Energy Systems Design:

Spiral Development Procedure

https://www.broccolibus.com/index.php/2020/01/26/skooliepalooza-2020-solar-discussion/

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Overview

Energy systems design for (mostly) off-grid vehicles.

A method for selecting from too many choices, options, and opinions.

Today's Topics

1. Spiral Design primer.
2. Requirements Activity!
3. How to talk about power.

Spiral Design Primer

The Design Spiral

- Learned informally the concept of "design spiral" process mostly during design and implementation of complex IT systems
- https://en.wikipedia.org/wiki/Spiral_model
- https://resources.sei.cmu.edu/asset_files/SpecialReport/2000_003_001_13655.pdf

Design Spiral Is A Tool

- Use it the same as a Welder, a computer, a saw.
- It is a mental tool for thinking through and understanding a large, complex project.

Is this about design spiral?

- We are not here to talk exclusively about Design Spiral - but the approach is core to this talk, if that makes sense.
- Just a brief discussion of design spiral as related to designing systems to facilitate partial to full time living in van and bus shaped over-the-road vehicles.

Energy Systems Definition

Q: What is our definition of an “Energy System”

A: An engineered system to support your objectives and requirements related to tools that "take energy to operate"

What do you use energy for?

- Driving
- Lighting
- Heating
- Cooling
- Cooking
- Bathing
- Youtube
- ...Many other things

Generally, anything that requires fuel or electricity to function.

How does a "design spiral" apply?

- Requirements
- Risks
- Expectations
- Time-to-build

There is no test to these slides, I promise. :)

0. Before we start.

- Artifacts are defined concurrently, not sequentially.
  - There are enough different variables each time this is done - you are building a prototype.
  - Highly likely nobody has ever done this exact combination before, even if you read about it on the internet

6 Design spiral invariant characteristics.

Invariant = "Never Changing"

1. The requirements are known in advance of implementation
2. The requirements have no unsolved, high risk implications.
3. The nature of the requirements will not change very much during development or evolution.
4. The requirements are compatible with stakeholder expectations.
5. The right architecture for implementing the requirements is well understood.
6. There is enough time to proceed sequentially during implementation.

Design Spiral Activities

Stakeholders = probably you or your spouse :)

In each cycle of the design spiral, the following activities occur:

1. Consider the winning conditions for all stakeholders.
2. Identify and evaluate alternative approaches to satisfy win conditions.
3. Identify and resolve risks that stem from selected approaches
4. Obtain approval from all stakeholders and commitment to refine.

Write It Down!

- This process works if you write things down in a planning notebook of some kind (electronic or otherwise)
- And can then turn the planning notebook into a prioritized list of to-do items. You can then tackle the list in any "project managey" sort of way - agile, waterfall, etc.

Example System Requirements?

- Comfortable interior climate as often as possible
- Food is always safe and refrigerated
- "zero worry" approach for family members
- long lasting
- low maintenance
- good status reporting (so I'm not paranoid of what is happening)
- take up least space possible (because of limited room)
- as light as possible (because in a vehicle, lighter is better)

Common Theme of Requirements

Q: What common feature is across all the requirements I listed?

A: No implementation of technology or tools are mentioned.

- When you get free stuff, it often gets high priority.
- "Free stuff" = "choices made for you" and reduces flexibility of your design spiral.

Example Requirements Walkthrough

- Work from requirements to reality. This will be your first trip around the spiral.
- Remember to stay "concurrent", which means consider all requirements holistically.

Example: Comfortable interior climate

Identify physical things that affect comfort:

- Insulation
- Windows
- Doors
- Airflow
- Humidity
- Temperature
- The Weather
- Probably lots of other stuff

Example: Comfortable interior climate

Identify specific technology that affects physical comfort:

- Identify specific technology that affects physical comfort:
- Roof vent fan, box fan, hand fans
- Window mount air conditioner, mini split, engine driven, bucket of ice
- Mr. Buddy, Woodstove, Diesel furnace, hydronic, propane furnace, more jackets
- Umbrellas, reflective paint, parking under trees, sun shades, reflectix
- How far can you drive?

Apply the Spiral Analysis

- Each technology you've identified, you must cross against each of your requirements.
- Sometimes it's kind of like doing your taxes. (you do that, right?)
- Cross reference all the boxes and apply the criteria you yourself defined.
- This is a PROCEDURAL effort, not best guess effort.

Spiral Cycle Activities

Ask the following questions for each technology:

- Consider the winning conditions for all stakeholders.
- Identify and evaluate alternative approaches to satisfy win conditions.
- Identify and resolve risks that stem from selected approaches
- Obtain approval from all stakeholders and commitment to refine.

Risk Management

- Each of the four cycle activities for each technology should have one or more risks attached after analysis.
- Common risks you will see over and over again.
    - Cost of implementation
    - Difficulty of implementation
    - Skillset to implement

Document the Risks

- Recording your risks for each of your planned technology solutions will begin to form a map.
- Common risk themes will help you, with actual data, identify the areas of domain you need to either mitigate, improve, or revise your requirements.

Congratulations!

- You have now taken one trip around the design spiral, for a single requirement!
- It's not an exercise you complete in one day or an hour.
- It takes a long time to consider and cross reference the requirements and proposed solutions.
- It is potentially exhausting.
- There are many factors that affect it, and the more requirements you can call out, the more accurate picture you paint for your plan and design.

This Is Not Trivial

- A design spiral approach is not something to take lightly - it takes significant effort to work through the thought processes that drive it.
- The thoroughness of this approach ensures minimal surprises.
- This process can be revisited whenever you feel there is a change in requirements.
    - But remember design spiral depends on requirements that stay relatively static.

As you can see, Energy Systems Design is affected from every aspect, and every choice you make.

This is the song that never ends!

- For example, the color of exterior paint and number of windows affects the thermal regulation
    - which affects the size of the air conditioning or heating
        - which affects the power collection requirements
            - which affects the power storage requirements
                - which affects the system efficiency
                    - which affects your comfort level
                        - which affects your choices of travel time and place
                            - ...and so on

Each affect is incremental and cumulative. No one choice greatly affects the outcome. But by sticking to the spiral iterative design, you can have far more control managing the individual aspects of the whole design process.

Requirements Activity!

What are your requirements?

- Think about your requirements and write some down.
- Requirements do not have specific technical answers or approaches.

Bad and Good Examples

Bad

Must have high quality components like Victron

Good

Must have well documented components with a reputation of low failure rates

Bad and Good Requirements

Good requirement statements are agnostic to tools or technology, and have specific statements that can be backed with another general statement.

- "well documented components" -> able to understand -> non-ambiguous installation
- "low failure rate" -> high reliability -> less worry -> long term less expensive -> less disruption to finance and activities

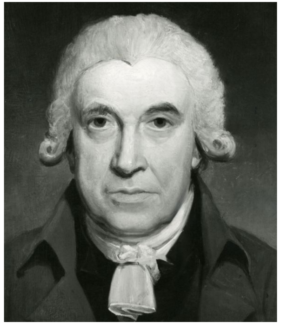
Discuss a Requirement

- Talk to your neighbor as if they are a "stakeholder" about one of your requirements. Your neighbor (stakeholder) can exercise various risk concerns such as cost, skills, and time to implement.
- Then, consider the resulting compromise and decide how this affects the remaining requirements.
- This repeated negotiation and analysis corresponds do the resulting plan that can be followed to build your system.

Talking About Power

Use the term Watts

The **watt** (symbol: **W**) is a unit of power. In the International System of Units (SI) it is defined as a derived unit of 1 joule per second,[1] and is used to quantify the rate of energy transfer. In SI base units, the watt is described a $kg\,m^2\,s^{-3}$, which can be demonstrated to coherent by dimensional analysis.



(James) Watt's Law

100 Amp Hour (12 volt battery?) = 1200 Watt Hours

120 volt appliance @ 10 amps = 1200 Watts

Watts = Volts x Amps

Amps = Watts / Volts

Volts = Watts / Amps

Watts over an hour = Watt Hours

Amps over an hour = Amp Hours

1000 Watts = 1 Kilowatt

10,000 Watts = 10 Kilowatts

Simplified Storage in Watts

- Example battery is rated at 100 Amp Hours and is 12 volts.
- Battery is actually about 13.5 volts
- Battery is 1.35 Kilowatt Hours rating.

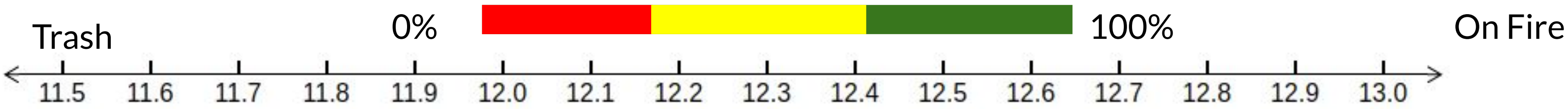
- This rating is not the full story.
- Chemistry plays a large part in true capacity.
- Lead acid can only discharge to “50 percent”
- Lithium batteries can discharge more, like “80 percent”

What does the percentage mean?

Lead Acid storage "percentage"

The chemistry dictates empty and full.

For example, this lead acid is completely discharged at 11.9, and full at 12.7

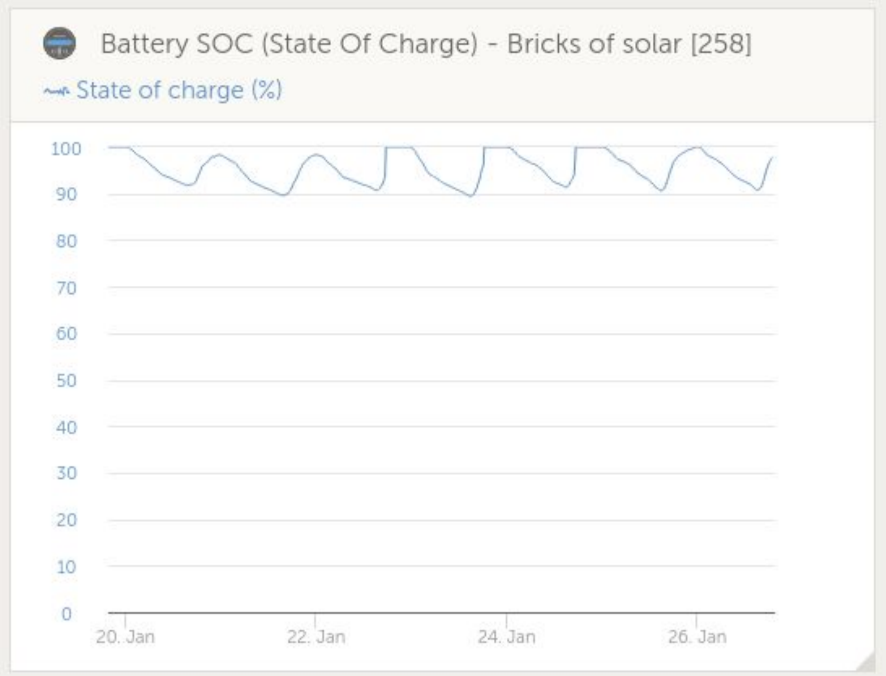


SOC Table for Lead Acid

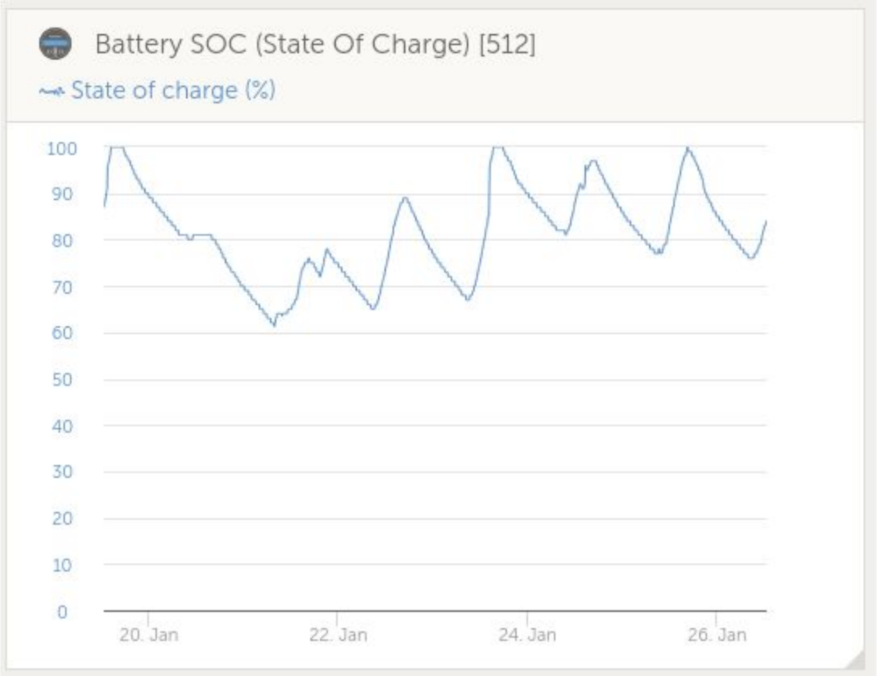
Approximate state-of-charge	Average specific gravity	Open circuit voltage			
		2V	6V	8V	12V
100%	1.265	2.10	6.32	8.43	12.65
75%	1.225	2.08	6.22	8.30	12.45
50%	1.190	2.04	6.12	8.16	12.24
25%	1.155	2.01	6.03	8.04	12.06
0%	1.120	1.98	5.95	7.72	11.89

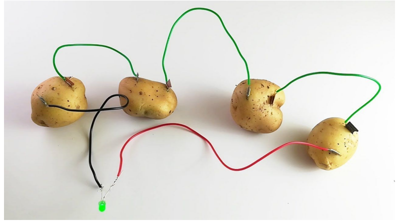
https://batteryuniversity.com/learn/article/how_to_measure_state_of_charge

Battery SOC: Lead Acid



Battery SOC: Lithium





You decide state of charge.

Doesn't matter if it's:

- Lead Acid
- Lithium
- Potatos with Nails

- Each chemistry is different
- Exceeding chemistry elasticity damages the battery
- Think of a battery bending like a paperclip. Bend too far/too many times and it breaks.

Chase down and remove inefficiencies

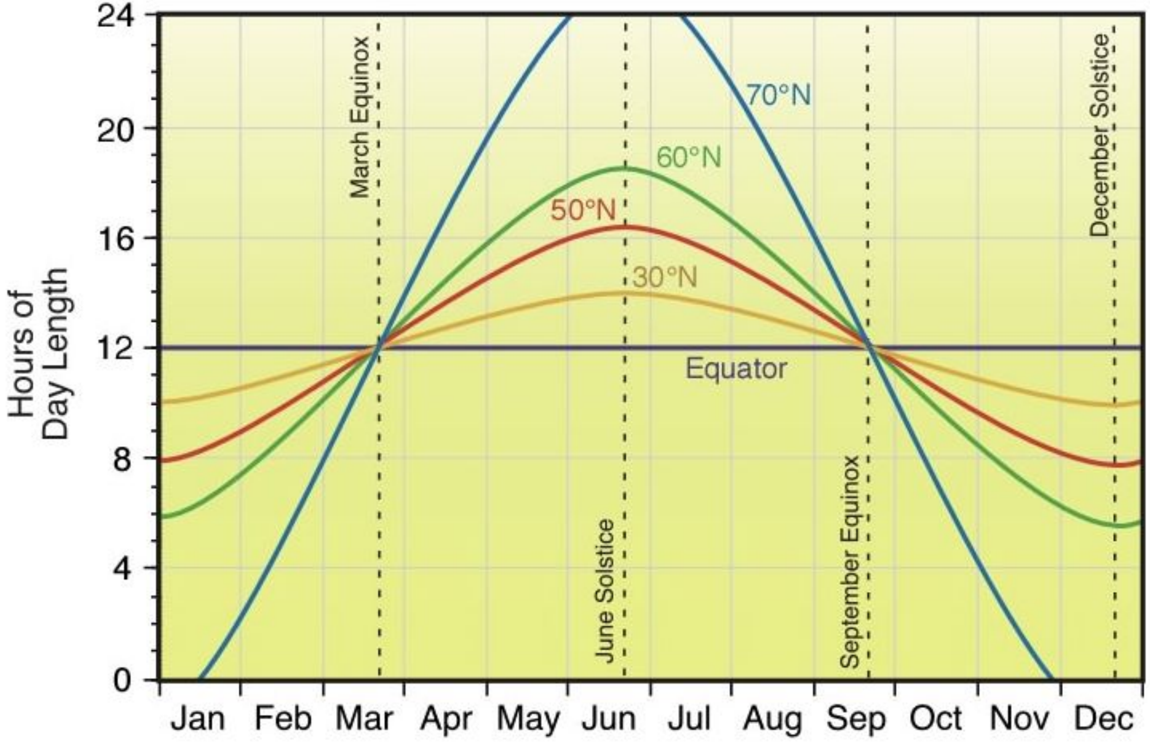
A cheap appliance that is inefficient is a compounding expense.

Every other component in your system has to support it. High demand devices become a cost multiplier.

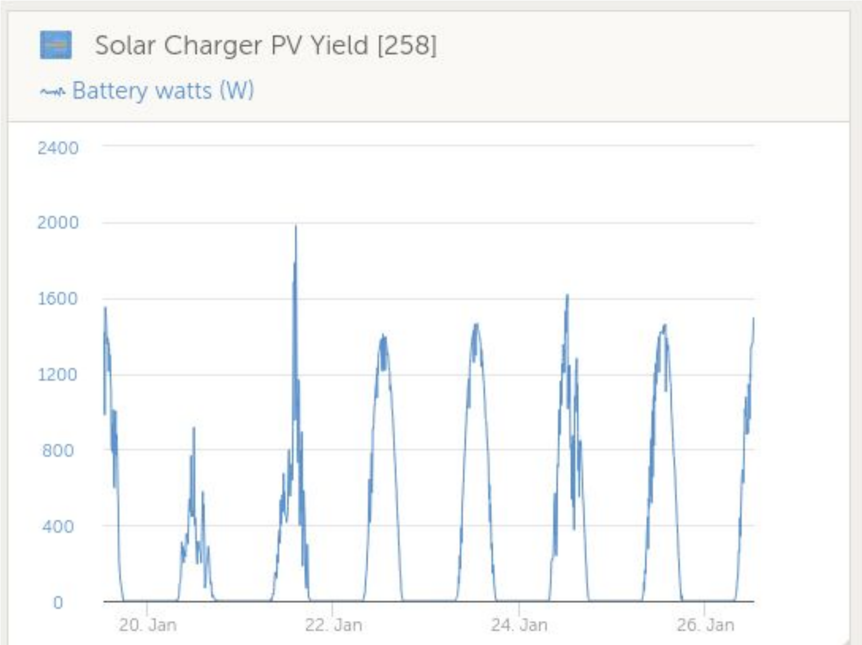
Usually just one inefficient device isn't enough to cause "tip over" to a next level of expenditure.

Use spiral design analysis to improve efficiency.

Yearly Expected Solar Yield



Daily solar yield example



The Power System as Bank Account

- Your battery is the savings account
- Power consumers are expenditures
- Power producers are income
- System efficiency (or inefficiency) is purchasing with a coupons or discounts, or paying a premium.
- Just balance the account each solar day.
- Use Watt Hours to model.
- Use spiral design to refine your system.

Thank you!
The End

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