International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Experimental Research on Improvement of Battery Reliability

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***Abstract*: *The heat control and maintenance of batteries is essential for effective operation of UPS in harsh environmental condition since battery working reliability ,performance, durability and its economy is directly related to the environmental temperature and air flow around batteries .Therefore, ideally, batteries should be use within its comfortable temperature range to get its optimum performance. Compact design of Batteries in enclosed environments necessitates thermal management of the battery system for optimum life and performance. This invention proposes an efficient vapour compression refrigeration system to effectively cool the batteries and maintain optimum battery surface temperature of 25 °C for better performance and extended battery life at 40°C external ambient temperature. Moreover Silica gel based Solid desiccant wheel is used to absorb moisture from air so that condensation in the battery cabinet can be minimized .Computational fluid dynamics and heat transfer simulation was performed to devise a initial concept. Experimental validation of the prototype was made to verify simulation results and actual temperature distribution*.**

Index Terms*: : *UPS, Battery, Vapour Compression Refrigeration, RBC (Replicable Battery Cartridge).

I. INTRODUCTION

Competitive environment necessitates modular design for power circuit and battery. This provides a greater flexibility for user to upgrade the UPS system during its life time. Depending on the user requirement several battery modules are assembled within the metallic enclosure. This results in modules operating at different temperatures during charging/Discharging cycles. The change in Temperature from one module to other in a battery pack causes to changes in charge or discharge behaviour in respective module and which in turn to electric unbalancement of modules or packs , finally decreases the pack performance. The object of temperature management in the battery cabinet is to ensure a battery pack maintained at optimum average temperature (25°C) provided uniform temperature distribution. This helps increasing battery life and reliability of the charging and discharging operations. To evaluate the battery pack design heat transfer, fluid flow is used. The simulated CFD analysis results are validated through real time testing.

Revised Manuscript Received on 30 July 2019.
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Originally there was an assumption that the UPS is being operated in controlled environment. In developing economy, the situation is totally different.UPS is being operated in harsh environment and this resulted in more failures. Also within warranty, the batteries were getting replaced multiple times. This had incurred huge cost impact and predicted failure rate is currently greater than 100%.
Ben Ye ,Md Rashedul H R et.al are investigated the temperature control and optimization of cooling plates for battery module for electrically operated vehicles [1]. The performance analyses of Li-Ion batteries are investigated under various thermal loads [2-4]. The situ method has used in order to analyze the performance characteristics batteries [5]. The latest progress and accurate state of charge conditions of Li –Ion batteries [6-7] are really helped to improve the reliability of battery in the present work. The technique of halogen conversion- interaction chemistry in graphite, Scalable Synthesis of Dual-Carbon and experimental examination of large capacity gives the good idea in order to improve the reliability of batteries [8-12].

1.1 Conceptual design

To evaluate the battery pack design and provide solution for battery thermal issues for harsh working environment, we have used heat transfer, fluid flow principles, CFD analysis and experimental thermal validation. Fig-1 shows integration of a Battery cabinet with cooler.

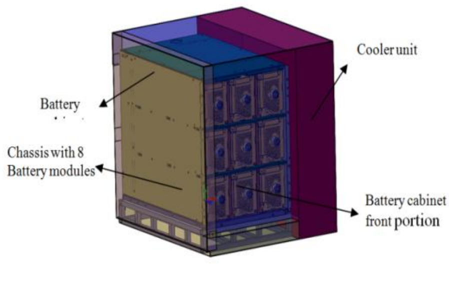


Fig -1: Integration of cooler with battery cabinet

1.2 Cooling Architecture

Vapour compression refrigeration system is attached to the side of the battery cabinet along with the desiccant dehumidification as shown in the Fig-2.

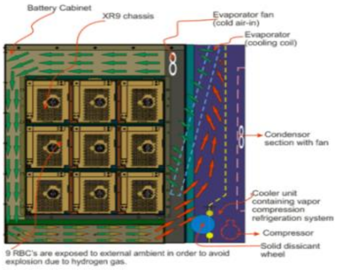


Fig -2: Battery cooler architecture concept

Cold air enters from top of the Battery cabinet and hot air exits at the bottom of the cabinet .This path covers most of the surface area of the battery enclosure to achieve uniform airflow and isothermal battery temperatures. To achieve effective cooling in the Battery module, cold air enters from evaporator coils into battery cabinet with the help of two 120 mm axial fans. Heat extraction from the batteries will be rejected by condenser to the external ambient with the help of forced convection .If the air temperature inside the battery cabinet reaches below 25°C , controller is set to switch off the compressor. This helps avoiding condensation and overcooling of the batteries. Moreover solid desiccant wheel is installed in the battery cabinet to take care of high humidity air and moisture accumulation above 25°C .The solid wheel is regenerated with the exposed hot air in the condenser side duct .Hydrogen gas that batteries produce during charging and discharging is very explosive .To prevent battery explosion issues, front portion of the Battery cabinet is exposed to the outside ambient to vent out hydrogen gases.

II. NUMERICAL CONCEPT OF THE CONCEPTUAL DESIGN.

Flotherm CFD simulation is performed to capture fluid flow and heat transfer in and around the battery cabinet and Vapour compression module was built using CRAC option and input cooling load and cooling coil temperature.

The boundary conditions considered for the thermal design are given below.

- Ambient temperature is 40°C.
- Batteries are modeled with orthotropic material with (In plane of 9 W/m-k and through plane of 5 W/m-K thermal conductivity) property. The properties were measured experimentally.
- Considered interface Impedance of $0.5^{0}C/in^{2}$-W between batteries.
- Heat loss of each 2 W is considered for 9 Ah batteries. Each RBC has 10 of 9 Ah batteries and accounting 20 W of heat loss. Hence total power dissipation of the system is around 120 W heat load
- Enclosure material is GI sheet with thermal conductivity of 60 W/m-k.
- Radiation is enabled to capture radiation heat transfer.
- CRAC option with 400W of cooling load is considered.

Replaceable battery pack module details are shown in the Fig-3.

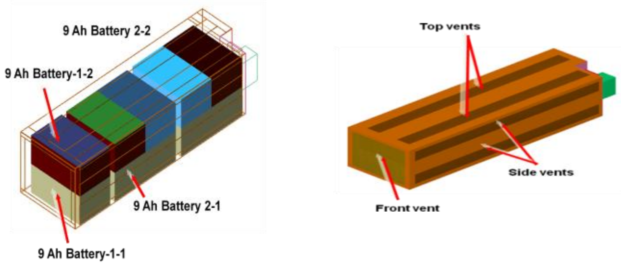


Fig -3: Battery Internal structure

2.1 Temperature contours

System was analyzed as a conjugate heat transfer model when it is surrounded by ambient air in computational domain and mixed convection inside the battery cabinet. The computational domain is extended in all three directions around the unit to capture natural convection and radiation phenomenon

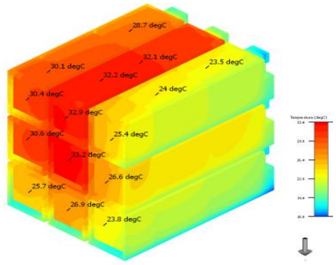
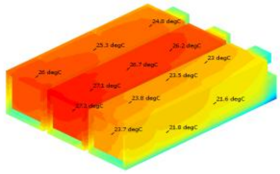
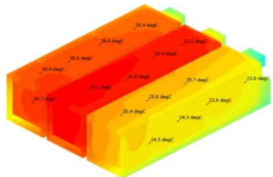


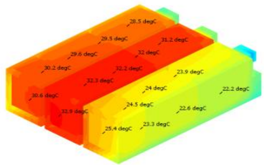
Fig -4: Surface temperature of the batteries



a) Bottom battery module



b) Middle battery module



c) Top battery module

Fig -5: Surface temperature of the battery module

Fig-4 shows the RBCs temperature distribution for the whole cabinet and battery subsystem surface contours are shown in the Fig-5 for each layer for bottom, middle and top portion. The middle battery layer shows highest temperature of $27^{0}C$ to 30 °C due to constrained location.

III. EXPERIMENTAL VALIDATION OF THE PROTOTYPE

Thermal test was carried out on a working prototype at 40 C thermal chamber and monitored battery surface temperature and air temperature inside the system. Thermal test setup is shown in the Fig-6 and experimental comparison results are shown in the Chart-1.There is good agreement between simulation and experimental results. The reliability of the battery is guaranteed due to isothermal battery cell temperature.

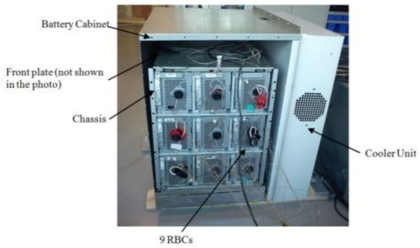


Fig -6: Thermal validation of prototype

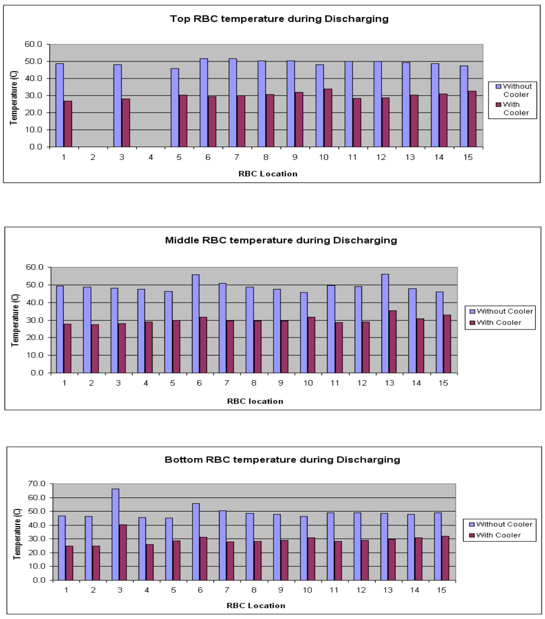


Chart -1: Experimental results

IV. CONCLUSIONS.

Cooling architecture proposed for the battery compartment has primary Heat and fluid transfer path which runs between refrigeration unit and Battery cabinet is a closed loop system to increase the cooling efficiency .The concept has secondary heat transfer open loop path between refrigeration unit and external ambient. In this approach cold air impingement occurs at the top and hot air suction at the bottom of the battery cabinet for the better isothermal temperature. Battery structural design will help enhancing heat transfer from the batteries as the metal structure exposed to the cold air will improve heat transfer and isothermal condition. There is greater improvement of battery temperature reduction with cooler. The proposed concept is able to cool uniformly across all modules in the Battery cabinet and therefore improves reliability of charging and discharging cycles. Flotherm simulation environment is able to capture fluid and heat transfer mechanism and results were showed in good agreement with experimental values with +/-5% error band. The reliable and rugged battery design is obtained for the environmental conditions

Controller is designed to switch off the compressor below 25°C to avoid over cooling and condensation inside the battery compartment. Moreover the solid Desiccant material is used at the bottom side along with the Vapour compression method to avoid moisture accumulation inside the battery cabinet. For regenerating the solid desiccant, 25% of the wheel surface is exposed to the compressor/Condenser side as hot ambient will refresh the material.

REFFERENCES.

1. Ben Ye, Md Rashedul Haque Rubel and Hongjun Li, “Design and Optimization of Cooling Plate for Battery Module of an Electric Vehicle”. Journal of applied sciences.2019,9(754);1-20.
2. K.Chattergy,P.Majundar,David.S,S.Rao.K, “Performance analysis of Li-Ion Battery under various thermal and load conditions”. Journal of electrochemical energy conversion and storage 2018, 16(2); 1-7.
3. Miwa.U,So.Y, Fumicak.T, “ Suspension synthesis of solid electrolytes”.Journal of power sources,2019,428;131-135.
4. T.De Avila.F,Z.Wuillemin,A.G.Marchetti, “Real –time optimization of experimental solid-oxide fuel-cell system”. Journal of power sources, 2019, 429; 168-179.
5. Dean J.Miller, Aurnaud.D, Liften Wang,“Exploring Lithium –Ion Battery performance through in situ characterization”.Microscopy socity of America,2015,21(S3);1541-1542.
6. Xin Zang,Xin-Gaj Wang,Z.Xie, Zhen.Z, “Recent Progress in rechargeable alkali metal-air batteries”. Journal of Green Energy & environment, 2016, 1(1); 4-17.
7. Qamar Naveed, Ahammad Hassan,”Accurate and Precise Grey Box Model of a Low-Power Lithium-Ion Battery and Capacitor/Super capacitor for Accurate Estimation of State-of-Charge”. MDPI Journals-Batteries,2019,5(3);50-57.
8. C.Yang,Ji Chen,Xiao Ji,”Aqueous Lithium-Ion Battery enabled by halogen conversion- interaction chemistry in graphite”. International Journal of science (Natures), 2019, 569; 245-250.
9. X. Feng,H.Cui,Z.Li,R.Miao,” Scalable Synthesis of Dual-Carbon Enhanced silicon-suboxide/silicon composite as anode for Lithium ion batteries”. Nano- , 2017,12(7);
10. Linda Gaines, “The future of automotive lithium –ion battery recycling: Charting a sustainable course”. Sustainable Materials and Technologies,2014,1(2);2-7.
11. . Wei.Y, Yang. H, Dou. H.S, Lin. Z, Wang.Z, Qian,.Y,“A novel two-dimensional coupled lattice Boltzmannmodel for thermal incompressible flows”. Journal of Appl. Math. Computation. 2018, 339;556–567.
12. Wang,.C, Zhang. G, Li. X., Huang.J, Wang. Z,Lv. Y, Meng, Situ.W,Rao.M,“Experimental examination of large capacity li FePOnr, 4nr, battery pack at high temperature and rapid discharge using novel liquid cooling strategy”. Int. Journal of Energy Res. 2018, 42; 1172–1182.

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