Practical Approaches for the Digital Twin Representation of Protection and Control Systems

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Introductions

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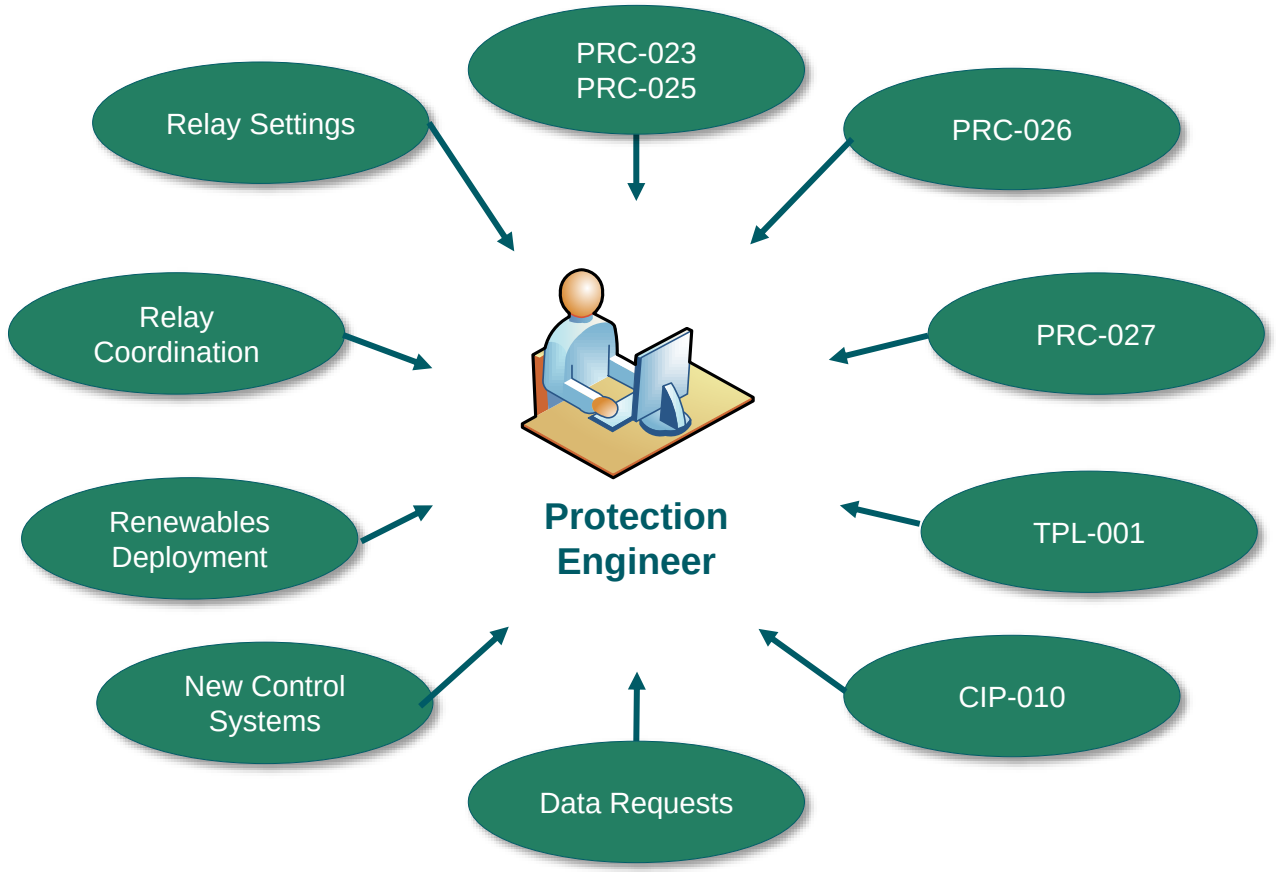
About Hydro One

- Hydro One is a publicly traded utility operating 97% of HV transmission and serving 1.3 million distribution customers in the province of Ontario.
- Ontario peak transmission demand roughly 25,000 MW.
- **Hydro One HV Transmission**: 500/230/115 kV levels (30,000 km ~ 19,000 mi).
- **Hydro One LV Distribution**: 44/27.6/13.8 kV levels (123,000 km ~ 77,000 mi).
- Interconnections with New York, Quebec, Manitoba, Michigan, Minnesota.

Introduction

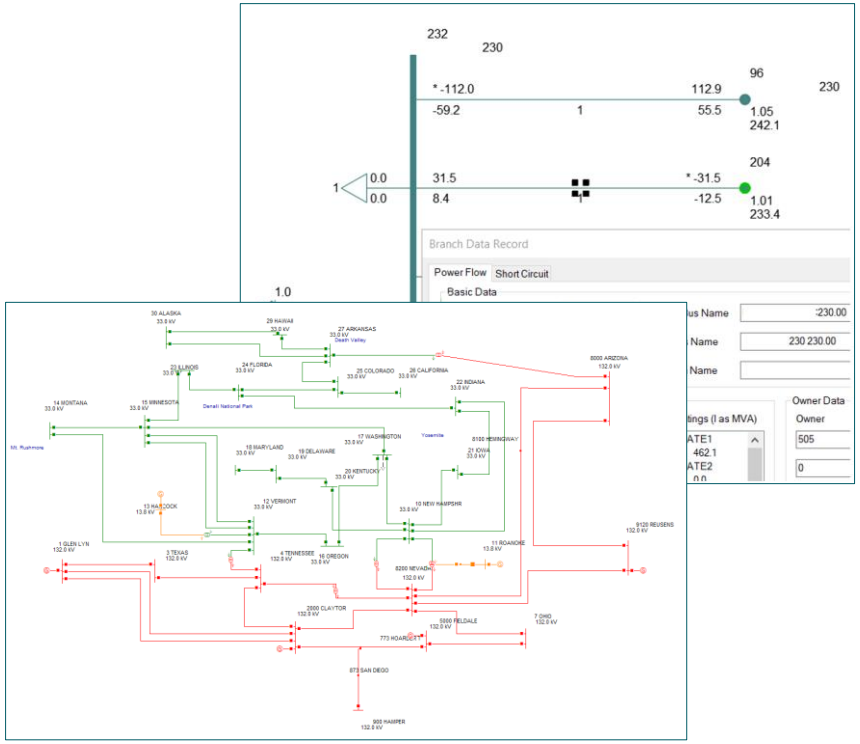
- Protection and Control engineers are faced with increasing requirements for reliability, changing technology, and (especially) expanded **compliance**.
- Engineering departments must meet these new challenges with fewer personnel, especially as experienced engineers retire
- Software-based models (“digital twins”) offer a compelling approach to meeting these challenges



This presentation will discuss the considerations in maintaining a Digital Twin model, as well how one major utility approached the question.

What is a Digital Twin?

“Virtual representation of an object or system designed to reflect a physical object accurately. It spans the object’s lifecycle, is updated regularly to match true system data, and uses simulation…. to help make decisions. ”



- Software representation of the power system, including its connections, characteristics, and functionality.
- Simulation that can replicate behavior, both in terms of system characteristics and equipment response, under different conditions.
- Enables decisions to be made or functionality to be confirmed.
- Performance and characteristics of protection systems: *do they respond appropriately and meet requirements?*

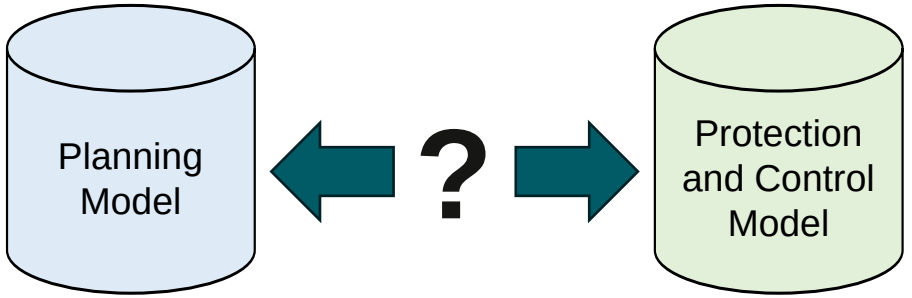
Need for Accurate Representation

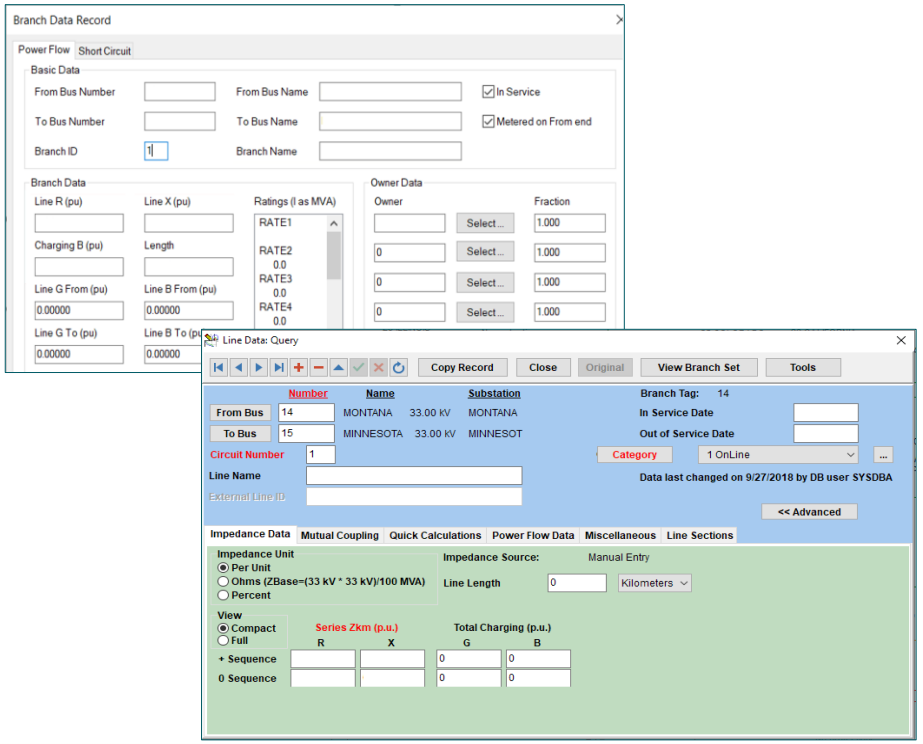
- Digital models are only as good as the data they're made up of – *accuracy* and *completeness* of representation are key to providing useful results.
- From Protection and Control perspective, there are generally two components:
  - System representation
  - Protection representation
- Building the model once is generally do-able; it may be a large effort, but it certainly can be done
  - But how to keep the model maintained across changes – both in the system and in the protection?

How can we keep our digital twin models up-to-date so they accurately reflect the actual system?

Alignment Challenges

- Protection and Control does not function in a vacuum – there are other digital twins used at the utility.
- P&C model would ideally align with those in other departments (Planning), however:
  - Models maintained by different departments
  - Departments have own conventions, ideas, and needs; models are built in different ways:
    - Topologies (some taps may not be applicable to both)
    - Parameters (zero-sequence impedance)
- Each department will have own update processes (independent from each other)





Alignment Challenges

1 Communication

- When and what should be updated?
- How to ensure that what's updated in one model is reflected in the next?

2 Alignment

- How to ensure that the system is represented the same way?
- Standardizing conventions, data, calculation methodologies

3 Ownership and Roles

- Who initiates the process and is responsible for the data?
- How are conflicts (inconsistencies) resolved?

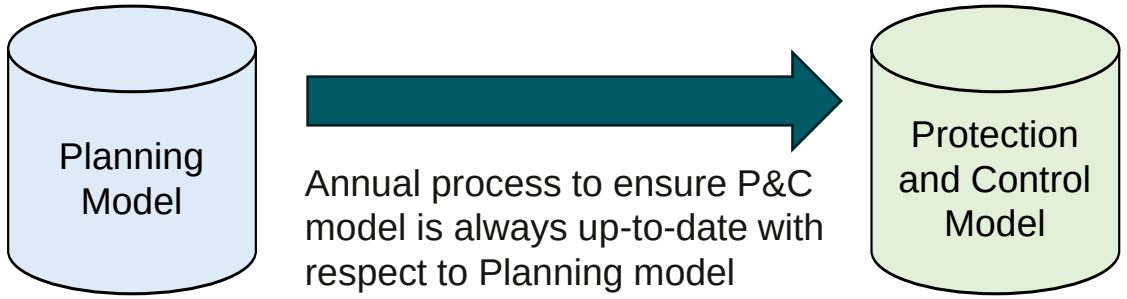
4 Department Collaboration

- Enhancing collaboration between departments to facilitate all of the above?
- **Utilities typically dedicate teams to update processes and methodologies**

Hydro One's Approach

"Utilities typically dedicate teams to update processes and methodologies"

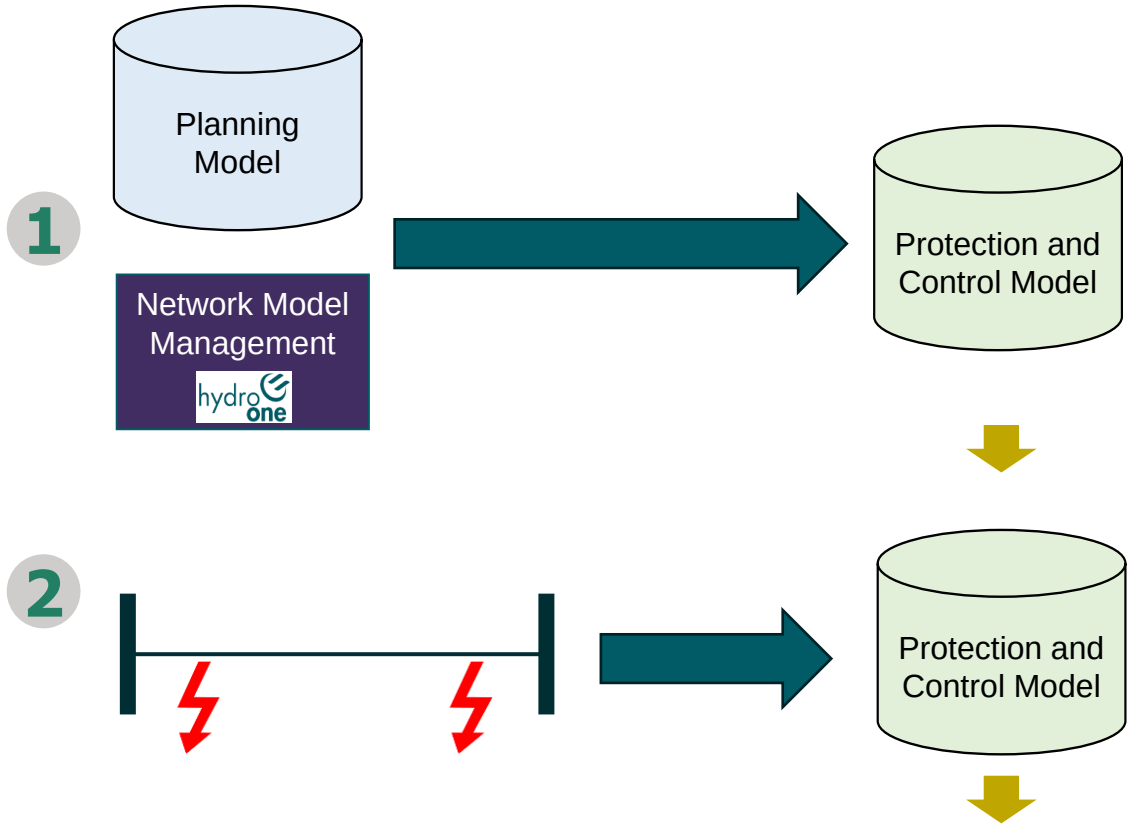
- Hydro One's process is different.
- Motivation was to ensure that the protection (short-circuit) model is always aligned with Planning for a given year.
- Instead of independently maintaining the short-circuit model...
- A new model is generated on an annual basis using the appropriate planning model as a basis



Needed for annually generated new model:

- Topology of system, including: buses, lines, equipment, connections
- Naming of buses, substations, equipment
- Equipment parameters
- Protection representation

Hydro One's Process – System



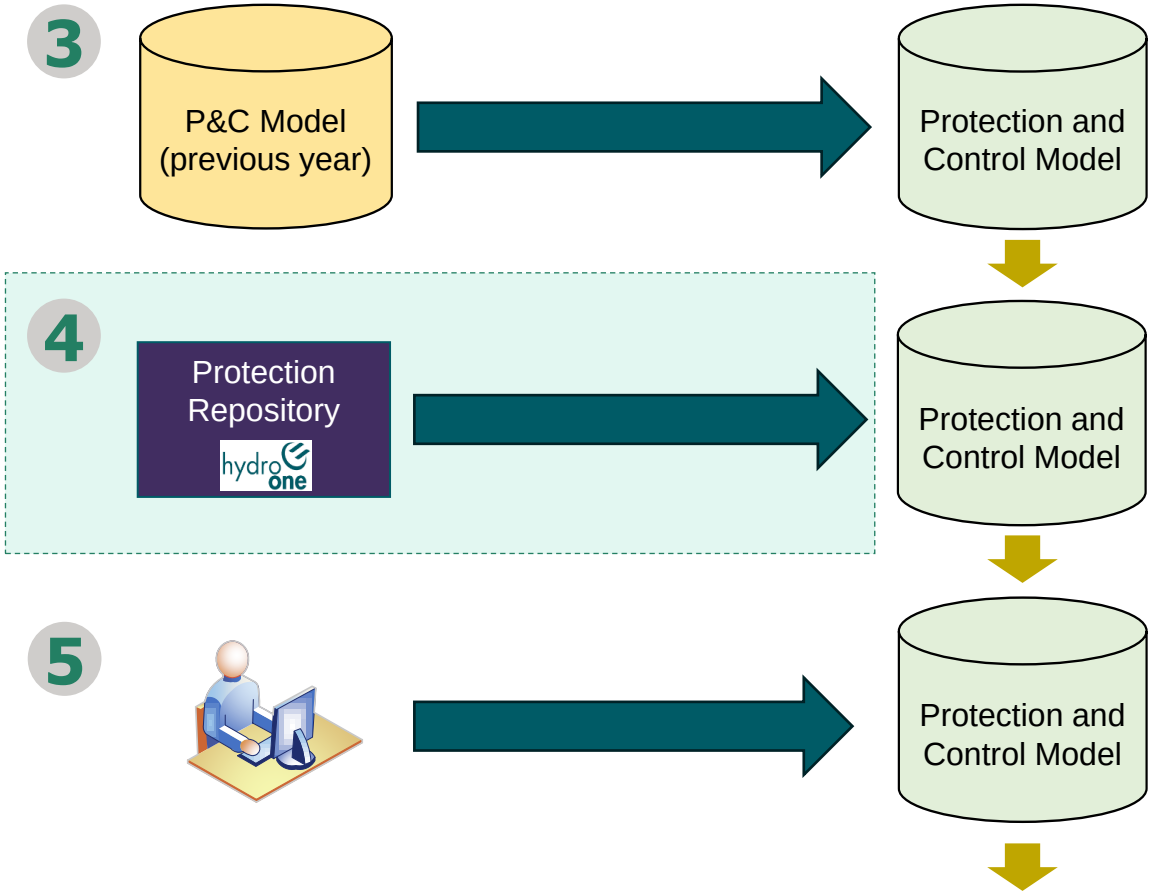
New P&C model is generated from the appropriate Planning model, including topology and nameplate data

Short-circuit study is performed to ensure both contain the same electrical representation of the system

Result: New P&C model that contains the same system as the base Planning model

But what about protection?

Hydro One's Process – Protection



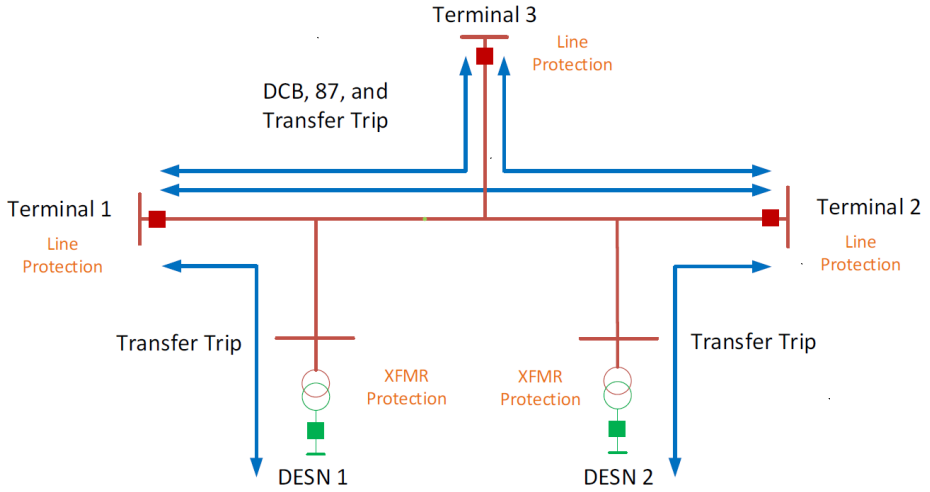
Previous year's protection model is merged into this newly generated one

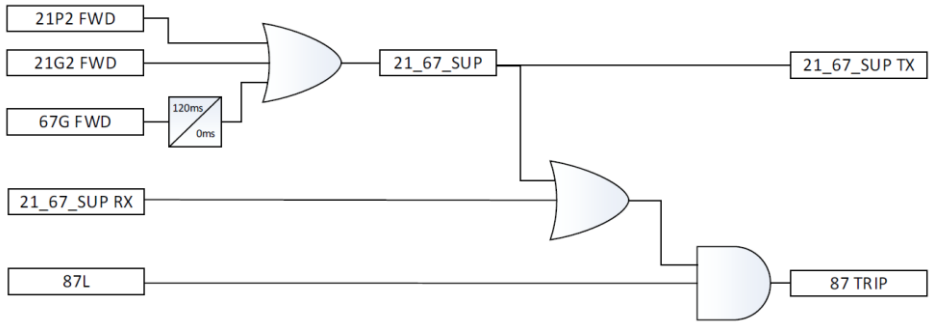
Protection updated from previous year is identified; representation is created in the digital twin model

Engineers confirm new protection representation through simulation testing

Result: New P&C model that contains up-to-date system and protection representation

Challenges for Protection Representation

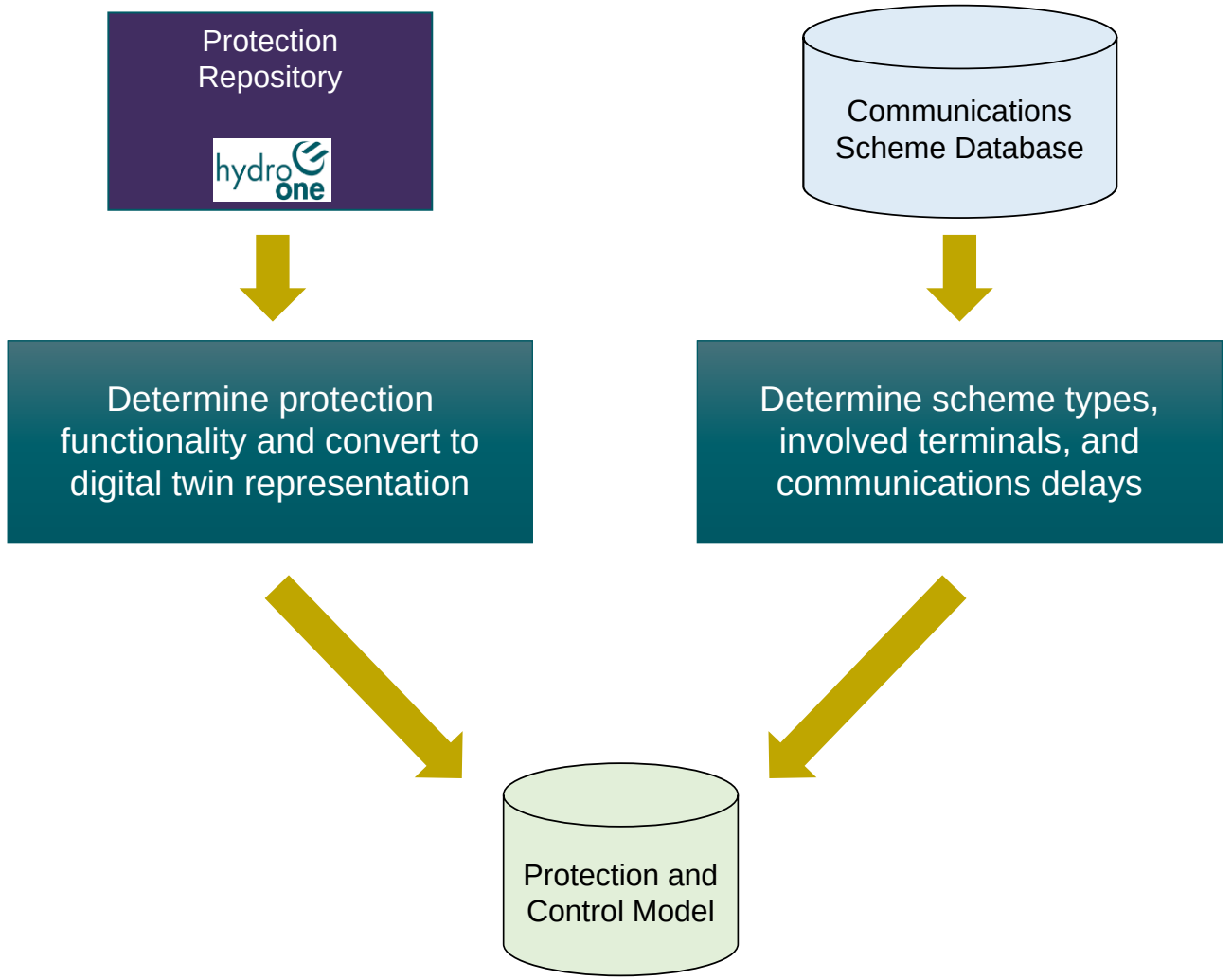




- Representing HONI protection schemes:
  - Protection schemes can be complex, with multiterminal lines including tap transformers (DESNs)
  - Need for custom implementation and logic in digital twin to properly represent protection functions – exceeded built-in software models!
- Line protection depends heavily on teleprotection schemes (POTT, DCB, TT, Line Differential):
  - Need to determine schemes and what terminals are involved
  - Need to implement additional supervisors
- How to determine what's changed?

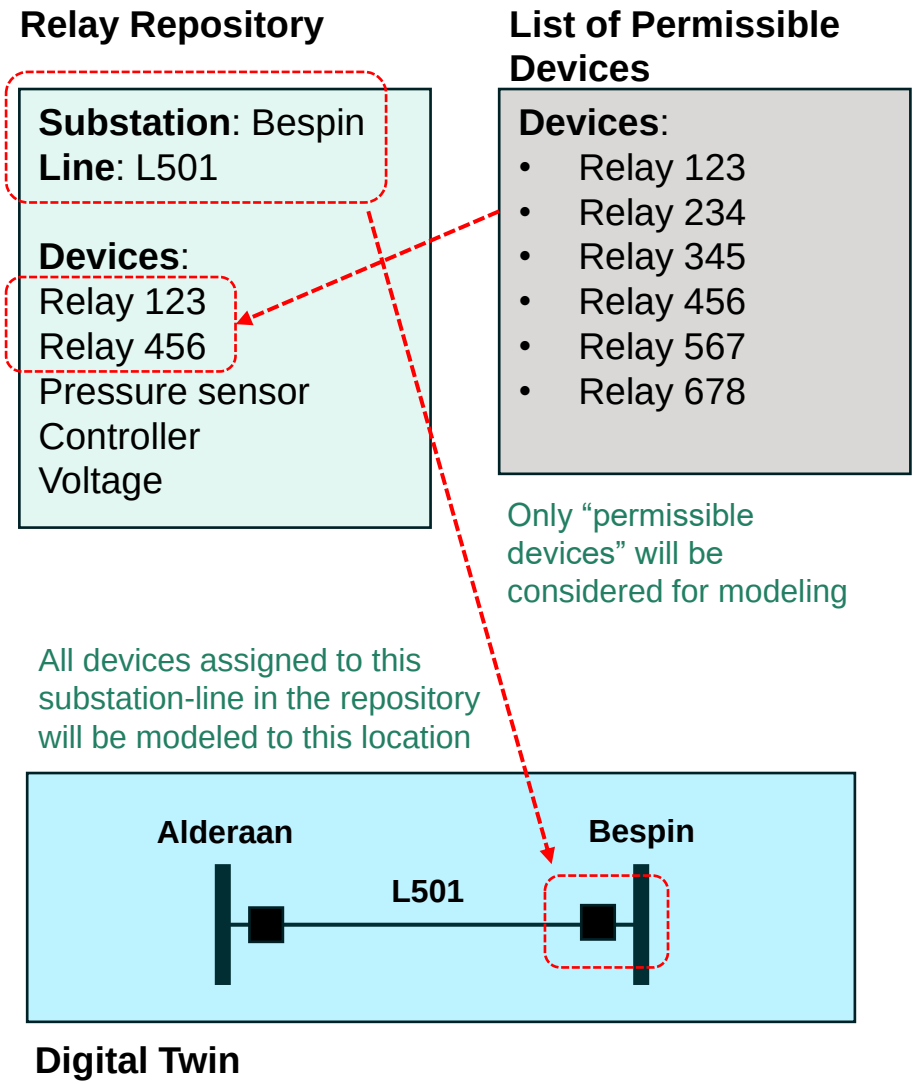
Protection Update Methodology

- Automation-based translation tools were adopted to aid in this modeling process
  - Connection to relay settings repository (gets relay configuration data)
  - Connection to communications database (gets communication scheme data)
- Tailored to meet HONI needs, especially in accommodating the protection complexities
- Support HONI's custom modules for communications schemes



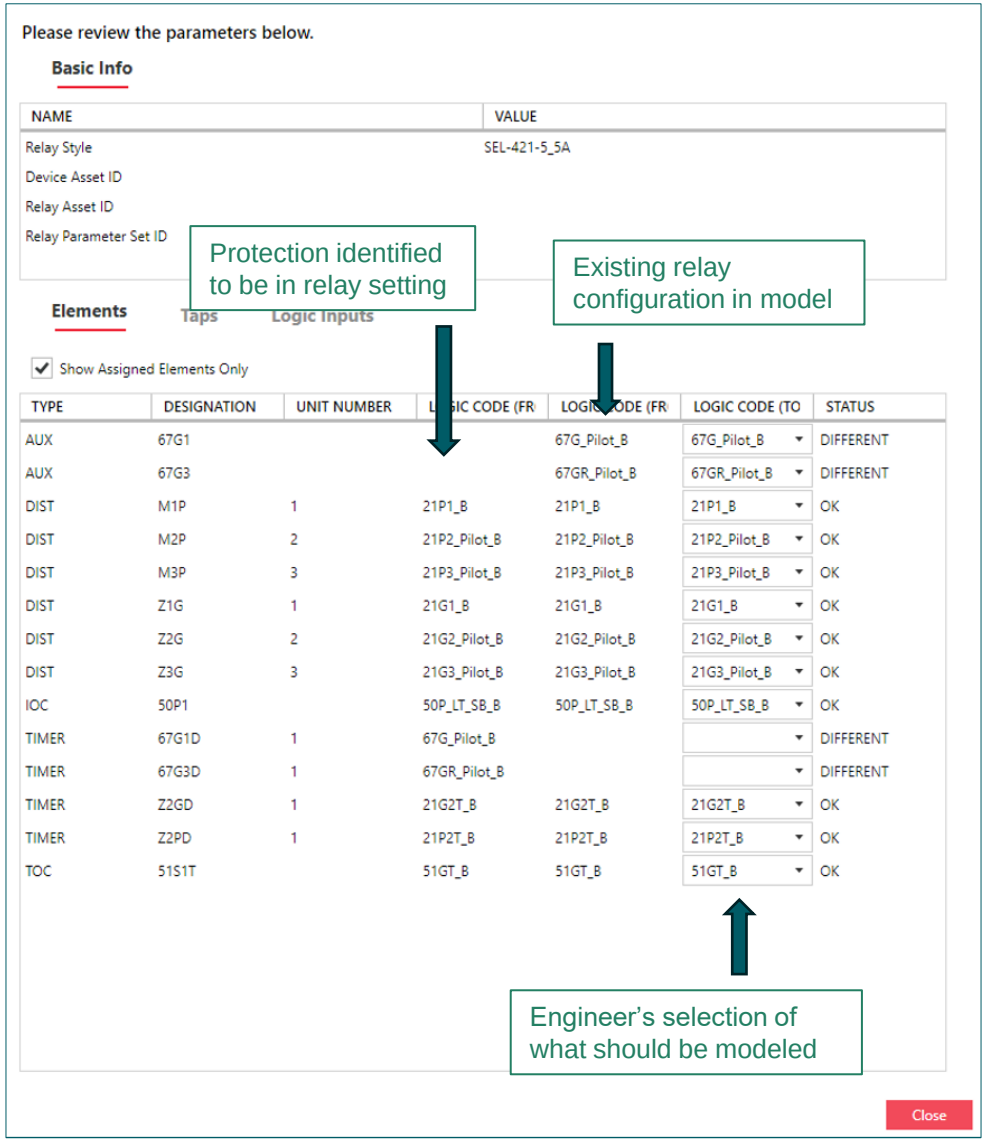
External Information

- Protection update process requires external information to properly create functional representation.
- Communications Table:
  - Not all data for communications schemes can come from relay settings
  - External communications database is needed for connections between terminals and mediums
  - Maintain a table of communications schemes for each transmission line
- Translation Table:
  - Alignment of data from Repository to Digital Twin Model (match entry to location)
  - Locational approach was adopted to ease updates; accept the need to maintain “acceptable” relays



Engineer Involvement

- Hydro One heavily relies on the expertise of our Protection and Control engineers.
- At no point do we want to take engineers out of the process and create a “black box”.
- The entire process reflects this philosophy; “break points” are provided to let engineers override the automation if needed.
- Protection configuration selection is one example:
  - Protection interpretation can be automated,
  - But, as part of our process, we require engineers to confirm protection model will be configured correctly



Engineers have the capability to review the protection interpretation and make changes if needed

Applications: PRC-026

- NERC PRC-026 standard requires detailed evaluation for unstable power swing region.
- Requires consideration of data from various sources.
  - Power system equivalents
  - Relay settings and characteristics
- Can use digital twin to accurately model and study the settings versus requirements.
- Can design and validate mitigation approach with help of automated scripts.
- Audit-ready plots can be generated by the software for reporting.

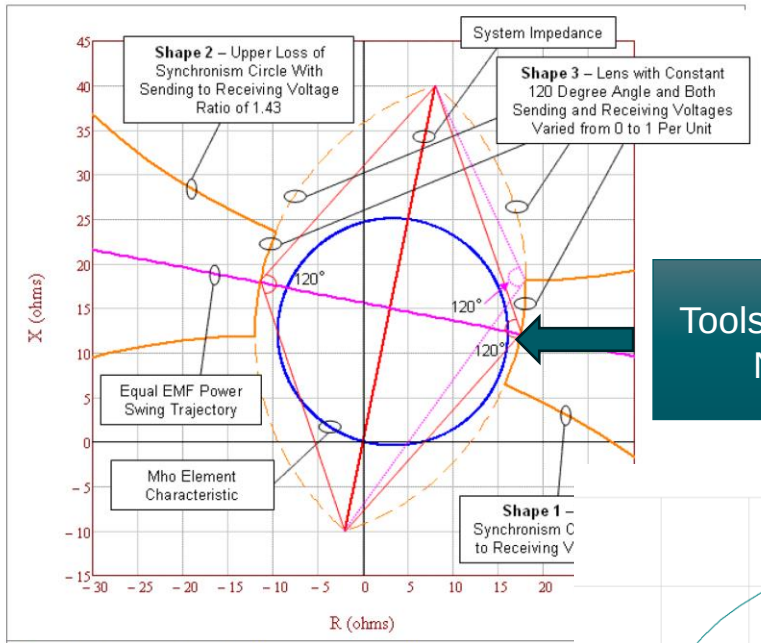
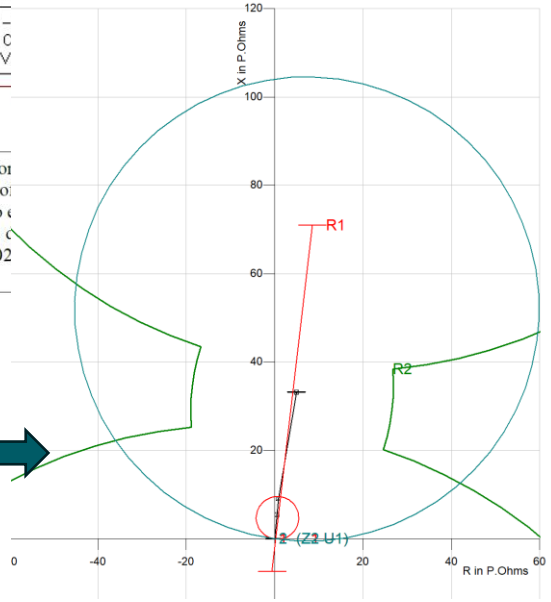


Figure 1: An enlarged graphic illustrating the unstable power swing regio of three shapes in the impedance (R-X) plane: Shape 1) Lower loss-o Shape 2) Upper loss-of-synchronism circle, and Shape 3) Lens. The mho is completely contained within the unstable power swing region (i.e., it portion of the unstable power swing region), therefore it meets PRC-02 Criterion A, No. 1.

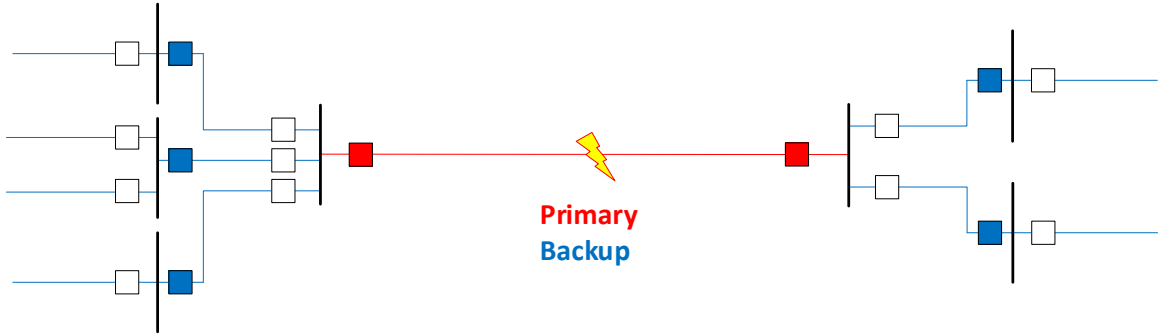
Tools Designed Based on NERC Guideline

Evaluation and Reporting in Software



Applications: PRC-027

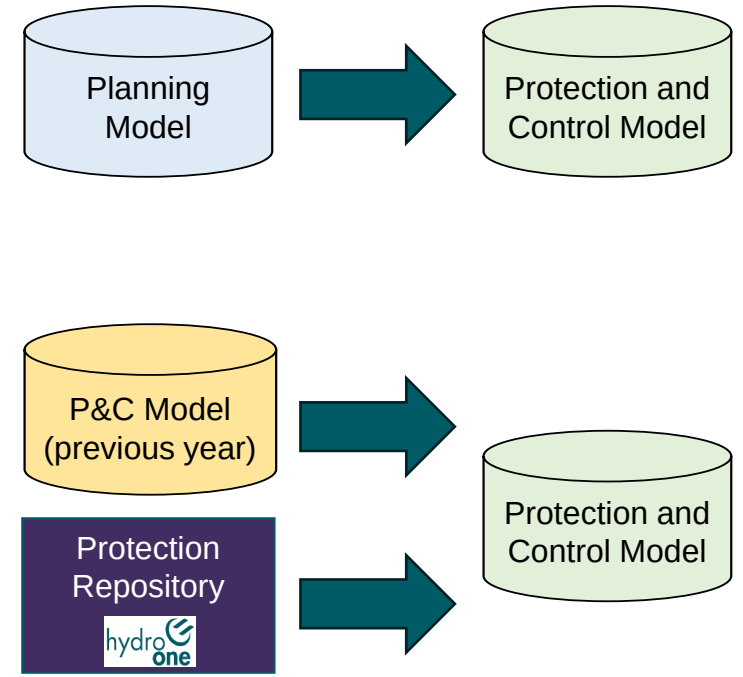
- NERC PRC-027 requires coordination study for buses with more than ±15% variation in fault current over 6-year period.
- Requires consistently keeping an accurate digital twin model every year for comparison.
- Coordination is a challenging study without computer models.
  - Large amount of backup relay tripping and teleprotection logic must be evaluated at once.
  - Each type of relay has slightly different operating principles.
  - Must consider hundreds of protection and power system contingencies (N-1).



- Can do extensive fault current comparisons and wide-area coordination studies using automated tools now that we have the digital twin of the protection system.

Conclusion

- Digital twins that can accurately represent system and protection behavior serve to help utilities, including Protection and Control engineers, make decisions while coping with challenges and meeting responsibilities.
- Maintaining a digital twin can be challenging, especially alignment with other models and maintaining through updates.
- Hydro One's annual update process ensures the P&C Model is always aligned with the Planning Model:
  - New P&C Model is generated every year from the latest applicable Planning Model
  - Protection from previous year is merged with new model, and new protection is updated
- Automation-based approach is used to update the protection representation, tailored to meet HONI's needs (complex schemes)
- Our philosophy is to leverage the expertise of our engineers. Automation processes were built to accommodate this philosophy



Thank you

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