Opportunities and Challenges in Power System Protection

ABB Corporate Research

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Power Systems with Highly Penetrated Renewable Source

Changing Patterns of Electricity Supply and Demands

-A power system with high levels of distributed and renewable is the trend

-This trend is set to continue and it will increase the complexity of operating a secure and cost effective power system

-Some Examples of Renewable Strategy*: US 2050: 60% China 2050: 85% Germany 2050: 80%

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Requirement and Trends for Power System Protection

Requirement

- Power system availability (reliability, stability).
- Speed, selectivity, Sensitivity and reliability of a protection system

Main Trends

- New Conception protection function improvement
  - High sampling rate related applications and Function integrations
  - Further improvement in protection dependability and security
- Renewable Source Connected (Converter) Power System Protection
- System related issues are combined such as oscillation detection
- Communication impact on protection
- IEC61850 applications and Digital Substations
- Wide area protection(System Integrity protection) and Cyber Security
- HVDC and FACTS related Protection Solutions
Challenges for Power System Protection for Renewable Power Systems

New Areas for Power System Protection

- **Weak System Protection Issue**
  - Need highly sensitive protection solution
  - Converter connected power line

- **Low Inertia with high speed protection demand**
  - It is needed to trip faults in a speed way in order to keep system stability with high penetration of renewable connected grids

- **High Impact of Fault Impedance**
  - Fault current from renewable source is very low

- **Variable Source Impedance During Fault period**


*Source 2: CIGRE B4 Session in 2014*
Why fast fault clearing time?

Faster clearing time means higher wind penetration is possible

Figure 14: The percentage of faults in Ireland leading to critical clearing times under 200 ms vs wind penetration [38]

Example 1 - Single Phase to Ground Fault Currents within 3 phases measured from Wind Farm

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Example 2-Type 3 Wind Farm (doubly Fed Induction Generator) 3-ph faults

- Three phase fault condition just in the 35 kV side from Windfarm in Type 3 Wind farm (fault currents have oscillations)
Transmission System Protection - Main Demands

- Speed and total fault clearing time is key for Transmission Protection Systems.
- Selectivity and dependency are also very important for transmission lines protection (parallel lines, high impedance faults).
- Security (no-mis-operation) is critical for all transmission line protection, especially for series compensated lines.
- Reliability is a general measure for a total protection system during its life cycle time.
Dr. Indy Sokhey (Chief Responsible for Protection in National Grid of UK) Presentation in March 7th in DPSP2016

Fast fault clearance is still key driver for grid customers
BPA (Utility in USA)- Demand on Fault Clearing Time <4 Cycle=66.68 ms

<table>
<thead>
<tr>
<th>Connection Voltage (Line-Line rms)</th>
<th>Total Clearing Time (Cycles)</th>
<th>Maximum Relay Operate Time (Cycles)</th>
<th>PCB Trip Time (Cycles)</th>
<th>Time Delayed Tripping Acceptable?</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100 kV</td>
<td>≤ 12-14*</td>
<td>≤ 4-6*</td>
<td>≤ 8</td>
<td>Yes</td>
</tr>
<tr>
<td>100 to 138 kV</td>
<td>≤ 7-9*</td>
<td>≤ 2-4*</td>
<td>≤ 5</td>
<td>Yes</td>
</tr>
<tr>
<td>161 to 230 kV</td>
<td>≤ 5-7*</td>
<td>≤ 2-4*</td>
<td>≤ 3</td>
<td>Yes</td>
</tr>
<tr>
<td>230 kV Main Grid to 345 kV</td>
<td>≤ 4</td>
<td>≤ 1</td>
<td>≤ 2</td>
<td>No**</td>
</tr>
<tr>
<td>500 kV</td>
<td>≤ 4</td>
<td>≤ 1</td>
<td>≤ 2</td>
<td>No**</td>
</tr>
</tbody>
</table>

UHV Transmission System demands fast fault clearing in order to keep system stability and to reduce possible damages on power system components.
Fault location and protection

- **Fault location based on Travelling wave theory**
  - Conventional Overhead lines
  - Cables
  - Mixed lines (cable + overhead lines)

- **New Protection Application Functions Based on Travelling Wave Theory**
  - Travelling wave based high speed protection for AC transmission lines
  - Travelling wave based HVDC protection

- **Time domain protection**
  - Superimposed principles
  - Others
Comparison of digital vs. traditional solution for static VAr compensator (SVC) project

- 4 ABB Relion relays vs. 14 traditional relays
- 50% reduction in number of panels – 4 to 2

Main protection - traditional relays

Main protection - digital substation
ABB’s digital substation product portfolio - Overview

- **Substation interface and HMI (Station level)**
  - ABB SAS 600 systems

- **Protection and Control (Bay level)**
  - Relion family control and protection IEDs

- **Interface to Switchgear (Process level – NCIT)**
  - ABB NCITs for GIS, CP-MU merging unit for ELK-CP14 and ELK-CP3 (current and voltage)
  - ABB LTB with integrated Fiber Optic Current Sensor FOCS-MU (current only)
  - Process level – stand-alone merging units
  - SAM600 modular process bus IO system
Wide Area Monitoring/Control/Protection (WAMPAC) Systems

Today’s ABB Solutions

- Digitalization
- Big data collection
- Communication
- Better system observation.
HVDC Line Protection—For Multi-terminal Systems and Embedded Systems

- HVDC transmission will be more and more in the power systems
- Voltage source converter (VSC) based HVDC links shows advantages in interconnections.
- Protection solution for HVDC lines is naturally required with the development of HVDC connections, especially for Multi-terminal HVDC (MTDC) transmission systems.
- Hybrid AC/DC line Protection Solutions
- HVDC system impact on HVAC protection