

Manitoba HVDC *Research Centre*

IEEE Power & Energy Society

*A Computer Vision Early-Warning Ice
Detection System for the Smart Grid*

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February 28, 2012 IEEE PES Luncheon Meeting

Winnipeg Canada



Presentation Agenda

- Introduction
- Ice Detection System (IDS) Overview
- Hoarfrost Detection Development
- IDS Current Status
- A New Tool For The Smart Grid
- The Future Of The IDS

Introduction: The MHRC

The Manitoba HVDC Research Centre (MHRC) is a division of Manitoba Hydro International Ltd. (MHI), a wholly owned subsidiary of Manitoba Hydro (MH).



Introduction: Ice Can Damage Overhead Conductors



Introduction: Ice Melting

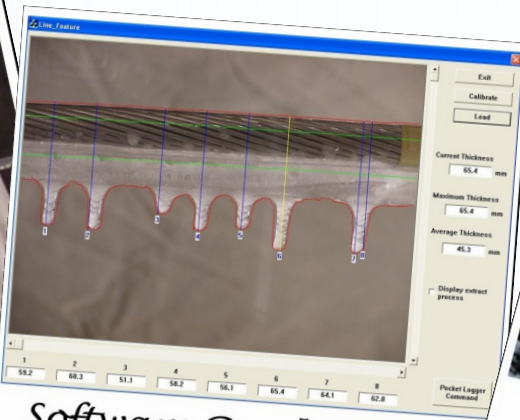


Introduction: IDS Timeline

- 2004 - MH R&D Committee and MHRC jointly developed the concept that ice could be detected on overhead lines using a vision based system
- 2004 - MHRC worked with the University Of Manitoba and the department of Virtual Reality (Dr. Qingjin Peng) on the Line Feature program
- 2006 - A complete prototype was built by MHRC and deployed for testing in Minnedosa (under the supervision of Monty Peckover, MH)
- 2008 – MHRC improved the design of the IDS and 23 stations were delivered to MH
- 2009 - First production stations installed by MH



Lab testing



Software Development



Prototype Installation

Current Ice Vision Stations in Manitoba

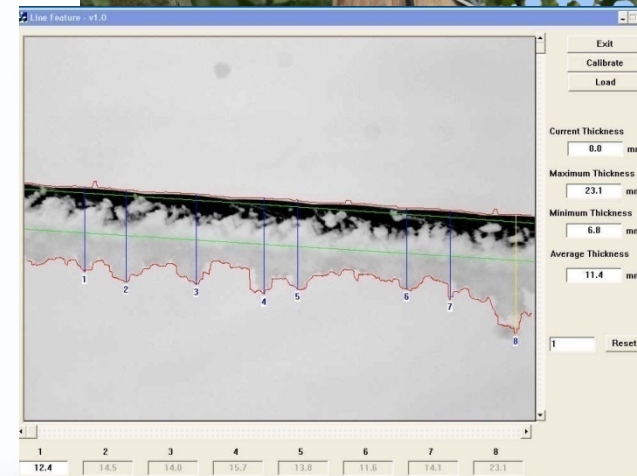


★ Installed
February 2012

★ Pending

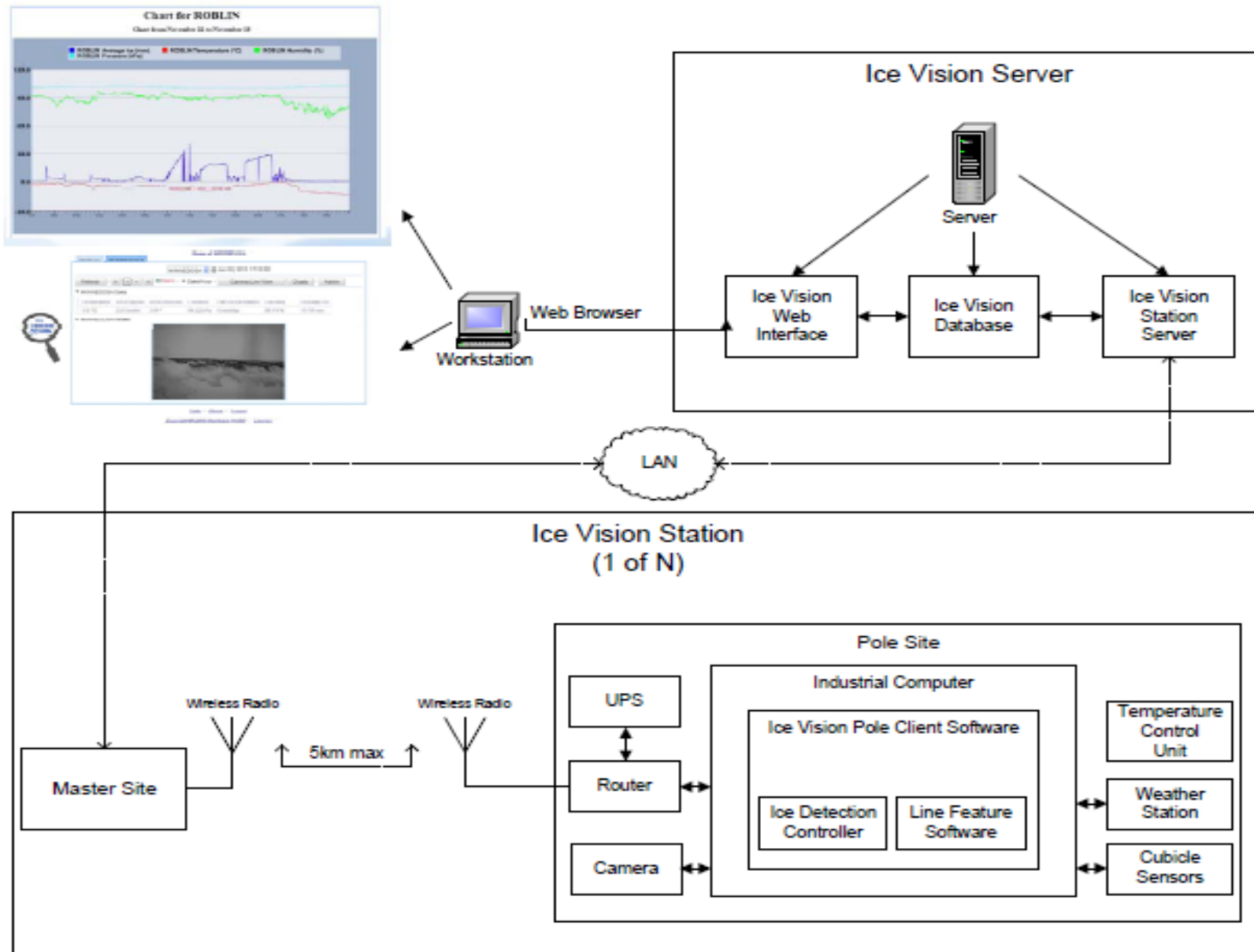
IDS Overview: Fact Sheet

- A vision-based ice accretion detector developed in collaboration with the University of Manitoba Virtual Reality Laboratory (MH research project)
- Utilize a vision recognition technique to automatically and autonomously measure ice profiles directly on the conductors of overhead lines
- Useful for assessing and prioritizing ice mitigation resources (Distribution Ice Melting Program)
- Quick remediation saves on wear and tear of infrastructures under icing conditions



IDS Overview: System Highlights

- Accurate measurement of ice profiles directly on live conductors, automatically and autonomously
- Collection of weather data including: temperature, wind (speed and direction), humidity, precipitation, atmospheric pressure
- Wireless communication for remote access, control and configuration of system
- Central storage of information and web-based data presentation
- Alarms via email or SMS text messaging. Alarms also Interfaced into MH Supervisory Control Centre SCADA.
- Real time picture of the conductor
- Graphing and trending of historical data



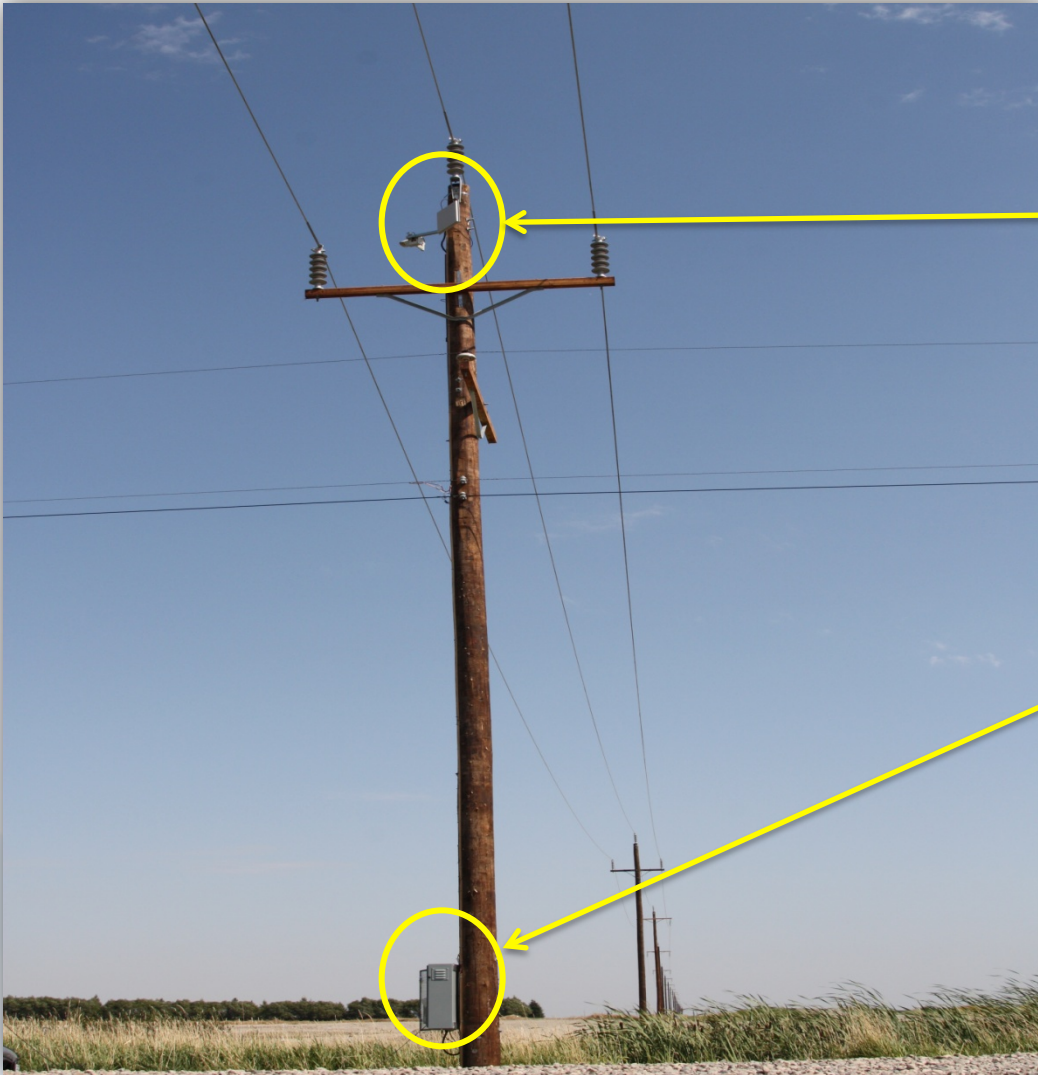
Ice Vision System Block Diagram

IDS Overview: Pole Equipment

As installed near St. Leon

Digital camera, Antenna
and Weather station

Electronics cubicle



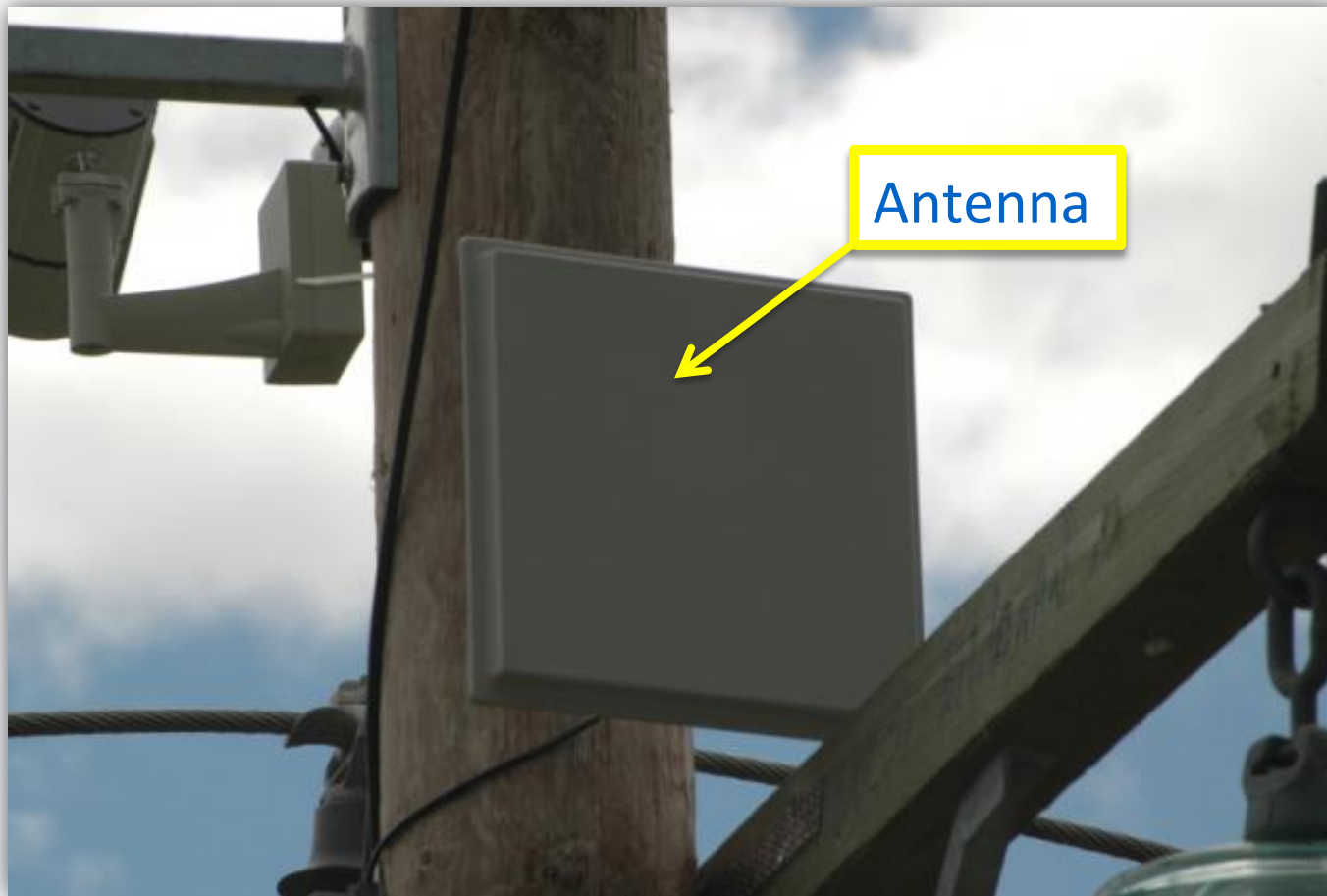
IDS Overview: Pole Equipment

Digital Camera

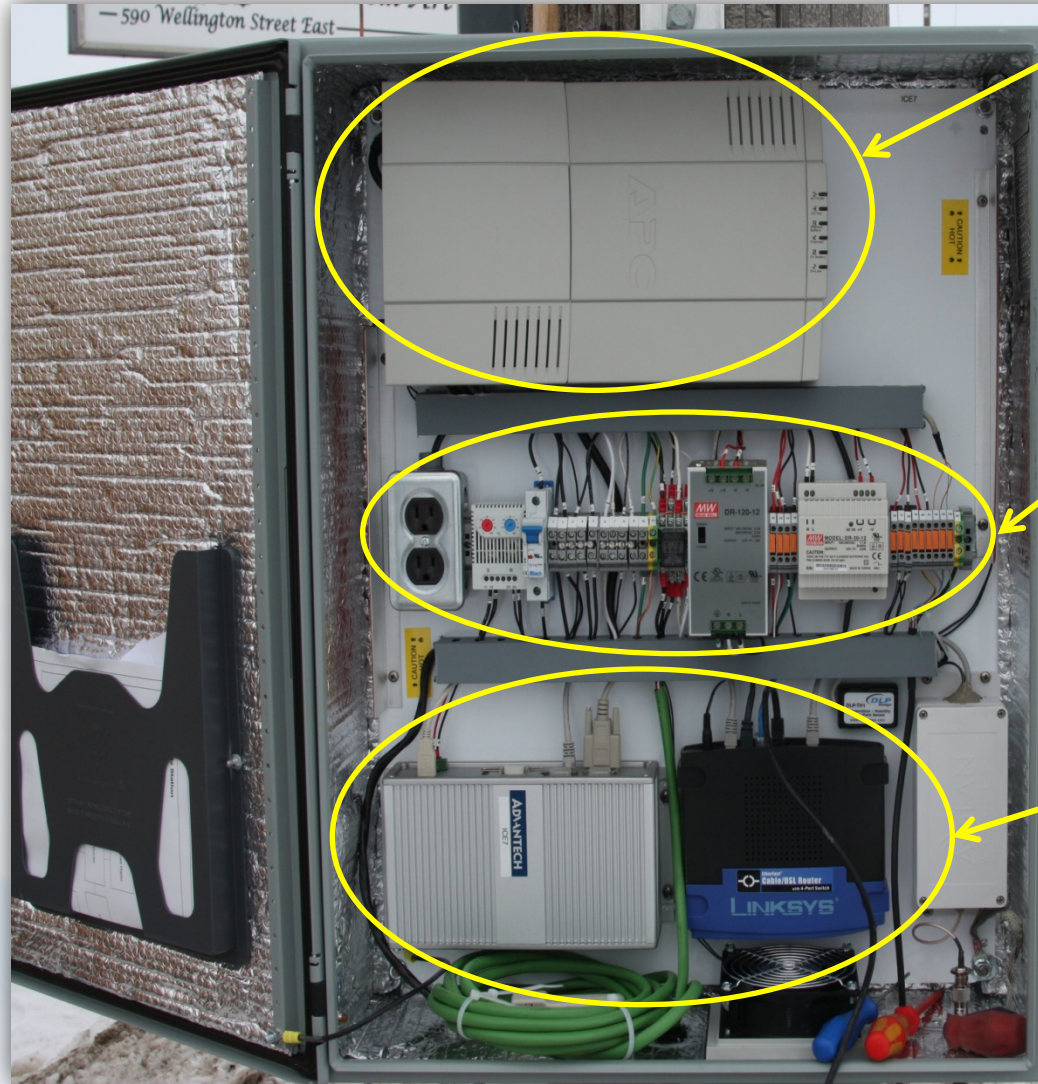
Weather Station



IDS Overview: Pole Equipment



IDS Overview: Pole Equipment

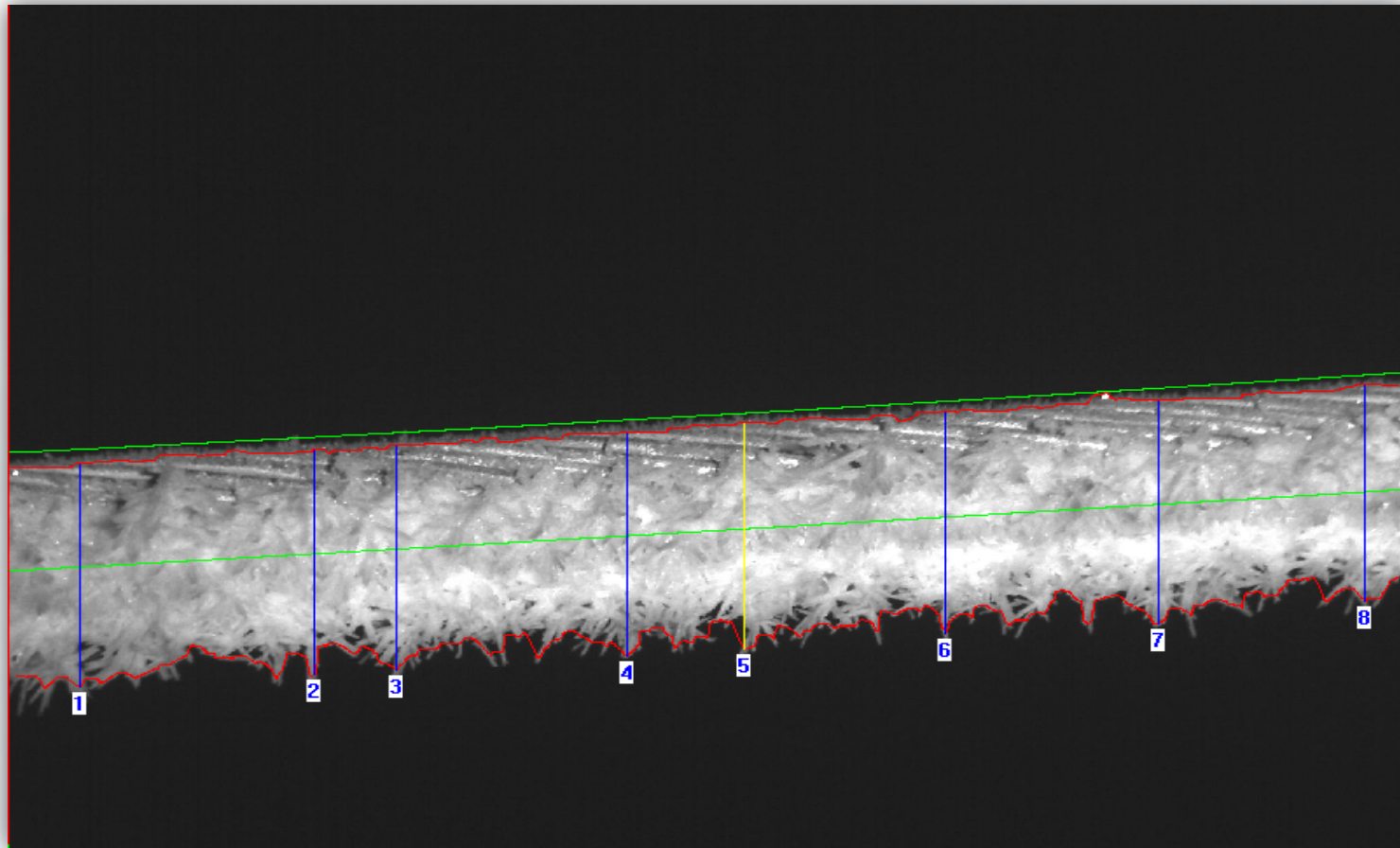


UPS
(Uninterruptible Power Supply)

Wiring, Power supply
cabinet temperature

CPU, Router, &
wireless
communications

IDS Overview: Line Feature Software



IDS Overview: Web Server Interface



Status of MINNEDOSA

Stations **MINNEDOSA**

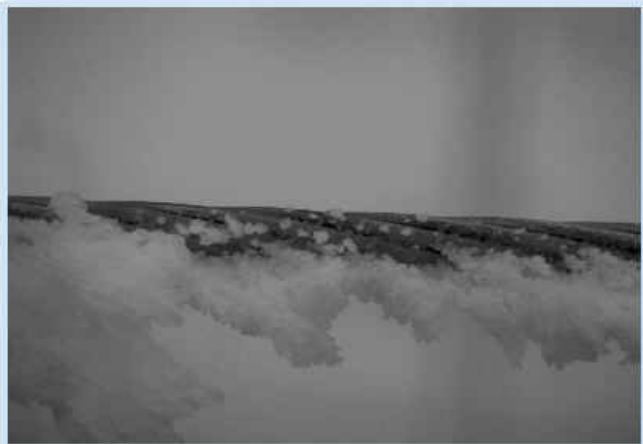
MINNEDOSA @ Jan 22, 2010 17:10:36

Refresh - |< < > >| Alarm - ▶ Date/Hour - Camera Live View Charts - Admin

▼ MINNEDOSA Data

Temperature	Wind Speed	Wind Direction	Pressure	Rain Accumulation	Humidity	Average Ice
-3.5 °C	23.5 km/hr	105 °	94.22 kPa	0 mm/day	95.19 %	10.16 mm

▶ MINNEDOSA Health



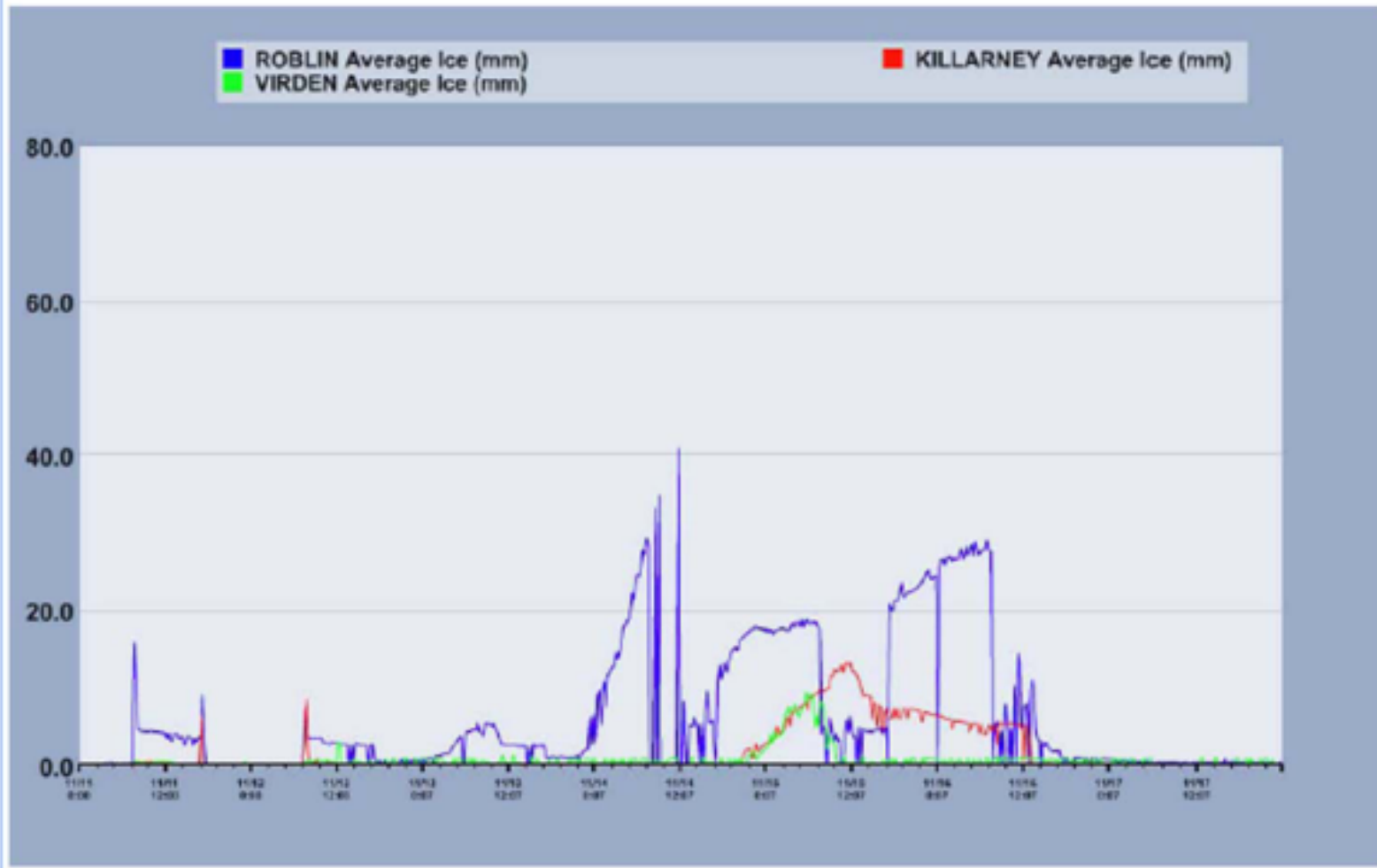
[Help](#) - [About](#) - [Logout](#)

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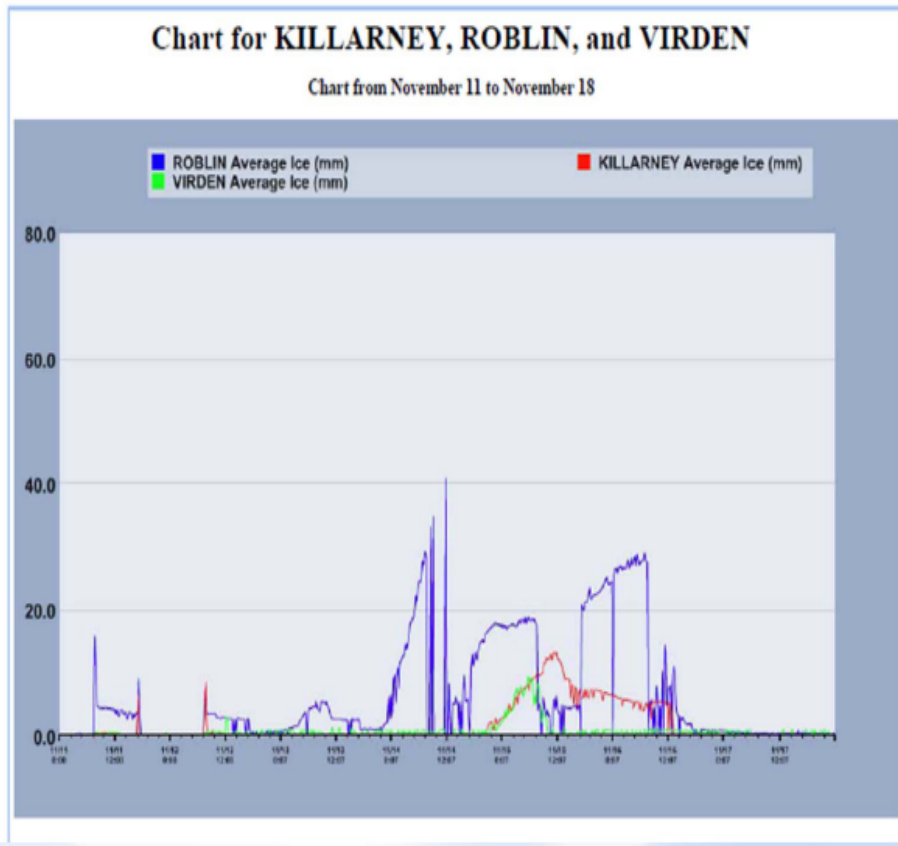
Ice Vision User Chart

Chart for KILLARNEY, ROBLIN, and VIRDEN

Chart from November 11 to November 18



IDS Overview: Web Server Charting



Roblin Station

Manitoba Hydro 66kV Line

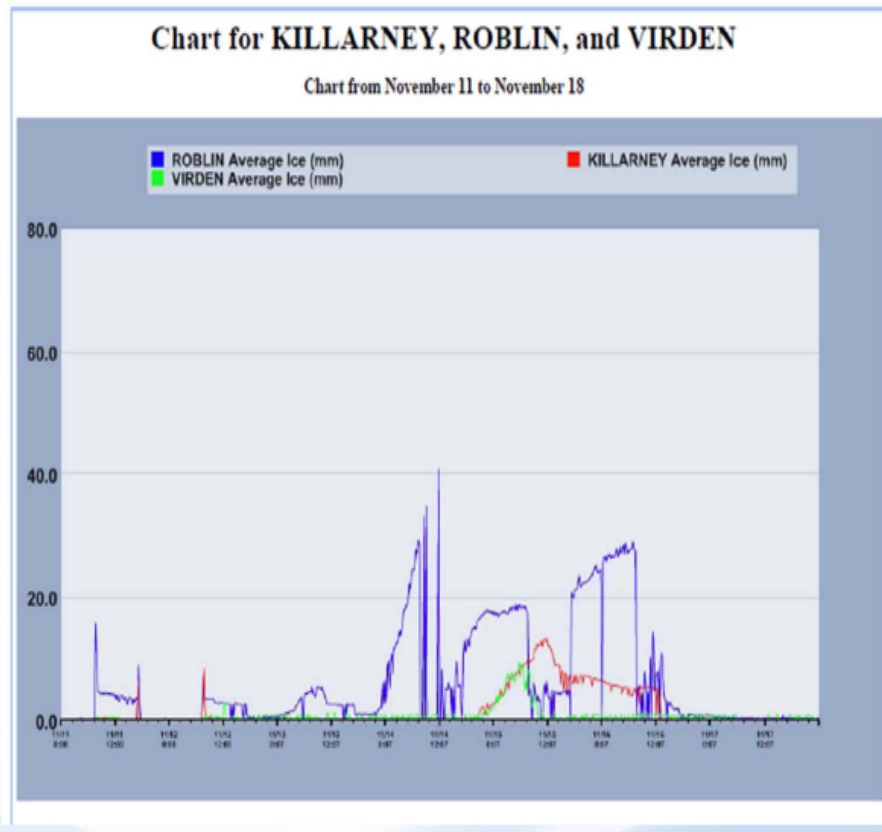
From: 05:30am, November 11, 2011

To: 12:52pm, November 17, 2011

Hoar Frost/Ice Formation



IDS Overview: Web Server Charting



Virден Station

Manitoba Hydro 66kV Line

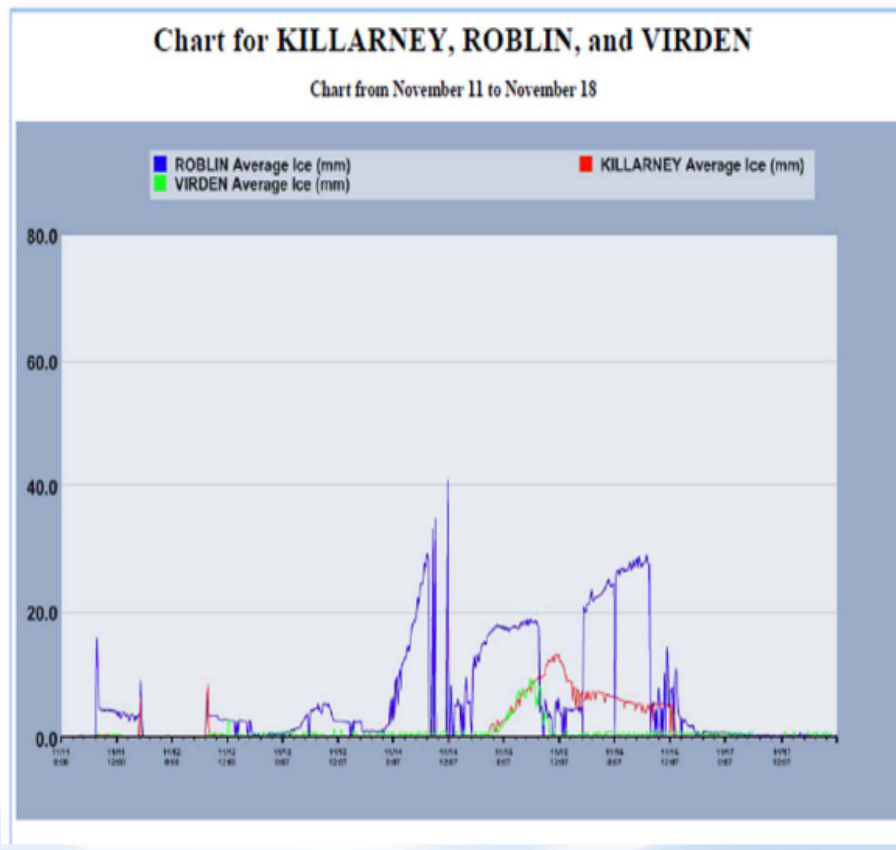
From: 12:14am, November 14, 2011

To: 11:59pm, November 17, 2011

Hoar Frost/Ice Formation



IDS Overview: Web Server Charting



Killarney Station

Manitoba Hydro 66kV Line

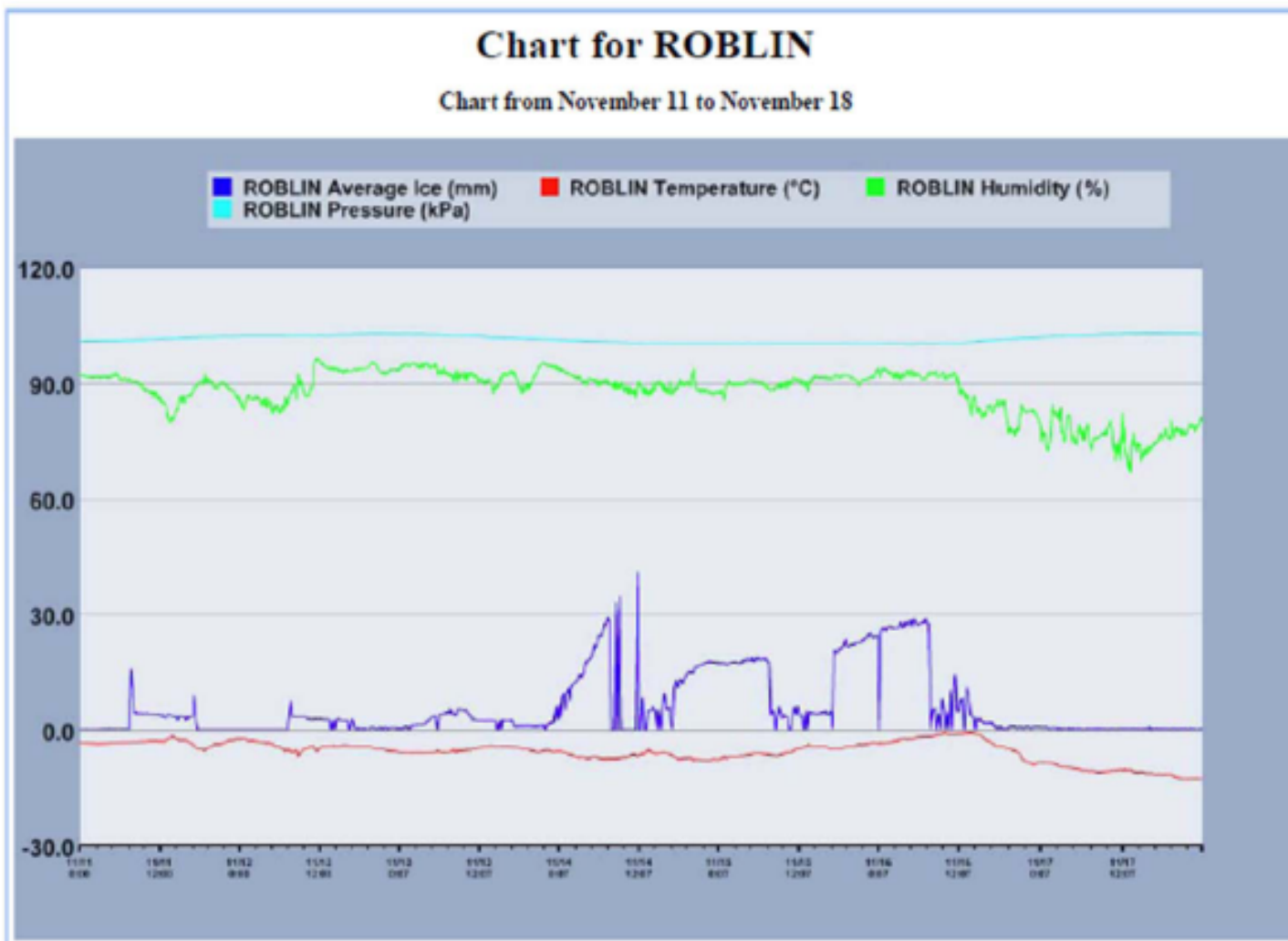
From: 12:12am, November 14, 2011

To: 11:57pm, November 17, 2011

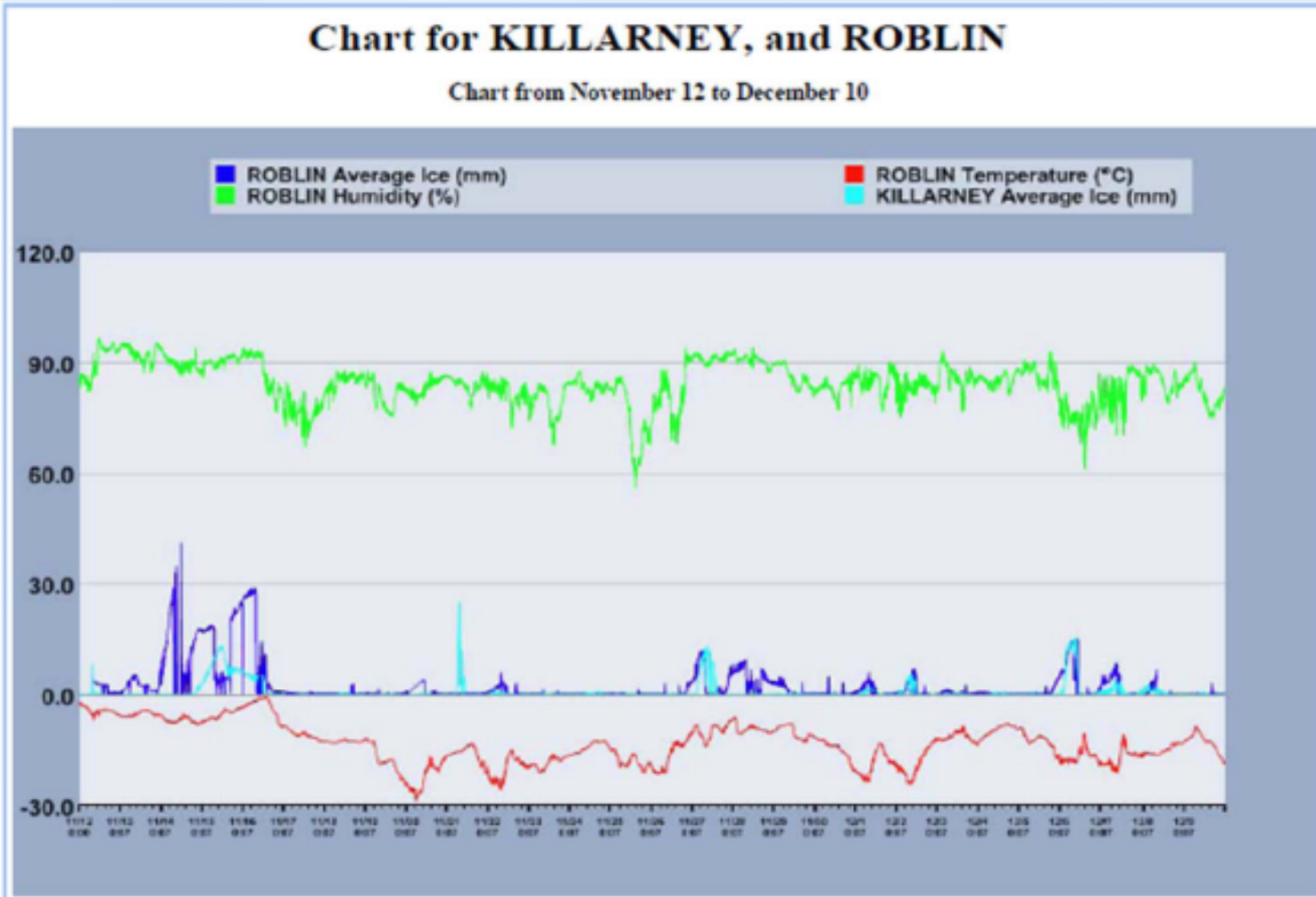
Hoar Frost/Ice Formation



Ice Vision User Chart

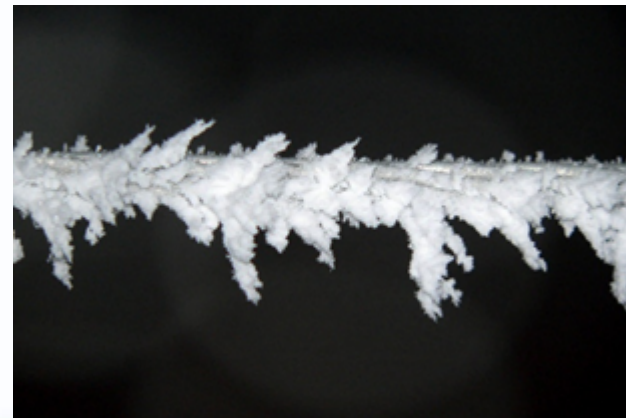
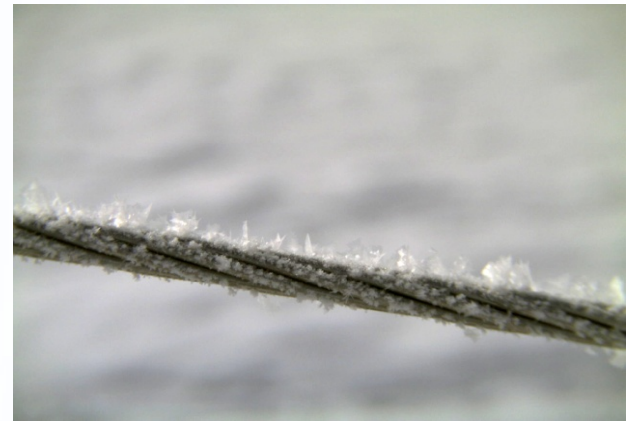


Ice Vision User Chart



Hoarfrost Detection

- Hoarfrost is lighter and more fragile than Ice BUT: it can turn into ice very quickly (much heavier)
- MH needs to identify rapid changes for deployment of ice mitigation procedures.
- CEATI funded project to investigate detection of hoarfrost to ice conversion.

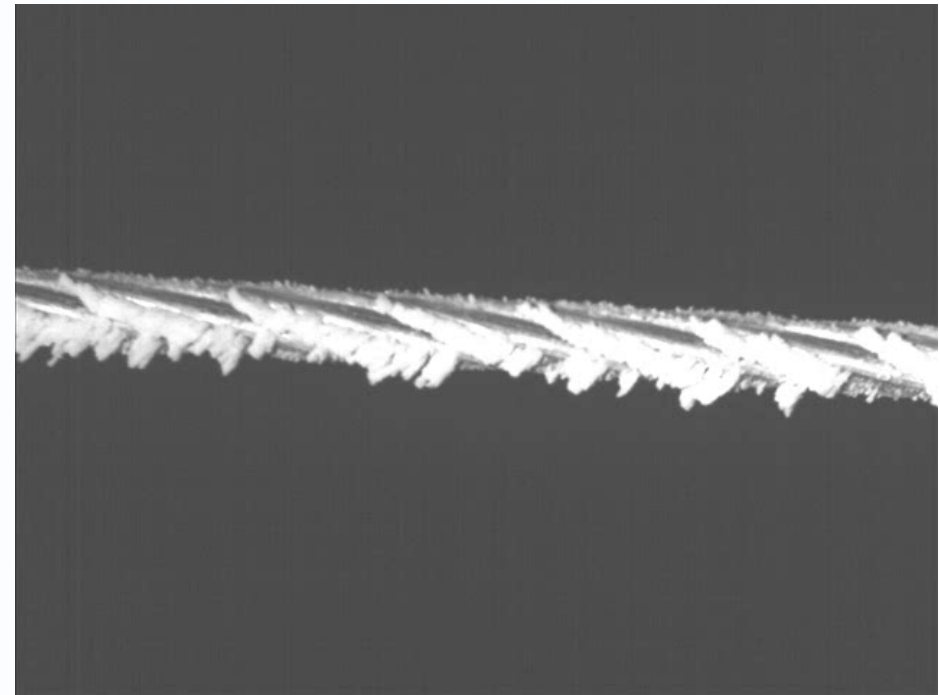
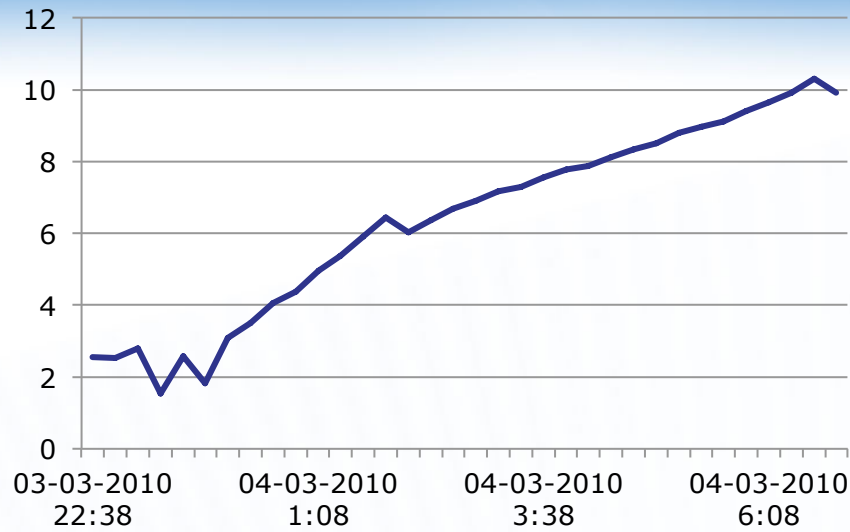


Hoarfrost Detection

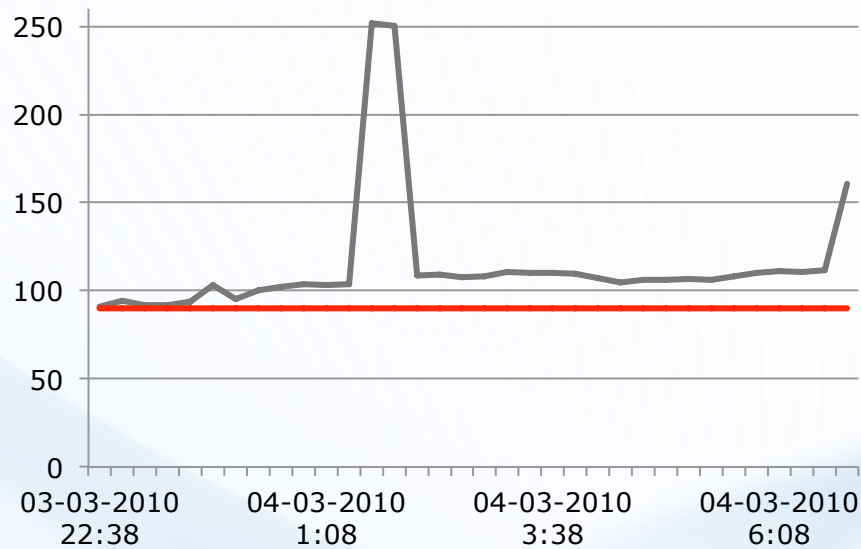
- **Principle**
 - Hoarfrost is an amalgamation of snow flakes (sharp edges)
 - Hoarfrost outline is more complex than ice
- **Compactness Factor**
 - Ratio between surface area and image perimeter
 - Helps assessing the complexity of shapes



Average Hoarfrost (mm)



Hoarfrost Frost Indicator



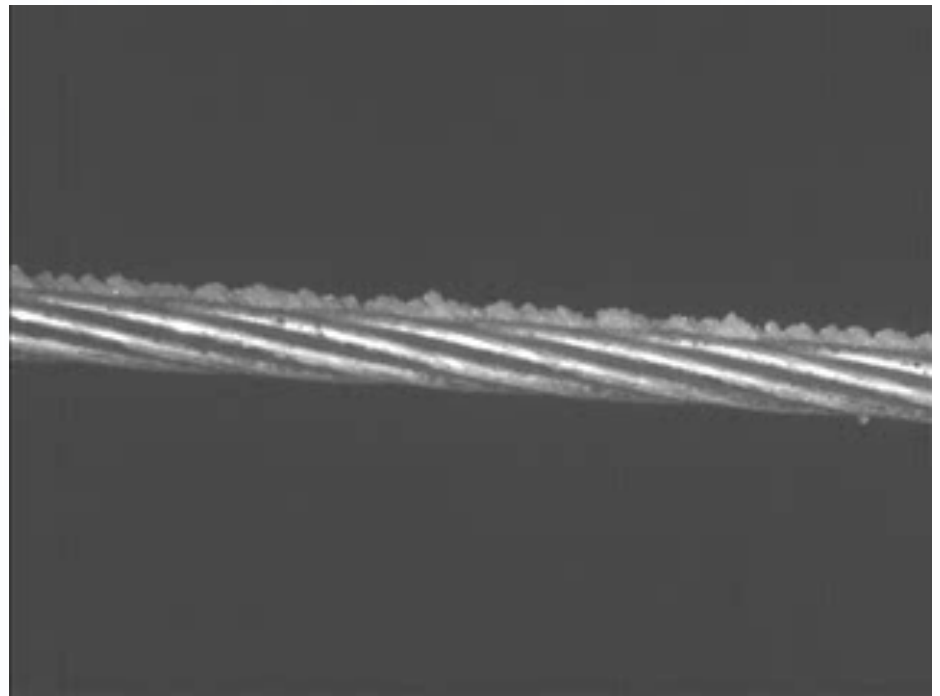
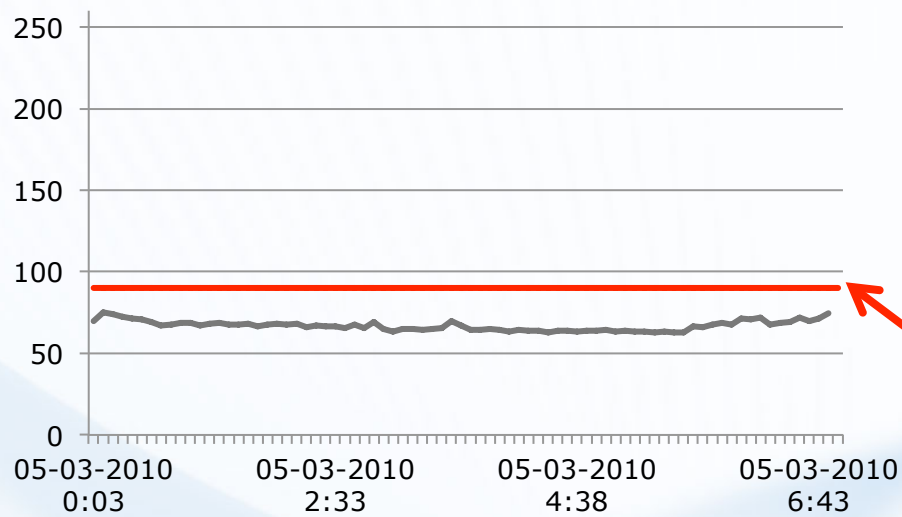
Hoarfrost Threshold

Average Ice (mm)

Manitoba HVDC *Research Centre*



Hoarfrost Frost Indicator



Hoarfrost Threshold

IDS Current Status

- 15 systems installed as of February 2012
- Positive reception from field crews:
 - Real time view on lines, allows for close monitoring during ice events and melting phase
- Growing pains
 - Some false alarms (detects ice when none is present)
 - Loose wires on weather station
 - Initial camera installation issues (T-line not centered or focused)
 - Replace one computer (twice) due to water damage. Further inspection shown a drip loop on camera wire was not installed. Rain was dripping in via the Ethernet cable and corroded the computer mother board
 - Wind and vibrations moved antenna out of alignment
 - One router failed
 - IP Camera failures (required firmware upgrade, shutter stuck open)
 - Communication channel wireless system failed (Infant)

IDS Current Status: Improving Detection

- Collected a 41180 image database from 5 stations between October 2009 and March 2010.
- 1456 false responses over the 40000+ images, (3.5%)
- MHRC improved the algorithm detection and provided a patch in October 2010

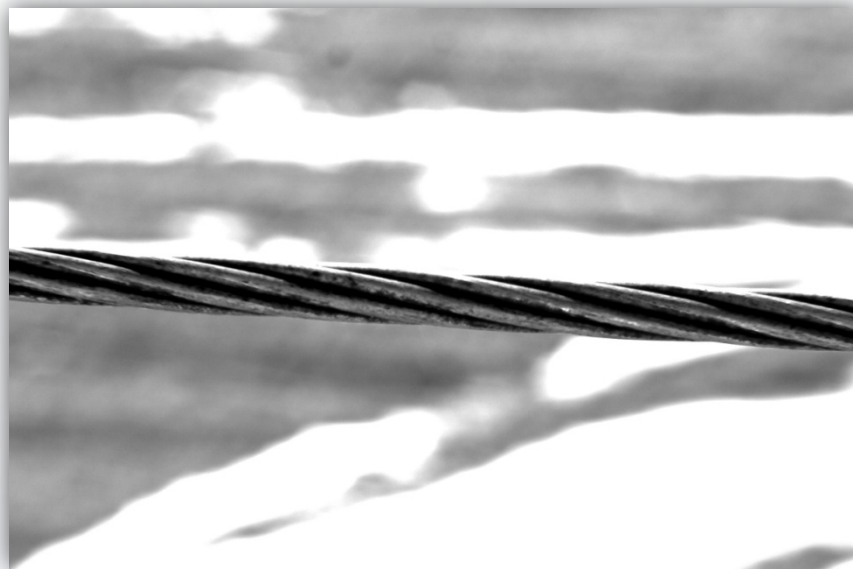
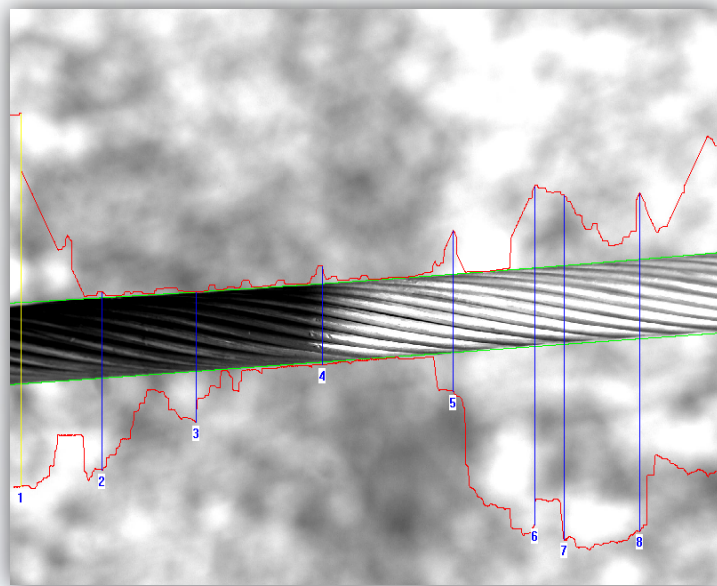


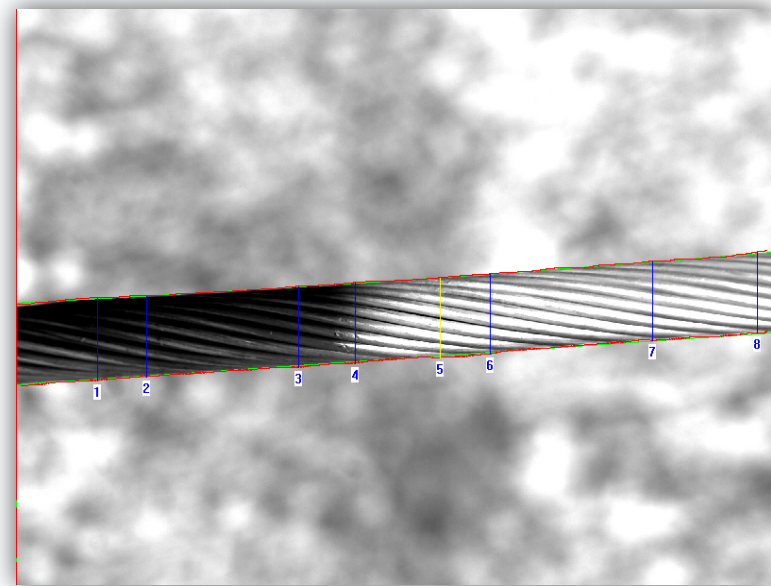
Image background in Spring

IDS Current Status: Improving Detection

Original Algorithm

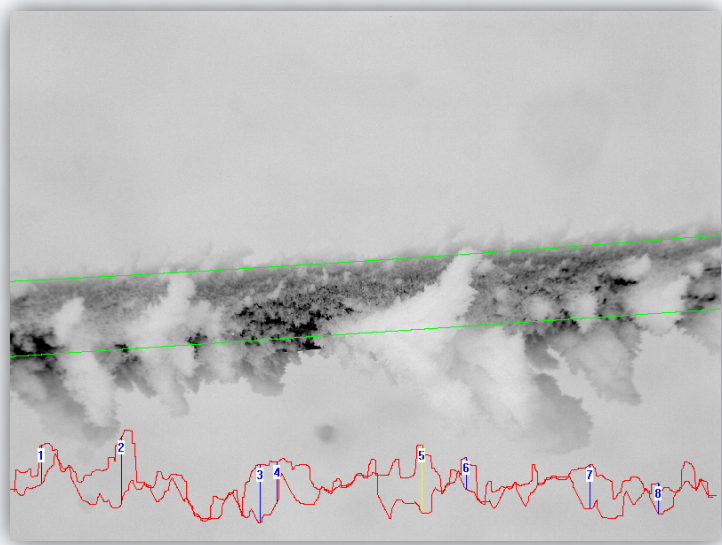


Enhanced Algorithm

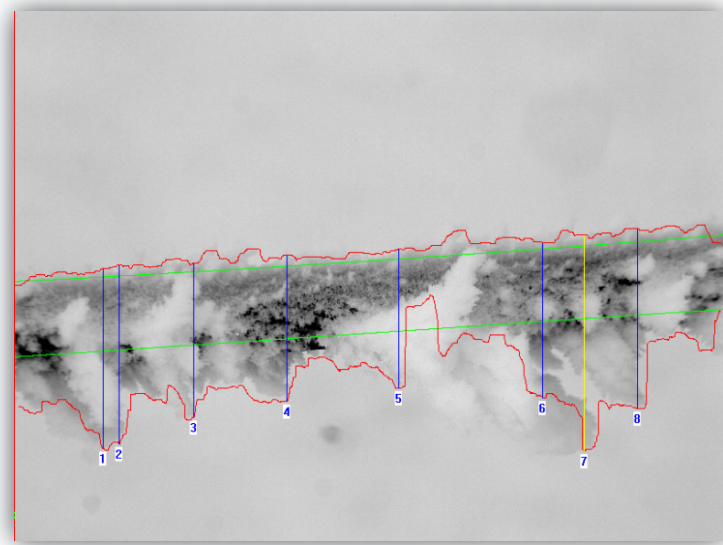


IDS Current Status: Improving Detection

Original Algorithm

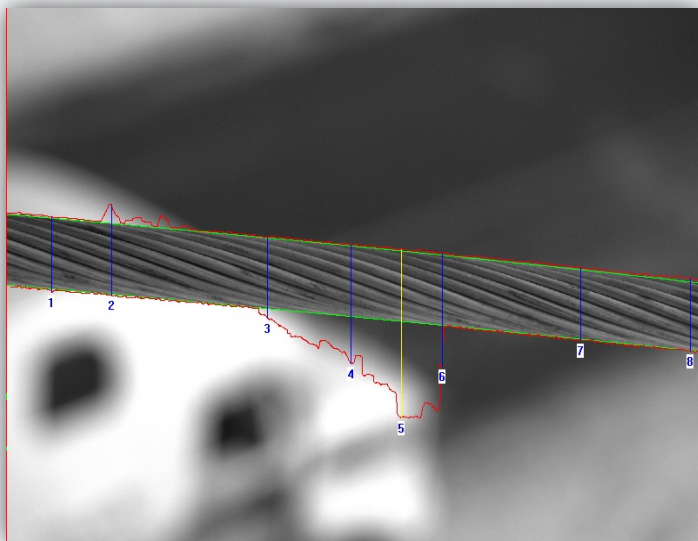


Enhanced Algorithm

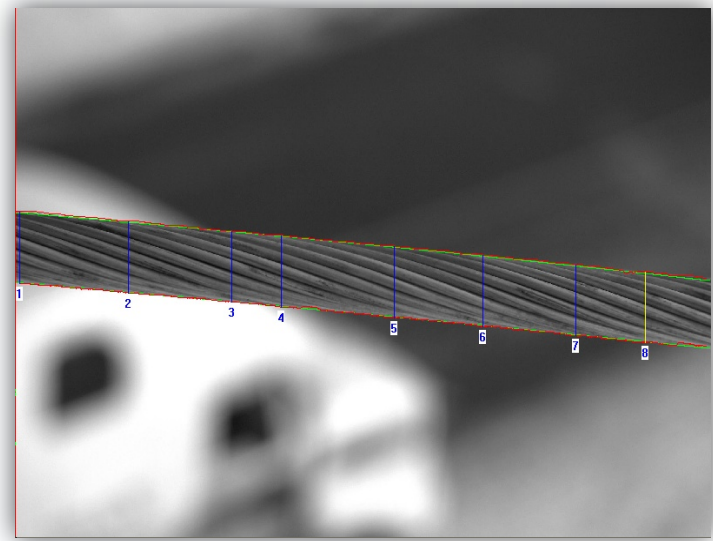


IDS Current Status: Improving Detection

Original Algorithm

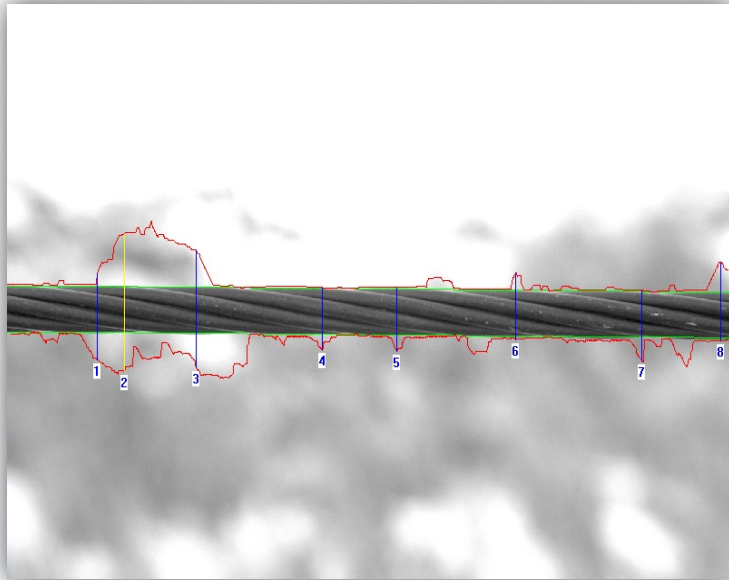


Enhanced Algorithm

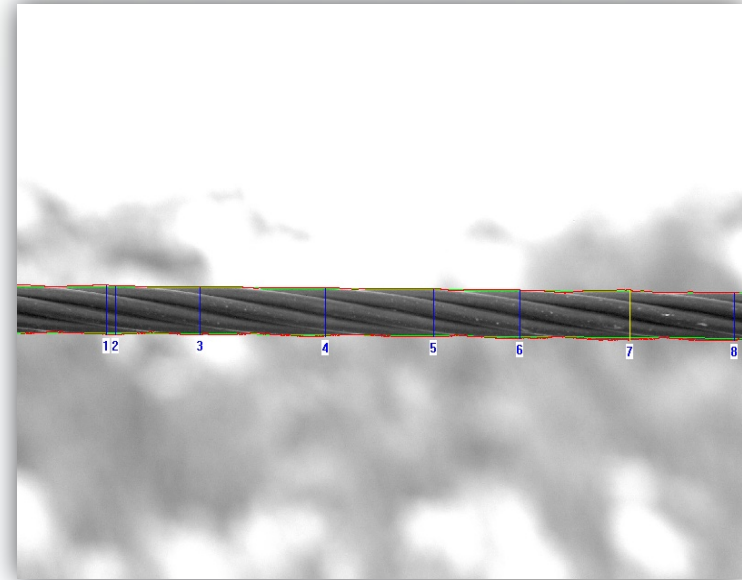


IDS Current Status: Improving Detection

Original Algorithm



New Algorithm



IDS Current Status: Improving Detection

Performance Of October 2010 Patch

	Total failure	Overall system reliability
Original algorithm	1456	96.46%
New algorithm	158	99.60%

- Continuous improvement process...
- More improvement to come based on the new images collected during the 2011/2012 season

IDS: A New Tool For The Smart Grid

- **Innovative “Intelligent” project for the Smart Grid developed in collaboration with Manitoba Hydro**
- **Improves reliability of MH energy distribution**
- **Literally allows keeping an eye on the power lines**
 - Ice monitoring
 - Melting phase
- **A hub of sensors deployed in the field – Upgradable to allow more monitoring:**
 - Line temperature
 - Line galloping alert
 - Fallen line detector
- **New technology requires new or revised skill sets (field training)**
- **New technology can change existing methods and processes**

The Future Of The IDS

- **Still has some false alarms events**
- **MH has some concerns about long term maintenance of the system**
- **Good feedback from field operators, strong motivator to enhance the system:**
 - Continuous improvement of the detection algorithm
 - Simplification of the design to address maintenance concerns: centralize the processing power, use of remote weather information when available...



Thank you...

