Interconnecting Distributed Generation (DG) to the Ontario Electrical Grid – A Biomass DG Case Study

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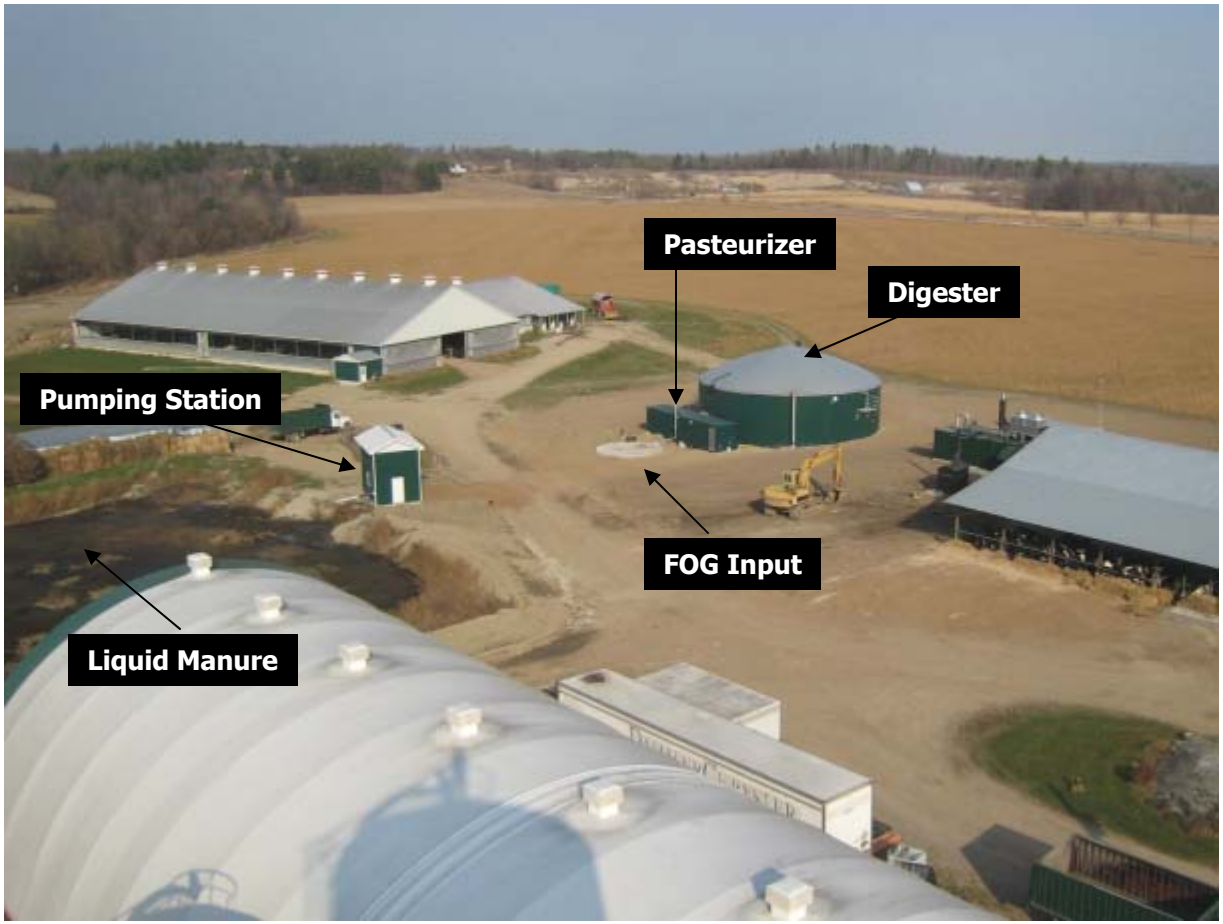
Typical Biogas Investor
Ben Green – Ledgecroft Farms

Ledgecroft Farms Fact Sheet

- Dairy Farm – 1100 Acres Tillable, 300 Acres Non-tillable
- 230 Milking Cows, 270 Heifers & Calves
- >$1M in Farm Machinery
- Two Full Time Employees, Three Seasonal Employees
- Three Family Members Involved Full Time
- Investment for Biogas Facility $2.5M-$3.0M

Ledgecroft Farms Site



Input System

Pastuerizer

Complete System

Generator, Transformer, OH Line

Electrical Building

Point of Common Coupling

Environmental Benefits of Biogas Generation

- Environmentally Safe Disposal Process for Restaurant Waste, Food Processing Waste & Manure
- End Product Is Odor Free, Environmentally Friendly Fertilizer
- Consumes Methane Gas That Otherwise Be Escaping Into the Atmosphere

Advantages of Biogas Generation

- Available 24/7
- Very Short Start Up Time –Therefore Dispatchable
- Locations Are in Prime Farm Land Where Rural Loads Are Higher & Generation Required
- Storage Capability

Existing Ontario Electricity System

- Sub-transmission System Supplies Distribution Stations (DS)
- Distribution Voltage Levels Range from 4.16 kV – 27.6 kV.
- Most Sub-transmission Lines Supply Loads Only (Unidirectional Power Flow)
- Small Number of Generators 10 MW and Below Connected to Sub-transmission

Typical Ontario Transformer Station (TS)

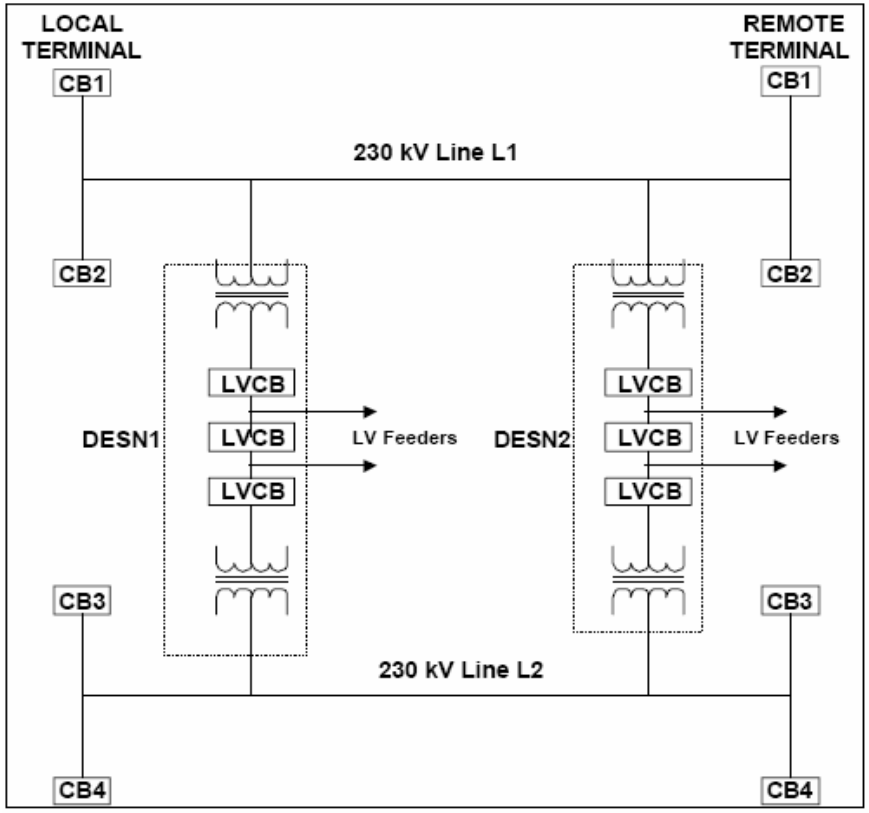
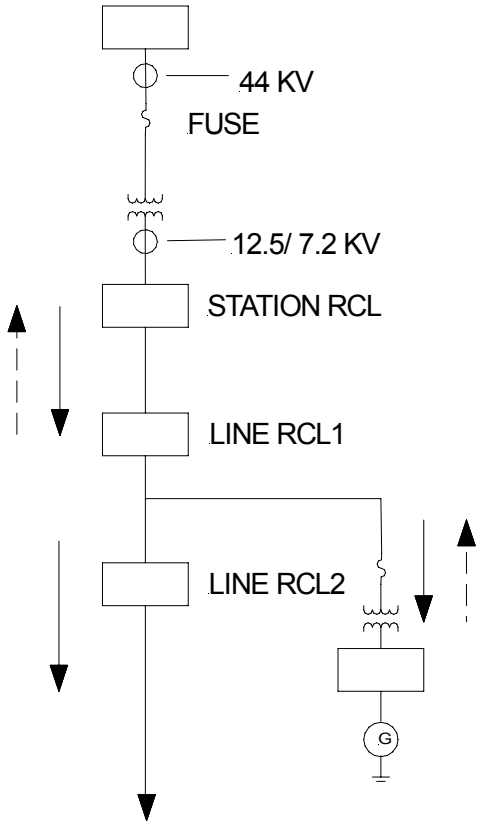


Figure 1 : Two Terminal, Two DESN, 1-Line Diagram

Rural Electricity System Load & Generation

- 44 kV/12.47 kV Fuse Protected Station Transformer
- Reclosers Typically Single Phase Kyle
- Four Wire Distribution
- DG Generating at 600 V



Rural Electricity System Load & Generation Issues

- Issues (from a Utility perspective)
  - Tripping DG for Line Faults
  - Impact on Reliability to Existing Customers
  - Equipment Damage if Island Forms
  - Non-detection Zones for Anti-islanding Protection
  - Equipment Damage due to Out-of-Phase Reclose

Hydro One Requirements for Small Biogas DGs

- Requirements to Connect
  - Island Operation Not Permitted Due to Concern for Equipment Damage & Liability
  - Transfer Trip Required from All Reclosers and Circuit Breakers to Prevent Island Operation & DG Feeding Faults
  - Directional Relaying Required to Prevent Tripping of Upstream Reclosers for Upstream Faults on The Feeder or Faults on Adjacent Feeders
  - Net Result for 500 kW Generator at Ledgecroft Farms $700K-$800K in Upgrades to Connect

Examination of Issues & Requiremets

- Use of Anti-islanding Protection Schemes as an Option to TT is Non-deterministic. Therefore, Unacceptable.
- Potential for Damage to Recloser due to Out-of-Phase Reclose for Small DGs Overstated – Fault Current Below Recloser Rating
- Most Reclosers are Single Phase Electro Mechanical with No Auxiliary Switches for Position Indication To Key TT Transmitter (TTX). Reclosers Must be Replaced with Modern Reclosers with Auxiliary Switches to Key TTX
- Adding Directional Relaying Requires Replacement of Recloser
- All Reclosers On Feeder Must be Replaced to Add TT and Directional Relaying. $150K-$200K per Recloser

Customer Impact on Reliability of Adding DG

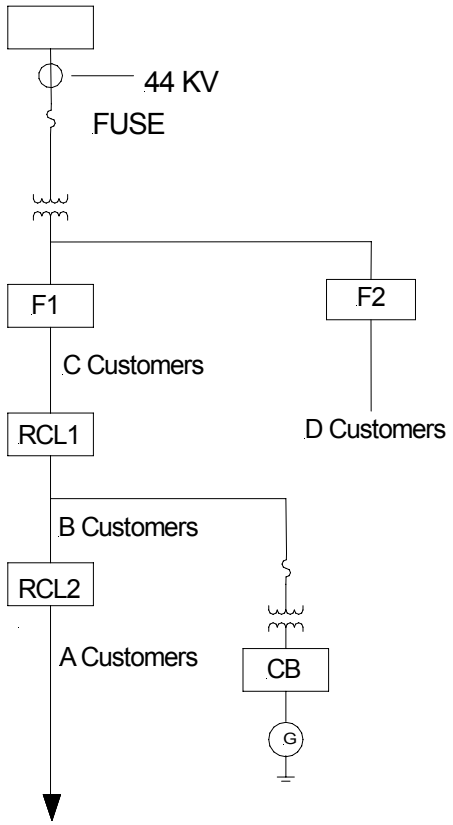
Fault @ A, Higher SC Current, DG Trips, RCL2 Trips, RCL2 Recloses, No Impact

Fault @ B, DG Trips, RCL1 Trips, RCL1 Recloses, No Impact

Fault @ C, DG Trips, F1 Trips, RCL1 Trips, F1 & RCL1 Reclose, No Impact

Fault @ D, DG Trips, F1 & F2 Trip, RCL1 Trips, F1, F2 & RCL1 Reclose, Customer Impact

Directional Relaying Only Required if DG Causes Trip on Resident Feeder for Fault on Adjacent Feeder



Protection Proposal to Resolve Issues - 1

- Use Line Protection Designed to Detect All Faults on the Feeder
- Protection is Biased to Allow Over-tripping. Over-tripping Acceptable, Failure to Trip Unacceptable
- Line Protection 100% Deterministic, Fault Levels Readily Calculated, Well Understood in the Industry
- DG Will Trip for All Faults Eliminating Concern for Power Quality to Customers in Island and Out-of-Phase Reclose

Protection Proposal to Resolve Issues - 2

- Island Formation Only Possible With Operating Error. Recloser Opened Manually With DG On Line
- Use Multiple Anti-islanding Techniques to Mitigate Non-Detection Zones. Non-Detection Zone Essentially Becomes 100% Match of DG Output and Load
- If Probability for Operating Error is 1 Out of 1000, and the Probability of Error Occurring in a Non-Detection Zone is 1 Out of 1000,Then Probability of Sustaining Island Becomes 1 Out of 1,000,000

Line Protection Implementation

- Use High Z Grounding of Generator to Reduce Ground Current
- Detect Ground Faults on Feeder by Measuring Current Through Ground Resistor
- Use LV Instrument Transformers
- Isolate DG by Tripping LV Circuit Breaker

Line Protection Description

- Protection Elements
  - Phase Instantaneous Directional O/C. Forward for Line Protection, Reverse for Generator BU
  - Phase Non-Directional Timed O/C for Overload Protection
  - Instantaneous Negative Sequence O/C for Phase and Ground Faults
  - Ground Instantaneous O/C for Ground Faults

Anti-islanding Protection

- Anti-islanding Protection Elements
  - Two Levels of Phase Over Voltage
  - Zero Sequence Over Voltage
  - Negative Sequence Over Voltage
  - Two Levels of Under Voltage
  - Two levels of Under Frequency
  - One Level of Over Frequency
  - Rate-of-Change-of-Frequency
  - Reactive Power Shift

Power Quality Monitoring

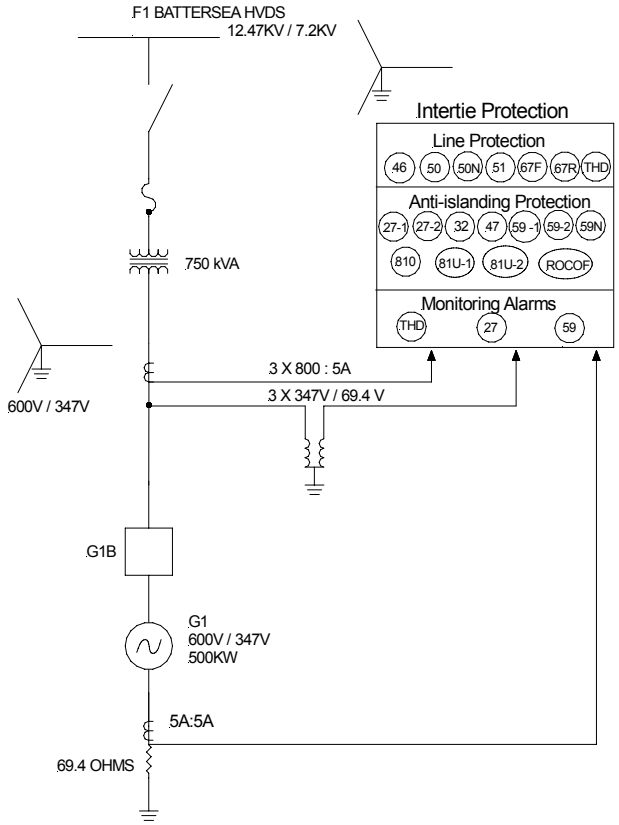
- THD Voltage Alarm
- Under Voltage Alarm
- Over Voltage Alarm
- Zero Sequence Over Voltage Alarm
- Negative Sequence Over Voltage Alarm
- Instantaneous & Momentary Sag
- Instantaneous & Momentary Swell

Data Logging

- Per Phase Voltage & Current
- THD on Voltage
- Zero Sequence Voltage
- Negative Sequence Voltage
- Zero Sequence Current
- Negative Sequence Current
- Three Phase Watts, Vars, VA
- 16 Channels Total, Sample Rate 15ms-1Hr

Single Line Diagram of Approved Application

- No HV Circuit Breaker
- No HV Instrument Transformers
- No Transfer Trip
- Line Protection Plus Anti-islanding Protection Adequate

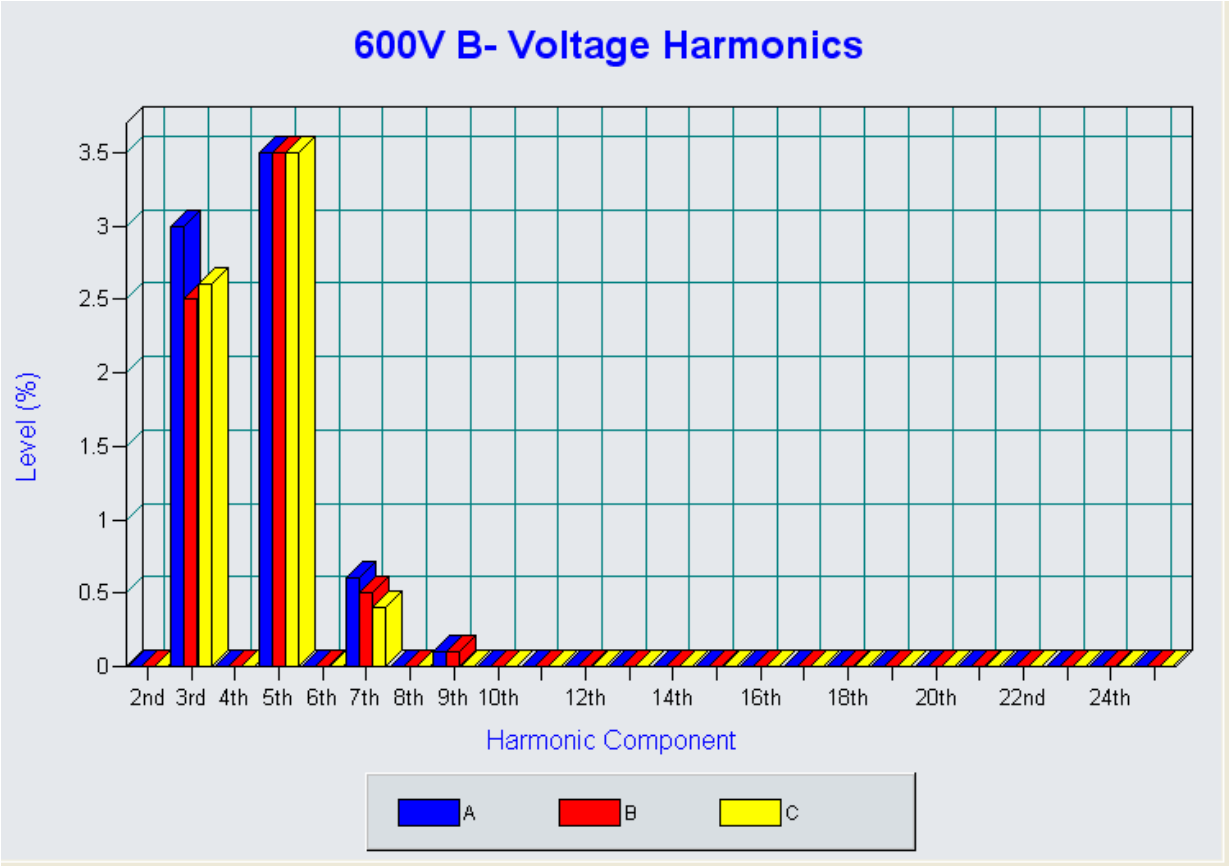


GE-F60 Feeder Relay

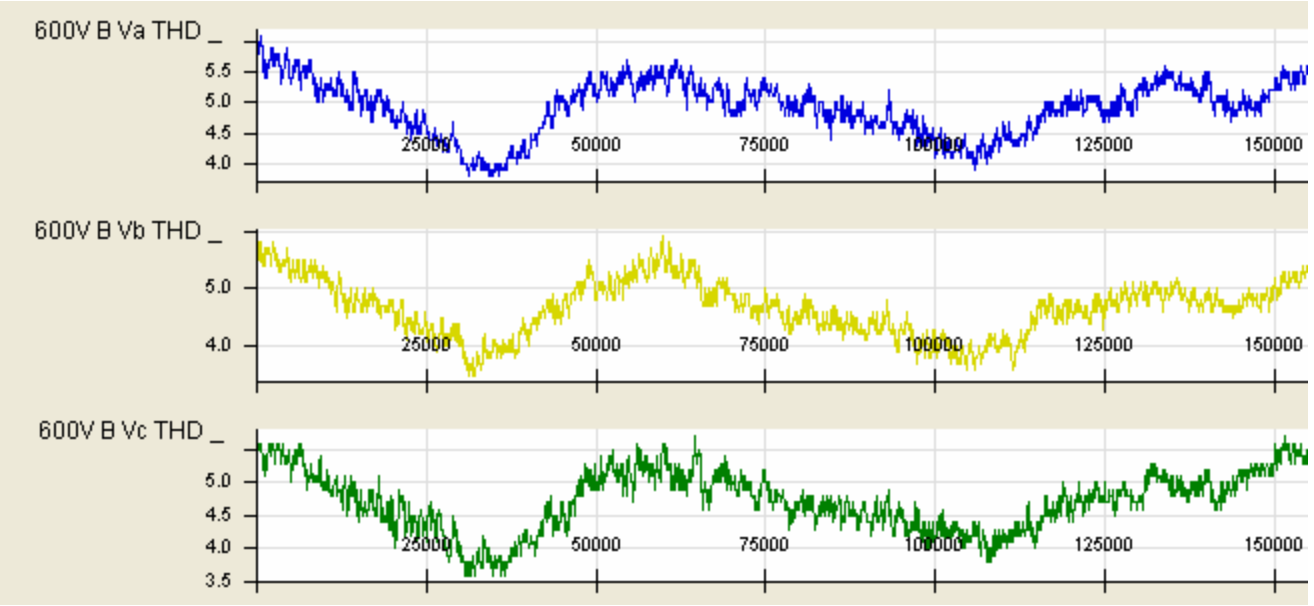
Extrapolation to Larger DGs

- For Larger DGs
  - HV Circuit Breakers, HV Instrument Transformers, or TT, if Required, Drive Interconnection Costs Up Significantly
  - Damage To Utility Equipment Due To Out-of-Phase Reclosing May Be An Issue
  - Directional Relaying May Be Required
  - Challenge – Maintain Equivalent Level of Protection at Lowest Possible Cost

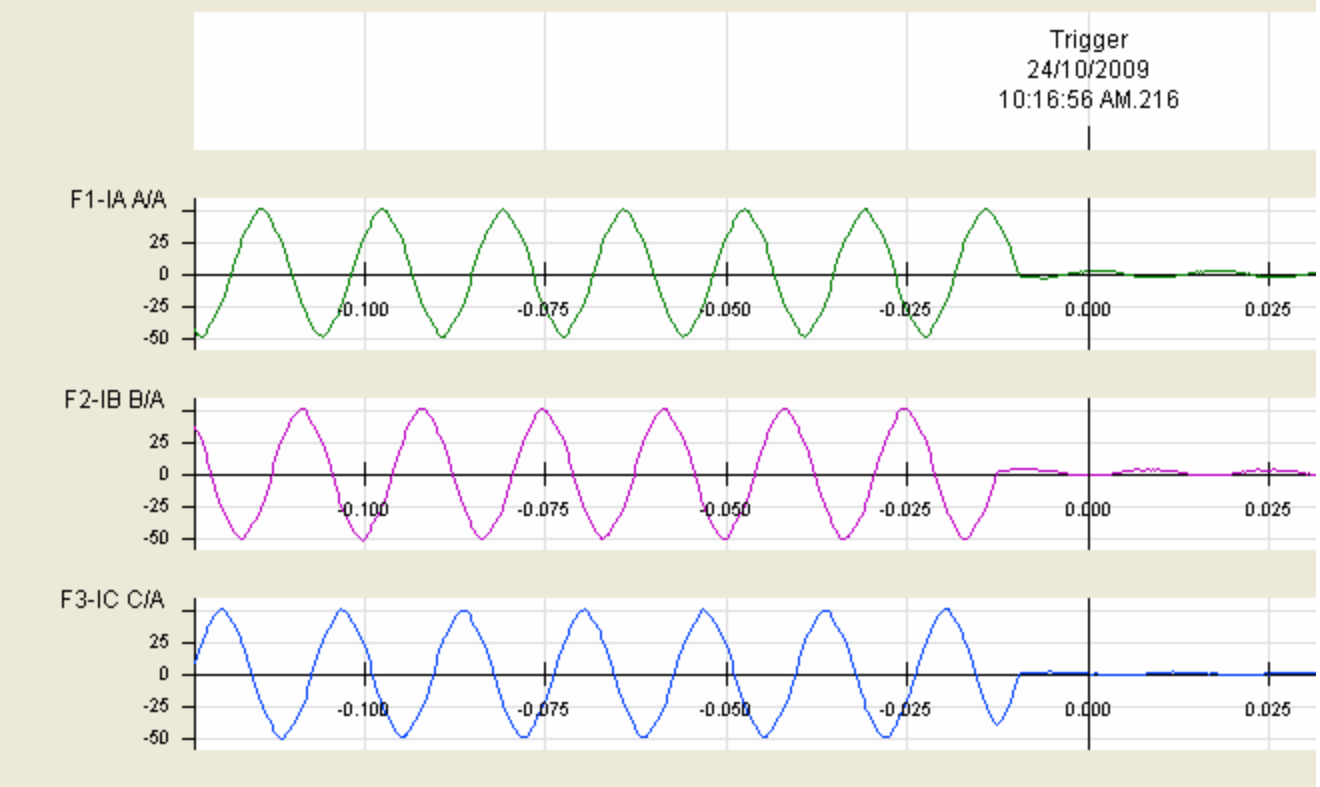
Implementation - High THD on Voltage



Data Logging Profiles THD



Troubleshooting Tools - Oscillography



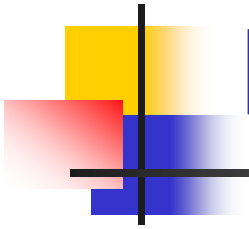
Trouble shooting Tools – Event Records

1946	Oct 23 2009 01:36:10.484317	PHASE UV1 DPO B
1945	Oct 23 2009 01:36:10.109495	THDTRP DPO
1944	Oct 23 2009 01:36:10.080343	PHASE UV2 DPO B
1943	Oct 23 2009 01:36:10.076178	THDTRP PKP
1942	Oct 23 2009 01:36:10.076178	THDALM OP
1941	Oct 23 2009 01:36:10.076178	THDALM PKP
1940	Oct 23 2009 01:36:10.061606	Osc Trigger Off
1939	Oct 23 2009 01:36:10.059521	UV ALARM Off
1938	Oct 23 2009 01:36:10.059521	NEG SEQ OV1 DPO
1937	Oct 23 2009 01:36:10.059521	UVALM DPO
1936	Oct 23 2009 01:36:10.055353	PHASE UV2 PKP B
1935	Oct 23 2009 01:36:10.055353	PHASE UV1 PKP B

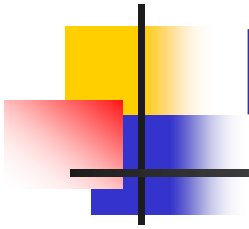
Implementation- Other Issues

- Generator Tripping on Negative Sequence Current
- Utility Standards and Generator Supplier Standards May be Incompatible
- No OPA Contract

Network Connectivity Requirements



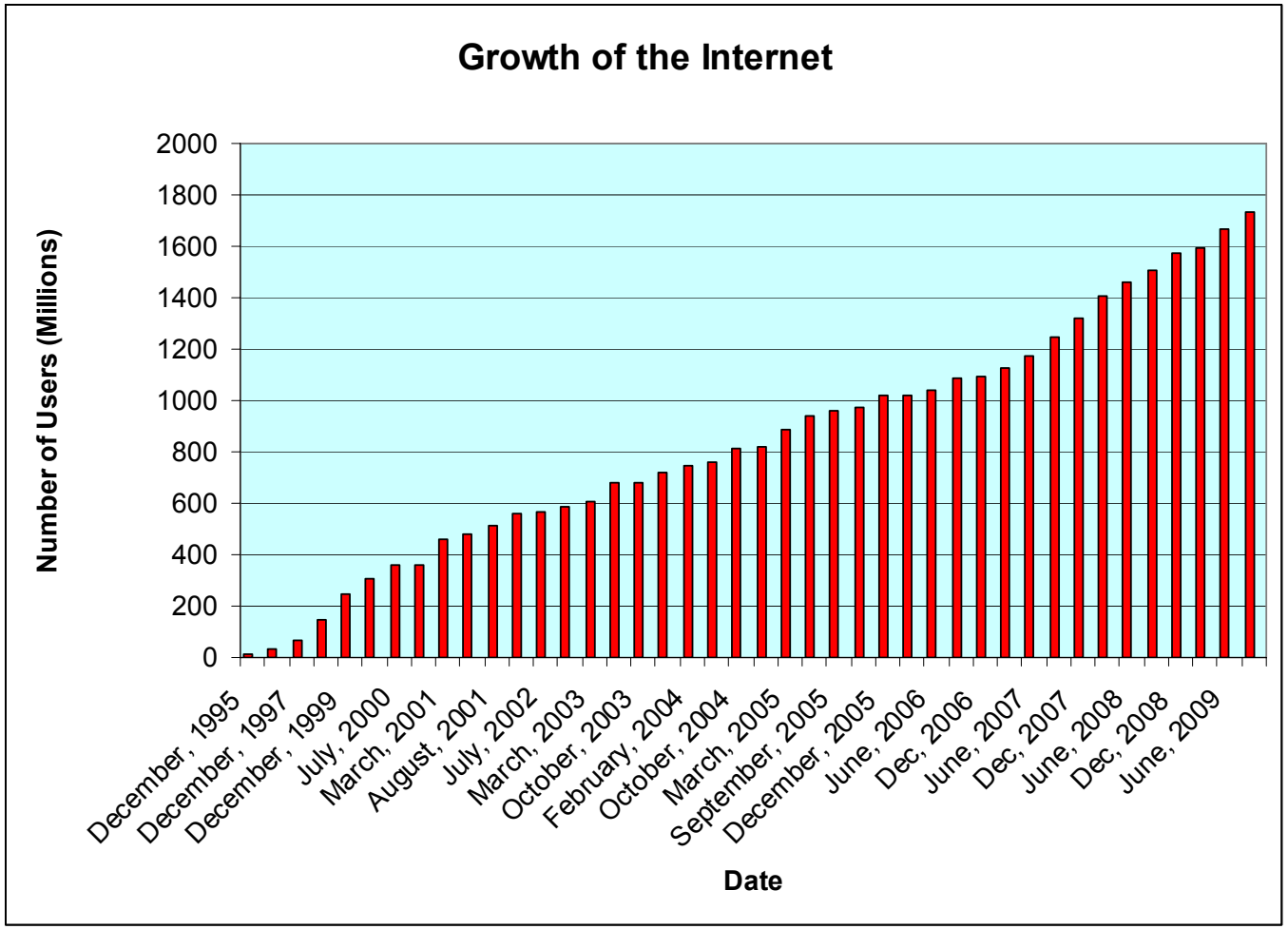
- LAN (Local Area network) connectivity
- WAN (Wide Area) Connectivity
- Communication network security
- Communication network reliability
- Communication network performance
- Communication network technology



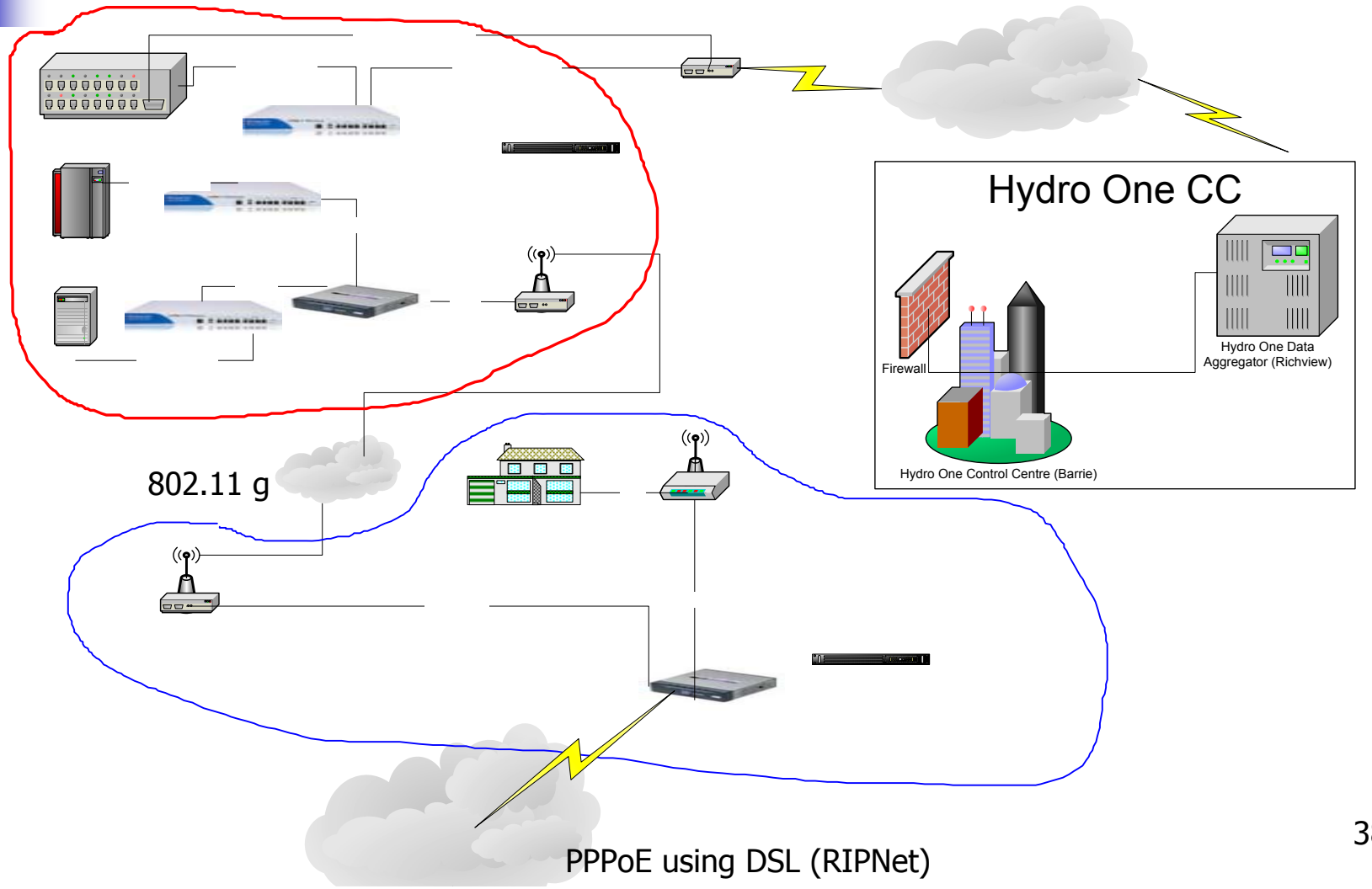
Network Selection

- Growth of the Internet since 1996 through 2009 was truly rapid
- Reaching a staggering 1,734 *million*
- 25% of the world's population

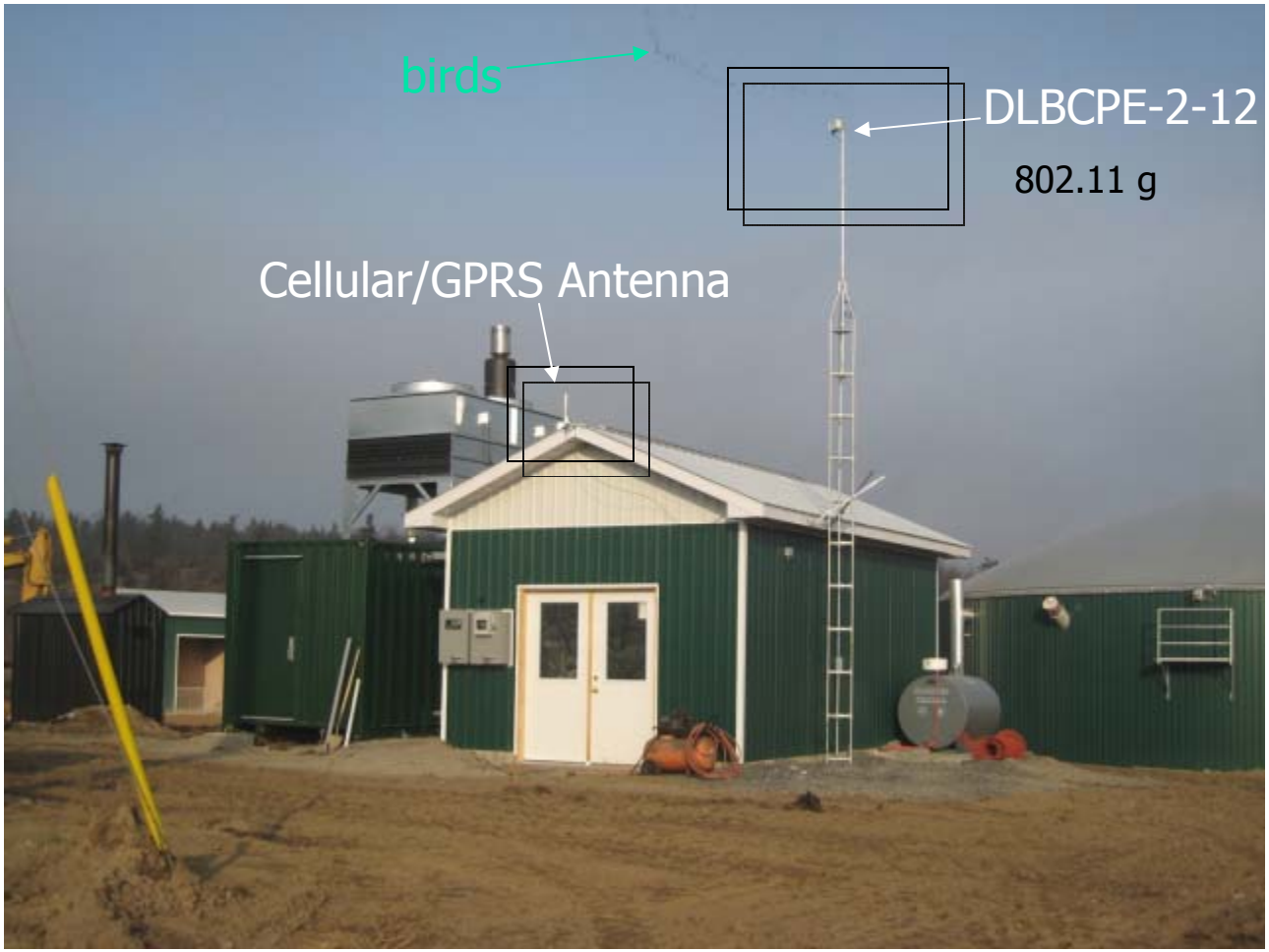
Growth of the Internet



Internet the Natural Choice

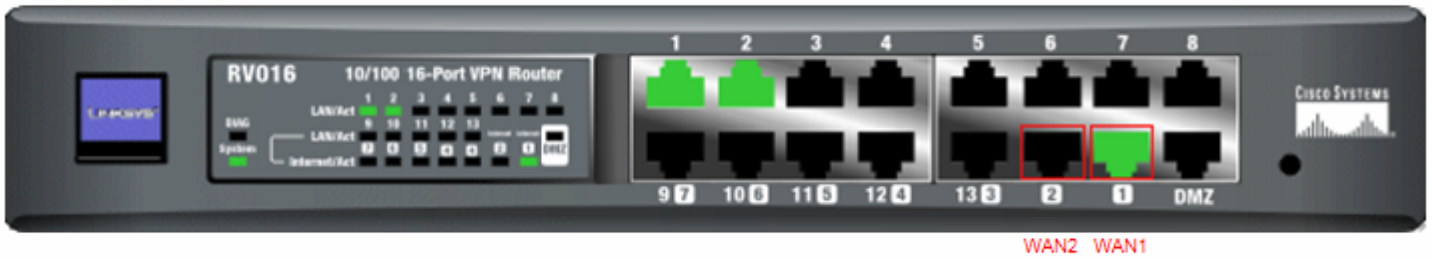


Electrical Building / VPN LANs



VPN LANs Remote Monitoring

VPN Router (e.g. for F60 LAN)



Managed WAN Switch (e.g. bridging all VPN routers)

SRW2008

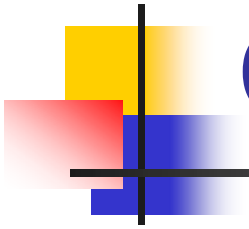
Link Down Link Up Administratively Down

Conclusions

- Small DGs Do Not Require TT & DIR Relaying
- Cost Effective Means For Protection & Monitoring Are Readily Available
- Power Quality Is A Concern In Rural Areas For The DG (Supplier) And the Utility (Provider)
- A Properly Architected Internet Solution Can Easily Meet Connectivity And Security Requirements

Recommendations

- Need to Develop Definitions and Limits That Are Practical For Power Quality And Performance In Rural Areas
- Need to Continuously Monitor Power Quality and Protection Performance At the DG & Utility Supply Sites Before and After DG Is Installed
- Need to Monitor The Performance of the Communication Links, Including Internet, Intranet Between the DG And All Stakeholders.
- Additional Study is Required to Extrapolate Protection and Control Practices for Small DGs Connected to the Distribution System



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