Innovative Configuration Design of Two-Wire Tip Mechanisms for a Tipping-Bucket Rain Gauge

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Abstract

This paper evaluates the measurement accuracy of the three designs of an innovative Tipping-Bucket Rain Gauge (TBRG) tip mechanism. A water-level detecting circuit is used to replace the conventional reed switch sensor, which addresses the disadvantages of the magnetic sensing method that became a factor in quantification uncertainties. The TBRG configuration designs were the bucket-feed, which detects the presence of water inside the bucket, and the bottom-feed and the center-feed, which use the tip-impact method in measuring rainfall. The constant flow method is used in the experimentation. The bucket-feed shows potential in precision rainfall measurement for having -3.84% and -2.68% accuracy errors at 6 mL/min and 11 mL/min respectively, without correction algorithm applied. The tip-impact application for the bottom-feed and the center-feed resulted in a higher error percentage from the volumetric flow samples. The result indicates that actual detection in the bucket brings more measurement accuracy than the tip-counting technique.

Keywords: rain data acquisition, tipping-bucket rain gauge, tip mechanism, water level detection

References

[1] L. G. Lanza and E.Vuerich, "The WMO field Intercomparison of rain intensity gauges," Atmospheric Research, vol. 94, no. 4, pp. 534-543, December 2009.

[2] F. L. Conti, D. Pumo, A. Incontrera, A. Francipane, G. L. Loggiaand, and L. V. Noto, "A weather monitoring system for the study of precipitation fields, weather, and climate in an urban area," In 11th International Conference on Hydroinformatics, pp. 1-8, 2014.

[3] M. G. Syahrul, "Design and implementation of tipping-bucket rain gauge," In 1st International Conference on Informatics and Computational Sciences, pp. 195-200, 2017.

[4] B. A. Indunil and H. A. P. K. Hettiarachchi, "Automated rain gauge station with a GSM data transmission link," In 2nd International Conference on Industrial and Information Systems, pp. 387-392, 2007.

[5] X. C. Liu, T. C. Gao, and L. Liu, "A comparison of rainfall measurements from multiple instruments," Atmospheric Measurement Technique, vol. 6, pp. 1585-1595, 2013.

[6] P. Muñoz, R. Célleri, and J. Feyen, "Effect of the resolution of tipping-bucket rain gauge calculation method on rainfall intensities in an andean mountain gradient," Water, vol. 8, pp. 534, 2016.

[7] T. K. V. Raghava and S. P. Wani, "Internet enabled tipping bucket rain gauge," In 2014 International Conference on Computer Communication and Informatics, 2014.

[8] V. S. Shedekar, K. W. King, N. R. Fausey, A. B. O. Soboyejo, R. D. Harmel, and L. C. Brown, "Assessment of measurement errors and dynamic calibration methods for three different tipping-bucket rain gauges," Atmospheric Research, vol. 178-179, pp. 445-458, 2016.

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[9] M. Stagnaro, M. Colli, L. G. Lanza, and P. K. Chan, "Performance of post-processing algorithms for rainfall intensity using measurements from tipping-bucket rain gauges," Atmospheric Measurement Technique, vol. 9, pp. 5699-5706, 2016.
[10] A. Tokay, P. G. Bashor, and V. L. McDowell, "Comparison of rain gauge measurements in the Mid-Atlantic Region," American Meteorological Society, pp. 553-564, 2010.
[11] R. K. Das and N. R. Prakash, "Design of an improvised tipping bucket rain gauge for measurement of rain and snow precipitation," International Journal of Instrumentation Technology, vol. 1, no. 1, pp. 44-59, 2011.
[12] P. Regtien and E. Dertien, "Inductive and Magnetic sensors," Sensors for Mechatronics 2nd Edition, pp. 145-182, 2018.
[13] L. X. Zhang, Y. Itoh, M. Yoshizawa, and K. Suzuki, "Basic phenomena of contact bounce in the electrical switching system," Elsevier Studies in Applied Electromagnetics in Materials, vol. 6, pp. 609-612, 1995.
[14] J. C. B. Lopez and H. M. Villaruz, "Low-cost weather monitoring with online logging and data visualization," In 8th IEEE International Conference Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management, 2015.
[15] M. M. Rashid, M. Rabani, M. Romlay, and M. M. Ferdaus, "Development of electronic rain gauge system," International Journal of Electronics and Electrical Engineering, vol. 3, no. 4, pp. 245-249, 2015.
[16] M. T. Tabada and M. E. Loretero, "Application of a low-cost water level circuit for an accurate pulse detection of a tipping bucket rain gauge as an alternative method for reed switch sensors," Environmental Monitoring and Assessment, vol. 191, no. 5, 2019.
[17] A. Broring, P. Beltrami, R. Lemmens, and S. Jirka, "Automated integration of Geosensors with the sensor web to facilitate flood management," Approaches to Managing Disasters-Assessing Hazards, Emergencies and Disaster Impacts, pp. 65-86, 2012.
[18] B. Kumar and N. Mandal, "Study of an electro-optic technique of level transmitter using Mach-Zehnder Interferometer and float as primary sensing elements," Proceeding of IEEE Sensors Journal, vol. 16, no. 11, pp. 4211-4218, 2016.
[19] R. Greswell, P. Ellis, M. Cuthbert, R. White, and V. Durand, "The design and application of an inexpensive pressure monitoring system for shallow water level measurement, tensiometry, and piezometry," Journal of Hydrology, vol. 373, pp. 416-425, 2009.
[20] Z. Liu and C. W. Higgins, "Does temperature affect the accuracy of vented pressure transducer in fine-scale water level measurement?," Geoscientific Instrumentation, Methods and Data System, vol. 4, pp. 65-73, 2015.
[21] J. Vetelino and A. Reghu, "Introduction to Sensors," Florida: Taylor and Francis Group, 2011.
[22] B. Su and X. Ma, "Water Level Sensor Based on a New design structure for irrigation water measurement," IFAC Proceedings Volumes, vol. 43, no. 26, pp. 39-44, 2010.
[23] A. Qurthobi, R. F. Iskandar, A. Krisnatal, and Weldzikarvina, "Design of capacitive sensor for water level measurement," Journal of Physics: Conference Series, vol. 776, 2016
[24] F. Reverter, L. Xiujun, and G. C. M. Meijer, "Liquid level measurement system based on a remote grounded capacitive sensor," Sensors and Actuators A: Physical, vol. 138, no. 1, pp. 1-30, 2007.
[25] J. Wei, C. Yue, Z. L. Chen, Z. W. Liu, K. A. A. Makinwa, and P. M. Sarro, "Implementation and characterization of a femto-farad capacitive sensor for pico-liter liquid monitoring," Proceedings of the Eurosensors XXIII Conference, pp. 120-123, 2009.
[26] J. Baoquan, Z. Zeyu, and Z. Hongjuan, "Structure design and performance analysis of a coaxial cylindrical capacitive sensor for liquid-level measurement," Sensors and Actuators A: Physical, vol. 223, pp. 84-90, 2015.
[27] K. Chetpattananondh, T. Tapoanoi, P. Phukpattaranont, and N. Jindapetch, "A self-calibration water level measurement using an interdigital capacitive sensor," Sensors and Actuators A: Physical, vol. 209, pp. 175-182, 2014.
[28] K. Loizou, and E. Koutroulis, "Water level sensing: State-of-the-art review and performance evaluation of a low-cost measurement system," Measurement, vol. 89, pp. 204-214, 2016.
[29] L. G. Lanza, M. Leroy, C. Alexadropoulos, L. Stagi, and W. Wauben, "WMO Laboratory Intercomparison of Rainfall Intensity Gauges-Final Report," Instrumental Department, INSA-IO, KNMI: De Bilt, Netherlands, 2005.
[30] M. Colli, L. G. Lanza, P. La BArbera and P. W. Chan, "Measurement accuracy of weighing and tipping-bucket rainfall intensity gauges under dynamic laboratory testing," Atmospheric Research, vol. 144, pp 186-194, 2014.
[31] S. Wijonarko, Sensus & Maftukhah, Tatik, "Instrumentation system for water balance measurements on Serkuk Subbasin, Kubu Watershed, Belitung," Proceedings of AIP Conference, vol. 1746, no. 1, 2014.
[32] R. A. Hodgkinson, T. J. Pepper, and W. D. Wilson, "Evaluation of Tipping Bucket Rain Gauge Performance and Data Quality," Bristol, Environment Agency, 2004.
[33] UNI 11452: 2012, "Hydrometry-Measurement of rainfall intensity (liquid precipitation)-Metrological requirements and test methods for catching type gauges," Ente Nazionale Italiano di Unificazione, Milano, Italy, 2012.