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 $\sim 0.3 \text{ sec} < H < \text{very large}$

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 $\approx 0.05$ second
Time scale of tenths of a second
Voltage dip at terminals of 5KW single phase motor driving a residential air conditioner

\[ H = 0.048 \text{ second} \]

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 when voltage dip is initiated

Rate of change of voltage in initiation of voltage dip

Presence of other motors and load on feeders etc.
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 $R + L\frac{di}{dt}$.

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 $\frac{di}{dt}$ 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