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LIFE HEALTH ESTIMATION FOR VALVE-REGULATED LEAD ACID BATTERIES AND ITS ENVIRONMENT EFFECT

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Abstract

Load, internal resistance, ambient temperature, and dis-charge cycle greatly influence of life health estimation for valve–regulated lead acid batteries, as load increases, it is directly proportional to the depth of discharge. Other operating conditions such as float voltage are strictly observed as the battery manufacturers already identified this threshold. Batteries deployed in good power grid with relatively few cycles during its life and in the event that a discharge occurs, the coup de fouet modeling technique where the dis-charge voltage versus reserve charge characteristic or the unified approach can be used to predict battery characteristics. The above – mention parameters are highly significant in determining useful life health estimation of valve-regulated lead-acid batteries. As revealed in this study, telecommunication and other allied stakeholders carefully understand the technology and ensure that basic requirements meet like consideration on air-conditioning system in the battery room, the load are monitored and not to exceed the recommended threshold as these aforementioned parameters are highly significant on the useful life health estimation of valve-regulated lead-acid batteries.

Keywords- Valve – regulated lead acid batteries, coup de fouet, health estimation, useful life.

1. INTRODUCTION

Batteries plays an important role in nation building. It is widely used in various industries from broadcasting, hospitals, power stations, and transportation but prevalent to information technology and telecommunications. Battery health estimation is absolutely essential to prevent outage and at the same time maximizing asset to reduce operational cost but this is the most challenging aspect in operation since battery state of health diverges based on different operational conditions. Batteries has become increasingly significant to store energy and fill the gap during commercial power failures to prevent outages. In fact, according to the research published by the Business Continuity Institute in association with British Standard Institution last February 2017, out of the top ten treats in the world IT and telecommunications outages rank 3rd and ranked 6th for the interruption of utility supply.

Poor detection of depleted or exhausted batteries are the main cause of service interruption in telecommunications products and services that resulted in revenue loss and poor customer experience. Recent study of supply chain industry in the study entitled "Counting the Cost of Supply Chain Disruption" conducted by the Business Continuity Institute supported by Zurich Insurance Group published in last November 2016, one of the major findings are unplanned information technology and telecommunications infrastructure related outages remains the top cause of disruption moving up from second place from sixth place in year 2015 and most of the cause are support utilities failure due to defective UPS batteries. However, the key takeaways of these problems should be the opportunities to established health estimation technique and early failure modes detection to minimize this problem.

Valve - regulated lead acid batteries compare to other types and battery technologies has a unique characteristics which an indicator of battery state of health – the coup de fouet (a phenomenon which occurs at the beginning of the discharge of battery, it corresponds to an abrupt voltage drop lasting few minutes then, the voltage recovers to the voltage plateau level) which is the modelling techniques used in this study to predict the useful life health estimation of identified valve - regulated lead acid batteries as bases to build an battery automated system (Wang, Fan, Wang, & Liu, 2019).

The data gathered across four geographical locations with unique parameters profile identified. Identified battery parameters gathered from a maintenance record manually recorded through identified routine maintenance as dataset of this study.

Result of the study will be used as an important contribution to automate battery monitoring system as a tool to predict potential failures and basically eliminate or reduced outages related to battery failures. Realizing this project would increase revenue through maximizing

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battery assets and improved services. Load, internal resistance, ambient temperature and discharge cycle are important parameters considered in this study greatly influence the estimated useful life of valve - regulated lead acid batteries. As load increases it is directly proportional to depth of discharge. Ambient temperature is one of the most influential parameters for life health estimation of valve regulated lead acid batteries, increase of temperature as result suggest accelerate thermal aging and increase in float voltage during normalization stage. By theory the increase of float voltage drops battery capacity. Other operating conditions such as float voltage are strictly observed as battery manufacturer already identified this threshold (Pascoe & Anbuky, 1999).

Battery sulfation contributes an aging mechanism of lead-acid batteries, due to not attaining the float voltage level or full charge and partial state of charge operation contributes to sulphation of crystals (can't be dissolved properly) and increase over the period of time. This happens every commercial power failure where the emergency back-up power system cut-in within 20 seconds through automatic transfer switch and these areas manifested by increase of internal resistance (Franke & Kowal, 2018).

In the event that a discharged occur (during commercial power failure), there are techniques available which can utilize the resulting data more effectively to assess battery state of health. The coup de fouet modelling technique where the discharge voltage versus reserve charge characteristic or the unified approach can be used to predict battery characteristics. Parameters identified like load, internal resistance, ambient temperature, discharge cycle & depth of discharge are highly significant in determining useful life health estimation of valve-regulated lead acid batteries.

2. PRESENTATION. DATA ANALYSIS AND INTERPRETATION

Test sites located in the four geographical locations are profiled ac-cording to commercial power supply availability of the test sites. Test sites categorized into two as to commercial power availability, the bad grid are areas with frequent commercial power failure and good grid are actually areas with minimal power disruptions as define in the research environment. This profile affects two important battery parameters, the discharge cycle and depth of discharge. The data compilation started from November 2017 to May 2018.

Lahug MSC rectifier system or DC power plant was built and com-missioned in the year 2011. The total load is 244 amperes or 14% % utilization from the total capacity of 1776 amperes. Supported with the two strings or banks of valve regulated lead-acid batteries FIAMM brand with the capacity of 3000 ampere-hour, float voltage charge at 20 degrees Celsius, 2.23 volts per cell. Boost recharge at 2.40 volts per cell with the maximum current of 0.25 at C10 (A).

Talisay MSC rectifier system or DC power plant was built and commissioned in the year 2011. The total load is 833 amperes or 31 % utilization from the total capacity of 2580 amperes. Supported with the two strings or banks of valve regulated lead-acid batteries FIAMM brand with the capacity of 3000 ampere-hour, float voltage charge at 20 degrees Celsius, 2.23 volts per cell. Boost recharge at 2.40 volts per cell with the maximum current of 0.25 at C10 (A).

CDO MSC rectifier system or DC power plant was built and com-missioned in the year 2011. The total load is 448 amperes or 26% utilization from the total capacity of 1679 amperes. Supported with the two strings or banks of valve regulated lead-acid batteries FIAMM brand with the capacity of 3000 ampere-hour, float voltage charge at 20 degrees Celsius, 2.23 volts per cell. Boost recharge at 2.40 volts per cell with the maximum current of 0.25 at C10 (A).

Iligan MSC rectifier system or DC power plant was built and com-missioned in the year 2011. The total load is 264 amperes or 14 % utilization from the total capacity of 1872 amperes. Supported with the two strings or banks of valve regulated lead-acid batteries FIAMM brand with the capacity of 3000 ampere-hour, float voltage charge at 20 degrees Celsius, 2.23 volts per cell. Boost recharge at 2.40 volts per cell with the maximum current of 0.25 at C10 (A).

Table 1 shows the numerical analysis for the relationship of coup de fouet - a phenomenon which occurs at the beginning of the discharge of battery, it corresponds to an abrupt volte modelling technique to load. As load increases the voltage drop incremental of a certain period widens as the data analysis shows highly significant results. The p-value is less than the significance level supported with confidence interval mean 0.95 of 0.1239.

Table 1 Analysis for Coup de Fouet as to Load

No. of Variables Analyzed	192
Mean	0.869
SE Mean	0.0411
CI mean @0.95	0.0811
Std. Dev.	0.569
Coef. Var.	0.655
Significance Level	0.05
P - value	< 0.01

The relationship of coup de fouet (a phenomenon which occurs at the beginning of the discharge of battery, it corresponds to an abrupt voltage drop lasting few minutes then, the voltage recovers to reach the plateau value) modelling technique to load. As load increases the voltage drop incremental of a certain period widens as the data analysis shows highly significant results. The p-value is less than the significance level supported with confidence interval mean 0.95 of 0.1239. This implies that variation of DC loads in amperes affect other related parameters like depth of discharge. Incorporating the changes occurring due to terminal voltage, current load and internal resistance to predict electromotive force (EMF) of battery, and further estimate SOC based on the electromotive force (Wang, Fan, Wang, & Liu, 2019). Variation of loads affect other parameters such as depth of discharge and discharge cycle. The higher the utilization experience the abrupt voltage dip within the twenty seconds of discharge or battery mode. Numerical analysis for the relationship of coup de fouet modelling technique to battery cell internal resistance. Increase of internal resistance is very highly significant as data shows on the table below. The p-value is less than the significance level supported with confidence interval mean 0.95 of only 0. 811.The results indicate internal resistance increase as corrosion increases because of the reduced conductivity (Bindner et. al, 2015). Another contributing factor is sulfation that contributes an aging mechanism of lead-acid batteries. Due to the lack of complete full charges or not attaining float voltage state, the partial state of charge operation sulphate crystals can't be dissolved properly and crystal sulphates grow over time. This resulted to decreasing charge acceptance and increase of internal resistance over time (Franke & Kowal, 2018). Numerical analysis for the relationship of coup de fouet modelling technique to ambient temperature. FIAMM SMG OPzV, 3000AH, 2Vdc, the battery cell model operates recommended nominal operating ambient temperature ranges from 20 to 23 deg. C. Operating beyond manufacturers design ambient temperature contributes to thermal accelerated aging conditions of the batteries (Pascoe & Anbuky, 2005). As a result, corrosion between plates increases with reduced conductive surfaces and eventually manifested into high internal resistance.

Table 2 Analysis for Coup de Fouet as to Ambient Temperature

No. of Variables Analyzed	192
Mean	24.51
SE Mean	0.1817
CI mean @0.95	0.3585
Std. Dev.	2.5189
Coef. Var.	0.1027
Significance Level	0.01
P - value	0.001

Increases in a battery's ambient temperature can offer status of health (SOH) data. This has a low to medium reliability because the temperature rise is small in comparison to the corresponding reduction in SOH, frequently rising only after the SOH has substantially diminished due to accelerated thermal aging. As the temperature rises, the float current rises as well, resulting in a reduction in battery capacity (Pascoe & Anbuky, 2005). The data analysis correlates coup de fouet modelling technique as to ambient temperature. Exposure of these batteries operational over a long period of time degrades manufacturers designed estimated useful life as data analysis shows highly significant results. The p-value is less than the significance level supported with confidence interval mean 0.95 of 0.3585.

This implies that variation of DC loads in amperes affect other related parameters like depth of discharge. In the study of Coleman et al. incorporated the changes occurring due to terminal voltage, current load and internal resistance to predict electromotive force (EMF) of battery, and further estimate SOC based on the electromotive force (Wang, Fan, Wang, & Liu, 2019). Variation of loads affect other parameters such as depth of discharge and discharge cycle. The higher the utilization experience the abrupt voltage dip within the twenty seconds of discharge or battery mode.

Table 3 shows the numerical analysis for the relationship of coup de fouet modelling technique to battery cell internal resistance. Increase of internal resistance is very highly significant as data shows on the table below. The p-value is less than the significance level supported with confidence interval mean 0.95 of only 0.811.

Table 3 nalysis for Coup de Fouet as to Ambient Temperature

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CI mean @0.95	0.0811
Std. Dev.	0.569
Coef. Var.	0.655
Significance Level	0.05
P - value	< 0.01

The results indicate internal resistance increase as corrosion in-creases because of the reduced conductivity (Bindner et. al, 2015). Sulfation is another factor that contributes to the aging mechanism of lead-acid batteries. Sulphate crystals grown over time due to a lack of complete full charges and incomplete state of charge (not attending float voltage level). As a result, charge acceptance decreased and internal resistance increased over time (Franke & Kowal, 2018).

Table 4 shows the numerical analysis for the relationship of coup de fouet modelling technique to ambient temperature. FIAMM SMG OPzV, 3000AH, 2Vdc, the battery cell model operates recommended nominal operating ambient temperature ranges from 20 to 23 deg. C. Operating beyond manufacturers design ambient temperature contributes to thermal accelerated aging conditions of the batteries (Pascoe & Anbuky, 2005). As a result, corrosion between plates increases with reduced conductive surfaces and eventually manifested into high internal resistance.

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P - value	0.001

The data analysis correlates coup de fouet modelling technique as to ambient temperature. Exposure of these batteries operational over a long period of time degrades manufacturers designed estimated useful life as data analysis shows highly significant results. The p-value is less than the significance level supported with confidence interval mean 0.95 of 0.3585.

Table 5 shows the numerical analysis for the relationship of coup de fouet modelling technique to battery depth of discharge. Commercial power failure which are related to battery depth of discharge and dis-charge cycle as the system back-up the load through battery mode to bridge the gap prior emergency back-up power system (gensets) cut -ins to supply the power requirements. and commercial power source. The data shows low significance of influence as p-value is more than significance level supported with confidence interval mean 0.95 of only 0.811.

Relationship of coup de fouet modelling technique to battery depth of discharge. Commercial power failure which are related to battery depth of discharge and discharge cycle as the system back-up the load through battery mode to bridge the gap prior emergency back-up power system (gensets) cut -ins to supply the power requirements. and commercial power source. The data shows low significance of influence as p-value is more than significance level supported with confidence interval mean 0.95 of only 0.9460.

Table 5 Analysis for Coup de Fouet as to Depth of Discharge

No. of Variables Analyzed	192
Mean	12.911
SE Mean	0.4796
CI mean @0.95	0.9460
Std. Dev.	6.64456
Coef. Var.	0.5147
Significance Level	0.01
P - value	0.315

Battery manufacturer clearly specifies the number of charge/discharge cycles within the battery lifespan or estimated useful life but predicting exactly would be difficult for operators since there are other co-important parameters to be considered. However, the results demonstrate that it is impossible to link the "coup de fouet" characteristics to battery health without taking into account the high-SOC level, the rest time preceding the discharge, and the depth of the subsequent discharge, putting the method's dependability in jeopardy. (Thanapalan, et al., 2013). This is in consideration that the number of discharge cycle and depth of discharge are insignificant since these test sites are back up with emergency backup power system with an average of twenty seconds in battery mode only.

Despite of the difficulty to determine the useful life health estimation of valve regulated lead acid (VRLA) batteries based on these identified parameters such as load, internal resistance, ambient temperature depth of discharge and discharge cycle. In the event that a discharged occur, there are techniques available which can utilize the resulting data more effectively to assess battery useful life health estimation or commonly also referred as battery state of health (SOH). The coup de fout phenomenon - the discharge voltage versus reserve charge characteristic or the unified approach can be used to obtain a direct indication of SOH (Pascoe & Anbuky, 2005).

The data analysis though prediction & estimation technique through regression analysis to model the significant parameters identified to model the useful life health estimation of identified valve-regulated lead acid batteries. Table 6 shows the useful numerical analysis results of coup de fouet considering all parameters identified. Considering all parameters considered, data analysis shows highly significant results. The p-value of 0.001 is equal to the significance level. Model adequacy checking are plotted using R Studio. Based on the residuals vs. fitted graph, it suggests that during battery discharge operation there is an abrupt decrease of voltage from float which 53.52Vdc until it reaches plateau region until it slowly decreases, this is a coup de fouet phenomenon which unique to valve regulated lead acid batteries only. This result is supported also by normal Q-Q plot.

The indication of non-linearity on the scale – location graph corresponds to an abrupt voltage drop lasting a few minutes, followed by a voltage recovery to reach the plateau value, which is the modelling technique used to predict the useful life health estimation of identified valve regulated lead acid batteries.

Table 6 Analysis for Coup de Fouet Considering All Parameters

Residual Standard Error	0.645 on 186 deg. of freedom
Multiple R-Squared	0.465
Adjusted R - Squared	0.454
F-Statistics	40.5 on 4 and 186 DF
Significance Level	0.001
P - value	0.001

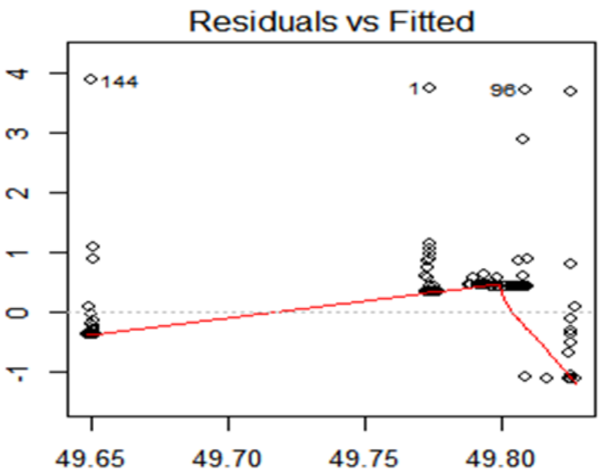

Figure 1 Residuals vs fitted

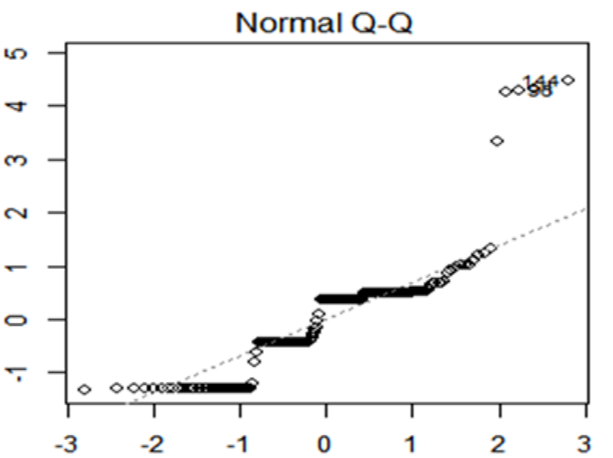

Figure 2 Normal Q-Q

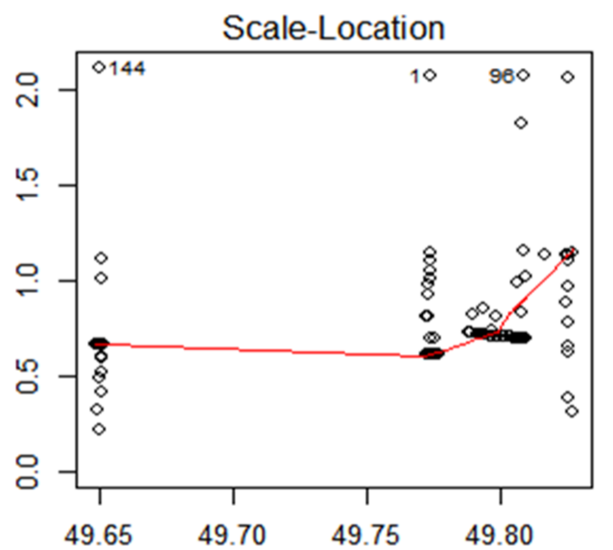

Figure 3 Scale Location

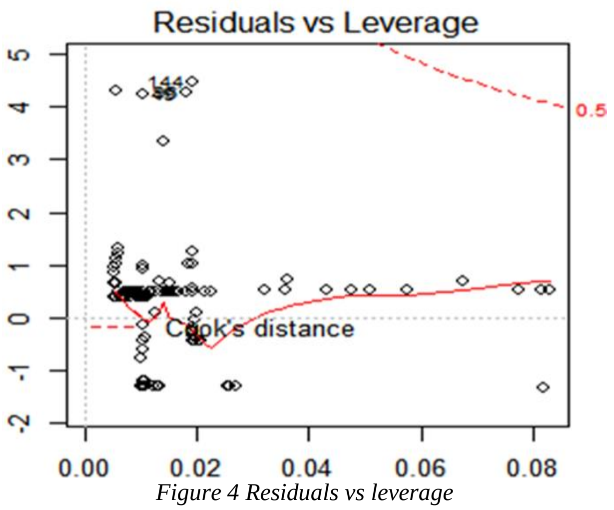

Figure 4 Residuals vs leverage

3. SUMMARY

Valve- regulated lead acid batteries (VRLA), a type of batteries frequently used in telecommunications industry. Valve - regulated lead acid batteries compare to other types and battery technologies has a unique characteristics which an indicator of battery state of health – the coup de fouet (a phenomenon which occurs at the beginning of the discharge of battery, it corresponds to an abrupt voltage drop lasting few minutes then, the voltage recovers to reach the plateau value) which is the modelling techniques used in this study to predict the useful life health estimation of identified valve - regulated lead acid batteries as bases to build an battery automated system.. Identified battery parameters gathered from a maintenance record manually recorded through identified routine maintenance as dataset of this study. Finally, the result of the study will be used as an important contribution to automate battery monitoring system as a tool to predict potential failures and basically eliminate or reduced outages related to battery failures. Realizing this project would increase revenue through maximizing battery assets and improved services.

4. CONCLUSION AND RECOMENDATIONS

Based on the findings and conclusion made, it was highly recommended that:

1. Revisit battery rooms and installed aircons based on the battery manufacturers recommended ambient temperature and ensure to set correct float voltage during commissioning.
2. Monitor load threshold and do not exceed same with the per cell battery resistance through battery tester.
3. To prevent battery sulfation, it is highly recommended to conduct CCDT or constant current discharge test periodically.
4. Consider all of this information as input data to battery automated system.

Future research should look into whether this technique can be used to measure capacity decline due to ageing and other deterioration causes, such as taking into account characteristics like exposure to low temperatures and low atmospheric pressure (build in high altitude sites or during transport). Regardless of the investigation's effectiveness, this technique will serve as a guide for stakeholders to have a fundamental understanding of VRLA technology.

REFERENCES

[1] Delaille, M. Perrin, F. Huet & L. Hermout; Study of the Coup de Fouet of Lead –Acid Cells as a Function of Their State of Charge and State of Health, 2006

[2] Mariani, K. Thanapalan, P. Stevenson, & J. Williams; Techniques of Estimating the VRLA Batteries Ageing, Degradation & Failure Modes, 2013

[3] Mariani, K. Thanapalan, P. Stevenson, & J. Williams; Investigation of the Influence of Active Material Structure on High-Rate Discharge Performance of VRLA Batteries, 2015

[4] Binder, T. Cronin, P. Lugsager, J. Maxwell, U. Abdulwahid & I. Baring-Gould; Lifetime Modelling of Lead Acid Batteries, 2005

[5] Ramadan, B. Pranama, S. Widayat, L. Amifia, A. Cahyadi & O. Wahyungoro; Comparative Study Between Internal Ohmic Resistance and Capacity for Battery State of Health Estimation, 2015

[6] Tran, A. Khan & W. Choi; State of Charge and State of Health Esti-mation of AGM VRLA Batteries by Employing a Dual Extended Kalman Filter and an ARX for Online Parameter Estimation, 2017

[7] He, Y. Zha, Q. Sun, Z. Pan, T. Lin; Capacity Fast Prediction and Re-sidual Useful Life Estimation of Valve Regulated Lead Acid Batteries, 2017

[8] Beaird, Battery State of Health Estimation Through Coup de Fouet: Field Experience, 2003

[9] Wong, L. Chang, R. Rajkumar & W. Leng, A New State of Charge Estimation Method for valve Regulated Lead Acid Batteries, 2017

[10] P. E. Pascoe; Study of VRLA Battery Behavioural Prediction, 2002