Finite Element Analysis of an Active Air-Cooling System on a 30V LIFEPO4 Battery for a Home Power Generation System

by Lingga Vidya Mandala Putra Nasir

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13

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I. Abstract

By seeing public awareness of the importance of using renewable energy for the sustainability of their children and grandchildren in the future, it has increased public attraction to sustainable and reliable home power plants. However, there are constraints in the application of sustainable home power generation systems, the integration of lithium iron phosphate (LiFePO4) batteries has become famous for their high energy density and long service life. However, efficient thermal management is essential to maintain performance and extend the life of these batteries. The study focused on optimizing the cooling system layout for 30V LiFePO4 batteries used in home power generation systems. Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) software are used to design and evaluate cooling systems. The cooling system in power generation plays a crucial role in maintaining the efficiency and safe operation of power plants. Power generation processes, whether they involve fossil fuels, nuclear energy, or renewable sources, typically generate a significant amount of heat that needs to be managed effectively

Keywords: cooling system

II. Introduction

Integrating solar photovoltaic (PV) technology with efficient energy storage systems has significantly advanced, supporting the global shift toward clean energy. Energy storage is crucial for managing excess PV power, ensuring power network stability, and mitigating demand peaks. Cooling systems play a vital role in maintaining optimal temperatures, extending the life of devices, and preventing overheating.

10

Lithium iron phosphate (LiFePO4) batteries, known for their high energy density and long lifespan, are integral to these systems. Effective thermal management is essential for maintaining battery performance. Advances in LiFePO4 battery technology since 1997 have improved their structure and electrochemical performance.This study aims to optimize battery life and capacity through innovative cooling system designs, ensuring safety and efficiency. A comprehensive review of literature and comparative data analysis informs the design process, emphasizing safety, materials, and performance.

In summary, advanced cooling and energy storage technologies are key to enhancing the performance and longevity of PV systems and batteries, supporting sustainable and reliable energy deployment.

Power plants are innovations in the world of renewable energy with systems that can be applied on a large or small scale, on a large scale that includes countries can use nuclear power plants, while for small-scale power plants can use solar cells, the biggest point that distinguishes between the two systems is the energy source utilized, for nuclear power plants the energy source comes from nuclear reactions in nuclear reactors as This nuclear reaction produces heat which is then used to produce steam and to drive turbines that produce electricity. While the way solar cells work uses solar energy as the main source to produce electricity. The cooling system in nuclear power plants is one of the most important and critical component systems, its main function is to keep the temperature of nuclear reactors and related equipment within safe limits during operation, the cooling system in nuclear power plants is very important because nuclear reactions produce very high heat, and if the temperature is not controlled properly it can cause risk problems, including nuclear accidents. The concept of nuclear system cooling will be applied in this analysis. This cooling system will work as a chiller that aims to cool the battery so that the battery can work optimally, and the battery life will be longer, not only that the benefit of the cooling system in power generation at home is the maximization of the volume of each battery so that the energy received is more than those who do not use the chiller.

III. Review Of Current Situation

Renewable energy is energy produced from energy resources that will naturally not be exhausted or quickly recovered and the process is sustainable if managed properly. Solar energy can also be converted into electrical energy, solar cells are a source of electrical energy that utilizes sunlight as an energy source. Solar panels or Photovoltaic (PV) is a technology that serves to convert or convert solar radiation into electrical energy directly. Such a large amount of energy produced from sunlight makes solar cells a very promising alternative source of future energy[9].Photovoltaics helps avoid some of the current engineering-related threats: electricity production. Photovoltaics can generate electricity for mankind for a variety of needs, scales, climates, and geographic locations[10]. Distributed renewable energy sources, like wind turbines and solar photovoltaic, are interesting ways to generate electricity. One of the severe problems with renewable sources is that they may not always work because of intermittent nature of renewable energy resources. However, this issue can be overcome by utilizing the suitable battery storage (BS). A large capacity of BS is require for a reliable power supply. In PV off-grid systems for rural electrification, batteries play a crucial role in storing solar energy. Batteries represent a substantial expenditure and should therefore be efficiently designed[11]. Solar cell systems can convert solar energy into electrical energy with the help of photovoltaic effect. Only 20% of the energy spectrum of sunlight is converted into electricity, but more than 50% is transferred to excess heat. An increase in the temperature of solar cells results in a decrease in power and efficiency. In addition, excess heat in solar cells can affect the silicon layer of solar cells and result in less-than-optimal performance. So, the temperature and uniformity of solar cells should be controlled with the use of appropriate cooling systems[12].

IV. Review of Related Literature

Over the past decade, global installed capacity of solar photovoltaic (PV) has dramatically increased as part of a shift from fossil fuels towards reliable, clean, efficient and sustainable fuels[1]. PV technology integrated with energy storage is necessary to store excess PV power generated for later use when required. Energy storage can help power networks withstand peaks in demand allowing transmission and distribution grids to operate efficiently. In terms of shorter periods of storage, it can be effective for smoothing out short peaks and distortions in voltage [13].

Battery storage is an effective means for reducing the intermittency of electricity generated by solar photovoltaic (PV) systems to improve the load factor, considering supply side management, and the offer of backup energy, for demand side management

V. Review of Related Products

a. Carbon

Carbon materials not only have the advantages of rich surface states, diverse structures, strong controllability and good chemical stability, but also show excellent electrical transport properties and highly active surface properties. Therefore, carbon materials have become ideal materials for various energy storage devices, which has aroused extensive research in the field of energy storage[14].

b. LIFEPO4

Owing to its excellent reversibility, good thermal and chemical stability, low cost, and environmentally friendliness, LiFePO4 is considered a relatively good cathode material for Li-ion batteries, and it was applied in energy storage facilities and electric vehicles[15], [16], [17].

VI. Research and Methodology

In this research using qualitative methods with sources of Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA). This research examines and will produce data in the form of journals of the results of this experiment. And, this research has a regular deadline structure as follows in **Figure 3.1**.

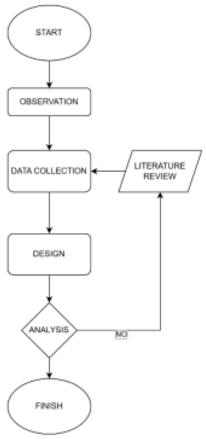

Figure 3.1 Flowchart of Project Activities

VII. Software

a. ANSYS

ANSYS is a general-purpose, finite-element modeling package for numerically solving a wide variety of mechanical problems. These problems include static/dynamic, structural analysis, heat transfer, and fluid problems, as well as acoustic and electromagnetic problems. There are two methods to use ANSYS[18].

b. SOLIDWORKS

The SOLIDWORKS CAD software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings. This document discusses concepts and terminology used throughout the SOLIDWORKS application. It familiarizes you with the commonly used functions of SOLIDWORKS[19].

VIII. Results

1. Project 1-4-5

Model (A4) > Steady-State Thermal (A5) > Solution (A6) > Results

Object Name	*Temperature*	*Total Heat Flux*	*Directional Heat Flux*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Body		
Definition			

Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Separate Data by Entity	No		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	25, °C	2,4031e-014 W/m²	-373,9 W/m²
Maximum	60,067 °C	647,19 W/m²	405, W/m²
Average	42,661 °C	148,54 W/m²	0,44581 W/m²
Minimum Occurs On	SYS\Cut-Extrude1		
Maximum Occurs On	SYS\Cut-Extrude1		
Minimum Value Over Time			
Minimum	25, °C	6,6576e-015 W/m²	-373,9 W/m²
Maximum	25, °C	2,4031e-014 W/m²	-53,414 W/m²
Maximum Value Over Time			
Minimum	30,01 °C	92,456 W/m²	57,857 W/m²
Maximum	60,067 °C	647,19 W/m²	405, W/m²
Information			
Time	6, s		
Load Step	6		
Substep	1		
Iteration Number	6		
Integration Point Results			

Display Option		Averaged

1.1 Project 3-4-3

Model (A4) > Steady-State Thermal (A5) > Solution (A6) > Results

Object Name	*Temperature*	*Total Heat Flux*	*Directional Heat Flux*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Body		
Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Separate Data by Entity	No		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	24,995 °C	5,4206e-014 W/m²	-378,96 W/m²
Maximum	61,215 °C	632,19 W/m²	390,59 W/m²
Average	45,281 °C	154,16 W/m²	0,79184 W/m²
Minimum Occurs On	SYS\Cut-Extrude1		
Maximum Occurs On	SYS\Cut-Extrude1		
Minimum Value Over Time			
Minimum	24,995 °C	5,4206e-014 W/m²	-378,96 W/m²

Maximum	24,999 °C	5,4206e-014 W/m²	-54,137 W/m²
Maximum Value Over Time			
Minimum	30,174 °C	90,313 W/m²	55,798 W/m²
Maximum	61,215 °C	632,19 W/m²	390,59 W/m²
Information			
Time	7, s		
Load Step	7		
Substep	1		
Iteration Number	7		
Integration Point Results			
Display Option		Averaged	
Average Across Bodies		No	

2. Project 5-2-3

Model (A4) > Steady-State Thermal (A5) > Solution (A6) > Results

Object Name	*Temperature*	*Total Heat Flux*	*Directional Heat Flux*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Body		
Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Separate Data by Entity	No		
Calculate Time History	Yes		

Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	24,554 °C	1,1581e-014 W/m²	-411,31 W/m²
Maximum	62,544 °C	798,32 W/m²	415, W/m²
Average	43,691 °C	165,69 W/m²	-0,3909 W/m²
Minimum Occurs On	SYS\Boss-Extrude2		
Maximum Occurs On	SYS\Boss-Extrude2		
Minimum Value Over Time			
Minimum	24,554 °C	5,7905e-015 W/m²	-411,31 W/m²
Maximum	24,936 °C	2,6751e-014 W/m²	-58,758 W/m²
Maximum Value Over Time			
Minimum	30,363 °C	114,05 W/m²	59,286 W/m²
Maximum	62,544 °C	798,32 W/m²	415, W/m²
Information			
Time	7, s		
Load Step	7		
Substep	1		
Iteration Number	7		
Integration Point Results			
Display Option		Averaged	

From these data it can be concluded from the design 1-4-5 has good heat transfer to reduce heat in the battery, for all batteries above using a series circuit, why design 1-4-5 can be given the best design label, because the design has an average temperature and heat flux results that are not too hot so that the battery life can be used long-term and continuous

IX. Conclusion

From the 3 data above, it can be concluded that the best design for solar cell batteries is the 1-4-5 design, this data is obtained from the table that was conducted in experiments using Ansys software and produced data in the form of heat flux, directional heat flux, and temperature tables that showed constant data.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9