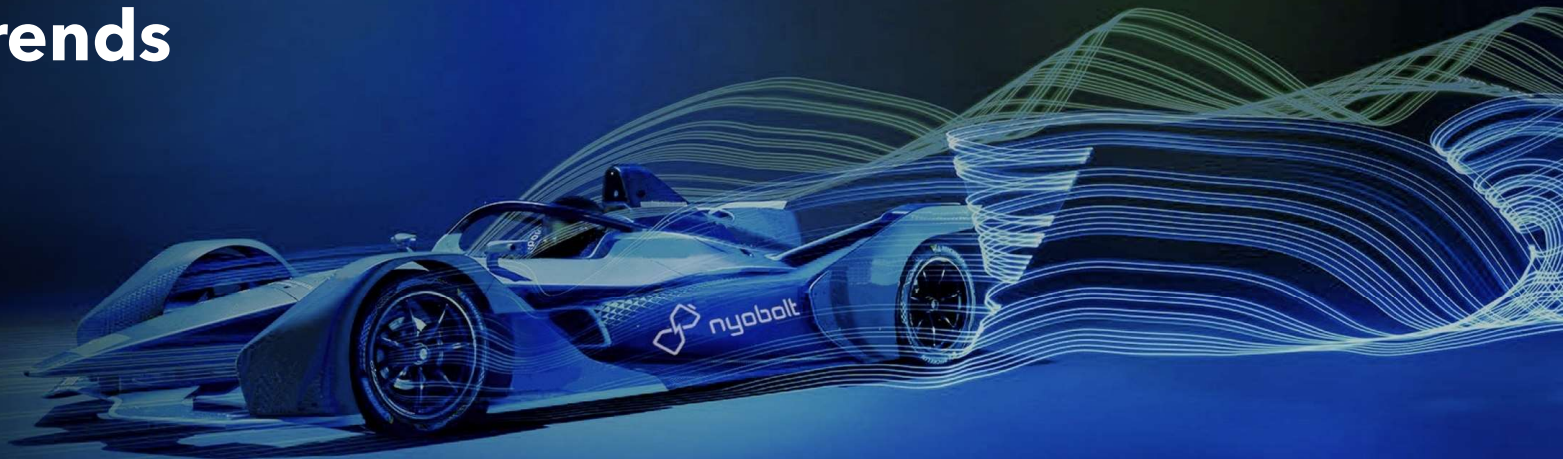




Power Electronics for EV Chargers

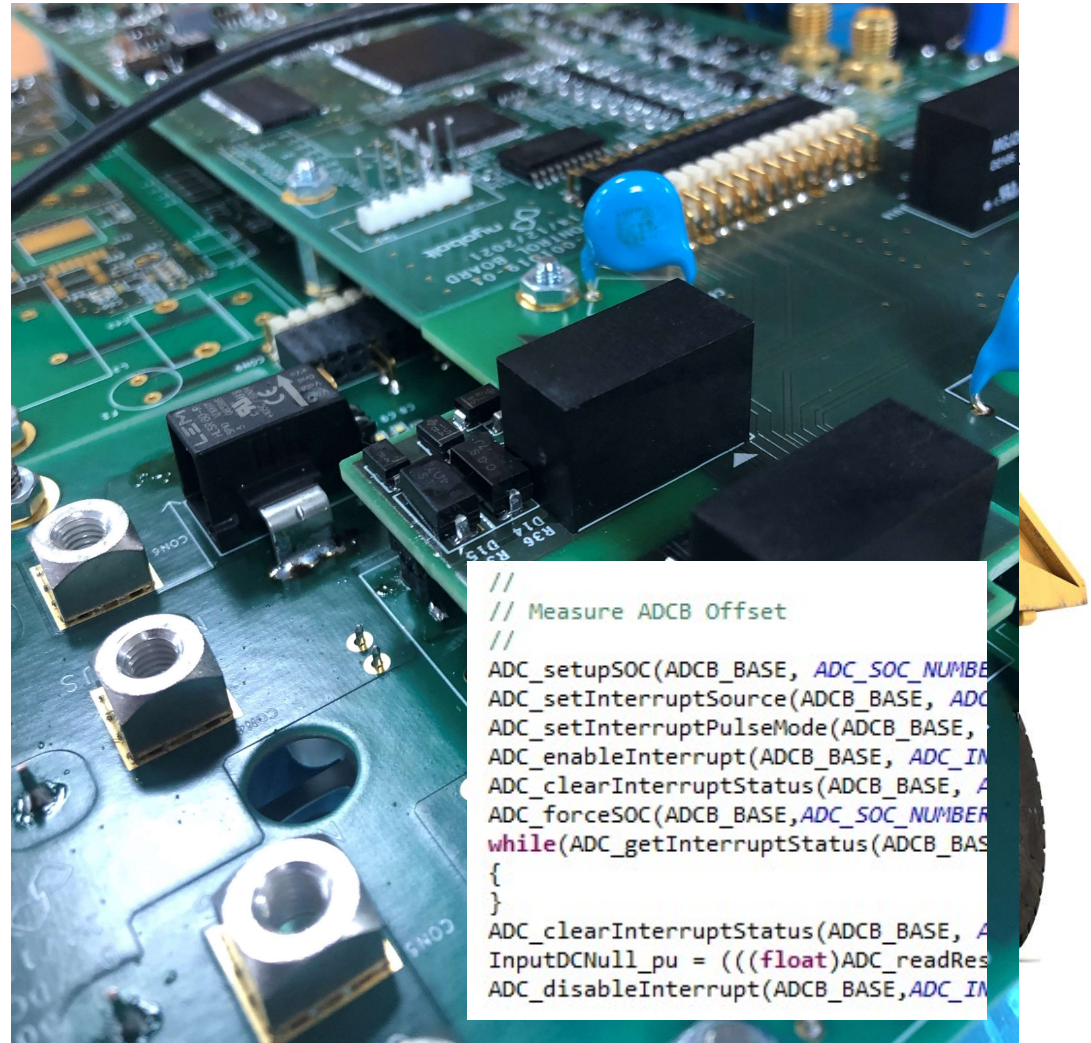
Status and Trends

Iain Mosely, 4th July 2023



Overview

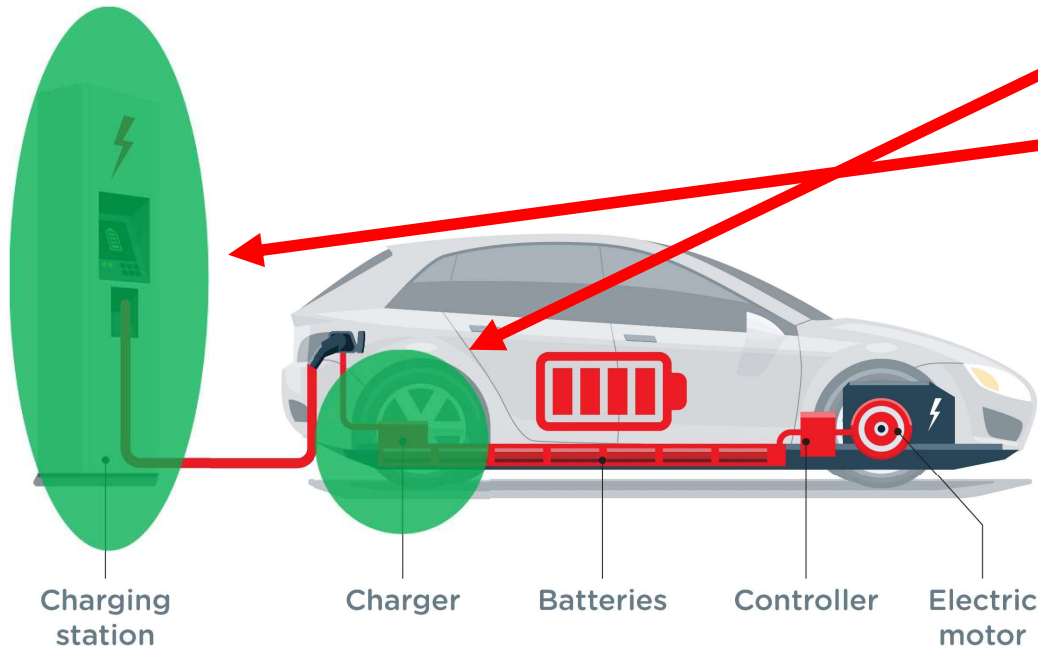
- Charging my vehicle – Where is the power electronics?
- What are the bottlenecks on charging time?
- Recent developments in battery chemistry
- Case study – electrification of mining...
- Power electronics engineers writing software – Huh?



Charging my Vehicle

EV Charging - Where Is My Power Electronics?

-Low Power 'AC Charging'



- AC/DC charger power electronics is on the car
- External 'Charging' station is an intelligent set of contactors used to route AC power to the vehicle
- Charge rates limited by external infrastructure capability and cost/kW of an on-board charger
- Battery C rate is unlikely to be a limiting factor

'AC' Charging Performance

-Limited by External Infrastructure

- 3kW Single Phase (230V/13A) ~ 12 miles per hour of charging
- 7kW Single Phase (230V/32A) ~ 25 miles per hour of charging
- 11kW Three Phase (3x 230V/16A) ~ 40 miles per hour of charging
- 22kW Three Phase (3x 230V/32A) ~ 80 miles per hour of charging
- Current capability of local AC feed or rating of on-board charger limits maximum power



What if I need to charge faster?

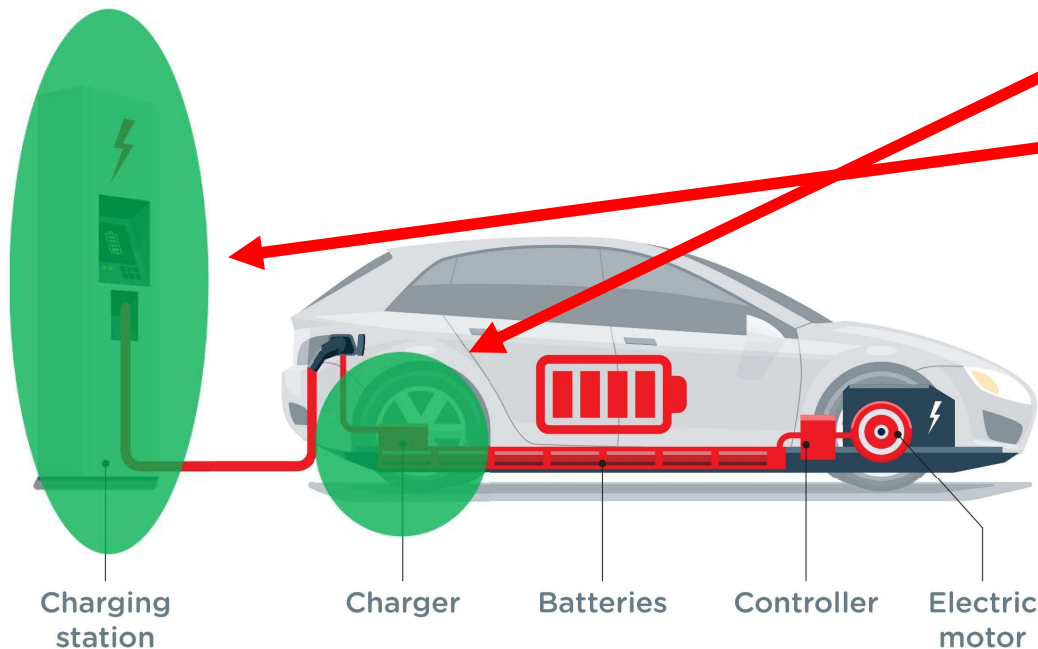
- Commercial applications often need to charge faster
- Time Charging = Lost Revenue
- Many fleet applications are looking to electrify
- Delivery services, factory automation, large trucks.....

nyobolt



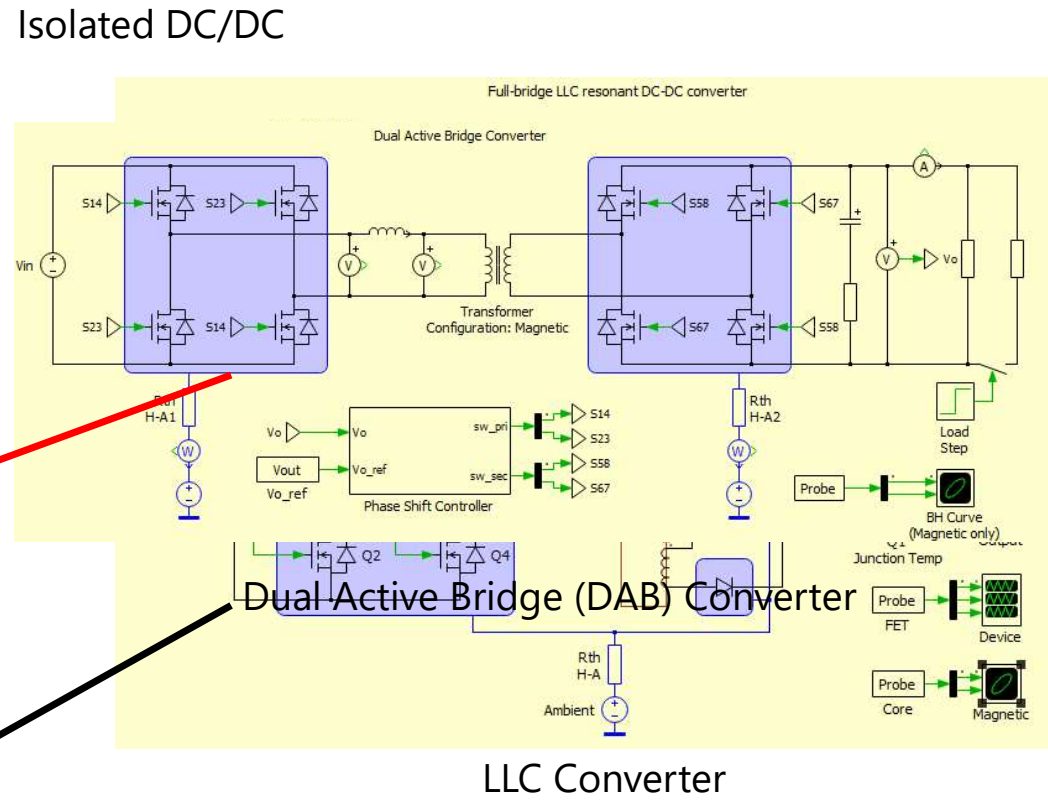
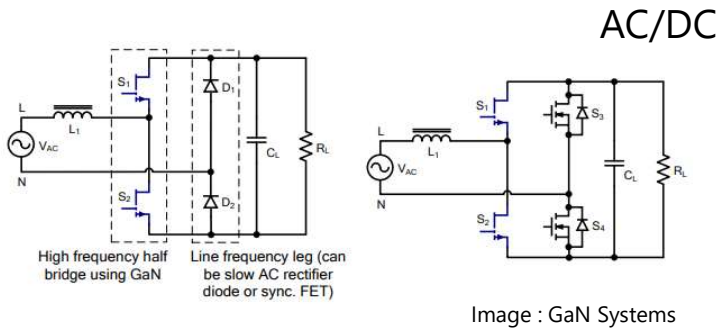
EV Charging - Where Is My Power Electronics?

-High Power 'DC Charging'



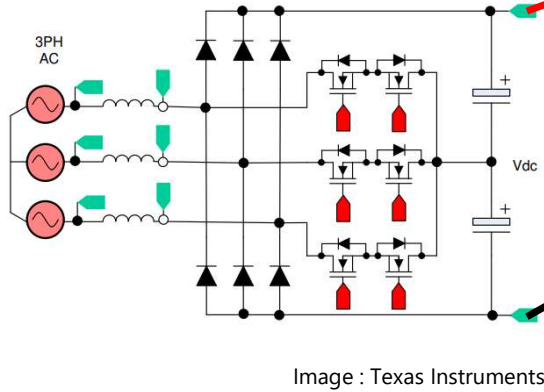
- On board charger is bypassed
- External DC charging station is now home to our power electronics and feeds DC power directly to the car battery
- External AC infrastructure is sized for the required power level of the charger
- Vehicle battery chemistry via BMS (C-rate) and DC charge cables are now the main limitation in charging rates

EV Charging - AC/DC Power Electronics



Single Phase

Three Phase



DC Rapid Charging

-How fast are they?

- 60kW is about 250 miles of range per hour (25 miles in six minutes)
- 150kW is about 600 miles of range per hour (60 miles in 6 minutes)
- 350kw is about 1400 miles of range per hour (140 miles in 6 minutes)
- ...however, charging time depends on many factors.....

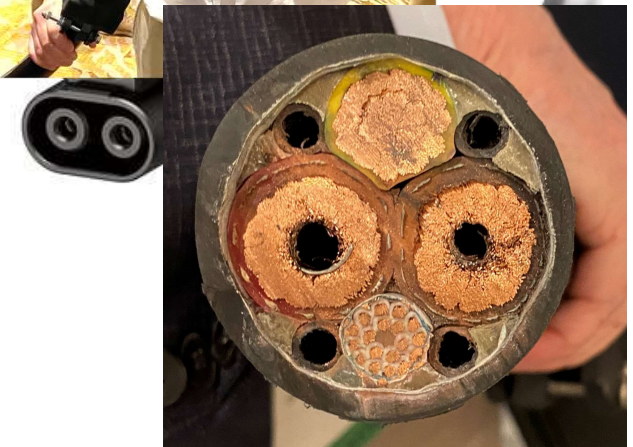


What limits charge rate?

Charge Rate

- Infrastructure Limits

- Normal CCS cable is 200A rated, liquid cooled gets us to 500A
- 400V battery with 500A capability would allow for 200kW charging (80 miles in 6 minutes)
- 800V battery with 500A capability would allow for 400kW charging (160 miles in 6 minutes)
- Megawatt charging system can take us to multiple MW level
- Local grid capability must be there
- And..... the battery pack must be able to accept these rates....

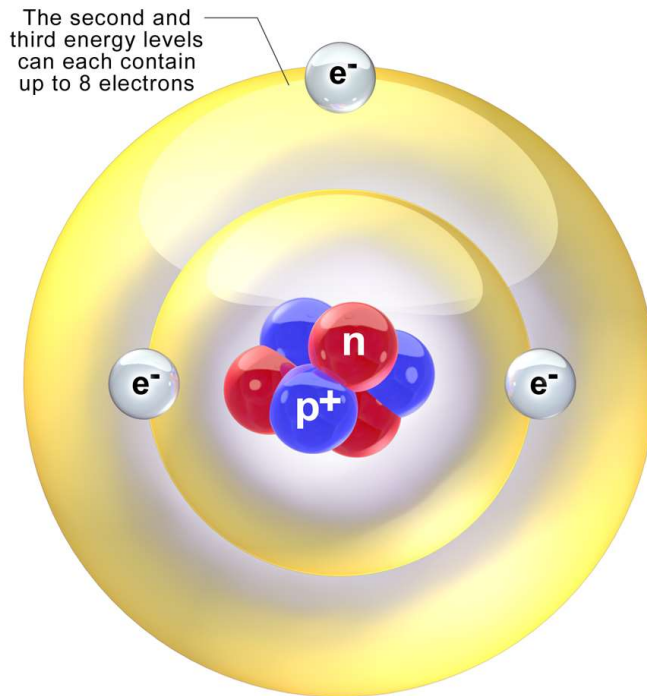


Developments in Battery Chemistry

Charge Rate

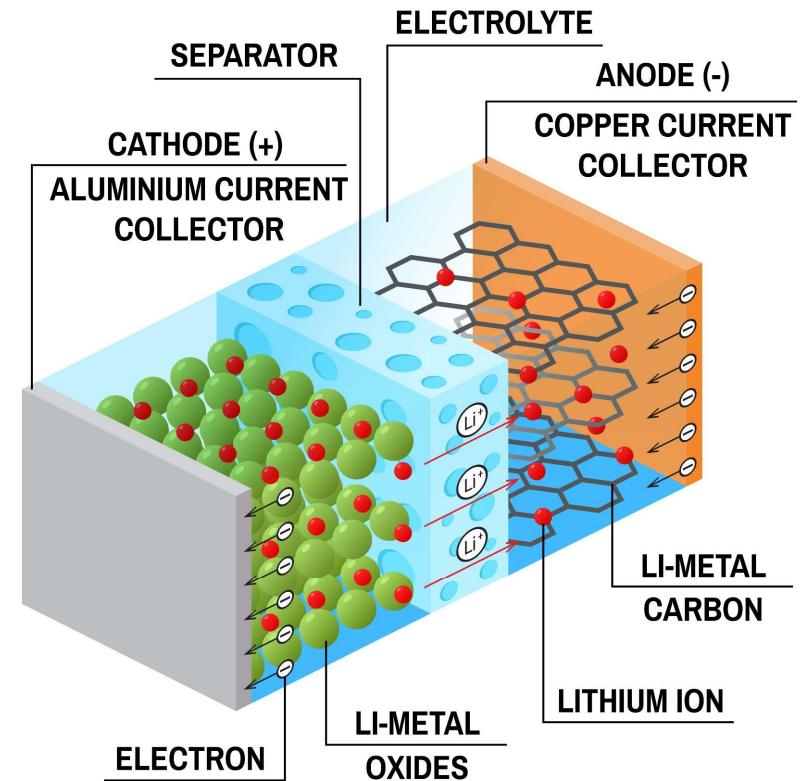
- What about the battery?

- Most batteries 1C
- The pack BMS at rates greater
- Cell temperature
- E.g. a 35kWh pack a maximum of 1C charger
- Main limit is at the active material
- Nyobolt is coming much faster to market



Lithium, Li
 Atomic number: 3
 Mass number: 6
 (3 protons + 3 neutrons)
 3 electrons

LITHIUM-ION BATTERY CHARGE





Very high power EV's...

Copper Mountain Mine

-12MW of Surface Haul Truck Trolley Assist

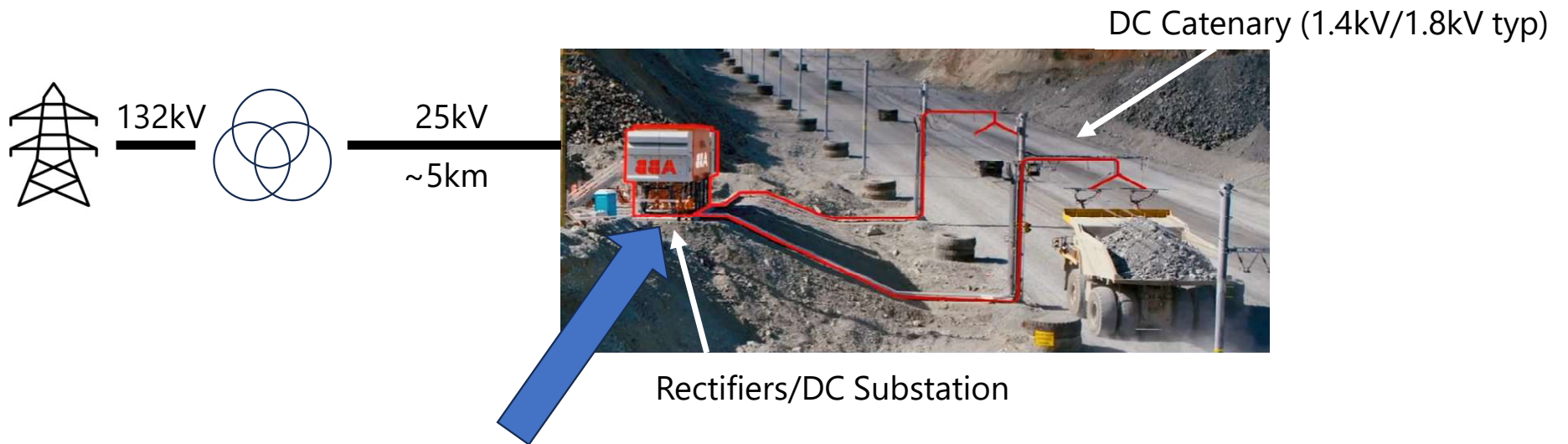
- Provides motive power to 400 tonne diesel electric haul trucks up a 1km slope
- Allows the truck motors to run at close to their 3MW capability (faster!)
- Significantly reduces diesel usage and emissions
- Next steps are for addition of batteries to allow regen when coming back down the incline
- Could charge on way up too but need extra power electronics
- How do we provide 12MW of DC power.....



Copper Mountain Mine

-How can we provide 12MW of DC power...?

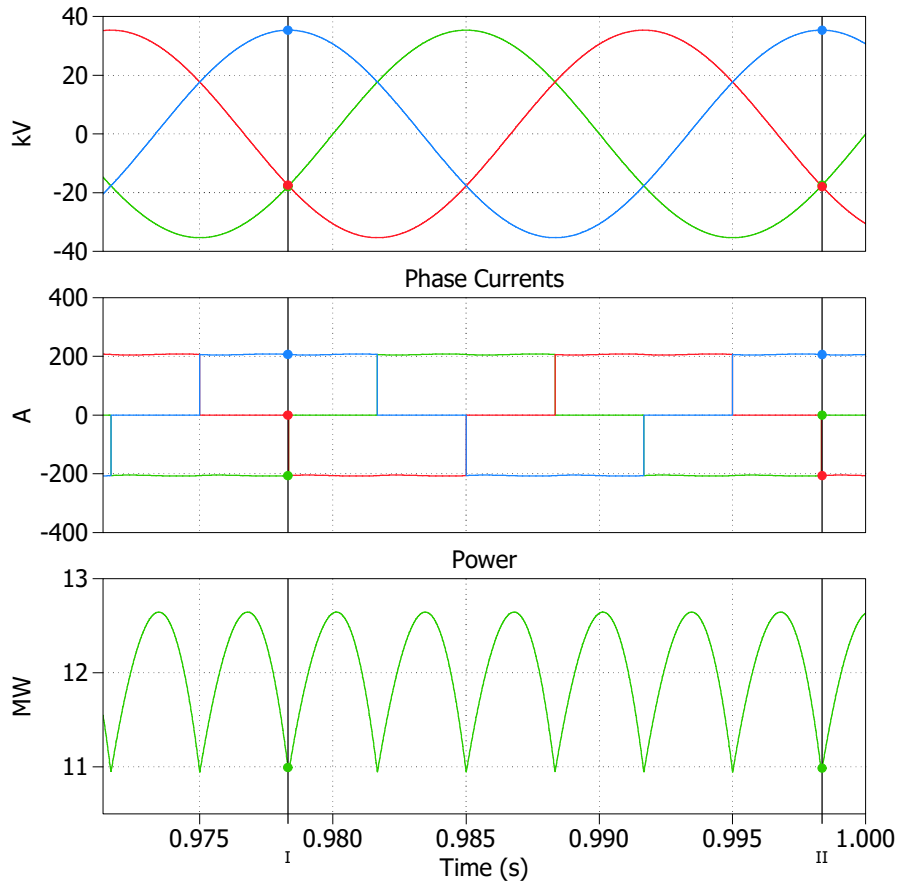
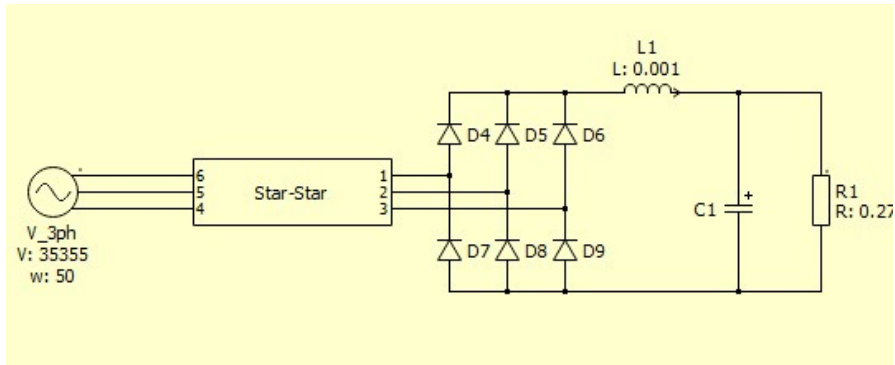
Borrow technology from railway electrification



What is in the DC substation....?

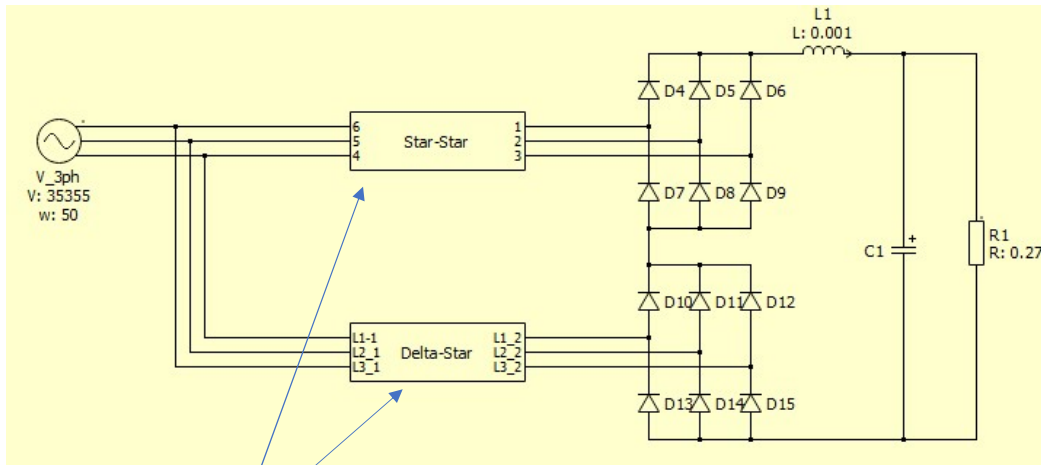
6 Pulse Rectifier

-Waveforms for 12MW of Power (1.8kV/6.6kA)

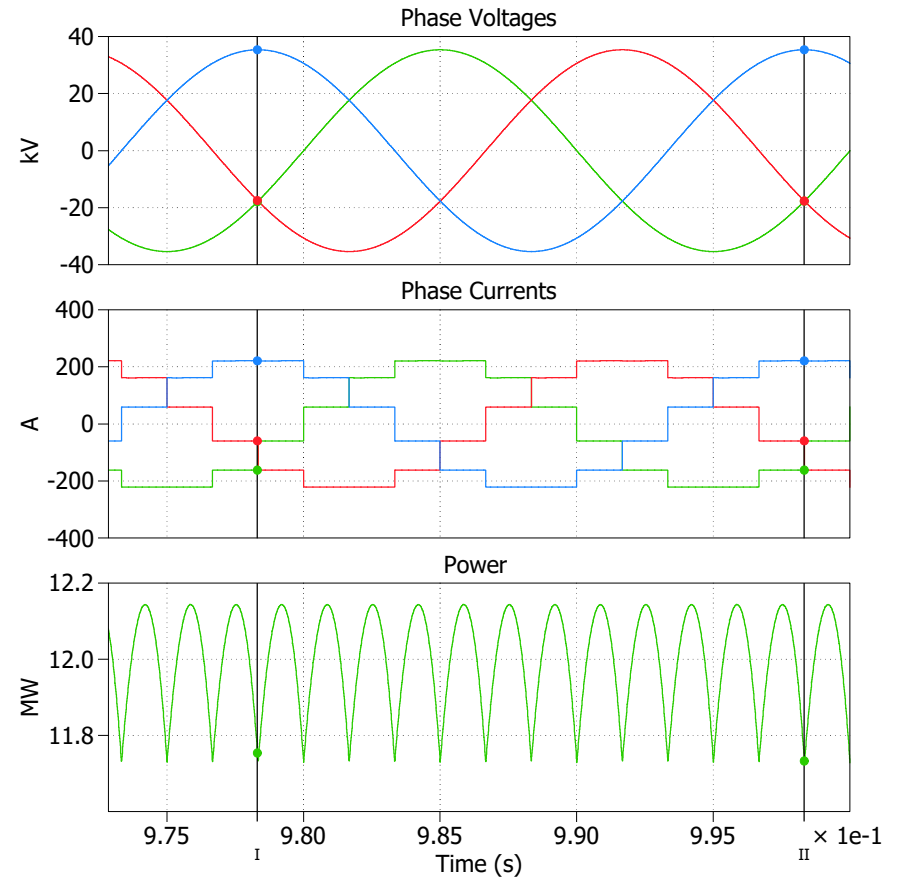


12 Pulse Rectifier

-Waveforms for 12MW of Power (1.8kV/6.6kA)



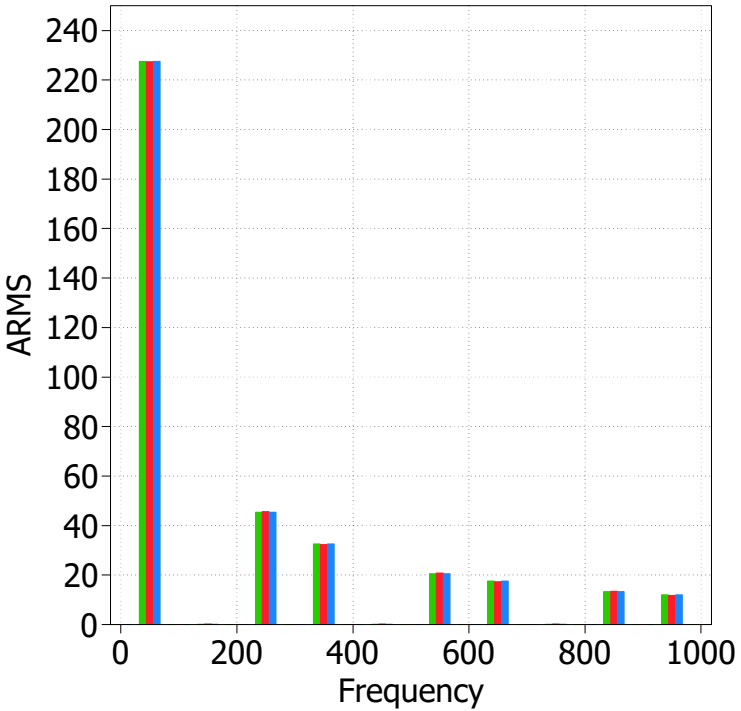
30° relative phase shift on secondaries



6 Pulse vs. 12 Pulse - Harmonics

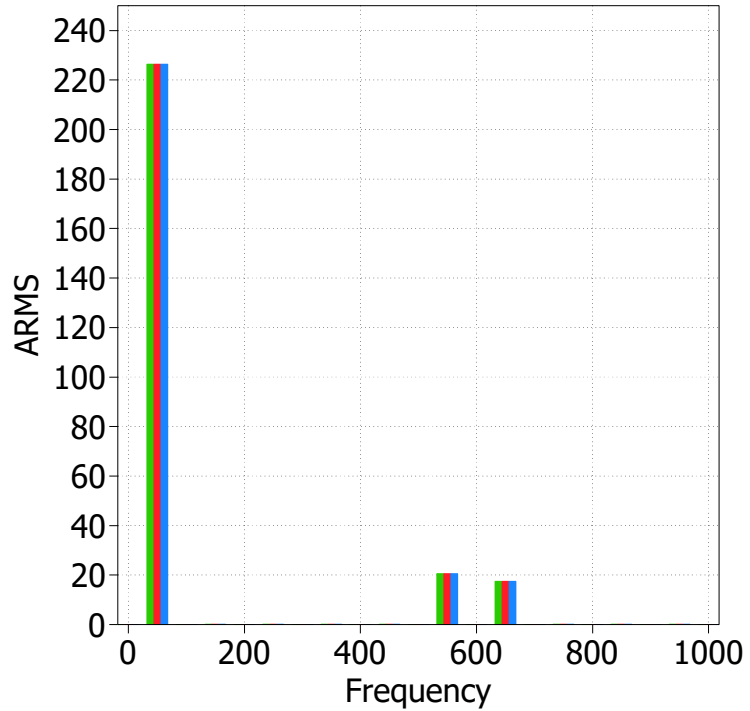
-12MW Throughput

6 Pulse
Phase Currents



Harmonics at n=5,7,11,13,17,19...

12 Pulse
Phase Currents



Harmonics at n=11,13,23,25,35,37...

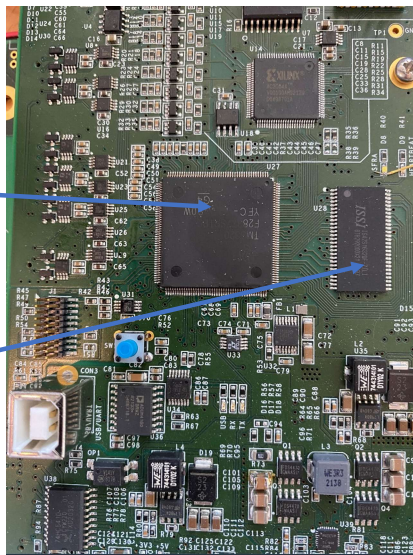
Power Electronics and Software...

Power Electronics and Software

-SDRAM Datalogging (Black box, 64MB)

C2000 32-bit processor

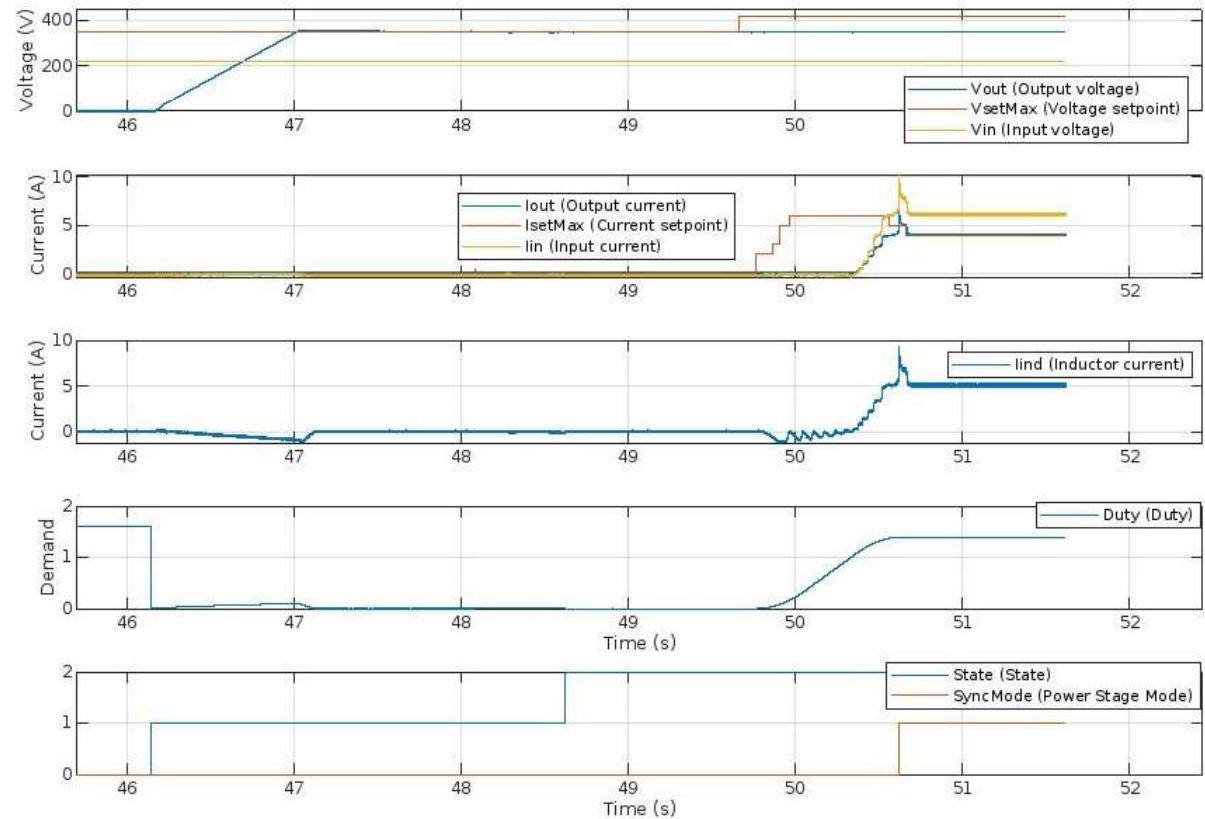
64 Mbyte SD-RAM



Custom Digital control Board

~60 seconds of full control law rate recording is possible

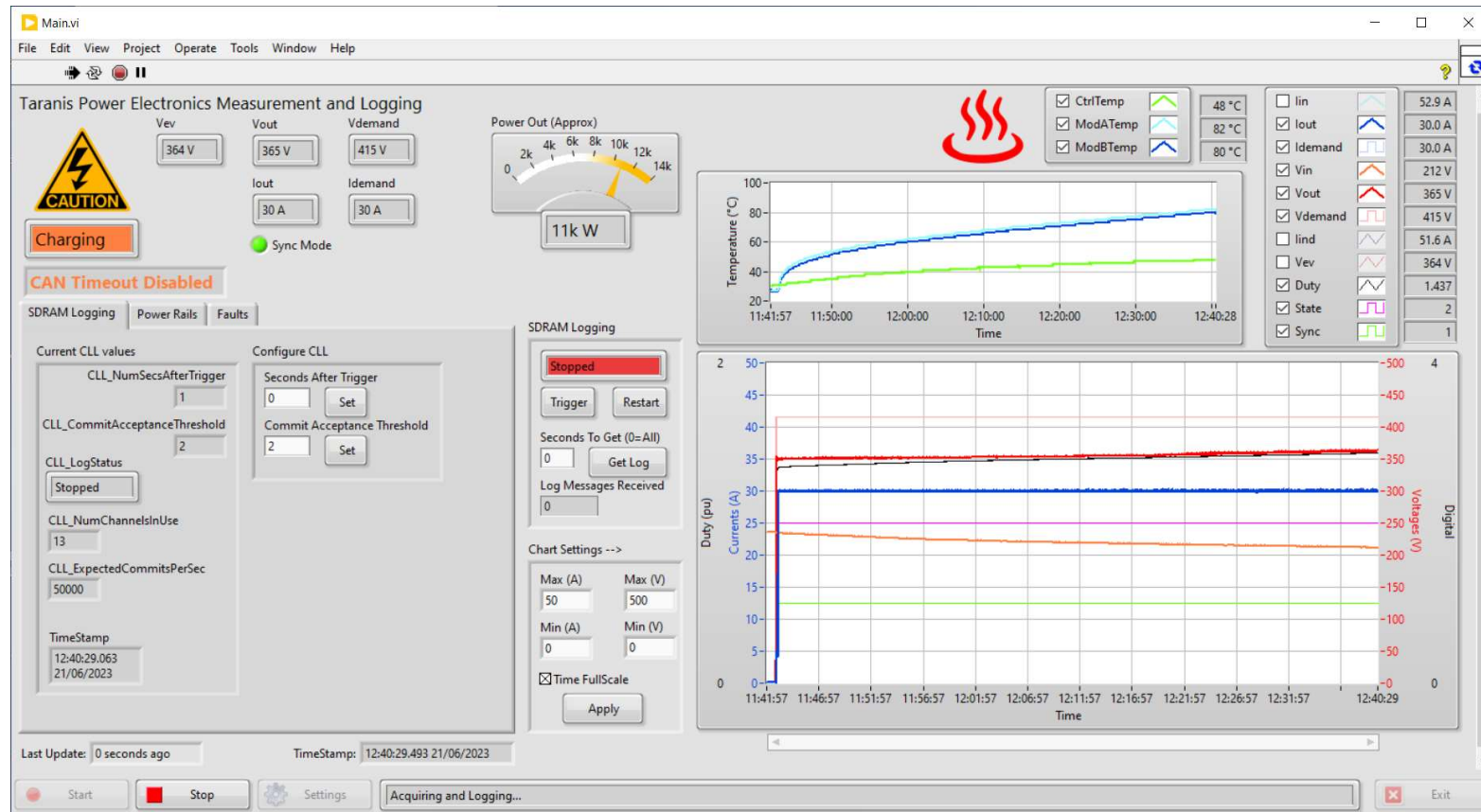
nyobolt



Power Electronics and Software

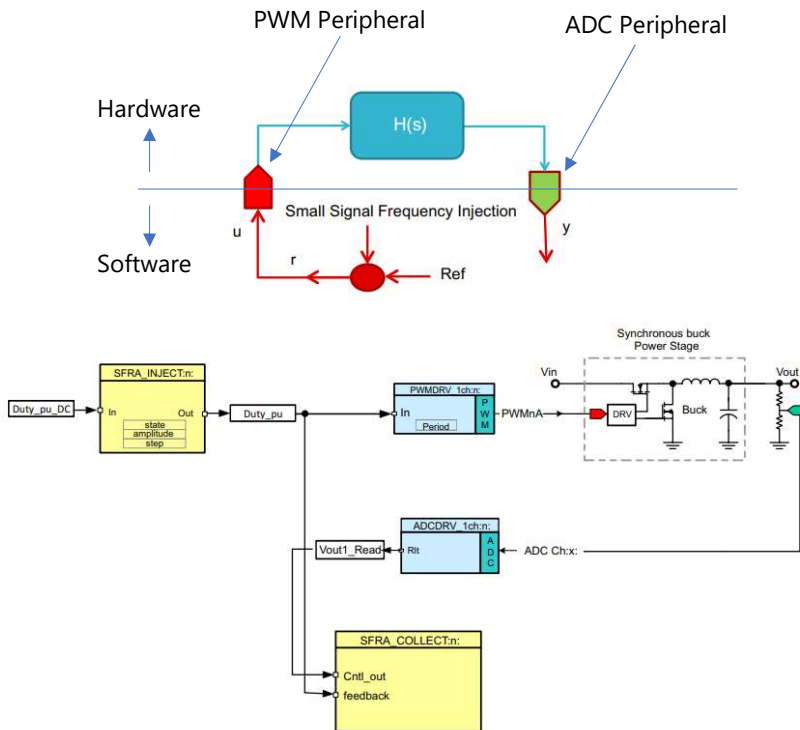
-Test Integration

'Real Time' data logging to Labview over CANBUS at 1ms update rate

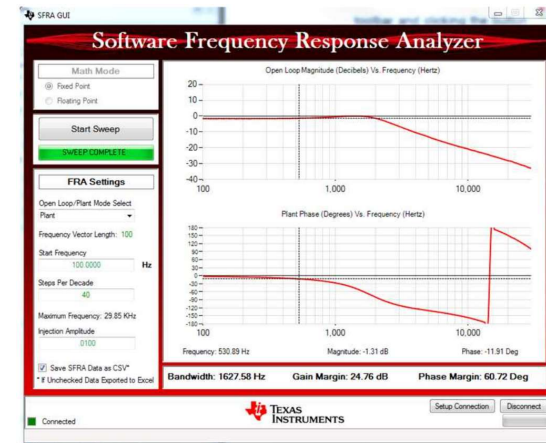


Power Electronics and Software

-Software Frequency Response Analyser (SFRA), by Texas Instruments



- Useful software tool to measure control loop behaviour in-situ
- No extra measurement equipment needed
- No issues with low frequency analogue injection
- Control via computer through UART and front-end program



Summary

- Power electronics is generally not the limiting factor in charge rates
- Batteries are no longer a bottleneck on charge rates
- Local infrastructure capability, charging cable ratings and solution cost will be the limiting factors
- Electrification is everywhere
- Power electronics is awesome!..... But skill up on embedded software too