Transmission Line Impedance and Synchrophasors

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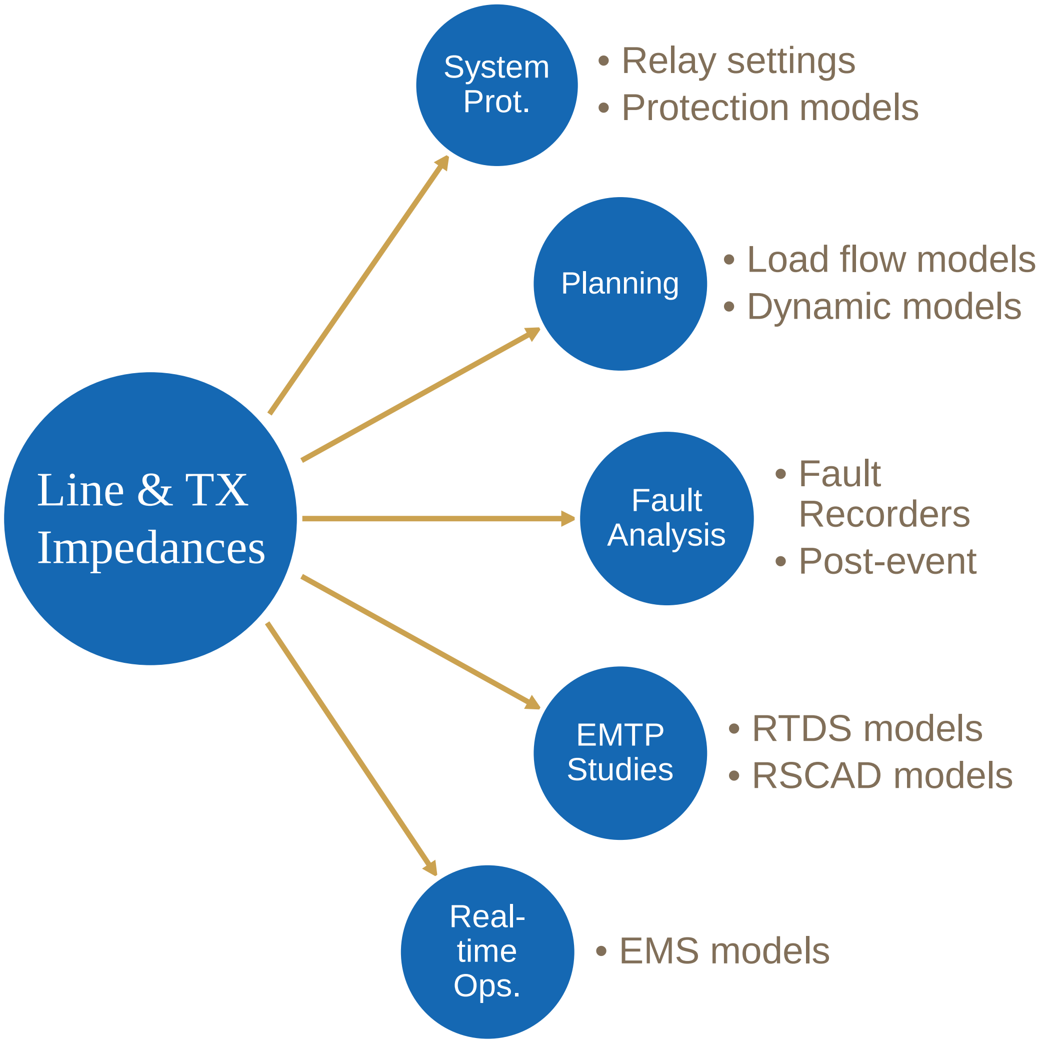
Background on Impedances

Most Power System applications use system impedances

- Relay & DFR settings
- Protection models
- Planning models
- Real-time EMS models
- Post-Event and Fault Analysis

Inaccurate impedances cause problems with all these applications

Transmission Lines and Transformers are the primary elements with impedances



Background on Impedances

Transformers

- Manufacturers perform impedance tests to international standards (IEEE, IEC, etc.)

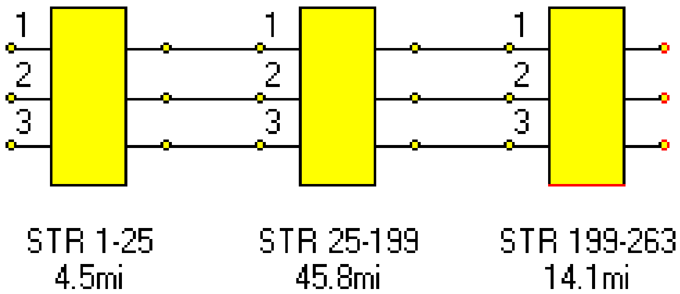
Transmission Lines

- Conductor manufacturers perform impedance tests to provide Ohms/mile
- But the impedance of an entire line is a collection of equipment and parameters:
  - Length (hundred of miles, thousands of towers)
  - Construction Build (variations due to landscape)
  - Environment (soil resistivity, temperature)
  - Mutual Impedance from other lines

Offline Traditional Method

- From the design of a transmission line, create a list of homogeneous line sections
- Reduces the number of calculations to perform, ideal for studies first done by hand, then by mainframe computers, and then by the first PCs
- Impedance results were "good enough", but method uses a lot of assumptions
- This method is often not accurate enough with the demands of today's power systems

Example of a 65-mile 500kV Un-transposed Line with 262 Strs

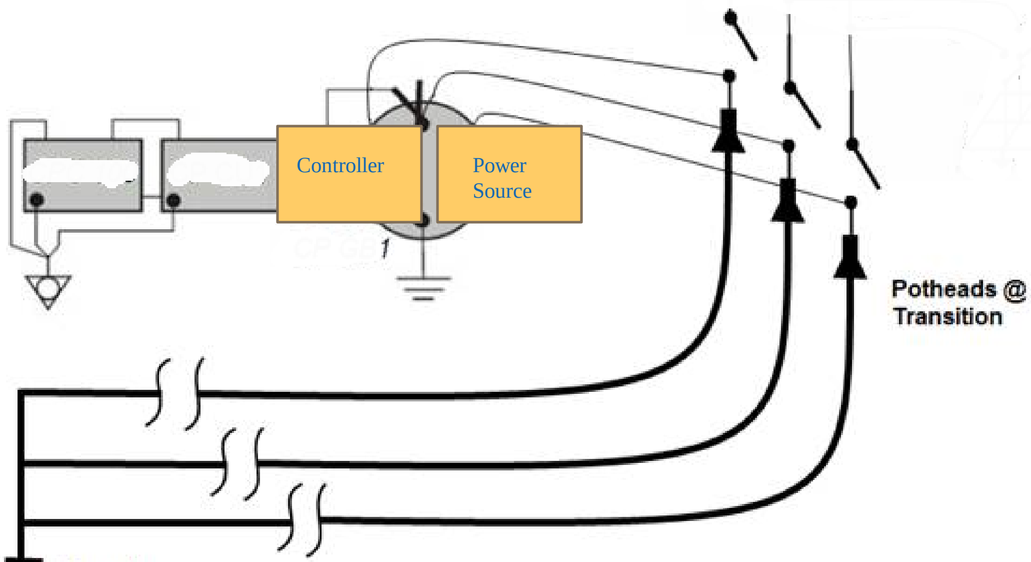


Offline Measurement

Requires a transmission line to be out of service.

Requires a power source to inject voltages/currents on the line.

Accurate results from a point in time

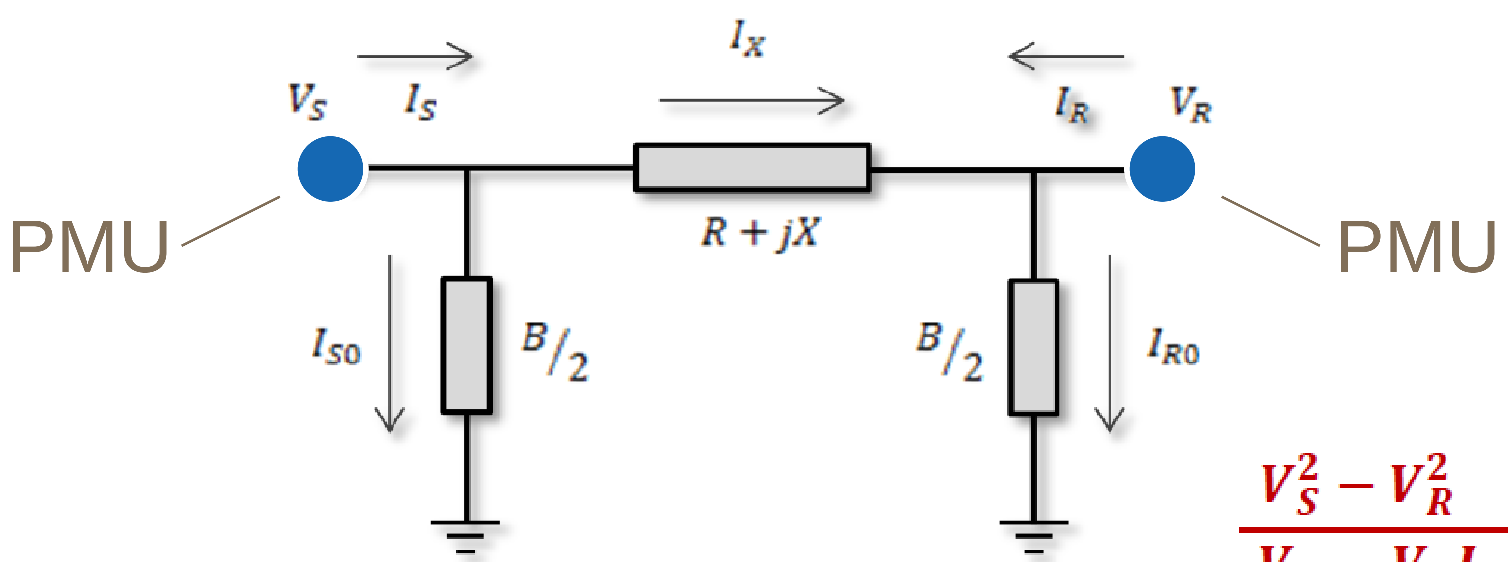


De-energized Transmission Line

Online Measurement with Synchrophasors

With PMUs at each end of a transmission line, calculate the impedance of a line continuously over time

- Lines remain energized
- Covers all system/weather conditions
- Removes any offline calculation assumptions



$$\frac{V_S^2 - V_R^2}{I_S V_R - V_S I_R} = R + jX$$

Online Measurement with Synchrophasors

Using synchrophasor data, we are calculating the positive sequence line impedance 500kV lines

Synchrophasor Line Z1 for 500kV line

Z1 = 3.663 + j39.42 Ohms

Original Line Z1 (Traditional method)

Z1 = 1.8362 + j38.28 Ohms

R = 50% difference, X = 3% difference

Using the PMU-based Line Z1 data for this 500kV line, improved fault location by 17% for an A-G fault using Double-Ended fault location method, compared to traditional method Line Z1

Online Measurement with Synchrophasors

Initial results very promising

- Reactance values showing nominal differences, resistance values need further investigation
- PMU-based values have improved Fault Locations

Plan to extend to zero sequence impedance calculation since we have PMUs monitoring all 3 phases

Working with many industry partners on this topic

New Synchrophasor Analytics under development for new DOE Grant

open ECA

open and Extensible Control & Analytics platform for synchrophasor data

Project Members

DE-OE-778

Project Schedule

Oct. 2015 – Sept. 2017

Project objective

- Develop an open-source software platform that facilitates the development and production use of synchrophasor based analytics
- Design or redefine the analytics comprised of the openECA platform and eventually enhanced them to pre-commercial status.

New analytics under development:

- Linear State Estimator + Topology estimator
- Local & Regional Voltage-VAR controller
- *Transmission Line Impedance calculation*
- Instrument Transformer calibration
- PMU Synchroscope

Conclusions

With the demands of today's modern power systems, traditional line impedance methods are often not accurate enough.

A combination of new methods should be used to solve line impedance concerns

1. Just before energization, use offline method with signal injections
2. Continuously monitor line impedance of all transmission lines using PMUs on all terminals of the lines.