Article DOI: https://doi.org/10.37284/eaje.9.2.5513

East African Journal of Engineering
eaje.eanso.org
Volume 9, Issue 2, 2026
Print ISSN: 2707-5389 | Online ISSN: 2707-5397
Title DOI: https://doi.org/10.37284/2707-5397

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Feasibility Assessment of a 5 MW Run-of-River Mini-Hydropower Plant on the Luswisi River at Bwenda Village, Ileje District, Tanzania

James Bigambo James[1], Joel Mbwiga[2] & Masoud Kamoleka[2]*

[1] Tanzania Electric Supply, P. O. Box 595, Mbeya, Tanzania.
[2] Mbeya University of Science and Technology, P. O. Box 131, Tanzania.
*Author for Correspondence Email: james.bigambo@gmail.com

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

Publication Date:

08 August 2026

Keywords:

Luswisi River, Run-of-river hydropower, Topographic survey, HOMER Pro, MATLAB/Simulink, Pelton turbine, Flow-duration curve, Tanzania.

ABSTRACT

This study assesses the technical and screening-level economic feasibility of a 5 MW high-head run-of-river mini-hydropower plant on the Luswisi River at Bwenda Village, Ileje District, Tanzania. The revised paper integrates the topographic survey, HOMER Pro model configuration and outputs, and MATLAB/Simulink dynamic-simulation results that were omitted from the earlier manuscript. The site is located at approximately 9° 20.1′ S and 33° 29.4′ E. GIS-based catchment delineation and RTK-GNSS/total-station survey data identify the intake, waterway and powerhouse corridor and establish a gross head of 153 m; a preliminary 5% hydraulic-loss allowance gives a net head of 145.35 m. Corrected monthly discharge ranges from 3.70 to 7.10 m³/s. At 90% combined efficiency, 5 MW requires approximately 3.70 m³/s at gross head and 3.90 m³/s at the preliminary net head. The HOMER Pro hydro-grid model uses the corrected monthly flow vector, a 5 MW hydro unit, local AC demand, grid backup/export, a 25-year project life, an 8% discount rate, TZS 18 billion capital cost, TZS 2 billion lifetime operation and maintenance cost, and TZS 168/kWh electricity value. The corrected screening analysis gives 41,062 MWh/year saleable energy, an LCOE of about TZS 43.0/kWh, NPV of TZS 54.8 billion, IRR of 37.9%, and simple payback of 2.6 years. MATLAB/Simulink results show damped transient behaviour: frequency returns to approximately 50 Hz, rotor speed converges toward 1.0 pu, torque and active/reactive power remain bounded, balanced three-phase voltages are maintained, the local load is supplied, and surplus active power is transferred to the grid interface. These results support feasibility-level development of two 2.5 MW Pelton units, subject to multi-year gauging, detailed hydraulic and geotechnical design, environmental-flow allocation, manufacturer data and utility interconnection approval.

APA CITATION

James, J. B., Mbwiga, J. & Kamoleka, M. (2026). Feasibility Assessment of a 5 MW Run-of-River Mini-Hydropower Plant on the Luswisi River at Bwenda Village, Ileje District, Tanzania. *East African Journal of Engineering*, *9*(2), 34-58. https://doi.org/10.37284/eaje.9.2.5513

 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

CHICAGO CITATION

James, James Bigambo, Joel Mbwiga and Masoud Kamoleka. 2026. "Feasibility Assessment of a 5 MW Run-of-River Mini-Hydropower Plant on the Luswisi River at Bwenda Village, Ileje District, Tanzania". *East African Journal of Engineering* 9 (2), 34-58. https://doi.org/10.37284/eaje.9.2.5513.

HARVARD CITATION

James, J. B., Mbwiga, J. & Kamoleka, M. (2026) "Feasibility Assessment of a 5 MW Run-of-River Mini-Hydropower Plant on the Luswisi River at Bwenda Village, Ileje District, Tanzania", *East African Journal of Engineering*, 9(2), pp. 34-58. doi: 10.37284/eaje.9.2.5513.

IEEE CITATION

J. B., James, J., Mbwiga & M., Kamoleka, 2026. "Feasibility Assessment of a 5 MW Run-of-River Mini-Hydropower Plant on the Luswisi River at Bwenda Village, Ileje District, Tanzania" *EAJE*, vol. 9, no. 2, pp 34-58, Aug. 2026.

MLA CITATION

James, James Bigambo, Joel Mbwiga & Masoud Kamoleka. "Feasibility Assessment of a 5 MW Run-of-River Mini-Hydropower Plant on the Luswisi River at Bwenda Village, Ileje District, Tanzania" *East African Journal of Engineering*, Vol. 9, no. 2, Aug. 2026, pp. 34-58, doi:10.37284/eaje.9.2.5513.

INTRODUCTION

Reliable electricity supply is essential for socio-economic development because it supports households, schools, health services, communication, small industries, agro-processing, and other productive activities (Taghizad-tavana et al., 2025). In many rural and semi-rural areas of Tanzania, electricity supply is still affected by limited grid coverage, voltage fluctuation, load growth, and long distances from major generation centres. These challenges create the need for locally available renewable energy resources that can strengthen electricity generation and improve supply reliability (Mdee et al., 2018).

Small hydropower is one of the most suitable renewable energy options in areas with adequate river flow and hydraulic head. Unlike solar and wind resources, run-of-river hydropower can generate electricity continuously throughout the day when river discharge is sufficient. However, the feasibility of a hydropower project depends on an accurate assessment of river discharge, available head, seasonal flow variation, turbine efficiency, environmental flow requirements, and grid interconnection conditions (Selvan et al., 2012).

The Luswisi River at Bwenda Village in Ileje District, Tanzania, has been identified as a potential site for a 5 MW high-head run-of-river mini-hydropower plant. The site has a measured gross head of 153 m, which places it in the high-head category. The corrected hydrological data show that monthly discharge ranges from 3.70 m³/s to 7.10 m³/s. The final dry-season flow corrections are 3.80 m³/s in August, 3.75 m³/s in September, 3.72 m³/s in October, and 3.70 m³/s in November. These values are important because they confirm that even the lowest-flow months meet or approximately meet the flow required for 5 MW operation on a gross-head basis. Hydropower output is estimated using the equation:$P = \rho g Q H \eta$ where $P$is power output, $\rho$is water density, $g$is gravitational acceleration, $Q$is discharge, $H$is head and $\eta$is the overall efficiency. At 90% efficiency and 153 m gross head, the required flow for 5 MW is approximately 3.70 m³/s. On a conservative net-head basis, the required flow is about 3.90 m³/s. Therefore, the corrected Flow Duration Curve interpretation indicates that the Luswisi River can support year-round rated operation at the feasibility-study level, subject to final deductions for environmental flow, hydraulic losses, planned outage, forced outage, and turbine manufacturer efficiency curves.

The high-head and moderate-flow characteristics of the site support the selection of Pelton impulse turbines. A configuration of two 2.5 MW units is preferred because it improves operational flexibility, allows partial-load operation during lower-flow periods, and increases reliability during maintenance. This arrangement is suitable for a

 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

grid-connected mini-hydropower plant because it allows staged operation and better control of power output (Alie, 2016).

This paper, therefore, presents a corrected feasibility assessment of the proposed 5 MW Luswisi River mini-hydropower plant. The study includes hydrological correction, power estimation, Flow Duration Curve interpretation, turbine selection, HOMER Pro techno-economic analysis, MATLAB/Simulink dynamic validation, grid interconnection requirements, and environmental safeguards. The main contribution of the paper is the corrected dry-season discharge interpretation, which supports the technical viability of the plant as a year-round rated run-of-river hydropower scheme.

Research Gap and Contribution

Previous work on Tanzanian hydropower has largely described national or regional potential, while many project-level studies report resource or software outputs without showing a traceable link between topographic measurements, hydrology, component sizing, annual energy and financial indicators. The earlier version of this paper did not include the mapped catchment and intake-powerhouse corridor, the HOMER Pro configuration and result screens, or the MATLAB/Simulink response diagrams contained in the research report. This revision closes those gaps by presenting the topographic dataset and survey method, documenting the corrected HOMER Pro inputs and dispatch assumptions, reproducing the archived software outputs with an explicit consistency note, and adding dynamic frequency, speed, torque, power, voltage and grid/load results. Gross-head and net-head calculations are still separated so that the software figures do not replace the transparent engineering calculation chain.

Aim, Objectives and Research Questions

The aim of the study was to determine whether the Luswisi River can technically and economically support a 5 MW grid-connected run-of-river mini-hydropower plant at feasibility-study level.

Determine the corrected monthly discharge regime, gross and preliminary net head, design flow, flow-duration characteristics and annual energy potential.

Select preliminary hydraulic, electromechanical and grid-interconnection components appropriate to the site.

Evaluate screening-level financial performance using NPV, IRR, simple payback and LCOE, including sensitivity cases.

Identify the environmental, social, data-quality and detailed-design conditions required before investment.

The corresponding research questions were: (i) what discharge and head are available, and how reliably can they support 5 MW; (ii) which turbine, penstock and generator arrangement is technically suitable; (iii) what screening-level economic indicators result from the stated assumptions; and (iv) what additional studies and safeguards are required before implementation?

MATERIALS AND METHODS

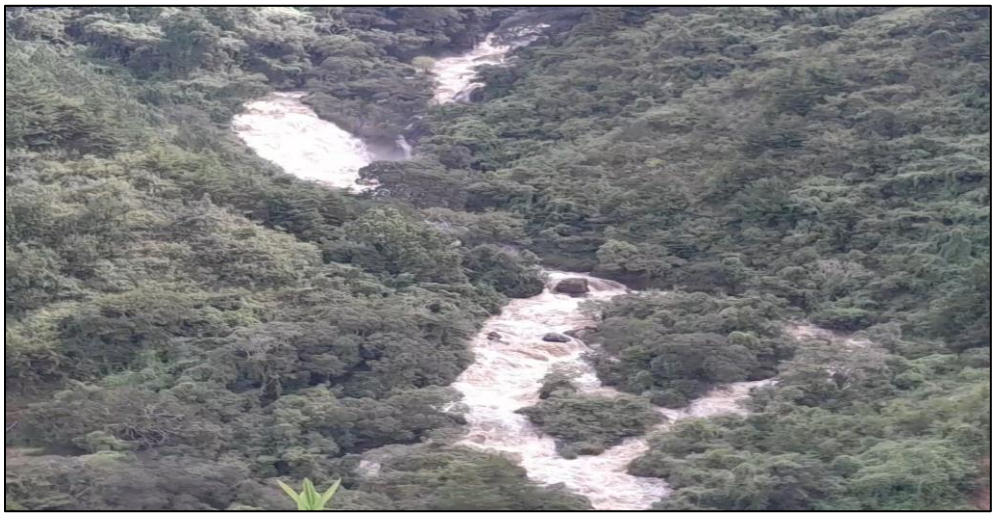
Background of the Study

The Luswisi River, flowing from the forest through Bwenda Village in Ileje District to Lake Nyasa Basin, is a significant natural resource with potential for small-scale hydropower generation (Margonis, 2017). Mini-hydropower systems, especially run-of-river schemes, are considered a promising solution for rural electrification in the area. These systems harness the river's flow to generate clean, decentralised, and low-carbon electricity, which can improve energy access and support local socioeconomic growth (Zukhrufiyati et al., 2019).

 This work is licensed under a Creative Commons Attribution 4.0 International License

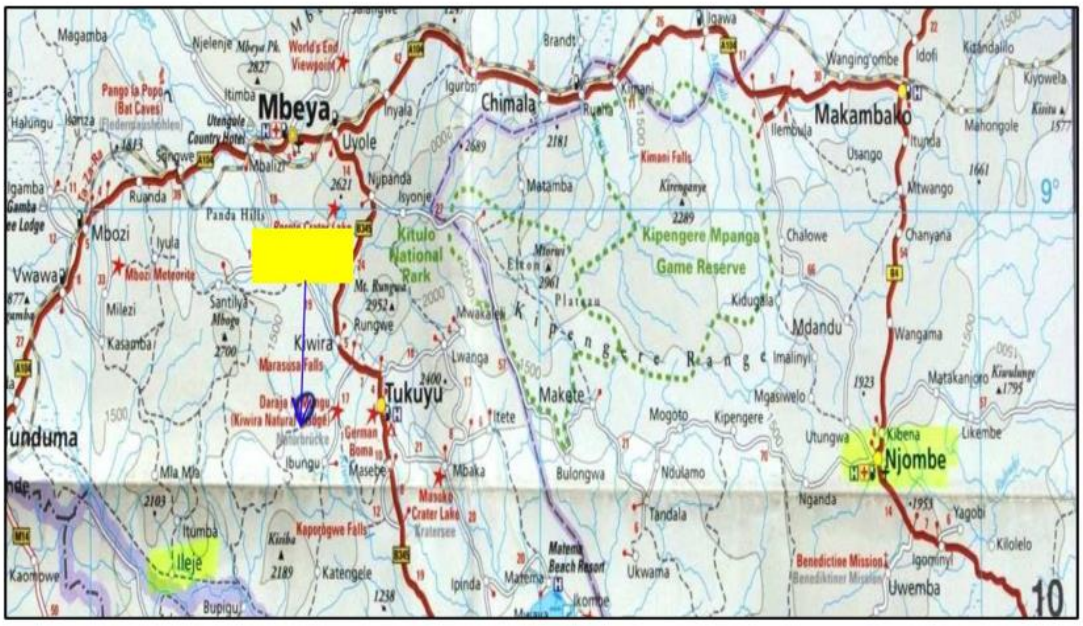
Article DOI: https://doi.org/10.37284/eaje.9.2.5513

Figure 1: Luswisi River



Grid electricity in Ileje District has always been an erratic source of energy; load shedding is always in place, and voltage fluctuations are prevalent. These interruptions, therefore, slow down socioeconomic development, with health services, schools, and small-scale industries in the district carrying the burden. Though the government, through the Rural Energy Agency (REA) and other agencies within the framework of rural electrification, attempts to develop the remote areas, existing infrastructure constraints, lack of funding, and limited institutional capacity have placed project implementation in slow motion (Hydro & Mapping, 2015). Energy problems in this district are compounded by the remote character of the district and the absence of any large-scale power infrastructure; therefore, decentralised renewable energy becomes essential for sustainable development (Iemsomboon et al., 2013).

Figure 2: Location of the Site at Bwenda



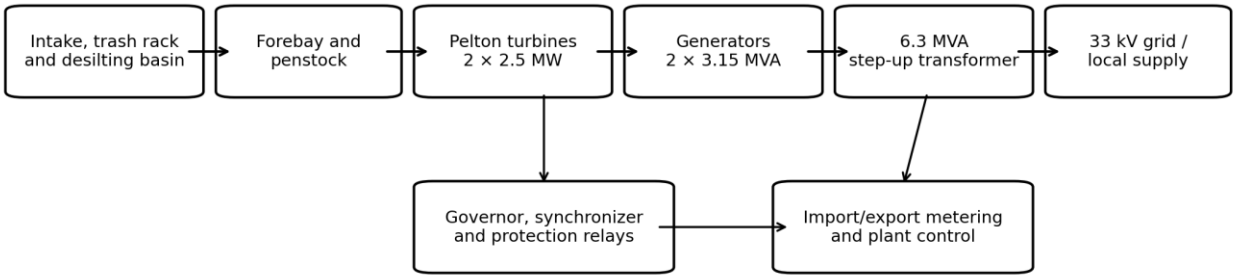
 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.1.4317

System Concept

The proposed scheme is grid-connected and run-of-river, comprising an intake and trash rack, desilting basin, forebay, penstock, Pelton turbine-generator units, step-up transformer, protection, metering and a 33 kV interconnection subject to TANESCO approval. The approximate project reference coordinates used in the underlying dissertation were 9°20.1′ S and 33°29.4′ E; final coordinates, land boundaries and easements require cadastral confirmation.

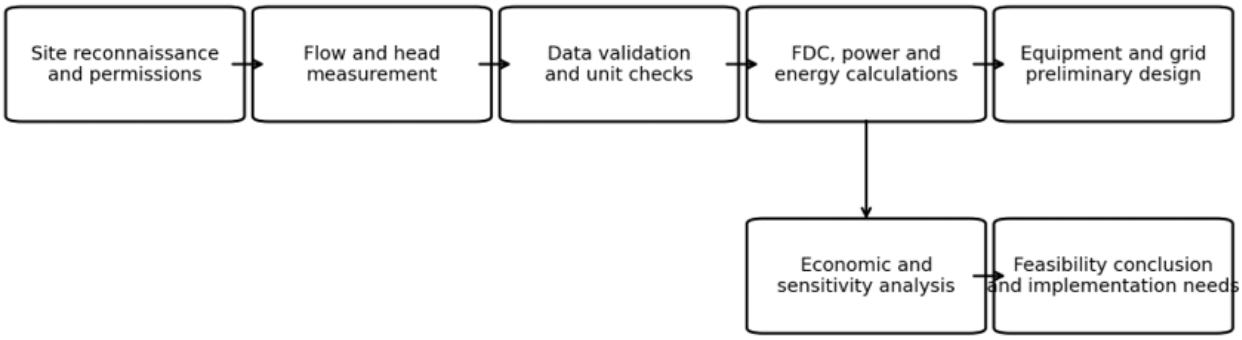
Figure 3: Preliminary Energy-Conversion and Grid-Interface Layout for the Proposed Plant.



Research Design and Analytical Sequence

A mixed engineering feasibility design was used. Primary and project-supplied data were organised into hydrological, topographical, demand, cost, environmental and grid categories. The analytical sequence was: field reconnaissance and permissions; flow and head measurement; validation and unit checks; flow-duration, power and energy calculations; preliminary component selection; discounted-cash-flow and sensitivity analysis; and identification of implementation requirements.

Figure 4: Revised Methodological Framework Showing Data Collection, Validation, Analysis and Feasibility Decision



River-discharge Measurement and Validation

River discharge was determined using the velocity-area method at a representative cross-section. The section was divided into subsections; width and depth were measured to obtain subsection area, and water velocity was measured at representative verticals. Total discharge was calculated as the sum of subsection area multiplied by mean velocity. Repeated readings were compared during each visit, abnormal observations caused by obstruction or

 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

timing error were rejected, and units were standardised to cubic metres per second before design calculations.

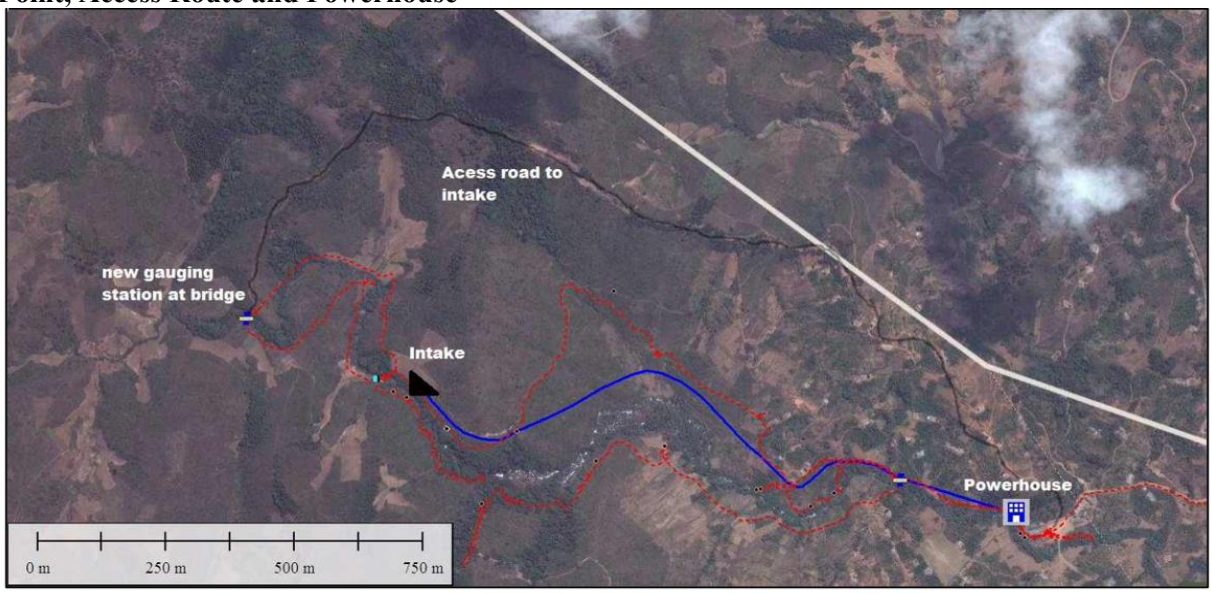
$$Q = \Sigma(A_i V_i) \quad (1)$$

The monthly series was checked for internal consistency, seasonal ordering and agreement between field sheets, calculation worksheets and the hydropower model input table. Particular attention was given to the dry-season corrections of 3.80 m³/s in August, 3.75 m³/s in September, 3.72 m³/s in October and 3.70 m³/s in November. These values are treated as the author's corrected feasibility dataset. Because only twelve-monthly values were available, the resulting FDC is a screening curve rather than a substitute for a multi-year daily gauging record.

Topographic Survey, Catchment Delineation and Hydraulic-Loss Allowance

The topographic assessment combined field reconnaissance, GIS/DEM catchment delineation and project survey observations. The proposed site is referenced at approximately 9°20.1′ S and 33°29.4′ E. The intake, access route, gauging point, proposed waterway and powerhouse were mapped to establish the physical arrangement of the run-of-river scheme.

Figure 5: Aerial Topographic Layout Showing the Proposed Intake, Waterway Alignment, Gauging Point, Access Route and Powerhouse



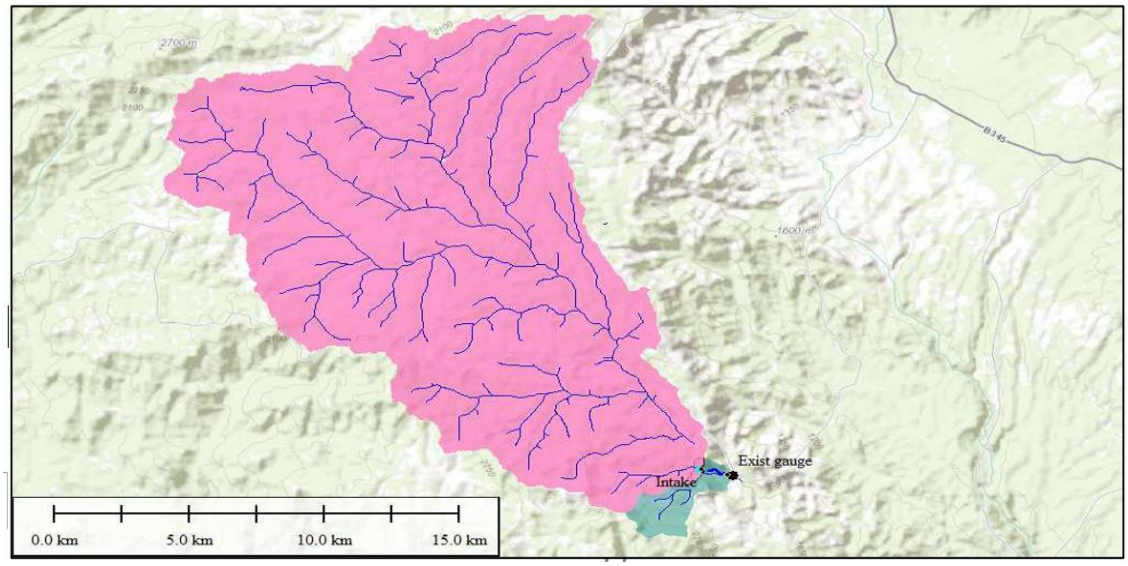
The contour survey was prepared in WGS 84 / UTM Zone 36S, with a reported 2 m contour interval and 1:3,000 map scale. RTK-GNSS or total-station observations were used to obtain benchmark and profile elevations. The elevation difference between the proposed intake/forebay and powerhouse positions gives the adopted gross head of 153 m. For preliminary feasibility checking, net head was taken as 95% of gross head, equal to 145.35 m. This 5% allowance represents aggregate friction and minor losses and must be replaced during detailed design by a Darcy-Weisbach calculation using the final penstock length, diameter, roughness, bends, valves and fittings. The mapped catchment boundary supports drainage interpretation, but a single verified catchment-area value should be calculated and reported after final GIS boundary validation.

$$H_{net} = Hg_{ross} - h_l = 153 - 7.65 = 145.35\,m \quad (2)$$

 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.1.4317

Figure 6: Contour Map of the Luswisi River Project Corridor at Bwenda Village.



Source: *Field survey by Hassan (2025), as reproduced in the research report*

Table 1: Topographic and Site-Data Summary Used in the Revised Paper

Topographic parameter	Adopted information	Use in the feasibility assessment
Project reference location	Approximately 9°20.1′ S, 33°29.4′ E	Locates the intake-powerhouse corridor at Bwenda Village
Survey/mapping tools	RTK-GNSS or total station; GIS/DEM; field reconnaissance	Establishes elevations, alignment, access and catchment drainage
Map reference	WGS 84/UTM Zone 36S; 2 m contours; scale 1:3,000	Provides the reported contour and profile framework
Gross head	153 m	Upper-bound hydropower and turbine-selection basis
Preliminary net head	145.35 m	5% aggregate loss allowance for feasibility screening
Principal mapped features	Intake, gauging point, access route, waterway and powerhouse	Defines the preliminary run-of-river arrangement
Outstanding verification	Closed survey, exact penstock profile, GIS catchment area and geotechnics	Required before detailed civil and hydraulic design

Power, Design-Flow, FDC and Annual-Energy Calculations

Hydropower was calculated from water density, gravitational acceleration, discharge, head and combined turbine-generator efficiency. The preliminary combined efficiency was 90%. The flow required for 5 MW was obtained by rearranging the power equation.

$$P = \rho g Q H \eta \quad (3)$$

$$Q_5 MW = P/(\rho g H \eta) \quad (4)$$

Monthly power was limited to the installed capacity of 5 MW. Monthly energy was calculated from capped power and the number of hours in each month. The FDC used the Weibull plotting position $P_e = m/(n+1) \times 100$, where m is the rank and n = 12. This monthly FDC supports preliminary

 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

comparison of design flow and seasonal reliability, but it cannot represent daily extremes, flood duration or within-month variability as accurately as long-term daily records (Liucci et al., 2014; Gasore et al., 2023).

$$E_{\mathrm{m}} = min(P_{\mathrm{m}}, 5\,MW) \times 24 \times d_{\mathrm{m}} \quad (5)$$

Preliminary Hydraulic and Electromechanical Sizing

The high head and moderate flow support a Pelton impulse turbine. Two 2.5 MW units were adopted instead of one 5 MW unit to improve maintenance flexibility and part-flow operation. A preliminary penstock diameter of 1.30 m gives a cross-sectional area of 1.327 m² and a velocity of approximately 2.94 m/s at 3.90 m³/s. Final selection requires water-hammer analysis, turbine manufacturer hill charts, nozzle sizing, speed selection and generator transient studies.

$$A = \pi D^2/4 = 1.327\,m^2; \quad V = Q/A \approx 2.94\,m/s \quad (6)$$

Load and Grid Assessment

The district demand series for 2020-2025 was used to compare local consumption with plant production. Because the proposed 5 MW capacity exceeds the reported 2025 peak demand of 1.908 MW, the plant must be designed for synchronised grid export. The preliminary interface includes generator breakers, synchronising equipment, a step-up transformer, feeder protection, import/export metering, plant control and utility protection coordination.

Economic Analysis and Sensitivity

The financial calculation used the values stated in the reviewed manuscript: TZS 18 billion initial capital cost, TZS 2 billion total operation and maintenance cost over 25 years, 8% real discount rate, and TZS 168/kWh electricity value. The lifetime O&M value was annualised as TZS 80 million/year. Screening saleable energy was taken as 95% of the calculated net-head energy to represent technical availability; environmental-flow and detailed auxiliary-loss deductions were not available and therefore remain outside the base calculation.

$$NPV = -C_0 + \Sigma[(R_{\mathrm{t}} - O\&M_{\mathrm{t}})/(1 + r)^{\mathrm{t}}] \quad (7)$$

$$LCOE = PV(lifetime\ costs) /PV(lifetime\ electricity) \quad (8)$$

A conservative sensitivity case reduced energy by 10% and tariff by 15% while increasing capital cost by 20% and annual O&M by 25%. A favourable case increased energy by 3% and tariff by 10% while reducing capital cost and O&M by 10%. These are screening scenarios, not substitute quotations or a bankable tariff agreement.

Ethical Considerations and Data Protection

The study involved engineering measurements, site observations and aggregated electricity-demand information. Local permission was obtained before site access; participants involved in consultations were informed of the study purpose and participated voluntarily. No names or personally identifying responses were retained in the journal dataset. Environmental and community interests were treated as feasibility constraints, including downstream water use, land access and consultation before construction.

HOMER Pro and MATLAB/Simulink Modelling Procedure

The research report contains HOMER Pro input/result screens and MATLAB/Simulink dynamic-response plots. These outputs are incorporated in the revised paper together with the

 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

numerical inputs required to interpret them. Because some archived HOMER screenshots were produced before the final dry-season flow correction, the revised monthly input vector and transparent engineering calculations are treated as the authoritative basis. The screenshots document the model architecture and output categories; the corrected tables document the final hydrological and financial interpretation.

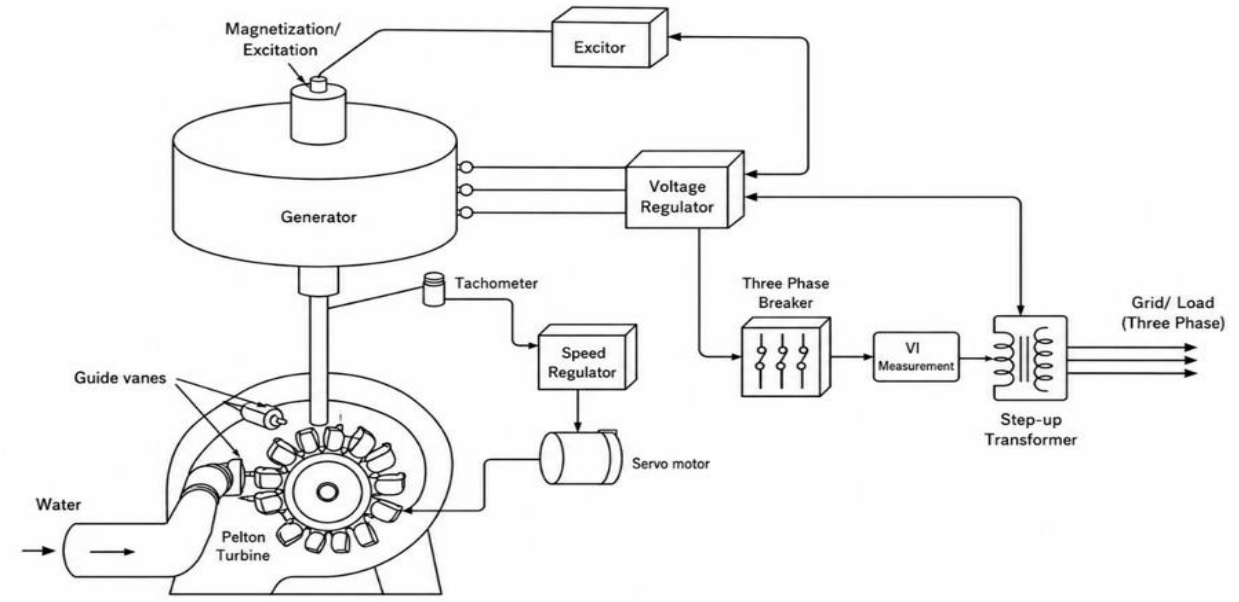
HOMER Pro Configuration

HOMER Pro was used to represent a grid-connected AC system containing a 5 MW generic hydropower unit, the local electrical load and the national-grid connection. The corrected January-December flow inputs are 5.20, 5.00, 6.30, 7.10, 5.80, 4.60, 3.90, 3.80, 3.75, 3.72, 3.70 and 4.80 m^3/s. The hydro unit is limited to 5 MW and operates with hydro priority: local demand is served first, surplus power is exported, and the grid supplies deficits during derating, outage or maintenance. The local HOMER load dataset is approximately 450.92 kW average, 10,822 kWh/day and 1,950.5 kW peak, with a 3% annual-growth scenario; district load records are separately used to assess the wider export requirement. Economic inputs are a 25-year project life, 8% real discount rate, TZS 18 billion capital cost, TZS 2 billion lifetime O&M and TZS 168/kWh electricity value. Model outputs reviewed include hydro production, load served, excess electricity, grid purchases and sales, renewable fraction, NPC, LCOE and sensitivity.

MATLAB/Simulink Configuration

MATLAB/Simulink was used for short-duration electromechanical validation of the Pelton turbine-generator system. The model contains the hydraulic turbine and governor, synchronous generator, tachometer and speed regulator, servo-controlled water admission, excitation system, automatic voltage regulator, three-phase breaker, voltage-current measurement, step-up transformer, representative local load and grid/export interface. The principal evaluation criteria were recovery of frequency to approximately 50 Hz, rotor-speed convergence toward 1.0 pu, damping of electromagnetic torque, stable generator and load active/reactive power, balanced three-phase voltage and current, continuous load supply and positive surplus-power transfer to the grid interface.

Figure 7: Pelton Turbine-Generator, Control, Excitation, Protection and Grid-Interface Arrangement Used as the MATLAB/Simulink Modelling Basis.



 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

Table 2: Complementary Roles and Data Structure of HOMER Pro and MATLAB/Simulink.

Modelling element	HOMER Pro representation	MATLAB/Simulink representation
Purpose	Annual energy balance and screening economics	Short-term dynamic and electrical validation
Hydraulic basis	Corrected monthly flow vector; 153 m gross head; 5 MW cap	Mechanical input to Pelton turbine-governor model
Electrical system	Hydro unit, AC load and bidirectional grid	Synchronous generator, breaker, transformer, load and grid
Control/dispatch	Hydro priority, grid backup and surplus export	Governor-speed loop and exciter-voltage loop
Main outputs	Production, excess, grid exchange, unmet load, NPC and LCOE	Frequency, speed, torque, P-Q, voltage and current
Consistency control	Final values follow corrected m^3/s data and transparent calculations	Responses checked for damping, balance and bounded operation

Table 3: Principal Feasibility Inputs and Their Analytical Role.

Input	Adopted value	Role in analysis
Installed capacity	5 MW	Capacity cap and design target
Gross head	153 m	Upper-bound hydraulic calculation
Preliminary net head	145.35 m	5% loss screening case
Monthly discharge	3.70-7.10 m^3/s	FDC, monthly power and energy
Overall efficiency	90%	Turbine-generator feasibility assumption
Turbine arrangement	2 × 2.5 MW Pelton	High-head operation and redundancy
Penstock diameter	1.30 m preliminary	Velocity and conveyance check
Economic life/discount rate	25 years/8%	Discounted cash-flow calculation
Capital/lifetime O&M	TZS 18 bn / TZS 2 bn	Screening cost assumptions
Electricity value	TZS 168/kWh	Revenue sensitivity assumption

Table 4: Data Collection, Validation and Limitation Controls.

Data category	Collection/derivation	Validation control	Main limitation
Discharge	Velocity-area measurements and monthly corrected dataset	Repeat readings, subsection summation, unit check	Only 12 monthly values; no long daily record
Head	Project topographic profile using RTK-GNSS/total station	Benchmark/elevation consistency and gross-net separation	Final survey closure and detailed losses required
Demand	District load records, 2020-2025	Annual average, peak and energy cross-check	Forecast and grid study required
Costs	Values provided in reviewed manuscript	Consistent TZS units and discounted cash-flow equations	No contractor quotations or financing terms
Environmental/social	Site observations and consultations	Downstream use, land and sediment screening	Formal ESIA and environmental flow not completed

 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.1.4317

RESULTS AND DISCUSSION

Topographic and Site Results

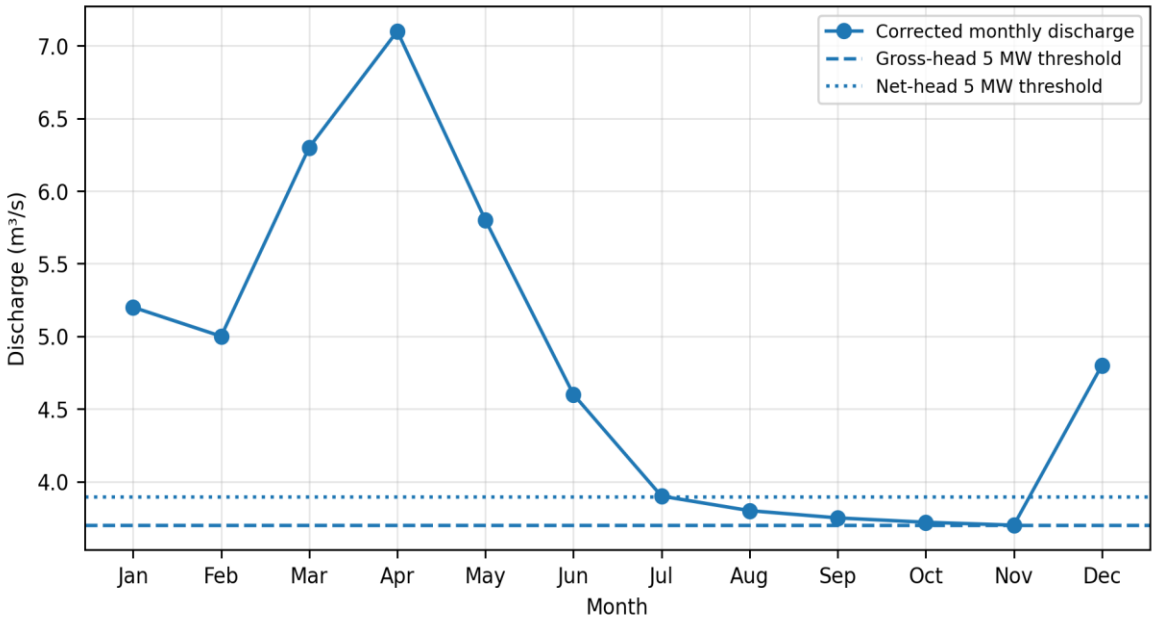
The mapped project corridor confirms a practicable high-head run-of-river arrangement. The intake is located upstream of the proposed powerhouse, with the waterway following the river valley and slope toward the lower powerhouse site. The field-survey contour map and aerial layout identify the principal civil-work locations, access route and gauging point. The 153 m gross elevation difference is therefore traceable to the mapped intake-powerhouse alignment rather than being an unsupported model assumption. This topography is the principal reason that a Pelton turbine can produce 5 MW using a moderate design flow of about 3.70-3.90 m³/s.

The GIS catchment figure shows a branching drainage network feeding the intake area and supports the seasonal hydrological pattern used in the monthly flow series. However, the map should not be interpreted as a substitute for a closed survey, verified catchment-area computation or geotechnical investigation. Final design must establish exact intake, forebay, penstock and powerhouse coordinates, longitudinal profile, land requirements, foundation conditions and construction access.

Hydrological Resource, Design Flow and FDC

The corrected flow series ranges from 3.70 m³/s in November to 7.10 m³/s in April. The 5 MW flow requirement is 3.70 m³/s when the full gross head is used, but 3.90 m³/s when the preliminary net head is used. Thus, all months meet the gross-head threshold, while August-November fall slightly below the net-head threshold. This distinction is important: the original year-round 5 MW statement is a theoretical upper bound, whereas the net-head result indicates modest dry-season derating unless hydraulic losses are held below the preliminary allowance or the turbine-generator package performs above the assumed combined efficiency.

Figure 8: Corrected Monthly Discharge Compared with Gross-Head and Net-Head 5 MW Design-Flow Thresholds.



 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

Figure 9: Monthly Flow-Duration Curve Based on the Corrected Twelve-Month Dataset.

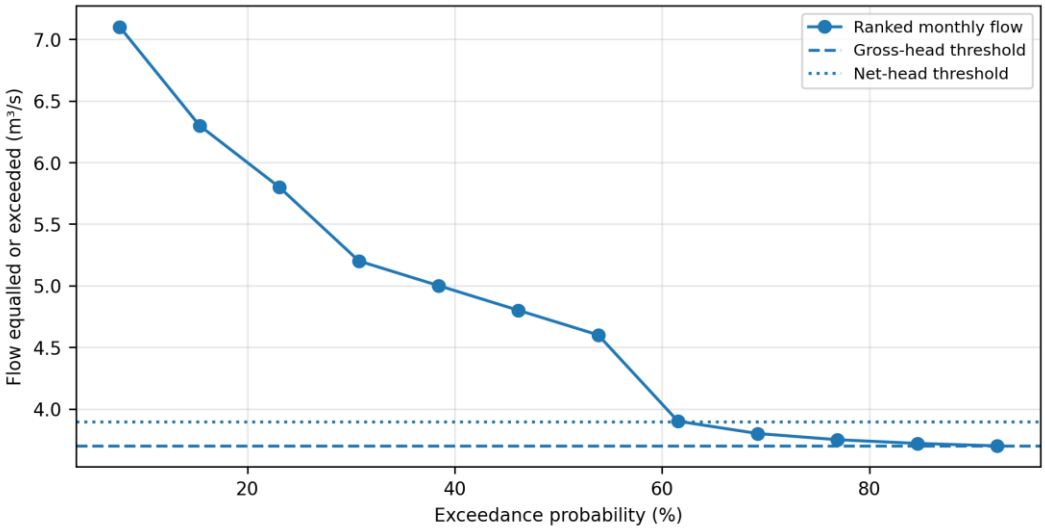


Table 5: Monthly Hydraulic Capability and Net-Head Energy Result.

Month	Q (m^3/s)	Gross P (MW)	Net P (MW)	Capped net output (MW)	Energy (MWh)	Interpretation
January	5.20	7.02	6.67	5.00	3,720.0	Rated at net head
February	5.00	6.75	6.42	5.00	3,360.0	Rated at net head
March	6.30	8.51	8.08	5.00	3,720.0	Rated at net head
April	7.10	9.59	9.11	5.00	3,600.0	Rated at net head
May	5.80	7.83	7.44	5.00	3,720.0	Rated at net head
June	4.60	6.21	5.90	5.00	3,600.0	Rated at net head
July	3.90	5.27	5.00	5.00	3,720.0	Rated at net head
August	3.80	5.13	4.88	4.88	3,628.1	Slight net-head derating
September	3.75	5.07	4.81	4.81	3,464.9	Slight net-head derating
October	3.72	5.03	4.77	4.77	3,551.8	Slight net-head derating
November	3.70	5.00	4.75	4.75	3,418.7	Slight net-head derating
December	4.80	6.48	6.16	5.00	3,720.0	Rated at net head

Table 6: Ranked Monthly Flows and Exceedance Interpretation.

Rank	Month represented	Ranked flow (m^3/s)	Exceedance (%)	Interpretation
1	April	7.10	7.7	Above net-head threshold
2	March	6.30	15.4	Above net-head threshold
3	May	5.80	23.1	Above net-head threshold
4	January	5.20	30.8	Above net-head threshold
5	February	5.00	38.5	Above net-head threshold
6	December	4.80	46.2	Above net-head threshold
7	June	4.60	53.8	Above net-head threshold
8	July	3.90	61.5	Above net-head threshold
9	August	3.80	69.2	Meets gross threshold; below net threshold
10	September	3.75	76.9	Meets gross threshold; below net threshold
11	October	3.72	84.6	Meets gross threshold; below net threshold
12	November	3.70	92.3	Meets gross threshold; below net threshold

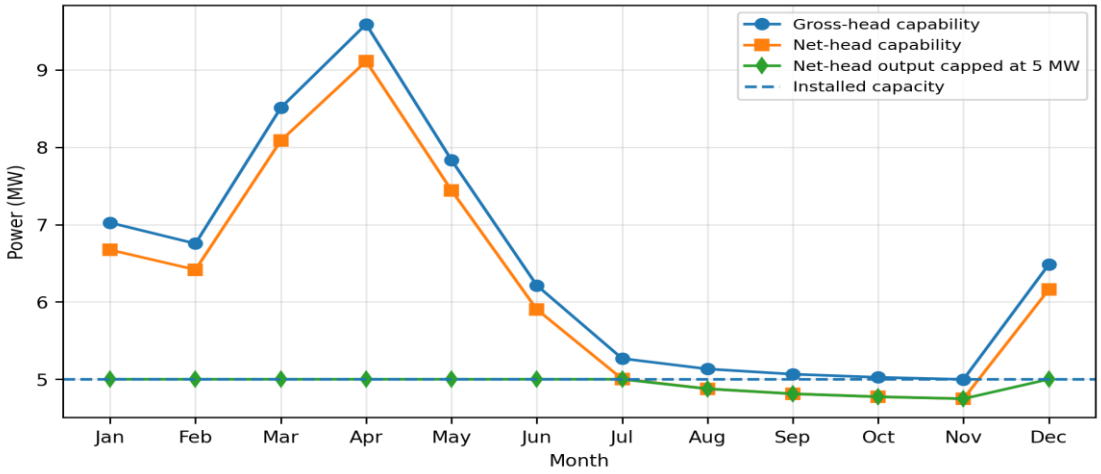
 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.1.4317

The use of an FDC to link river flow and design capacity is consistent with established run-of-river practice (Othman et al., 2017). However, recent tropical case studies emphasise that capacity selected near the low-flow boundary may minimise unused high flows but can create stronger sensitivity to dry-season variability and environmental releases (Gasore et al., 2026). The Luswisi result extends the Tanzanian resource literature by providing a site-specific head-flow-power calculation, but its reliability is lower than studies based on multi-year daily discharge. A gauging campaign covering several hydrological years is therefore necessary before financial close.

Power Capability and Equipment Selection

Figure 10: Gross-Head and Net-Head Monthly Power Capability Compared with the 5 MW Installed Capacity.



At gross head, the uncapped hydraulic capability reaches 5.00-9.59 MW; at preliminary net head it reaches 4.75-9.11 MW. The installed-capacity cap therefore governs production in January-July and December, while August-November is governed by water and net head. The 153 m head places the site within the practical operating range of a Pelton impulse turbine. A two-unit arrangement reduces the consequence of a single-unit outage and permits one unit to operate when flow is insufficient for both units. This agrees with optimisation literature showing that turbine number, design flow and penstock losses should be jointly selected rather than treated as fixed inputs (Yildiz et al., 2024).

Table 7: Preliminary Hydraulic and Electromechanical Selection.

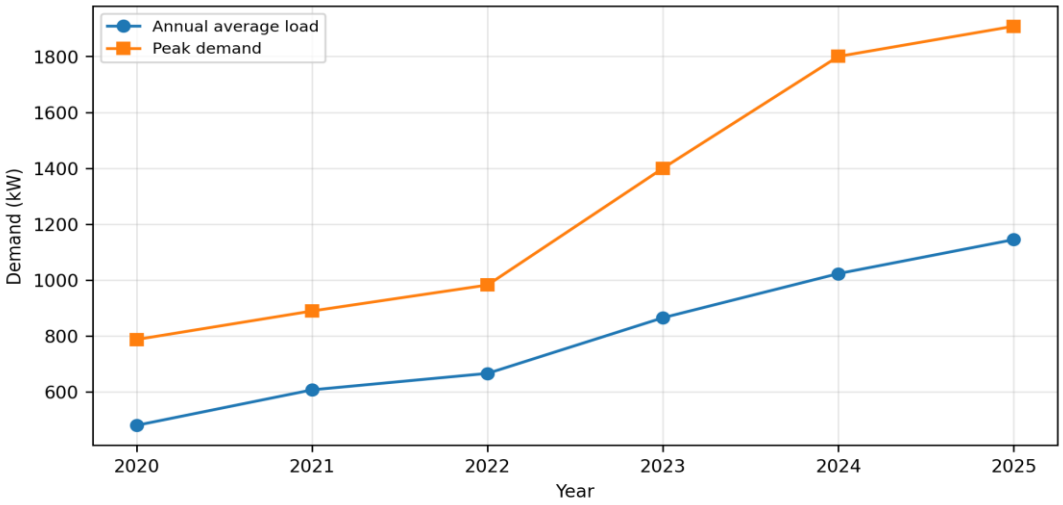
Component	Preliminary selection	Engineering basis / next verification
Turbines	2 × 2.5 MW Pelton units	High head; verify manufacturer efficiency and nozzle range
Generators	Approximately 3.15 MVA each	Allows margin at typical power factor; confirm voltage and inertia
Transformer	Approximately 6.3 MVA, step-up to 33 kV	Confirm utility voltage, vector group and impedance
Penstock	1.30 m diameter preliminary	2.94 m/s at 3.90 m³/s; complete friction and water-hammer analysis
Controls	Governor, excitation, synchronizer and SCADA	Required for stable grid-parallel operation
Protection	Voltage, frequency, overcurrent, earth fault and reverse power	Finalise through utility protection-coordination study

 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

Demand, Energy Balance and Grid Implication

Figure 11: Reported Annual-Average and Peak Electricity-Demand Growth in Ileje District, 2020-2025.

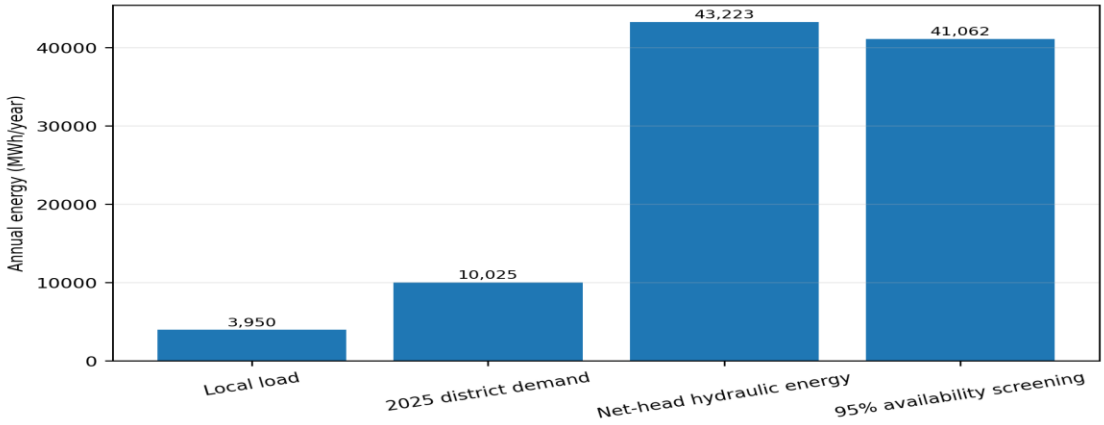


Reported annual average demand increased from 479.92 kW in 2020 to 1,144.42 kW in 2025, and peak demand increased from 787 kW to 1,908 kW. The plant is therefore larger than the reported district peak and cannot be justified as a stand-alone local-load plant. Its feasibility depends on a firm grid-export arrangement, dispatch coordination and revenue metering.

Table 8: Load-Growth Data Used for Grid-Export Interpretation.

Year	Average load (kW)	Peak demand (kW)	Daily energy (kWh/day)	Annual energy (MWh/year)
2020	479.92	787	11,518	4,204.1
2021	606.83	889	14,564	5,315.9
2022	665.67	982	15,976	5,831.2
2023	864.83	1,400	20,756	7,575.9
2024	1,022.75	1,800	24,546	8,959.3
2025	1,144.42	1,908	27,466	10,025.1

Figure 12: Annual Energy Comparison for Local Load, District Demand and Calculated Hydropower Scenarios.



 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.1.4317

The theoretical gross-head upper bound is 43,799 MWh/year, essentially the 5 MW maximum of 43,800 MWh/year. The preliminary net-head calculation is 43,223 MWh/year, equivalent to a 98.7% hydraulic capacity factor. Applying 95% technical availability gives 41,062 MWh/year and a 93.7% screening capacity factor. The large surplus above the 2025 district-energy estimate confirms that grid export is not optional; it is central to the project configuration and financial case.

Screening-level Economic Results

The completed discounted-cash-flow calculation produces favourable indicators under the manuscript assumptions. The base LCOE of approximately TZS 43.0/kWh is well below the assumed electricity value of TZS 168/kWh. The corresponding NPV is positive, IRR exceeds the 8% discount rate, and simple payback is short. These findings are directionally consistent with studies showing that small run-of-river hydropower can be cost-competitive when dependable flow, adequate head, grid access and controlled civil costs are present (Tsuanyo et al., 2023). However, the result should not be interpreted as a bankable tariff or investment offer because the cost estimate is not based on detailed bills of quantities and no power-purchase agreement was supplied.

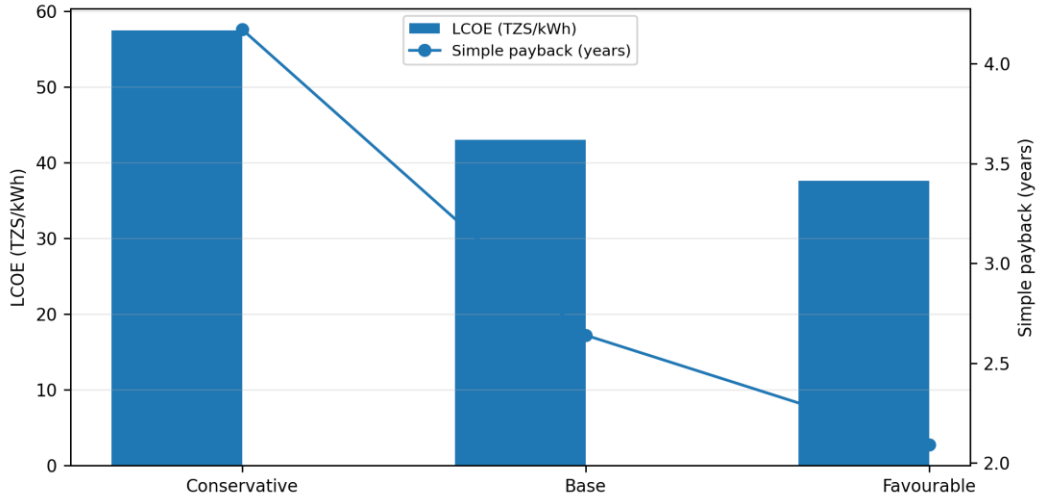
Table 9: Base Screening-level Financial Indicators.

Indicator	Result	Interpretation
Annual screening energy	41,062 MWh/year	Net-head energy × 95% technical availability
Annual gross revenue	TZS 6.90 billion/year	At TZS 168/kWh
Annual O&M	TZS 80 million/year	TZS 2 billion spread over 25 years
LCOE	TZS 43.0/kWh	Discounted lifetime cost per discounted kWh
NPV	TZS 54.8 billion	Positive at 8% discount rate
IRR	37.9%	Above the assumed discount rate
Simple payback	2.6 years	Undiscounted screening payback

Table 10: Economic Sensitivity Results.

Scenario	Energy (MWh/y)	Tariff (TZS/kWh)	Capex (TZS bn)	LCOE	NPV (TZS bn)	IRR (%)	Payback (y)
Conservative	36,956	142.8	21.6	57.5	33.7	23.9	4.2
Base	41,062	168.0	18.0	43.0	54.8	37.9	2.6
Favourable	42,294	184.8	16.2	37.6	66.5	47.8	2.1

Figure 13: Sensitivity of LCOE and Simple Payback to Energy, Tariff and Cost Assumptions.



 This work is licensed under a Creative Commons Attribution 4.0 International License

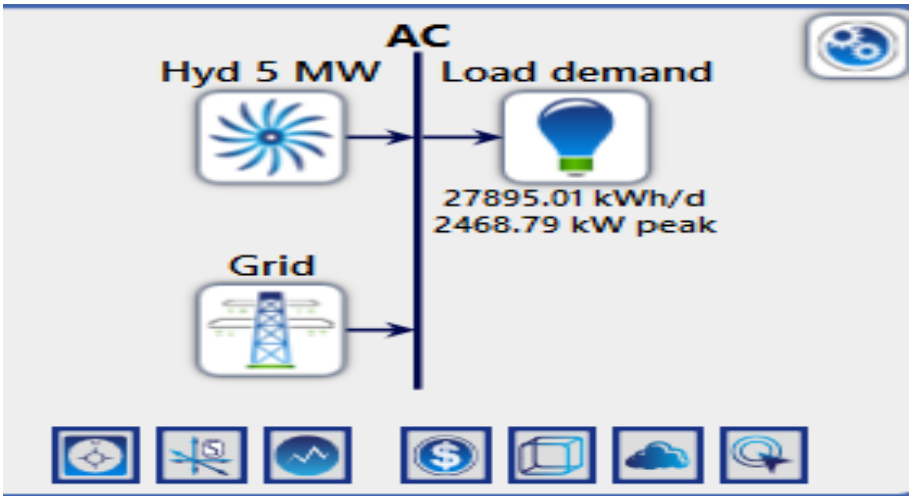
Article DOI: https://doi.org/10.37284/eaje.9.1.4317

Even the conservative screening case remains positive, but this apparent robustness is driven by the assumed TZS 168/kWh value and low lifetime O&M. The most material uncertainties are the actual export tariff, civil-works cost, environmental-flow deduction, hydrological persistence and financing structure. The economic contribution of this revision is therefore a transparent calculation and sensitivity range, not a claim that the project is already bankable.

HOMER Pro Model Inputs and Simulation Results

The HOMER Pro architecture reproduced from the research report consists of the hydropower plant, AC load and national grid. The model is intended to test a hydro-primary, grid-supported system rather than a grid-dominated system. The corrected hydrological vector is essential: the final August-November values are 3.80, 3.75, 3.72 and 3.70 m³/s, respectively. At the 153 m gross head, these values meet or closely meet the 5 MW design-flow threshold, while the preliminary net-head calculation gives only slight derating. The annual-energy and financial values in the revised manuscript therefore follow the corrected calculation chain even where an archived screenshot displays an earlier model run.

Figure 14: HOMER Pro System Architecture Showing the 5 MW Hydropower Component, AC Load and Grid Connection



Source: *Archived HOMER Pro output result*

Table 10: HOMER Pro Configuration and Corrected Simulation Interpretation.

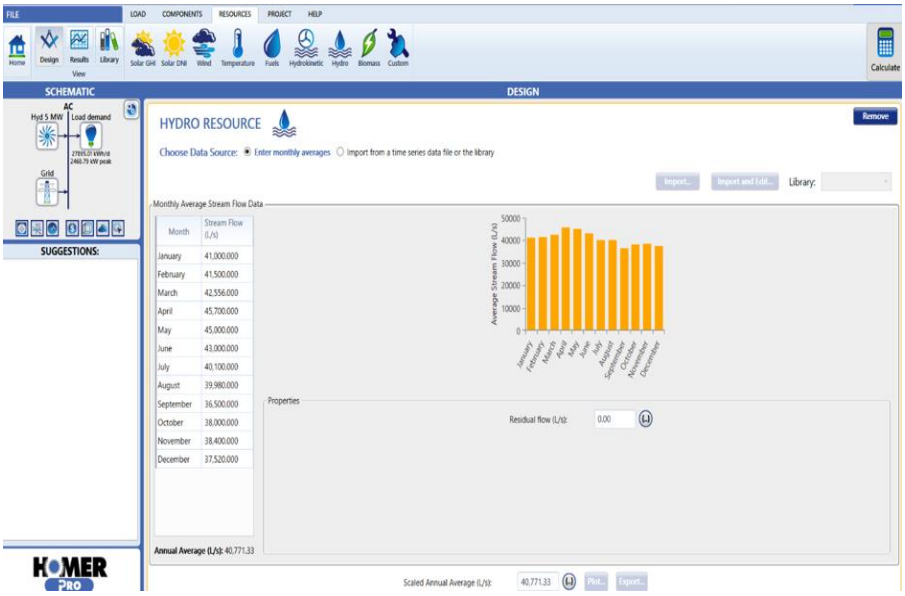
HOMER Pro / corrected-model item	Value or result	Interpretation
System architecture	5 MW hydro + AC load + bidirectional grid	Hydro supplies load first; grid is backup and export sink
Corrected monthly discharge	5.20, 5.00, 6.30, 7.10, 5.80, 4.60, 3.90, 3.80, 3.75, 3.72, 3.70, 4.80 m³/s	Final January-December input vector
Head and efficiency	153 m gross; 145.35 m preliminary net; 90%	Defines gross and net monthly capability
Installed-capacity limit	5 MW	Surplus water is bypassed when hydraulic capability exceeds 5 MW
Local HOMER load	450.92 kW average; 10,822 kWh/day; 1,950.5 kW peak	Base local-load model used in the research report
Load growth	3% per year	Long-term demand scenario over 25 years

 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

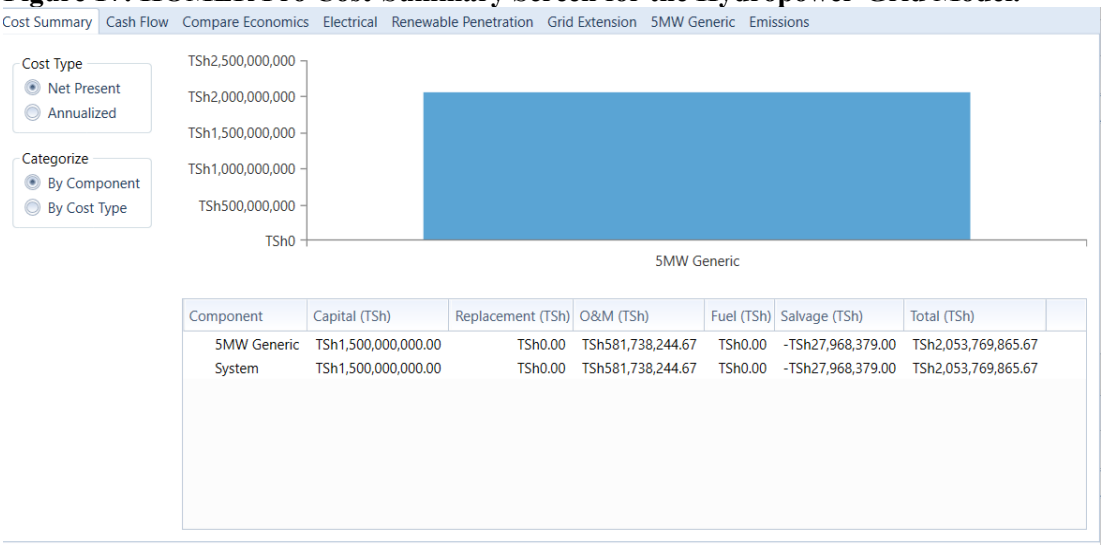
HOMER Pro / corrected-model item	Value or result	Interpretation
Gross/net annual energy	43,799/43,223 MWh/year	Gross upper bound and preliminary net-head result
Saleable screening energy	41,062 MWh/year	Net energy × 95% technical availability
Base financial result	LCOE TZS 43.0/kWh; NPV TZS 54.8 bn; IRR 37.9%; payback 2.6 y	Corrected screening-level interpretation
Grid implication	Large annual surplus relative to local load	A grid-export agreement is central to utilisation and revenue

Figure 15: HOMER Pro Hydro-Resource Input Interface.



The final corrected monthly flow vector is reported in Table 9 and supersedes any earlier dry-season values visible in the archived screen.

Figure 17: HOMER Pro Cost-Summary Screen for the Hydropower-Grid Model.



 This work is licensed under a Creative Commons Attribution 4.0 International License

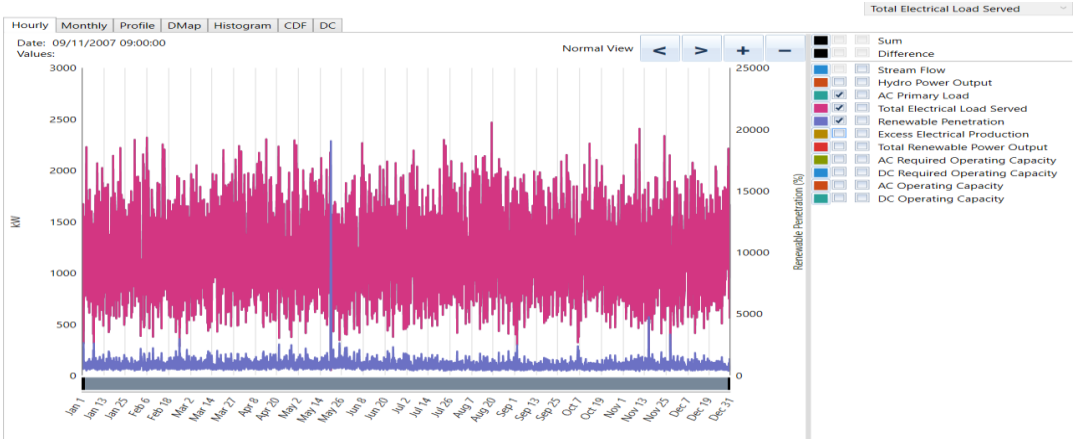
Article DOI: https://doi.org/10.37284/eaje.9.2.5513

Figure 18: HOMER Pro Time-Series Detail for Electrical Load, Grid Interaction and Component Operating Capacity



Source: *Research report simulation output*

Figure 19: Year-long HOMER Pro Time Series of Total Electrical Load Served



Source: *Research report simulation output*

The archived screens demonstrate that the load profile, hydropower resource, grid and economic result categories were implemented in HOMER Pro. They also reveal why numerical consistency is important: an earlier run can appear grid-dominated when the hydro-resource unit or dry-season values are entered incorrectly. After applying the corrected m^3/s vector, the engineering calculation predicts near-rated hydro output throughout the year, approximately 41.1 GWh/year after the 95% availability factor, and substantial export potential. The software figures are therefore retained as modelling evidence, while the corrected tables provide the reproducible numerical result.

MATLAB/Simulink Dynamic Simulation Results

The MATLAB/Simulink outputs provide dynamic evidence complementary to HOMER Pro. The simulated frequency shows a short-damped disturbance and returns to approximately 50 Hz. Rotor speed exhibits a small overshoot and

 This work is licensed under a Creative Commons Attribution 4.0 International License

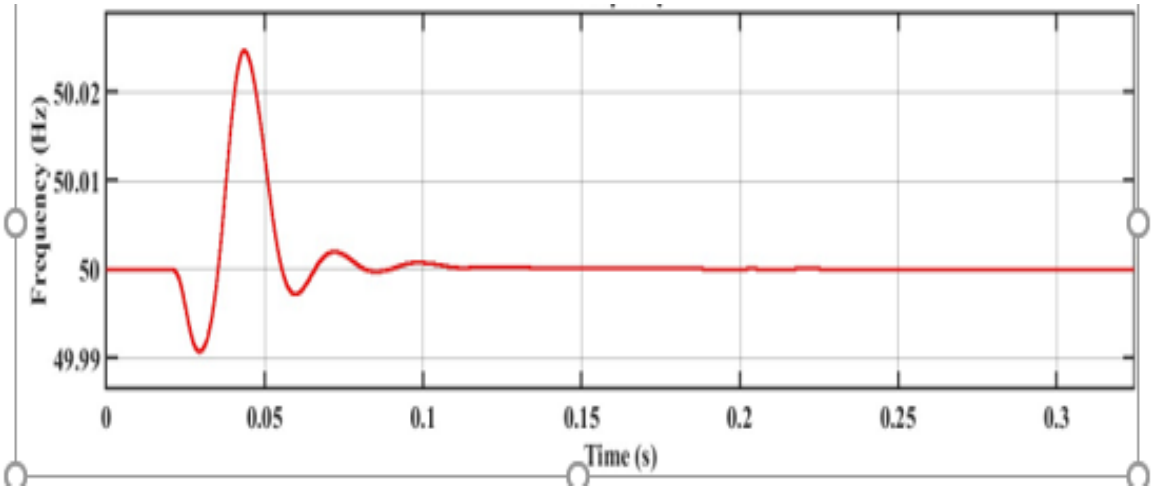
Article DOI: https://doi.org/10.37284/eaje.9.2.5513

undershoots before converging toward 1.0 pu, indicating effective governor action. Electromagnetic torque is bounded and settles after the initial transient. Generator active power remains in the megawatt range, the local load receives stable active power, and positive surplus active power is delivered to the grid/load interface. Generator, grid-side and load-side voltage/current waveforms remain balanced and periodic after the transient interval.

Table 10: MATLAB/Simulink Dynamic Results and Feasibility Interpretation.

Simulink output	Observed response	Engineering implication
Frequency	Short dip/overshoot followed by recovery to about 50 Hz	Governor and electromechanical balance are stable
Rotor speed	Damped oscillation converging toward 1.0 pu	No sustained overspeed or loss of synchronism
Electromagnetic torque	Transient oscillation followed by bounded steady operation	Mechanical input and electrical torque reach equilibrium
Generator P-Q	Active power stabilises in the MW range; reactive power remains bounded	Plant operates as an active source with controllable voltage support
Load P-Q	Load active power is continuously supplied	Representative local demand remains energised
Surplus-to-grid P-Q	Positive active power after the transient	Confirms the need and capability for grid export
Generator voltage	Balanced sinusoidal three-phase waveform	Suitable output for transformation and interconnection
Grid-side V-I	Balanced periodic voltage and current	Power transfer through the transformer interface is stable
Load-side V-I	Stable balanced voltage and current after transient	Consumers receive usable three-phase supply
Limitation	Short-duration representative model	Detailed governor, water-hammer, fault and protection studies remain necessary.

Figure 20: Frequency Response of the Proposed Hydropower Generator During Dynamic Simulation

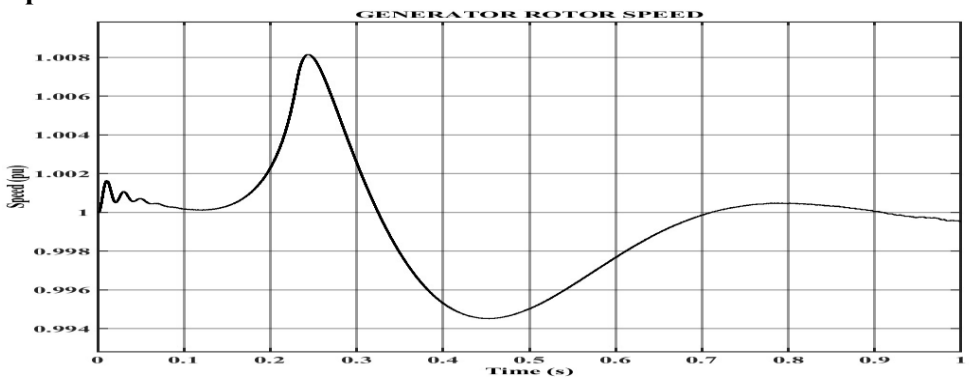


Source: *MATLAB/Simulink output result*

 This work is licensed under a Creative Commons Attribution 4.0 International License

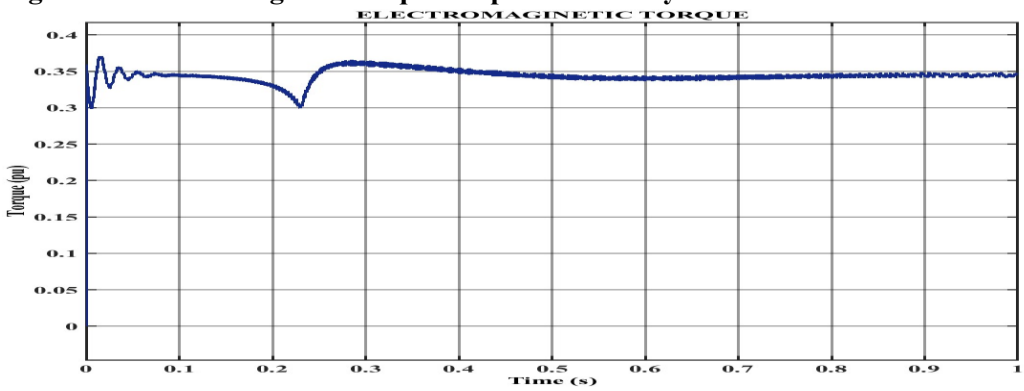
Article DOI: https://doi.org/10.37284/eaje.9.2.5513

Figure 21: Generator Rotor-Speed Response in Per-Unit During Transient and Steady-State Operation



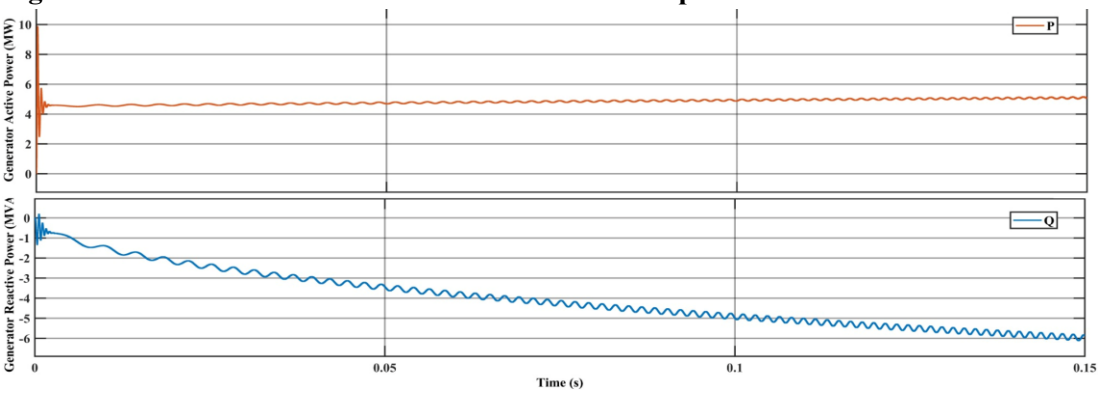
Source: *MATLAB/Simulink output*

Figure 22: Electromagnetic-torque Response of the Synchronous Generator



Source: *MATLAB/Simulink output*

Figure 23: Generator Active- and Reactive-Power Response

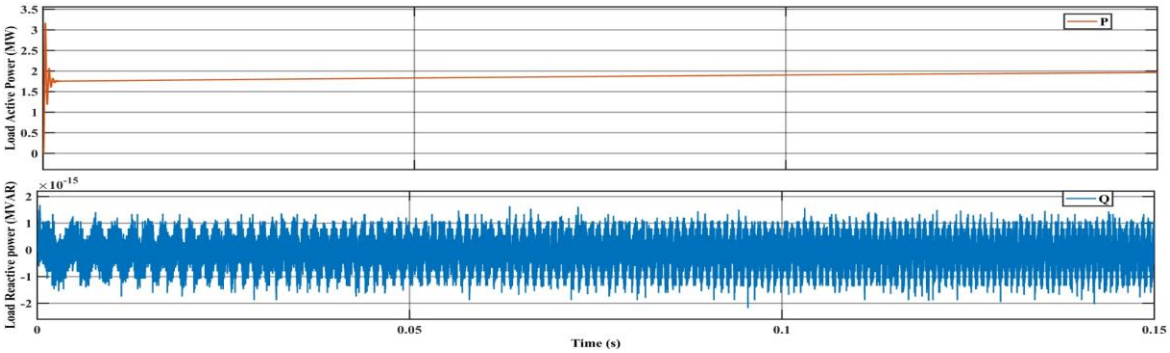


Source: *MATLAB/Simulink output*

 This work is licensed under a Creative Commons Attribution 4.0 International License

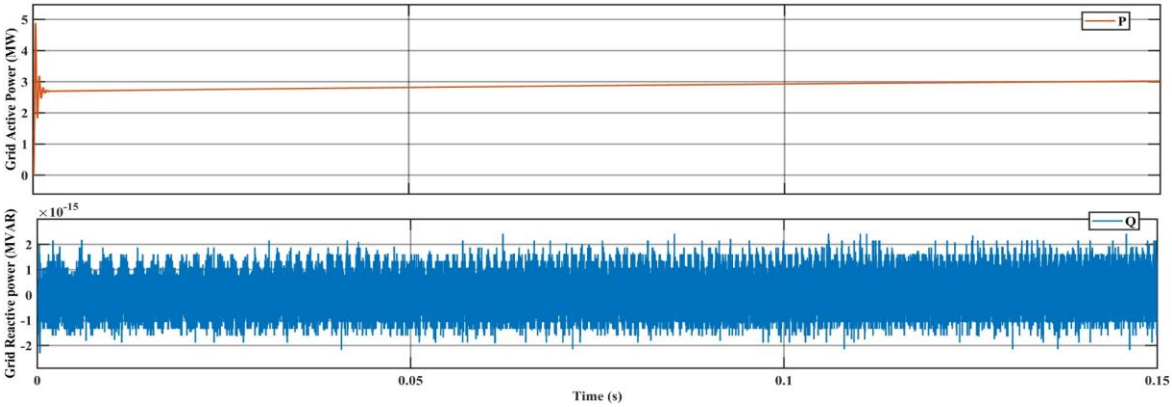
Article DOI: https://doi.org/10.37284/eaje.9.2.5513

Figure 24: Local-Load Active- and Reactive-Power Response



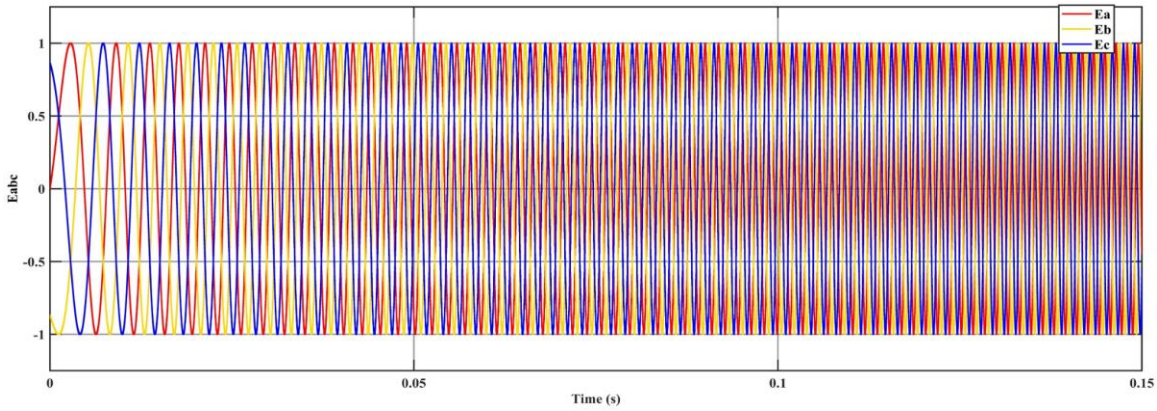
Source: *MATLAB/Simulink output*

Figure 25: Surplus Active and Reactive Power Transferred to the Grid/Load Interface.



Source: *MATLAB/Simulink output*

Figure 26: Three-phase Generated-Voltage Waveform at the Generator Terminals

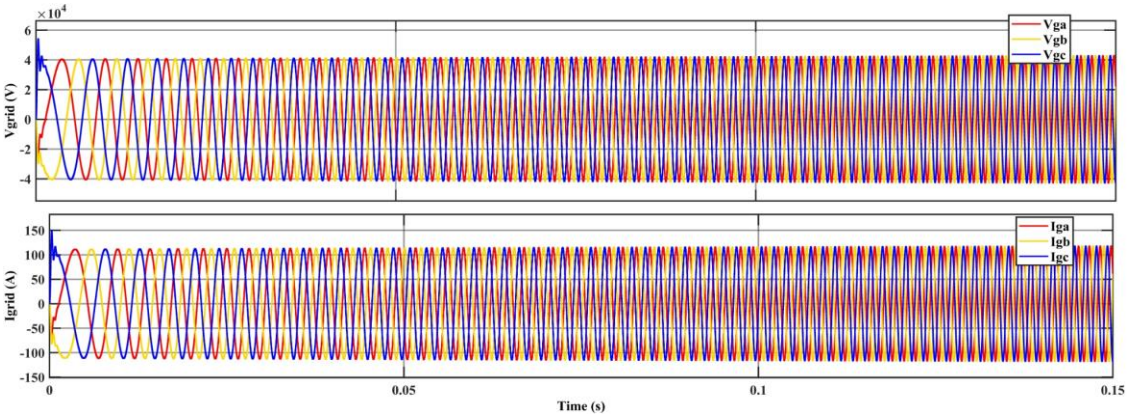


Source: *MATLAB/Simulink output*

 This work is licensed under a Creative Commons Attribution 4.0 International License

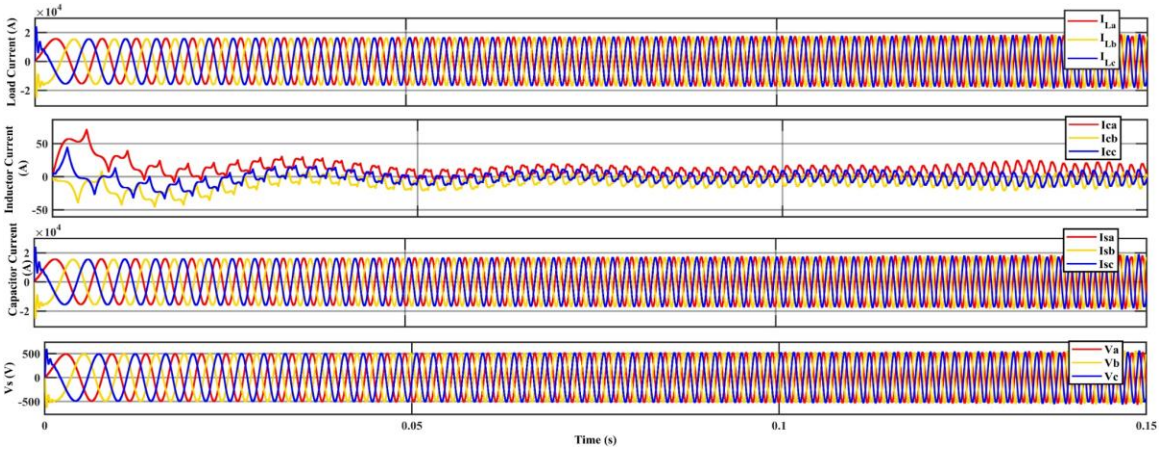
Article DOI: https://doi.org/10.37284/eaje.9.2.5513

Figure 27: Grid-side Voltage and Current Waveforms



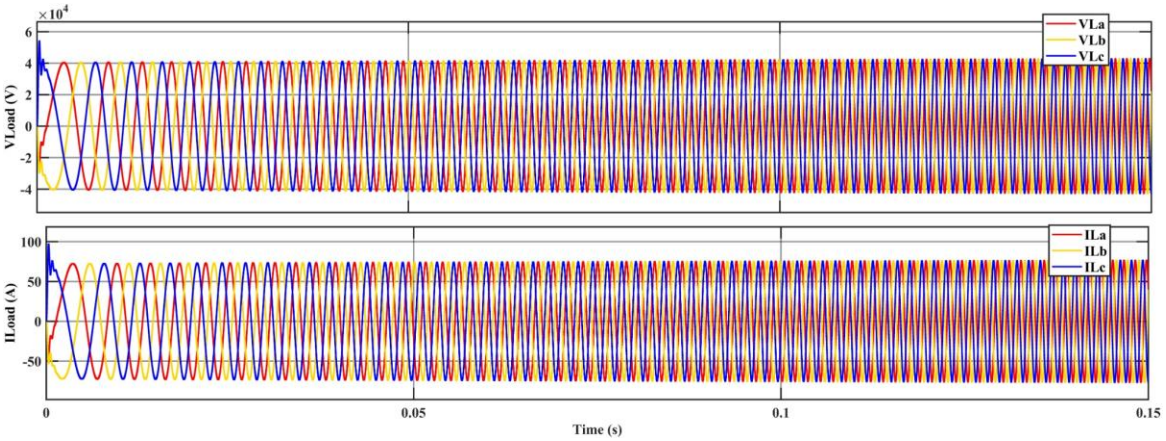
Source: *MATLAB/Simulink output*

Figure 28: Load, Inductor, Capacitor and Output Voltage-Current Responses



Source: *MATLAB/Simulink output*

Figure 29: Load-side Voltage and Current Waveforms after the Grid-Interface Stage



Source: *MATLAB/Simulink output*

Taken together, the MATLAB/Simulink responses support the same operating logic as the corrected HOMER model: the hydropower unit can supply the local load, maintain stable electrical variables after

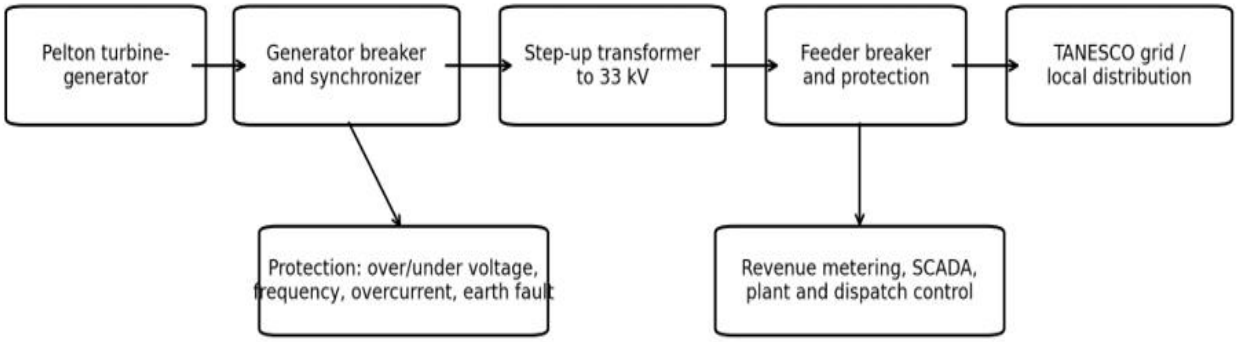
 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

a disturbance and export surplus power. This convergence is preliminary rather than bankable validation. The final model must use manufacturer turbine-generator inertia, governor and excitation parameters; actual penstock and water-column dynamics; utility fault levels; protection settings; and the final transformer and feeder data.

Grid Interconnection, Environmental and Implementation Requirements

Figure 30: Preliminary Grid Interconnection, Synchronisation, Protection and Metering Concept.



The generator cannot be connected directly to the network. Voltage, frequency and phase angle must be matched before breaker closure, and the generator, transformer and feeder require coordinated protection. Revenue metering is required for exported and imported energy. Because the proposed plant exceeds the local peak demand, the interconnection study must also assess fault level, voltage rise, feeder thermal capacity, reactive-power capability, islanding, dispatch and communication requirements.

Environmental-flow reservation, sediment management and community water use directly affect the exploitable discharge. Research on the water-energy-ecosystem nexus shows that maximising generation without explicit ecological and downstream-use constraints can produce misleading designs (Basso et al., 2020). The current annual-energy figures therefore remain pre-ESIA values. The intake must include screening and desilting; the design must provide flood bypass and safe drainage; and land access, construction impacts and community benefit arrangements must be resolved before procurement.

Table 11: Priority Requirements before Detailed Design and Investment.

Requirement	Action	Decision significance
Hydrology	Install gauge and obtain multi-year daily flow record	Validates firm flow, floods, droughts and FDC
Environmental flow	Complete ecological and downstream-use assessment	Determines divertible flow and net annual energy
Topography/geotechnics	Close survey, investigate intake, penstock and powerhouse foundations	Confirms head, route, quantities and civil risk
Hydraulics	Darcy-Weisbach losses, surge/water-hammer and transient analysis	Confirms net head and penstock class
Turbine-generator	Obtain manufacturer curves and quotations	Confirms efficiency, unit number, speed and cost
Grid study	TANESCO load flow, short circuit, protection and connection approval	Confirms 33 kV feasibility and export limit

 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

Requirement	Action	Decision significance
Commercial	Secure tariff/PPA and financing terms	Controls revenue, NPV and bankability
Community/land	Consultation, easements, compensation and benefit plan	Reduces social and implementation risk

Comparison with Existing Evidence and Study Contribution

The findings agree with Tanzania-wide assessments that hydropower remains a significant but underdeveloped resource and that smaller projects require site-specific verification beyond national potential estimates (Mdee et al., 2018). They also agree with regional mapping work showing substantial technical potential in Sub-Saharan Africa, while demonstrating why geospatial screening alone cannot establish plant capacity or annual energy at a specific river reach (Korkovelos et al., 2018).

Compared with published run-of-river design methods, this study uses the same core relationship among discharge, head, efficiency, FDC, design flow and energy (Barelli et al., 2013; Liucci et al., 2014). Its distinctive contribution is the integrated Luswisi case calculation linking corrected monthly flow, 153 m head, gross-versus-net performance, two-unit Pelton selection, grid-export need and screening financial indicators. In contrast to studies based on long daily records and optimisation algorithms (Gasore et al., 2026), the Luswisi analysis remains a feasibility screening because only monthly data and preliminary costs were available.

CONCLUSION

The Luswisi River at Bwenda Village has strong feasibility-level potential for a grid-connected high-head run-of-river plant. The topographic survey and GIS figures identify the intake-powerhouse corridor and support the adopted gross head of 153 m. Corrected monthly discharge is 3.70-7.10 m³/s. A 5 MW plant requires approximately 3.70 m³/s at gross head and 3.90 m³/s at the preliminary 145.35 m net head. Theoretical gross-head annual energy is 43,799 MWh, preliminary net-head energy is 43,223 MWh, and the 95% technical-availability screening result is 41,062 MWh/year.

The technically appropriate preliminary configuration is two 2.5 MW Pelton units with an approximately 1.30 m penstock, synchronous generators, a step-up transformer, coordinated protection and bidirectional grid metering. The revised HOMER Pro section documents the hydro-grid architecture, corrected resource inputs, load, economic assumptions and archived result screens. The corrected screening analysis gives an LCOE of approximately TZS 43.0/kWh, NPV of TZS 54.8 billion, IRR of 37.9% and simple payback of 2.6 years under the stated assumptions. MATLAB/Simulink results show recovery to approximately 50 Hz, rotor-speed convergence toward 1.0 pu, bounded torque and P-Q responses, balanced three-phase voltages, continuous load supply and surplus grid export. Final investment remains conditional on multi-year daily gauging, verified catchment area and survey closure, environmental flow, detailed penstock and water-hammer analysis, geotechnical investigation, manufacturer data, updated HOMER files and TANESCO interconnection approval.

REFERENCES

Alie, W. (2016). Design and Analysis of Small Hydro Power for Rural Electrification. *Global Journal of Researches in Engineering*, *16*(6), 25–45.u

Basso, S., Lazzaro, G., Bovo, M., Soulsby, C., & Botter, G. (2020). Water-energy-ecosystem nexus in small run-of-river hydropower : Optimal design and policy. *Applied Energy*,

 This work is licensed under a Creative Commons Attribution 4.0 International License

Article DOI: https://doi.org/10.37284/eaje.9.2.5513

280(October), 115936. https://doi.org/10.1016/j.apenergy.2020.115936

Gasore, A., Butt, A., Ho, S., & Gasore, A. (2026). Assessing the promise and performance of a ' fit- for-purpose' land administration system for urban areas of Rwanda land administration system for urban areas of Rwanda. *Planning Practice & Research*, *00*(00), 1–23. https://doi.org/10.1080/02697459.2026.2641713

Hydro, S., & Mapping, R. (2015). *S ITE V ISITS R EPORT : E XISTING Small Hydro Resource Mapping in Tanzania* (Issue April).

Iemsomboon, P., Pati, T., & Bhumkittipich, K. (2013). Performance study of micro hydro turbine and PV for electricity generator, case study: Bunnasopit school, Nan Province, Thailand. *Energy Procedia*, *34*, 235–242. https://doi.org/10.1016/j.egypro.2013.06.752

Korkovelos, A., Mentis, D., Siyal, S. H., Arderne, C., Rogner, H., Bazilian, M., Howells, M., Beck, H., & Roo, A. De. (n.d.). *A Geospatial Assessment of Small-Scale Hydropower Potential in Sub-Saharan Africa*. https://doi.org/10.3390/en11113100

Margonis, P. (2017). *Modeling and Optimization of a Hydroelectric Power Plant for a National Grid Power System Supply. Case Study: Stratos Hydroelectric Dam*. *March*. dias.library.tuc.gr/view/manf/67652

Mdee, O. J., Nielsen, T. K., Kimambo, C. Z., & Kihedu, J. (2018). *Assessment of hydropower resources in Tanzania. A review article. Tanzania, University of Dodoma (41.78.64.25).* *4*, 1–10.

Othman, A., Khairudin, W. M., & Othman, J. (2017). *Water flow measuring methods in small hydropower for streams and rivers - A study*. *12*(24), 14484–14489.

Selvan, M. M., Mehta, C. R., & Varshney, A. C. (2012). Potential of micro-hydropower generation systems in India. *AMA, Agricultural Mechanization in Asia, Africa and Latin America*, *43*(2), 25–31.

Taghizad-tavana, K., Nezhad, A. E., Hagh, M. T., & Canani, A. (2025). *Hybrid Renewable Energy Systems for Off-Grid Electrification : A Comprehensive Review of Storage Technologies, Metaheuristic Optimization Approaches and Key Challenges*. 1–44.

Tsuanyo, D., Amougou, B., Aziz, A., Nka Nnomo, B., Fioriti, D., & Kenfack, J. (2023). Design models for small run-of-river hydropower plants: a review. *Sustainable Energy Research*, *10*(1), 1–23. https://doi.org/10.1186/s40807-023-00072-1

Yildiz, V., Brown, S., & Rougé, C. (2024). *Importance of Variable Turbine Efficiency in Run - Of - River Hydropower Design Under Deep Uncertainty*. https://doi.org/10.1029/2023WR035713

Zukhrufiyati, A., Triyono, J., Ginting, S., & Irianto, E. W. (2019). *Determination Of Dependable Flow For Microhydro*. *September*, 1–7.

 This work is licensed under a Creative Commons Attribution 4.0 International License