



Energy for  
generations

# Hydro Generator Rotor Earth Fault

## Installation of Carbon Dust Collection System

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- Introduction
- Rotor Earth Fault Relay Replacement
- Rotor Pull – Cleaning, Testing & Inspection
- Findings
- Installation of Carbon Extraction System.

## ESB Ardnacrusha

### 4 Unit Power Station

3 x Francis Turbines (1929)

1 x Kaplan Turbine (1934)

Total Capacity 86MW



ESB Ardnacrusha, Ireland

- Planned replacement of Generator Rotor Earth Fault (REF) Relay on Unit 4.
- Following REF Relay replacement – standing trip on HMI (Resistance < Min. Value) preventing the unit from starting.
- Subsequent electrical testing determined genuine earth fault on the rotor.
- Decision to pull rotor to determine the cause of the earth fault, further testing and cleaning.

Visual inspection completed with the machine assembled – restricted access to some areas.

The insulation resistance of the complete rotor circuit was made;

- Rotor poles
- Rotor leads
- Slip rings
- Poor results, test voltage only rose to  $\approx 50V$  (Test voltage set to 250V DC)

Rotor winding split into sections (50%-25%), and IR testing repeated

- Slip Rings results  $G\Omega$  @250V DC
- Rotor poles – each section equally poor results, test voltage not reached.

Issue appears to be global, and required rotor to be extracted for further inspections and testing.

# Rotor Pull



Extracted Rotor



Slip rings located beneath generator rotor.  
Rotor cooling fans located at top and bottom.



# Rotor Pole Removal



Rotor Poles Disassembly – 36 Poles



Rotor Rim Exhaust

# Rotor Pole Contamination



Rotor Pole



Rotor Pole Shim



# Rotor Pole Contamination - Findings

- Significant carbon dust and oil deposits on the poles
  - Pole windings
  - Pole shoe
  - Pole shims
  - Rotor rim
- Due to the carbon dust built up, tracking paths to ground
- Contamination found on the inner radius of the rotor pole windings
  - No filler, silicon, RTV etc. inserted to prevent debris between pole winding and shoe
  - This was found to be the root cause of the rotor earth faults
  - Once cleaned, IR values were measured in the MΩ range

## Rotor

- Winding resistance
- Insulation resistance (IR)
- Pole drop test

## Stator

- Insulation Resistance (IR)
- Polarisation Index (PI)
- Offline Partial Discharge
- Tan-Delta
- EI-Cid
- Wedge Mapping

## What Next? – How to prevent reoccurrence of...

...Forced Outage?

...Lost Revenue?

...Significant Costs / Resourcing?

## “MERSEN DustCollector”

Vacuum based system that extracts the airborne carbon dust out of the machine, thus preventing future short circuits caused by low insulation between rotor coils and ground.



MERSEN DustCollector AA4



- Design and installation of new brush holders.
  - Reuse existing brush holder supports
  - Designed for the current carrying capacity
- Brush holder incorporates vacuum port on trailing edge that allows the dust to be extracted from the surface of the slip ring / brush
- Vacuum piping installed to a common manifold where larger piping connections to the vacuum system.
- Carbon dust collected passes through cyclone to separate from air and stored for disposal.



New Brush Holder Installation



MERSEN Brush Holder Detail



Installation of MERSEN DustCollector Brush Holders

# DustCollector

Very successful project!!

REF reading of  $>999M\Omega$  during operation.

Subsequent visual inspections and electrical testing noted that the machine is “clean” and the testing results indicate that the rotor winding is in a healthy state with no issues of contamination.



MERSEN DustCollector AA4



# Further Works

- Due to the successful installation in Ardnacrusha, the MERSEN DustCollector system was installed in a number of other units in the ESB Hydro fleet.
- Most recent installation was Turlough Hill – 4 x 73MW Pump Storage Station
- Bi-Direction Units – first for MERSEN installation and required some additional Engineering and Design.



ESB Turlough Hill, Ireland



# Turlough Hill, MERSEN DustCollector Installation



MERSEN DustCollector



ESB Turlough Hill Installation



# Turlough Hill, MERSEN DustCollector Installation



Vacuum Piping Manifold



Diverter Switch

# Turlough Hill, MERSEN DustCollector Installation

- Turlough Hill Unit 2 suffered from an issue relating to the oil mist separator and build up of carbon dust within the brushgear compartment.
- The Unit required cleaning every 3-4 months, as REF alarms were being received. This resulted in the unit coming offline for approximately 4 hours every 3-4 months.
- Following the installation of the MERSEN DustCollector this unit was inspected 6 months after installation and little to no carbon dust was evident in the brushgear compartment – therefore the unit shall run to each planned annual inspection without intermediate brushgear cleaning outages.
- This is a significant saving for ESB, and maintains the Turlough Hill Units available for dispatch for the Irish Transmission System Operator.

# Thank you, Questions?

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