

Received Date: 9th November, 2025
 Revision Date: 15th December, 2025
 Accepted Date: 2nd February, 2026

Control of Isolated Micro-Hydro Power Plant with ELC for Un-balanced Load

Sushant Basnet^{1*}, Bharat Thapa², Narayan Kumar Tamang³, Indraman Tamrakar⁴

¹Dept of Electrical Engineering, Kathmandu Engineering College, Nepal. E-mail: isushantbasnet@gmail.com

²Dept of Electrical Engineering, Kathmandu Engineering College, Nepal. E-mail: bharatthapa9804@gmail.com

³Dept of Electrical Engineering, Kathmandu Engineering College, Nepal. E-mail: tamangnarayan212@gmail.com

⁴Professor, Dept of Electrical Engineering, Kathmandu Engineering College, Nepal. E-mail: imtamrakar@ioe.edu.np

Abstract— In isolated micro-hydro power (MHP) systems, maintaining frequency and current balance under varying and unbalanced loads is essential for stable and reliable operation. Conventional Electronic Load Controllers (ELCs) regulate generator frequency by diverting excess power to dump loads; however, they activate dump loads equally across all phases, disregarding load asymmetry. This approach leads to current imbalance, zero-sequence currents, and excessive heating in the neutral conductor, which can compromise generator performance and lifespan. This paper proposes a novel phase-wise ELC control strategy that dynamically adjusts the number of dump loads in each phase independently based on real-time current measurements. By comparing each phase current with a reference full-load value, the controller ensures balanced generator operation under unbalanced consumer loads. The proposed system was modeled and simulated in MATLAB/Simulink under three scenarios: conventional ELC with balanced load, conventional ELC with unbalanced load, and the proposed ELC with unbalanced load. Simulation results show that the proposed ELC significantly reduces current imbalance, minimizes neutral current, and stabilizes rotor speed, thereby improving system efficiency and operational reliability in isolated MHP applications.

Keywords — ELC, load asymmetry, current imbalance, zero-sequence currents, dump loads.

I. Introduction

Isolated micro-hydro systems often face operational issues related to voltage and frequency instability. These fluctuations occur because consumer loads vary continuously throughout the day, disturbing the balance between mechanical input power and electrical output. In conventional hydro systems,

mechanical governors are employed to regulate turbine speed; however, their high cost and maintenance demands make them less suitable for small-scale installations. To address this limitation, Electronic Load Controllers (ELCs) are widely adopted as a cost-effective alternative. An ELC functions as an electronic governor by maintaining a constant total electrical load on the generator automatically diverting surplus power to a dump load as shown in Fig.1. The generator is driven by the un-regulated turbine with constant mechanical power output. Whenever consumer's load decreases by certain amount, the ballast load automatically consumes more power by the same amount thereby keeping the speed of the generator constant to acceptable value.

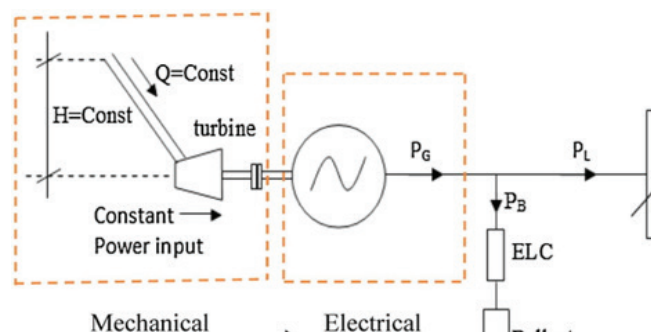


Fig.1: Schematic diagram of isolated MHP plant with ELC

II. Problem Identification and Objective

The existing Discrete Resistance ELC are designed in such a way that it turns ON same number of dumps loads in all three phase even the load is unbalanced. When the load changes, ELC senses frequency and compares with Reference frequency to get a frequency error. The error is passed through a PI controller to get a control signal to turn ON equal number of dump loads in all three phases. It simply makes the power balance to maintain a constant frequency within acceptable range. This will result un-

* Corresponding Author

balanced currents in the generator. In such a case, one phase of generator may over load while other phase is under loaded. The unbalanced generator currents produce Zero Sequence current as per theory of symmetrical components and they sum up in Neutral conductor. This may exceed the current carrying capacity of the Neutral conductor and get over heated.

The objective of this research is to develop a new control logic in Discrete dump load ELC so that generator's current is balanced even the consumer's load is un-balanced.

III. Proposed Scheme

This paper addresses the short comings of traditional Electronic Load Controllers (ELCs), which are not capable of properly handling unbalanced loads in isolated micro-hydro power systems. The proposed solution involves designing a new control logic that dynamically balances the generator's phase currents by independently managing the number of dump loads in each phase. The main logic is to turn ON different number dump loads in each phase in proportional to un-balanced load so that generator currents become balanced. The proposed control logic is shown in Fig.2.

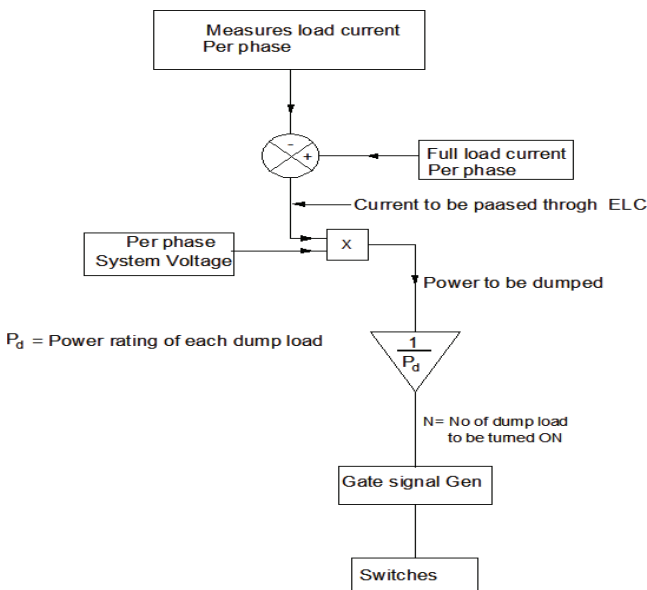


Fig.2: New control logic for ELC

The proposed control algorithm operates as, control system starts by initializing all necessary components, including current sensors, microcontrollers, and switching devices. Each phase (R,Y,B) is assigned a separate control circuit to ensure independent monitoring and control. Current sensors are installed in each of the three phases (I_R , I_Y , and I_B). These sensors continuously measure the actual load current flowing through each line in real time. The current measured in each phase is compared against the rated full-load current (I_F) to identify any excess or deficit in load. The difference is

calculated using the following expression:

$$I_{diff} = I_{measured} - I_{fullload} \quad (1)$$

This difference (positive or negative) indicates the amount of correction needed through dump load adjustment.

Using the current difference calculated in the previous step, the system determines the number of dump load resistors (ballast loads) that should be turned ON or OFF in each phase:

$$\text{Number of dump loads} = \frac{I_{diff}}{I_{Ballast}} \quad (2)$$

Where:

$I_{Ballast}$ = Current rating of one ballast load

Based on the computed value of N, each phase's control circuit independently adjusts the number of dump loads.

A Phase with higher consumer loads will have less number of dump loads activated.

A Phases with lighter loads will have more number of dump loads activated.

This ensures that the generator current remains balanced even the load currents are un-balanced. The entire system operates in a continuous feedback loop. It keeps monitoring the current in each phase and dynamically adjusts the dump loads in real time to maintain phase current balance and stable system performance.

IV. Modeing of Proposed Scheme

There will be a separate control circuit in each phase. Therefore, for un-balanced load, the number of dump load to be turn ON each phase will be different. The phase with higher load will have a smaller number of dump loads ON and the phase with low load will have a greater number of dump loads ON. This will result balanced generator currents even the consumer's load in un-balanced.

Here, speed-droop curve characteristics is used to calculate power rating of dump load for each phase as follow:

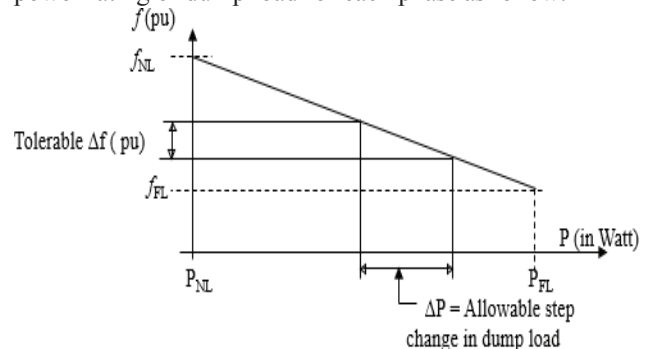


Fig.3: Speed Droop Characteristics curve

For a given droop curve and tolerable change in frequency(Δf), the excess power to be dumped by the ELC can be calculated as:

$$\text{Allowable step change in dump load } (\Delta P) = \Delta f / K$$

$$\text{Slope of Speed droop curve } (K) = \frac{\Delta f (\text{Tolerable change in frequency})}{\Delta P (\text{Allowable step change in dump load})}$$

$$\text{Then, } \Delta P (\text{Allowable step change in dump load}) = \frac{\Delta f}{K}$$

$$\text{Then, } N (\text{Nos of dump load required in each phase}) = \frac{\text{Capacity of Generator}}{3 \times \Delta P}$$

V. Simulation Model and Results

The proposed scheme is simulated to check-up the technical feasibility of the scheme. Fig.4 shows the overall simulation model developed in MatLab-Simulink.

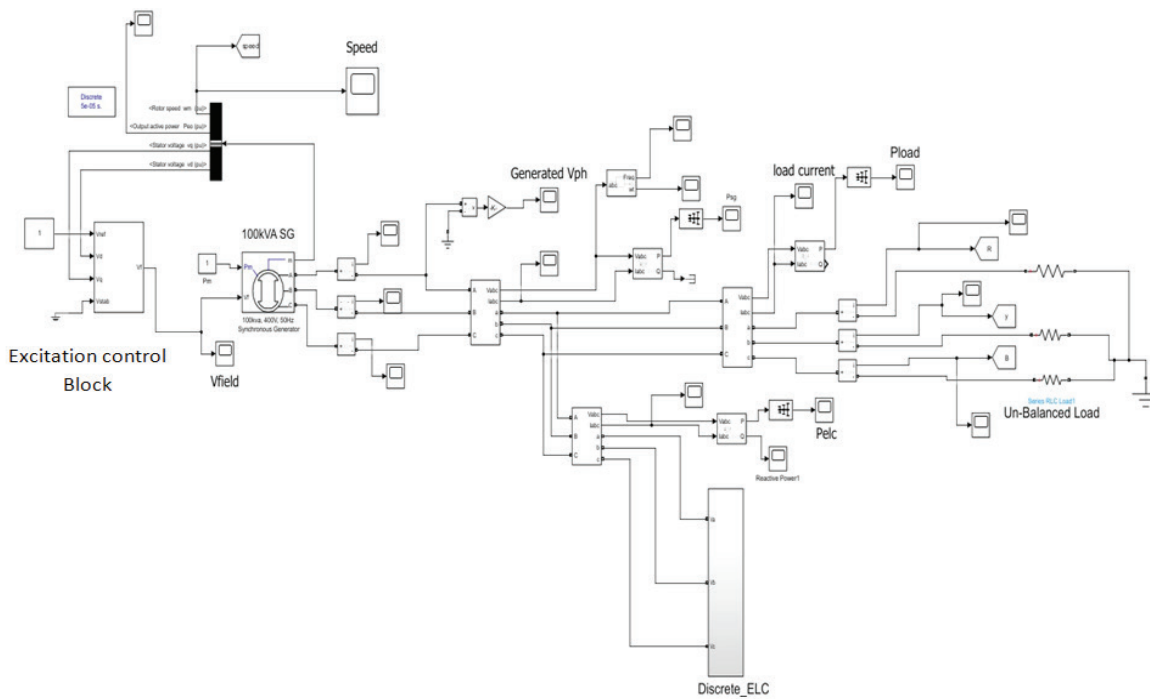


Fig.4 Overall simulation model developed in MatLab-Simulink.

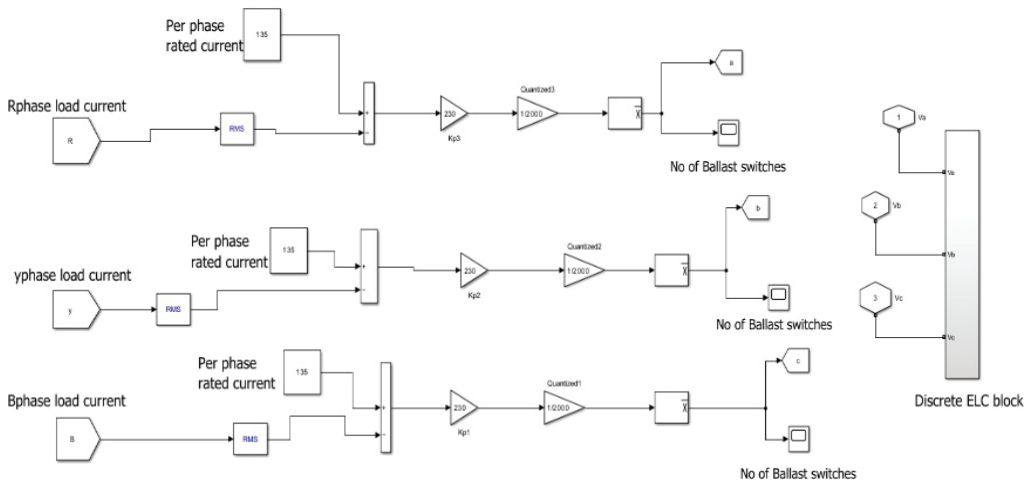


Fig.5 shows the detail of logic simulated in the Discrete_ELC Block.

Fig.6 shows the detail of discrete resistance dump load block.

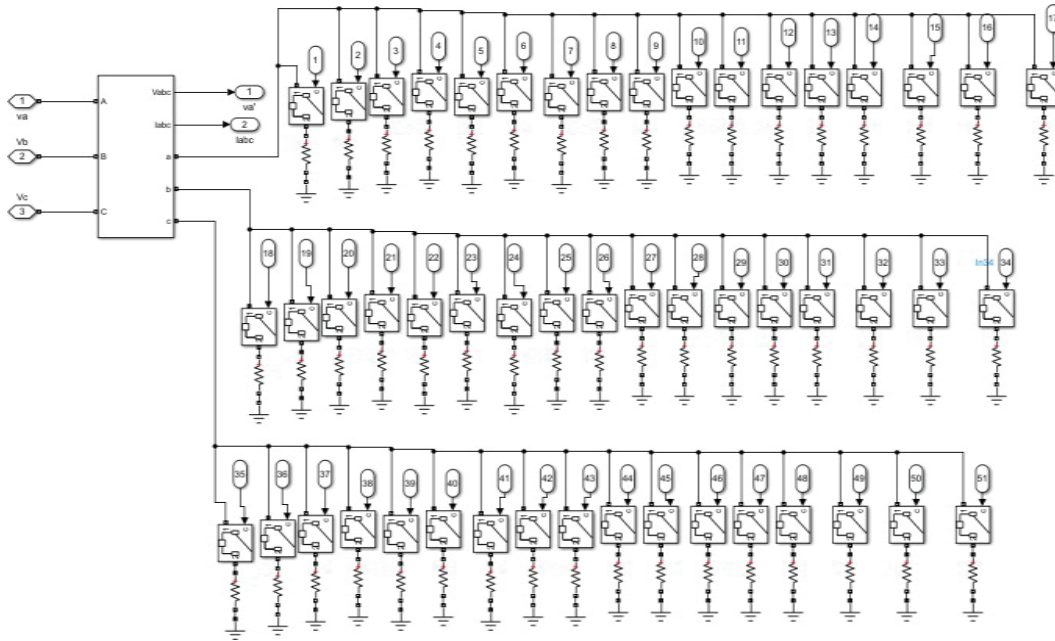


Fig.6: Detail of discrete resistance dump load block.

Simulation Results:

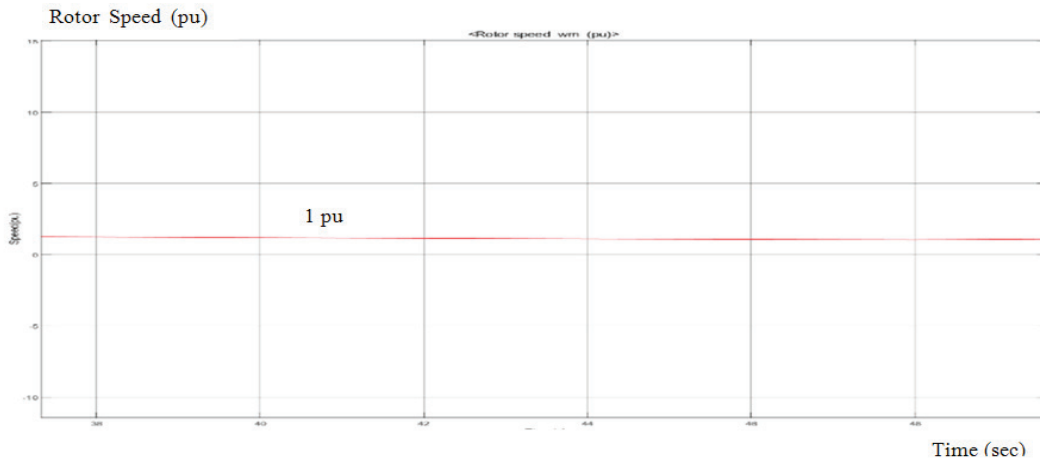


Fig.7: Speed response with un-balanced load

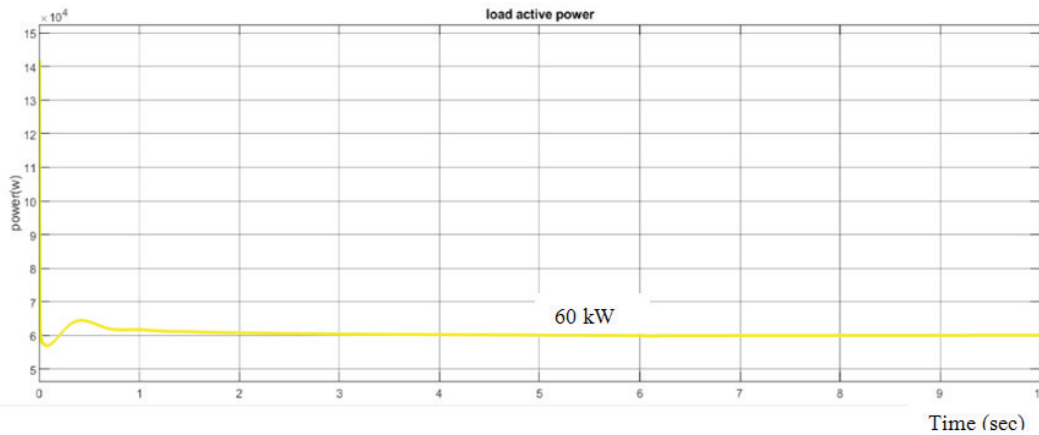


Fig.8 Plot of active power consumed by load

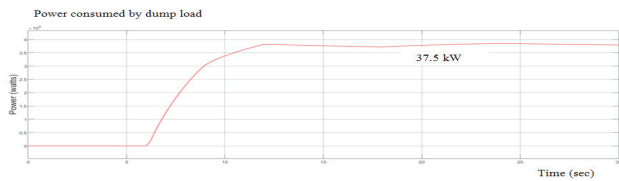


Fig.9 Plot of active power consumed by dump load

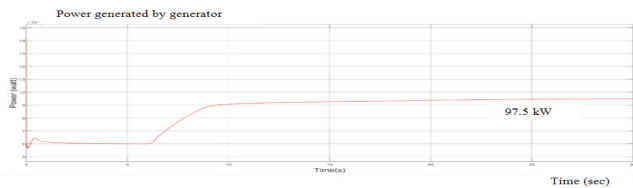


Fig.10 Plot of active power generated by generator

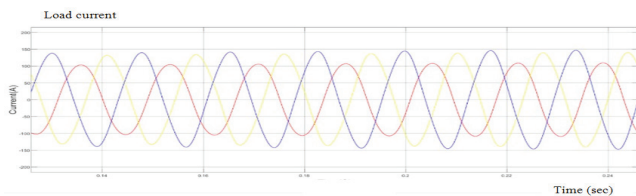


Fig.11 Waveform of load current

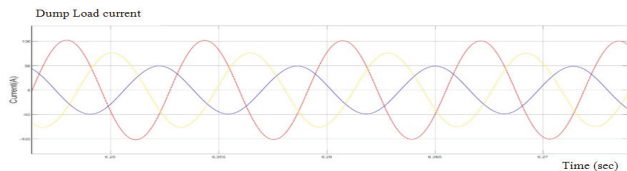


Fig.12 Waveform of dump load current

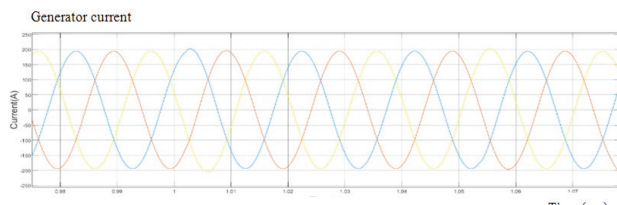


Fig.13 Waveform of generator current

VI. Results and Conclusions

Simulation Result shows that rotor speed is constant to 1 pu even the load is unbalanced. There is power balance between generated power, power consumed by the load and power consumed by the ELC dump load.

Due to unbalanced load, the waveform of load currents in three phase are unbalanced. Accordingly, the current drawn by ELC is unbalanced to results balanced currents in generator's winding.

The simulation results validates that the control logic proposed in this research works perfectly to make generator's current balanced even the consumer's load is un-balanced.

References

- [1] Chan, J., & Lubitz, W. (2016, October), "Electronic loadcontroller(ELC) design and simulation for remote ruralcommunities:A powerhouse ELC compatible with household distributed-ELCs in Nepal. In *2016 IEEE Global Humanitarian Technology Conference (GHTC)*. <https://doi.org/10.1109/GHTC.2016.7857275>
- [2] Protel Multi Energy.(2013). *Catalog of electronic loadcontroller*. http://www.pme-bandung.com/file/1510_BROSUR%20ELC_Eng.pdf
- [3] D a h a l , R . , J h a , S . K . , & A d h i k a r y , B . (2016,January), "Performance of droop based load controller interconnected microhydro power plants." *2016 4th International Conference on the Development in Renewable Energy Technology (ICDRET)*.
- [4] Tamrakar, I., Adhikari, R., & Bhattarai, R. (2013, October), " Improved electronic load controller for three phase isolated micro- hydro generator." , *Fifth International Conference on Power and Energy Systems*.