FIDVR
The transient behavior of loads

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Load modeling issues

Load composition
    lighting
    electronic power supplies
    single phase motors
    three phase motors

Static characteristics (for load flow)
    constant P,Q   constant I,B   constant G,B   variations on the theme

Behavior in transients
    stay-on/shutdown   discharge and LED lighting
    slow-down/reaccelerate   miscellaneous motors
    run/stall   residential air conditioners

Asymptotic behavior
    linear dynamics   control gain and bandwidth
    mode changes   sensitivity to voltage/frequency conditions

Load modeling issues

Incandescent lighting / resistance heating
Was/is reasonable to treat as algebraic function of voltage/frequency

Discharge and new-technology lighting
We are increasingly concerned that algebraic modeling is reasonable only within narrow voltage/frequency bands

Large rotating machines - generators/motors
We can model large machines very closely but we are often quite lax about modeling the driven loads

General population motor loads
Phasor-level modeling can reveal characteristics in steady operation but cannot address behavior in the initiating parts of grid transients

Turbine generators

Time scale of 1 - 10 seconds
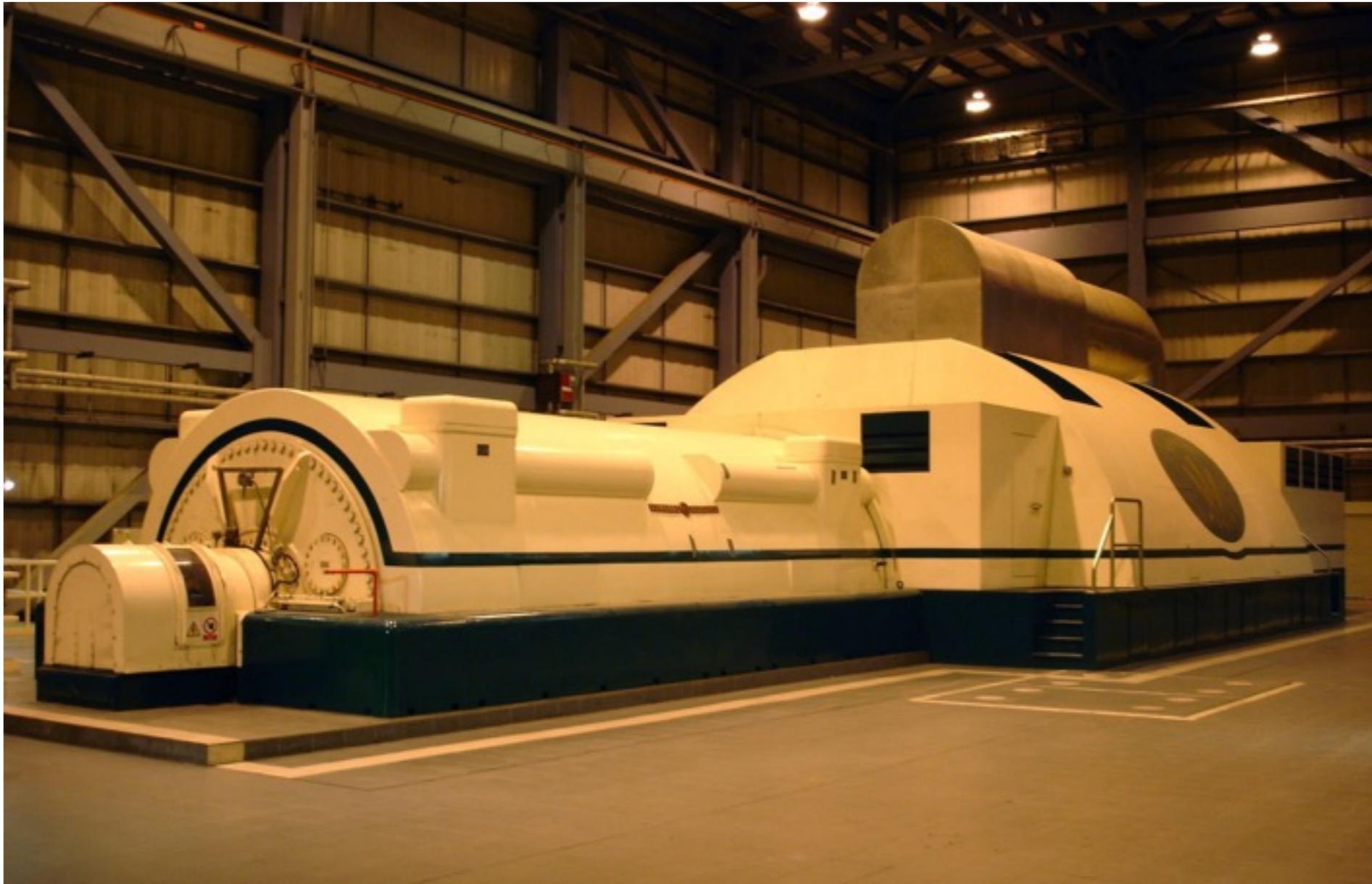
Industrial motors

Inertia constant   ~0.3 sec < H < very large
Time scale of 0.5 - 10 seconds
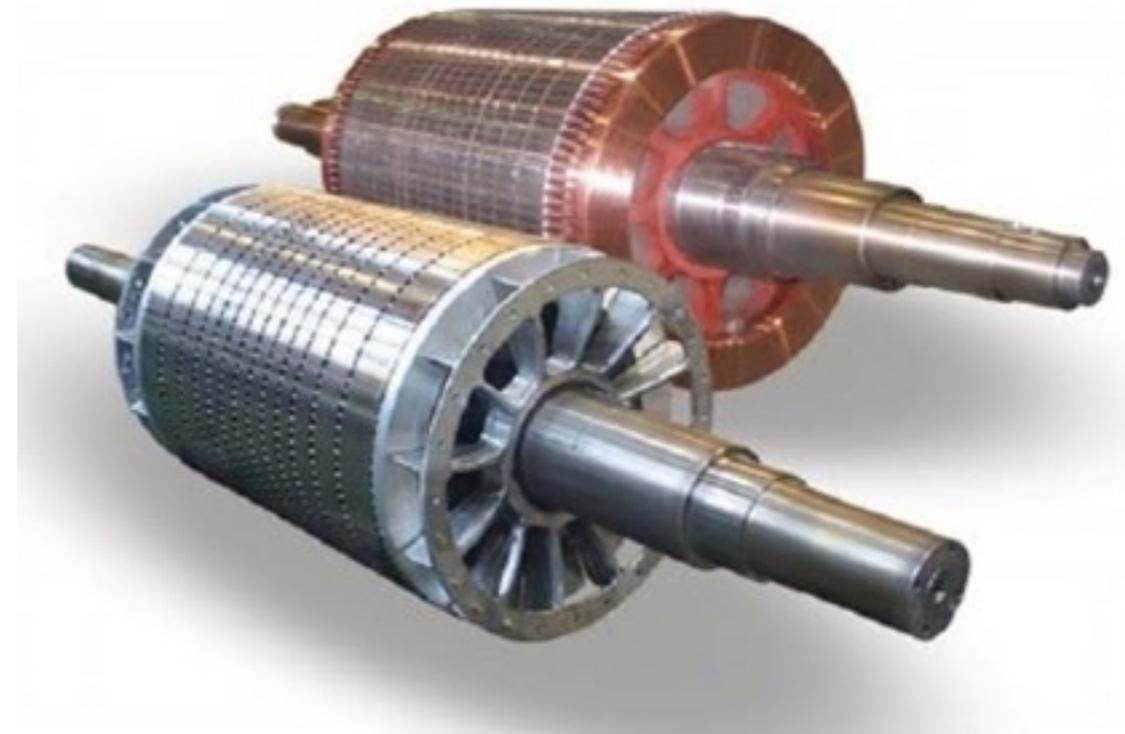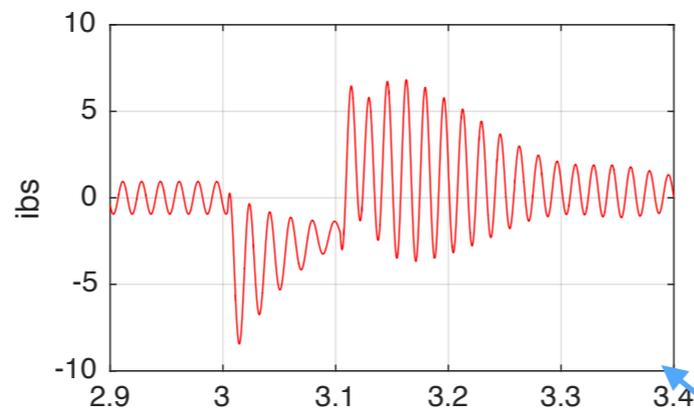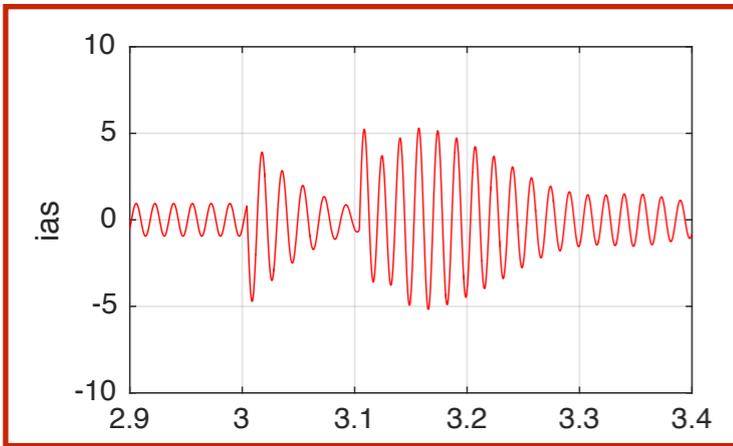
Short circuit at terminals of 100KW three phase motor driving a pump -

H = 0.3 second
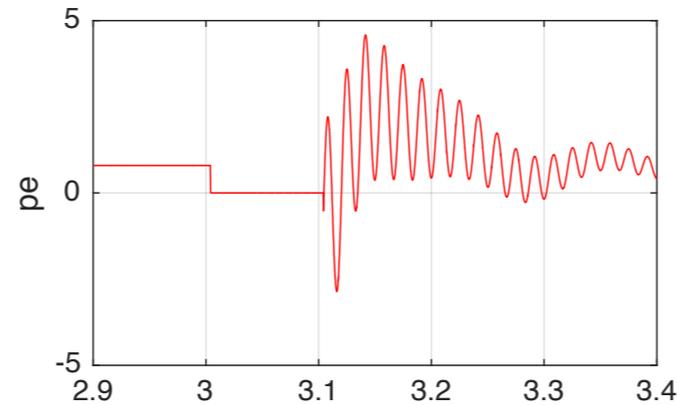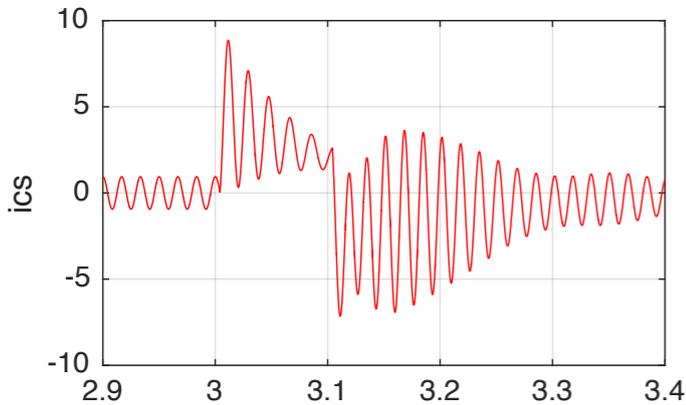
Motor contributes significant short circuit current

Speed dips during fault - reacceleration is decisive
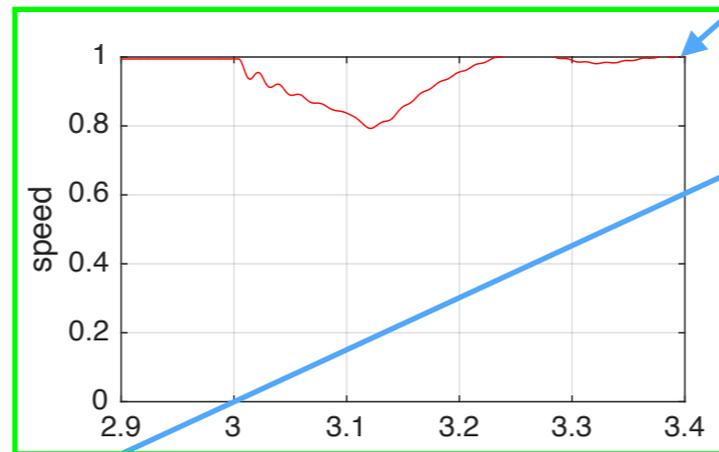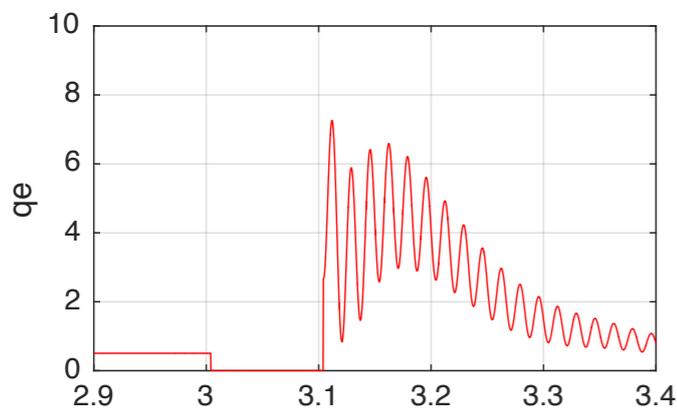
Immediate **negative** peak of torque transient approaches **six times** rated torque

Well understood behavior
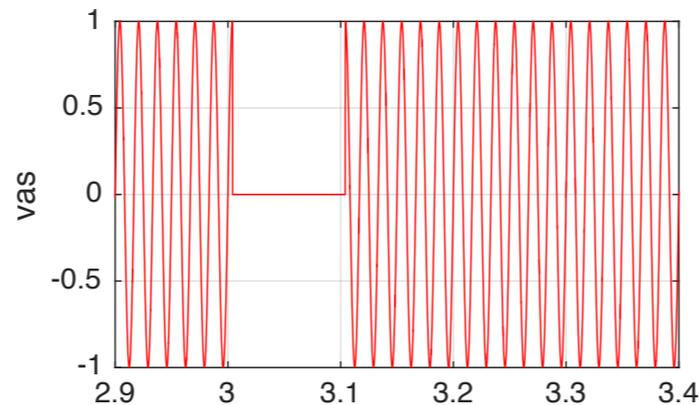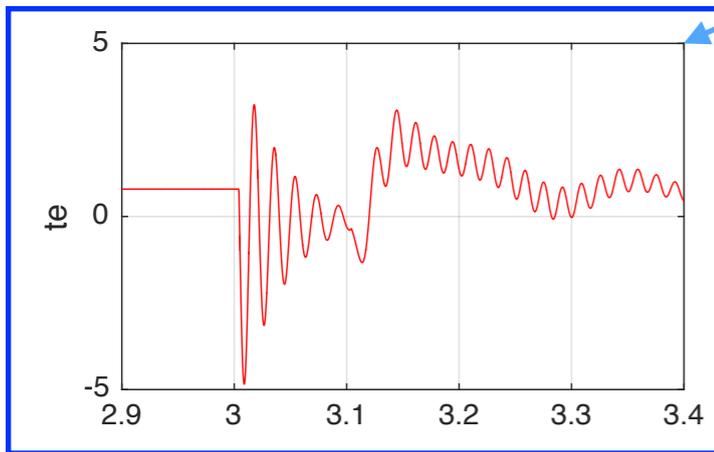
Central to circuit breaker rating standards

Voltage dip at terminals
of 100KW three phase
motor driving a pump -

H = 0.3 second

Current contains AC and unidirectional
components

Reactive power reverses during voltage
dip - motor contributes to support of
voltage

Immediate **negative** peak of torque
transient approaches **six times** rated
torque

Response to alternating torque is
observable in speed transient,
but only to minimal extent
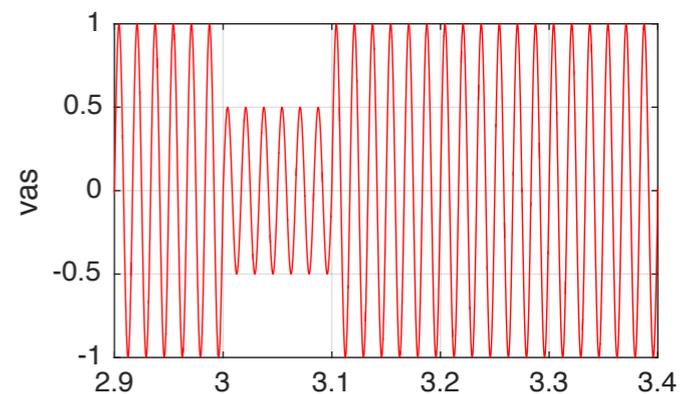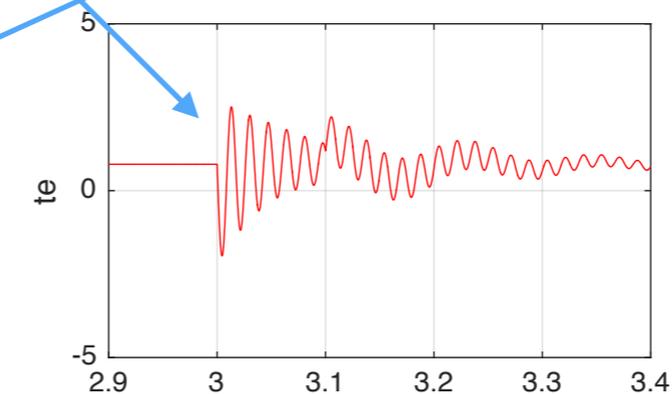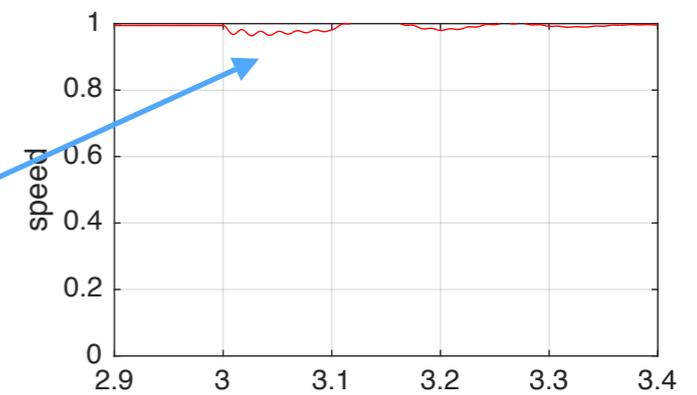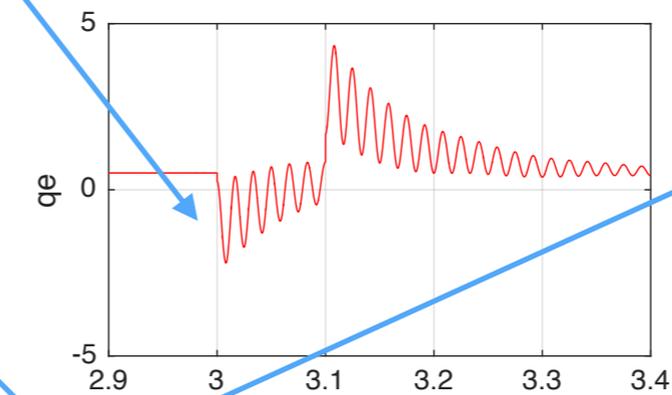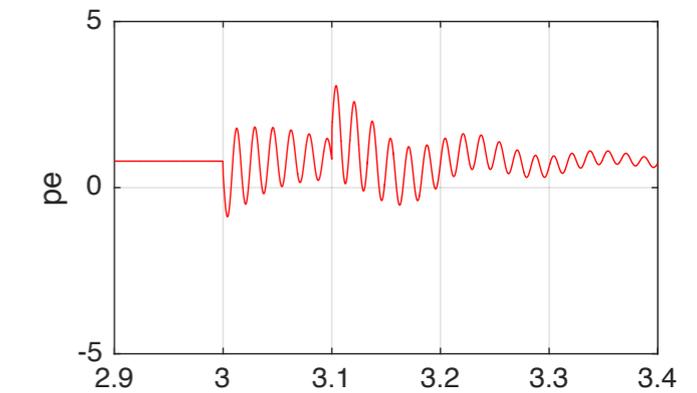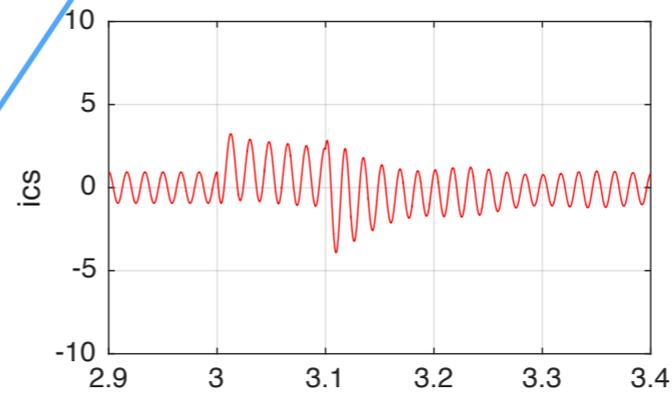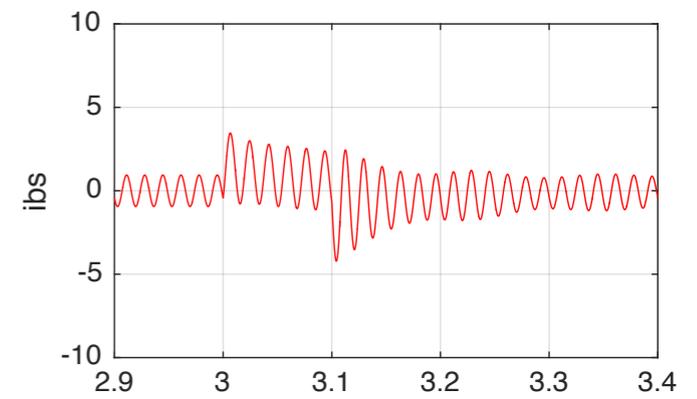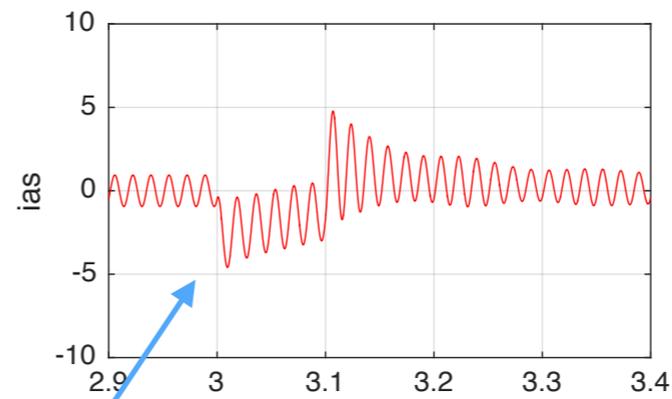
Air conditioner rotor - approximately 5kW

Hmotor ~= 0.05 second
Time scale of tenths of a second

75 mm

310 mm
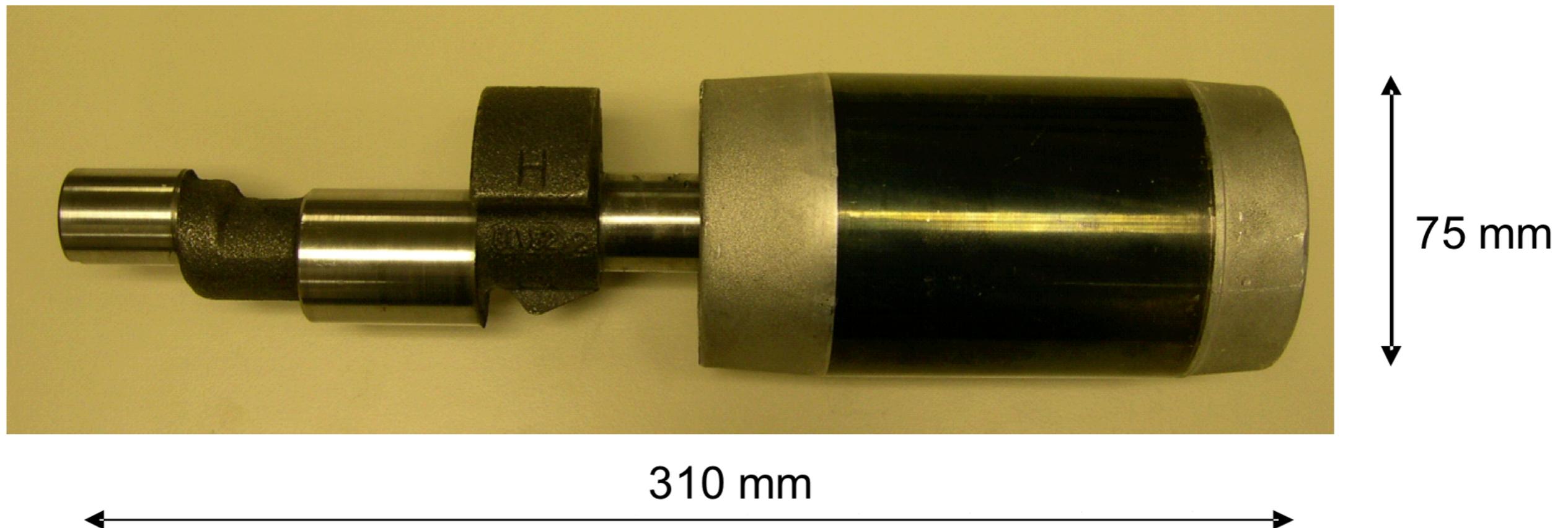
Voltage dip at terminals of 5KW single phase motor driving a residential air conditioner

H = 0.048 second

Speed is pulled down very strongly by the negative electromagnetic torque

Motor stalls and does not restart

Immediate **negative** peak of torque transient approaches **eight times** rated torque

Current drawn by stalled motor is **five times** normal load current
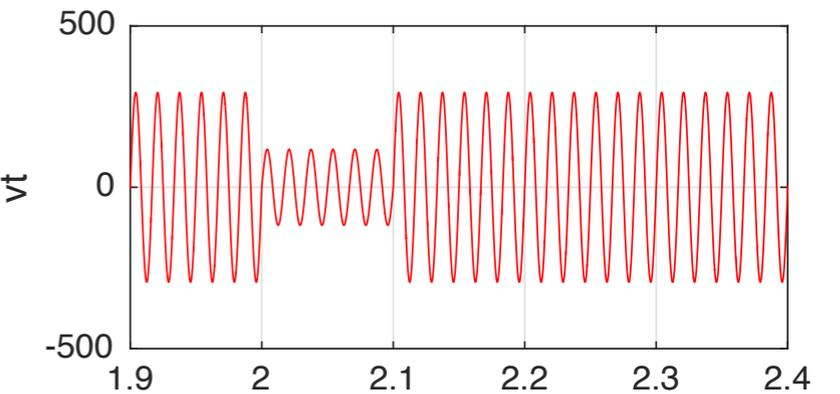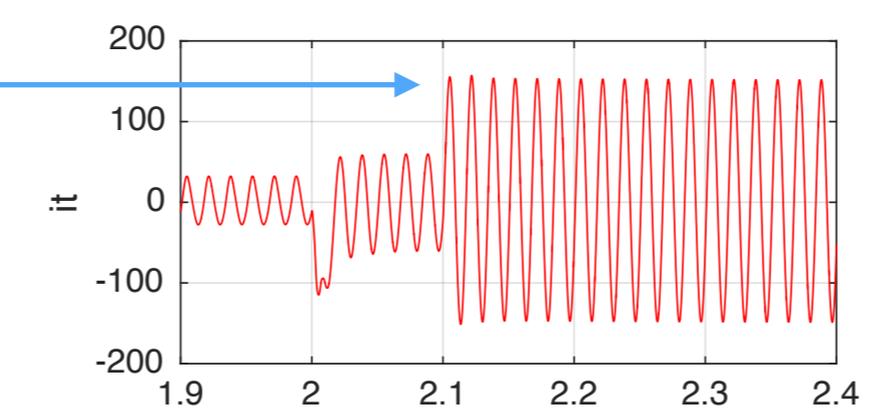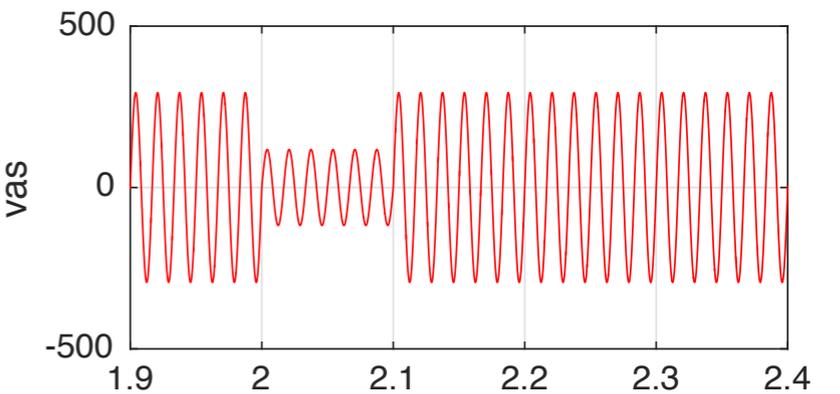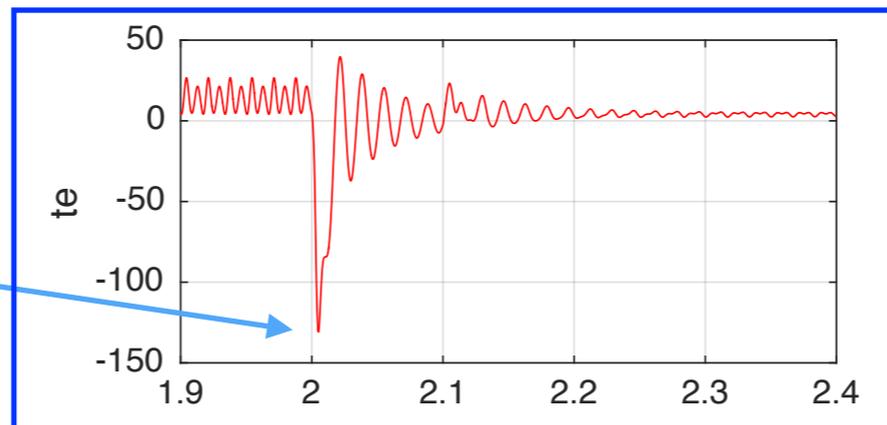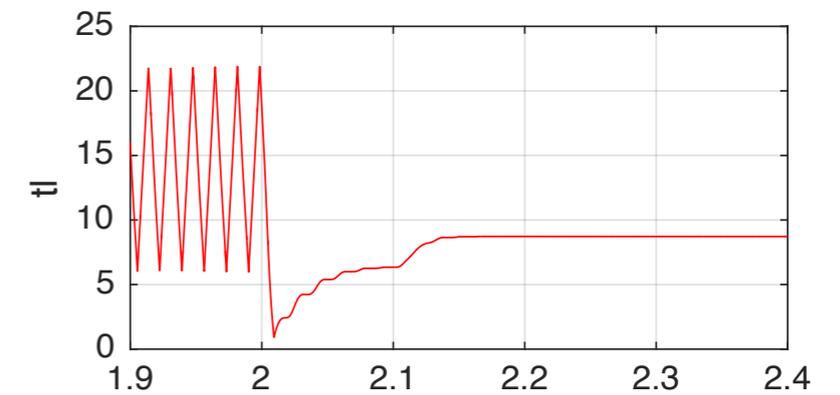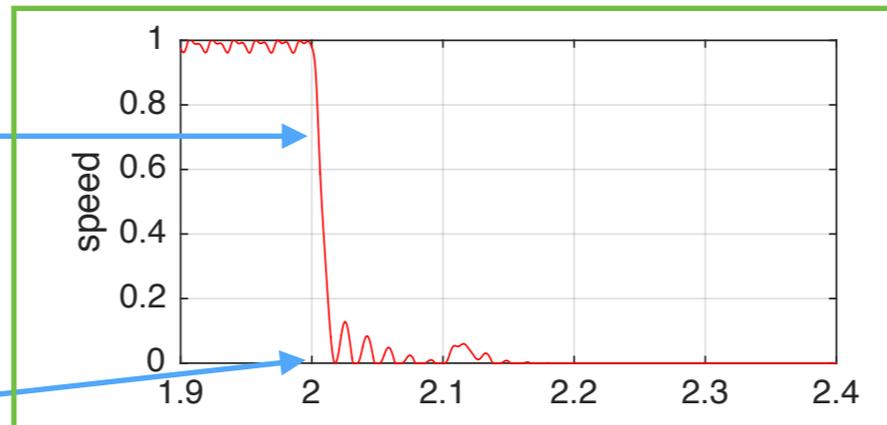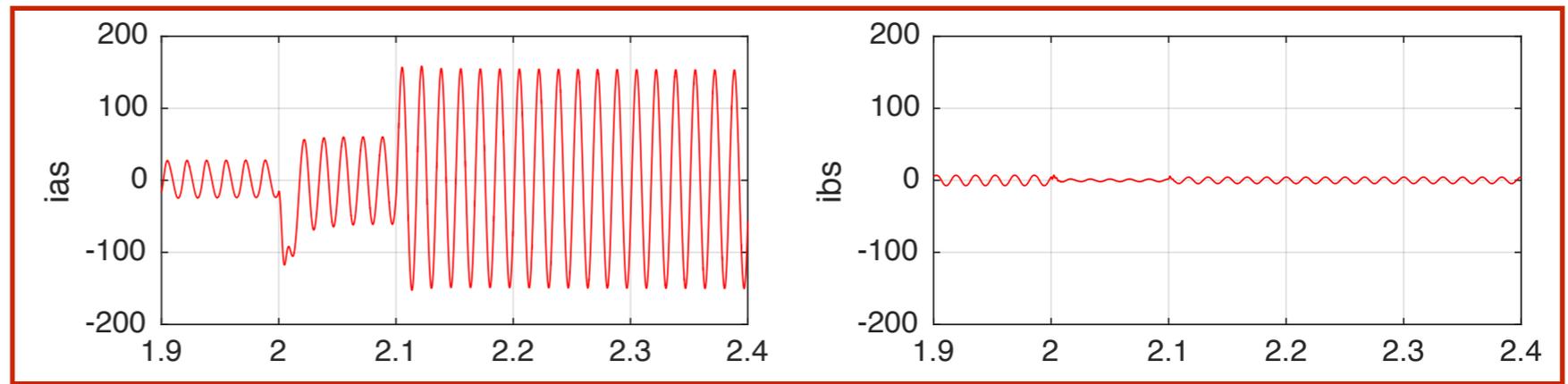
FIDVR is not only a positive sequence issue
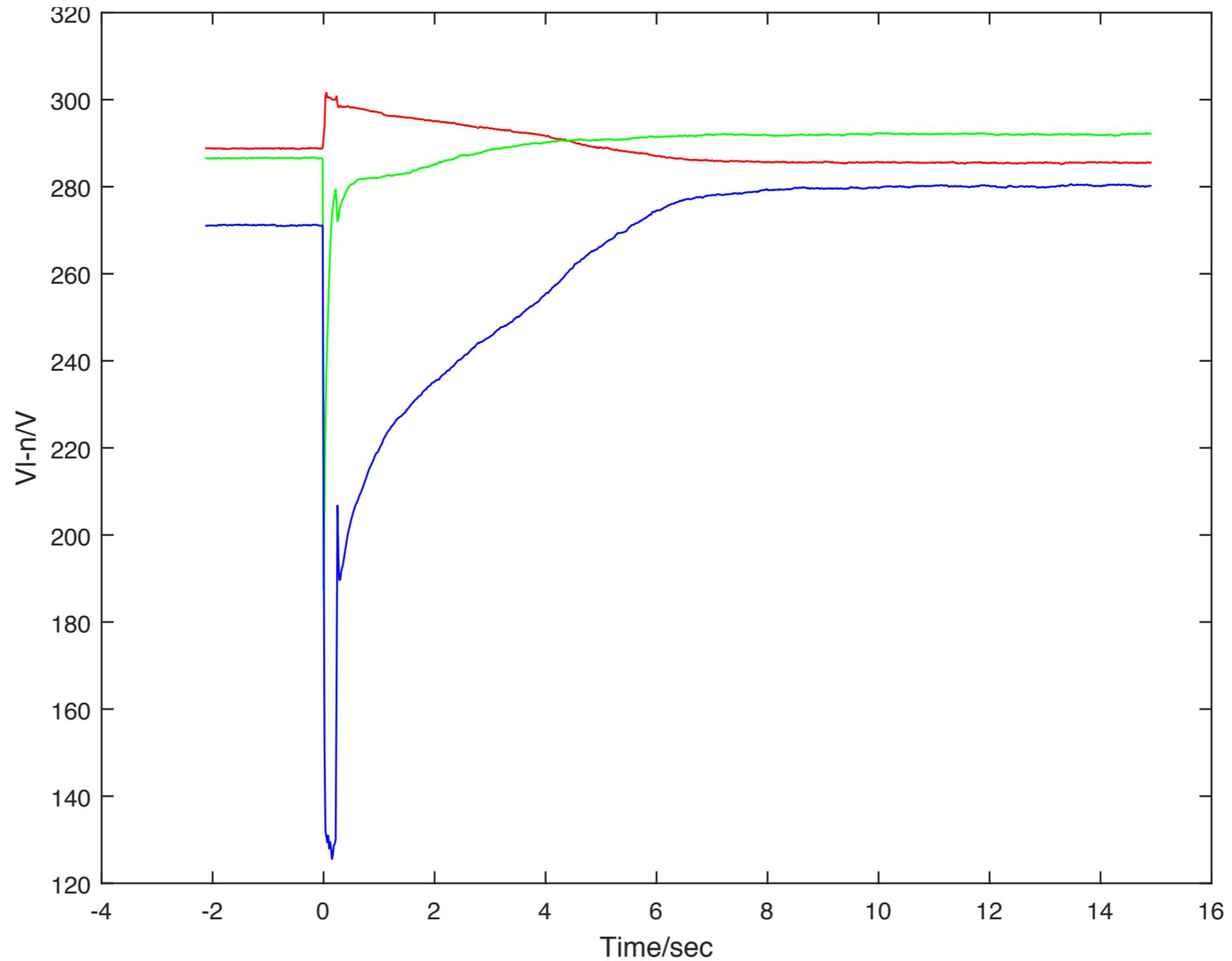
Motor behavior is sensitive to

Supply system impedance

Driven load type and characteristics (torque/speed/angle)

Electrical phase at moment whe voltage dip is initiated

Rate of change of voltage in initiation of voltage dip

Presence of other motors and load on feeders

etc.

electromagnetic torque

speed

load torque

terminal voltage
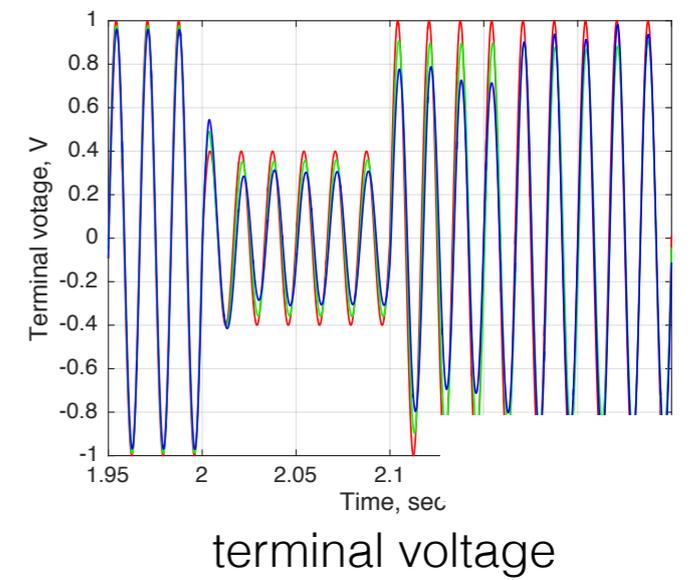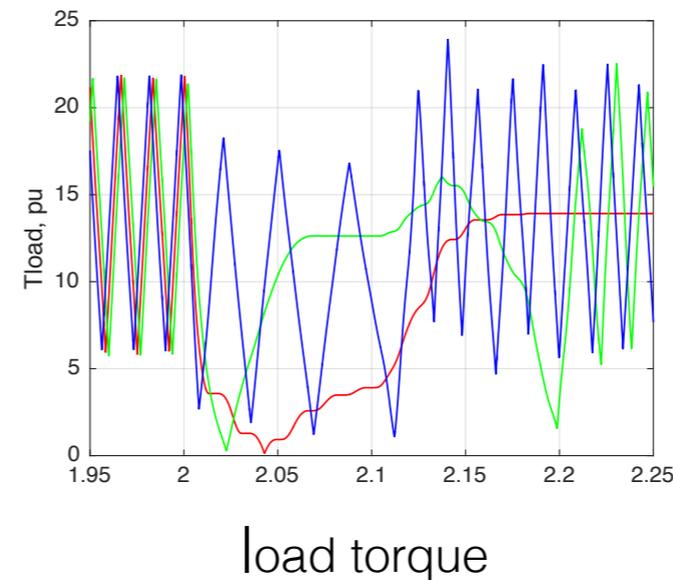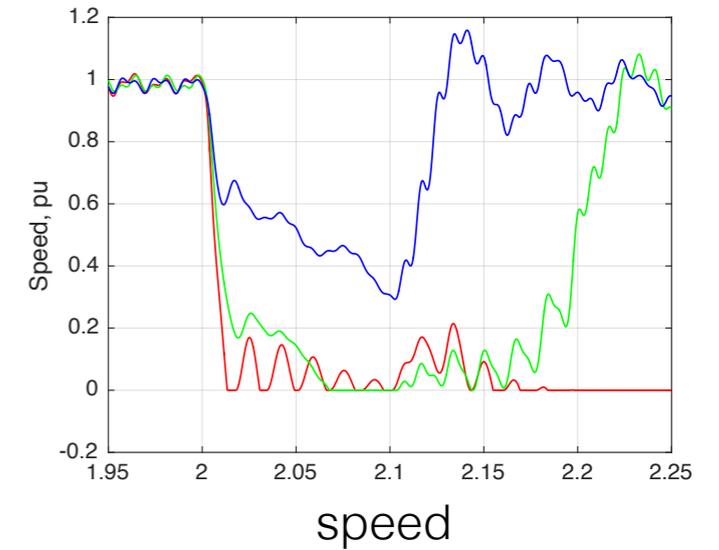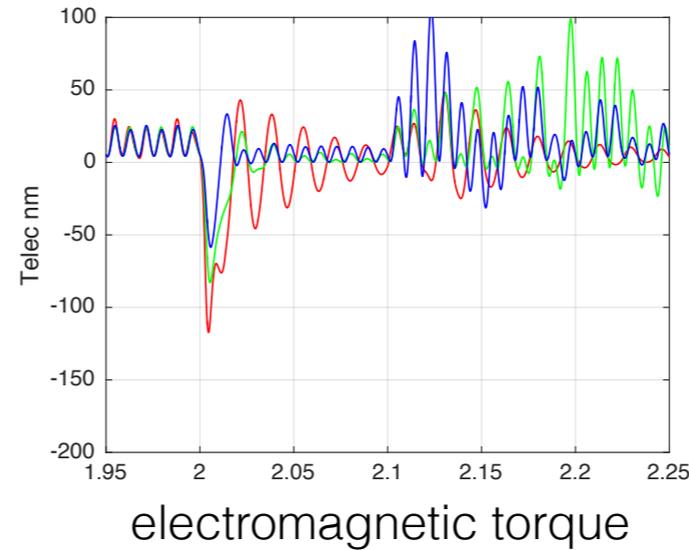
What **generators and large rotating equipment** will do depends on things that we can model with phasor calculation and positive sequence networks

What **small motors and electronic equipment** will do depends on things that happen much faster than can be seen by models based on phasor calculation

We cannot see what we want with   R + jX

We could, *perhaps,* see a lot if we could use   R + Ldi/dt

Even after living through 25 iterations of Moore's law, the computers that I can use are not fast enough or big enough to handle grid-size systems at the di/dt level

When they do become available, the assembly of the required data will be a task of the same scale as we have today

We have to proceed

    based on the physical understanding that we
    have, combined with carefully assembled
    empirical information

      there are practical steps that we should take

End