Reactive Power and Load Transient Behavior Issues

John Undrill
EAC September 2015

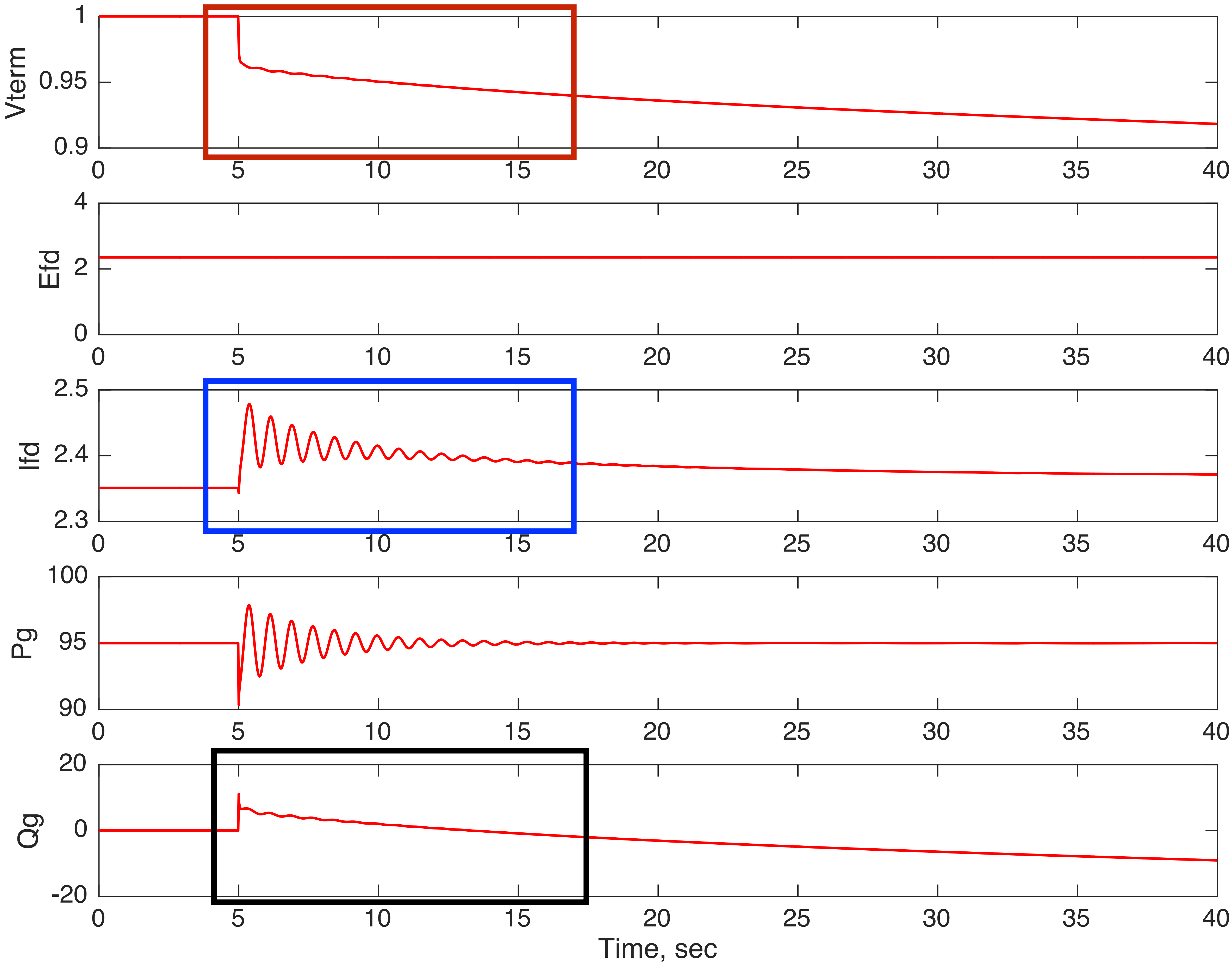
100 MVA Generator Manual excitation control

Initial near-instantaneous increase in reactive power output

Initial near-instantaneous increase in field current

Increase in reactive power output fades and reverses as generator field current returns to original value

Supporting increase in reactive output is present for many seconds



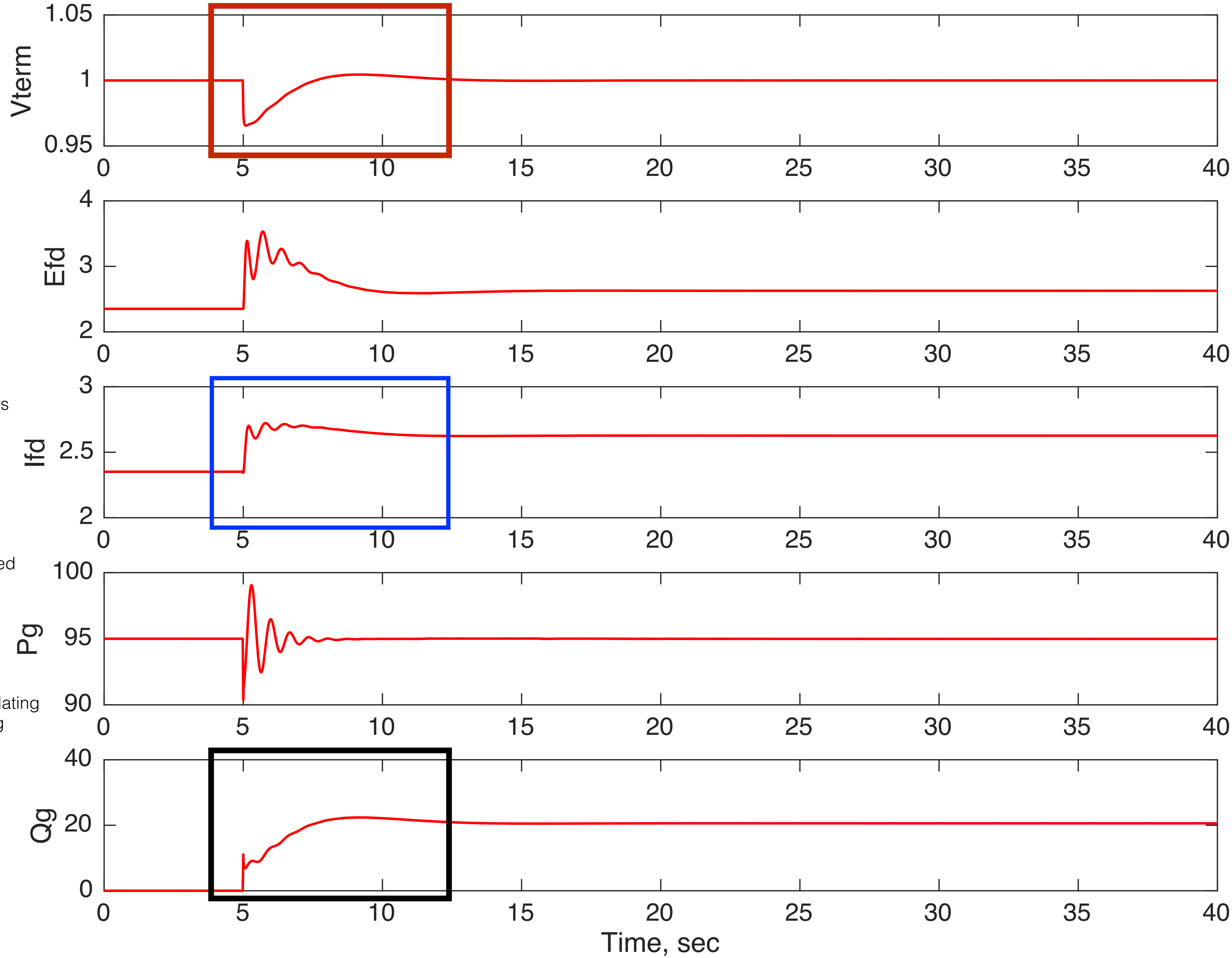
100 MVA Generator
Automatic voltage
regulator

Initial near-instantaneous increase in reactive power output

Same initial increase in field current

Increase in reactive power output is sustained and augmented by voltage regulator action

Operation of excitation controls in voltage regulating mode is a long-standing requirement

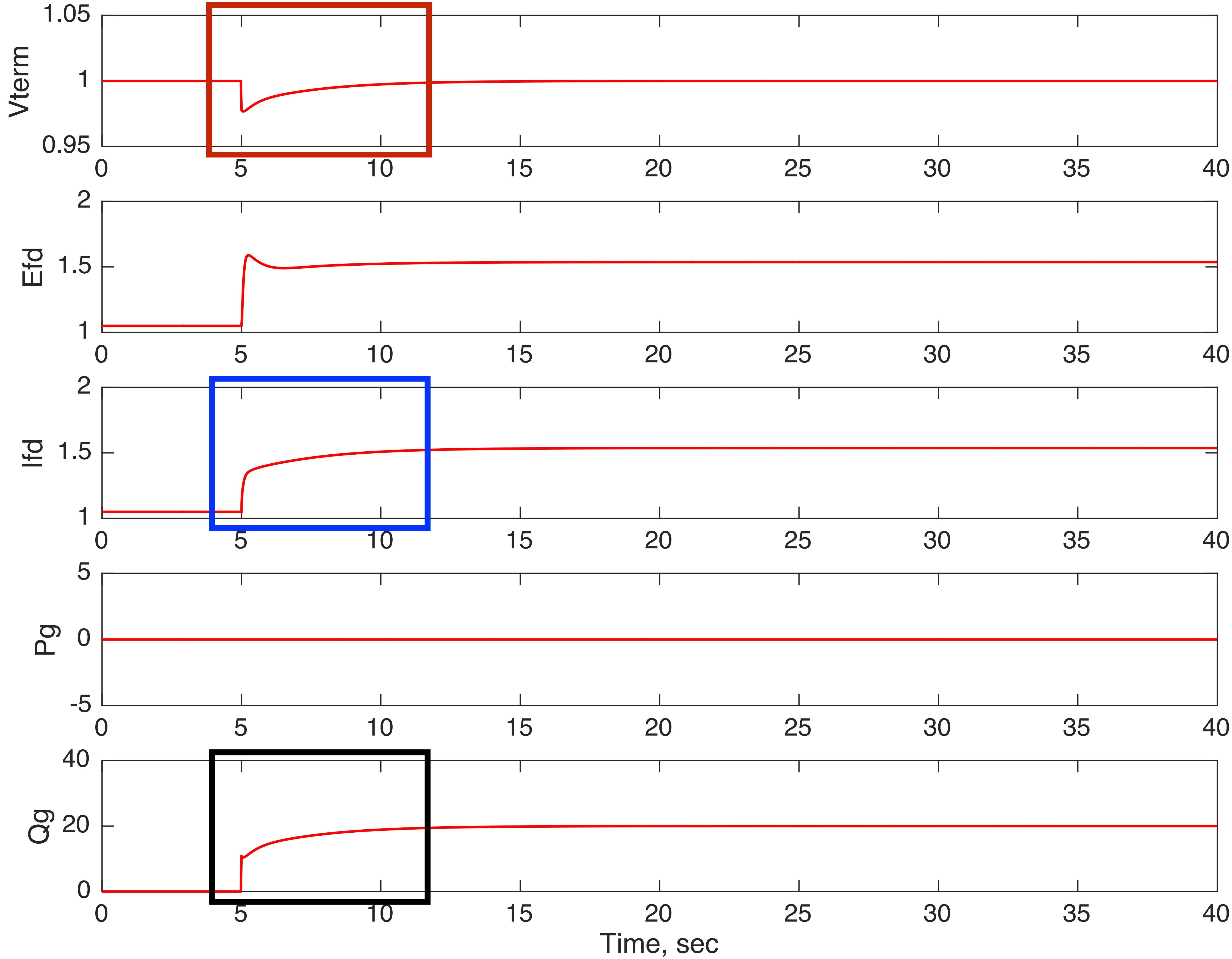


100 MVA Synchronous Condenser
Automatic voltage regulator

Initial near-instantaneous increase in reactive power output

Same initial increase in field current

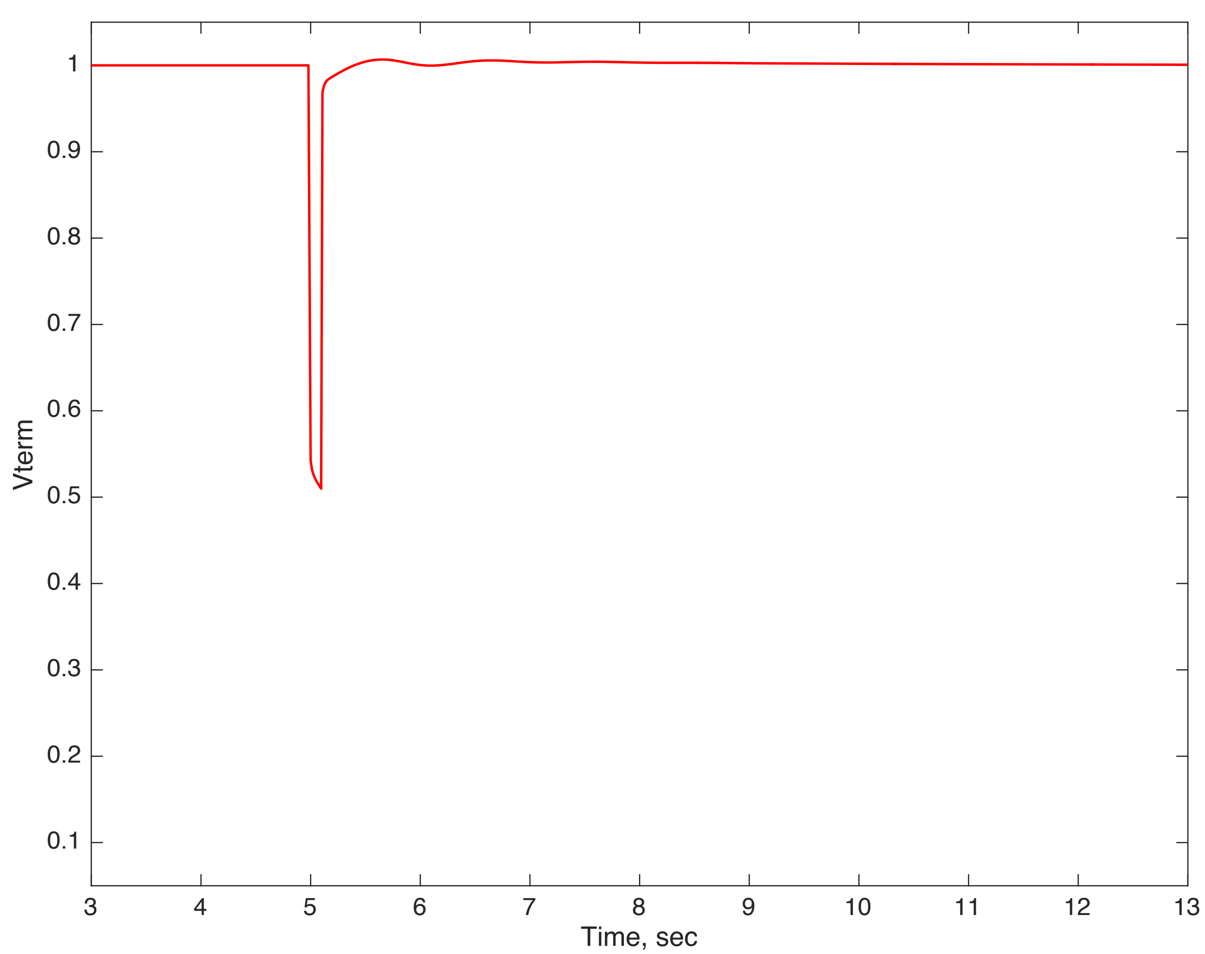
Increase in reactive power output is sustained and augmented by voltage regulator action



Voltage dip and recovery

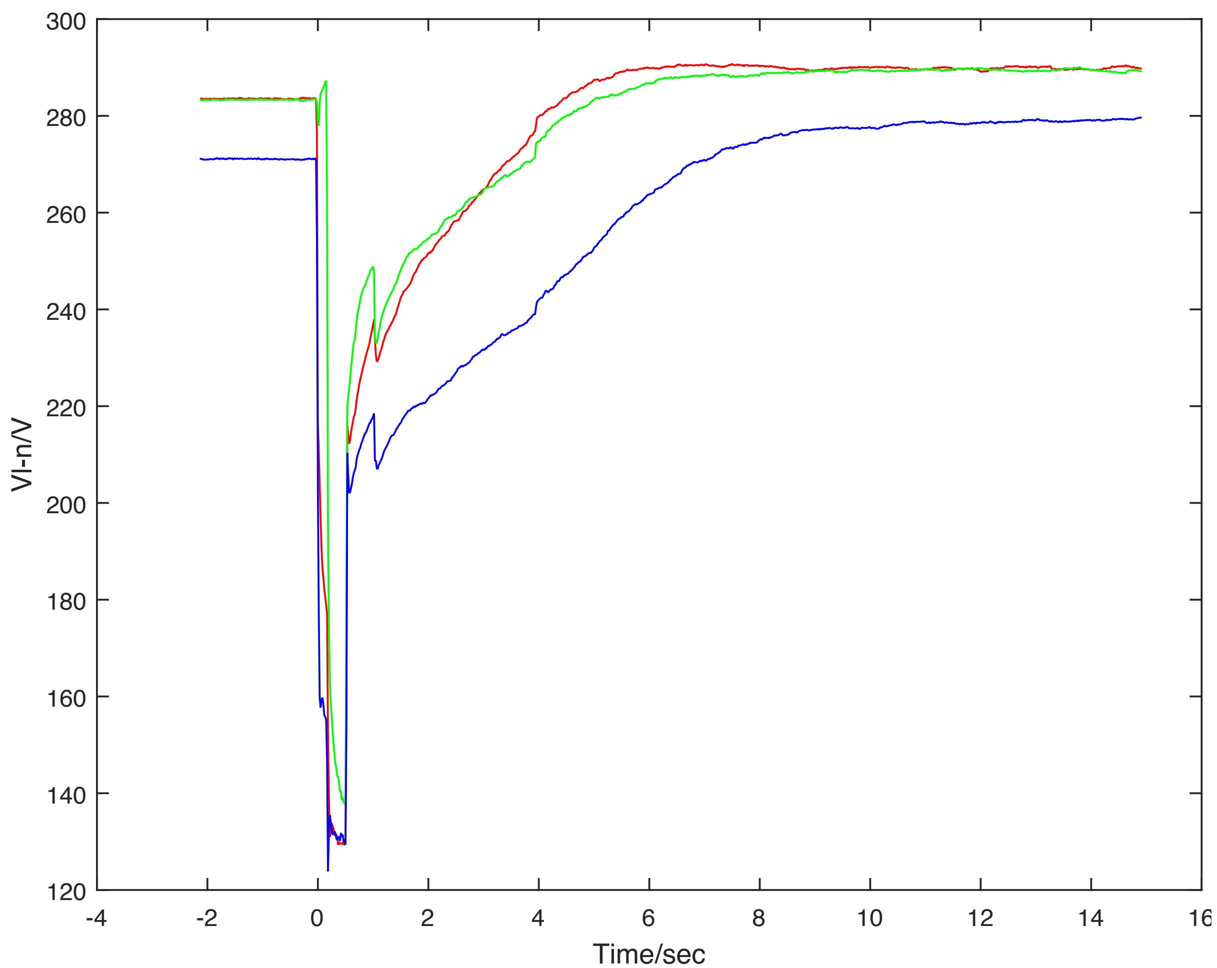
In many cases simulations show results

like this



Now-available recording technology shows recordings of reality

like this

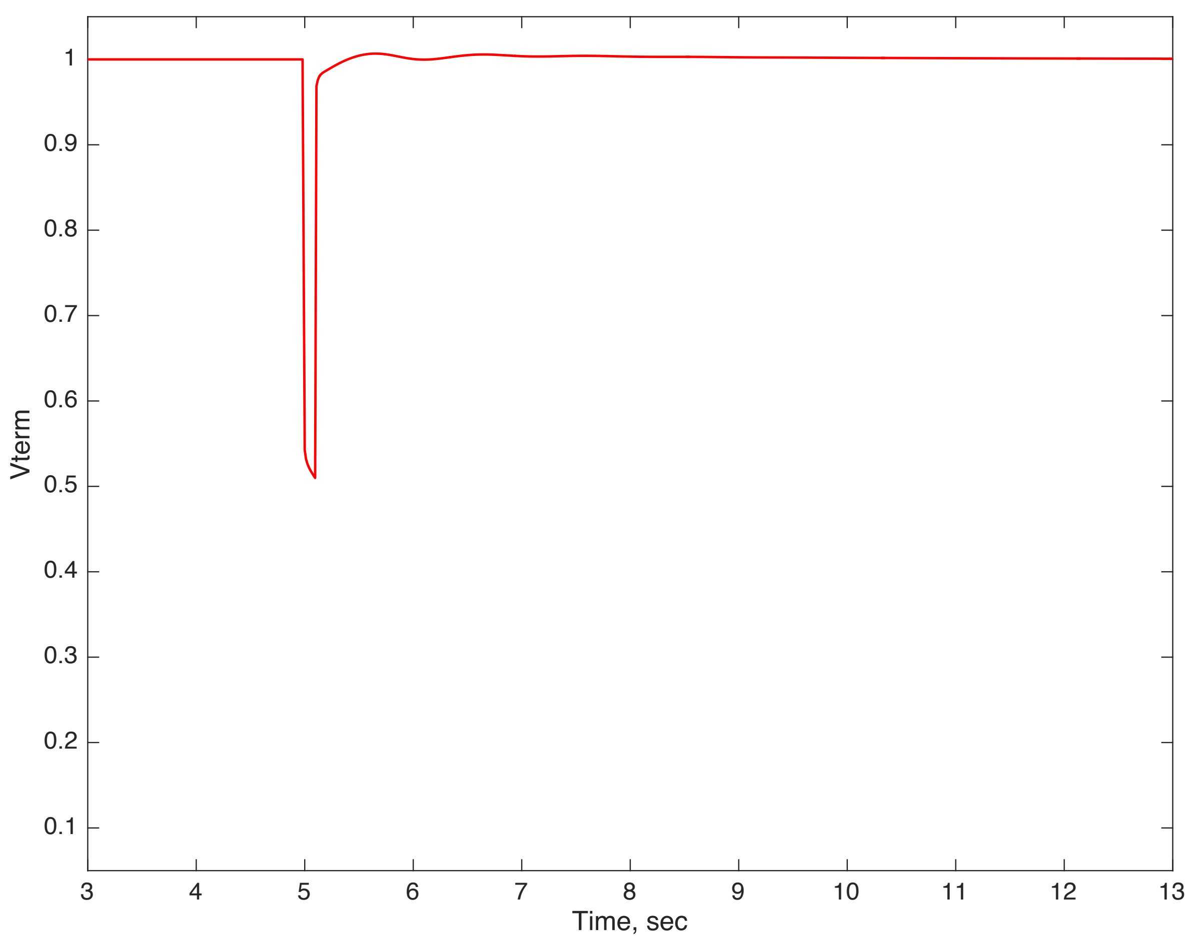


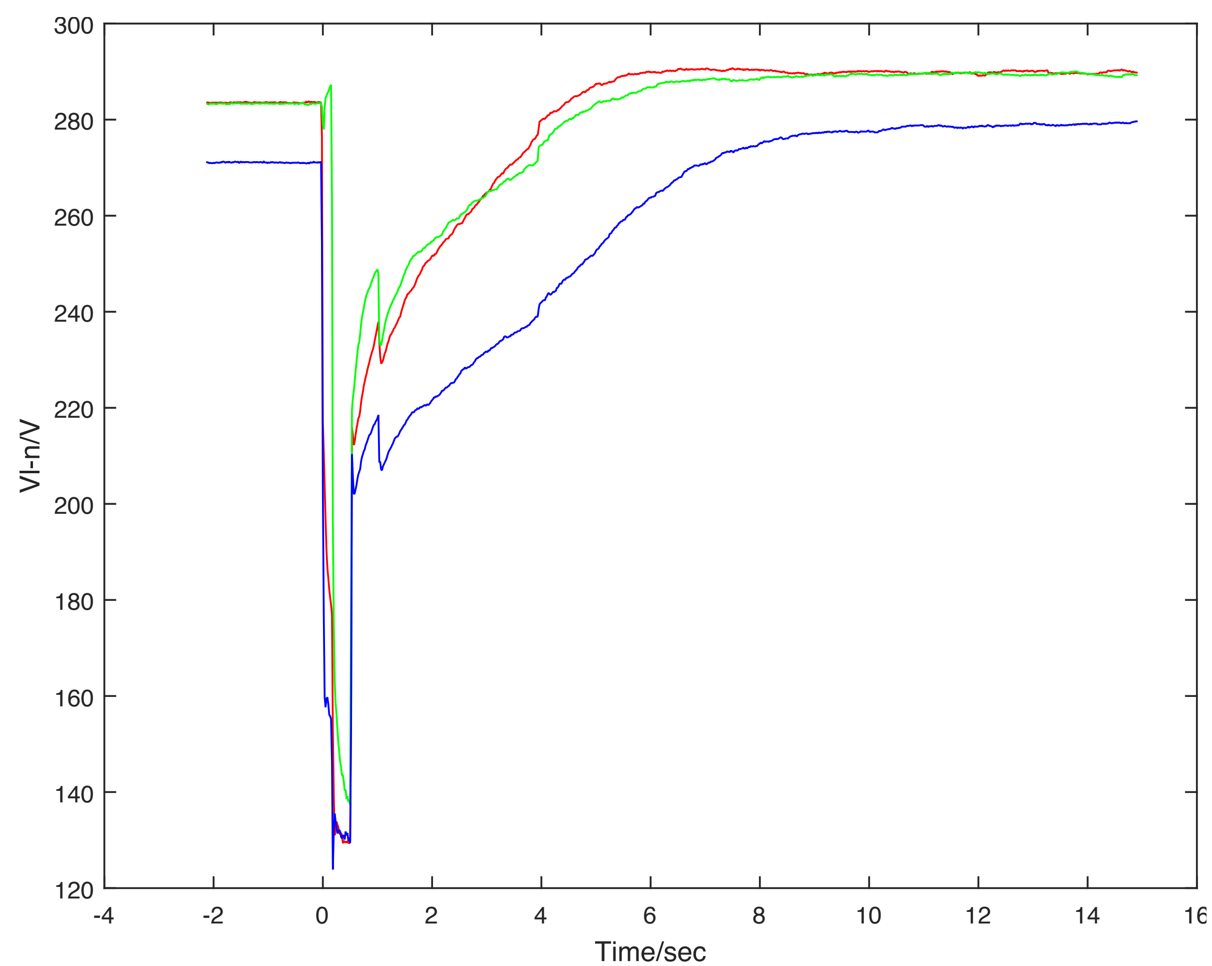
Voltage dip and recovery

Is there something, incomplete, optimistic, or otherwise wrong with our simulations ??

Delayed voltage recovery like this is observed quite but it is far from universal

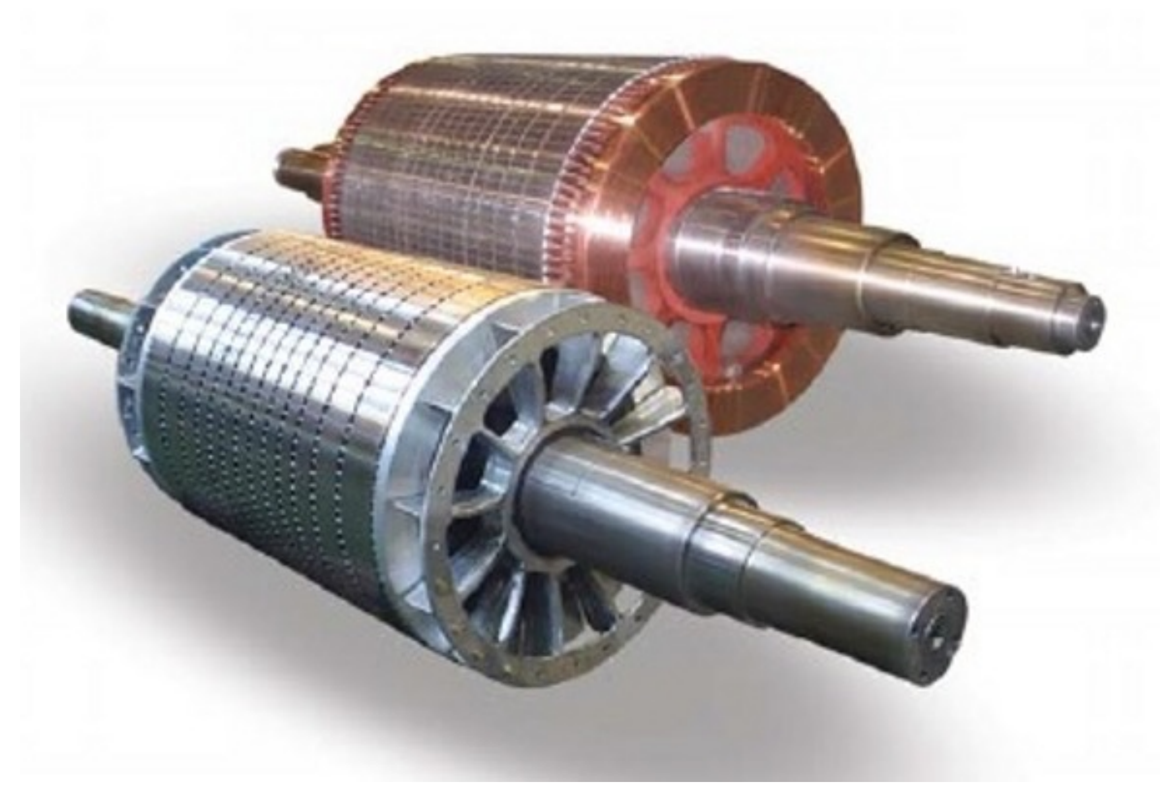
Do we know the cause ??

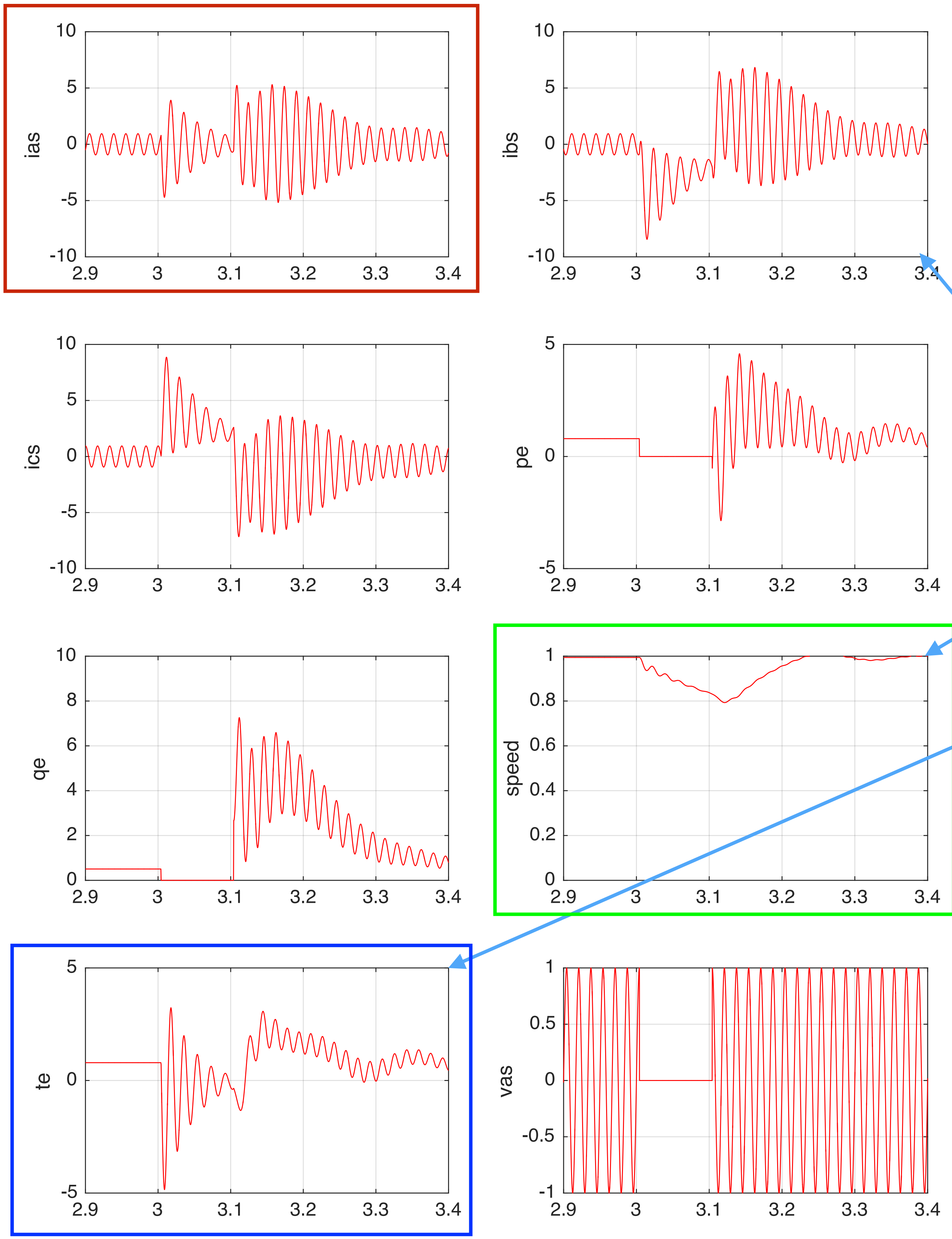




Industrial motors

Inertia constant H = 0.3 second
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

Short circuit at terminals of 100KW three phase motor driving a pump -

H = 0.3 second

Motor contributes significant short circuit current

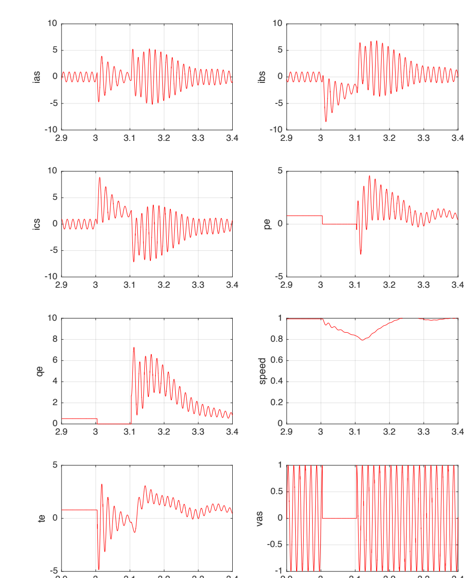
Thereby provides voltage support during the transient

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

Speed dips during fault - reacceleration is decisive

Well understood behavior

Central to circuit breaker rating standards



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

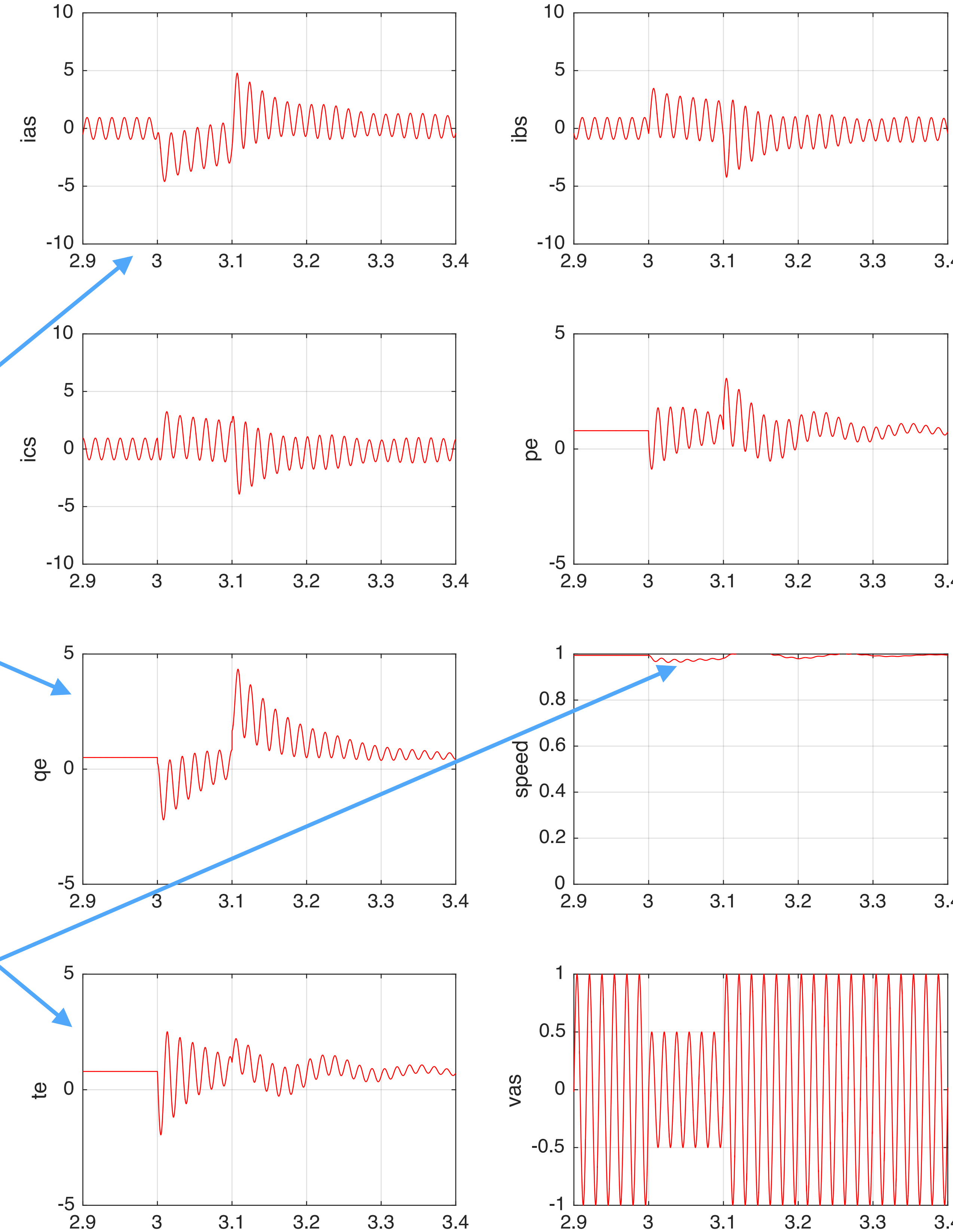
H = 0.3 second

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



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

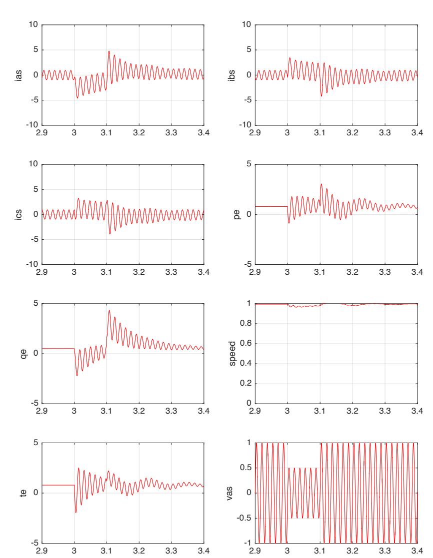
H = 0.3 second

Current contains AC and unidirectional components

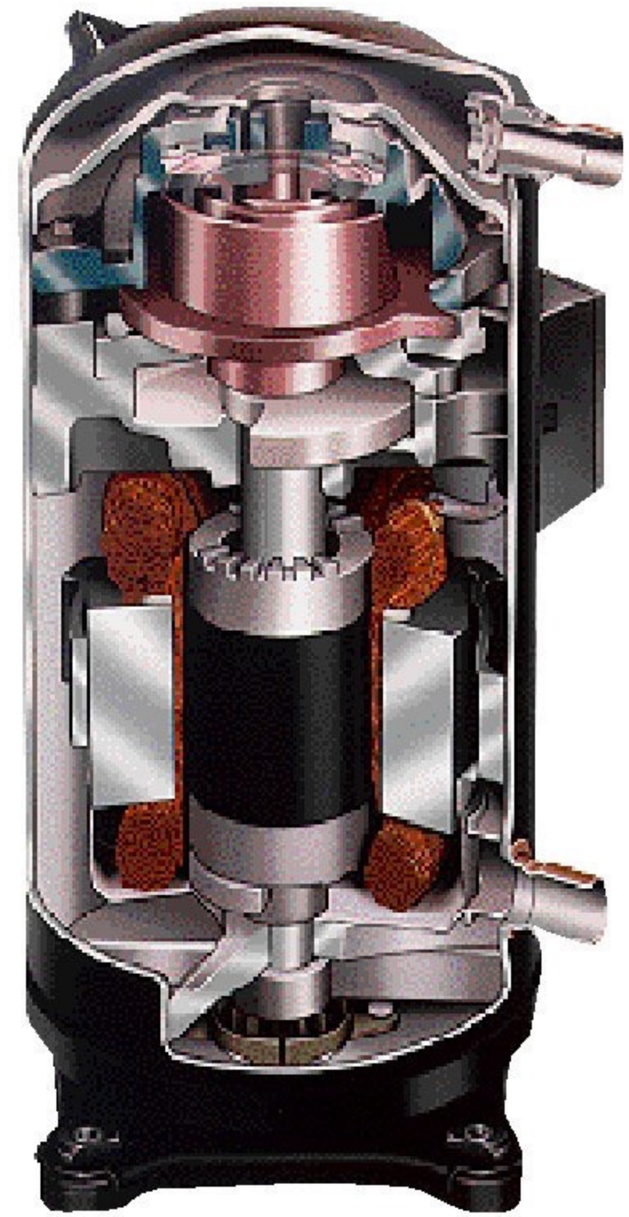
Reactive power reverses during voltage dip - motor contributes to support of voltage

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



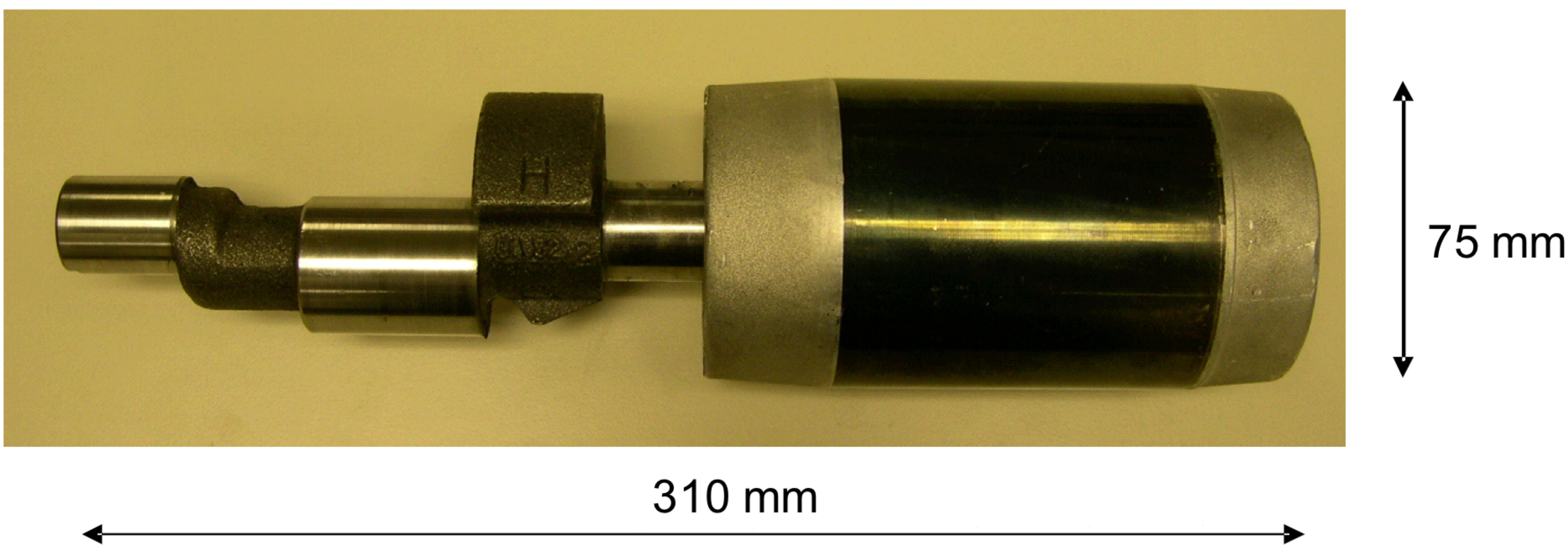
Delayed voltage recovery is recognized to be associated with behavior of residential air conditioners with direct-connected compressor motors



Air conditioner rotor

Hmotor ~= 0.05 second

Time scale of tenths of a second



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

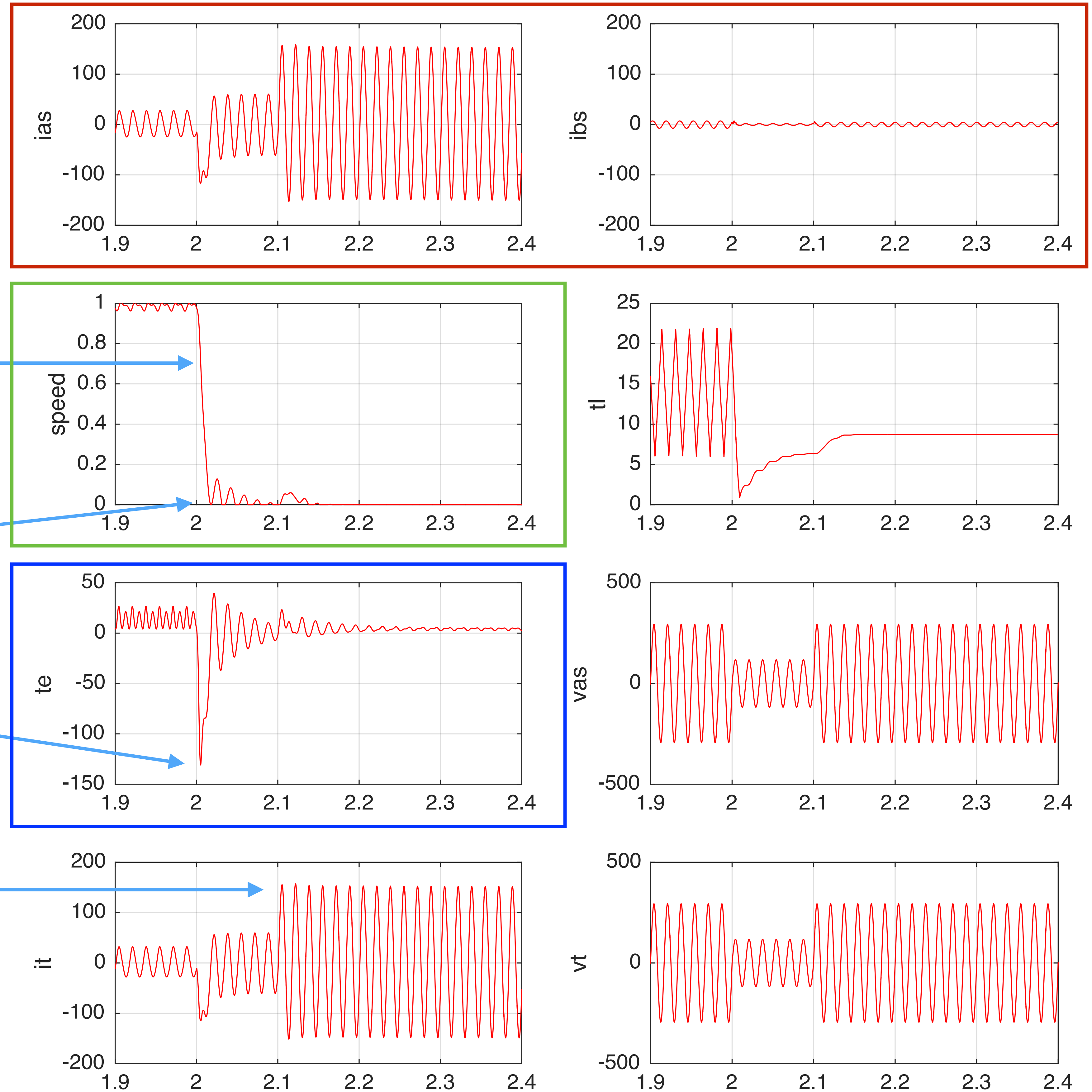
H = 0.048 second

Speed is pulled down very strongly by the negative electromagnetic torque

Motor stalls and does not restart

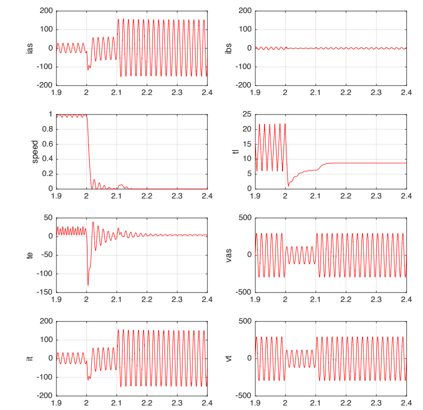
Immediate **negative** peak of torque transient approaches **eight times** rated torque

Current drawn by stalled motor is **five times** normal load current



Voltage dip at terminals of 5KW single phase residential air conditioner motor

H = 0.048 second



Speed is pulled down very strongly by the negative electromagnetic torque

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

Motor stalls and does not restart

Current drawn by stalled motor is **five times** normal load current

Reactive load of stalled motors is several times greater than when they are running - prevents recovery of voltage

Motor behavior is sensitive to

Supply system impedance

Load torque-speed characteristic

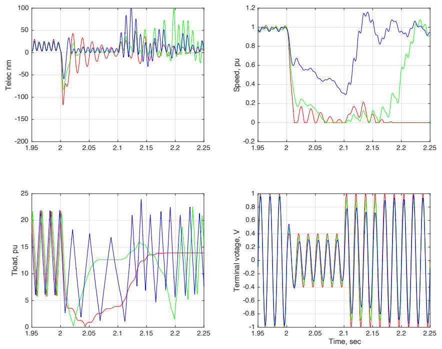
Load torque-angle characteristic

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.



It is not yet clear how air conditioning load
will evolve in the USA

It is likely, though, that the penetration of electronically coupled motors will increase rapidly in across the full field of driven loads