Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı, S. 279-283, Ağustos 2020

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue, pp. 279-283, August 2020

Research Article

Data Acquisition Module Design for Remote Monitoring of Uninterruptible Power Supply and Regression Models of Battery Life

Metehan Avkıran[1,*], Vedat Gül[2], Savaş Şahin[1], İbrahim Tanağardıgil[2]

[1] Izmir Katip Çelebi University, Faculty of Engineering and Architecture, Department of Electrical and Electronics Engineering, İzmir, Türkiye (*ORCID: 0000-0002-4165-3441)

[2] Tescom Elektronik A.Ş, Department of Research and Development, İzmir, Türkiye

(Bu yayın 26-27 Haziran 2020 tarihinde HORA-2020 kongresinde sözlü olarak sunulmuştur.)

(**DOI:** 10.31590/ejosat.779967)

ATIF/REFERENCE: Avkıran, M., Gül, V., Şahin, S. & Tanarğardıgil, İ. (2020). Data Acquisition Module Design for Remote Monitoring of Uninterruptible Power Supply and Regression Models of Battery Life. *Avrupa Bilim ve Teknoloji Dergisi*, (Special Issue), 279-283.

Abstract

In this study, the design of embedded system-based data acquisition card is implemented for uninterruptible power supply (UPS) for providing dataset of power, current, temperature, battery voltage values. The dataset is acquired with the developed data acquisition card designed with by using serial communication protocol and transmission control protocol/internet protocol. The obtained dataset is transrecevied with the its designed interface by using the Visual Studio program. Also, the battery life estimation of UPS is performed by various regression models with machine learning algorithms. Battery status, battery electrical energy consumption and temperature data were analyzed with root mean square error and R^2 score tests. Random forest regression performed better than other regression models for the obtained dataset for the battery life. The battery life estimatation might be important for UPS performance.

Keywords: data acquisition card, interface, remote monitoring, battery life, machine learning, regression models.

Kesintisiz Güç Kaynağı için Uzaktan İzlemeyi Sağlayan Veri Paylaşım Modül Tasarımı ve Regresyon Modelleri ile Akü Ömrü Tahmini

Öz

Bu çalışmada, kesintisiz güç kaynağının (UPS) elektrik güç, akım, sıcaklık, akü voltajı değerlerinin veri kümesini elde etmek için gömülü sistem tabanlı veri toplama kartı tasarımı yapılmıştır. Veri seti, seri iletişim protokolü ve iletim kontrol protokolü / internet protokolü kullanılarak tasarlanan geliştirilmiş veri toplama kartı ile elde edilir. Elde edilen veri seti, Visual Studio programı kullanılarak tasarlanan arayüzü ile aktarılmaktadır. Ayrıca, UPS'in akü ömrü tahmini, makine öğrenme algoritmalarından çeşitli regresyon modelleri tarafından gerçekleştirilmiştir. Akü durumu, akü elektrik enerjisi tüketimi ve sıcaklık verileri, ortalama karekök hatası ve R^2 testi ile analiz edilmiştir. Rassal Orman regresyonu, pil ömrü için elde edilen veri seti için diğer regresyon modellerinden daha iyi performans göstermiştir. Akü ömrünün tahmini UPS performansı için önemli olabilir.
Anahtar Kelimeler: Veri paylaşım kartı, arayüz, uzaktan kontrol, akü ömrü, makine öğrenmesi, regresyon modeli

1. Introduction

Uninterruptible power supplies (UPS) are devices that provide uninterrupted electrical power for the connected devices (Nasiri et al., 2008). Such devices are widely used in important sectors such as industry, healthcare and military (Gu et al., 2020). UPS might be designed at different operating conditions corresponding to the electrical power, electrical voltage, and current values suitable for the different sectors (Morrison and Egan, 2000; Mondal and Keisling, 2012). The electrical variable dataset of UPS might be monitored by using several communication ports and protocols depending on the area used (Hazen, 2003). Commonly used serial communication ports are RS232 and RS485 (Chai et al., 2008; Zhang et al., 2005). Communicaiton protocols are used as transmission control protocol/internet protocol (TCP/IP) and controller area network (CANBus) widely used in the industrial applications (Kaiser and Brudna, 2005; Yun et al., 2019; Wang and Dai, 2012). UPS data can be remotely controlled these communication ports and protocols (Medina et al., 2009). It was noted that monitoring UPS data set is a necessary issue for maintaining them (Morrison and Wells, 2009). Once the electrical energy is not supplied from the grid, UPS might supply the electrical energy to the connected systems with its batteries. So, such batteries performance is important for both sustainable electrical energy and efficienciey of UPS (Asumadu et al., 2006). Therefore, in order to estimate batter life, the regression models might be used (Lin and Lin, 2019).

In this study, the design of embedded system-based data acquisition card is implemented for 10kVA UPS for providing dataset of power, current, temperature, battery voltage values. The dataset is acquired with the developed data acquisition card with serial communication protocol and TCP/IP. The battery life estimation of UPS is performed by several regression models. Battery status, battery electrical energy consumption and temperature data were analyzed with root mean square error (RMSE) and R^2 score tests. The obtained results are compared each other.

The rest of the paper is presented in the following sections, In Section 2, hardware design of data acquisition card briefly, software part of data transmitting and battery life estimation with regression models. In Section 3, the results from the prototype of the system are given, and conclusions and recommendations are presented in Section 4.

2. Material and Method

The developed data acquisition card module and UPS is given in the Fig.1. It consists of developed data acquisition card, transmitting data stage and interface design, respectively. There are two options for monitoring data remotely, they are provided with LAN connections and static IP connections.

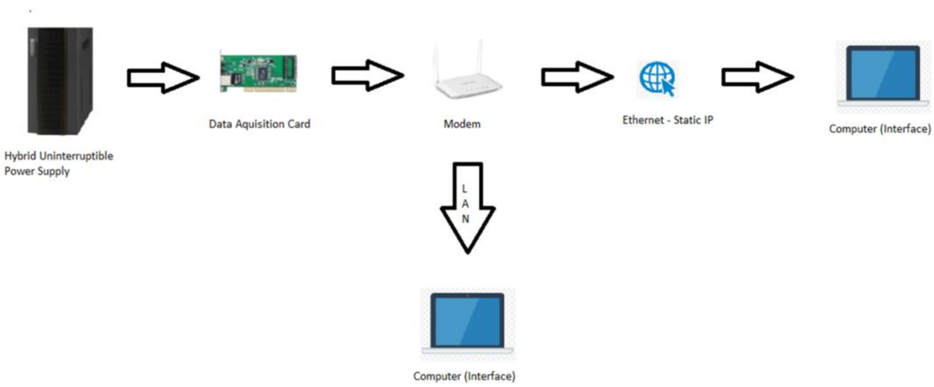
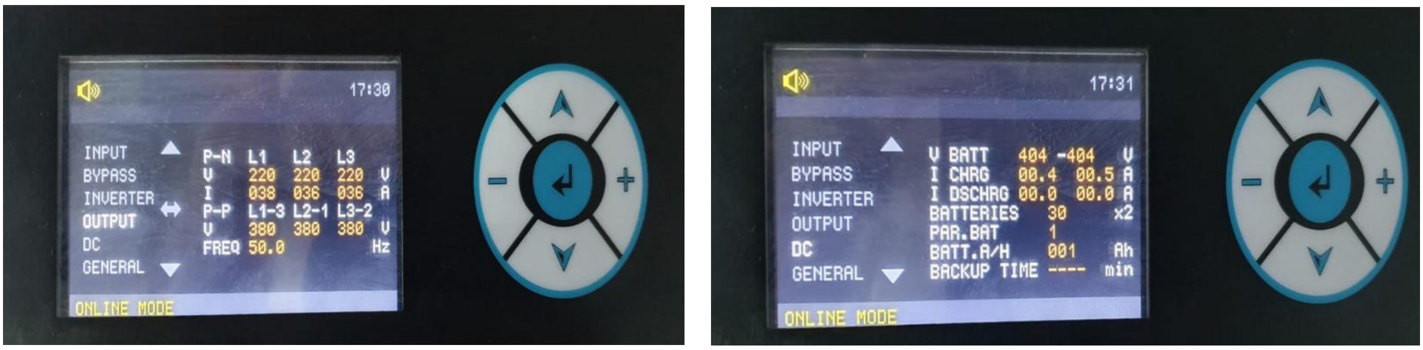


Figure 1. The developed system for remote monitoring of the UPS

2.1. Developed Data Acquisition Card

The main components are given as follows ESP32-WROOM as microprocessor, RS-232 communication port as communication port, and LAN8710 as ethernet module. ESP32 is a series of low-cost, low-power system on a chip microcontroller with included Wi-Fi and dual-mode Bluetooth (Nikolov and Nakov, 2019). The RS232 is a standard originally introduced for serial communication transmission of data (Han and Kong, 2010). Ethernet modules enable the computer to communicate and stay in touch with all systems included in the network. The voltage, current, temperature and power data are displayed on the front panel of the UPS in Fig.2.



(a) (b)

Figure 2. The snaphot of the developed data acquisition card (a) UPS values, (b) battery values

2.2. Transmitting Data and User Interface

The communication protocol of the 10kVA UPS was used with the devloped algorithm given in Fig. 3 where the flowchart of communication algorithms is used for dataset transmitting. The correctness procedure of the data streamimg is controlled with frame control function where each frame is check checked individually in terms of the number of incoming characters with parse command. TCP/IP communication protocol was used for the user interface monitoring UPS dataset in Fig.4. Once IP connection is provided, UPS dataset can be obtained remotely.

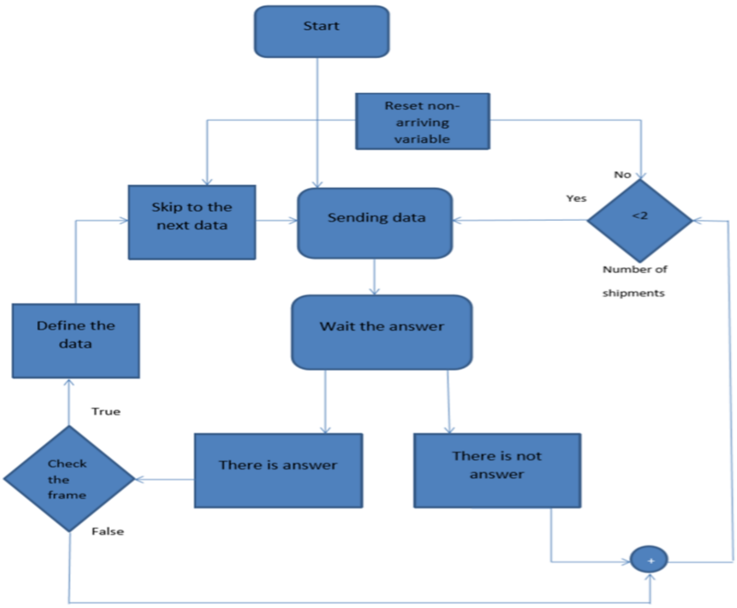


Figure 3. Flowchart of communication algorithms for dataset transmitting

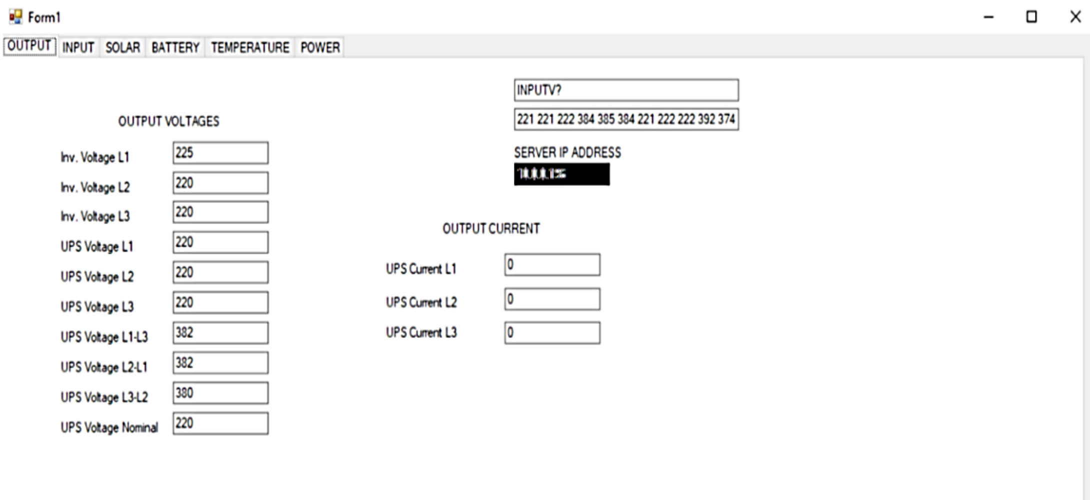


Figure 4. User interface with system variables

2.3. Regression Models

Regression analysis might be assumed as a process of statistical methos which is used to estimate relationships between dependent and independent variables. The machine learning method aims to at learning the pattern recognition having several different algorithms and/or methods such as random forests, decision tree, support vector machines, neural networks, k-nearest neighbor and naive bayes (Pal, 2005). So it is to powerful method to provide the best fit for the obtained data (Freedman, 2009). In this study, it is aimed to estimate battery life of UPS by using regression models of machine learning algorithms. Regression model analysis provides both predicting and estimating of the relationship considered variables (Mason et al., 1991).

3. Result and Discussion

Battery life estimation of UPS is made with regression models by using machine learning algorithms. The data set is obtained from the 10kVA UPS produced by TESCOM A.Ş (Tescom, 2020). The attributes of the dataset used are as follows: discharge current, battery (+), battery (-), battery usage time and temperature. The overall dataset was preprocessed and analyzed thoroughly. Nine different regression models were examined to estimate battery life. These regression models are as follows; support vector machine, linear, light gradient boosting machine (LGBM), extreme gradient boosting (XGB), gradient boosting, random forest, decision tree, multi-layer perceptron (MLP) and K-neighbours regression. When applying these regression models, battery charge percentage and estimated time attributes in the data set were considered and in order to evaluate the their performances RMSE and R^2 score are used.

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{m}(y_i - \grave{y}_i)^2}{m}} \tag{2}$$

where y_i is the estimated time data in the data set, $\grave{y}_i$ is the value of the estimated time after the prediction of the regression model.

$$R^2 = 1 - \left[\frac{\sum_{i=1}^{m}(y_i - \grave{y}_i)^2}{\sum_{i=1}^{m}(y_i - \tilde{y}_i)^2}\right] \tag{3}$$

where y_i is the estimated time data in the data set, $\grave{y}_i$ is the value of the estimated time after the prediction of the regression model and $\tilde{y}_i$ is the is the average of the estimated times in the dataset.

As a result of data pre-processing, the battery charge percentage and estimated time are performed with random forest regression model is appropriate for battery charge estimation in Table 1 where the lowest RMSE value and the R^2 score value is closest to 1. It is depicted in Fig.5. The RMSE and R^2 results of random forests regression model is 63.1265 and 0.9964, respectively.

Table 1. RMSE and R^2 score values of regression models

Regression Models	**Root Mean Square Error**	**R^2 Score**
Support Vector Machine	1057.0299	0.0008
Linear Regression	77.2032	0.9946
LGBM Regression	465.0893	0.8065
XGB Regression	93.5188	0.9921
Gradient Boosting Regression	66.7964	0.9960
Random Forest Regression	63.1265	0.9964
Decision Tree Regression	117.6133	0.9876
Multi-Layer Perceptron Regression	965.1574	0.1670
K-Neighbours Regression	104.8204	0.9901

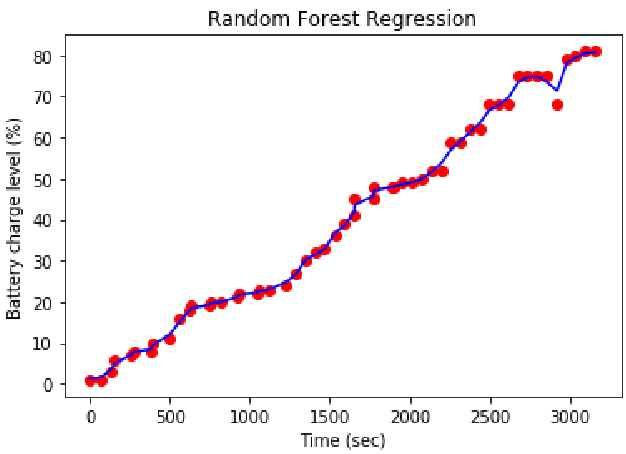


Figure 5. Battery charge estimation versus time

4. Conclusion and Recommendations

The embedded system-based data acquisition card is desgined and implemented for 10kVA UPS for observing dataset of power, current, temperature, battery voltage values. The operating dataset of UPS variables are acquired with the developed data acquisition card having serial communication protocol and TCP/IP. The battery life estimation of UPS is examnined by nine regression models with machine learning algorithms. Battery status, battery electrical energy consumption and temperature data were analyzed with RMSE and R^2 score. Random forest regression performed better than other regression models for the obtained dataset for the estimation of the battery life.

5. Acknowledge

This work is supported by the Scientific and Technical Research Council of Turkey (TUBITAK) under 2209B-Bachelor Final Thesis Focused on Industry Program with Project number 1139B411901093

References

Asumadu, J.A., Haque, M., Vogel, H., Willards C., (2006), Precision Battery Management System. 2005 IEEE Instrumentationand Measurement Technology Conference Proceedings.

Chai, Y., Sun, J.Y., Gao, J., Tao, J.L., Ji, J., Bao, F.H. (2008), Improvement of I2C Bus and RS-232 Serial Port under Complex Electromagnetic Environment. 2008 International Conference on Computer Science and Software Engineering.

Freedman, D.A., (2009), Statistical Models: Theory and Practice. Cambridge University Press. ISBN 978-1-139-47731-4.

Gu, B., Lee, H., Kang, C., Sung, D., Lee, S., Yun, S., Park, Sung K., Cho. G., Kim, N., and Cha. S.W. (2020), Receding Horizon Control of Cooling Systems for Large-Size Uninterruptible Power Supply Based on a Metal-Air Battery System. Journal of Energies 13(7), 1611.

Han, X., Kong, X., (2010), The Designing of Serial Communication Based on RS232. 2010 First ACIS International Symposium on Cryptography, and Network Security, Data Mining and Knowledge Discovery, E-Commerce and Its Applications, and Embedded Systems.

Hazen, Mark E. (2003), Understanding Some Basic Recommended Standards for Serial Data Communications - A comparison of RS-232, RS-422 and RS-485. High Performance Analog, Intersil Corporation.

Kaiser, J., Brudna, C., (2005), A publisher/subscriber architecture supporting interoperability of the CAN-Bus and the Internet. 4th IEEE International Workshop on Factory Communication Systems.

Lin, C.Y., Lin C., (2019), Using Ridge Regression Method to Reduce Estimation Uncertainty in Chlorophyll Models Based on Worldview Multispectral Data. IGARSS 2019 - 2019 IEEE International Geoscience and Remote Sensing Symposium.

Mason C.H., Perreault, W.D., JR. (1991), Collinearity, Power, and Interpretation of Multiple Regression Analysis. Research Article

Medina, V., Gomez, I., Oviedo, D., Dorronzoro, E., Martin, S., Benjumea, J., Sanchez, G., (2009), IEC-60870-5 application layer over TCP/IP for an open and flexible remote unit. 2009 IEEE International Symposium on Industrial Electronics.

Mondal, S., Keisling, E. (2012), Efficient data center design using novel modular DC UPS, server power supply with DC Voltage and modular CDU cooling. IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES).

Morrison, C., Wells D., (2009), Computer Literacy BASICS: A Comprehensive Guide to IC3. Books

Morrison, R., Egan, M.G. (2000), A new power-factor-corrected single-transformer UPS Design. IEEE Transactions on Industry Applications (Volume: 36).

Nasiri, A., Nie, Z., Bekiarov, Stoyan B., Emadi, A. (2008), An On-Line UPS System With Power Factor Correction and Electric Isolation Using BIFRED Converter. IEEE Transactions on Industrial Electronics (Volume 55 pg. 722 – 730).

Nikolov, N., Nakov, O., (2019), Research of Secure Communication of Esp32 IoT Embedded System to .NET Core Cloud Structure using MQTTS SSL/TLS. XXVIII International Scientific Conference Electronics - ET2019.

Pal, M. (2005), Random forest classifier for remote sensing classification. International Journal of Remote Sensing, 26(1), 217-222

Tescom. (2020), [online] Available: http://www.tescom-ups.com/katalog/TR/HYBRID.pdf

Wang, Y.D., Dai, X.M., (2012), Ethernet Interface Solution Based on TCP/IP Protocol. 2012 IEEE 11th International Conference on Signal Processing Signal Processing (ICSP), 2012 IEEE 11th International Conference on.

Yun, S., Kim, J., Kim H., (2019), Reinforcement Learning as a Pre-Diagnostic Tool for TCP/IP Protocols on In-Car Networks 2019 IEEE 90th Vehicular Technology Conference (VTC2019-Fall).

Zhang. H.B., Huang, S.H., Zhou Y.Q. (2005), Design of RS-485 Hub for Automatically Switching the Transmitting and Receiving Status. Electrical Measurement & Instrumentation.