Relay Protection Condition Assessment Based on Variable Weight Fuzzy Synthetic Evaluation

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Introduction

A method

Variable Weight Fuzzy Synthetic Evaluation (VWFSE)

- It is used for relay protection condition assessment.
- It is a improved method of fuzzy synthetic evaluation (FSE).
Methods

Fuzzy Synthetic Evaluation

Variable Weight Fuzzy Synthetic Evaluation

Case Study

Conclusion
Methods

Expert Assessment Model

Intelligent Technologies

Fuzzy Theory

Fuzzy Synthetic Evaluation
A considerable ambiguity and uncertainty relationship between the condition of relay protections and their assessment parameters.
Fuzzy Synthetic Evaluation (FSE)

- It is a common method for condition assessment and is getting more and more attention.
- FSE is designed to group raw data into several different categories according to membership functions.

Deficiency

- The weights of assessment parameters are constant.
- The assessment result is not satisfied.
Variable Weight Fuzzy Synthetic Evaluation (VWFSE)

The Key Point of VWFSE

1. Build of Synthetic Evaluation System
2. Membership Function
3. Determining Weights
4. Fuzzy Judgment Result Vector
VWFSE-Hierarchy Assessment Structure

- **Basic Condition A**
  - Relay Protection System
  - Synthetic Assessment Parameter B
  - Synthetic Assessment Parameter C

- **Environment Temperature**
  - Relative Humidity
    - a1
  - Anti-accident Measure
    - an

- **Assessment Parameter**
  - b1
  - bn
  - c1
  - c2
  - cn
**Fuzzy Distribution Method**

**Relative Humidity**

<table>
<thead>
<tr>
<th>Normal Condition</th>
<th>Caution Condition</th>
<th>Abnormal Condition</th>
<th>Failure Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \frac{1}{0.95-x} ) ( x \leq 0.75 )</td>
<td>( \frac{x}{0.75} ) ( 0 &lt; x \leq 0.75 )</td>
<td>( \frac{x}{0.85} ) ( 0 &lt; x \leq 0.85 )</td>
<td>( \frac{x-0.75}{0.2} ) ( 0.75 &lt; x \leq 0.95 )</td>
</tr>
<tr>
<td>( \frac{0.95-x}{0.2} ) ( 0.75 &lt; x \leq 0.95 )</td>
<td>( 1 ) ( 0.75 &lt; x \leq 0.85 )</td>
<td>( 1 ) ( 0.85 &lt; x \leq 0.95 )</td>
<td>( 1 ) ( 0.95 &lt; x )</td>
</tr>
<tr>
<td>( 0 ) ( 0.85 &lt; x \leq 0.95 )</td>
<td>( 1-x ) ( 0.95 &lt; x \leq 1 )</td>
<td>( 1-x ) ( 0.95 &lt; x \leq 1 )</td>
<td>( 1 ) ( 0.95 &lt; x )</td>
</tr>
<tr>
<td>( 0 ) ( 0.95 &lt; x )</td>
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<td>( 0 ) ( 0.95 &lt; x )</td>
</tr>
</tbody>
</table>

**trapezoid distribution**
Fuzzy relation matrixes $R_{n \times m}$

$$
R_{n \times m} = 
\begin{bmatrix}
    r_{11} & \ldots & \ldots & r_{1m} \\
    \vdots & \ddots & \ddots & \vdots \\
    \vdots & \ddots & \ddots & \vdots \\
    r_{n1} & \ldots & \ldots & r_{nm}
\end{bmatrix}
$$

where $r_{nm}$ is the value of membership function.
VWFSE – Determining Weights

The weights

Fuzzy Analytic Hierarchy Process

Variable Weight Theory
VWFSE – Determining Weights

Fuzzy Consistent Judgment Matrix

\[ J_{n \times n} = \begin{bmatrix} j_{11} & j_{12} & \cdots & j_{1n} \\ j_{21} & \ddots & \vdots & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ j_{n1} & \cdots & \cdots & j_{nn} \end{bmatrix} \]

Constant Weights

\[ w_i = \frac{1}{n} - \frac{1}{2a} + \frac{1}{na} \sum_{k=1}^{n} j_{ik} \quad a = \frac{(n-1)}{2} \quad (1) \]

Variable Weights

\[ X_i = \frac{C_a - C_i}{C_a - C_p} \quad (2) \]

\[ v_i = \frac{w_i}{\sum_{p=1}^{n} \frac{w_p}{x_i / x_p}} \quad (3) \]
VWFSE-Fuzzy Judgment Result Vector

\[ B = V \Box R_{n \times m} \]

where \( \Box \) denotes the fuzzy operator.

Weighted averaging operator
**VWFSE - The Procedure**

1. **Part one**
   - Select assessment parameters
   - Build the hierarchy assessment structure

2. **Part two**
   - Build the fuzzy relation matrix $R_{n \times m}$

3. **Part three**
   - Form the variable weight vector $V$

4. **Part four**
   - Calculate the fuzzy judgment result vector $B$
   - Confirm the assessment result
## Case Study

<table>
<thead>
<tr>
<th>Assessment parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Relay protection device</strong></td>
<td></td>
</tr>
<tr>
<td>Environment Temperature</td>
<td>42°C</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>86%</td>
</tr>
<tr>
<td>Familial Defects</td>
<td>Once and repaired</td>
</tr>
<tr>
<td>Operating Life</td>
<td>3 years</td>
</tr>
<tr>
<td>Anti-accident Measure</td>
<td>All done</td>
</tr>
<tr>
<td>Beyond Periodical Inspection Period</td>
<td>Half a year</td>
</tr>
<tr>
<td>Software Fault Condition</td>
<td>10 times</td>
</tr>
<tr>
<td>Module Fault Condition</td>
<td>Twice</td>
</tr>
<tr>
<td>Communication Equipment Fault Condition</td>
<td>Once</td>
</tr>
<tr>
<td>Power Supply Operating Life</td>
<td>3 years</td>
</tr>
<tr>
<td><strong>Secondary circuit</strong></td>
<td></td>
</tr>
<tr>
<td>Operating Environment</td>
<td>59°C</td>
</tr>
<tr>
<td>Operation Box Familial Defects</td>
<td>Once and unreported</td>
</tr>
<tr>
<td>Circuit Anti-accident Measure</td>
<td>All done</td>
</tr>
<tr>
<td>Circuit Infrared Temperature</td>
<td>13°C beyond environment temperature</td>
</tr>
<tr>
<td>Circuit Fault Condition</td>
<td>Twice</td>
</tr>
<tr>
<td>Insulation Resistance</td>
<td>0.9MΩ</td>
</tr>
<tr>
<td>Corrosion</td>
<td>5%</td>
</tr>
<tr>
<td>Blocking</td>
<td>Twice in cable holes</td>
</tr>
<tr>
<td><strong>Channel condition</strong></td>
<td></td>
</tr>
<tr>
<td>The Value of Differential Current</td>
<td>0.5 times smaller than normal range</td>
</tr>
<tr>
<td>The error rate of Optical Fiber Channel</td>
<td>0.5 times smaller than alarm value</td>
</tr>
<tr>
<td>The interruption of Optical Fiber Channel</td>
<td>None</td>
</tr>
</tbody>
</table>
### The Weights Comparison Table

<table>
<thead>
<tr>
<th></th>
<th>FSE</th>
<th>VWFSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{A1}$</td>
<td>$0.14, 0.16, 0.26, 0.12, 0.22, 0.1$</td>
<td>$V_{A1} = [0.147, 0.502, 0.136, 0.071, 0.092, 0.05]$</td>
</tr>
<tr>
<td>$W_{A2} = [0.267, 0.4, 0.2, 0.133]$</td>
<td>$V_{A2} = [1, 0, 0, 0]$</td>
<td></td>
</tr>
<tr>
<td>$W_{B1} = [0.158, 0.358, 0.292, 0.192]$</td>
<td>$V_{B1} = [0.195, 0.467, 0.19, 0.147]$</td>
<td></td>
</tr>
<tr>
<td>$W_{B2} = [0.342, 0.308, 0.208, 0.142]$</td>
<td>$V_{B2} = [0.142, 0.719, 0.052, 0.088]$</td>
<td></td>
</tr>
</tbody>
</table>
## Fuzzy Relation Matrix Table

<table>
<thead>
<tr>
<th></th>
<th>FSE</th>
<th>VWFSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{A2}$</td>
<td>$\begin{bmatrix} 0 &amp; 0 &amp; 0 &amp; 1 \ 0.57 &amp; 0.779 &amp; 0.105 &amp; 0 \ 0.018 &amp; 0.368 &amp; 1 &amp; 0.632 \ 0.816 &amp; 1 &amp; 0.20369 &amp; 0 \end{bmatrix}$</td>
<td>$\begin{bmatrix} 0 &amp; 0 &amp; 0 &amp; 1 \ 0.57 &amp; 0.779 &amp; 0.105 &amp; 0 \ 0.018 &amp; 0.368 &amp; 1 &amp; 0.632 \ 0.816 &amp; 1 &amp; 0.20369 &amp; 0 \end{bmatrix}$</td>
</tr>
<tr>
<td>$R_{B1}$</td>
<td>$\begin{bmatrix} 0.209 &amp; 1 &amp; 0.822 &amp; 0.088 \ 0.287 &amp; 1 &amp; 0.007 &amp; 0 \ 1 &amp; 0.449 &amp; 0.086 &amp; 0 \ 1 &amp; 0.8 &amp; 0.3 &amp; 0.071 \end{bmatrix}$</td>
<td>$\begin{bmatrix} 0.209 &amp; 1 &amp; 0.822 &amp; 0.088 \ 0.287 &amp; 1 &amp; 0.007 &amp; 0 \ 1 &amp; 0.449 &amp; 0.086 &amp; 0 \ 1 &amp; 0.8 &amp; 0.3 &amp; 0.071 \end{bmatrix}$</td>
</tr>
<tr>
<td>$R_{B2}$</td>
<td>$\begin{bmatrix} 0.939 &amp; 0.57 &amp; 0.047 &amp; 0.061 \ 0.25 &amp; 0.833 &amp; 1 &amp; 0.667 \ 1 &amp; 0 &amp; 0 &amp; 0 \ 0.135 &amp; 0.939 &amp; 1 &amp; 0.895 \end{bmatrix}$</td>
<td>$\begin{bmatrix} 0.939 &amp; 0.57 &amp; 0.047 &amp; 0.061 \ 0.25 &amp; 0.833 &amp; 1 &amp; 0.667 \ 1 &amp; 0 &amp; 0 &amp; 0 \ 0.135 &amp; 0.939 &amp; 1 &amp; 0.895 \end{bmatrix}$</td>
</tr>
<tr>
<td></td>
<td>FSE</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>------------</td>
</tr>
<tr>
<td>Normal</td>
<td>Normal</td>
<td>Caution</td>
</tr>
<tr>
<td></td>
<td>0.393</td>
<td>0.344</td>
</tr>
</tbody>
</table>

\[
\mathbf{B} = \begin{bmatrix} 0.393 \\ 0.344 \\ 0.148 \\ 0.116 \end{bmatrix}
\]

\[
\mathbf{B}' = \begin{bmatrix} 0.235 \\ 0.276 \\ 0.142 \\ 0.346 \end{bmatrix}
\]
Conclusion

VWFSE

- VWFSE is proposed
- variable weights are the main feature
- solves the deficiency of FSE ‘s
- result is more objectively and accurately
- the example proves the effectiveness
Conclusion

Parameters
- More teleindication information
- Running condition data of power grids

Structure
- Improve the hierarchy assessment structure
Welcome Criticism!

Thank You!

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