Short-Term Load Forecasting with Predicted Weather Data

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- Introduction
- Critical Problem and solution
- Case Study
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1. Introduction

Energy consumption in building sector

Load forecasting

Benefits

Prediction Model

Influential factors
Global Perspective

Fig. Average annual change in residential Building sector energy consumption, 2012–40 (percent per year)

Source: International Energy Outlook 2016, Chapter 6
Local Perspective

Source: EMSD (Electrical & Mechanical Services Department)
Hong Kong Energy End-use Data 2016

64%
- Energy Management System
- Clean Energy System Design
- Smart Grid and Smart Building
Forecasting Models

White Box Model

Grey Box Model

Black Box Model

Physical

Hybrid

Data Driven

Intelligent

Regression

Genetic Algorithm

Neural Networks

Support Vectors Machine

Artificial Neural Network

- Popular to apply in many fields
- Robust to errors
- Successfully applied in load prediction

\[ R_i = w_i^T x_i \]
\[ O_i = f(w_i^T x_i) \]

Chapter 4: 81-126.
Building Load Influential Factors

2. Critical problem and solution

Forecasting methods
Weather Forecasting
General Data-driven Forecasting Procedure

- **Raw data collection**
  - **Weather**
    - Dry bulb temperature
    - Humidity
  - **Seasonality**
    - Hour,
    - Day of week
  - **Historical Load**
    - Previous day
    - Previous week

- **Raw data analysis**
- **Model calibration**
  - ANN
  - SVM
- **Forecaster**
  - Temperature Forecast
  - Previous Loads
- **Error analysis**
- **Report**

- Filters erroneous data
- Chooses most important influential factors
- Regroups data
Critical problems

Load Prediction

1: Which kind of data is available?

2: What is the final goal of prediction?

3: Which of the data should be chosen as inputs?

4: How many money supported of the forecasting program?
Forecasting Framework

Method 1
General information (Public temperature forecasting, hour index)
Forecasting model development
Forecasting report

Method 2
+Building specific information (weather forecasting information, building operation schedule, historical load data)
Influential factors chosen
Forecasting model development
Forecasting report

Method 3
+sub-system operation schedule, sub-system historical record
Influential factors chosen
Sub-system category
Forecasting model development
Forecasting report
General Data-driven Forecasting Procedure

Raw data collection
- Weather
  - Dry bulb temperature
  - Humidity
- Seasonality
  - Hour, Day of week
- Historical Load
  - Previous day
  - Previous week

Raw data analysis
- Filtering erroneous data
- Chose most important influential factors
- Regrouping data

Model calibration
- ANN
- SVM

Forecaster
- Temperature Forecast
- Previous Loads

Error analysis

Report
Typical Daily Temperature and RH Profile

Temperature (°C) vs. Relative humidity (%) over 24 hours.
Temperature Prediction

\[ T_{\text{current}} = T_{\text{max}} - \beta_{\text{Multiplier}} \times (T_{\text{max}} - T_{\text{min}}) \]

- \( T_{\text{current}} \): Air temperature of current Hour of Day
- \( T_{\text{max}} \): User supplied Max Dry-bulb Temperature
- \( T_{\text{min}} \): User supplied Min Dry-bulb Temperature
- \( \beta_{\text{Multiplier}} \): Range multiplier value which provides the deviation ratio between the maximum dry-bulb temperature and given hour

Daily average temperature profile
Relative Humidity Prediction

Step 1: Calculate water vapor saturation pressure

\[ p_{qb} = 610 \times 10^{\frac{7.45T}{235+T}} \]

where \( T \) is the temperature, \( p_{qb} \) is the water vapor saturation pressure.

Step 2: Generate reference water vapor pressure \( P_c \)

The estimation of \( P_c \) can be calculated from the equations below:

\[ P_1 = \phi_{day} \times p_{qb_{max}} \]
\[ P_2 = \phi_{night} \times p_{qb_{min}} \]
\[ P_c = \frac{P_1 + P_2}{2} \]

where \( \phi_{day} \) = daytime relative humidity, \( \phi_{night} \) = relative humidity at night, \( p_{qb_{max}} \) = daily Maximum water vapor saturation pressure, \( p_{qb_{min}} \) = daily Minimum saturation pressure.

Step 3: Calculate relative humidity (RH)

Because of that Hong Kong is Coastal cities, assuming the reference water vapor pressure was relatively stable within a day,

\[ \phi = \frac{P_c}{p_{qb}} \times 100\% \]
Prediction Error (MAPE)

- **Dry-bulb temperature**
- **Relative humidity**

<table>
<thead>
<tr>
<th>Month</th>
<th>MAPE %</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>4.0</td>
</tr>
<tr>
<td>February</td>
<td>8.0</td>
</tr>
<tr>
<td>March</td>
<td>5.0</td>
</tr>
<tr>
<td>April</td>
<td>3.0</td>
</tr>
<tr>
<td>May</td>
<td>2.0</td>
</tr>
<tr>
<td>June</td>
<td>1.0</td>
</tr>
<tr>
<td>July</td>
<td>2.0</td>
</tr>
<tr>
<td>August</td>
<td>3.0</td>
</tr>
<tr>
<td>September</td>
<td>4.0</td>
</tr>
<tr>
<td>October</td>
<td>5.0</td>
</tr>
<tr>
<td>November</td>
<td>6.0</td>
</tr>
<tr>
<td>December</td>
<td>5.0</td>
</tr>
<tr>
<td>Overall</td>
<td>5.0</td>
</tr>
</tbody>
</table>
3. Case study

Study Case Introduction

Raw Data Collection

3 Forecasting Methods

Forecasting Results
Study Case

- University academic buildings

- Daily open hour:
  Weekday 07:00-23:00
  Weekend 07:00-18:00

- Cooling is also needed in the winter season
## Raw Data Collection

<table>
<thead>
<tr>
<th>Weather Data</th>
<th>Historical Record</th>
<th>Schedule</th>
<th>Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>The collected weather recorded data was provided by Hong Kong observatory. The weather data include dry-bulb temperature, humidity, global solar radiation, rainfall, clearness of sky, cloud condition and wind</td>
<td>The historical energy consumption data of study case is hourly recorded by the building management system</td>
<td>The building and sub-system information are provided by CDFO (Campus development and facility office)</td>
<td>The data cover the period of the whole year 2014 and 2015</td>
</tr>
</tbody>
</table>
Method 1

1. Follow the general data driven prediction procedure

2. Only use public information
Method 2

1. Prepare raw data

2. Filter less importance factors

3. Regroup data

4. Develop prediction model

5. Forecaster application and generate report
Load Cloud Chart
Different Influential Factors

Importance reference value

Dry-bulb temperature
Global solar radiation
3 Vis
4 Clid
5 Dir
6 Spd
7 Gust
8 Wet-bulb temperature
9 Dew-point temperature
10 RH
11 Hour
12 Day of week
13 Month
14 historical load
ANN Model Architecture

Input layer

Dry bulb T
Wet bulb T
Hour index
Day of week
Historical load

Hidden layer

Output layer

Energy Load
Method 3
Method 3

1. Lighting and power
2. Other
3. Air conditioning
Method 3

a. Weather independent ANN model

b. Weather dependent ANN model
Method 3

Raw data collection

Weather
- Dry bulb temperature
- Humidity

Seasonality
- Hour,
- Day of week

Historical Load
- Previous day
- Previous week

Raw data analysis

Disaggregation

Lighting and power

ANN model 1

ANN model 2

ANN model 3

Forecaster
- Temperature Forecast
- Previous Loads

Other

Air condition

Assemble and report
## Forecasting Results

### Method 1

<table>
<thead>
<tr>
<th></th>
<th>Overall MAPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record weather</td>
<td>8.89</td>
</tr>
<tr>
<td>Predict weather</td>
<td>8.97</td>
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</tbody>
</table>

### Method 2

<table>
<thead>
<tr>
<th></th>
<th>Overall MAPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting and Power</td>
<td>5.88</td>
</tr>
<tr>
<td>Air conditioning</td>
<td>7.33</td>
</tr>
<tr>
<td>Other</td>
<td>9.38</td>
</tr>
<tr>
<td>Overall</td>
<td>5.08</td>
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</tbody>
</table>

### Method 3

<table>
<thead>
<tr>
<th></th>
<th>Overall MAPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting and Power</td>
<td>X</td>
</tr>
<tr>
<td>Air conditioning</td>
<td>7.65</td>
</tr>
<tr>
<td>Other</td>
<td>X</td>
</tr>
<tr>
<td>Overall</td>
<td>5.21</td>
</tr>
</tbody>
</table>
4. Conclusion
Summary

01 The input data filtering and regrouping can improve energy consumption forecasting accuracy;

02 The proposed weather data prediction method can be applied in load forecasting;

03 Provide different methods to meet the various purposes about building load forecasting is practical.
Thank you

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