DFIG Wind Turbine Modeling

Team Power Team

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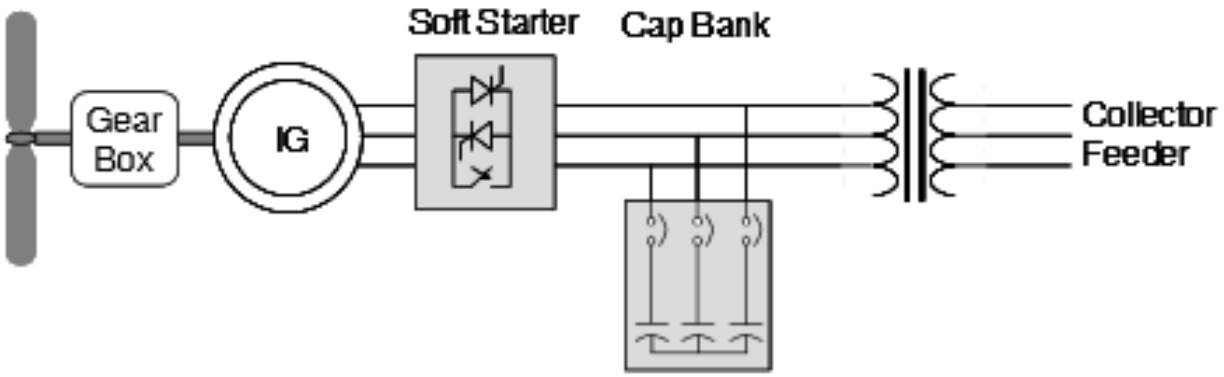
Presentation Includes:

- Introduction to type I, type II and type III wind turbine generators (WTGs)
- Students' Type III WTG control system scheme
- Students' Physical DFIG model

Presentation Includes:

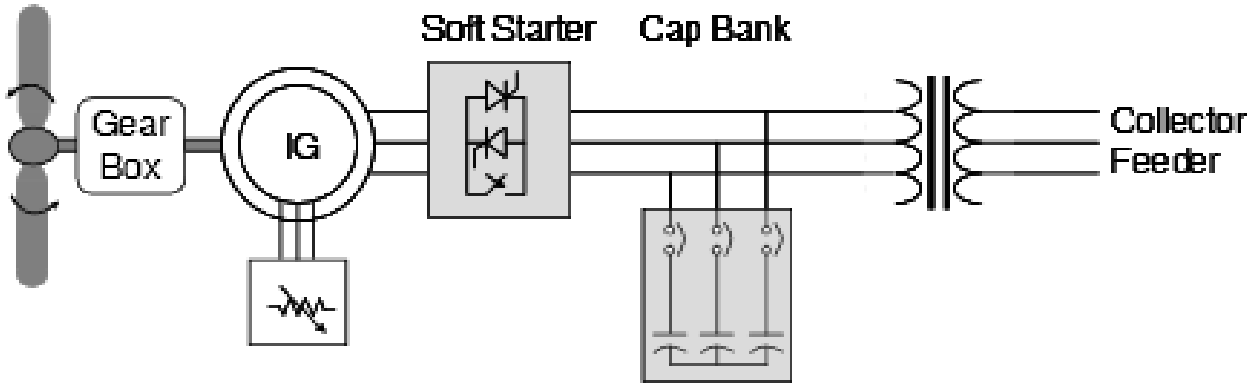
- Software model of WTG fed power system
- Current standing
- Future work

Type I WTG



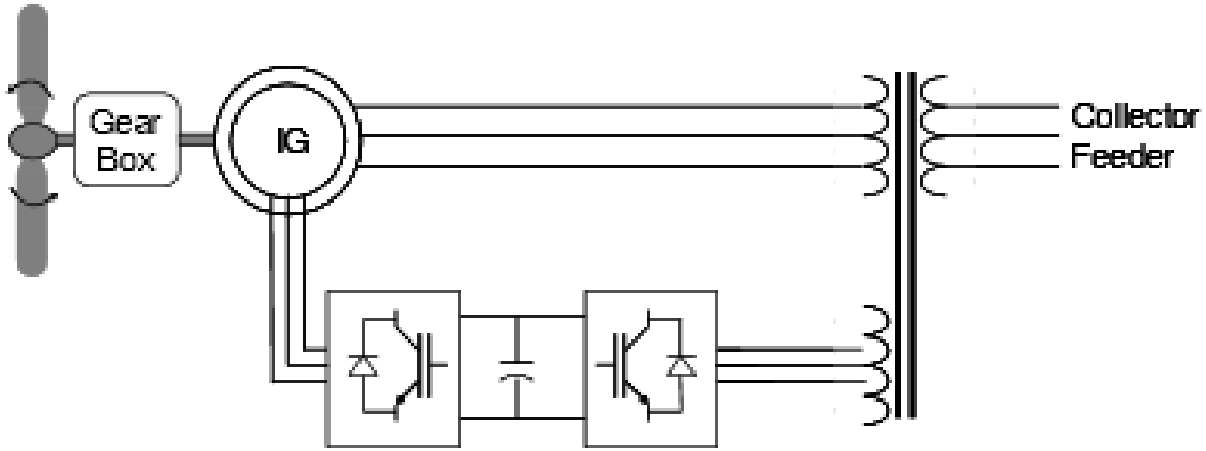
- Squirrel-cage induction generator
- Connected to transmission step-up transformer directly
- Turbine speed is fixed (or nearly fixed) to grid frequency
- Generates real power when turbine shaft rotates faster than the electrical grid frequency
- Low-cost, reliable

Type II WTG



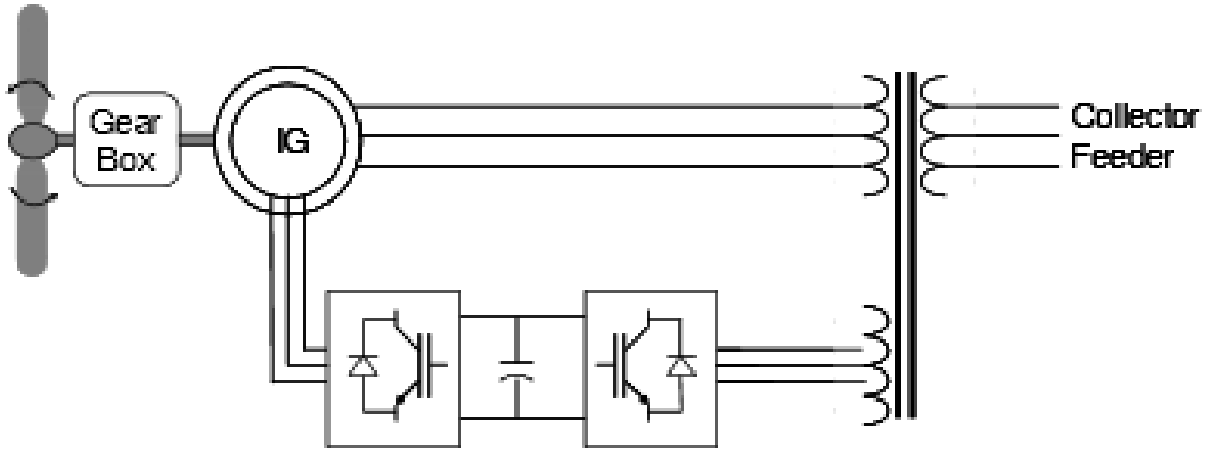
- Wound rotor induction generator
- Also connected to transmission step-up transformer directly, but includes variable resistance in rotor circuit
- Can produce power at higher wind speeds than Type I WTGs

Type III WTG



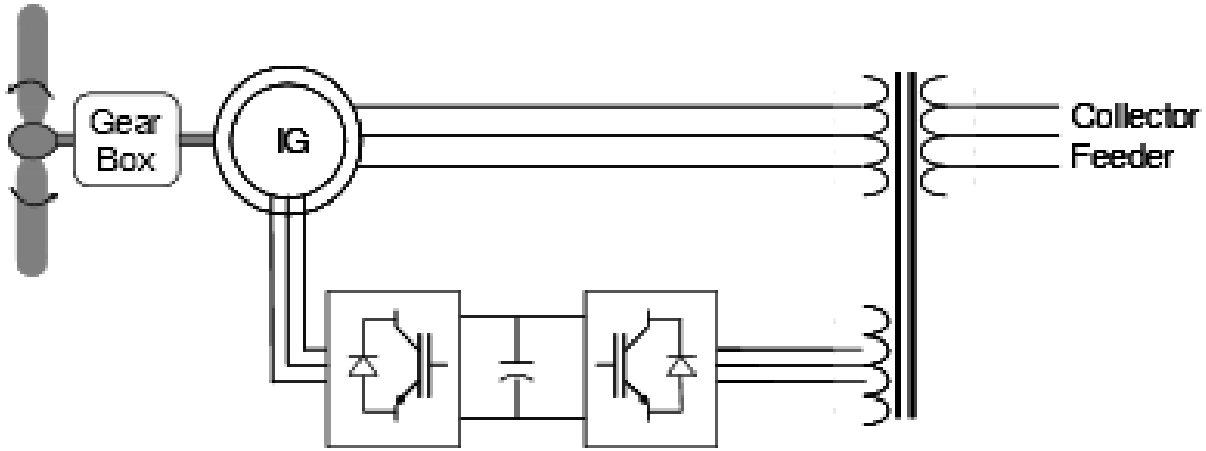
- Variable frequency AC rotor excitation
  - Current regulated voltage-source converter
  - Immediate adjustment of rotor current's magnitude and phase
  - Exchanges power via back-to-back AC-DC converters

Type III WTG



- Small adjustments to rotor circuit have large effect on stator circuit
- Can operate with wind speeds+/- 50% of synchronous speed

Type III WTG



- Separate real and reactive power controls while running asynchronously
- More expensive than Type I and II WTG due to power electronics controls
- Type III WTGs behave like a controlled current source during faults

WTG Type Comparison

	Type I	Type II	Type III
Machine Used	Squirrel Cage Induction Generator	Wound Rotor Induction Generator	Doubly-Fed Induction Generator
Wind Speed Control	2-3 %	10 %	50 %
Separate Real/Reactive Power Control	No	No	Yes
Cost	Lowest cost	Mid to low cost	High cost

Behavior During Faults

- Type I and II WTGs behave similar to large induction machines, producing fault currents of 5-6 pu
  - Faults are usually easily detected

Behavior During Faults

- Faults on Type III WTG typically produce fault currents of 1.1-2.5 pu
  - Faults are difficult to protect without nuisance tripping

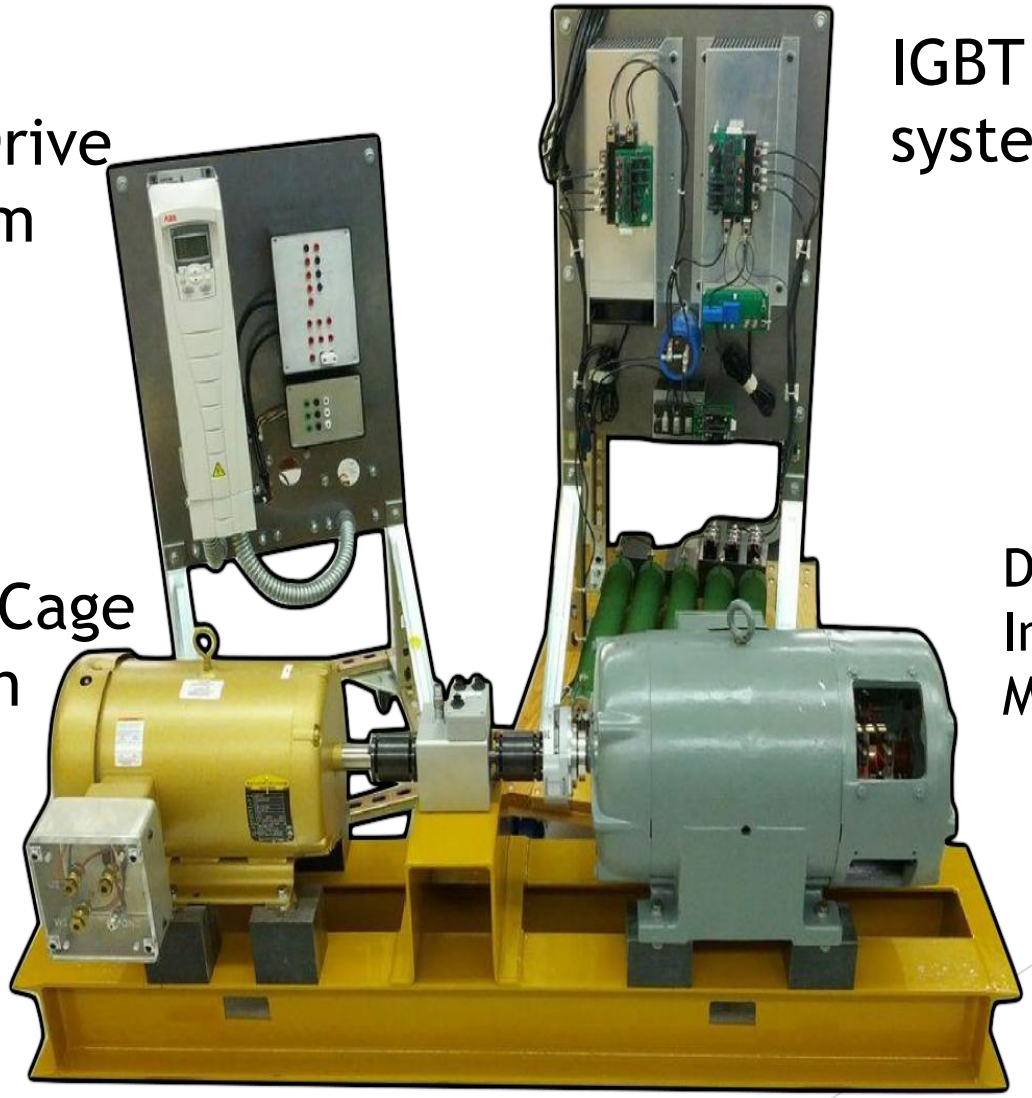
DFIG Project: The Hardware

- Machines
  - Senior Design 2013
- Motor Drive System
  - Tim Lenberg (2014) and Mike Beacham (current)
- DFIG Control System
  - Tim Lenberg (2014), Mike Beacham, Cody Swisher, Tiras Newman (current)

The Hardware:

ABB Drive System

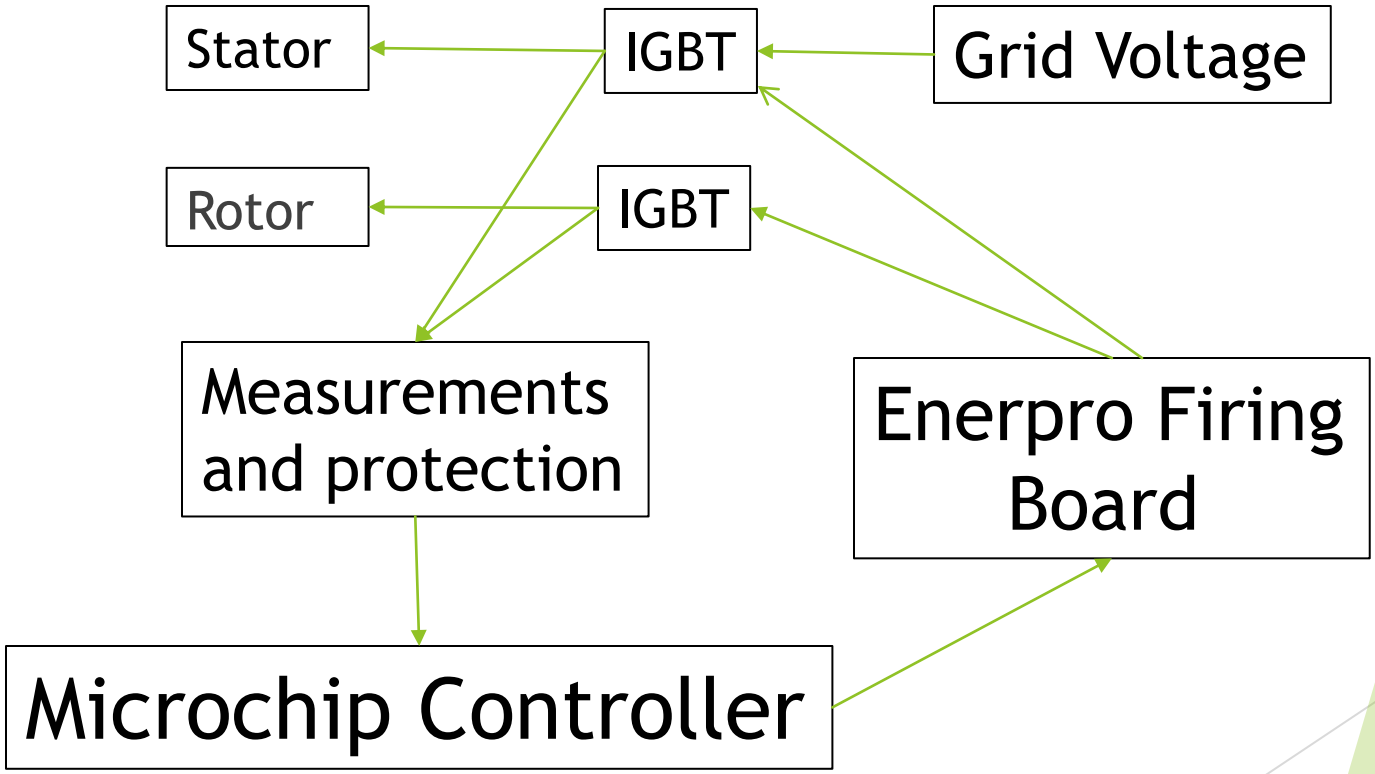
IGBT Drive system



Squirrel Cage Induction Machine (SCIM)

Doubly Fed Induction Machine (DFIG)

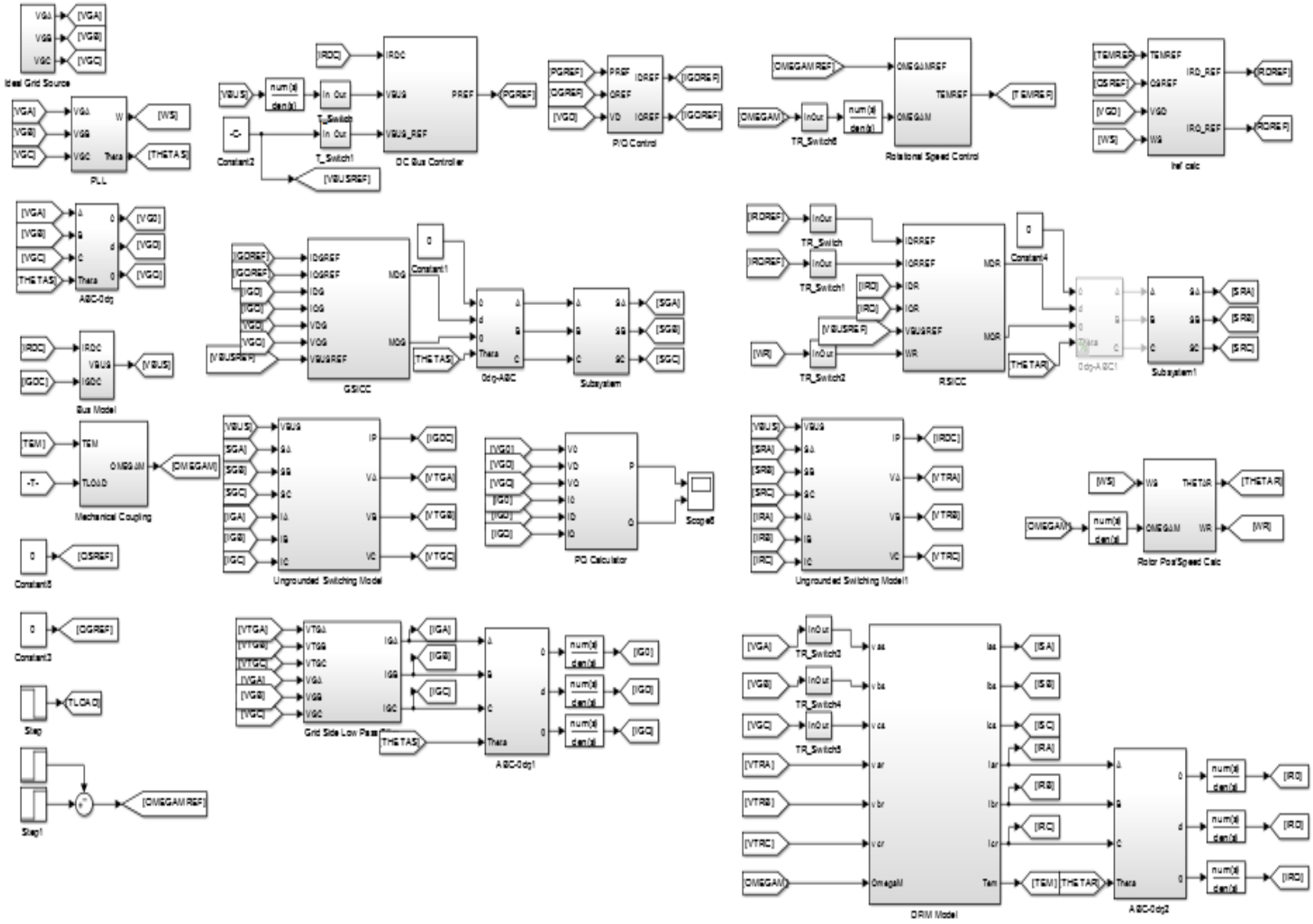
IGBT Drive (Insulated Gate Bipolar Transistor)



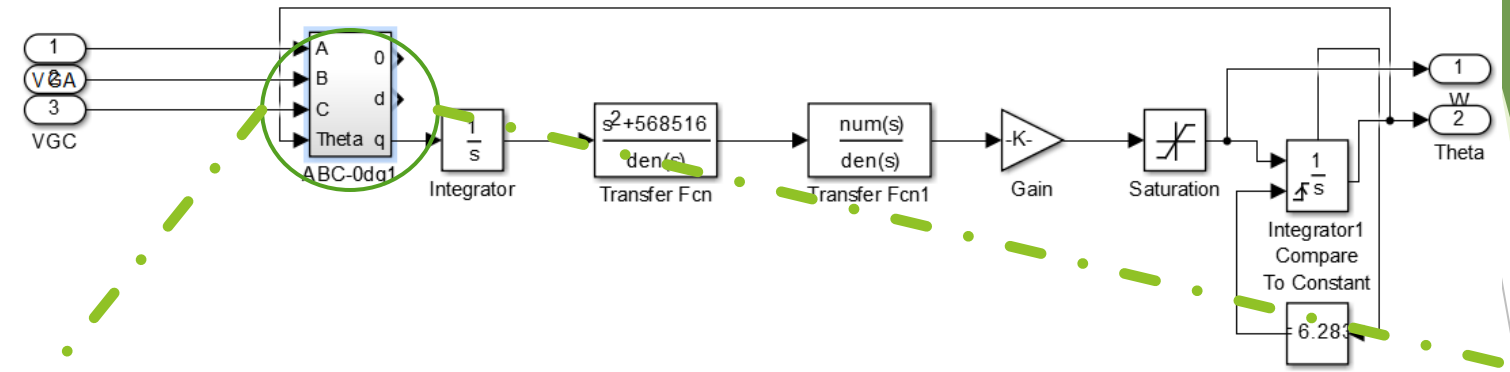
Controller: Work in progress

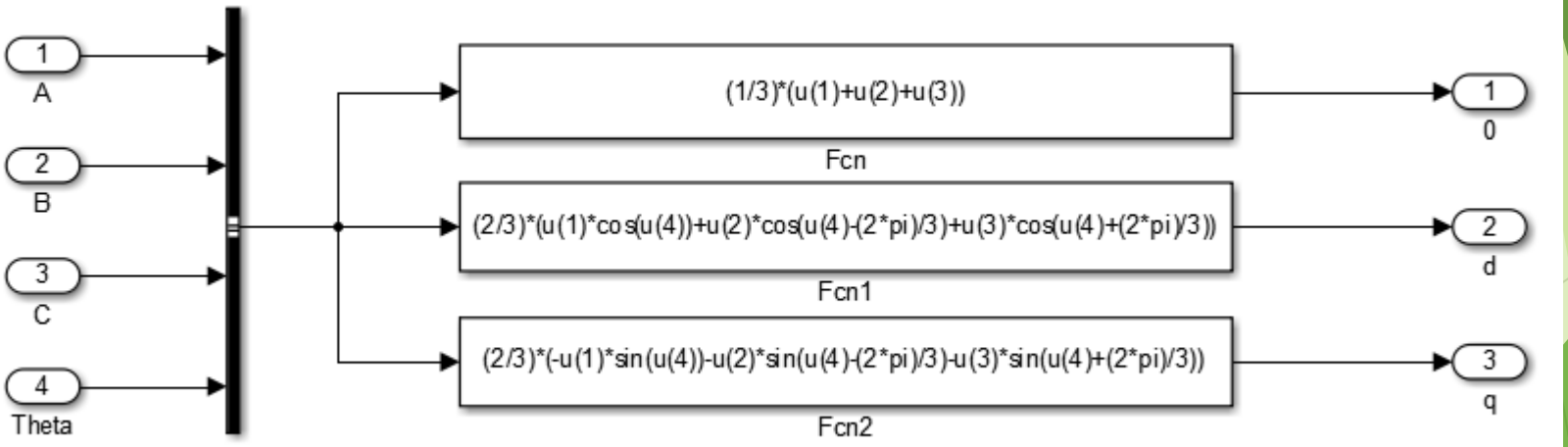
- Microchip PIC24 microcontroller
  - Programmed in C language
  - Gathers data
  - Synchronous (dq0) reference frame calculation
  - Sends firing signals to Enerpro device
- MATLAB Model
  - Simulink Block Diagram
  - Similar to what we needed
    - Modification currently underway

Simulink Control System



Simulink Control System





Park Transform

- Transforms rotating A, B and C phases into a two-axis (dq) reference frame (vectors)

$$V_d = \frac{2}{3}\left(V_a \sin(\omega t) + V_b \sin(\omega t - 2\pi/3) + V_c \sin(\omega t + 2\pi/3)\right)$$

$$V_q = \frac{2}{3}\left(V_a \cos(\omega t) + V_b \cos(\omega t - 2\pi/3) + V_c \cos(\omega t + 2\pi/3)\right)$$

$$V_0 = \frac{1}{3}\left(V_a + V_b + V_c\right),$$

Simulation Model

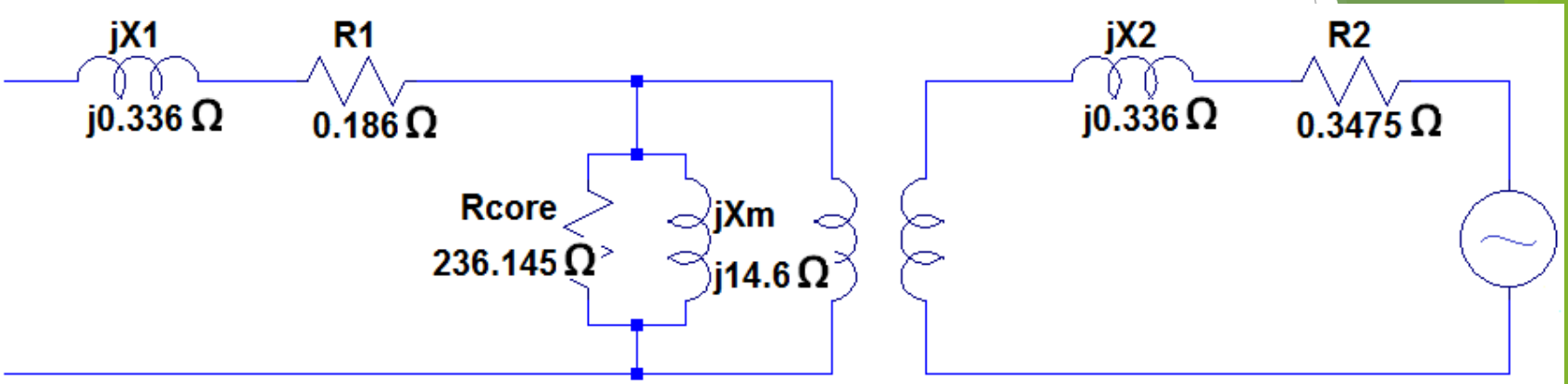
RTDS
(Real Time Digital Simulator)

- The simulator operates in REAL TIME
- Closed Loop Testing
  - For Protective Relays
  - Power System Models
  - Fault Simulations
  - Other Loop Studies

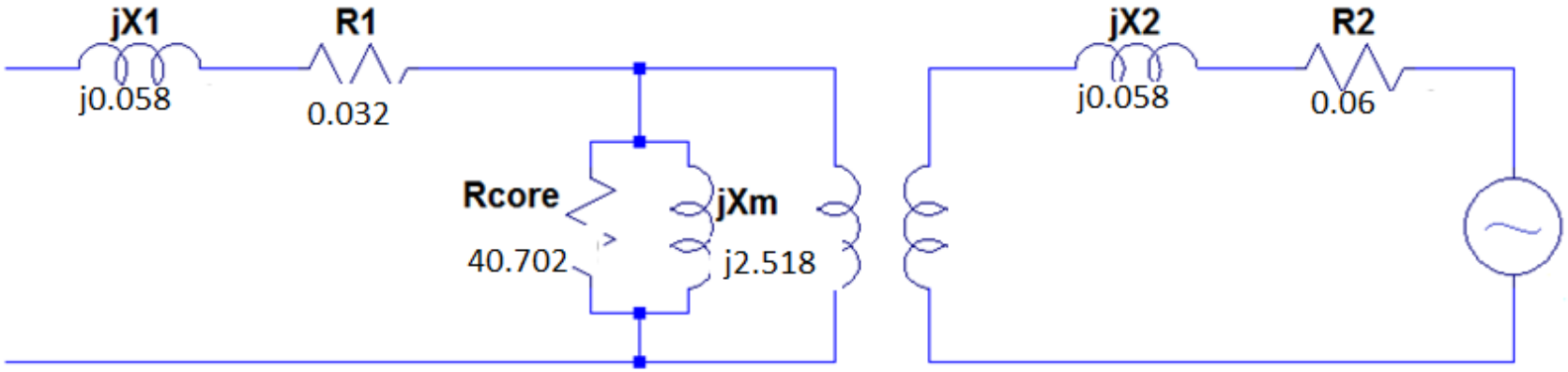
The RTDS

DFIG:

- Parametarization of DFIG
  - Short circuit, open circuit, locked rotor tests



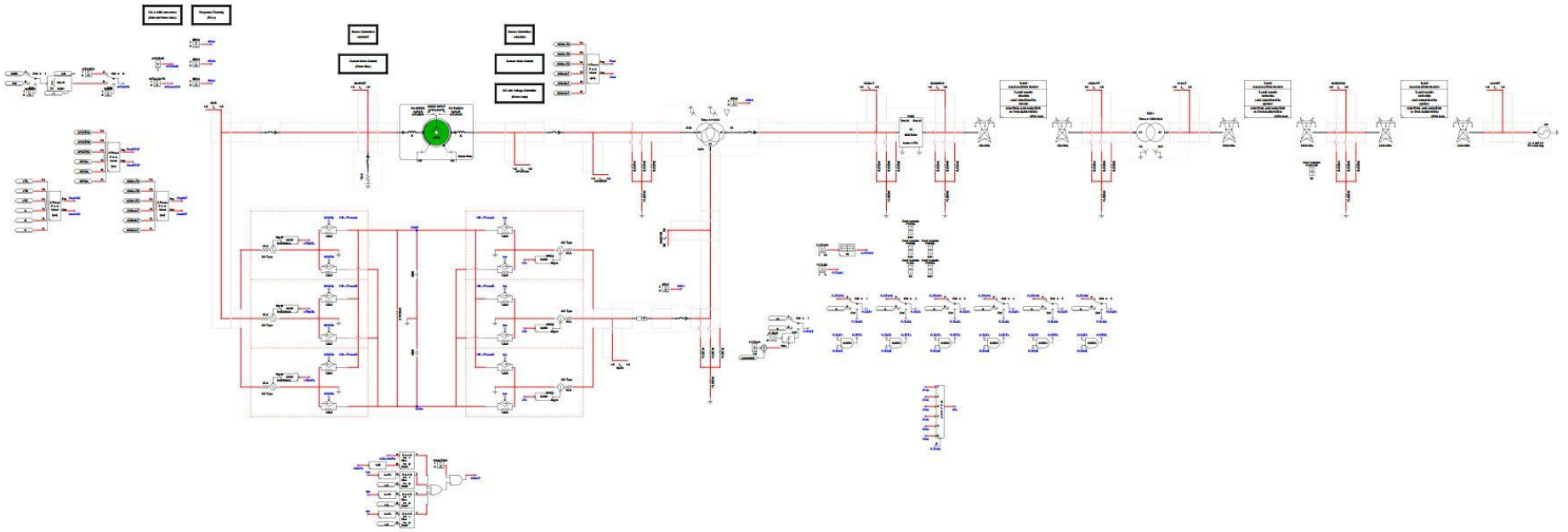
DFIG Equivalent Circuit



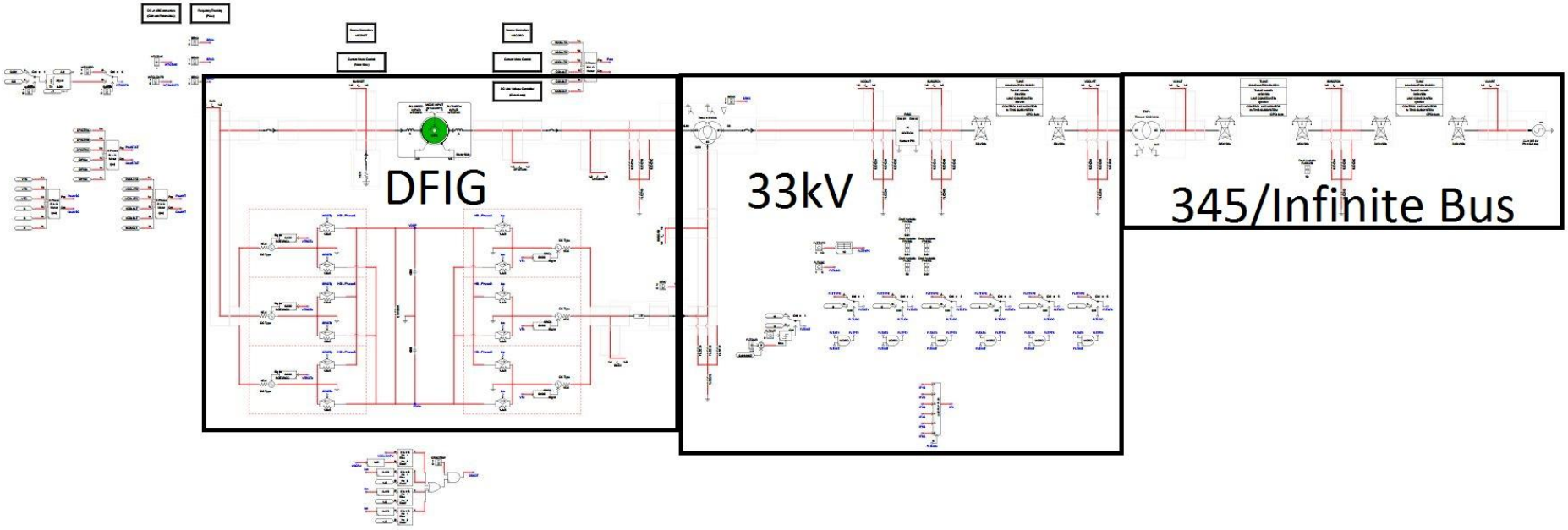
DFIG Equivalent Circuit (Zbase=5.8 Ω) Sbase = 7.457 kVA
Vbase = 208 V

RSCAD Model

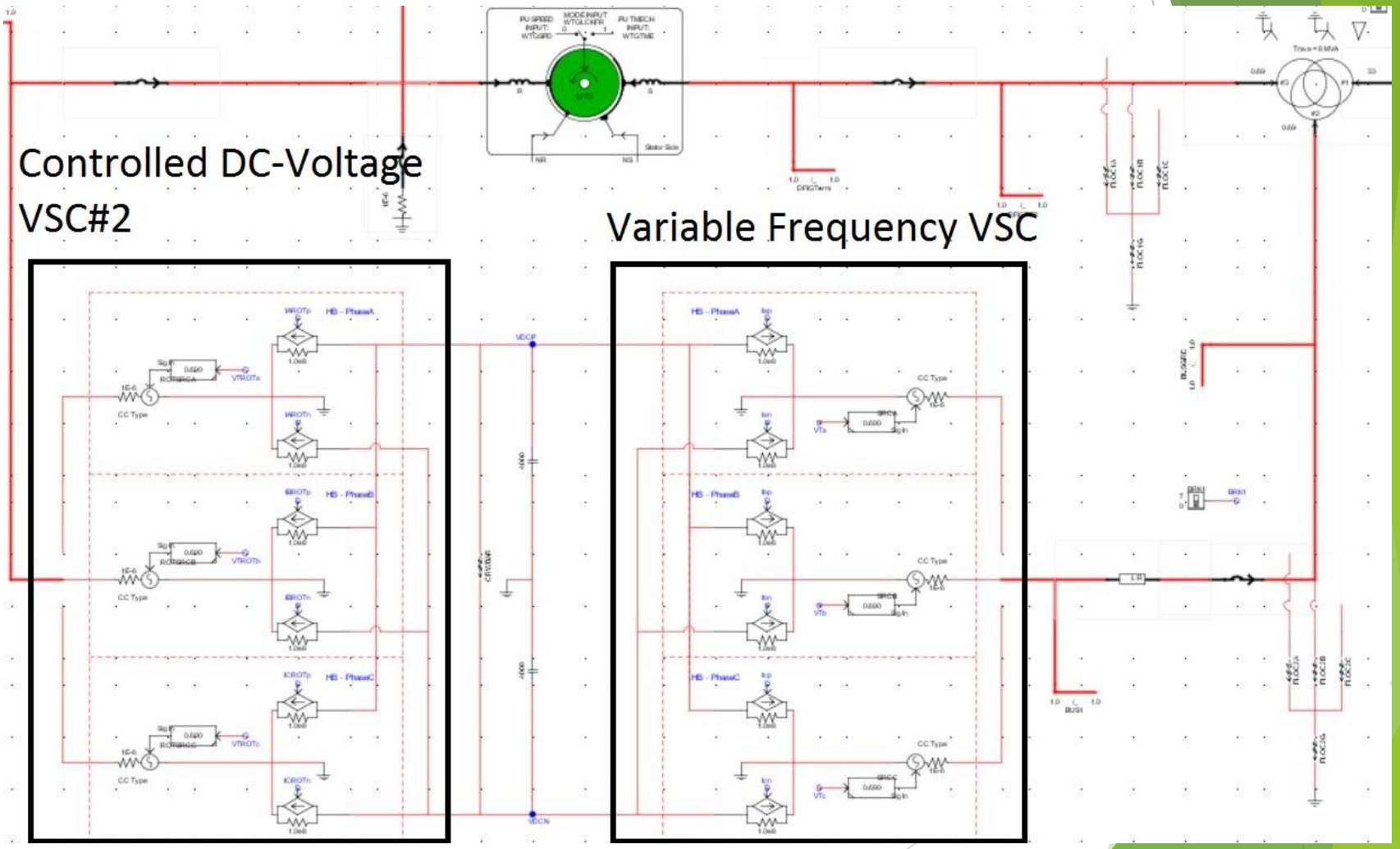
(Originally by Rishabh Jain)



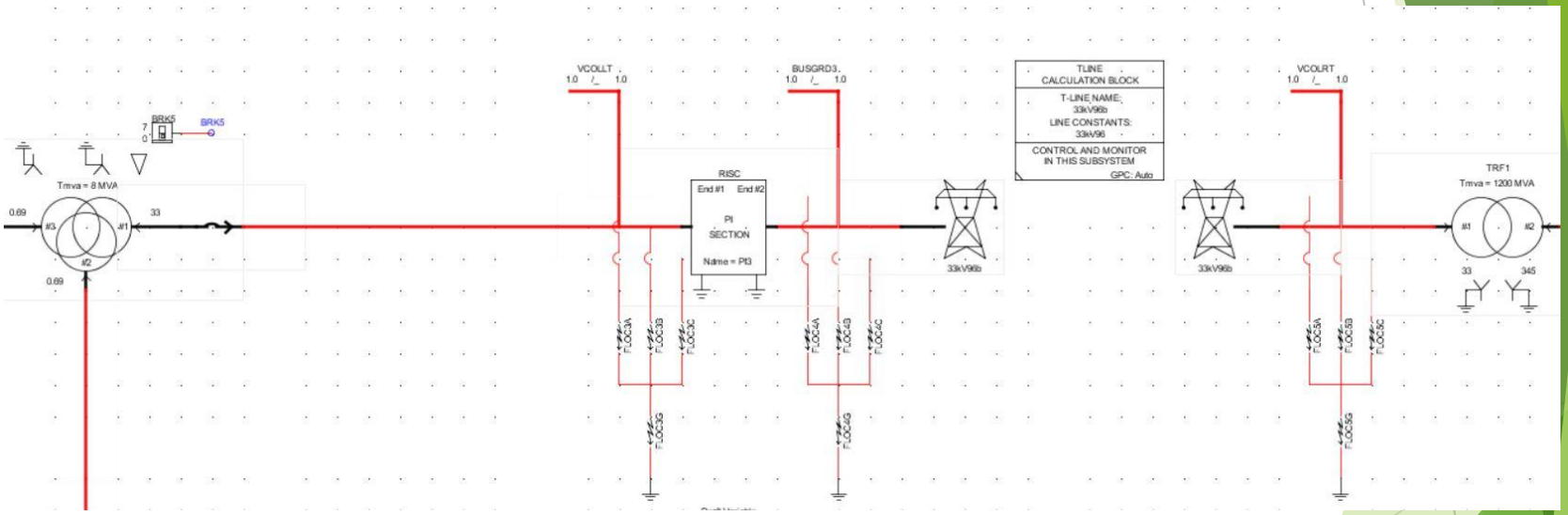
System



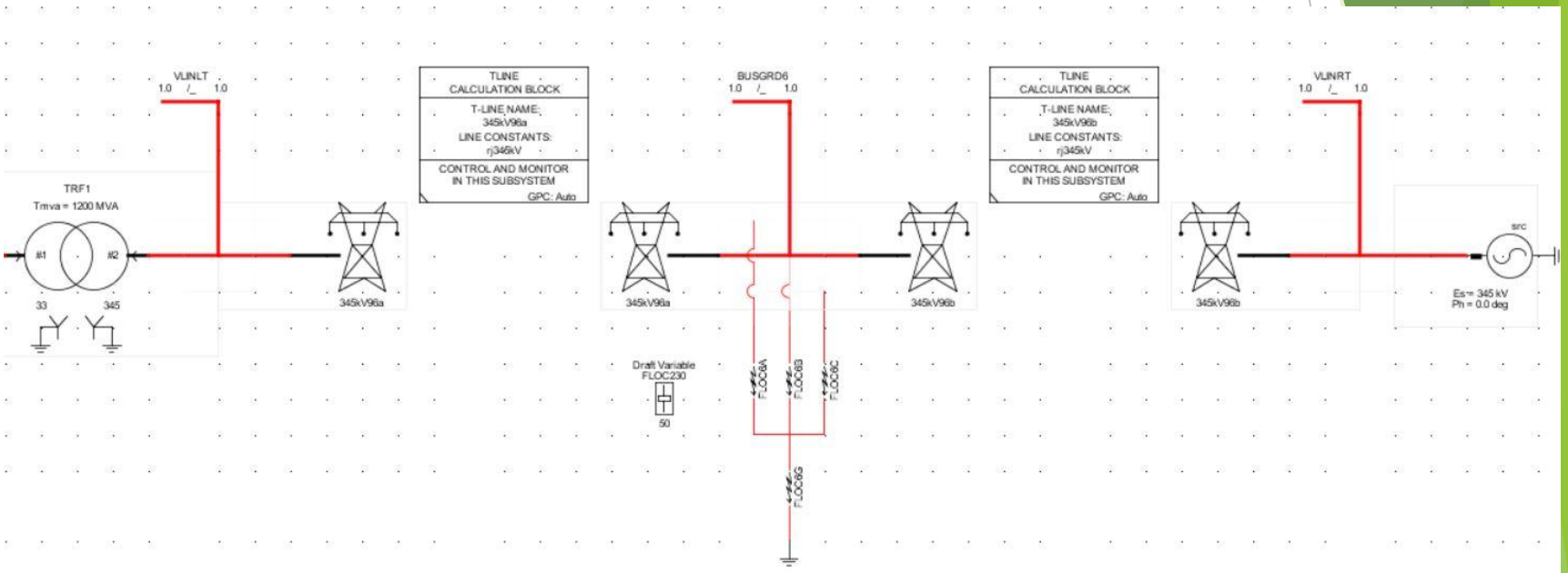
VSC



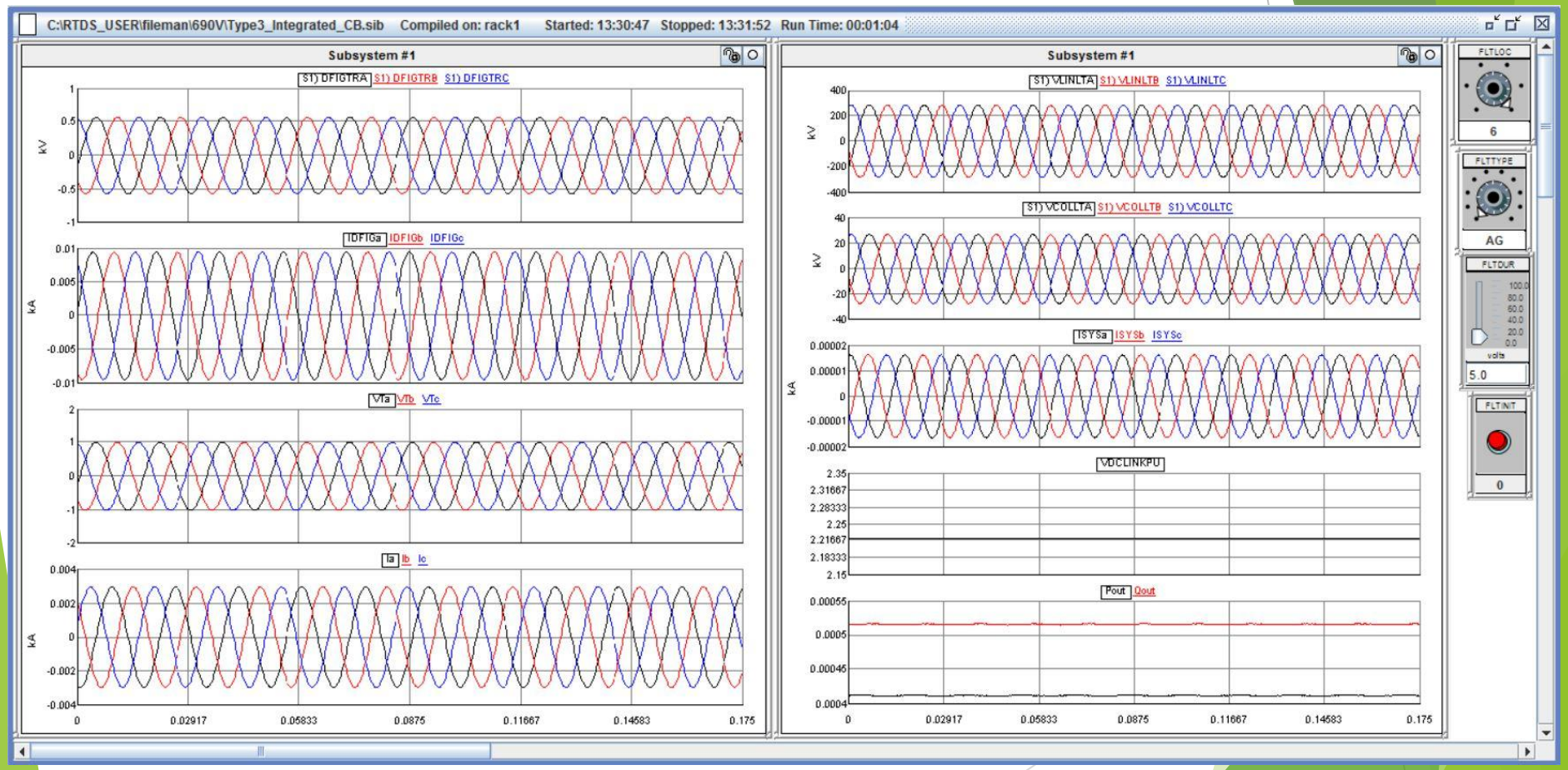
DFIG – 33kV system



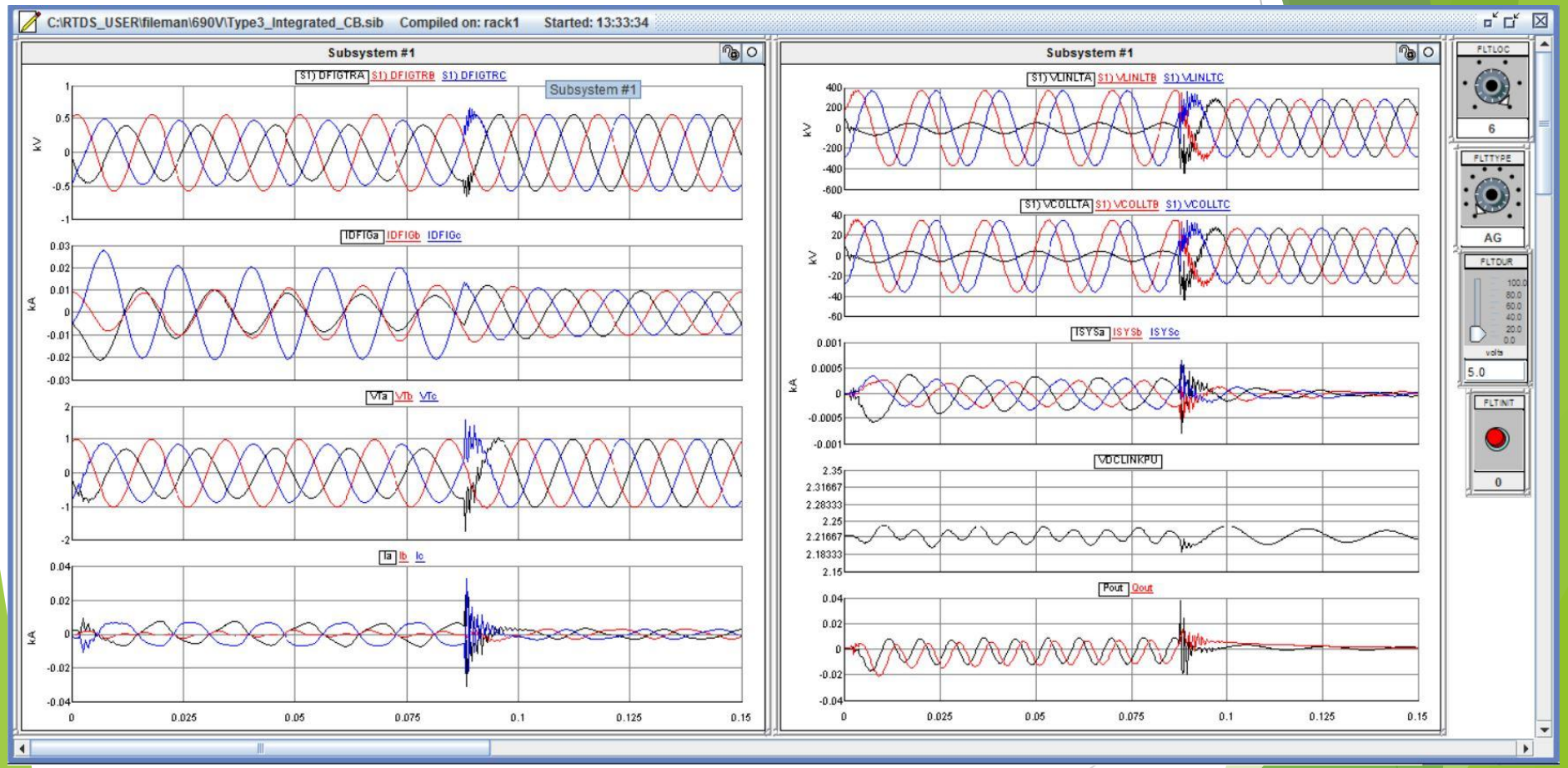
345kV system



Steady State Simulations



A-Ground Fault Simulations



Where the Project Stands

- RSCAD Model is now finished and providing expected results
  - 690V
  - 208V
- Control scheme currently in initial phases
  - Park's transformation being coded into microcontroller

What's Next

- Implement and verify controls
- Test DFIG on Model Power System
- Compare physical DFIG to RSCAD simulation