FEARNA STORAGE

Fearna Pumped Storage Hydro Scheme - EIA Report

Additional Information

Appendix B – Calculation of Temperature Effect per Cycle

December 2025

Quality Information

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Revision History

Revision	Revision Date	Details	Authorised
01	December 2025	Issue to ECU	Fraser Allison

Extract from Mott Macdonald Fearna PSH Temperature Investigation

Calculation of Temperature Effect per Cycle

Storage, Capacity and Duration

The Fearna project is being developed with 36.6GWh of storage available. This is governed by the storage capacity of the upper reservoir at Loch Fearna, 41Mm^3. The lower reservoir, Loch Quoich, has a much larger storage capacity of approximately 362Mm^3. The existing Quoich hydro scheme also utilises this reservoir.

Key Operating Parameters

Upper reservoir (Loch Fearna):

- Maximum TWL = +600 mAOD
- Minimum TWL = +540 mAOD

Lower reservoir (Loch Quoich):

- Maximum TWL = +196.38 mAOD (5 m below Quoich Dam spillway)
- Minimum TWL (lowest Quoich operating level) = +176.38 mAOD
- Gross head range: 338.62 m to 423.62 m
- Rated gross head for plant selection: +390 m
- Rated net head for plant selection: +385.4 m
- Design flows:
  - Q at max head = 518 m^3/s (generating) / 389 m^3/s (pumping)
  - Q at rated head = 573 m^3/s (generating) / 430 m^3/s (pumping)
  - Q at min head = 521 m^3/s (generating) / 391 m^3/s (pumping)

Definition of 'Cycle'

In the context of this calculation, a "cycle" refers to a complete sequence of operations in the hydro pump storage scheme. This includes both the pumping phase, where water is pumped from the lower reservoir (Loch Quoich) to the upper reservoir (Loch Fearna), and the generation phase, where water is released from the upper reservoir to generate electricity. Each cycle involves both phases, and the term is used to describe the entire process from start to finish.

Approach For Calculating Temperature Effect per Cycle

The key steps involved in calculating the temperature effect per cycle of a pumped storage hydro scheme are outlined below:

1. Initial Setup and Parameters:

- Define the key parameters including:

  Q_d - Discharge Rate (m^3/s)

  V_F - Storage Volume in Loch Fearna (Mm^3)

  H - Rated Net Head for Plant Selection (m)

  η - Combined efficiency of hydraulic system, turbines and generators,

  c - Specific Heat Capacity of Water (J/kg.^{0}C) ρ - Density of Water (kg/m^3)

2. Energy Calculations:

- Calculate the energy input for pumping and the energy output from turbines.
- Determine the heat generated due to inefficiencies.

3. Temperature Increase Calculation:

- Calculate the temperature increase per cycle due to the heat generated.

<u>Assessment of Temperature Effect</u>

The following calculation predicts the temperature increase at the discharge point of the turbines per full cycle.

Key Parameters selected:

- Discharge Rate (Q_d): 573 m^3/s
- Storage Volume in Loch Fearna (V_F): 41 Mm^3 (41×10^6 m^3)
- Rated Net Head for Plant Selection (h): 385.4 m
- Combined efficiency of hydraulic system, turbines and generators (η): 93% (0.93)*
- Specific Heat Capacity of Water (c): 4184 J/kg.^{0}C
- Density of Water (ρ): 1000 kg/m^3

* Note on efficiency: The combined efficiency comprises the following component efficiencies – Hydraulic losses assumed to be 1.5% – Turbine efficiency assumed to be 96% – Generator efficiency assumed to be 98.5% Combined Efficiency (η) = 0.985*0.96*0.985= 0.931. The transformers losses are excluded from this calculation. This is considered to be a conservative value as it assumes all system losses are transferred into the water as heat, where as in reality much will be dissipated as vibration, noise, and heat in the air. In reality, the energy transferred into the water will primarily be the hydraulic losses and the cooling water system.

Calculation:

1. Energy Input for Pumping:

E input = V_F × ρ× g × h = $41 \times 10^6 m^3 \times 1000\ kg/m^3 \times 9.81\ m/s^2 \times 385.4\ m \approx 1.55 \times 10^{14}$ J

2. Energy Output from Turbines:

E output = E input × η = 1.55×10^{14} J × 0.9 ≈ 1.40×10^{14} J

3. Heat Generated:

Qheat = E input – E output = 1.55×10^{14} J − 1.40×10^{14} J ≈ 1.085×10^{13} J

4. Temperature Increase per Cycle:

ΔT = Qheat x V_F × ρ × c = 1.085×10^{13} J x 41×10^6 m^3 × 1000 kg/m^3 × 4184 J/kg. ^{o}C ≈ 0.063°C