal cost 152

6.3.4 Key project economic parameters considered 153

6.3.5 Totara Valley simulation results 154

7 THE DESCRIPTIVE STATISTICS 155

7.1 SPOT PRICE STATISTICS 155

7.2 STATISTICS OF RURAL NEW ZEALAND 159

7.2.1 Demographics 159

7.2.2 Income, occupation and household amenities 159

7.3 STATISTICS ON THE DISTRIBUTION SYSTEM OF KUMEROA/ TOTARA VALLEY 160

7.3.1 ICP/customer classification and the load use pattern 160

7.3.2 Statistics of the "country feeder" 161

7.4 LOAD RESEARCH DATA 163

7.4.1 Aggregate farm loads 163

7.4.2 Monthly energy consumption of individual installations 163

7.4.3 The Summer load profiles 167

7.5 THE SOLAR HOT WATER SYSTEM PERFORMANCE 167

7.6 THE PERFORMANCE OF THE PV MODULES 171

8 THE ANALYSIS OF TOTARA VALLEY SIMULATION MODEL RESULTS 172

8.1 THE BASIC FRAMEWORK USED IN THE ANALYSIS 172

8.1.1 The project financial indicators 172

8.1.2 The scope for generalising the analysis 173

8.1.3 The approach used for analysing the effect of subsidies 174

8.2 THE SINGLE FARM BASED DISTRIBUTED GENERATION APPLICATIONS 175

8.2.1 Wind energy projects 175

8.2.2 Photovoltaic projects **182**

8.2.3 Micro hydro projects **183**

8.2.4 Projects involving standby diesel generators and wind-diesel hybrids **187**

8.3 COMMUNITY OWNED DISTRIBUTED GENERATION SYSTEMS 192

8.3.1 Separately metered community owned distributed generation systems **193**

8.3.1.1 Wind energy projects **194**

8.3.1.2 Diesel generators **196**

8.3.1.3 Wind/diesel hybrids **198**

8.3.1.4 Pumped hydro units and wind/pumped hydro hybrids **200**

8.3.1.5 Battery banks and wind battery hybrids **201**

8.3.1.6 The effect of load control on separately metered community owned DG **202**

8.3.2 Gross import/gross export metered community distributed generation systems **202**

8.3.2.1 Results related to Totara Valley Zone B **204**

8.3.2.1.1 Wind energy projects **204**

8.3.2.1.2 Diesel generators **206**

8.3.2.1.3 Wind/diesel hybrids **208**

8.3.2.2 Results related to Totara Valley Zone C **210**

8.4 ACCEPTABILITY OF THE RESEARCH HYPOTHESES 210

9 THE KEY RECOMMENDATIONS FOR FUTURE PROGRESS 212

9.1 THE NATURE OF THE DECISION ENVIRONMENT 212

9.2 EDUCATION OF RURAL ELECTRICITY CUSTOMERS ON DISTRIBUTED ENERGY OPPORTUNITIES 213

9.2.1 Importance of having to have all the information influencing an economic decision **214**

9.2.2 Demonstration of renewable energy schemes **215**

9.2.3 Lines company initiatives **216**

9.2.4 Social benefits **216**

9.3 GOVERNMENT INCENTIVES FOR DG IMPLEMENTATION 216
9.3.1 The right level of financial incentive 216
9.3.2 The right time to provide the financial incentive 218
9.4 LINES COMPANY MARKETING AND STRATEGIC PLANNING 219
9.4.1 Dealing with reduced revenue 220
9.4.2 Distributed generation as an alternative to capacity augmentation 221
9.5 TECHNOLOGICAL DG RESEARCH AND DEVELOPMENT 222
9.5.1 Low cost micro hydro 223
9.5.2 Application of the induction generator 224
9.5.3 Wind resource assessment 224
9.5.4 Home made distributed energy performance and economic forecasting tools 225
9.5.5 Voltage flicker 227
10 SUMMARY AND CONCLUSIONS 229
10.1 SCOPE FOR FUTURE RESEARCH 230
BIBLIOGRAPHY 231
Appendix A: The electricity grid of New Zealand
Appendix B: Illustration of some typical distributed energy systems
Appendix C: The role plaid by a grid connected mini hydro power station in managing power system emergencies - *a Sri Lankan Experience*
Appendix D: Common low voltage metering schemes used for small scale DG applications in Australia
Appendix E: 11 kV "Country Feeder" Line Parameters for Steady State Power Flow Modelling
Appendix F: Product and pricing options of ScanPower
Appendix G: Field notes and work papers related to the selection of the energy metering scheme
Appendix H: The mathematical models used for the calculation of the solar hot water system performance
Appendix I: Field tests done on Solarex MSX 50 PV modules and the OK 4E-100 grid interactive inverter
Appendix K: Mathematical models used in the *electricity pricing worksheet*

Appendix L: Mathematical models used in the *central worksheet*
Appendix M: Mathematical models used in the *final calculations worksheet*
Appendix N: Totara Valley/Kemeroa load data estimation
Appendix O: Graphical presentation of calculations pertaining to *load worksheet*
Appendix P: Specific assumptions made on Totara Valley DG simulations
Appendix Q: Additional simulation results of the case study

List of Tables

		Page
Table 2.1:	NZEM Service Providers and their role	**17**
Table 2.2:	Summary of new storage technologies	**29**
Table 3.1:	Wind power classification used in US research	**55**
Table 3.2:	Established statistical relationships between specific speed and net head for different turbine designs	**61**
Table 4.1:	Different configurations of load models and their applications	**80**
Table 4.2:	The algorithm for the estimation of real time community load	**86**
Table 5.1:	The details of parameters logged in respect of the solar hot water system of Farm A	**108**
Table 6.1:	An extract from the central worksheet of the Excel spreadsheet model showing input data cells and remarks	**116**
Table 6.2:	An illustration of derived data on the operation of a fuelled generator set extracted from the *central worksheet*	**118**
Table 6.3:	The metering and billing scenarios simulated by the model	**133**
Table 6.4:	Input data to the *final calculations worksheet*	**143**
Table 6.5:	Derived data used for the accounting performance indicators of the project	**144**
Table 7.1:	The disposition of customers based on the classification used by ScanPower	**161**
Table 7.2:	Abbreviations used for customer/ICP category	**161**
Table 7.3:	Statistics pertaining to the 11 kV "country feeder"	**162**

List of Figures

Page

Fig. 1.1: Generation stake in New Zealand as of January 2000 out of a total installed capacity of 8378 MW **2**

Fig. 1.2: Electricity retailing stake in New Zealand as on January 2000 out of a customer base of 1.7 million **2**

Fig. 1.3: Electricity distribution stake in New Zealand as on January 2000 **2**

Fig. 2.1: New Zealand's power system framework depicting key fixed assets and its ownership **13**

Fig. 2.2: A USA study on the economies of scale of different modern DG Technologies **14**

Fig . 2.3: Supply & demand dynamics and how the spot price is discovered in the NZEM. **16**

Fig. 2.4: The progress of retailer switching by customers since April 2000 **20**

Fig. 2.5: Money flows and physical flows of electricity in the electricity market in New Zealand **26**

Fig. 2.6: Illustration of the concept of peak lopping through energy storage **28**

Fig. 2.7: Modern electrical energy storage applications for power systems **29**

Fig. 2.8: The effect of load shedding on the load duration curve **33**

Fig. 2.9: The effect on the feeder protection scheme upon connecting a large DG unit **36**

Fig. 2.10: Illustration of the star topology in metering **39**

Fig. 2.11: World Domestic Electricity Prices **42**

Fig. 3.1: The photovoltaic effect in a solar cell **47**

Fig. 3.2: I-V characteristics of Shell SM110-24P PV Module for varying irradiance levels **48**

Fig. 3.3: I-V characteristics of Shell SM110-24P PV Module for varying cell temperatures at 1000 W/m^2 irradiance level **48**

Fig. 3.4: The experimental set up for determining I-V characteristics of a PV module **49**

Fig. 3.5: The concept of Maximum Power Point Tracking **49**

		Page
Fig. 3.6:	General Configuration of a Vertical-Axis Wind Turbine (VAWT)	**52**
Fig. 3.7:	General Configurations of Horizontal-Axis Wind Turbines (HAWTs)	**53**
Fig. 3.8:	The Power Curve of a typical large modern wind turbine	**54**
Fig 3.9:	The layout of a micro-hydro power station	**59**
Fig. 3.10:	The specific speed and net head of different type of turbines, optimized from an efficiency viewpoint	**61**
Fig. 3.11:	Impression of a low cost New Zealand rural pumped hydro project	**64**
Fig. 3.12:	Application-technology match of different FGS technologies	**65**
Fig. 3.13:	Input-output characteristics of a diesel generating set	**67**
Fig. 3.14:	The flows of reactants of a simple fuel cell	**68**
Fig. 3.15:	The discharge curve of a deep cycle battery with a nominal rating of 400 Ah	**71**
Fig. 3.16:	Cycle Life Vs Depth of Discharge of BP Solar PVSTOR battery models	**72**
Fig. 3.17:	A domestic solar hot water system incorporating a wetback	**74**
Fig. 4,1:	Assumed shapes of load profiles of two customers of same customer class, under simple form load models	**78**
Fig. 4.2:	A rural community consisting of two residential types and three industrial types	**84**
Fig. 4.3:	The load profile of 'Class 1' load shape category	**87**
Fig. 4.4:	The load profile of 'Class 2' load shape category	**88**
Fig. 4.5:	The load profile of 'Class 3' load shape category	**88**
Fig. 4.6:	The load profile of 'Class 4' load shape category	**88**
Fig. 4.7:	The load profile of 'Class 5' load shape category	**89**
Fig. 4.8:	The load profile of 'Class 6' load shape category	**89**
Fig. 5.1:	The 11 kV Electricity Distribution Configuration for Kumeroa and Hopelands areas	**92**

		Page
Fig. 5.2:	The topography of Totara Valley and the demarcation of the farms and buildings	**94**
Fig. 5.3:	Bi-monthly energy consumption of key loads at Farm A, based on electricity bills received from July 2001 trough July 2002	**95**
Fig. 5.4:	Illustration of the gross import/gross export metering concept	**97**
Fig. 5.5:	The electricity distribution system for each farm at Totara Valley	**99**
Fig. 5.6:	Illustration of the proposed 3 phase 4 wire TOU metering system	**101**
Fig. 5.7:	Illustration of the single point gross import/gross export whole community metering concept for a fringe of the grid community	**102**
Fig. 5.8:	The hardware arrangement for the load monitoring system of each farm	**105**
Fig. 5.9:	Illustration of metering points of the solar hot water system of Farm A	**109**
Fig. 6.1:	DG system exporting excess electrical energy in completing its designated tasks	**112**
Fig. 6.2:	DG system importing the balance electrical energy in fulfilling its designated tasks	**112**
Fig. 6.3:	A DG system with no designated task involving energy supply to the customer	**113**
Fig. 6.4:	The structure of the computer program	**117**
Fig. 6.5:	Illustration of energy flows and control signal flows of the DG system	**119**
Fig. 6.6:	The flow chart of the customer load synthesis algorithm	**123**
Fig. 6.7:	The *wind worksheet* process flow chart in respect of a given category of wind turbine generators	**127**
Fig. 6.8:	The data processing at the *solar worksheet*	**128**
Fig. 6.9:	The data processing at the *hydro worksheet*	**129**
Fig. 6.10:	The data processing at the *electricity pricing worksheet*	**131**
Fig. 6.11:	Net metering arrangement	**134**
Fig. 6.12:	Gross import/gross export metering arrangement	**134**
Fig. 6.13:	Separate generation (and load) metering arrangement	**135**

		Page
Fig. 6.14:	The load flow path used for the algorithms in the *central worksheet*	**136**
Fig. 6.15:	The data processing at the *central worksheet*	**138**
Fig. 6.16:	The data processing at the *final calculations worksheet*	**145**
Fig. 6.17:	Illustration of the concept of annual cash disbursements for additional capacity, as an alternative to capital investment	**151**
Fig. 6.18:	The relationship between the total cost, marginal cost and average cost	**152**
Fig. 7.1:	Monthly average weekday sport prices at Haywards GXP in 2002	**156**
Fig. 7.2:	Monthly variability of weekday sport prices at Haywards GXP in 2002	**156**
Fig. 7.3:	Monthly average weekend sport prices at Haywards GXP in 2002	**157**
Fig. 7.4:	Monthly variability of weekend sport prices at Haywards GXP in 2002	**157**
Fig.7.5:	The national average half-hourly daily load	**158**
Fig. 7.6:	The pattern of national daily average load in April 2002	**158**
Fig. 7.7a	Proportion of the population living in rural areas by Regional Council area	**159**
Fig. 7.7b	New Zealand regions	**159**
Fig. 7.8:	The zones covered by the simulation	**161**
Fig7.9:	The half hourly average values of Totara Valley load data monitored	**164**
Fig7.10:	The half-hourly variability of Totara Valley load data	**165**
Fig. 7.11:	Monthly energy consumption at Farm A installations based on utility tariff meters	**166**
Fig. 7.12:	Monthly energy consumption at Farm B installations based on utility tariff meters	**166**
Fig. 7.13:	Monthly energy consumption at Farm C installations based on utility tariff meters	**166**
Fig. 7.14:	The summer and winter half-hourly average loads for Totara Valley based on previous load research data	**168**

Page

Fig. 7.15: Totara Valley summer loads as a percentage of winter loads, based on previous load research data **168**

Fig. 7.16: The Solar hot water performance in March 2003, calculated from measured data **169**

Fig. 7.17: The results on experiment on the hot water system conducted between 20 May 2003 to 31 May 2003 with wetback (WB) as the only heat source **169**

Fig. 7.18: The average daily sunshine on a horizontal plane in Farm A **170**

Fig. 7.19: The cumulative energy generation of the 100Wp AC PV module on Farm C since commissioning on 25 September 2002 **170**

Fig. 8.1: The continuum of possible subsidy levels available for DG projects **174**

Fig. 8.2: The financial viability of small WTG units based on the capacity, the metering option and the level of financial subsidies **176**

Fig. 8.3: The breakeven WTG capacities for different mean annual wind speeds **177**

Fig. 8.4: The sensitivity of providing a subsidy for a small WTG project in an 8 m/s site under a net metering arrangement **178**

Fig. 8.5: The breakeven line charge rescale factors under a net metering regime that cause NPV zero under different wind regimes **179**

Fig. 8.6: The breakeven line charge rescale factors under a gross import/gross export metering regime that cause NPV zero under different wind regimes **180**

Fig. 8.7: The annual foregone revenue of a lines company under a net metering scheme for different WTG capacities installed under different wind regimes under existing pricing **180**

Fig. 8.8: The annual foregone revenue of a lines company under a gross import/gross export metering scheme for different WTG capacities installed under different wind regimes **181**

Fig. 8.9: The gross generation capacity and the net present value of PV projects **183**

Fig. 8.10: The financial viability of two different MH technologies with no subsidy **184**

Page

Fig. 8.11: The financial viability of two different MH technologies with full project investment met via an interest free loan 185

Fig. 8.12: The water flow rate of the Totara stream used for the simulation 185

Fig. 8.13: The financial viability of a small standby diesel generator operating during the evening load peaks to offset energy drawn by the farm supply under gross import gross export metering 188

Fig. 8.14: The financial viability of a small standby diesel generator operating as a demand side response to winter peaks signalled by the lines company under gross import/gross export metering 188

Fig. 8.15: Annual **c**ash inflows from a small standby diesel generator operating as a demand side response to one hour winter peaks signalled by the lines company for 50 days under gross import/gross export metering 189

Fig. 8.16: The initial cost structure of a small grid connected diesel standby generating unit 189

Fig. 8.17: The configuration of a community owned, separately metered DG system 193

Fig. 8.18: The financial viability of medium grid connected, separately metered WTGs 194

Fig. 8.19: The financial viability of medium grid connected, separately metered WTGs installed without any subsidy but operating under a lines company incentive scheme for providing firm capacity during winter, characterised by peak periods on 50 days, with each peak period lasting for 1 hour 195

Fig. 8.20: The financial viability of medium grid connected, separately metered standby diesel generator operating under a lines company incentive scheme for providing firm capacity during winter 196

Fig. 8.21: The initial cost structure of a project, involving small/medium grid connected diesel standby generating unit, as suggested by the computer model 197

Fig. 8.22: The financial viability of medium grid connected wind-diesel hybrid system (of equal rated capacity) operating under a lines company incentive scheme for providing firm capacity during winter, characterised by peak periods on 50 days, with each peak period lasting for 1 hour 199

Page

Fig. 8.23: The configuration of a community owned gross import/gross export metered DG system **203**

Fig. 8.24: The financial viability of medium grid connected, gross import/gross export metered WTGs for Totara Valley Zone B **204**

Fig. 8.25: The annual foregone revenue of the lines company under a gross import/gross export metering scheme for different WTG capacities under different wind regimes under existing line charges for Totara Valley Zone **205**

Fig. 8.26: The financial viability of a grid connected, gross import/gross export metered standby diesel generator operating in Totara Valley Zone B under a lines company incentive scheme for providing firm capacity during winter **207**

Fig. 8.27: The financial viability of a state subsidised gross import gross export metered wind diesel hybrid system for Totara Valley Zone B, in an 8 m/s wind regime **209**

Fig. 9.1: The decision environment concerning grid connected distributed generation **212**

Thesis Amendments

Some clarifications/amendments have been incorporated in response to examiners' comments. These appear opposite the relevant pages.

An errata is supplied at the end of the thesis.

Executive Summary

I. INTRODUCTION & BACKGROUND

Rural electricity supply is often characterised by long distribution lines and higher proportion of transformers than in urban areas. The quantity of energy conveyed is generally low due to dispersed population densities. In order to realise the required rate of return on distribution assets invested in rural areas, lines companies have to charge rural customers a higher $/kWh tariff for the electricity lines services. However, to date, most lines companies have been providing electricity services to rural customers at cross-subsidised rates, from urban customers. According to the provisions of the Electricity Act 1992, after 1 April 2013 a lines company can terminate its services to any customer to whom they cannot provide electricity lines services profitably. Thereby some rural customers face the risk of either having to pay very high line charges or loose their electricity supply.

Although stand alone remote area power systems and mini-grids are an option for rural communities who may become affected, staying connected to the grid while making use of local energy resources is a preferable option, provided economics allow. This is due to several benefits including better utilisation of renewable energy resources, greater supply reliability and improved voltage profile.

This research project was undertaken to provide analysis for policy makers, lines companies and rural investors on the viability of distributed generation in a rural setting and to provide recommendations concerning problem areas.

Although several commercial software packages are currently available to study the performance and economics of grid connected distributed generation systems, these are not capable of critically analysing distributed generation issues relevant to New Zealand. In particular such issues as

- impacts of diverse metering arrangements;
- time dependent electricity prices;
- benefits of peak shaving by load control and peak lopping by dispatchable distributed generation; and
- the effect of state subsidies;

are not addressed in the commercial software. For this reason, a dynamic distributed generation model was developed to simulate the above scenarios. In developing the model, an effort was made to include generic distributed generation scenarios that would be valid to the whole of New Zealand and not just to a given rural community.

II. METHODOLOGY

Data was collected from Totara Valley, which is a small rural North Island sheep and beef farming community situated at the end of a 26km long radial distribution feeder and used as a case study for several Massey University studies. The primary data collected for this research were the community demographic data, electricity supply and distribution data, real time load data, solar hot water temperature and flow data, photovoltaic data (grid connected), solar irradiation and ambient temperature data. Secondary data required for the model was collected from a variety of sources including Massey University research studies and publications.

In order to realize economies of scale, the metering of a single farm was assumed to be made through the secondary side of its dedicated transformer. Such metering was actually implemented on 3 transformers in the case study community, with a view to implement it for commercial purposes at a later point in time. It was observed that each transformer dedicated to a single property farm distributes electricity to several installation control points such as the farmhouse, cottages, woolshed, freezer shed and the workshop.

Three specific community scenarios were simulated using the model for different distributed generation (DG) and metering configurations. These were;

- Individual farm based DG applications
- Small community based centralised DG applications, and
- Medium community based centralised DG applications.

The size of the small and medium communities, in terms of the number of residential connections, was 32 and 50 respectively. Three metering configurations were also simulated:

- net metering,
- time of use gross import/gross export metering; and
- separate generation/load metering.

In addition, in cases where specific demand side responses are made in response to price signals from the lines company (e.g. operation of a dispatchable DG unit during critical peak periods), it was assumed that there would be a separate, ripple-activated meter to determine the firm capacity/energy supplied to the lines company. Although the computer model was designed to accommodate peak shaving through customer initiated load control as a demand side response, this was not simulated as it was not possible to identify loads of significant magnitude within the case study community.

III. Observations

Micro-hydro turbine

The model outputs showed that from a pure economic standpoint of the investor, only low cost micro hydro technologies would be economical for individual farm based applications. It was also observed for the micro hydro system, as simulated, that net metering was marginally more advantageous to the investor than gross import/gross export metering because of the steady flow of water (hence energy supply) all year round. The relatively low cost micro hydro unit derived its economic advantage through a very simplified electro mechanical technology that involves an induction generator and a reverse engineered water pump.

Small wind turbines

Small wind turbine generators could become acceptable in individual farm based applications only if the state subsidies for wind energy projects were provided, the site had a wind regime in excess of 7 m/s, and the investor also appreciated the social values of wind energy investment. For example if a zero interest loan was made available to finance a small wind project, a wind turbine generator was installed on an 8 m/s site and the farm load was net metered, then the farmer would have an incentive to opt for a wind turbine of 7 kW rated capacity, rather than a smaller one.

The simulations indicated that net metering is less attractive than gross import/gross export metering from a lines company perspective, but would only become a commercial threat in the shorter run if the state subsidised wind projects substantially to encourage implementation or if the cost of the system was reduced.

For community scale centralized applications, given a good wind resource availability, the economic viability of a small wind turbine was found to be dependent on three broad factors;

- whether the generation is separately metered or gross import/gross export metered (for payment purposes)
- state subsidies available and
- the size of the wind turbine generator.

The level per kilowatt of state subsidies required for community wind projects was found to be considerably less than for individual farm based applications, with larger wind projects requiring lower levels of subsidies. For this reason it was observed that, with the appropriate level of subsidy, community scale projects would enable larger capacity wind projects to be realised. The simulations also indicated that the capacity contribution made by wind turbine generators during critical peak periods would of value to both lines companies and investors. However due to the intermittent nature of the wind resource, the value would be of advantage only if the lines company is facing a capacity problem on a more regular basis.

Diesel generation

Simulations also suggested that the use of a diesel standby generator for any form of demand side response (either to take advantage of time of use tariffs or economic incentives provided by line companies for peak lopping) is not economical for individual farm based applications. However, simulations showed that peak lopping could become economical if low cost technologies are used, such as supplying firm capacity through an induction generator being driven by a diesel engine. The induction generator is attractive for small applications if a motor and its inter-connecting switchgear (starter, circuit breaker etc.) had previously been installed for some other economic activity and could be used with minor modifications.

The simulations indicated that the use of a diesel generator in excess of 50 kW for peak lopping, which is only realisable for community scale applications, is a very viable investment option. The larger the installed capacity of the generator the greater the return on investment.

Hybrid systems

Wind diesel hybrids were found to be more profitable than diesel only provided there is some form of state subsidy available for the wind energy component of the project. The simulations also showed that if subsidies are too great they would give lines companies an opportunity to exploit its monopoly position and reduce the rates they currently pay for firm capacity/energy supplied. It was assumed that the lines company would be willing to pay a fee as an annuity (i.e. a payment made every year) that is equal to the avoided marginal cost of capacity augmentation, after deducting a 10% margin to administer the payment scheme. If the 11 kV feeder to the community gets overloaded, it was found that a lines company could afford to pay up to $ 120.00 for each kW of capacity provided during the network overload periods.

Other dispatchable generation units

Simulations also indicated that small scale pumped hydro or a battery (deep cycle lead/acid) storage systems of the order of 15~18 kW would not be economical to provide firm capacity.

Solar systems

Application of photovoltaic (PV) systems was found to be uneconomic at current costs for PV panels, even though they have already been installed at Totara Valley, though this was for convenience rather than to determine an optimum system.

Analysis of real-time data on the installed solar hot water system suggested that it performs well in the summer and autumn (e.g. 27% efficiency in March), but diminishes in winter and early spring when the home occupants use their wetback stove for heating. The solar hot water system was also not designed to cater for the hot water needs of the laundry, which uses a separate electric hot water cylinder. Application and operation of a solar hot water system under such circumstances result in poor financial return on investment with only two permanent residents.

IV. RECOMMENDATIONS

In making recommendations on distributed energy related issues, an attempt was made to accommodate and reconcile the interests of the three key stakeholders; the investor, the lines company and the state.

A potential investor's lack of understanding in order to evaluate different distributed energy options was identified as the most critical problem. This causes small-scale investors to build an extra risk premium which undermines the uptake of DG, because distributed energy projects currently do not generate adequate cash flows to cover the risks. It is recommended that in addition to advising potential investors on the various renewable DG options, they should also be encouraged to select the best renewable energy option to suit the relevant circumstances. For this purpose, it is necessary to list the key decision variables and illustrate how those affect the decision outcome (i.e. the optimum technology combination). In addition to renewables, communities should also be advised on possible opportunities to provide firm capacity (or firm energy) to the lines company and the technology options available to achieve this.

The social benefits of rural distributed energy projects is important for rural investors to consider to create a utility (satisfaction). This would bring a salutary effect in influencing their investment decisions. Any social benefits should be quantified and made as objective as possible.

Establishment of a demonstration community owned, grid connected, distributed generation scheme is a strategy that could be implemented to educate the public on the benefits of renewable energy. Only well informed citizens would be able to best utilise any subsidies in order to maximise personal investment objectives. This in turn would serve to meet the state's objective of maximising the uptake of renewables at the lowest cost.

At current costs state subsidies would be vital to maximise the uptake of small-scale grid connected renewable DG applications.

From a lines company perspective, it is myopic to view DG as inconsequential. Small-scale renewables, technological growth and regulatory control can cause risk to lines companies unless they appreciate the benefits of DG and device plans to manage it. As a general rule, it is recommended that lines companies accommodate small scale DG with minimum charge for inter-connection. As DG is introduced to the network, lines companies can commence gradually removing any cross-subsidies built into rural connections so that part of the foregone revenue owing to rural DG projects could be recovered from rural customers who benefit from DG. It also provides an incentive for rural entrepreneurs to undertake distributed energy projects. At a later point in time assuming an increase in the uptake of DG and lowering of the technology costs, lines companies could introduce inter-connection charges for new DG projects.

For a lines company facing capacity problems, as an alternative to capacity augmentation, it can pay an annuity to DG owners to provide firm capacity/energy at the rate of avoided marginal cost of capacity investment. A lines company could use its monopoly position and reduce this annuity over time, depending on other factors such as carbon credits or subsidies for renewables. A prudent way a lines company could handle community scale centralised DG projects would be to stipulate metering systems that do not directly affect their revenues and device tariffs, which take into account capacity drawn during critical peak periods.

Low cost micro hydro, diversification of the use of the induction generators, voltage flicker on weak distribution networks due to wind turbine generators (and methods of minimising it including the possibility of using wind/diesel hybrids), wind resource assessment (also making wind data available through a geographic information system), devising accurate DG performance producing and economic forecasting tools were the key areas identified as future research areas.

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