speed variable electromechanical and hydraulic drives are employed in the form of efficient shredders and high-density knives compared to the conventional drives used in LoA 4 turbines. Also, LoA 5 and 6 use a diffuser in the extraction, which is exclusively automated with frequency variable drives, thus consuming less power while producing quality sugar with adaptive control on parameters. However, this is contrary to when LoA 4 is employed where mill tandems are withdrawing relatively high power to operate at the expense of low quality and production rate. Level 5 (SCADA) or Level 6 (DCS) automation requires an additional shredder that consumes power compared to LoA 4 that does not require shredding. Only efficient and economical shredders and high-density knives should be installed to reduce power consumption and ultimately reduce both the cycle and set up time and thus enhance efficient production.

IV. Conclusion

The rate of power consumption of the entire juice extraction process line when employing LoA 4 (conventional automation) was relatively higher with a total of 45044 kW compared to when LoA 5 (SCADA) or LoA 6 (DCS) are used with a total power consumption of 42058 kW and 42008 kW respectively. Therefore, using LoA 5 or 6, the overall power consumption was lower than the conventional milling technologies. This is attributed to the characteristics of the LoA 5 and 6, where speed variable electromechanical and hydraulic drives are employed in the form of efficient shredders and high-density knives compared to the conventional endeavors used in LoA 4 turbines. Also, LoA 5 and 6 use a diffuser in the extraction, which is exclusively automated with frequency variable drives, thus consuming less power while producing quality sugar with adaptive control on parameters. However, this is contrary to when LoA 4 is employed where mill tandems are withdrawing relatively high power to operate at the expense of low quality and production rate. It can be seen that LoA 5 and 6 have virtually negligible setup involved except when it is after a general plant overhaul as a result of minimum variations in the process parameters due to their real-time monitoring and control. In summary, lean automation, which consists of LoA 5 (SCADA) and LoA 6 (DCS), according to Garcia [23], provides the optimum lean automation that local sugar industries require to have a sustainable and competitive process performance. Therefore, it should be considered for adoption and implementation within the sugar processing line as the appropriate advanced manufacturing technique to minimize resource wastages in the sugar industry.

Acknowledgment

We would like to thank Mumias Sugar factory for permitting us to set up the experiment and conduct research in the factory. We also appreciate the University of Nairobi's well-equipped library for providing resource materials for literature and document review relevant to this research.

References

[1] Kenya Sugar Board report (KSB, 2007)
[2] Kenya National Assembly, 2015
[3] Kenya Sugar Board report (KSB, 2010)
[4] Kenya Sugar Board report (KSB, 2013)
[5] Ondiek G.O and Kisombe S.M (2015) Survey on Adoption of Lean Manufacturing Tools and Techniques in Sugar Processing Industries in Kenya, Industrial Engineering Letters, ISSN 2224-6096 (Paper) ISSN 2225-0581 (online) Vol.3, No.10, 2013 pg 92-104
[6] Shaman, G & Sanjiv, K, J (2013) A literature review of lean manufacturing, International Journal of Management Science and Engineering Management, Volume 8, 2013 - 4, Pg 241-249, https://doi.org/10.1080/17509653.2013.825074
[7] Upadhye, N., Deshmukh, S. G., & Garg, S. (2010). Lean manufacturing system for medium size manufacturing enterprises: An Indian case. International Journal of Management Science and Engineering Management, 5,362–375.
[8] Seth, D., &Gupta, V. (2005). Application of value stream mapping for lean operations and cycle time reduction: An Indian case study. Production Planning & Control, 16, 44–59.
[9] Dennis, P. (2007). Lean production simplified. New York: Productivity Press.
[10] Zafarzadeh, M (2013) A guideline for efficient implementation of automation in a lean manufacturing environment, product and process development, innovative production, KPP 231 Master thesis, Malardalens University.
[11] Liker, J.K. (2004) The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer, McGraw-Hill, New York.
[12] Padraic, J, K (2010) Packaging Machinery: Sustainability and competitiveness, Sustainable Manufacturing Initiative Sector focus study series, International trade administration, Department of commerce, USA
[13] Oliverio, J.L. & Avila, A.C.R.D. & Faber, A.N. & Soares, P.A. (2014). Juice extraction systems: Mills and diffusers - The Brazilian experience. International Sugar Journal. 116. 190-202.
[14] Hedelind, M. & Jackson, M. (2008b). Industrial Robotics in the Lean Enterprise - A Case Study. The 6th International Conference on Manufacturing Research. Brunel University, UK.
[15] Orr, S. C. 1997, Automation in the Workplace: An Australasian Perspective, Technovation, Vol. 17, No. 2, pp. 83-105.
[16] Hedelind, M.; Jackson, M. & Hellström, E. (2008a). Robotics for SME´s – Investigating a Mobile, Flexible, and Reconfigurable Robot Solution. Proceedings of the 42nd International Symposium on Robotics.
[17] Hollingum, J. (1994). ABB Focus on "Lean Robotization". Industrial Robot, Vol.21, No.2, pp.15-16
[18] Harris, C. & Harris, R. 2008, Can Automation Be a Lean Tool? Automation That Enhances Flow Is Lean; Automation That Reduces Uptime and Extends Changeover Is Not Lean, Manufacturing Engineering, Vol. 141, No. 2, pp. 27-34.
[19] Chen, H. (2010). Lean Automated Manufacturing: Avoiding the Pitfalls to Embrace the Opportunities. Assembly Automation, Vol. 30, No. 2, pp. 117123.
[20] Hoque, Z. (2000). Just-In-Time Production, Automation, Cost Allocation Practices and Importance of Cost Information: an Empirical Investigation in New Zealand-Based Manufacturing Organisations. The British Accounting Review, Vol. 32, No. 2, pp.133-159.
[21] Kent, G. & Lewinski, J. (2007) Milling and Diffusion Extraction—Theory and Practice, Proc. Int. Soc. Sugar Cane Technol., Vol. 26, 2007
[22] Ali. H, Arif. W et.al (2012) Classical model-based analysis of cost of poor quality in a manufacturing organisation, African Journal of Business Management Vol. 6(2), pp. 670-680, Available online at http://www.academicjournals.org/AJBM, DOI: 10.5897/AJBM11.2332.
[23] Garcia. F (2015) Integrating Six Sigma and Lean Manufacturing the Challenges & Benefits, Advent Design Corporation
[24] Martinez A. and Pérez M. (2001), Lean indicators and manufacturing strategies, International Journal of Management Science and Engineering Management, 8:4, 241-249, DOI: 10.1080/17509653.2013.825074