Estimation of Power Distribution in Substation Components using Object Oriented Analysis and Design

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An object oriented model for the estimation of power that is distributed to the substation components is analysed and designed. The substation component comprises agriculture, industrial and residential regions. The important contribution of this paper is to evaluate the distribution of power in specified time slot of six hours and calculate the average power distributed to the substation components. The object oriented analysis (OOA) is examined in the first level and object oriented design (OOD) in the next level. The object oriented principles encapsulation, polymorphism and inheritance is effectively carried out for the power distribution system. The distribution results are shown by the mat lab and starUML softwares. The unified modelling language (UML) is used to show the structural form of power distribution system and its components in a simplified form.

Keywords: OOAD, OOA, OOD, Power Distribution System, UML

Introduction

The power distribution system is extensively complex and large. Most of the techniques are carried out to obtain the solution for load flow and power losses. In power system engineering, object oriented analysis and design (OOAD) methodology was accepted as an alternative over other methodologies due to its flexibility, reusability and maintainability. Literature concentrates various applications of object oriented concepts for the power distribution system. The operational performance of the power distribution system in terms of determining hours of power supply as well as obtaining the probabilities of consecutive hours of power at any time of a day for the 11kv distribution power system$^6$. They explained about the operational and failure features of the network in terms of availability and quality of power, types of fault and frequency of occurrence of faults. Periodical estimation of power distribution is evaluated by kilo-volt-ampere hours. Hence, the determination of hours of power supply for the 11kv power distribution system is extended for the average estimation of power for the first six hours time intervals for the individual and combined components of substation. In this paper, the power that is distributed to the components of substation will be estimated by the OOAD principles$^{10}$. The component of substation is partitioned into three regions. The classified regions in our work are agricultural, commercial and residential$^8$. The ohm’s law is used to find the voltage, current and power. The object oriented concepts polymorphism, encapsulation and inheritance principles is used to develop the programming concepts. The object oriented analysis (OOA) is performed in the first level and object oriented design (OOD) is considered in the next level. The structural form is effectively shown by the unified modelling language (UML).

Object Oriented Analysis of Power Distribution System

Object oriented analysis states, the requirements needed to solve the particular problem domain. In this, the power distribution system is taken as the key concept. The requirement needed for the power distribution system is analyzed in the analysis phase. The power distribution system is taken as main class and the substation is considered as the sub class. The substation receives 33kV of power from the distribution system$^5$. This 33kV is stepped down to 11kV and distribute to the base station computer. The
base station computer is used for the stepped down activities. From here it is distributed to the agriculture, commercial and residential regions.

Application of UML for Power Distribution System

The UML is used in presenting the object-oriented solution in an efficient manner. In UML diagrams three different perspectives may be used, which are conceptual, specification and implementation. The class diagram and activity diagram are shown here for the principles of power distribution system.

Class diagram

A class diagram is a collection of static modelling elements such as classes and their relationships, connected as a graph to each other and to their contents. The class diagram consists of three partitions. The class name, attributes and operations. In Figure 1, the power distribution system, substation, agriculture, commercial and residential are the class names. The power distribution system is the main class. It uses pds_id as an attribute and step down () as an operation. The power distribution system class receive the power from the transmission system and distribute to the next component. The substation class receives the power from the power distribution system component and distributed to its subclasses. The attributes volt, power and current are used to step down the power and ss_id is used to denote the substation identification. The operations accept () and distribute () is used to receive and distribute the power from the main class to the sub classes. Figure: 1.Class Diagram representing the overview of Power Distribution System. The individual sub classes’ agriculture, commercial and residential consists of volt, power and current as an attribute to evaluate the power received from the substation. The operation receive () is used to accept the power from the

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**Fig.1 - Class Diagram representing the overview of Power Distribution System**
substation component. The agriculture class is stepped down to 12.47V to 34.5V, the commercial class is stepped down to 4.16V to 34.5 V and residential class is stepped down to 12.0V to 24.8V. The power will be distributed only within the stepped down ranges to the respective regions. The class diagrams do not show temporal information, which is required in dynamic modelling. The main task of object modelling is to graphically show what each object will do in the problem domain, describe the structure and the relationships among objects by visual notation.

Activity diagram

The purpose of an activity diagram is to provide a view of flows inside a use case or several among several classes. An activity diagram is similar to a state chart diagram, where a token denoted by a black dot represents an operation. In Figure 2, the name of the activity is shown by the round box symbol; the diamond symbol represents the decision takes place in between the activities. The end of the operation is shown by the black dot enclosed by a circle. When an operation symbol appears within an activity diagram or other state diagram, it indicates the execution of the operation. The substation operation receives the power from the transmission lines and based upon the voltage level it is distributed to the agriculture, commercial and residential operations.

Object Oriented Design of Power Distribution System

In the design phase, consider each substation divisions as an object. Evaluate the power distributed for a six hours time interval and average distribution of power in all the three regions for six hours time intervals. In the following sections of this paper, the class names are given in Arial to differentiate it from the normal text. Figure 2. Activity Diagram represents the power distribution system.

Fig.2- Activity Diagram represents the power distribution system
operation i.e., receive_. The polymorphism method uses single method in different activities. Encapsulation method uses the components of substation that is binded in a single class power distribution system. Finally the inheritance method inherits the components of substation regions from the substation class and that to from the power distribution system class. The class name, attributes and operations used in each component is shown in Table1.

Power distribution system calculations
The power distribution system and its components are taken as an object. The object can able to communicate with other objects. The object-oriented design method for power flow calculation is estimated by the principles of ohm’s law\(^1\). The ohm’s law is used for the calculation of power as shown in Table 2. The mathematical formula of ohm’s law is discussed in 3 ways:

- If a current I should flow through a resistor R, the voltage V can be calculated as
  \[ V = I \times R \]  
  ... (1)

  From (1), the voltage distributed for first six hours and its average can be calculated as
  \[ V_T = (S_i \times R_i + (R_a \times I_a)) \]  
  ... (2)

  Where \( V_T \) is the total voltage distribution
  \( S_x \) is the first six hours distribution
  \( R_i \) & \( R_a \) are the resistor for hour and average distribution
  \( I_i \) & \( I_a \) are the current for hour and average distribution

- If a Voltage flows across a resistor R, the current I can be calculated as
  \[ I = \frac{V}{R} \]  
  ... (3)

  From (3), the current distributed for first six hours and its average can be calculated as
  \[ I_T = \frac{R_i + I_i}{R_a + I_a} \]  
  ... (4)

  Where \( I_T \) is the total current distribution

  - From (2) and (4) the resistor R can be calculated as
    \[ R_T = \frac{V_T \times I_T}{\frac{R_i + I_i}{R_a + I_a}} \]  
    ... (5)

  - The total power P distributed for first six hours and its average is calculated from (2) and (4).
    \[ P = V_T \times I_T \]  
    ... (6)

  From (2), (4) and (6) the current, voltage and power can be estimated. To evaluate the current, voltage and power, the resistance is used from (5).

The Principle method used for power distribution system
The above mentioned three regions from the substation component can receive the power only within the allotted ranges. Due to any circumstances, if there is any overflow of power distribution occurred; those powers will be shifted to the base station computer. From here the power can be distributed properly to the particular regions. This may most likely arise only when there is a temporary shutdown in any of the individual region.

Distribution of power in agriculture, residential and commercial regions
The value obtained from the voltage calculations in all the three different regions, can be able to evaluate the power values as shown in Table 3. Figure 3 shows

<table>
<thead>
<tr>
<th>Region</th>
<th>Voltage(V)</th>
<th>Resistance(Ω)</th>
<th>Power(W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>719</td>
<td>10</td>
<td>510.4</td>
</tr>
<tr>
<td></td>
<td>360</td>
<td>10</td>
<td>648.0</td>
</tr>
<tr>
<td></td>
<td>900</td>
<td>20</td>
<td>405.0</td>
</tr>
<tr>
<td></td>
<td>663</td>
<td>20</td>
<td>145.8</td>
</tr>
<tr>
<td></td>
<td>454</td>
<td>30</td>
<td>681.0</td>
</tr>
<tr>
<td></td>
<td>677</td>
<td>30</td>
<td>304.6</td>
</tr>
<tr>
<td></td>
<td>242</td>
<td>10</td>
<td>580.8</td>
</tr>
<tr>
<td></td>
<td>819</td>
<td>10</td>
<td>663.8</td>
</tr>
<tr>
<td></td>
<td>612</td>
<td>20</td>
<td>183.6</td>
</tr>
<tr>
<td></td>
<td>163.3</td>
<td>10</td>
<td>266.1</td>
</tr>
<tr>
<td></td>
<td>900</td>
<td>20</td>
<td>405.0</td>
</tr>
<tr>
<td></td>
<td>112.0</td>
<td>10</td>
<td>125.5</td>
</tr>
<tr>
<td></td>
<td>698</td>
<td>10</td>
<td>481.6</td>
</tr>
<tr>
<td>Commercial</td>
<td>819</td>
<td>10</td>
<td>663.8</td>
</tr>
<tr>
<td></td>
<td>612</td>
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<td>125.5</td>
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<tr>
<td></td>
<td>698</td>
<td>10</td>
<td>481.6</td>
</tr>
<tr>
<td>Residential</td>
<td>441</td>
<td>20</td>
<td>970.2</td>
</tr>
<tr>
<td></td>
<td>502</td>
<td>20</td>
<td>125.5</td>
</tr>
<tr>
<td></td>
<td>122.4</td>
<td>10</td>
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<td></td>
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<td>20</td>
<td>723.9</td>
</tr>
<tr>
<td></td>
<td>112.5</td>
<td>10</td>
<td>126.0</td>
</tr>
</tbody>
</table>
the average power distributed in all the three regions for the first six hours. It shows the consumption of power is more in commercial region in the 4th hour than compared to the other two regions. The same principles can be extended for the remaining time intervals and obtain the amount of power distributed for any time periods.

Conclusion

The object oriented model is used for the estimation of power distributed to the substation components. The use object oriented method provides better solution than the non object oriented methods for the estimation of power that is distributed to the substation components. The use of object concepts provides flexibility, reusability and maintainability for the evaluation of power distribution system. Ohm’s law is used for the power calculations. UML is used to represent the power distribution system in a structural form. The softwares starUML and mat lab is used here, for the efficient distribution of power from the substation components. This method can be extended to find the distribution of power in various time slots and for the distribution of power between various substations to reduce the excess workload of feeders.

References