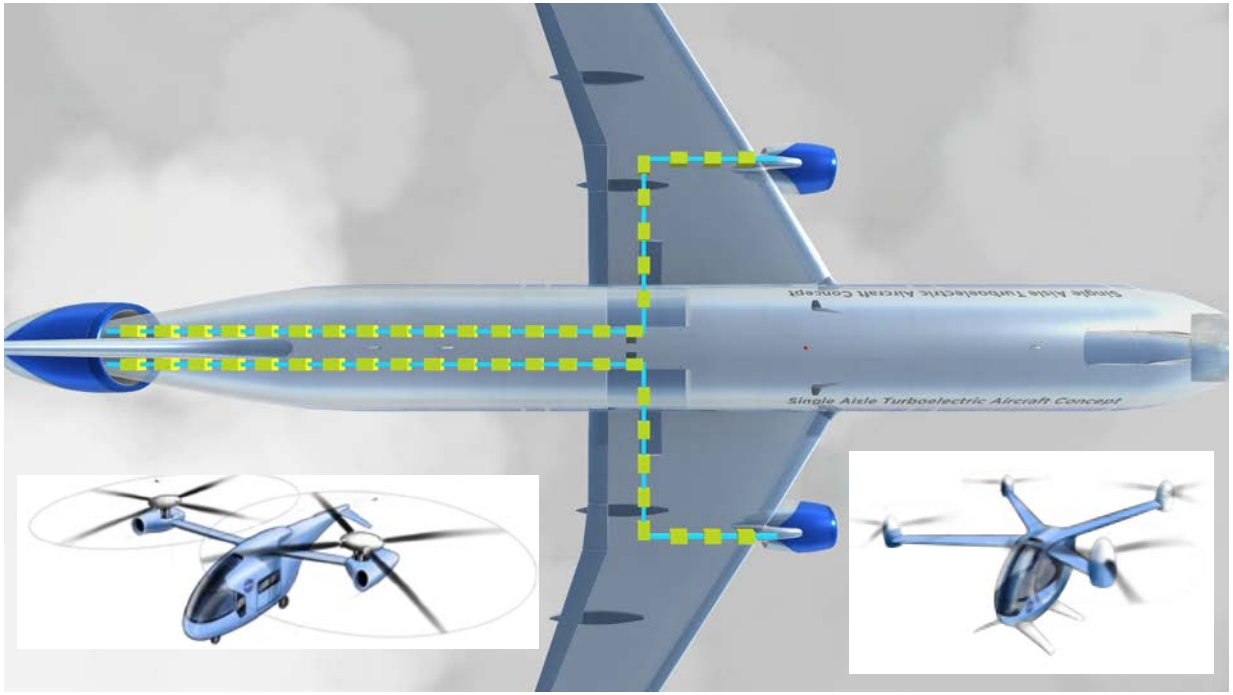
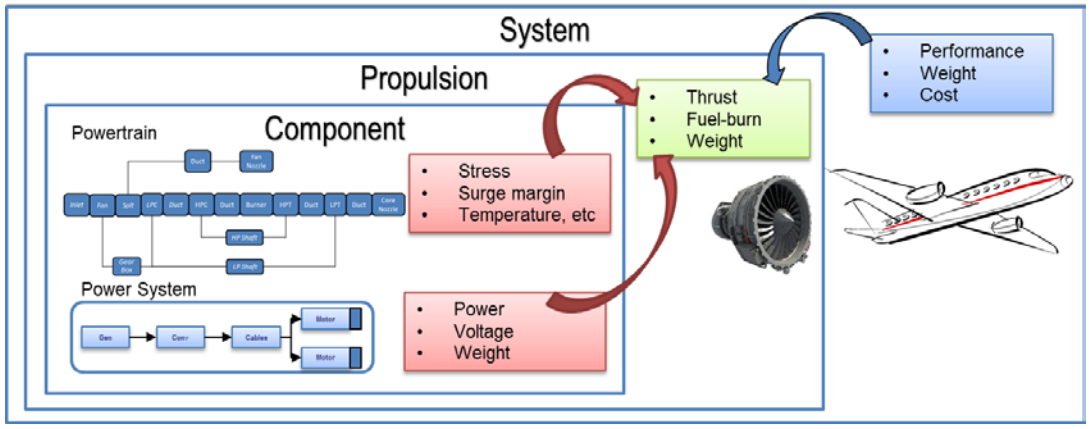
NPSS ELECTRICAL PORT DEVELOPMENT



David Sadey, Jeff Csank, and Tom Lavelle
NASA Glenn Research Center
NPSS Governing Board Technical Session, February 28th, 2019

HISTORY AND OBJECTIVE

- 2018 NPSS Meeting
  - Previous electrical work focused on how electrical analysis could be done within NPSS
    - All examples relied solely on data port to pass power/electrical data
  - Consortium agreed on letting NASA lead development of a formal definition of the Electrical Port for NPSS
    - NASA chosen as a non-competitive entity



APPROACH

- Initial proposed design submitted as formal NPSS enhancement to the Consortium Bugzilla System as CR1478
- Created NASA GIT Repository to continuously release port definition to Consortium Members/ Public
  - Component Toolbox and Examples Included
  - https://github.com/nasa/NPSS-Power-System-Library
- Incorporated multiple rounds of feedback from community for revision
  - Final Interpreted Port available as of Dec. 2018

ELECTRICAL PORT OVERVIEW

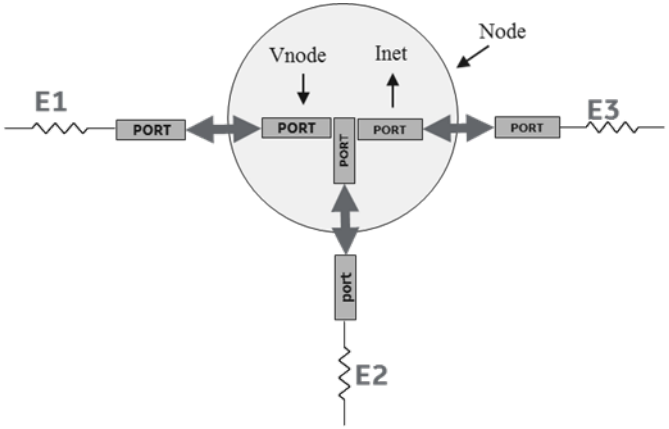
- Include electrical port and interpreted port:
  - #include "InterpretedPort.int"
  - #include "ElectricPort.prt"
- Set electrical power system type
  - setOption("ElectricPowerType",*type*);
    - Direct Current “DC”
    - Alternating Current “AC”
    - 3 phase AC “AC3”
- Created Complex Number Class
  - Allows for ease of computation (+,-,*,/) using complex numbers (polar and vector)
- Link ports
  - linkEports(*Port1, Port2, Connection Type*);
    - Connection Type
      - Port
      - Node
  - linkPortI(*Port1, Port 2*);

ELECTRICAL PORT Power Type

- Port Power System Types
  - “DC” Variables
    - Power (S), voltage (V), and current (I)
  - “AC” Variables (Assumes RMS)
    - Power (S), voltage (V), current (I), power factor (PF), frequency (Hz)
  - “AC3” Variables (Assumes RMS)
    - Power (S), voltage (V), current (I), line to neutral voltage (VLN), line-to-line voltage (VLL), power factor (PF) , frequency (Hz)
- Power, Voltage, Current variables are complex conjugates (Real, Imaginary) (DC assumes imaginary component is zero)
- Write to port:
  - Set Current and Voltage values in degrees
    - setIVRMSphaseDeg(real ImagRMS, real Iangle, real VmagRMS, real Vangle)
  - Set Current and Voltage values in Radians
    - setIVRMSphaseRad(real ImagRMS, real Iangle, real VmagRMS, real Vangle)

ELECTRICAL PORT – Node Connection

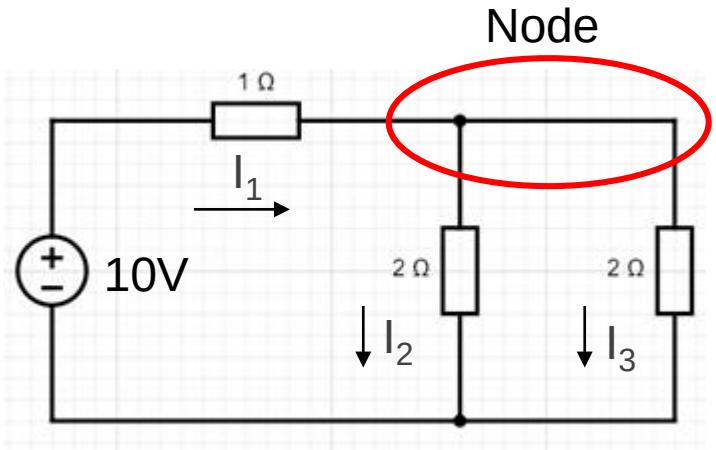
- Electrical Node Definition
  - Developed to handle > two port-to-port connections
  - Generates three internal electric ports, to be paired with external ports
  - Sets input voltage (Vnode) to all internal ports
  - Calculates net current of all internal ports
  - Solver drives net current balance to zero by iterating on node voltage



- Can easily expand process to additional connections

CIRCUIT EXAMPLE - DC

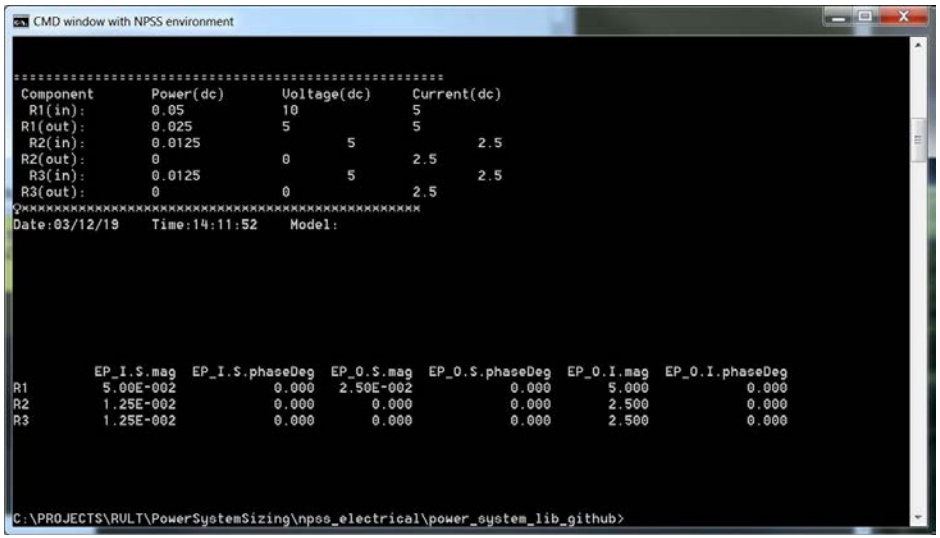
- Simple DC Circuit example uploaded to public repository
- 1 Dependent Variable (Node Voltage)
- 1 Independent Variable (Vab)
- Solver iterates dependent variable / balances node current to solve system
- Verifies DC Port



https://www.electronics-tutorials.ws/resistor/res_5.html

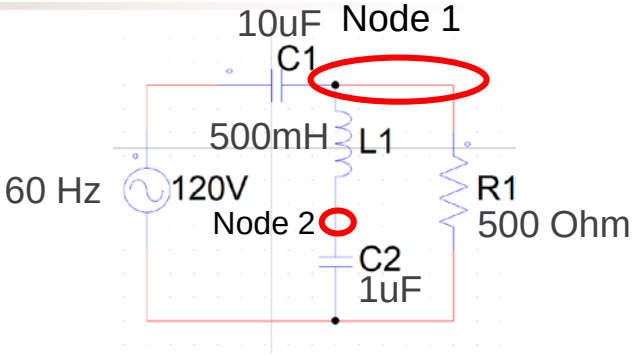
$I_1 = 5A$

$I_2 = I_3 = 2.5A$



CIRCUIT EXAMPLE - AC

- Extended AC example
- Verifies AC1 Port
- 1 Independent Variable (AC Source)
- 2 Dependent Variables (Node 1 and 2 Voltages)



CMD window with NPSS environment

```
 Voltages
C1: 88.1223 + 42.2068j
L1: 94.8634 + 45.4355j

 Component Voltage  Drops
C1: 31.8777 + -42.2068j
L1: -6.7411 + -3.2287j
C2: 94.8634 + 45.4355j
R1: 88.1223 + 42.2068j

 Currents
C1: 0.159116 + 0.120176j
L1: -0.0171288 + 0.0357626j
C2: -0.0171288 + 0.0357626j
R1: 0.176245 + 0.0844135j

 Power
 C1(in): 0.0190939 + -0.0144211j
C1(out): 0.0190939 + -0.00387444j
 L1(in): 2.44249e-018 + -0.00387444j
L1(out): 2.22045e-018 + -0.00417082j
 C2(in): 0 + -0.00417082j
C2(out): 0 + -0j
 R1(in): 0.0190939 + 8.88178e-019j
R1(out): 0 + 0j

C:\PROJECTS\RVLT\PowerSystemSizing\npss_electrical\power_system_lib_github>_
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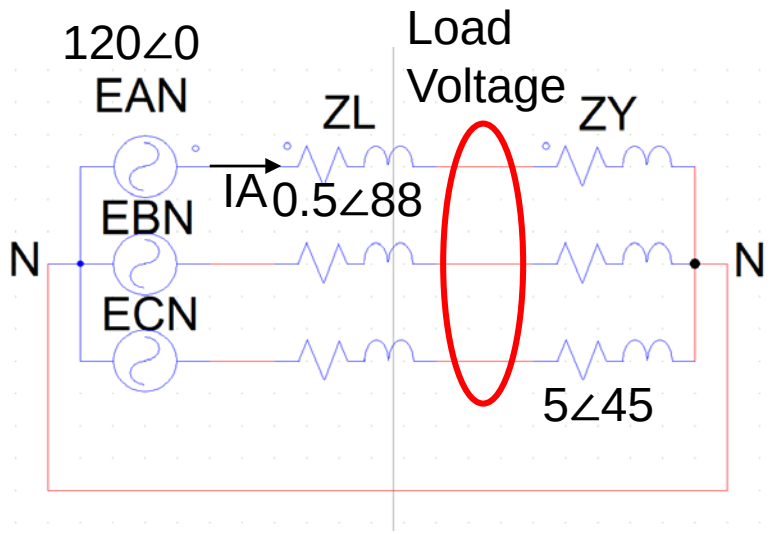
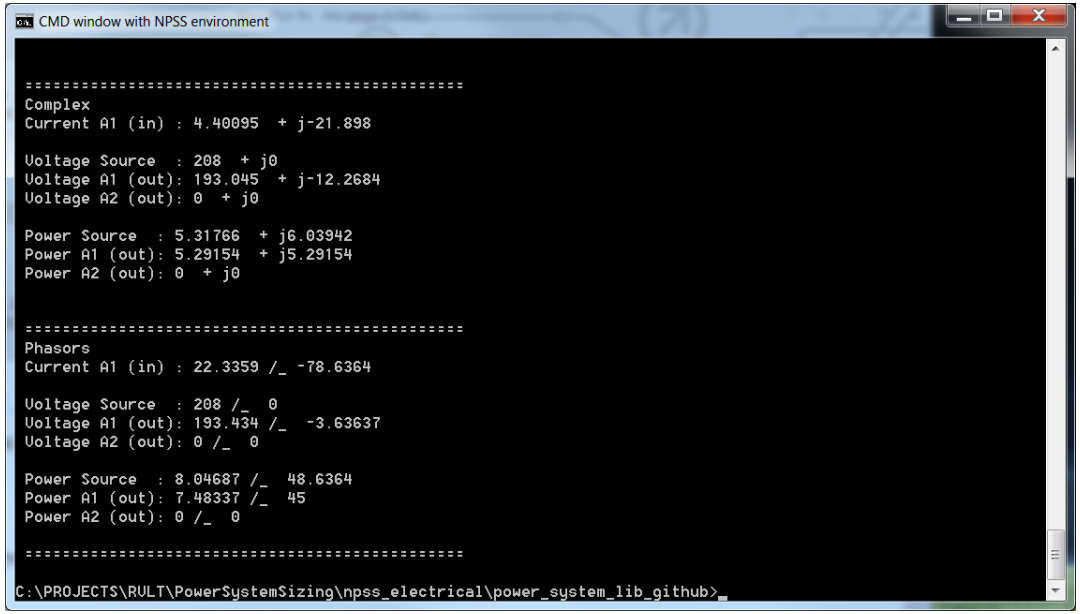
3- PHASE POWER SYSTEM EXAMPLE

- Power System Example
- Verifies AC3 Port
- 1 Independent Variable (3PAC Source)
- 1 Dependent Variable (Load Voltages)



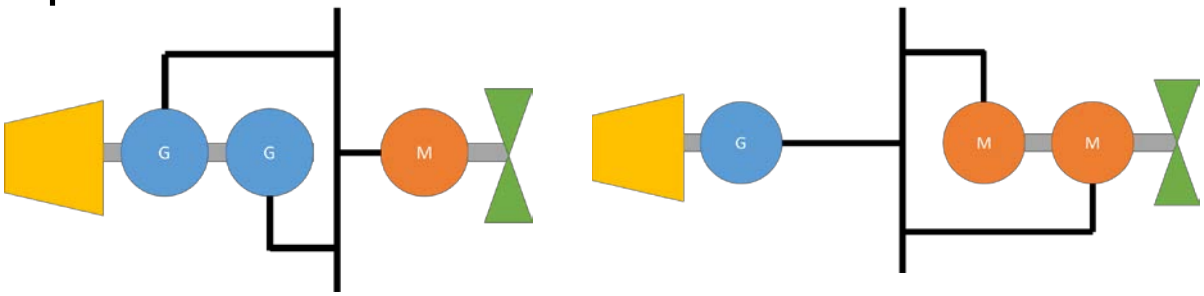


COMMUNITY TOOLBOX

- Created Community Toolbox to model typical Power System components that may exist on a vehicle power train
  - Generator
  - Circuit Breakers
  - Cables
  - Motors
- Components have on- and off- design capability
- Limited components count and fidelity due to constant port changes
- Verified Inverter/Rectifier MATLAB Models will be converted and added shortly
- Battery Models will be developed and used with Mission Analysis

AIRCRAFT EXAMPLE

- TBD SHUTDOWN
- Basic Examples of a Turbo-Electric System are available on the NASA Repository (2 Gen, 1 Motor; 2 Motor, 1 Gen)
  - Models are simplified; frequency coupling of the generator/motor across the AC network is not considered, machines are assumed to be phase-locked
  - Demonstrates on- and –off design capabilities to size and assess performance of the system over the duration of the flight profile



- Realistic AC and DC System Examples will be developed over the next few months for Public Release

CONCLUSION AND FUTURE WORK

- Developed and verified interpreted electrical port
  - Multiple rounds of community/consortium feedback
- Demonstrated electrical port capability to solve circuits and power systems (on- and off- design)
- Developed and demonstrated additional tools for community
  - Power System Toolbox
  - Electrical Node Connection
  - Simple to medium difficulty examples
- Plan to
  - Develop Higher Fidelity Components for Toolbox
  - Add Inverter/ Rectifier/ Battery Models Shortly
  - Release Turbo-/ Hybrid- Electric Power System Models for an Aircraft within the next few months

THANKS

- Revolutionary Vertical Lift Program for their support
- Jesus Garcia, Randy Cepress for support/ node development
- NPSS Consortium for continuous feedback on port