DISTRIBUTION PROTECTION COORDINATION PROGRAM USING GIS

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ABSTRACT
Korea Electric Power Corporation (KEPCO) covers all power distribution lines in Korea. There are 16 districts and 189 branches around the country. To integrate and manage power distribution processes centrally, KEPCO developed the New Distribution Information System (NDIS) based on the GIS (Geographic Information System). NDIS provides efficient power distribution line management and improves resource accuracy.

KEPCO developed distribution protection coordination program using NDIS as its base. Using a GIS schematics diagram, the NDIS distribution protection coordination program provides coordination data for protecting device settings (substation circuit breakers, reclosing switches, sectionalizers, auto section switches, line fuses, etc).

INTRODUCTION TO NDIS
KEPCO’s NDIS History
KEPCO decided to upgrade from its older distribution system (based on the IBM Geographical Facility Info System) to NDIS (New Distribution Information System). This decision was made to more effectively address its company-wide information management requirements.

In 1997, KEPCO began its search for new technology which had the capacity to handle a number of growing issues; namely, the ability to handle numerous engineering drawings, with increasing numbers of poles, distribution transformers, distribution lines, etc. KEPCO was also hampered by limitations inherent in a text-only system. There were other considerations as well, such as the need to prevent outages and prepare for high quality services. KEPCO’s needed to comply with NGIS (National GIS) requirements which were enforced by the Korean government as part of a ten year project.

Therefore, KEPCO organized a new team in 1997: the Marketing & Distribution Information System Team. The team conducted overall work flow analysis, business process reengineering (BPR), made general drawings, and developed new programs which were customized to meet specific user requirements in distribution lines between 1997 and 2001.

KEPCO first launched NDIS at its Inchon branch in 2001, as a test operation. Along with Inchon and Seoul, other KEPCO branch offices were slated for NDIS installation, following the completion of the initial data capture projects. The following table shows the NDIS DB construction results.

< Table 1 > KEPCO’s Facility in NDIS

<table>
<thead>
<tr>
<th>Facility</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution lines:</td>
<td>8,148 lines</td>
</tr>
<tr>
<td>Poles:</td>
<td>8,052,929 units</td>
</tr>
<tr>
<td>High-voltage power line length:</td>
<td>378,459 c-km</td>
</tr>
<tr>
<td>Transformer:</td>
<td>1,885,632 units</td>
</tr>
<tr>
<td>Switch:</td>
<td>96,364 units</td>
</tr>
</tbody>
</table>

NDIS Functions
By applying new IT technology to distribution works, NDIS can make controls and processes for planning, design, construction, operation and statistic reporting. The control is easier, faster and more accurate. The following are NDIS applications:

- Design and construction management
- Outage management and operation
- Protection coordination
- Engineering calculations such as load analysis and short/ground current calculation
- Business/interior wiring and metering
- High voltage schematics/skeletons diagram

< Fig 1 > NDIS Integration Diagram
PROTECTION COODINATION ISSUES

Objectives of the protection coordination

The main objectives of the protection coordination are:
- Reduction in interruption duration
- Reduction in the frequency of interruptions
- Reduction in the area of interruption
- Improvement in reliability of the systems
- Improvement in customer satisfaction
- Increase in the competitiveness of the electric company

Protective device

The first purpose of the protective device is to isolate the faulted section from the normal sections, which means the protective device shall be able to be open when a fault occurs on the downstream side of the device. If there are two or more protective devices on the upstream side of the fault point, the device nearest to the fault point shall open and others shall remain closed. The protective coordination means coordinate the protective device to properly operate as shown below.

- The protective device shall be cooperated with the backup device
- The protective device is recommended to be located on the downstream side of important customers, the area with the highest load density.
- It is efficient for the protective device to divide the load amount equally.

< Fig 2 > Backup & Protecting device

KEPCO has about 7,343 protective & back-up devices on 8,148 distribution lines all over the country.

Coordination Methods

There are 3 methods for coordinating distribution lines:
- Using differences in response times
  - Timing relay, recloser, line-fuse
- Using differences in fault currents:
  - Instant relay
- Using differences in operation counter
  - Sectionalizer, reclosing device

PROGRAM OVERVIEW

Background

KEPCO decided to upgrade the protection coordination program from its old version (PC stand-alone program) to NDIS, based on a new program using GIS DB & other technology. Because GIS DB provides the factors used in protection coordination calculations, the user does not have to draw diagrams and input data like load current and customer power usage data, etc.

Protection Coordination Program Features

The protection coordination program (PCP) provides coordination data for device when new high-voltage customers request electricity, new protective devices are installed or existing devices are rearranged. The NDIS protection coordination program provides information for sections, accumulated load-currents, and fault-current data using GIS. The information from protective devices can be received from the facility DB, so users only check the data for protective device settings. NDIS PCP provides protective coordination reports, diagrams, TC curve etc. The main features of the distribution protection coordination program are:

- Automatic drawing of schematics diagram using GIS DB
- Provides accumulated load current and fault current calculated by NDIS using customer power usage data, power line span data, etc.
- Provides protection device setting data from automatic calculations using basic device data, OCR time TAP setting, OCR pickup setting, device operation cycles, etc.
- T–C (Time–Current) curve graphically shows the relationship between input current and operation time.

For job processes, user can create protection coordination reports and process job flows for manager approval using the WFM (Work Flow Management) system.

Coordination Procedures

Coordination procedures are:

- Protective coordination request starting
- The D/L selection for protection coordination
- Coordination serial number creation
- Coordination map generation
- New-customer & device registration
- Coordination map re-generation
- Main-Transformer information check
• Circuit-Breaker information check
• Recloser information setting
• Other device information setting
• Calculation & reporting

< Fig 3 > Procedure Diagram

Schematic diagram generation procedures are:
- Basic diagram creation from facility map
- Acquisition of main transformer data
- Creation of section data and checking

PROGRAM FUNCTIONS

Protection Coordination Diagram
A protection coordination diagram is generated by the NDIS facility map automatically on power-line relation rule. The main displayed attributes are sub-station, main transformer, distribution line, node pole no, load section, load node point, protective device, terminal pole no, high-voltage customer, load current, fault current etc.

< Fig 4 > Schematics Diagram Generation

Load Current Calculation
Load current = DL Max current × protective device side facility capacity/ DL facility capacity

- DL Max current = Net DL Max current + ∑(new High Voltage customer contract watt × consumption ratio/(√3×22.9×0.95))
- DL facility capacity = ∑section facility capacity (Transformer + High Voltage customers + new High Voltage customers)
- Protective device side facility capacity = ∑load section facility capacity (Transformer + High Voltage customers + new High Voltage customers)

To consider prerequisites are:
- Load current equation fix
- Section facility capacity handle & update period
- Section facility capacity calculation base

Fault Current Calculation
Short circuit fault current is used for phase value setting, earth fault current is used for ground value setting.

- I3s (3 phase short circuit current) = (100/%Z1) × DL capacity/(√3×22.9)
- I2s (2 phase short circuit current) = (√3/2)×I3s
- Ig (Single-phase earth-fault current) = (3×100)/(%2Z1+%Z2+%Z0+3%Rf) × DL capacity /(√3×22.9)

Recloser Settings
There are two main functions for recloser settings. The first one is the automatic setting function that displays recloser setting values on a schematic diagram. The user clicks the setting button and the program locates the backup DL relay or recloser and calculates the setting value by itself. The program then provides the function locating TC curve optimized with the backup device. The second function is the manual setting function that examines coordination time changes (fast/delay curve) and sequences in automatic setting values. Registration values are minimum trip current and X-multiplier constant, reclosing time, maximum fault-current, minimum fault-current, minimum rating value, maximum rating value, instantaneous time, backup instantaneous time, time delay, backup time delay etc.
T-C Curve
T-C (Time-Current) curve is a method to present the relationship between the current and operating time of the protective devices. Generally, the X-axis of the TC curve represents the ratio of actual current to preset current (called the pick-up multiple). The Y-axis means the operation duration time in seconds or cycles. NDIS PCP provides two functions. The first one is a multiple function that changes to desired curves using a time-constant multiple to T-C curve. The second one adds functions that change to the desired curve using a time-constant added to the T-C curve.

Conclusions
Geographical Information System (GIS) is a universally recognized tool used to assist utilities in the efficient management of distribution networks. KEPCO’s GIS supports technical operations (such as technical calculation, network analysis) and builds a base to provide management information on the distribution field. KEPCO’s GIS system is a core system to interface with other power systems. KEPCO GIS’s initial focus is power facility design and maintenance management, as well as facility history management. But nowadays KEPCO emphasis on applying technical applications like load forecasting, load balancing, fault prediction using GIS technology & DB. The meaningful result from that approach is protection coordination program. Users had to draw diagrams manually on the PC-based system before NDIS protection coordination program was developed. NDIS eliminates tedious work for engineers. This program processing is done in real-time, not batch processed, so users could set device coordination at any time across all 8,148 distribution lines. This program can also provide optimized coordination reports to engineer. As a result, KEPCO finally minimized interruption duration. The coordination history is stored in the DB. The DB will be used to analyze protection coordination trends. For future upgrades, KEPCO will consider the program’s real-time interface with SCADA. For improved accessibility to other programs, KEPCO introduce web-based GIS and plans to add that system to the program.

References