KPIT

16 Sept' 20

Impact Analysis of Faults in an EV

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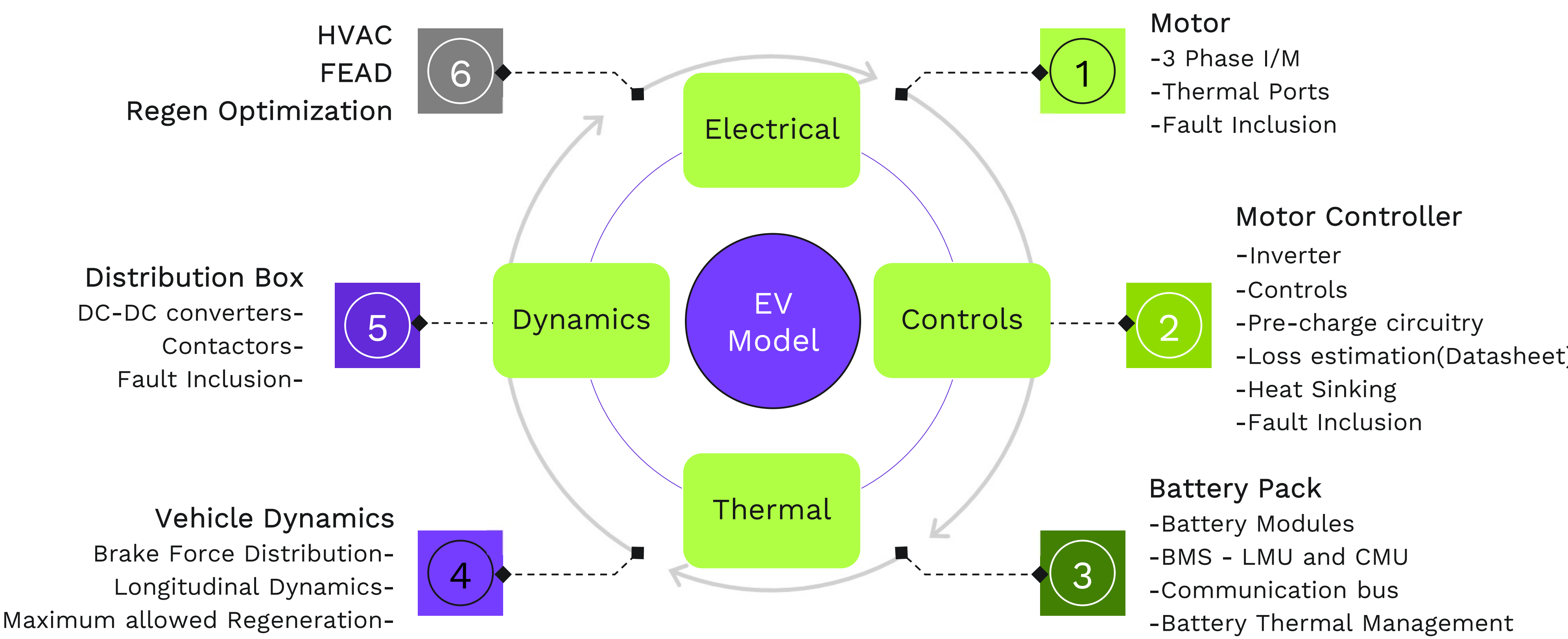
CTO Organization
KPIT Technologies Limited

EV Model



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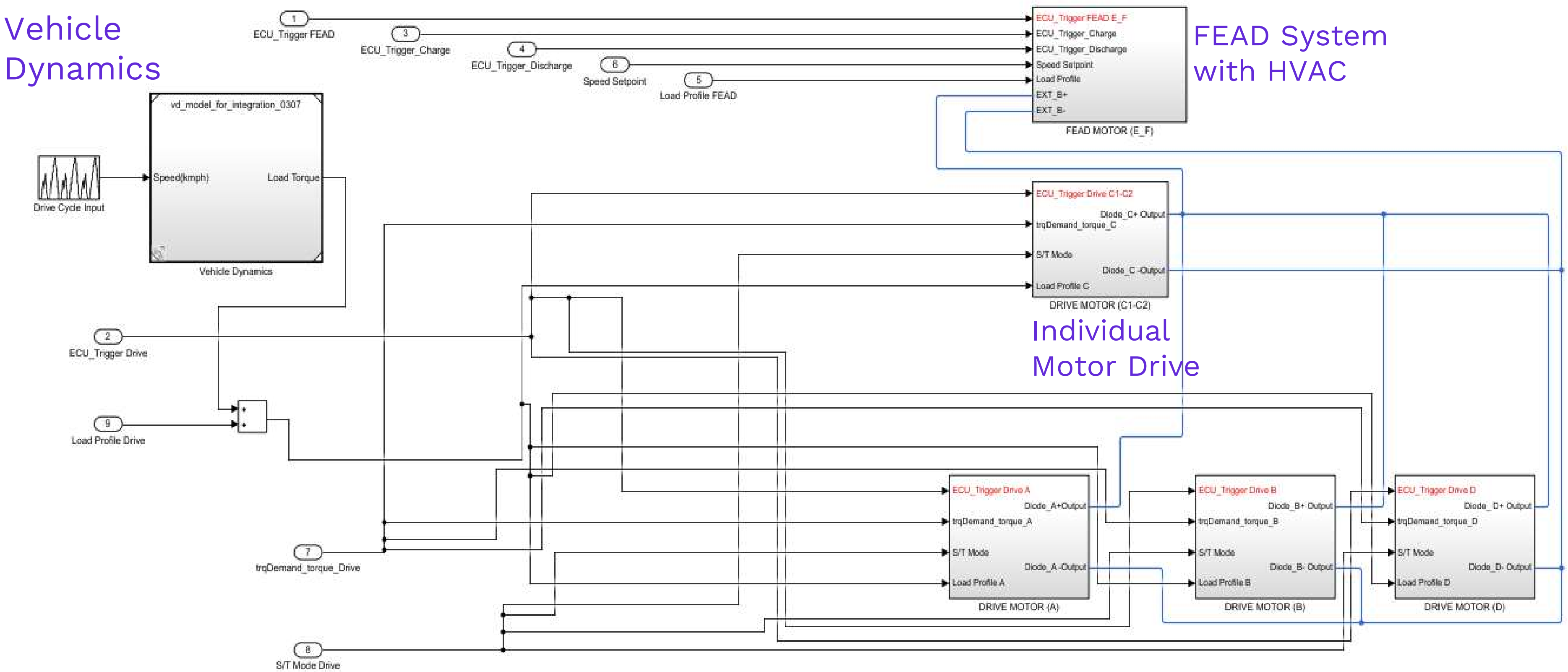
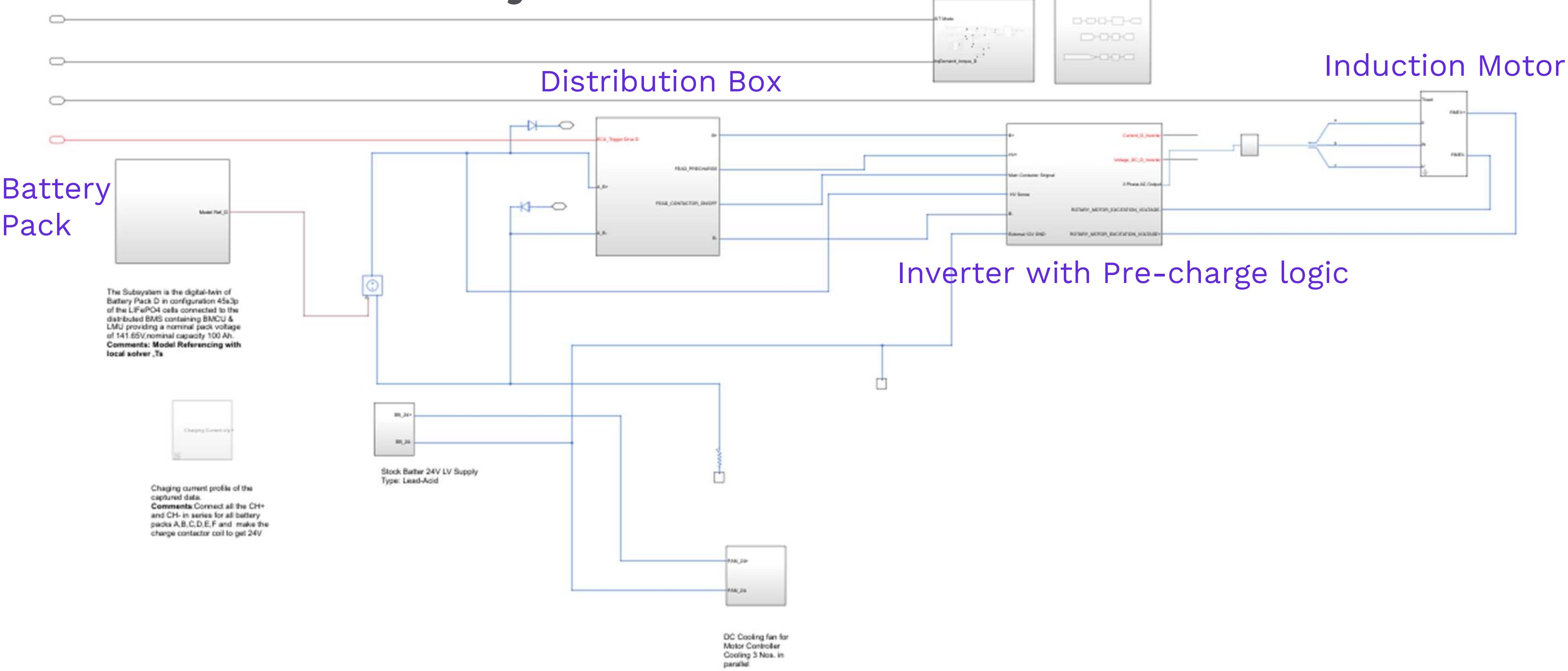
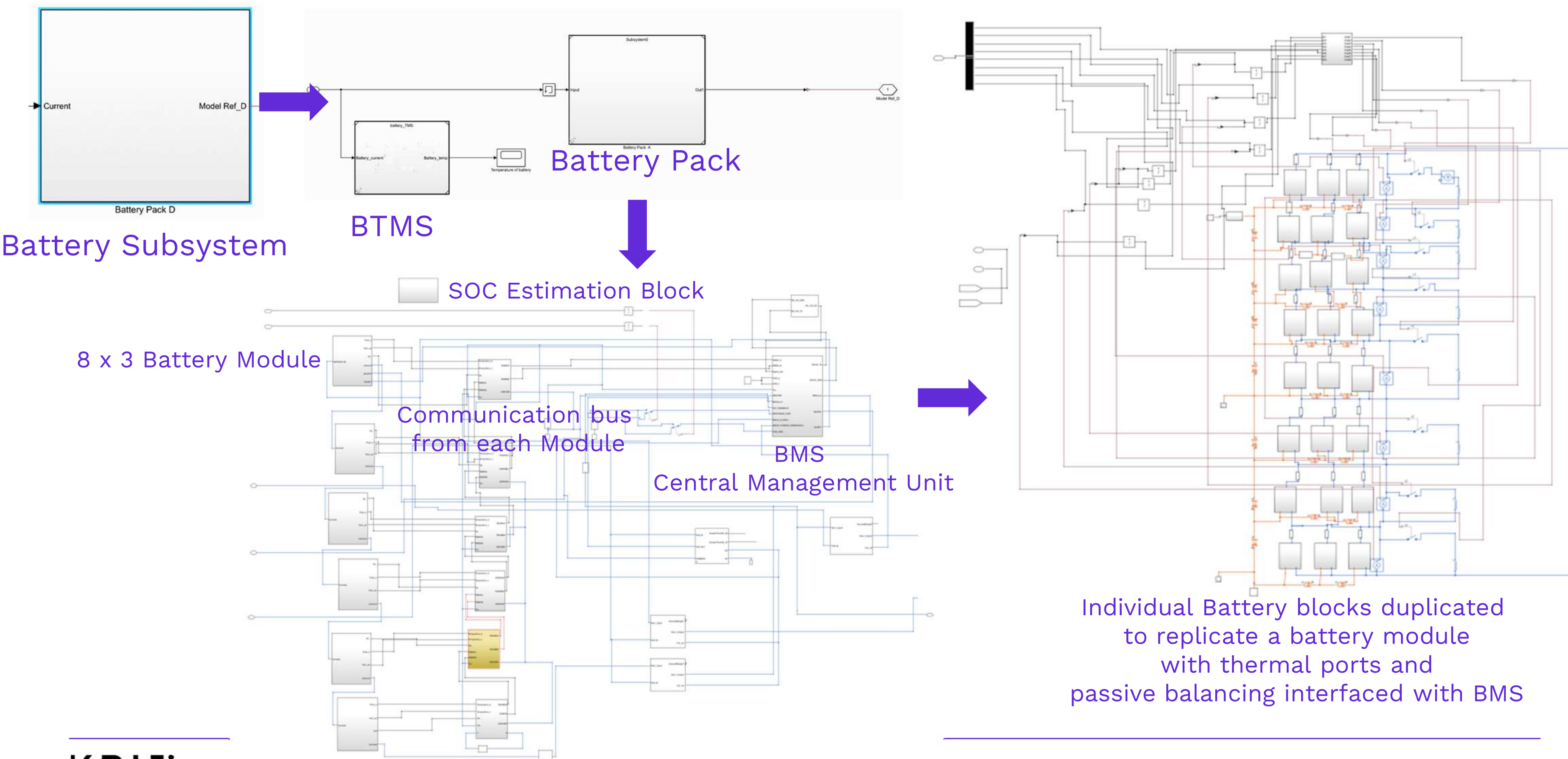
Framework:


Vehicle Dynamics
FEAD System with HVAC
Individual Motor Drive
ECU_Trigger FEAD
ECU_Trigger_Charge
ECU_Trigger_Discharge
Speed Setpoint
Load Profile FEAD
ECU_Trigger FEAD E_F
Load Profile
EXT_B+
EXT_B-
FEAD MOTOR (E_F)
vd_model_for_integration_0307
Speed(kmph)
Load Torque
Drive Cycle Input
ECU_Trigger Drive C1-C2
Diode_C+ Output
trqDemand_torque_C
S/T Mode
Diode_C -Output
Load Profile C
DRIVE MOTOR (C1-C2)
ECU_Trigger Drive
Load Profile Drive
trqDemand_torque_Drive
S/T Mode Drive
ECU_Trigger Drive A
Diode_A+Output
trqDemand_torque_A
Diode_A -Output
Load Profile A
DRIVE MOTOR (A)
ECU_Trigger Drive B
Diode_B+ Output
trqDemand_torque_B
Diode_B- Output
Load Profile B
DRIVE MOTOR (B)
ECU_Trigger Drive D
Diode_D+ Output
trqDemand_torque_D
Diode_D- Output
Load Profile D
DRIVE MOTOR (D)

Individual drive system view



Battery pack(Exploded View)



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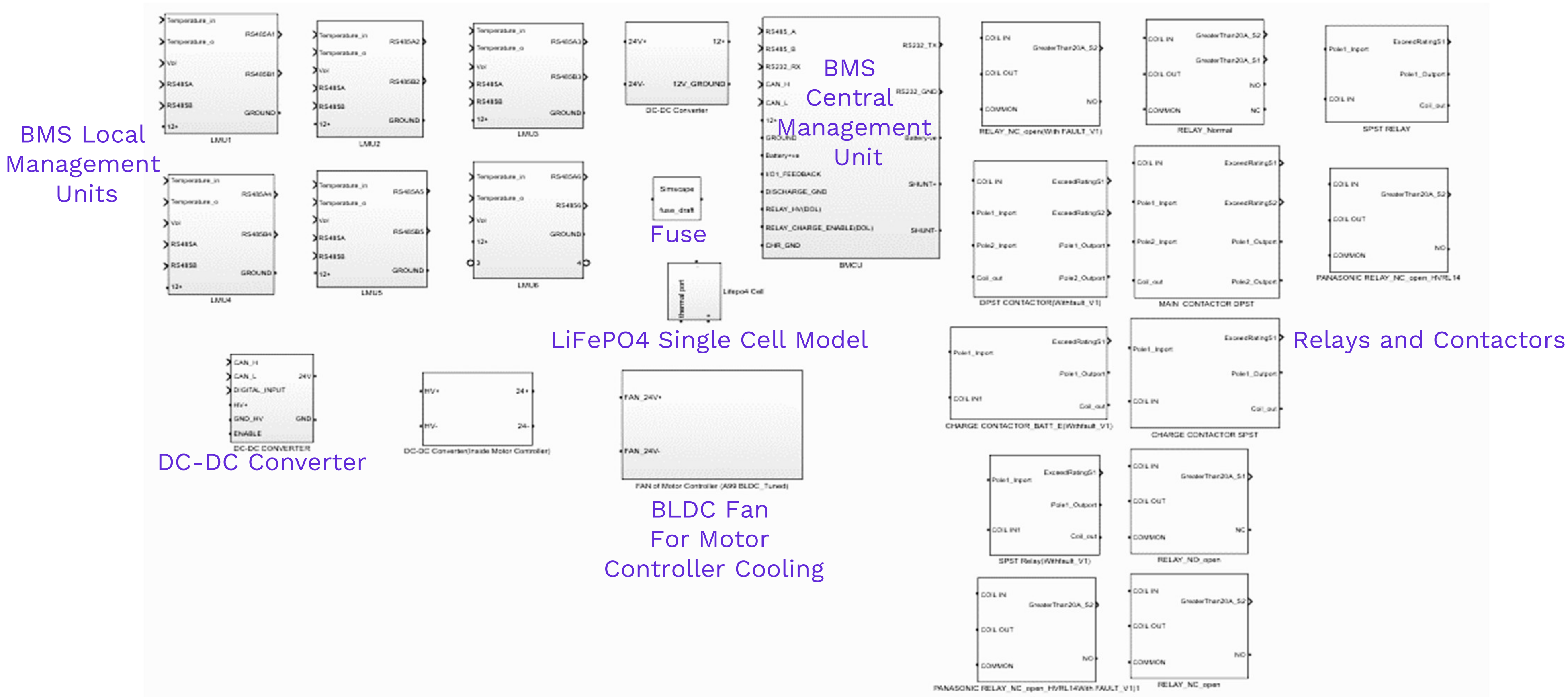
Base Libraries



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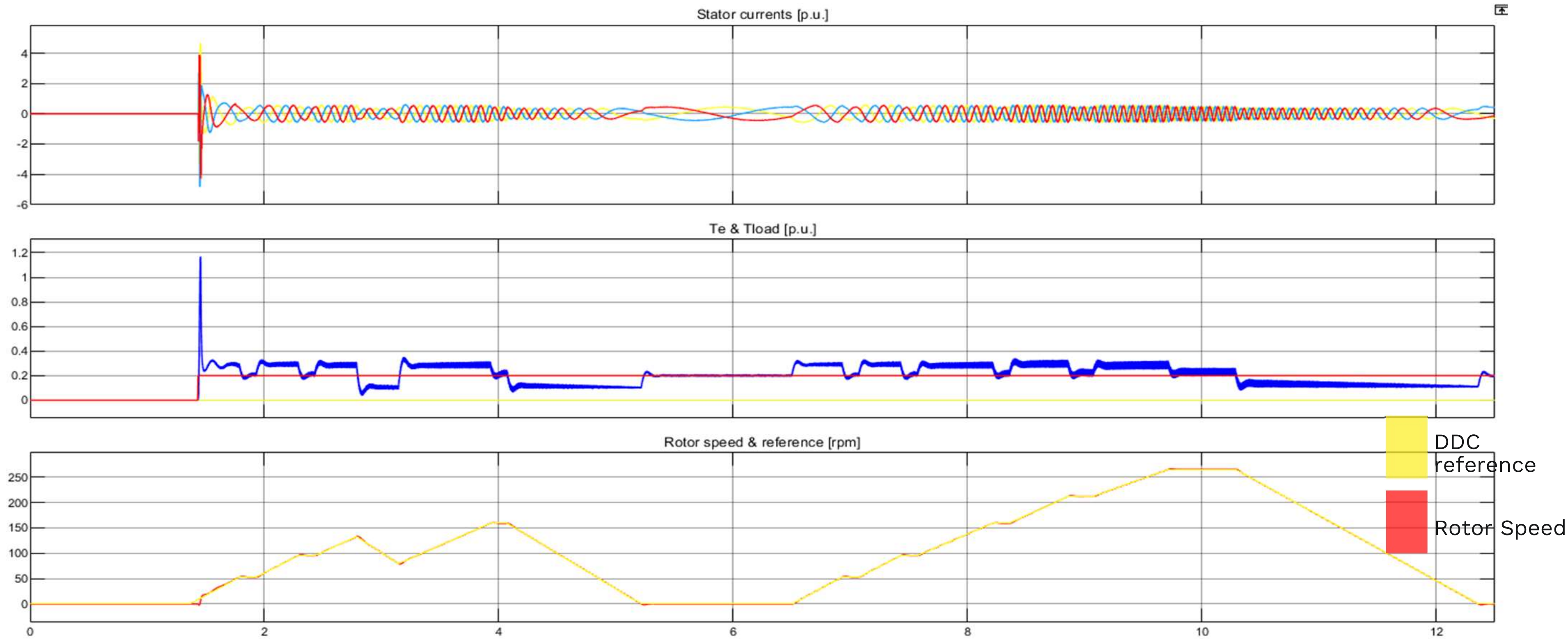
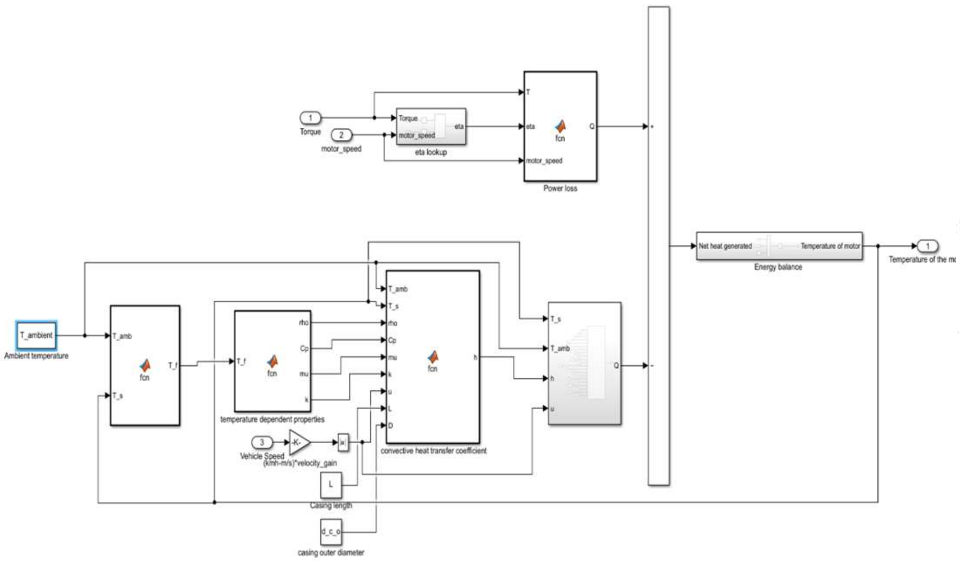
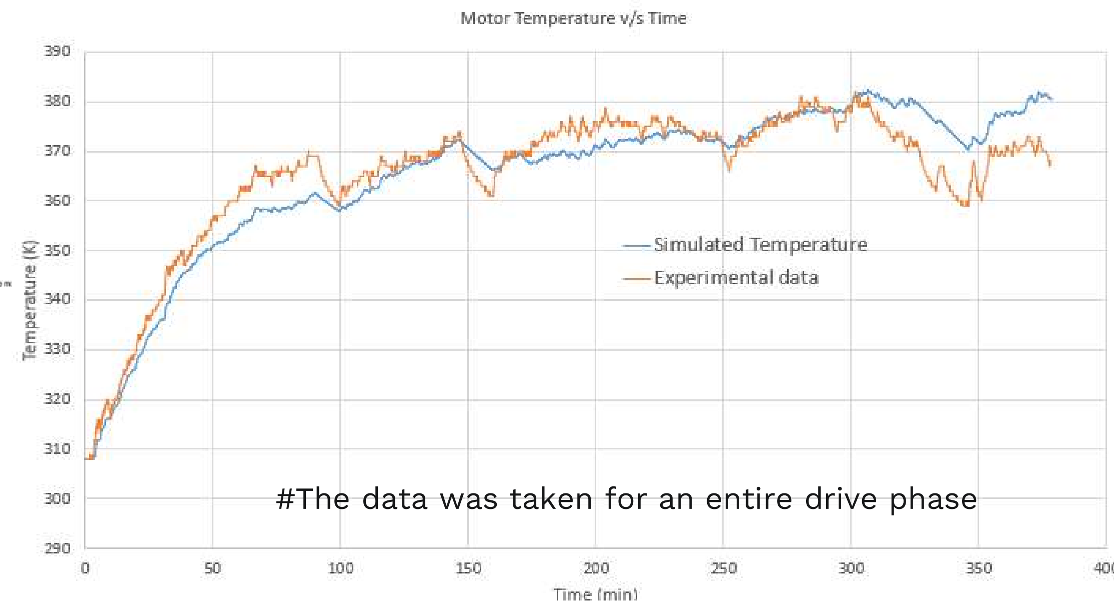
Test Case: (Vehicle tested for Delhi Drive Cycle)

The rotor speed is seen to track the drive cycle reference



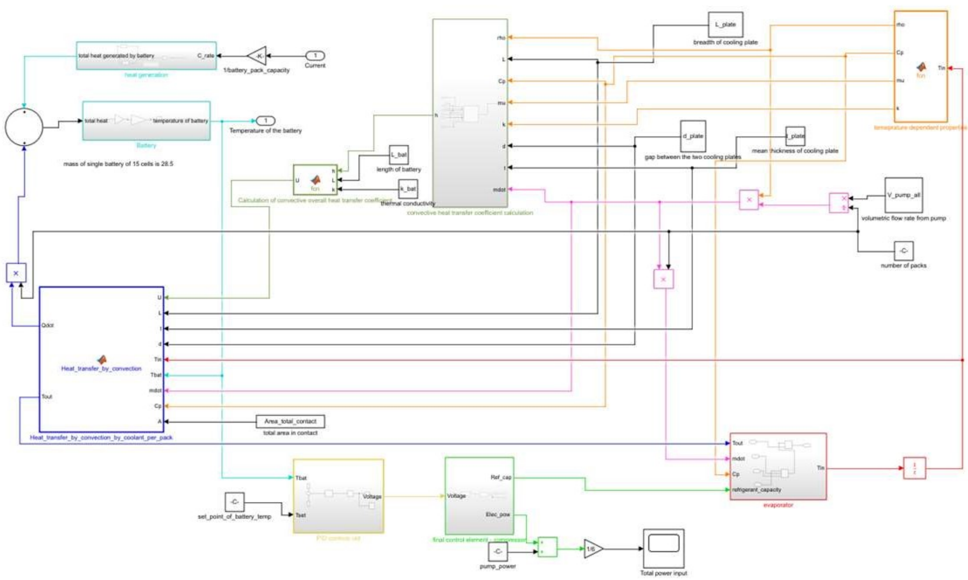
Case: Motor Air Cooling model Validation

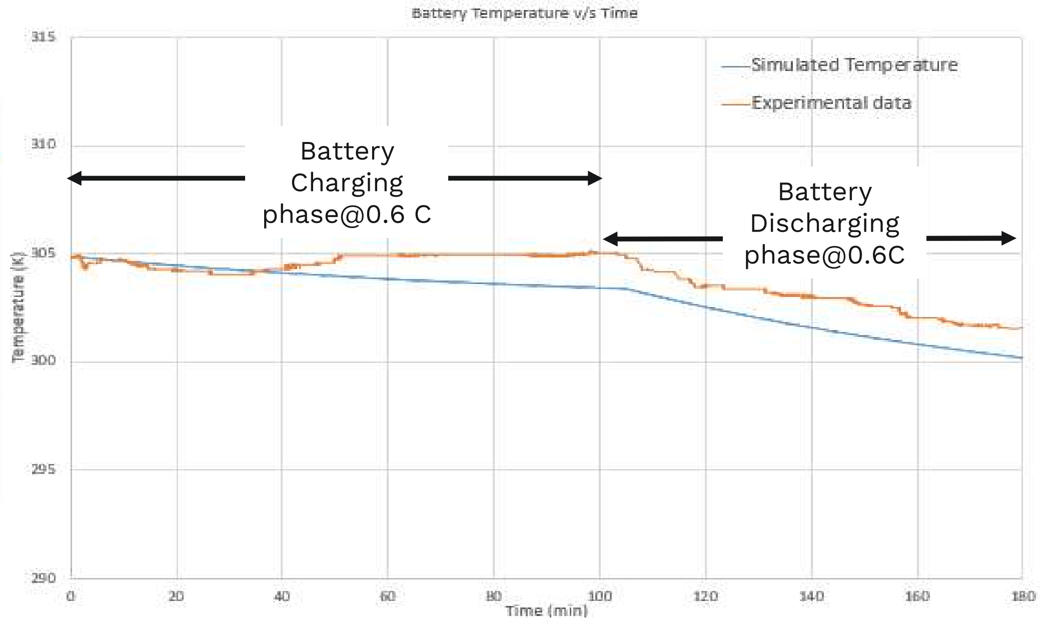




- When tested with available drive data, natural air cooling models were used to depict the convergence and a maximum tolerance of 9 K was observed in the motor temperature data generated by simulation.

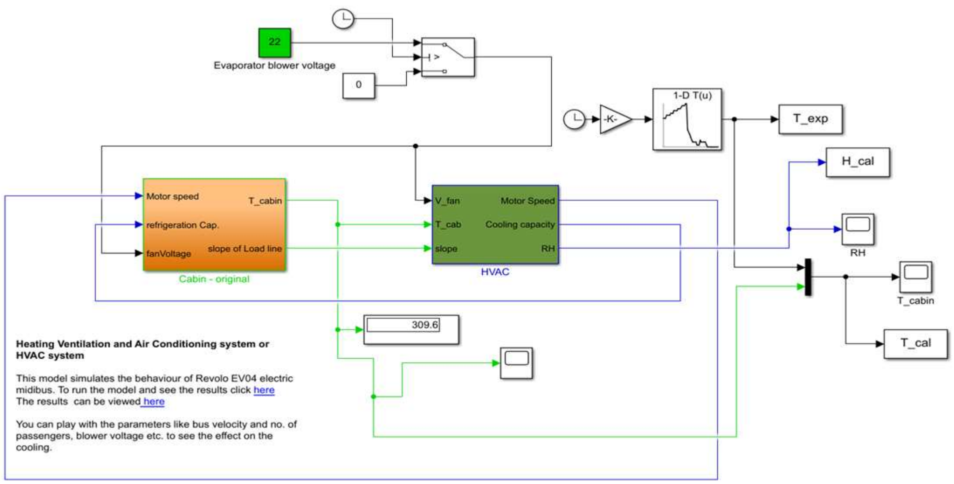
Case: Battery Liquid Cooling Model Validation

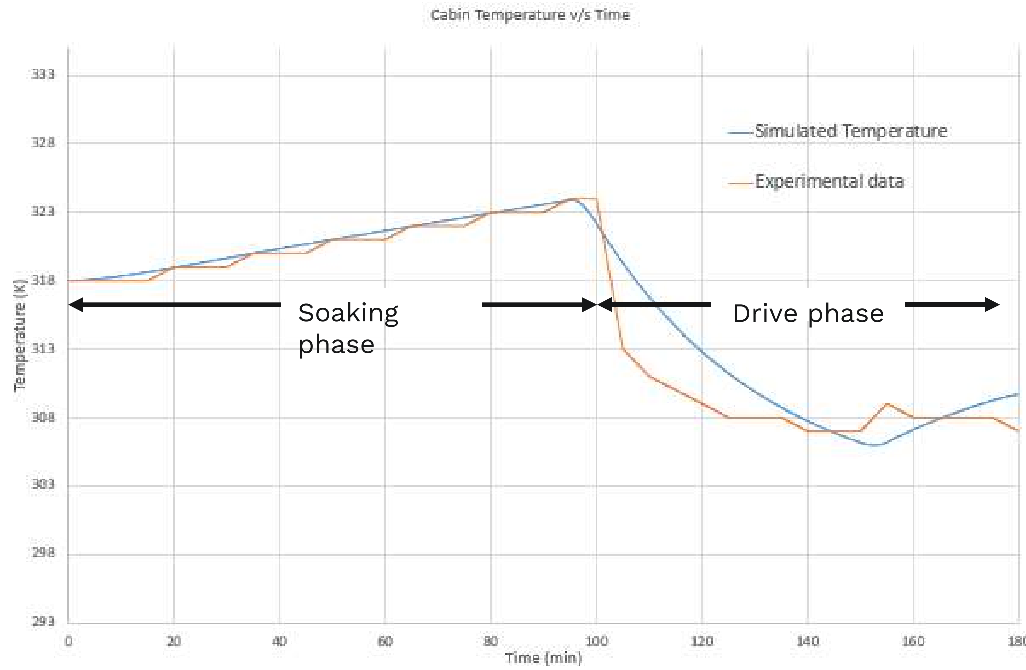




- When validated with available test data, the convergence was seen and a tolerance of 1 K was observed in the battery temperature data generated by simulation.
- A battery module was used for the experiment.

Case: HVAC(Heating Ventilation and Air Conditioning) Model Validation





- Validated with available data, convergence was seen with a tolerance of 3.5 K was observed in the cabin temperature data generated by simulation.

Fault Injection

Motor Faults

- Phase to Ground Short
- Double Phase Short Circuit
- Double Phase to Ground
- Three Phase Short Circuit
- Three Phase to Ground
- Single Phase Open Fault
- Single Phasing followed by another open Phase

Inverter Faults

- Open Circuit in one IGBT
- Open circuit in two IGBTs of same/different leg
- IGBT Short circuit fault
- Jitter Fault in one/ both IGBTs of the same leg
- Short Circuit across DC Link through a resistor

Contactor Faults

- De-latch fault
- Latch Fault
- Chattering Fault

Wire Faults

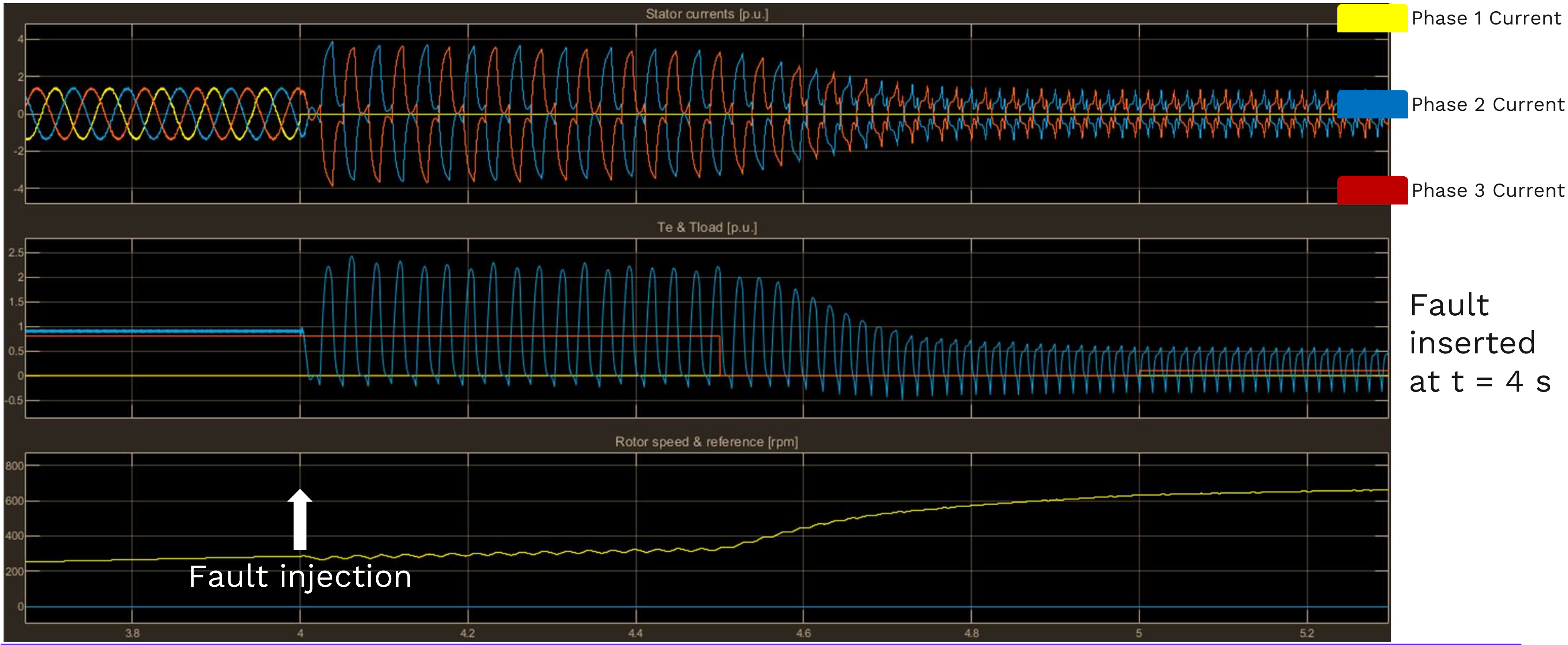
- Open Circuit
- Short Circuit
- Chattering of connection

Thermal Faults (integration in Progress)

- Motor Over temperature
- Battery Over temperature
- IGBT Over temperature

Test Case: (Motor Single-Phasing Fault)

- The average torque remains the same and the same power is delivered by the remaining two stator phases. So, value of current in each phase increases and the third phase, being open, carries zero current.



Fault inserted at t = 4 s

Test Case: (Contactor Chattering Fault)

- The relay/Contactor shows a repeated ON-OFF behavior due to the chattering fault injected at t=4.5s. This leads to a pattern showing torque production upto reference torque i.e, 0.4 p.u. and consequent reduction of torque till zero.

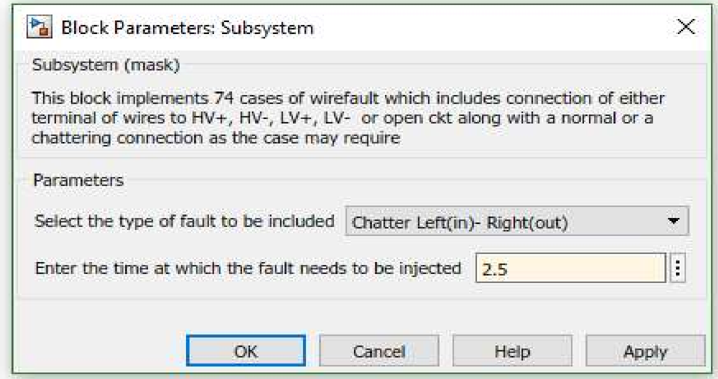
Fault inserted at t = 4.5 s

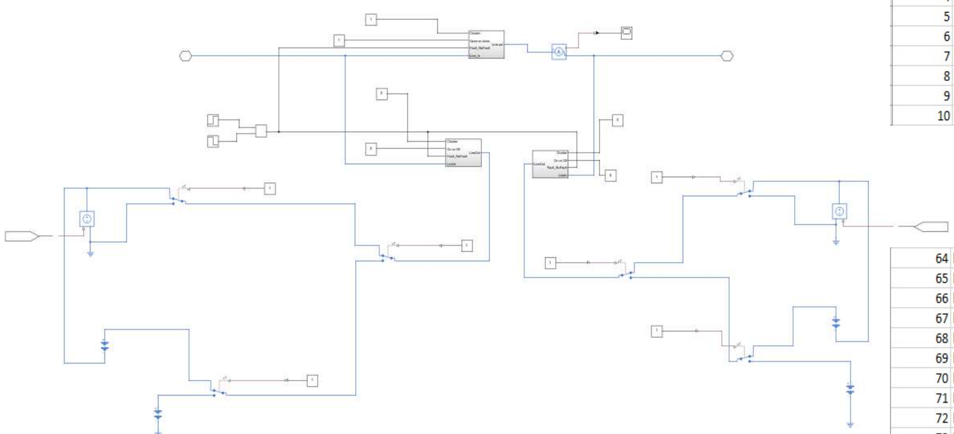
Developed Torque
Load Torque

Wire Faults :

Wire faults are the faults arising out of a loose or broken electrical connection which can be categorized into chatter, open and short circuit at either terminal

User has the flexibility to insert a selected type of wire fault at defined instants to check effect of faults at various instants during the operation of the drive





Fault Numb	Fault Description	WirePar	WirePar1	WirePar2	WireParL1	WireParL2	WireParL3	WireParR1	WireParR2	WireParR3	ChatterOrNOT	ChatterOrNOTL	ChatterOrNOTR
0	No Fault	1	0	0	0	0	0	0	0	0	0	0	0
1	Chatter Left(in)- Right(out)	0	0	0	0	0	0	0	0	0	1	0	0
2	left(in)- right(out) open circuit	0	0	0	0	0	0	0	0	0	0	0	0
3	left(in) open - right(out) HV GND	0	0	1	0	0	0	0	0	0	0	0	0
4	left(in) open - right(out) HV GND chatter	0	0	0	0	0	0	0	0	0	0	0	1
5	left(in) open - right(out) LV GND	0	0	1	0	0	0	0	1	0	0	0	0
6	left(in) open - right(out) LV GND chatter	0	0	0	0	0	0	0	1	0	0	0	1
7	left(in) open - right(out) HV+	0	0	1	0	0	0	1	0	0	0	0	0
8	left(in) open - right(out) HV+ Chatter	0	0	0	0	0	0	1	0	0	0	0	1
9	left(in) open - right(out) LV+	0	0	1	0	0	0	1	0	1	0	0	0
10	left(in) open - right(out) LV+ chatter	0	0	0	0	0	0	1	0	1	0	0	1
64	left(in) LV+ - right(out) HV+ chatter	0	1	0	1	0	1	1	0	0	0	0	1
65	left(in) LV+ - right(out) LV+	0	1	1	1	0	1	1	0	1	0	0	0
66	left(in) LV+ - right(out) LV+ chatter	0	1	0	1	0	1	1	0	1	0	0	1
67	left(in) LV+ chatter - right(out) HV GND	0	0	1	1	0	1	0	0	0	0	1	0
68	left(in) LV+ chatter - right(out) HV GND chatter	0	0	0	1	0	1	0	0	0	0	1	1
69	left(in) LV+ chatter - right(out) LV GND	0	0	1	1	0	1	0	1	0	0	1	0
70	left(in) LV+ chatter - right(out) LV GND chatter	0	0	0	1	0	1	0	1	0	0	1	1
71	left(in) LV+ chatter - right(out) HV+	0	0	1	1	0	1	1	0	0	0	1	0
72	left(in) LV+ chatter - right(out) HV+ chatter	0	0	0	1	0	1	1	0	0	0	1	1
73	left(in) LV+ chatter - right(out) LV+	0	0	1	1	0	1	1	0	1	0	1	0
74	left(in) LV+ chatter - right(out) LV+ chatter	0	0	0	1	0	1	1	0	1	0	1	1

A total of 74 wire fault cases can be permuted based on the nature of the wire fault to be inserted.

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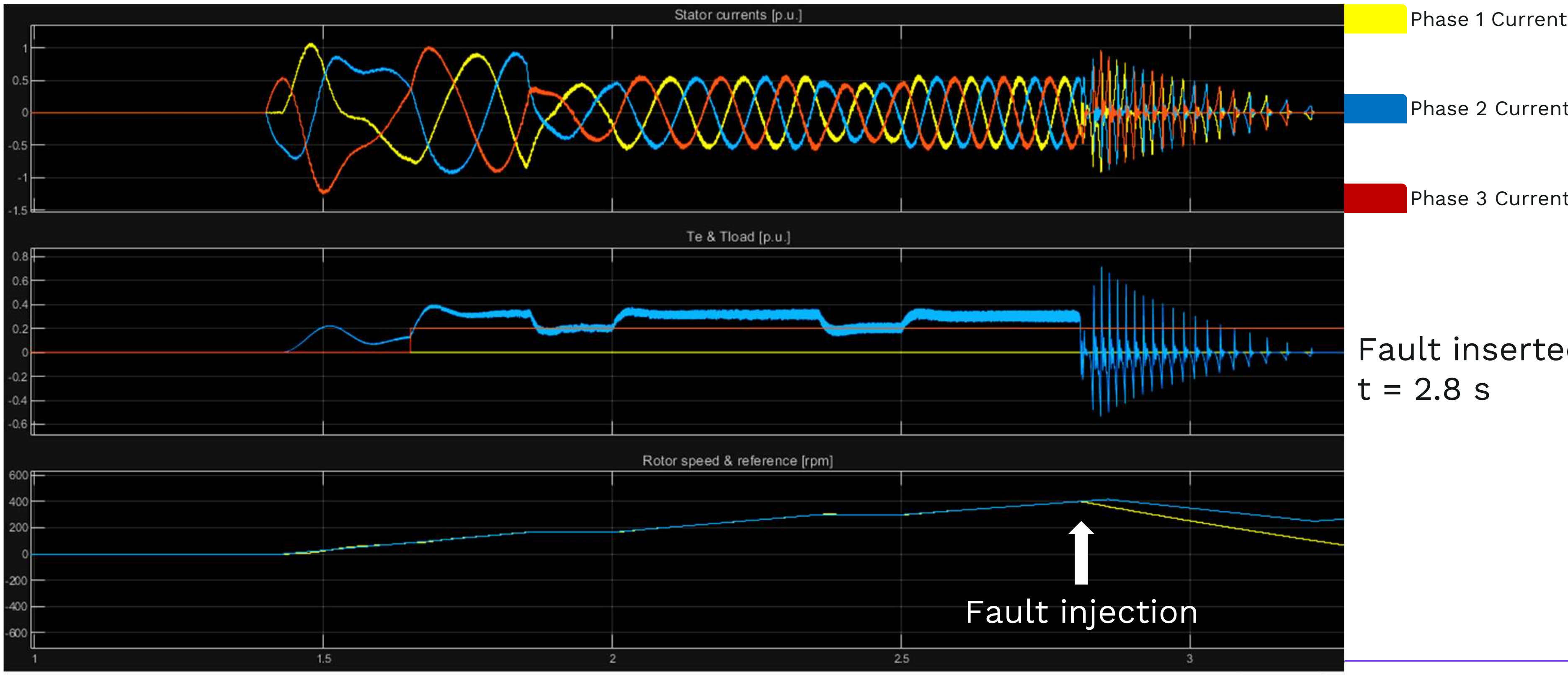
Test Case: (Open circuit Wire fault in Battery supply B+)

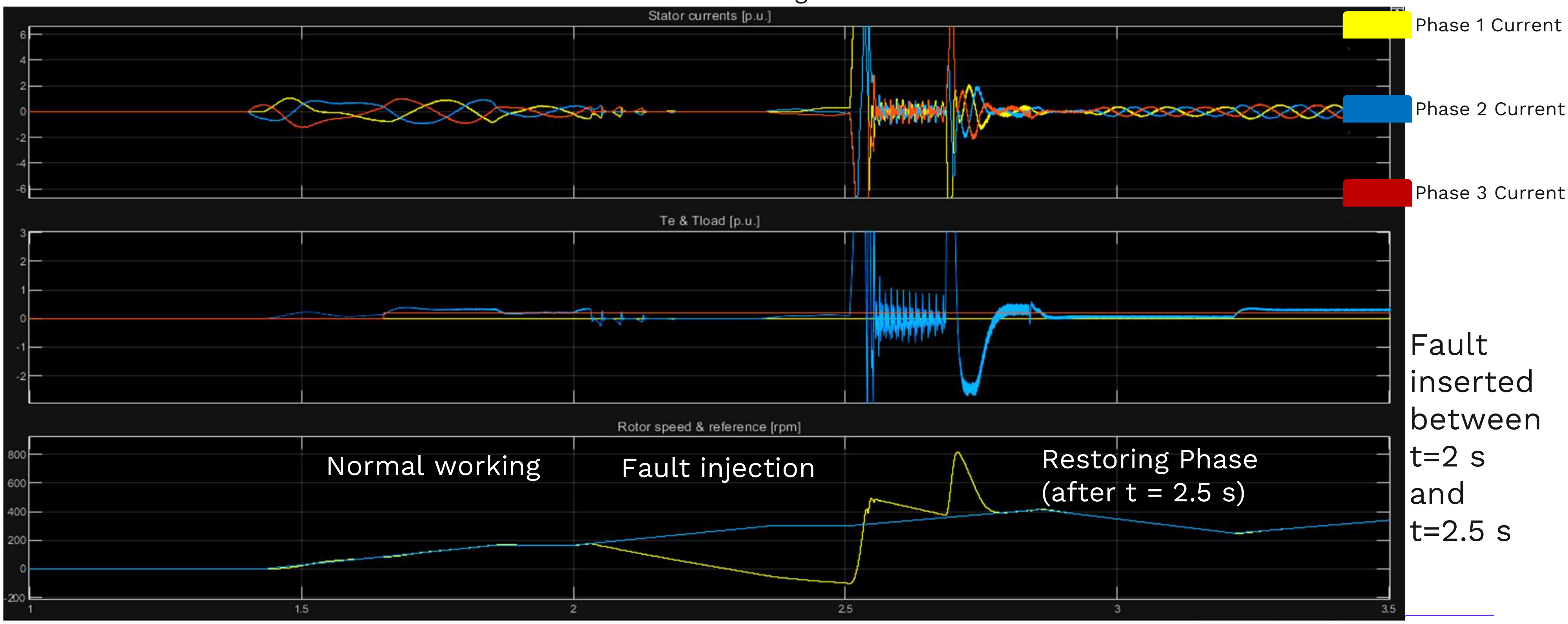
- The battery supply gets disconnected due to fault in wire and the stator currents are seen to decay gradually. The stator currents after the open circuit fault insertion is supplied by the dc link capacitor.



Fault inserted at t = 2.8 s

Test Case: (chatter Wire fault in contactor excitation coil)

- Chatter wire fault was injected into the relay excitation coil which is having no direct effect on the power system. The chatter lasting for 0.5s disrupts the drive behavior. The chatter results in failing of excitation, thereby preventing any electromechanical action. The drive restores its normal working condition after the fault is removed.



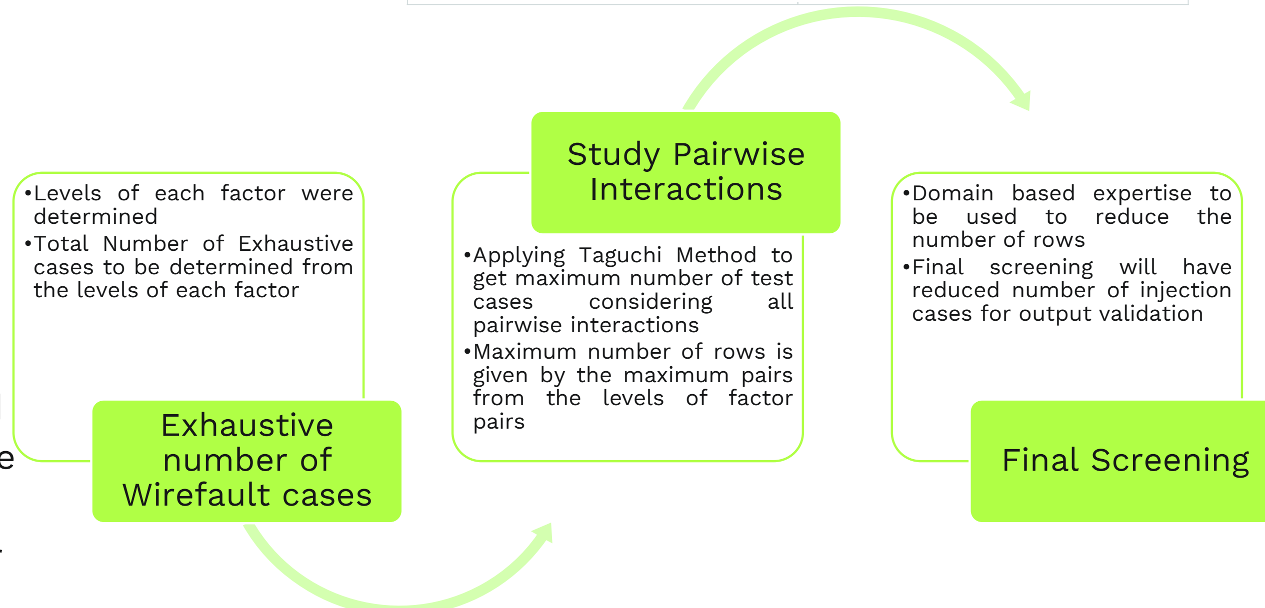
Fault inserted between t=2 s and t=2.5 s

Wirefault Injection

Arriving at an optimum number of cases

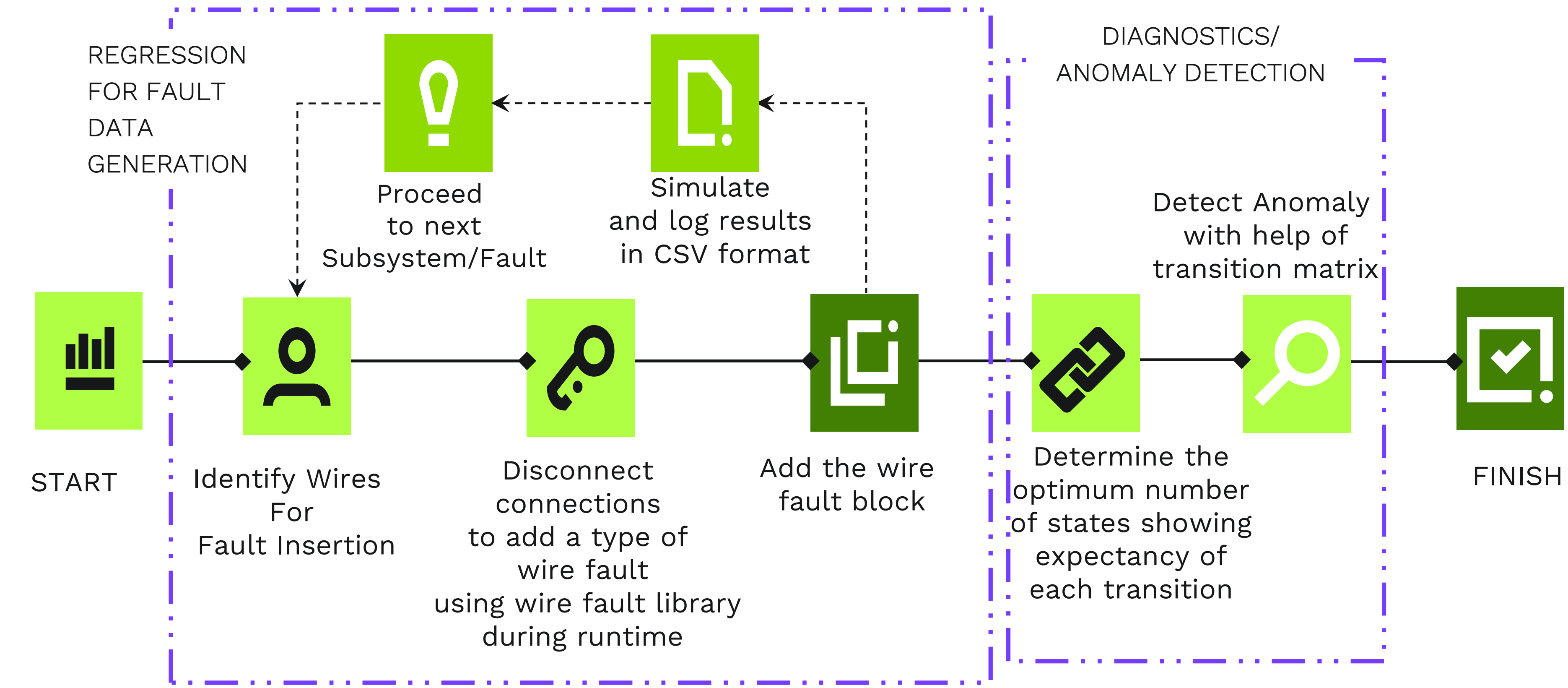
Factors	Levels
Type of Wire fault	74
Time instance of injection	3
Wire selected for Injection	~100

- Pairwise interactions with three factors: $^{74}C_1 \; x \; ^{3}C_1 \; , ^{3}C_1 \; x \; ^{100}C_1 \; , ^{100}C_1 \; x \; ^{74}C_1$
- The maximum number of rows to be considered is $^{100}C_1 \; x \; ^{74}C_1$
- All other pairwise interactions are included within the above number of cases
- Final number of cases to be screened to be done based on domain expertise and probability of occurrence of the fault based on its physical location or proximity to certain subsystems



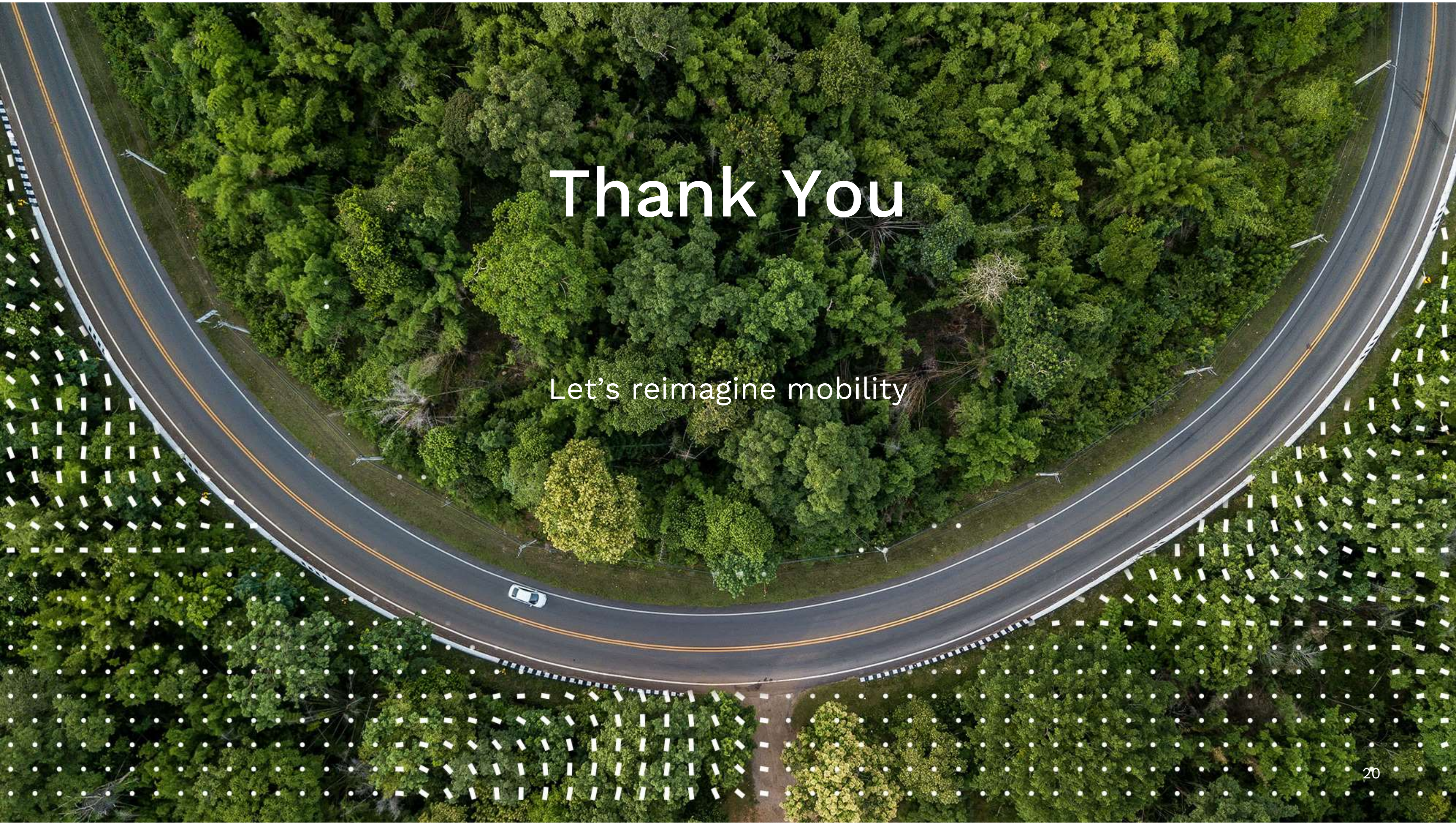
Wire Fault Injection Algorithm

Algorithm architected to run a regression for every wire fault in every subsystem



Highlights

Importance	Experience and Challenges	Benefits
Virtual Failure Modes and Effect Analysis(FMEA) with occurrence detection and severity analysis	Need to achieve low simulation time for executing an iterative simulation process for different test cases without compromising much on fidelity	Minimization of time and resources used by the Manufacturers
Minimizing the occurrence of damages and mitigate the severity of the faults on physical system	Need for extensive data gathering for trying different frameworks for fault diagnostics	A better sense of trust and increased belief in the brand amidst the Users
Makes way for Future Diagnostics and further Prognostics	It presents a perfect blend of model-based designing and data sciences for fault diagnostics	
Ensures a safer and reliable mobility experience		



Thank You

Let’s reimagine mobility