Reference 21 (1)

LP-2010-007

Lower Churchill Project
HVdc Labrador – Newfoundland Transmission Link

Ice loadings on HVdc line crossing Long Range Mountains

Report#1: General conditions, preliminary inspection, selection of test sites and proposals for further procedure

Landsvirkjun
POWER

June 2010

Landsvirkjun

Key page

LV report no.:	LP-2010-007	Date:	11. June 2010

Number of pages: 23 Copies: 2 Distribution: ☐ Open ☒ Limited until

Title:	Lower Churchill Project, HVdc Labrador - Newfoundland transmission Link, Ice loading on HVdc line crossing Long Range Mountains, Report #1
Authors/Company:	Landsvirkjun Power, Svein M. Fikke Meteorological Consultant - overhead lines and Arni Jon Eliasson, Consultant
Project manager:	Albert Gudmundsson
Prepared for:	Nalcor Energy, St. Johns., Newfoundland and Labrator, Canada
Co operators:	

Abstract:

This report comprises the following.

- Travel report for September 2009
- General icing conditions to be studied for this LRM project
- Notes from Line Route Survey 21-23 September 2009
- Selection of Test Sites
- Proposals for further studies

Keywords: Newfoundland, transmission line, Long Range Mountains

ISBN no.:

ISSN no:

Landsvirkjun's project manager's signature

Albert Gudmundsson

Landsvirkjun Power

in collaboration with

Svein M. Fikke, Meteorological Consultant – Overhead Lines,

and

Árni Jón Elíasson, Consultant

Lower Churchill Project
HVdc Labrador – Newfoundland Transmission Link

Ice loadings on HVdc line crossing Long Range Mountains
Report #1: General conditions, preliminary inspection, selection of test sites and proposals for further procedure

Svein M. Fikke
Meteorological Consultant – Overhead Lines

Landsvirkjun
POWER

Landsvirkjun
POWER

Key page

LP report no.: LP-2010-007

Date: 7. April 2010

Number of pages: 23 Copies: 1 Distribution: ☐ Open ☒ Limited until

Title: Lower Churchill Project, HVDC Labrador - Newfoundland transmission Link, Ice loading on HVDC line crossing Long Range Mountains, Report #1

Authors/Company: Landsvirkjun Power, Svein M. Fikke Meteorological Consultant - overhead lines and Arni Jon Eliasson, Consultant

Project manager: Albert Gudmundsson

Prepared for: Nalcor Energy, St. Johns., Newfoundland and Labrator, Canada

Co operators:

Abstract:

This report comprises the following.

- Travel report for September 2009
- General icing conditions to be studied for this LRM project
- Notes from Line Route Survey 21-23 September 2009
- Selection of Test Sites
- Proposals for further studies

Keywords: Newfoundland, transmission line, Long Range Mountains

ISBN no.:

ISSN no:

Landsvirkjun Power's project manager's signature

Table of Contents:

Ice loadings on HVdc line crossing Long Range Mountains Report #1: General conditions, preliminary inspection, selection of test sites and proposal for further procedure

Authors:
Svein M. Fikke, Meteorological consultant – Overhead lines
Árni Jón Elíasson, Consultant

1. INTRODUCTION

This project was ordered by Landsvirkjun Power, on behalf of Nalcor Energy – Lower Churchill Project (NE-LCP).

This work is performed by Svein M. Fikke, Meteorological Consultant – Overhead lines and Arni Jon Eliasson, Consultant in cooperation with Landsvirkjun Power.

This report, Loading Exposure on Long Range Mountains has following parts:

- Travel report from September 2009
- General icing conditions to be studied for this Long Range Mountains (LRM) project
- Notes from Line Route Survey 21-23 September 2009
- Selection of Test Sites
- Proposals for further procedure
- Annex A: Basic concepts of atmospheric icing

2. TRAVEL REPORT FROM SEPTEMBER 2009

2.1. Overall schedule

The following activities took place in September 2009:

15 September:	Travel Oslo to Reykjavik (SMF).
16 – 17 September:	Project meetings at Landsvirkjun Power, Reykjavik.
18 September	Travel to St. John’s, NF (ÁJE and SMF).
19 September	Stay in St.John’s.
20 September	Travel to Deer Lake.
21 – 22 September	Helicopter surveys of line route. Selection of sites for test spans. Return from Deer Lake.
23 September	Meeting with NE-LCP in St. John’s.
24 September	Return from St. John’s.

2.2. Summary of meetings in Reykjavik 16 – 17 September 2009

These meetings summarized the overall concepts of:

1. The HVdc overhead line system from Lower Churchill Project to Newfoundland and possible to markets.
2. The plans for the line route survey on Long Range Mountains scheduled for 21 – 22 September 2009.
3. Modeling of in-cloud icing using numerical weather prediction (WRF) model.
4. Analysis of maximum in-cloud icing – Using routine meteorological data to evaluate design value of in-cloud ice loading.
5. Testing on insulators covered in contaminated Rime ice.

3. ICING TYPES FOR THIS LRM PROJECT

Atmospheric icing is a generic term for several processes that result in various forms of ice accretions on objects in the airflow. For more detailed discussion see Annex A.

Excess loading from atmospheric icing has always been a severe challenge for owners and operators of overhead power line networks in Newfoundland. Due to the severe impacts on social security as well as the economic importance, such phenomena have been studied during many years in the area. An excellent summary of these efforts was given by Dr. Asim Haldar, Newfoundland and Labrador Hydro, in his paper “Twenty years of Ice Monitoring Experience on Overhead Lines in Newfoundland and Labrador”, presented to IWAIS XII in Yokohama, Japan, 2007 [1].

Dr Haldar’s paper shows in particular the large amounts of freezing rain that may appear in this area, as well as significant rime icing in elevated areas. Although wet snow accretions are not observed in critical amounts on the power networks in Newfoundland, it is agreed to include this process as well in order to evaluate its relative importance for the power line.

It is therefore anticipated that the following icing types are important to consider for this transmission line route:

- Freezing rain
- Rime icing
- Wet snow

These icing forms, in relation to the topographic influences on them, will be discussed further in following chapters of this report.

4. GENERAL NOTES FROM LINE ROUTE SURVEY 21 – 22 SEPTEMBER 2009

4.1. 21 September 2009

This day was used for a general view of the main route for the power line between Deer Lake and the Daniel’s Harbour. Some potential sites for test spans were looked at with special attention.

4.2. 22 September 2009

After reviewing and evaluation of sites exposed to potentially significant amounts of atmospheric icing (rime ice and wet snow) the following locations were selected:

Position	Latitude	Longitude	Height above sea level (m)
1	50°06’ 3.3’’N	057°25’ 27.9’’W	600
2	50°03’ 49.7’’N	057°23’ 53.2’’W	530
3	45°57’52’’N(approximated)	57°22’17’’W(approximated)	485

4.3. General impressions of the line route

The part of the line route inspected on this survey is shown in Figure 1. We flew from Deer Lake to the line route and followed it over the LRM towards Daniel’s Harbour.

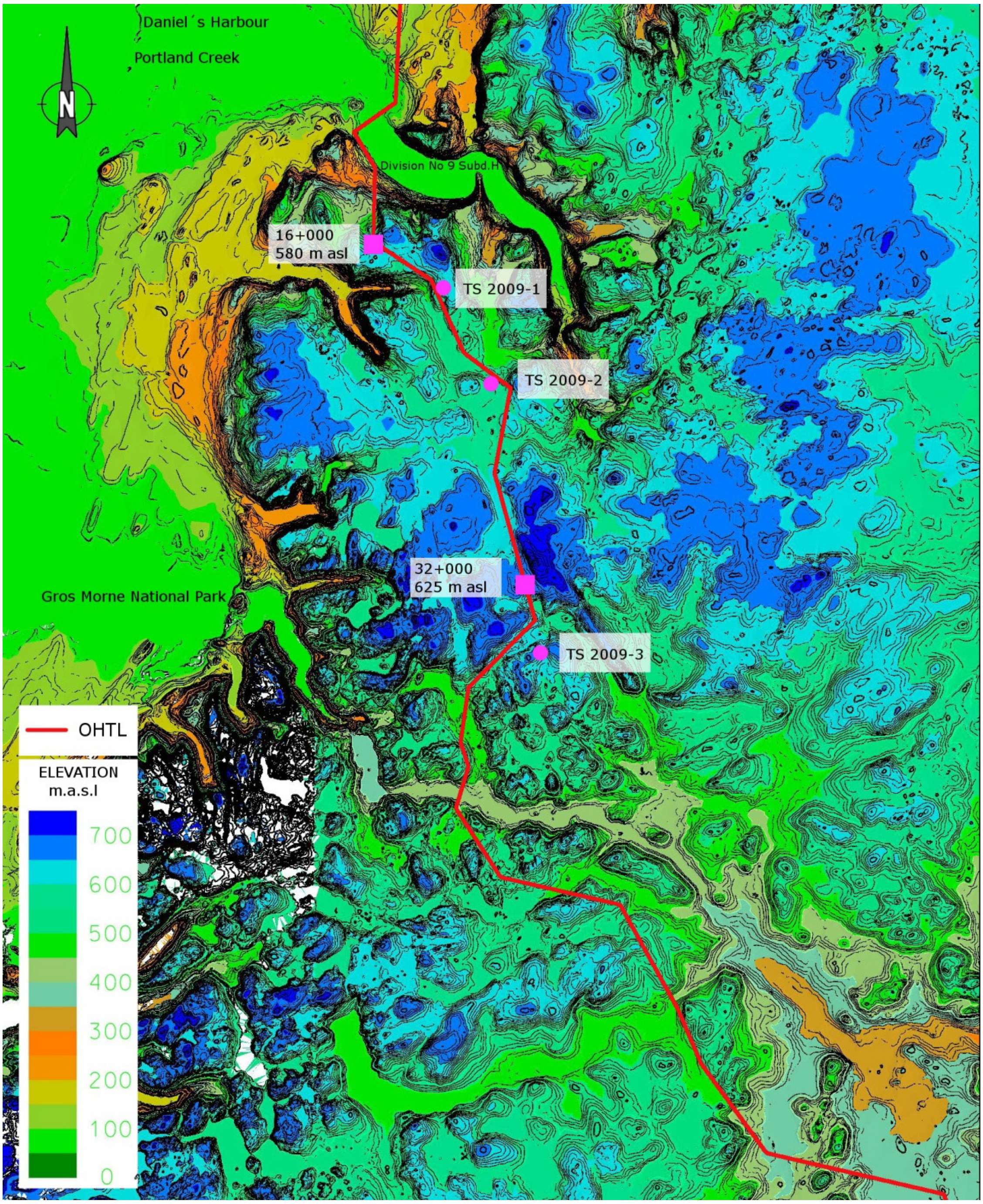

Figure 1. Overview of line route passing the Long Range Mountains

The first landing location was at Sharp Hill where we could see the line route all the way to the coast. On the return flight potential locations of test sites were studied, as well as more details of the line route in general.

Based on this quick overview from the helicopter we could notice as a general impression of this part of the line route that the route is mainly well protected in valleys and lower parts of the terrain, in between rolling hills on either side of the route.

The lower parts of the line route on the eastern side of the mountain range were mainly located in forest areas, with some scattered open moorland or farmland.

In particular it was noted that the forests in the area consisted of mainly spruce and pine trees. The trees seemed to be rather slim and tall, without visible damages to the tree tops from earlier severe icing events, see Figures 2, 3 and 4.

Closer to the central parts of LRM the line route enters into higher altitudes. From the map it seems that the exposure to more severe icing increases above about 450 - 500 m a.s.l.

In the western part of this section the line route comes up to almost 600 m a.s.l . Here the terrain opens towards the Gulf of St. Lawrence, especially towards the sector SW-W. In this area the risk of rime icing will increase rapidly with height as well as with exposure towards the Gulf.

This particular area needs therefore to be studied carefully before final ice loadings are selected.

On the western side the line route runs along the coast line and is therefore not exposed to more severe icing conditions than in general for the lowland areas.

Figure 2 Near Deer Lake. The trees seem to be tall and slim with no damage from ice loads on tree tops.

Figure 3. Further towards line route. Still undamaged tree tops in the foreground, less dense forest on hilltops.

Figure 4. Near lake crossing.

4.4. Influence of tower height

The tower heights of this planned HVdc line may be in the range of 40 – 50 m. This means that apparently significant sheltering from higher side terrain may become significantly less, or even disappear, at typical conductor levels in the area. This must be considered when wind and ice loads are evaluated for this line. (Note: The conductors of test span 1 (see below) will be almost of the same level as the conductor height of the HVdc line close to this site.)

5. SELECTION OF TEST SITES

It was decided that three locations would reflect the most critical aspects on this particular line route alternative across the Long Range Mountains.

The line route along the Long Range Mountains towards the Strait of Belle Isle crossing is so far not discussed in details. The same applies for the line route east of LRM and alternative routes crossing LRM.

5.1. Test site #1

LATITUDE: 50°06’3.3’’ N

LONGITUDE: 57°25’27.9’’ W

HEIGHT ABOVE SEA LEVEL: 600 m a.s.l.

This site is the most exposed and critical point of the mountain crossing. Although the main line route follows a sheltered valley, the conductors will still reach up to critical levels on this section of the line route.

Figure 5 shows the view from test site #1 towards the Gulf of St. Lawrence in the SW. As can be seen from the picture there is no higher mountains between the line route and the sea, and also there is a valley that will channel moist air from the Gulf perpendicular to the line route. The line route is below the hilltop in the foreground.

Figure 5. Test site #1 towards W

The moist air from the Gulf will be lifted as it is channelled up the valley. Hence the air mass is cooled and water vapour is condensed into droplets which will enhance rime icing in this location.

5.2. Test site #2

LATITUDE: 50°03’49.7’’N

LONGITUDE: 57°23’53.2’’W

HEIGHT ABOVE SEA LEVEL: 530 m a.s.l.

This site was selected because it represents a significant part of the line route which lies in relatively sheltered valleys, but where icing may occur in combination with winds more or less parallel to the line route. In addition this particular site is somewhat exposed perpendicular to the line route due to an opening in the terrain towards north.

Figure 6 shows the valley towards NW where the Gulf of St. Lawrence can be seen.

Figure 6. Test site #2 towards NW

5.3. Test site #3

LATITUDE: 45°57’52’’N (approximated)

LONGITUDE: 57°22’17’’W (approximated)

HEIGHT ABOVE SEA LEVEL: 485 m a.s.l.

This test site was selected to represent potential icing cases from the eastern sector. This area is further inland from the coast compared with the Sites # 1 and 2 which were close to the western coastline. As can be seen from Figure 7 there are no particular features of the landscape that should enhance the risk of icing on this point. However, the site represents the mountain planes of the area where there are no significant sheltering effects from the eastern sector.

Also, this site was selected because it was the southernmost point near the line route before it stepped down to lower altitudes.

The test span is recommended to be oriented in the N – S direction. The line route close to this site has a sharp angle point FROM NNW-SSE TO NE-SW , and the direction of the test span is anticipated to represent the most important wind direction perpendicular North of this angle point.

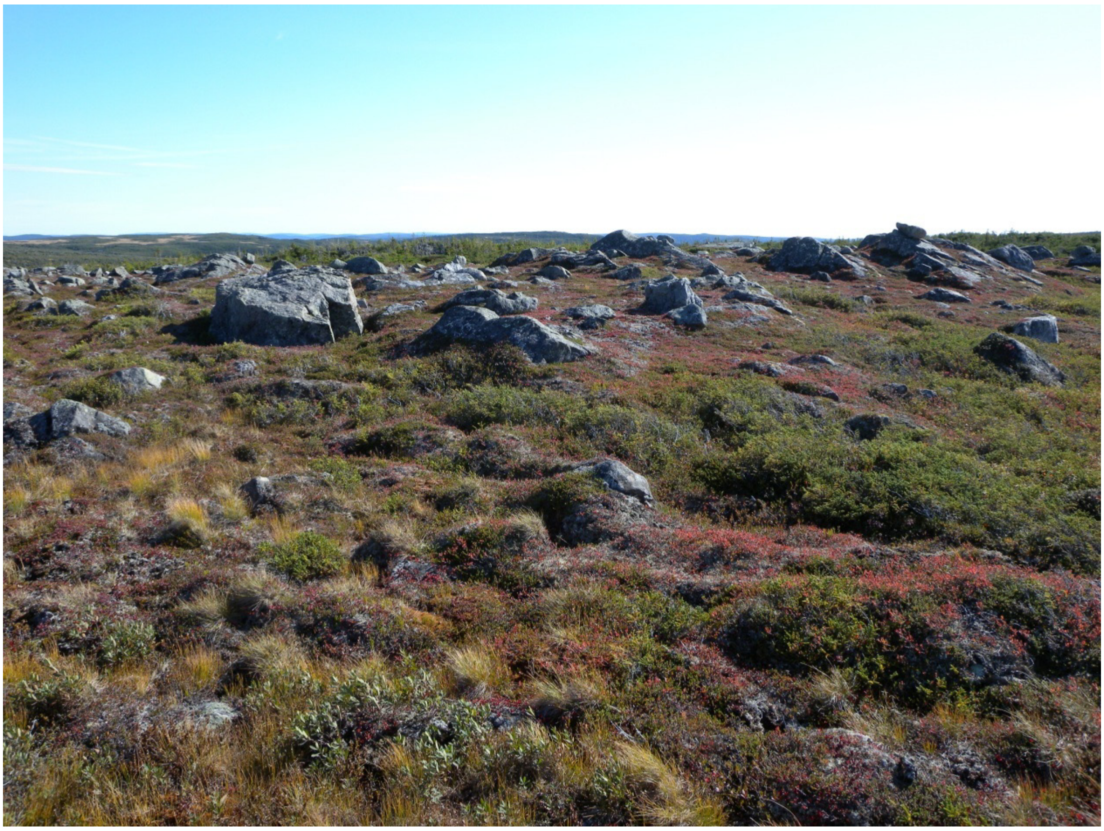

Figure 7. Test site #3. Towards SE

5.4. Other observations

From the helicopter it was possible to see two of the old measuring towers in the area. An example of this is shown in Figure 8.

Both of the towers we could observe appeared to be in a good condition with their guy wires apparently intact as well.

Figure 8. Example of old test sites.

6. PROPOSALS FOR FURTHER STUDIES

During a meeting with Landsvirkjun Power 04-05 March 2010 in Reykjavik it was decided to recommend the following further activities on in this project:

6.1. Review of earlier studies

The report of Meteorological Research Inc. (MRI) of 1973 [4] describes icing studies based on the Leavengood model.

As this study is up to now the reference study of icing conditions, including extreme ice loads for this line, it is recommended to:

- Repeat and update the Leavengood model to 2009 data (if possible).

As informed by Nalcor the current design loads applied in Newfoundland are higher than those recommended in Canadian Standard, in particular due to severe events of freezing rain. An important input to the current practice is the results from the Hawke Hill test site [1].

It is therefore important to:

- Review background data, documents and arguments for current design practices in Newfoundland.
- Study the Hawke Hill test site and results.

6.2. Other icing models

To complete the picture of earlier model studies it is recommended to:

- Apply the Harstveit model [6] for rime ice for the higher levels on the western side of LRM.
- Apply the Sakamoto-Admirat model [7] for wet snow on both sides of LRM.

6.3. WRF model

It is strongly recommended to incorporate the modern advancements of numerical weather prediction models (NWPs) for the final ice and wind load assessments in this project. In the later years a particular "weather research forecasting model" (WRF) has been developed by several international universities, especially in the USA [8]. In this model the physical and dynamic properties and behaviour of the three-dimensional atmosphere are described much more accurately thanks to the development of powerful computers and data information from the atmosphere. In this WRF model the water cycle in the atmosphere is particularly described in physical terms rather than in statistical terms and schemes, as was necessary earlier.

Studies of atmospheric icing has been successfully applied earlier on icing events in mountain terrain especially in Norway, Switzerland, UK as well as other countries [9].

The WRF studies should be performed stepwise, foremost as a tool to understand the overall weather conditions leading to severe icing events, as well as to study the influence from topography on local icing conditions.

At this stage it is recommended to study icing events in this order of sequence:

1. The icing event in middle of January 2010, as reported by K. Tucker in his report dated 19 January 2010 [10].
2. The icing event on Hawke Hill of March 1997 reported in [1], since this event was studied in details with measurements and the MRI model.
3. Selected extreme icing events (two to three) identified by 6.1 and 6.2 above.

6.4. Load assessments

From the procedures described above it is anticipated that the studies will indicate extreme values of:

a. The highest ice loadings on the most exposed tops of the western side of LRM.

b. Loads from freezing rain in lowlands on both sides of LRM.

c. Loads from wet snow (although loads are not expected to be higher than those from freezing rain it is recommended to check the probable differences).

d. Intermediate loads in between the high and low extreme areas will be assessed section by section, based on topography and WRF model output.

7. REFERENCES

[1]	Haldar, A.: Twenty years of ice monitoring experience on overhead lines in Newfoundland and Labrador. IWAIS XII, Yokohama, Japan, October 2007
[2]	Cigré TB 291 Guidelines for meteorological icing models, statistical methods and topographical effects”. Working Group B2.16, Task Force 3, April 2006
[3]	CIGRÉ TB 179 Guidelines for field measurement of ice loadings on overhead power line conductors. Task Force 22.06.01, February 2001
[4]	Meteorological Research Inc. (MRI). Report to Newfoundland and Labrador Hydro, 1973
[6]	Harstveit, K.: Validation of an in-cloud icing model based on cloud water gradient calculated from metar airport data. IWAIS XIII, Andermatt, Switzerland, September 2009
[7]	Admirat, P. and Sakamoto, Y.: Wet snow on overhead lines: A state of the art. IWAIS IV, Paris, France, September 1988
[8]	W. C. Skamarock, J. B. Klemp, J. Dudhia, D. O. Gill, D. M. Barker, W. Wang, and J. G. Power, 2005: A description of the Advanced Research WRF Version 2. NCAR Technical Note, NCAR/TN-468+STR.
[9]	Nygaard, B.E.K.: Evaluation of icing simulations for the COST 727 icing test sites in Europe. IWAIS XIII, Andermatt, Switzerland, September 2009
[10]	Tucker, K.B.: Long Range Mountains Site Visit January 19, 2010. Nalcor report

8. ANNEX A – BASIC CONCEPTS OF ATMOSPHERIC ICING

Atmospheric icing is a generic term for several processes that result in various forms of ice accretions on objects in the airflow. For clarification the text in Annex A is edited from Cigré TB 291 "Guidelines for meteorological icing models, statistical methods and topographical effects. Working Group B2.16, Task Force 3, April 2006 [2] (Figures are not included here).

8.1. Classification of icing types

Icing is classified into the following two types. Each type is sub-grouped as follows:

a) Precipitation Icing

Glaze due to freezing rain
Wet snow accretion
Dry snow accretion

b) In-Cloud Icing

Glaze due to super cooled cloud/fog droplet
Hard rime
Soft rime

It is important to notice that an ice accretion may be a mixture of two or more ice types, for instance soft rime, hard rime and wet snow, due to variations in the meteorological parameters during the icing event. Various shapes, densities, adhesion strengths, etc. result accordingly.

Various types of ice accretion may occur on transmission lines. These are classified as glaze, rime (soft and hard), snow (wet and dry) and hoar frost. Table 1 shows a summary of the different types of ice accretion with typical density ranges as defined by CIGRÉ TB 179 [4].

Table 1: Classification of ice types with typical density ranges – Reference [3]

Ice and snow type	**Density (kg/m^3)**	**Description**
Glaze ice	700-900	Pure solid ice, sometimes icicles underneath the wires. The density may vary with the content of air bubbles. Very strong adhesion and difficult to knock off.
Hard rime	300-700	Homogenous structure with inclusions of air bubbles. Pennant shaped against the wind on stiff objects, more or less circular on flexible cables. Strong adhesion and more or less difficult to knock off, even with a hammer.
Soft rime	150-300	Granular structure, "feather-like" or "cauliflower-like". Pennant shaped also on flexible wires. Can be removed by hand.
Wet snow	100-850	Various shapes and structures are possible, mainly dependent on wind speed and torsional stiffness of conductor. When the temperature is close to zero it may have a high content of liquid water, slide to bottom side of the object and slip off easily. If the temperature drops after the accretion, the adhesion strength may be very strong.

Dry snow	50-100	Very light pack of regular snow. Various shapes and structures are possible, very easy to remove by shaking of wires.
Hoar frost	<100	Crystal structure (needle like). Low adhesion, can be blown off.

8.1.1. Glaze Ice

Glaze ice (Figure A.1) occurs in a temperature inversion situation in valleys on calm warm fronts. Raindrops in the warm (above 0ºC) air region can fall through a few hundred meters of sub-zero air to ground level. The raindrops are then super-cooled, i.e. still in the liquid phase but at sub-zero temperatures e.g.-1 to -5ºC. Glaze icing may also result from in-cloud icing when the in-flux of cloud water is very high.

On contact with a physical object, which may be an overhead line or tower structure, the raindrops freeze rapidly with virtually no trapped air within the accretion. Glaze icing produces the densest form of icing – a typical density being 900 kg/m3 – and high ice loads are reached within hours. Icicles are often seen below the conductors as the raindrops freeze as they run off the lines. The widely reported Canadian ice storm of January 1998 was due to glaze icing.

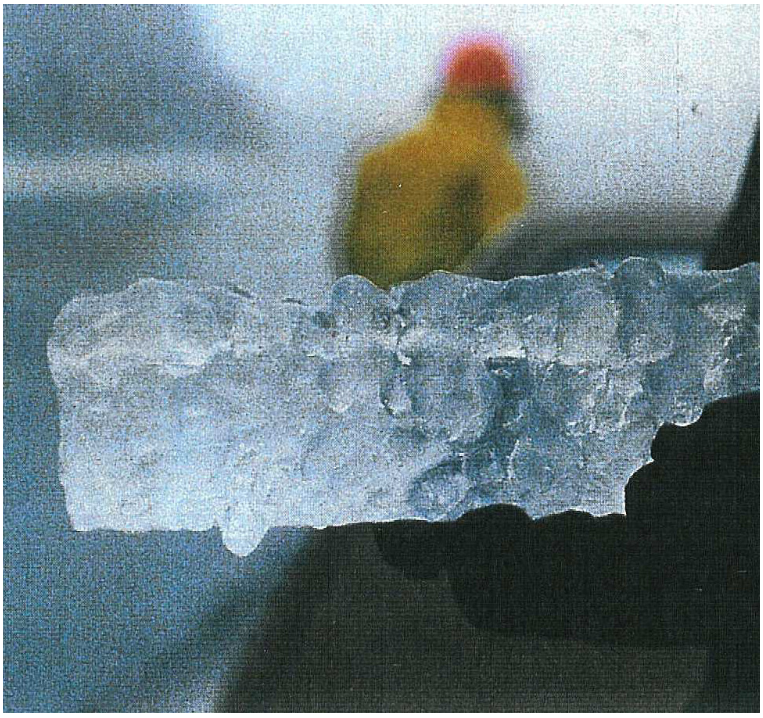

Figure A.1. Example of glaze ice [2].

8.1.2. Rime Ice

Rime ice (Figure A.2) accretion occurs when small, super cooled water droplets (~10 μm) travel along with the wind flow in temperatures typically below –5°C, freeze spontaneously on contact with a physical body. The accretion formed is often strongly asymmetric with leading vanes into the wind direction. This type of icing is often referred to as "in-cloud" icing and is common in hilly areas over the cloud base. The density of rime varies depending on the size and speed with which the water droplets freeze. Hard rime ranges in density from 300 to 700 kg/m3 while soft rime has densities of 150-300 kg/m3. Ice loads take days or even weeks to reach damaging levels. Rime ice often accretes more rapidly on small conductors or sharp edges.

Figure A.2. Example of rime ice [2].

8.1.3. Wet Snow

Wet snowflakes occur as ice crystals suspended in a liquid water matrix at temperatures just above the freezing point, usually between 0,5 and 2ºC. At liquid water contents (LWC) between 15 and 40% the flakes adhere readily to objects (Figure A.3). They can reach a terminal velocity which is less than the local wind speeds. At LWC levels below 15% the snow often fails to accrete on structures and lines but can penetrate into motors or other components. At LWC levels above 20% the accretion often falls off objects.

The force of the wind compresses the snow on the surface and the accretion will become more compacted over time, meaning the porosity will decrease and density value as high as 850 kg/m^3 may be reached within the deposit. This phenomenon does not increase the overall snow load on the conductor but will affect only its density. A process of circular accretion can lead to very high loads being reached in a matter of hours. The physical process of wet-snow adhesion is still not well understood.

Figure A.3. Example of wet snow [2].