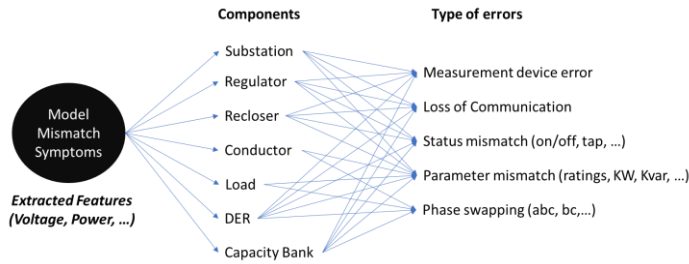# Digitizing Distribution System Model Validation

Project Goal: To significantly reduce the manhours in tracing the root causes of model mismatch through developing an automated tool to digitize the model validation process

Project Outcome: A **model mismatch root cause recommendation system (MMRCRS)** for utility engineers

Problem Overview

Components
- Substation
- Regulator
- Recloser
- Conductor
- Load
- DER
- Capacity Bank

Model Mismatch Symptoms

Extracted Features (Voltage, Power, …)

Type of errors
- Measurement device error
- Loss of Communication
- Status mismatch (on/off, tap, …)
- Parameter mismatch (ratings, KW, Kvar, …)
- Phase swapping (abc, bc,…)

Simulation Environment

OpenDSS Model 1
- Simulate real system
- Time series power flow
- Input: False
- Control: True
- Scenarios: Faults
- 1 min

1. Source side voltage
2. Substation regulator tap position
3. Regulator RG60 tap position
4. Cap bank status on the bus 611 and 675
5. Recloser status

Measurements

Python Bridge

OpenDSS Model 2
- Simulate DMS model
- Snapshot power flow
- Input: True
- Control: False
- Scenarios: Mis-match
- 15 min

Static data   Dynamic data

Run OpenDSS Model 1 as the real system

Run OpenDSS Model 2 as the DPF model

Measurement Data   Model Output

Voltage Deviation Alert

Model Mismatch Root Cause Recommendation System

User Interface

Corrective Actions

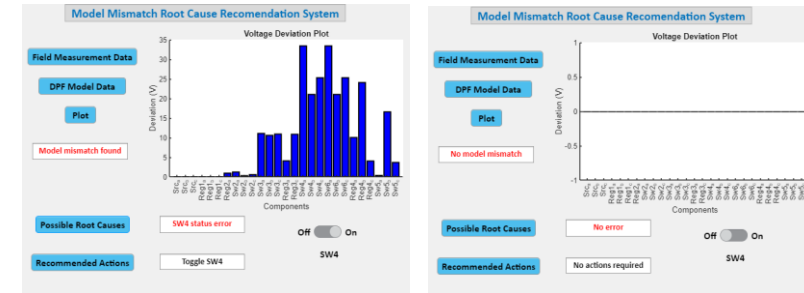## MMRCRS Solution Implementation

1. Data-Augmented Expert Search System

ALGORITHM 1: DATA-AUGMENTED EXPERT SEARCH SYSTEM
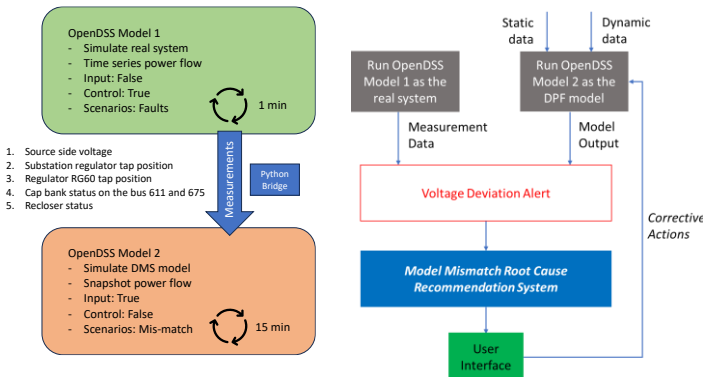**Input:** weather data, field measurement data, DPF output data
Output: model mismatch root cause and corrective action plans

1 **Similar day clustering**   //identify similar days according to weather data
2   Calculate Euclidean distance based on weather data
3   Rank the distance and select top 50 days of normal operations
4 **Outlier detection** //
5   Field measurement data check
6   DPF model data check
7   Cross check
8 **Corrective actions**
9   If voltage is out of bounds while power is within bounds: change regulator tap settings
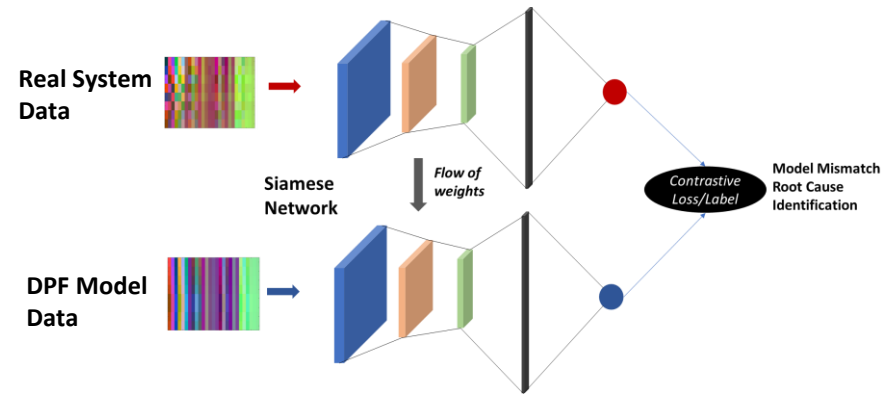10   If both voltage and power are out of bounds, check all devices in the outlier section

2. Deep Learning-based Root Cause Classification

Real System Data

DPF Model Data

Siamese Network

Flow of weights

Contrastive Loss/Label

Model Mismatch Root Cause Identification

RGB image embedding of voltage, real power, and reactive power

The Siamese Network to extract and compare RGB images from Model 1 and Model 2

Software Prototyping

Performance and Impact

- **Performance metrics**: fulfilled with voltage deviation ≤ 2V, and computation time < 1 hour for one substation; 3 milestones achieved

- **Delivery**: MMRCRS Solution Package to Duke

- **Impact**: Promising results approved by Duke Energy for next step; Supported by other utilities for testing, FP&L and Consumers Energy

- **Future Plans**: NDA for testing the production system; algorithm improvement; tech transfer