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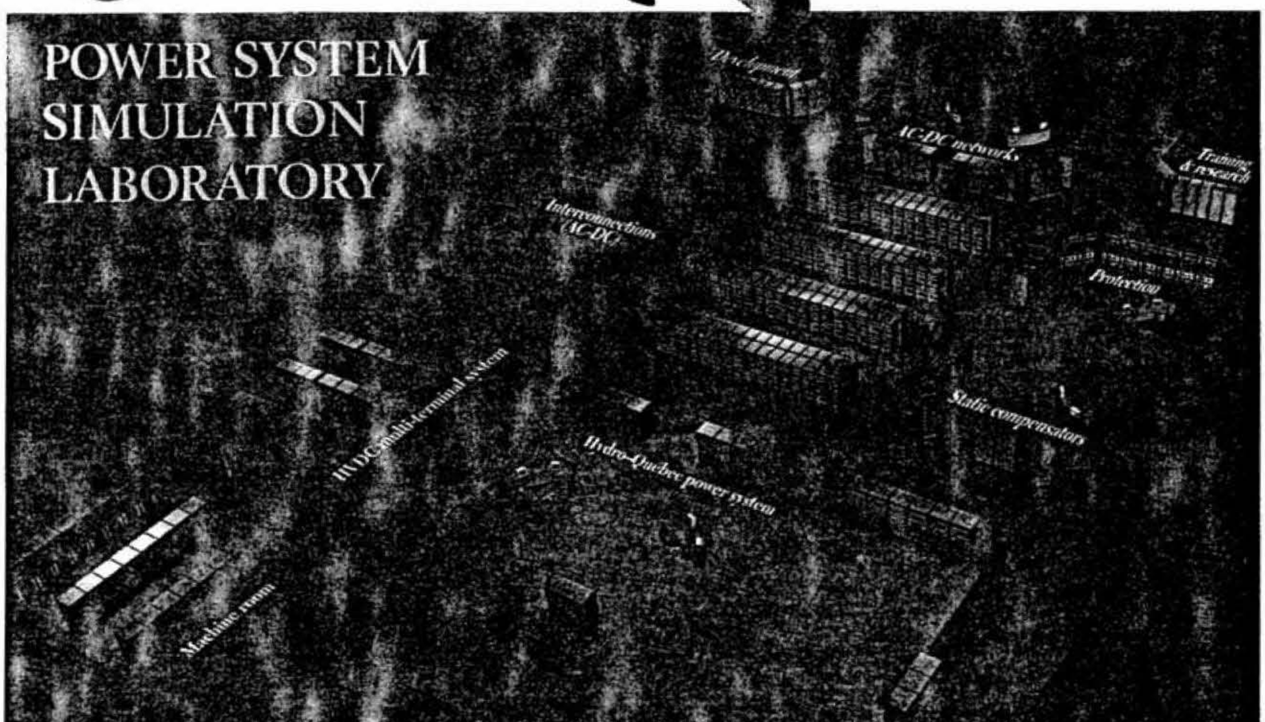

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NEWFOUNDLAND AND LABRADOR HYDRO'S WIND AND ICE LOAD MONITORING TEST FACILITY

by A. K. Haldar, M. A. Marshall, W. J. Nugent, B. C. Hemeon, and T. J. Gardiner

This paper is an overview of a recently commissioned test site to monitor wind and ice loads on a test transmission line near St.-John's Newfoundland. Data obtained from the site are being used to validate several mathematical models that provide design parameters for transmission lines.

Cet article présente un aperçu d'un banc d'essai mis sur pied récemment près de St. John's, Terre-Neuve afin d'étudier des conditions d'opérations difficiles des lignes de distribution électrique (vent, glace, etc.). Les données ainsi obtenues servent à valider les modèles mathématiques utilisés pour générer certains paramètres de conception.

Several structural failures, causing power outages, have occurred on Newfoundland's Avalon Peninsula because of heavy wind and ice loads. In 1984, many failures were concentrated in an area where two major high voltage lines cross Hawke Hill[1]. These failures were attributable to the dynamic effects of high winds on the top of the hill resulting from wind speedup effects combined with severe ice accretion (ice growth by means of gradual additions) on the transmission lines.

To understand such problems better, Newfoundland and Labrador Hydro (NLH) constructed a full-scale test site at Hawke Hill in 1993 to monitor wind and ice loads on a non-energized transmission line. This research project is also part of a national study to improve existing design codes for transmission lines in Canada.

The objective of this project is to collect loading data and related meteorological parameters on a test line that has been constructed on Hawke Hill. This test site is designed to serve as an instrumented monitoring station to continuously record: wind speed, wind direction, temperature, precipitation, ice accretion, load along the insulator string, swing angles in both directions (transverse and longitudinal) on the conductor at the insulator attachment point, conductor tension, strains in selected members of the tower, load in the guy wires and finally, the vibration of the conductor with and without dampers.

Data collected from the test site will be used to validate several ice accretion models, wind models, vibration models, and NLH's model of how the tower structure might/will deform based on wind, ice accumulation, etc.

Planning and developing of the overall monitoring study included:

- the design and procurement of various meteorological and load sensors
- design of a PC-based data acquisition (DAQ) system
- implementation of a DAQ program using the C programming language
- development of a data analysis and presentation (DAAP) program using MATLAB(tm), a high-performance interactive computer language, for scientific and engineering numeric computations [1].

Sensors

At the test site, there are three structures: A central guyed steel V-tower (the main structure), and two wooden end structures. A single conductor (795 26/7 ACSR "Drake") is strung from one wooden end structure through the middle phase connection of the central tower to the other end wooden structure. These three structures form a straight line in the east-west direction, with the end structures approximately 213.4 metres from the central tower. Refer to Figure 1.

Each end structure is instrumented in an analogous fashion. A conductor load cell is installed to measure the conductor tension. In addition, a guy support load cell, to measure guy tension, is connected in-line with the conductor. Each end structure load cell has its own signal conditioner housed in a small junction box that is attached to the load cell. Both load cells and their associated electronics are connected to a larger junction box, which is attached directly to the pole approximately 15 metres from the ground level. These junction boxes are equipped with an ambient heater and two line drivers to drive the d.c. signals over the 213.4 metre distance to the control panel in the equipment shelter. Both end structures are connected directly to a control panel via one power and one signal cable.

Most of the sensors are installed on the central tower. The central tower is supported by four guy wires (9/16 inch thickness, 7 strands, grade 180). A load cell is connected in series with each guy to measure the tension. Further, there are two swing transducers and an axial load cell installed between the insulator string and the centre of the tower bridge. Bracing members on the bridge provide an ideal location for most of the meteorological sensors. These include: a heated anemometer (wind speed indicator) and an ice detector. All these sensors (except the anemometer and ice detector) are connected to a large junction box located in the centre of the upper bridge of the tower. This junction box provides a shelter for a signal conditioner, line drivers, and an ambient heater. The box is also connected to the ground control centre housed in the equipment shelter, by a power cable and a signal cable. Strain gauges have been installed on selected members at the base of the tower to measure the loads transferred to the foundation by the tower.

At two locations near the equipment shelter, there are six meteorological sensors: two temperature gauges (dry thermistors), a dew cell and relative humidity sensor, housed in a Stevenson's screen[2], and two precipitation

1. Hawke Hill is located on the Avalon Peninsula, approximately 55 kilometres west of the St. John's Airport, at an elevation of 274 metres.

2. A Stevensosn's screen is a shelter which houses the two dry thermistors, a dew cell, and the relative humidity sensor. Its main purpose is to protect the sensors from direct sunlight and rain, but it is designed to allow air to flow through freely.

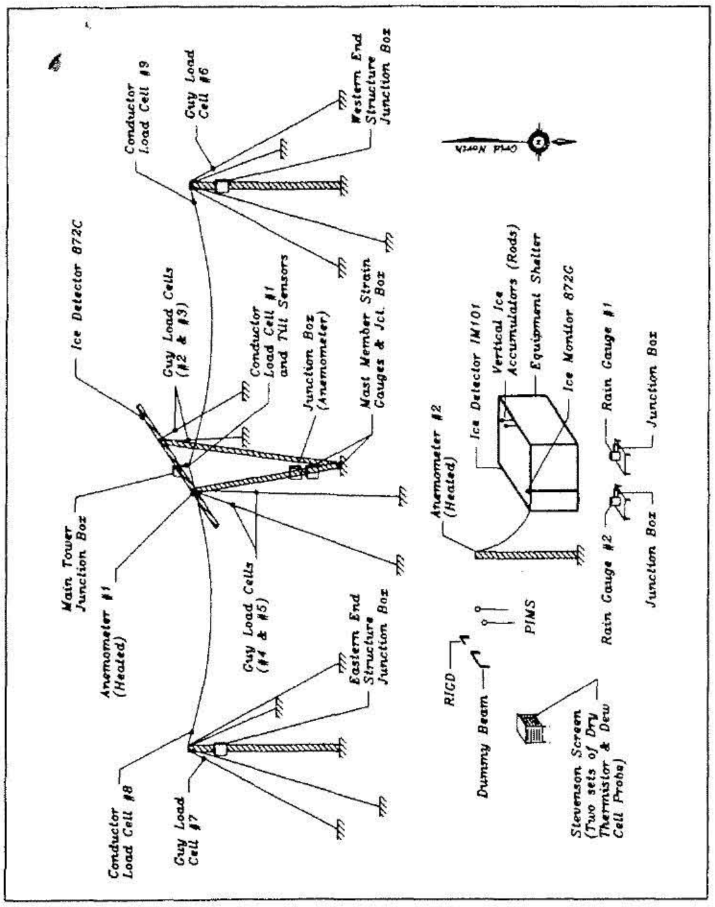

Figure 1 : Equipment Layout and Designations.

gauges. Additionally, there are two passive ice meters[1] (PIMs), an experimental remote ice growth detector[2] (RIGD) [2], and a *dummy beam* to manually check the accumulated ice mass reported by the RIGD.

These devices are installed at positions near the equipment shelter, but not too close to obstruct accurate data collection. Two different ice detectors are installed on the roof of the equipment shelter. Also, in the immediate vicinity, a second anemometer is installed at the top of a power service pole. Each sensor is connected to the control centre in the equipment shelter by the appropriate signal and power cables.

PC-Based DAQ System

Figure 2 presents the DAQ system configuration. Three types of DAQ boards are used in the PC-based system:

1) analog-to-digital (A/D) boards (quantity 3)
2) counter board (1)
3) communications digiboard (1).

Each A/D board can handle sixteen single ended or eight differential inputs. These boards provide twelve bit resolution. Besides the analog input channels, there are two digital-to-analog channels, and eight digital inputs and output channels. The three A/D boards are configured to provide 16 single ended and 16 differential channels.

A counter board is used to interface with the wind sensors (anemometers), which supply a pulse whose duration is proportional to the wind speed. This board also provides eight digital input and eight digital output channels. Only the counter channels are presently used for this investigation.

Eight additional serial ports are made available to the DAQ PC via a digiboard. These ports are used to interrogate the three ice detectors, and the four signal conditioning modules located on the end structures. (Refer to Figure 2.) This board also provides the communication channel to the NLH head office in St. John's (Hydro-Place).

DAQ Software

All the data from the site are transmitted to Hydro-Place via a modem over a dedicated lease line. A DAQ program, written in the C programming language, was developed to meet the following objectives:

- each sensor should have a dynamic sampling rate induced by the existing wind and ice conditions at the site;
- a report by exception algorithm should be set up to provide real time relay of the data to Hydro-Place.

To simplify the compliance with these objectives, the DAQ program loads a configuration file at start-up. Defined in this file is the sampling frequency and deadband assigned for each channel, based upon the existing wind and ice conditions.

The DAQ program also controls the communication of the data stored directly on the PC at the site at Hawke Hill to Hydro-Place. There the data are archived on NLH's main frame computer. If the dedicated telephone line linking Hawke Hill and Hydro-Place is lost for any reason (e.g., power outages at Hydro-Place), limited emergency storage is available on the Hawke Hill computer. Later, when the communication is restored to Hydro-Place, the stored data are transferred to the Hydro-Place computer. (For more details about the DAQ program, refer to Reference [3].)

DAAP Program

A DAAP program is used to extract meaningful information from the binary coded data that are transmitted from the remote site by the DAQ program. These data are transmitted continuously, and are subdivided into hourly files. Depending upon the weather conditions at the remote site (e.g., wind speeds during critical periods), an hourly data file could be as large as 22 MB. This file consists of 58 channels (33 are presently active), and each channel can be sampled at up to 20 Hz. For this phase of project, conventional programming languages (e.g., FORTRAN or C) would have been very cumbersome, particularly regarding dimensioning, type declaration, and storage allocation. Also, to carry out data analysis quickly and frequently was a critical requirement of the project.

For these reasons, MATLAB[tm] was an appropriate choice, because its basic data element is a matrix. It does not require dimensioning, type declaration and storage allocation. The DAAP program in MATLAB[tm] is written in a menu-driven, interactive environment, and it communicates with the user in a clear unambiguous manner [4]. Figure 3 provides a compendium of the roles played by the DAQ and DAAP programs.

Concluding Remarks

This paper presented an overview of the project, which required the coordination and cooperation of various groups at NLH (e.g., structural, electrical, software, etc.). The Hawke Hill test site has been operational since January 1993. It took approximately nine months to develop the first phase described in the paper. The project is expected to run for another three years. Analysis is underway of the voluminous amount of data

1. A passive ice meter is a device consisting of 12 tubular rods forming a rectangular frame. After an icing event, the thickness of the accumulated ice on the rods is measured manually with a step of vernier calipers.
2. The remote ice growth detector is a sensor which transmits an electrical signal proportional to the weight of accreted ice on a 1 metre long cantilever beam. This device is being developed by NLH's Technical Support Group.

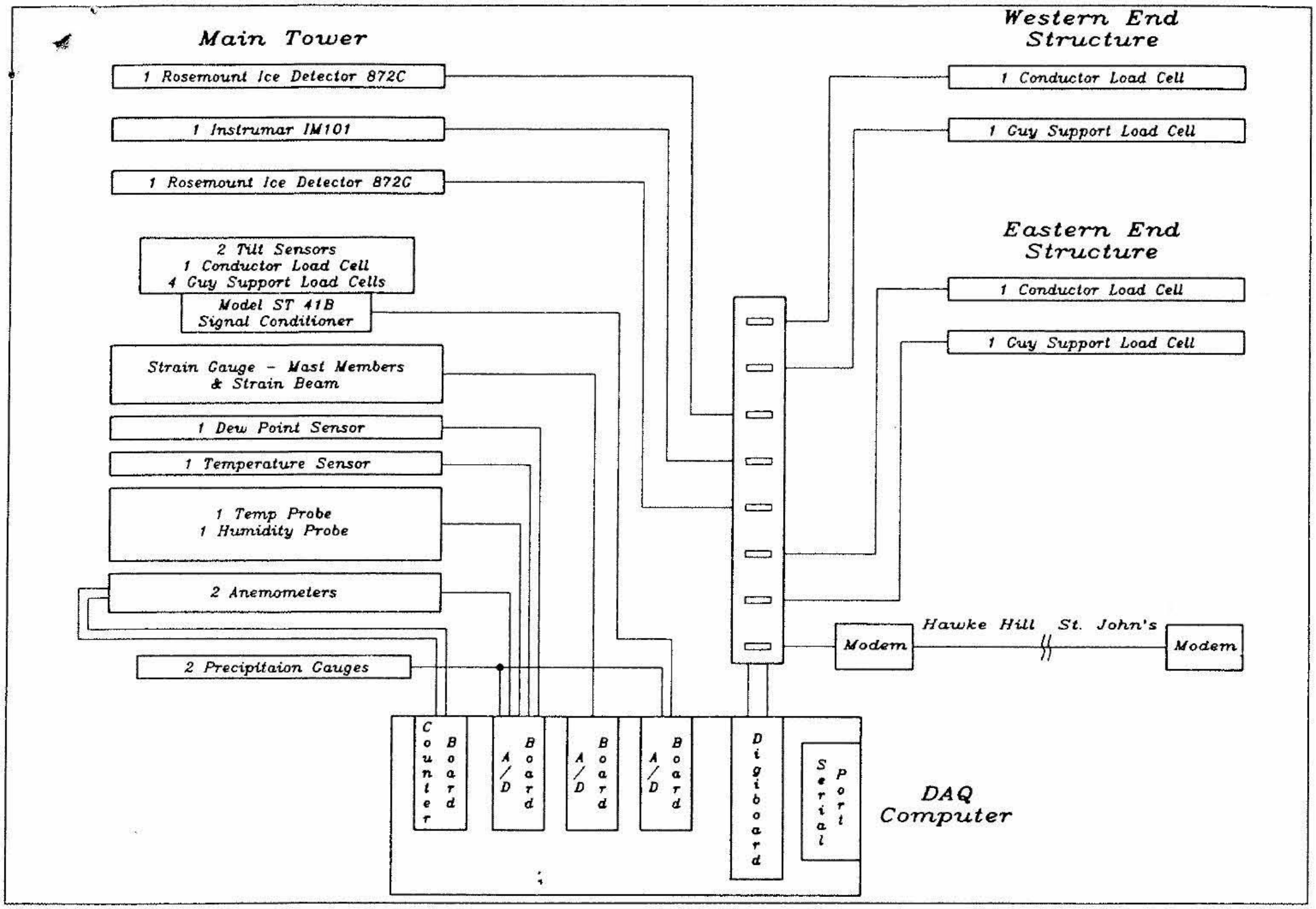

Figure 2 : Schematic of the data aquisition system.

acquired thus far.

Because of the nature of the project, and the research benefits of such a site, many other projects may be developed in the future. Presently, plans are on the way for future expansions. This includes the addition of trapezoidal conductors to investigate the wind drag on such conductors.

Acknowledgments

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