A.I. Application
in Power Transmission System Operation
Imagine there is a “superman” who is able to

- sense the status of the transmission system,
- know the control action for certain contingencies, or the operation limits when no control action is available
- take necessary control actions, or apply operation limits

In my mind, this is the goal of A.I. application in power transmission system operation.
1. AI Application Idea in Power System

This is perfect ANN data sample set arrangement!
1. AI Application Idea in Power System

Deep Learning

ImageNet

Doing things right

Doing the right things
1. AI Application Idea in Power System

“How we're teaching computers to understand pictures”

(5’45” ~ 9’30”)

TED
Ideas worth spreading
1. AI Application Idea in Power System

If a test sample is from the training sample set, then the “AI” model can 100% correctly recognize.
1. AI Application Idea in Power System

The same analogy can be used with power transmission system

✓ Replace “image” by “scenario”
✓ Off-line calculation for “big data”, actually the “whole” data,
  • Input: system condition + contingency
  • Target: control action or operation limit
✓ Using the data sample to train “Artificial Neural Network” model
✓ Using the trained “Superman” to real time system operation

That’s the idea of A.I. application in power transmission system operation.
1. AI Application Idea in Power System

- By adding more sample points, we can cover all system scenarios at required accuracy.
- The shaded areas are the system capability wasted if simple model used.
1. AI Application Idea in Power System

Image Recognition
(its sample data is in an open space)

- Image
- Digitalized image
- ANN Algorithm
- Result

Digitalized Scenario

- Digitalized Scenario
- ANN Algorithm
- Result (Control, limits)

Transmission Operation Application
(its sample data is confined in an enclosed space)
1. AI Application Idea in Power System

There are many AI tools to use
2. Example -- Vancouver Island RMR

\[ P = f(x_0, x_1, x_2, x_3) \]

- \( x_0 \), Jordan generation MW
- \( x_1 \), available VAR at VIT
- \( x_2 \), OOS element
- \( x_3 \), VI load pattern
2. Example -- VI RMR: PV Calculation
2. Example -- PSS®E/Python Automation

PSS®E/Python Automatic Production Line (APL)

Load Pattern (5)  OOS (30)  VIT VAR (4)  JorMW (7)  Numerical Control Machine

Loop 4 4200  Loop 3 840  Loop 2 28  Loop 1 7 scenarios

SIEMENS POWER TECHNOLOGIES INTERNATIONAL

100000 BUS POWER SYSTEM SIMULATOR--PSS®E-33.7.0

INITIATED ON MON, APR 23 2018  14:08

Start PV calculation for None outage (#0)...at time: 2018-04-23 14:08:59

--- ratio: BenchMark ---

<table>
<thead>
<tr>
<th>x</th>
<th>-50</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>130</th>
<th>150</th>
<th>170</th>
</tr>
</thead>
</table>

BC Hydro
Power smart
2. Example -- VI RMR DATA Samples

Two variables: \( P = f(x_0, x_1) \)
2. Example -- VI RMR DATA Samples

Three variables:

\[ P = f(x_0, x_1, x_3) \]
2. Example -- VI RMR DATA Samples

Four variables:

\[ P = f(x_0, x_1, x_2, x_3) \]
### 3. A.I. Application – Raw Data

| x1 | x2 | x3 | x4 | x5 | x6 | x7 | x8 | x9 | x10 | x11 | x12 | x13 | x14 | x15 | x16 | x17 | x18 | x19 | x20 | x21 | x22 | x23 | x24 | x25 | x26 | x27 | x28 | x29 | Y |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |
| 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 1   |

Rearrange the previous data sample format ...

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[BC Hydro: Power smart]

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3. A.I. Application -- ANN Model

\( X = [x_1, x_2, \ldots, x_{33}]^T \)
\( A = [a_1, a_2, \ldots, a_{10}]^T \)
\( B1 = [b_1, b_2, \ldots, b_{10}]^T \)
\( Y = [y_1, y_2, y_3, \ldots, y_{10}] \)
\( B2 = [b] \)

\[ A = [w_{1j}]X + B1 \]
\[ [y_i] = [S(a_i)] \]
Output = \( b + \Sigma(y_i \times w_{2j}) \)
\( i = 1, 2, \ldots, 10 \)
\( j = 1, 2, \ldots, 33 \)
3. A.I. Application – Error Analysis
3. A.I. Application – Error Analysis

Error between original and ANN output of VI load
## 4. VI RMR Update and Benefit

JOR Gen and VIT VAR RMR Requirements

<table>
<thead>
<tr>
<th>Condition</th>
<th>Jordan MW Output</th>
<th>Available VIT MVAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>If VI MW load:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 2039</td>
<td>≥ 2098</td>
<td>≥ 2153</td>
</tr>
<tr>
<td>Or C&amp;SVI MW load:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 1356</td>
<td>≥ 1395</td>
<td>≥ 1432</td>
</tr>
<tr>
<td>then Jordan MW output must be:</td>
<td>on line</td>
<td>≥ 50</td>
</tr>
<tr>
<td>and available VIT MVAR must be:</td>
<td></td>
<td>≥ 195</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Load ratio</th>
<th>Prob.</th>
<th>Existing OO</th>
<th>New</th>
<th>Increment</th>
<th>Existing OO</th>
<th>New</th>
<th>Increment</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 66.5%</td>
<td>6.9%</td>
<td>2039</td>
<td>2175</td>
<td>+136</td>
<td>2281</td>
<td>2304</td>
<td>+23</td>
</tr>
<tr>
<td>&gt; 65%</td>
<td>13.8%</td>
<td>2206</td>
<td>2206</td>
<td>+167</td>
<td>2281</td>
<td>2305</td>
<td>+24</td>
</tr>
<tr>
<td>&gt; 60%</td>
<td>30.5%</td>
<td>2265</td>
<td>2265</td>
<td>+226</td>
<td>2281</td>
<td>2315</td>
<td>+34</td>
</tr>
<tr>
<td>&gt; 55%</td>
<td>31.8%</td>
<td>2275</td>
<td>2275</td>
<td>+236</td>
<td>2281</td>
<td>2313</td>
<td>+32</td>
</tr>
</tbody>
</table>
5. A.I. Application -- Demo

EXCEL DEMONSTRATION

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**Daily VI RMR**

**2018-10-21**

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**Weekly VI RMR**

**2018-10-21**

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