I2.03 Net-Zero Charging Infrastructure Planning for Electric Aircraft

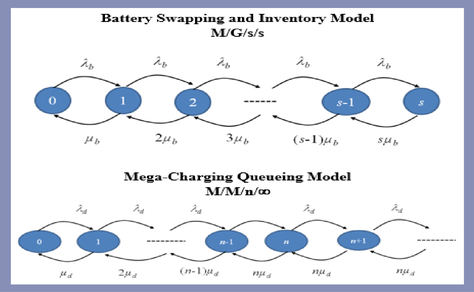
Javier Guerrero, Lauren Cravy, Alejandra Guardiola

Sponsor: Dr. Tongdan Jin, Faculty Advisor: Dr. Gerardo Trevino

TEXAS STATE
INGRAM SCHOOL OF ENGINEERING

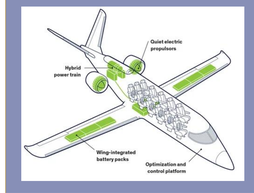
Problem Ideology

- Propose a design solution for the establishment of a Net-Zero Charging Infrastructure for airports of a comparable size to Austin-Bergstrom International Airport (ABIA).
- Explore battery swapping and mega-charging solutions for promoting sustainable air travel using priority queueing network model.



Project Motivation

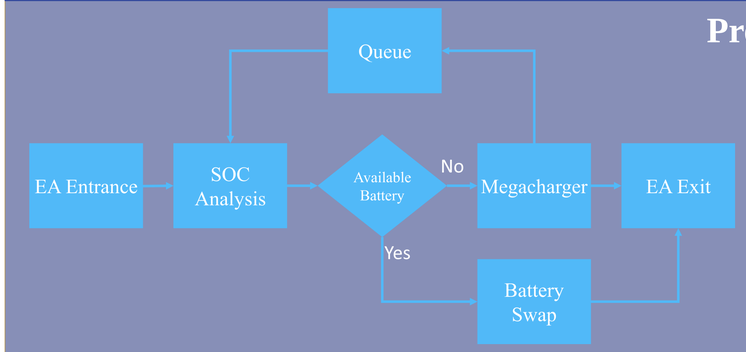
- To lessen the carbon emissions of airplanes that run on fossil fuels as aviation accounts for 30% of global transportation carbon footprint.
- The team will study and simulate the appropriate battery swapping, mega-charging, weather condition, power generation, and cost optimization needs for a commercial airport.



Project Constraints

- Southwest Airline Flight Information (7-Day Period/Flight Demand)
- Layover Time Between Flights is less than one hour (Current System Parameters)
- Cost Component of Net-Zero Infrastructure (Installation, Maintenance, Tax Credit)
- On-Shore vs. Off-Shore wind generation

Phase I: Queuing Network for Battery Services



Scenario	S (battery)	N (charger)	B(s)	E[b]]	E[s.b.a]	C(n, Φ)
1	6	2	0.29	5	1.49	0.3439
2	5	2	0.38	4	1.09	0.3300
3	4	2	0.49	3	0.77	0.2780
4	3	2	0.61	2	0.51	0.1993
5	2	3	0.73	2	0.30	0.0176
6	2	4	0.73	2	0.30	0.0022
7	2	5	0.73	2	0.30	0.0002

Probability of Mega-Charging Waiting

$$C(n,s)=\frac{\frac{(B(s)\lambda_b/\mu_d)^n}{n!(1-B(s)\lambda_b/(n\mu_d))}}{\sum_{k=0}^{n-1}\frac{(B(s)\lambda_b/\mu_d)^k}{k!}+\frac{(B(s)\lambda_b/\mu_d)^n}{n!(1-B(s)\lambda_b/(n\mu_d))}}$$

Total Mega-Charging Service Time

$$t_{schg}=t_q+t_c=\frac{C(n,s)}{n\mu_d-\lambda_d}+\frac{1}{\mu_d}$$

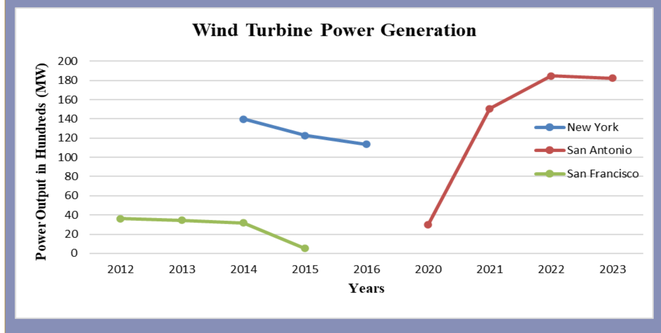
Probability of Blocked Swap

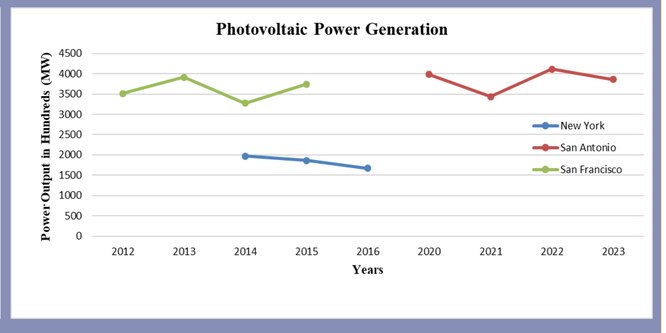
$$B(s)=\Pr\{X=s\}=\frac{\frac{(\lambda_b/\mu_b)^s}{s!}}{\sum_{k=0}^{s}\frac{(\lambda_b/\mu_b)^k}{k!}}=\frac{\frac{\theta^s}{s!}}{\sum_{k=0}^{s}\frac{\theta^k}{k!}}$$

Length of Charging Queue

$$E[N_b]=\sum_{k=0}^{s}k\Pr\{X=k\}=\frac{\lambda_b}{\mu_b}\left(1-\Pr\{X=s\}\right)=\theta\left(1-B(s)\right)$$

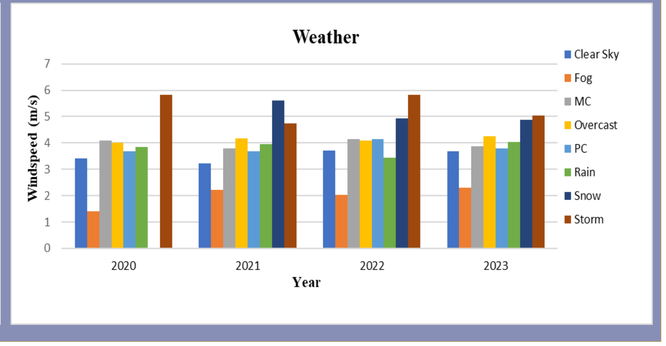
Phase II: Net-Zero for Power Generation





Cost Model

$$f(P_{WT}^c,P_{PV}^c)=\phi_{WT}a_{WT}P_{WT}^c+\phi_{PV}a_{PV}P_{PV}^c+\sum_{t=1}^{T}P_{WT,t}b_{PV}+\sum_{t=1}^{T}P_{PV,t}b_{PV}-\sum_{t=1}^{T}P_{WT,t}c_{PV}-\sum_{t=1}^{T}P_{PV,t}c_{PV}$$



Human Factors/Ethics

- Electricity Safety Factor
- Shipping and handling of battery
- Swapping Battery Weight
- Mega Charger Safety Guideline

- Climate Justice - Net-Zero Emissions
- Environmental Justice - Noise Reduction
- Power Resilience - Less Maintenance

Relevant Coursework

- IE 3320: Engineering Statistics
- IE 3330: Quality Engineering
- IE 3340: Operations Research
- IE 3360: Methods Engineering & Ergonomics
- IE 4310: Design of Industrial Experiments
- IE 4320: Integrated Production Systems
- IE 4360: Human Factors Design
- IE 4370: Probabilistic Operations Research

Conclusion & Future Effort

- Proposed an integrated design synthesizing queueing network with distributed renewables.
- Model implemented in Austin airport considering random flight arrivals subject to required layover time.
- Net-zero target economically viable based on onsite wind and solar generation.
- Future Consideration: Extend single airport to an airport network (large hubs and regional airports).

Team Members

Alejandra Guardiola (L), Javier Guerrero (M), Lauren Cravy (R)

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