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Development and Validation of an Automated Electronic Load Controller (AELC) for Electric Generator Assembly

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Abstract*— Electric generators are machines that provide electricity specially during power interruptions or when electric power is not yet available in the area. Although it is always claimed by manufacturing companies of electric generators that the system produces a stable electric outputs, fluctuations of electricity arise due to variation on the load the generator carries that causes the damage to appliances or facilities. This study focused on solving this problem by designing and fabricating an automatic electric load controller (AELC) that can help in producing a stable voltage and frequency generated that can be used not only in farms but also at home and other establishments without damaging the facilities loaded. Proportional integral derivative (PID) was also included in the program. This study also simulated the use of the AELC for a microhydro electric generators by using an assembled 3KVA electric generator without mechanical governor. The developed AELC was tested using a fabricated electric generator and was found to be efficient in terms of the maintained RPM of 1800/60 Hz and voltage of 220 volts.

Index Terms—*ELC, electric generator, micro hydro, Arduino Microcontroller, PID*

I. INTRODUCTION

In Micro Hydropower Plants (MHP), frequency and voltage fluctuations are problems that needed to be addressed. The problems arise because various loads are depending on the appliances being used by households. At night, higher frequency and voltage in the electric generator will result when the household electric consumers are already asleep and never use electricity. During this condition, appliances can be damaged when plugged in utilizing the high voltage. Meanwhile, during the day when the electric consumers are at a peak, the electric generator is in a low voltage condition and may not be enough for electric motors and refrigerators which may also cause damage to appliances.

Moreover, an existing electronic load controller (ELC) with a typical dump load, there are stresses created due to unbalance loading, continuous loading, and bearing fault [28]. These include electrical, mechanical, and thermal stresses that need to be addressed. Another problem in the existing ELC is the dump loads that normally use electric water heater consisting of a large water reservoir that is expensive and spacious. Also, clogging at its water supply is possible. When the reservoir is totally drained because of evaporation, the water heater could be destructed and the ELC would not function anymore.

Automation is very important nowadays, especially with increasing demand for production rates and productivity. It is also commonly attributed to more efficient use of materials and better quality of products. Improving the efficiency of electric generators is very important to attain maximize the use of energy output, a decreased facility of appliance damages due to uncontrolled fluctuating flow of current and may also to improved safety of workers because it may lessen their time of checking the generator.

Reports claimed that there is a very small efficiency of a single-phase synchronous generating set of low power and that the power of the generator must be matched to the power supplied to loads. Also, reports claimed that the existing ELC in regulating electric voltage and frequency still creates power wastage.

Hence, this study will solve the problem of the maximization of fuel used through an increased utilization of the electricity generated and minimization of the fluctuations independent of the loads it carries, and thus, may also result in lowering the pollutant emission in the environment. In this study, the design and fabrication of an automated electronic load controller (AELC) were used in assembled electric generator and for a micro-hydropower (MHP) generators. The significant result of this study would be of great help in maintaining a constant frequency of electric current even upon the variations of loads. The designed AELC in this study was programmed to monitor and measure the speed (rpm) and balance the power delivered to dump load and consumer loads.

This study generally aimed to develop of an automated electronic load controller (AELC) for electric generator assembly.

II. MATERIALS AND METHODS

2.1 The materials and equipment as well as their respective purpose of utilization in this study are shown in Table 1.

Table 1. Materials and equipment and their specific purposes in the study

MATERIALS	PURPOSE
Hall Effect sensor	Used to determine the RPM in the generator head
Current sensor	Used to determine the current loads
Voltage sensor	Used to determine the voltage of the generator

Neodymium magnet	Used to sense by the Hall Effect Sensor
Arduino Mega 2560	An open-source technology and was utilized in programming the AELC
XD-05	Areal time clock and data logger
LM 7805	A regulator that is attached to the voltage and current sensors
TRIAC module	An electronic switch that was used to control the power from 0-100%
Incandescent bulbs	Utilized as the consumers' loads that consume the electricity from the assembled electric generator
High power resistor	Utilized as the dump load that consumes electricity temporarily from the generator
3KVA electric generator assembly (without mechanical governor)	Utilized for power generation and used in the performance evaluation of the AELC
Laptop	Used to program the Arduino Microcontroller

2.2 Design and Development of the Automated Electronic Load Controller

In designing the automated electronic load controller (AELC), commercially available materials were considered and utilized. Careful planning of the design was done to attain the optimum parameters through testing, evaluation and simulation. The necessary materials were bought through on-line purchasing such as the neodymium magnet, hall effect sensor, Arduino mega 2560microcontroller, 2x16 LCD module, TRIAC module and high-power resistor, Arduino UNO microcontroller. Current and voltage sensors were also used to monitor the current and voltage of the generator. Moreover, incandescent bulbs were utilized as the lamp loads. The rated power of the generator was proportionally balanced using the formula:

$$P_{rated} = P_{dump} + P_{load} \qquad (1)$$

Moreover, the formula used in computing the power is the product of the voltage and current produced (equation 2).

$$P = VI \qquad (2)$$

In the calibration of the Hall Effect sensors, equations 3 and 4 were utilized in programming the RPM.

duration = pulseIn (pin, HIGH, 15000000) (3)
RPM = 60000000/duration (4)

The frequency, Hertz, was also computed from the RPM readings using the formula:

$$Hertz = (RPM \times 4)/120 \qquad (4)$$

In the fabrication and development of an Automatic Electronic Load Controller (AELC), calibration and formulation of the codes for the program of the controller were performed to attain the main objective of the study which is to maintain the RPM of the generator head. Maintaining these parameters of the generator would be of equal importance to the safety of household appliances and equipment where electricity was being used.

The design also includes a plan for the safety of the user from electric shock by placing protective covers on the dangerous parts of the AELC device. The AELC was placed in a box to protect it from environmental factors. The high-power resistors that were utilized as dump loads were placed in a separate box that had been designed to be fully ventilated. An AC fan was also used to avoid the accumulation of heat inside.

2.3 Determination of Generator Initial RPM before the Operation

The AELC was connected to an assembled electric generator while the dump load was not yet activated. A 3KVA assembled generator was run at 1800 RPM while at 90% load using the load board. The load board was shut down using the breaker to determine the initial RPM without load. This RPM was used as the set point for the evaluation of the assembled electric generator with AELC.

2.4 Simulation of the Electric Generator Assembly

The electric generator assembly without a mechanical governor was set at 1800 RPM/ 60 Hertz and has been subjected to varying loads. It was validated using an Oscilloscope. An XD-05 data logger and a real-time clock were installed in the AELC for data gathering. The loads consisted of thirty (30) pieces of 100 watts incandescent bulbs which were turned on and off one at a time after each reading. The testing was done by running the engine until the completion of the simulation. The frequency, RPM, current, and voltage were automatically recorded from 0 loads to 3000-watt loads.

2.5 Testing the Electric Generator Assembly with AELC

The assembled generator was run to each initial RPM. Any key was pushed on the LCD button to start the AELC and to let it run for seconds to run the PID program. The bulbs were turned on one at a time and also turned off one at a time. This was done using the breaker with a large current to simulate the actual scenario in the actual MHP. The dump load was automatically activated depending on the applied load to maintain the 1800 RPM.

2.6 Performance Evaluation of the AELC

The performance of the AELC was tested and evaluated using a fabricated 3KVA electric generator without a mechanical governor. The performance was compared against the performance of the generator before and after the AELC was employed in the system.

2.7 Statistical Analysis

The study was conducted to test the efficiency of the fabricated AELC installed in the electric generator by comparing its performance with the electric generator without the AELC which was the control. RPM and voltage were used as the parameter to be measured. Linear regression analysis was done for the calibration of sensors. Moreover, a t-test was performed to verify the significant difference between the two methods and to know if installing an AELC to the electric generator was significant and accepted.

3. Results and Discussion

3.1 Performance of the AELC

The performance of the AELC was evaluated by comparing the parameters before and after the AELC was employed in the electric generator assembly. The real-time registered readings of the voltage, load current, dump load current, and the RPM were presented in Figure 1. Moreover, the results of the performance evaluation of the AELC showed that the RPM and the frequency were the parameters that had been maintained. It was found out that even the voltage was also regulated

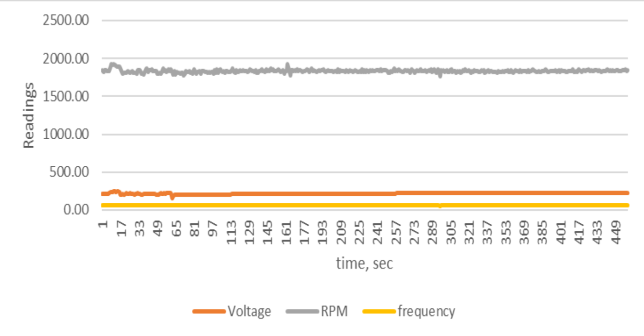

Figure 1. Performance of AELC

3.2 Revolution per Minute (RPM)

The RPM remained constant at varying loads. The RPM was not affected with respect to the variations of the loads as represented by the incandescent bulbs due to the response of the dump loads that resisted it. This can be attributed to the presence of dump loads that responded to the varying loads.

The response of the dump load to the RPM every time there was a change in the power load can be depicted in Figure 38. When the p being utilized so that the RPM would be maintained at 1800 RPM as showed in Figure 2. Furthermore, Figure 3 shows that the RPM of the generator without the AELC gradually decreased as the number of load utilized was increased.

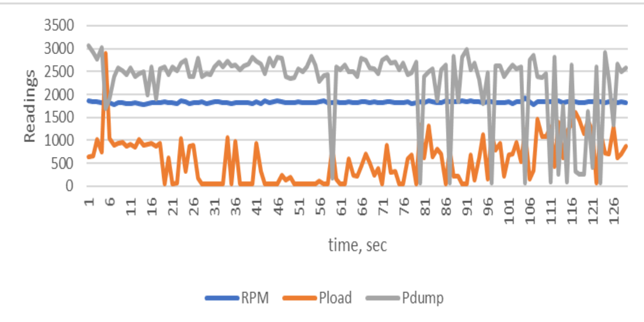

Figure 2. RPM with AELC

Statistical analysis showed that there was significant difference between the RPM readings from the electric generator without the AELC and with the AELC. The standard deviation of the RPM from the electric generator without the AELC (81.61) was much greater than the standard deviations of the RPM from the electric generator with AELC (32.53).

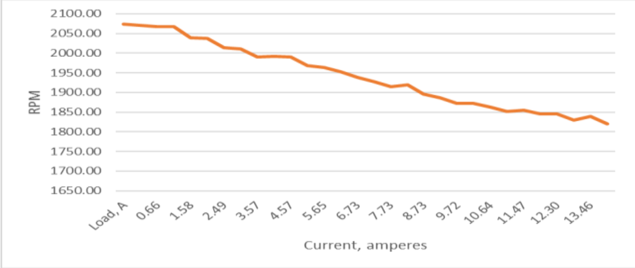

Figure 3. RPM Without AELC

3.3 Voltage

In this study, it was also observed that employing the AELC also regulated the voltage as shown in Figure 4. Statistical Analysis shows that the voltage was maintained at 220 ± 0.456 volts. The voltage of the generator without the AELC. It shows that the voltage gradually decreased as the number of load increased. The voltage was 220 ± 2.232.

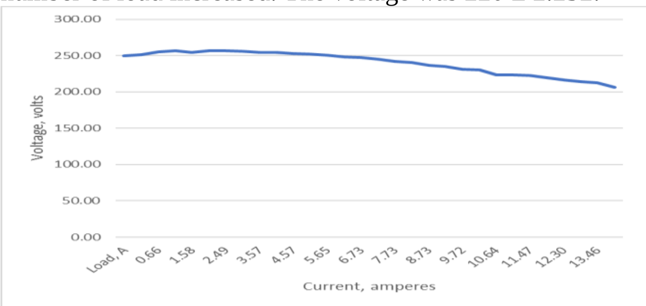

Figure 4.Voltage with AELC

Statistical analysis showed that there was a significant difference between the voltage readings from the electric generator without the AELC and with the AELC. The standard deviation of the voltage from the electric generator without the AELC (17.58) was much greater than the standard deviation of the voltage from the electric generator with AELC (10.89).

3.4 Efficiency of the Use of AELC in the Electric Generator Assembly

Comparison among the Hertz values also showed that there was a significant difference between the frequencies of the electric generator with and without AELC. The standard deviation of the Hertz from the electric generator without the AELC (2.71987) was greater than the standard deviation of the Hertz from the electric generator with AELC (1.08412).

The standard deviations of the RPM/frequency and voltage of the electric generator with and without the AELC revealed that the AELC enhanced the efficiency of the electric generator. The lower value of the standard deviation meant lower fluctuation of the electric generator.

The efficiency was also determined by comparing the RPM, voltage and frequency with standard values as shown in Table 2. The percent (%) accuracy with respect to the RPM, voltage, and frequency outputs of the electric

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generator with AELC was higher than that of the generator without AELC. It was found that the RPM is 97.852% accurate compared to the RPM standard value of 1800, the voltage is 99.281% accurate compared to the standard value of 220 volts, and lastly, the frequency is 97.812% accurate as compared to the standard 60 Hertz

The cost of AELC was computed to be PHP 8,120.00.

4. CONCLUSION

Based on the results of this study, the RPM produced by the electric generator assembly without the AELC is not stable. Fluctuations occur as the number of loads varies. These fluctuations were eliminated when AELC was employed in the electric generator assembly even with varying loads. The RPM, voltage, and frequency have been proven to be maintained and regulated by using the developed AELC.

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6. REFERENCES

1. Abed, A.A. (2018). Improved power factor of electrical generation by using clustering neural network. *International Journal of Applied Engineering Research* 13(7), 4633-4636. Retrieved from http://www.ripublication.com

2. Abu-aisheh, A.A., & Batarseh, M.G. (2016). *DC-DC Converters*. In Electric Renewable Energy Systems. https://doi.org/10.1016/C2013-0-14432-7

3. Adhikari, R., Bhattarai, R., & Tamrakar, I. (2013, October). Improved Electronic Load Controller for Three Phase Isolated Micro-Hydro Generator *In Fifth International Conference on Power and Energy Systems*. Kathmandu, Nepal.

4. Akinwole, O.O. & Oladimeji, T.T. (2018). Design and implementation of Arduino Microcontroller based automatic lighting control with I2C LCD display. *Journal of Electrical & Electronic Systems 7*(2), 258. Retrieved from https:// doi: 10.4172/2332-0796.1000258

5. Castillo, G., Ortega, L. Pozo, M. & Dominguez, X. (2016). Control of an island Micro-hydropower plant with self-excited AVR and combined ballast load frequency regulator. *In IEEE Ecuador Technical Chapters Meeting (ETCM). doi:10.1109/etcm.2016.7750868*

7. Clark, R.N. (2014). Wind Turbine Components and Descriptions: Essential Components to have a Productive, Reliable, and Safe Wind Machine. In *Small Wind*. Academic Press. Retrieved from https://doi.org/ 10.1016/B978-0-12-385999-0.00003-5

8. Costello, C. (2017, October 24). Common Generator Problems and How to Avoid Them. *Healthcare Facilities Today*. Retrieved from https://www. Healthcarefacilitiestoday.com

9. Dessai, D. D., Gonsalves, G. B., Luis, M. R., & Samantha, M. (2017). Dark detector system for paper waste detection. *International Journal for Scientific Research & Development5*(1), 873–875.

10. Hatto, P. (2010). *Standards and Standardization Handbook.* Retrieved from https://www.iec.ch

11. International Electrotechnical Commission (IEC), (2017).Tips and tricks for designing with voltage references. Retrieved from https://www.iec.ch/

12. Khaligh, A., Onar, O.C. (2018) Energy Sources. In *Power Electronics Handbook* (4th ed.) Rashid, M.H. (Ed.). Elsevier, Inc. Retrieved from https://doi.org/10.1016/C2012-007333-4

13. *Kathirvel, C., Porkumaran, K., &Jaganathan, S. (2015). Design and Implementation of Improved Electronic Load Controller for Self-Excited Induction Generator for Rural Electrification.* The Scientific World Journal 2015. *Retrieved from http://dx.doi.org/10.1155/2015/340619*

14. Kathirvelan, J., Varghese, B., Ponnary, U. A., Kamar, F., & Jacob, R. T. (2014). Hall effect sensor based portable tachometer for RPM measurement. *International JournalComputer Science and Engineering Communications 2*(1), 100–105.

15. Kezunovic, M. (2005). The fundamentals of power system protection. In *The Electrical Engineering Handbook*, Chen, W.K. (Ed.) Elsevier, Inc.

16. Kelemenová, T., Kelemen, M., Virgala, I., Miková, Ľ., Frankovský, P., & Lörinc, M. (2015). Experimental verification of Hall effect sensor properties. *Journal of Automation and Control 3*(3), 75–78. https://doi.org/10.12691/automation-3-3-7

17. Khaligh, A., Onar, O.C. (2018) Energy Sources. In *Power Electronics Handbook* (4th ed.) Rashid, M.H. (Ed.). Elsevier, Inc. Retrieved fromhttps://doi.org/10.1016/C2012-007333-4

18. Knight, D. (2015, November). Buck converters and their cool applications. *In https://www.allaboutcircuits.com*

19. Kusakana, K., Munda, J.L. &Jimoh, A.A. (2008). Economic and environmental analysis of Micro Hydropower system for rural power supply. In *Conference Proceedings of the 2nd IEEE*

ISSN 2063-5346

International Conference on Power and Energy Joho Baharu, Malaysia.Retrieved from https://doi:10.1109/PECON.2008.4762516

20. Louis, L. (2018). Working principle of arduino and using it as a tool for study and working principle of arduino and using it. *International Journal of Control, Automation, Communication and Systems1*(2), 21-29. https://doi.org/10.5121/ijcacs.2016.1203
21. Masoum, M.A.S. & Fuchs, E.F. (2015). *Power quality in power systems and electrical machines* (2nd ed.).Retrieved from https://doi.org/10.1016/B978-0-12-800782-2.00001-4
22. McDonald, A. & Carroll, J. (2016). *Offshore wind farms: Technologies, design and operation.* Retrieved from https://doi.org/10/1016/B978-0-08-100779-2.00008-8
23. Miller, B. G. (2017). *Clean Coal Engineering Technology* (2nd ed.). Retrieved from https://doi.or/10.1016/B978-0-12-811365-3.00005-3
24. Mohammed, O. Youssef, T., Cintuglu, M.H. &Elsayed, A. (2017). Design and simulation issues for secure power networks as resilient smart grid infrastructure. In Smart Energy Grid Engineering. Academic Press. Retrieved from https://doi.org/10.1016/B978-0-12-805343-0.00012-7
25. Murthy, S.S. (2016). *Electric renewable energy systems*. Retrieved from https://doi.org/10.1016/B978-0-12-804448-3.00012-8
26. Novakovic, B. &Nasiri, A. (2016). *Electric renewable energy systems*. Retrieved from https://doi.org/10.1016/B987-0-12-804448-3.00001-3
27. Riaz, M.H., Yousaf, M. K., Izhar, T., Kamal, T., Danish, M., Razzaq, A. &Qasmi, M.H. (2018, April 9). Micro hydro power plant dummy load controller. In *Conference Proceedings of the 1st International Conference on Power, Energy and Smart Grid* (ICPESG). Mirpur University of Science and Technology, Pakistan. Retrieved from doi**:**10.1109/ICPESG.2018.8384511
28. Singh, R.R., Kumar,A. B., Shruti, D., Panda, R., & Raj, T.C. (2018). Review and experimental illustrations of electronic load controller used in standalone Micro-Hydro generating plants. *Engineering Science and Technology , an International Journal 21*(2018), 886-900. Retrieved at https://doi.org/10.1016/j.jestch.2018.07.006