RIYA Presentation on Problem Formulation (Summer 2022)

Understanding Thermal Design for EV Inverters With Advanced Switching Devices

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Mini project

Understanding Energy Storage and Power Generation Technique of Augwind Energy

Energy Storage Technology of Augwind Energy

- Suggested by a CEO of big company
- Augwind Energy employ Compressed-Air Energy Storage (CAES) method
- In CAES, air is compressed and stored. When needed, compressed air is heated and its exhaust is utilized to rotate turbine yielding electrical power
- Peculiarities of the technology – 1) Use of water piston for compression of air, 2) using mixture of air and water to rotate turbine blades [1]
- Lack of research questions restricted the topic to understanding only

Patented Technology of Augwind Energy

Fig. 1 Pipeline of CAES technology implemented at AUGWIND Energy

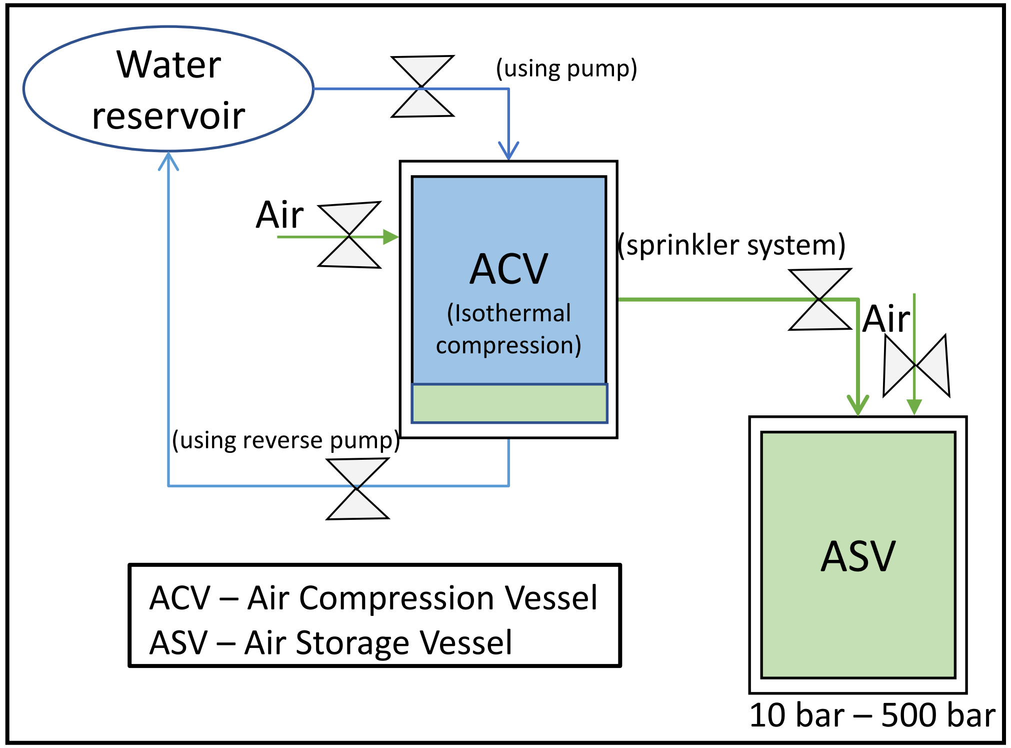


Fig. 2 Energy storage system

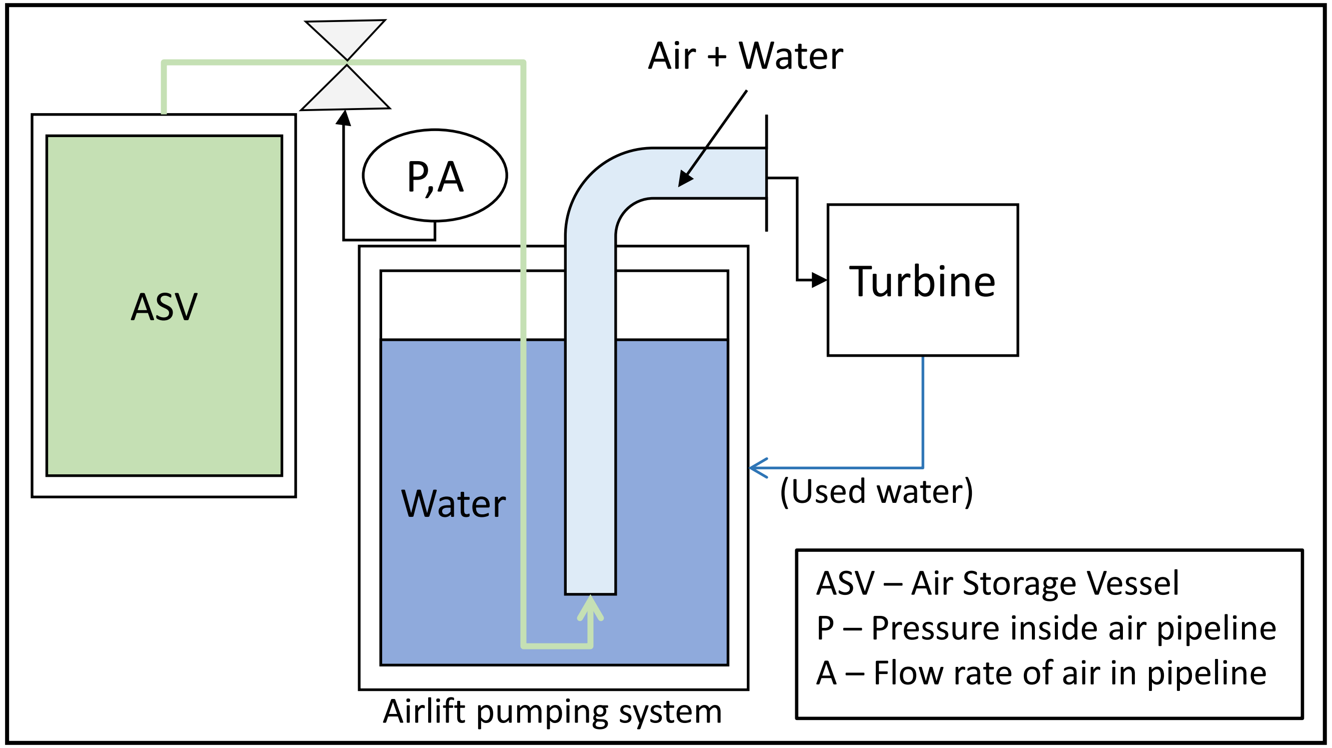


Fig. 3 Electrical power generation

Steps Involved in CAES

Energy Storage System

1. Water is stored in a reservoir
2. Stored water pumped into air compression vessel (ACV) (Use of sprinklers and control valves)
3. Air is pushed by water to air storage vessel (ASV)
4. ASV is filled with compressed air isothermally
5. ACV is emptied using reverse pump
6. Loop is continued to fill desired number of ASV

Electrical Power Generation System

1. Consists of air flow, pressure controller, airlift pumping system, Water Collecting Tank (WCT) and a turbine
2. Compressed air discharged into airlift pumping system
3. Air enters base of riser though openings provided (inlet holes are uniformly distributed over perimeter of riser)
4. Water in the riser mixes with air flow – *entrained flow*
5. Entrained flow pushed by water through riser
6. Outlet of riser leads to entry of turbine
7. Turbine rotation by entrained flow
8. Air in flow escapes through outlet on top
9. Water brought to WCT by returning tube

Major project

Understanding Thermal Design for EV Inverters With Advanced Switching Devices

Introduction

Motivation: Inverter is used in an electric vehicle to convert DC power stored in battery to 3-phase AC power required to drive a motor. Due to conduction and switching losses, conversion modules loose power in form of heat which can damage electronic circuit. Thus, study of thermal management system for an inverter is necessary [2].

Goal: Understanding thermal management aspects for evolving larger format EV and usage of newer switching technology using 2-D numerical simulation model.

- Currently working in parallel with two SVC members MES Inc. and Causis E-Mobility

Literature Review

Author (Journal/conference, year)	Topic	Learnings
Shaolin Yu et. al. (IEEE Access, 2021) [3]	The Potential Impact of Using Traction Inverters With SiC MOSFETs for Electric Buses	Requirements of PMSM drive for an electric bus
Martin Schulz (Conference: PCIM Asia 2016) [4]	Heavy Duty Applications - A Challenge for Power Semiconductor Devices	Specifications of an inverter used in an electric bus
Karimi et. al. (9th International Conference on Power and Energy Systems (ICPES), 2019) [5]	Thermal Concept Design of MOSFET Power Modules in Inverter Subsystems for Electric Vehicles	Thermal limits of inverter modules and numerical method for its analysis
Quian et. al. (IEEE Access, 2018)	Thermal Management on IGBT Power Electronic Devices and Modules	Inverter cooling techniques

EV power requirements

Heat generation and simulation

Problem Formulation

- Objective-1: Get inverter details from the associated company
- Objective-2: Modification in inverter geometry by removing unnecessary geometric specifications from thermal point of view. Ex. grooves, nuts and bolts, etc.
- Objective-3: Estimating heat generation from IGBT modules using existing methods
- Objective-4: Performing numerical simulation in ANSYS

Previously Performed Simulations at CLEAR - 1

- Hemanth Dontamsetty, RIYA Scholar 2021 performed thermal analysis for BYD tang inverter using simulations
- Simulations predicted maximum temperature of 49.3^{0}C inside inverter

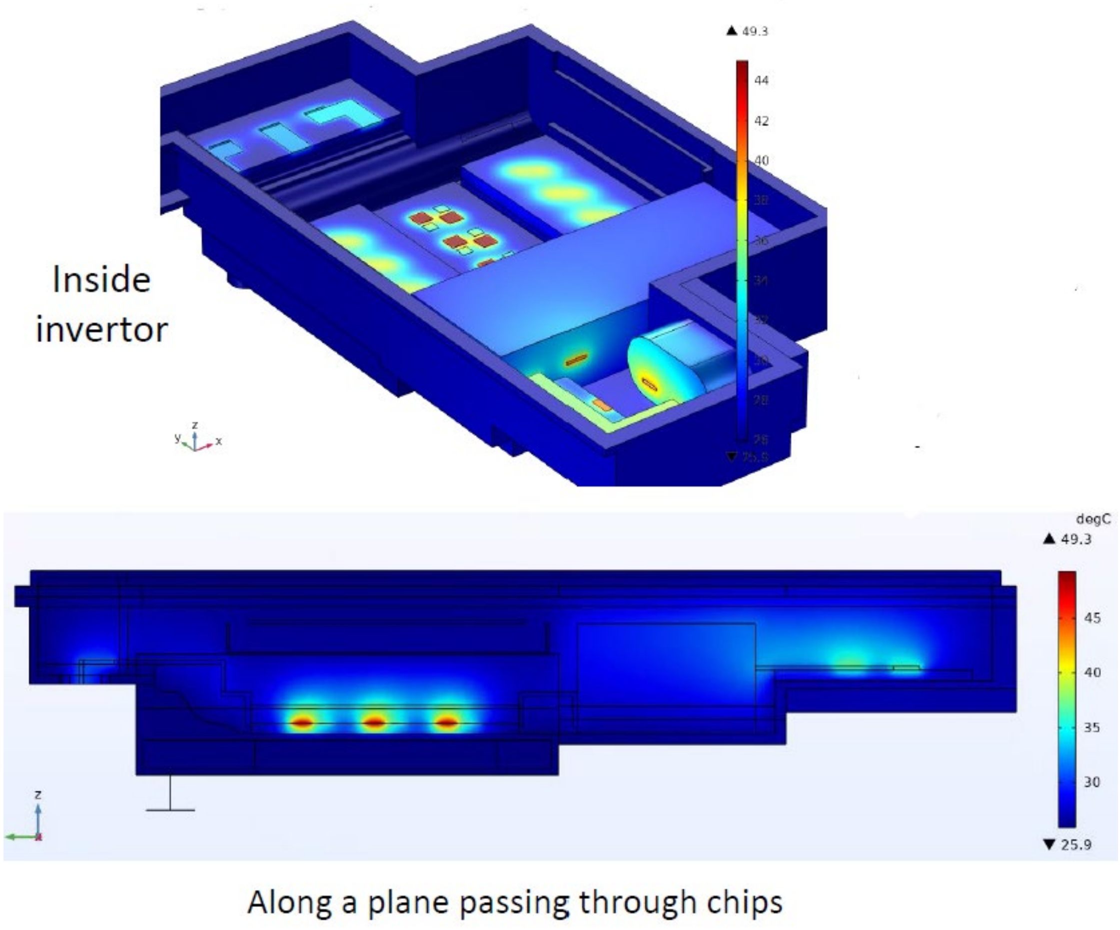
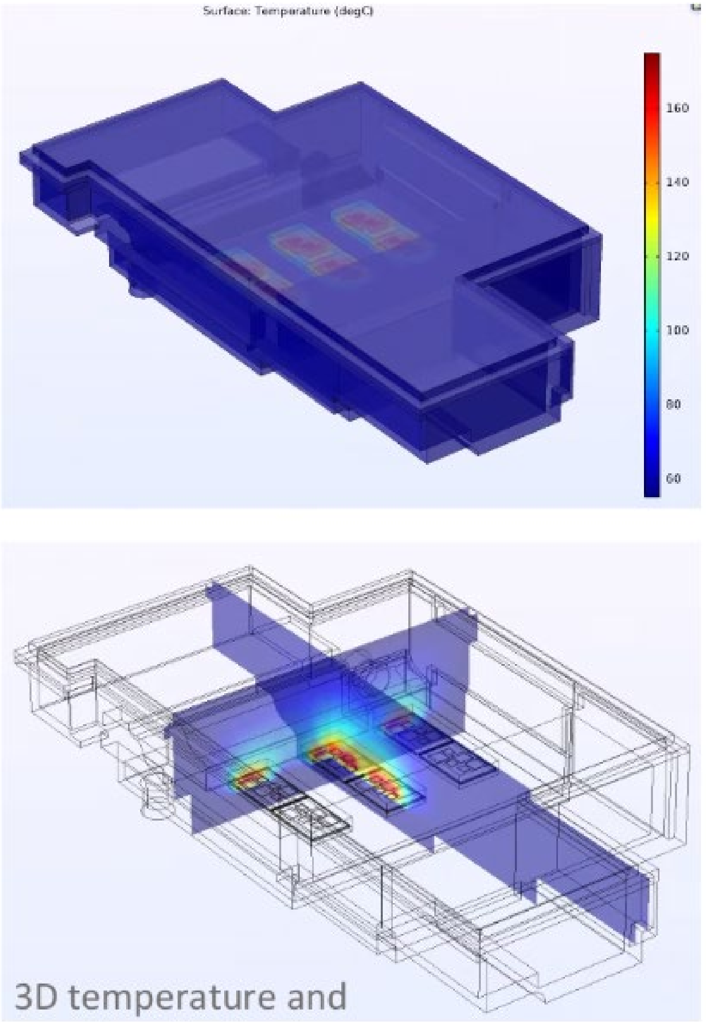


Fig. 4 Temperature distribution inside BYD tang inverter [6]

Previously Performed Simulations at CLEAR - 2

- Court Freund, undergraduate researcher analysed temperature distribution inside PM100 DX inverter if IGBT modules have highest permissible temperature (175^0C)



3D temperature and heat flux distributions

Fig. 5 Temperature distribution inside PM100 DX inverter [7]

The Ohio State University

Conclusions

- Understood energy storage and power generation system of Augwind Energy
- Learnt power requirements for an EV (cars, buses)
- Understood reasons for heat generation in an inverter and its effects

Progress made so far

- Performed literature review
- Learnt heat generation calculation for IGBT modules
- Understood simulation procedure

Next steps

- Calculating heat generation from IGBT modules after getting inverter details
- Implementing 2-D model for thermal analysis in ANSYS

Appendix I: Lessons Learnt

- Working of an electric vehicle
- Electrical circuit of an inverter
- Power and current rating of inverters used in electric cars and buses
- Heat generation in IGBT modules
- Various inverter cooling techniques

Appendix II: References

[1] https://uspto.report/patent/app/20210075297

[2] Karimi, D., Behi, H., Jaguemont, J., El Baghdadi, M., Van Mierlo, J., & Hegazy, O. (2019, December). Thermal concept design of MOSFET power modules in inverter subsystems for electric vehicles. In *2019 9th International Conference on Power and Energy Systems (ICPES)* (pp. 1-6). IEEE.

[3] Yu, S., Wang, J., Zhang, X., Liu, Y., Jiang, N., & Wang, W. (2021). The potential impact of using traction inverters with SiC MOSFETs for electric buses. *IEEE Access*, *9*, 51561-51572.

[4] Schulz, M. (2016, June). Heavy Duty Applications-A Challenge for Power Semiconductor Devices. In *PCIM Asia 2016; International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management* (pp. 1-5). VDE.

[5] D. Karimi, H. Behi, J. Jaguemont, M. El Baghdadi, J. Van Mierlo and O. Hegazy, "Thermal Concept Design of MOSFET Power Modules in Inverter Subsystems for Electric Vehicles," 2019 9th International Conference on Power and Energy Systems (ICPES), 2019, pp. 1-6, doi: 10.1109/ICPES47639.2019.9105437.

[6] Hemanth Dontamsetty, "EV Inverter Housing Thermal Analysis", CLEAR lab, The Ohio State University, 2021

[7] Court Freund, "Heat generation and heat dissipation analysis for EV inverters", CLEAR lab, The Ohio State University, 2021

[8] C. Qian et al., "Thermal Management on IGBT Power Electronic Devices and Modules," in IEEE Access, vol. 6, pp. 12868-12884, 2018, doi: 10.1109/ACCESS.2018.2793300.