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DRQAT-V-3-0-0: Engineers Manual

Peng Xu, Rongxin Yin
Environmental Energy Technology Division
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

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Table of Content

| | |
|--|----|
| DRQAT-V-3-0-0: Engineers Manual..... | 1 |
| Table of Content..... | 2 |
| 1 Introduction..... | 1 |
| 1.1 Overview..... | 1 |
| 2 Structure of DRQAT..... | 2 |
| 3 The DQRAT Files and Folders..... | 5 |
| 4 The DOS programs..... | 10 |
| 4.1 Structure of the DOS programs..... | 10 |
| 4.2 Running the DOS Program..... | 13 |
| 4.3 Detailed information about production of building model..... | 14 |
| 5 Input Macros ^[1] | 28 |
| 5.1 Introduction..... | 28 |
| 5.2 Example..... | 28 |
| 6 Interface between the Windows and DOS programs..... | 31 |
| 6.1 Input & Output files..... | 31 |
| 7 Windows Interface of DRQAT..... | 39 |
| 7.1 Introduction to Delphi..... | 39 |
| 7.2 Data transfer using Delphi..... | 39 |
| 8 Prototypical Large Office and Retail Buildings..... | 46 |
| 8.1 Prototypical Office Model..... | 46 |
| 8.2 Prototypical Retail Model..... | 52 |
| 9 Building Models of DRQAT..... | 54 |
| 9.1 Building Type..... | 54 |
| 9.2 Constructions..... | 56 |
| 9.3 Zone Conditions..... | 57 |
| 9.4 Schedules..... | 58 |
| 9.5 Systems..... | 58 |
| 10 Reference..... | 60 |
| 11 Glossary..... | 62 |

1 Introduction

1.1 Overview

This Engineers Manual describes the DRQAT (Demand Response Quick Assessment Tool) program, which allow potential end users to evaluate demand reduction, operating cost savings, and occupant thermal comfort impacts associated with the use of building thermal mass control. It provides the user with information necessary to understand in detail the DRQAT program.

This software is a quick assessment tool for evaluating **Demand Reduction** and **Cost Savings** in large commercial buildings. It is composed of WINDOWS programs, DOS BATCH programs, AWK programs and INPUT MACROS programs. It can run independently under the case of changing building parameters with Microsoft EXCEL or any text editors, and also can be operated by windows program with friendly interface for changing building parameters. The input and output files of this software are all text files (*.csv), which can be edited by EXCEL or text editors.

This Engineers Manual contains a summary of the data structure used to perform the calculations. The operation, structure, and post process calculations are described in a step-by-step manner for each of the major section of this program.

The program described in this manual includes:

- DOS: It calls the Main batch file which includes all of the sub DOS batch files and also the AWK files to produce a whole building model. It then calls EnergyPlus to run the completed building model.
- Input Macros: An auxiliary program in EnergyPlus, used to incorporate external files containing pieces of IDF into the main EnergyPlus input stream. Other features of this program are described in the “Input Macros” section of this manual.
- Delphi: Delphi language, a set of object-oriented extensions to standard Pascal. Delphi is a high-level, compiled, strongly typed language that supports structured and object-oriented design. It is used in this program to develop the interface of DRQAT.

2 Structure of DRQAT

DRQAT consists of three main parts: user interface, input & output, and internal data process. Figure 1 shows the basic structure of the DRQAT, the data transfer, and the relationships between these parts of the software.

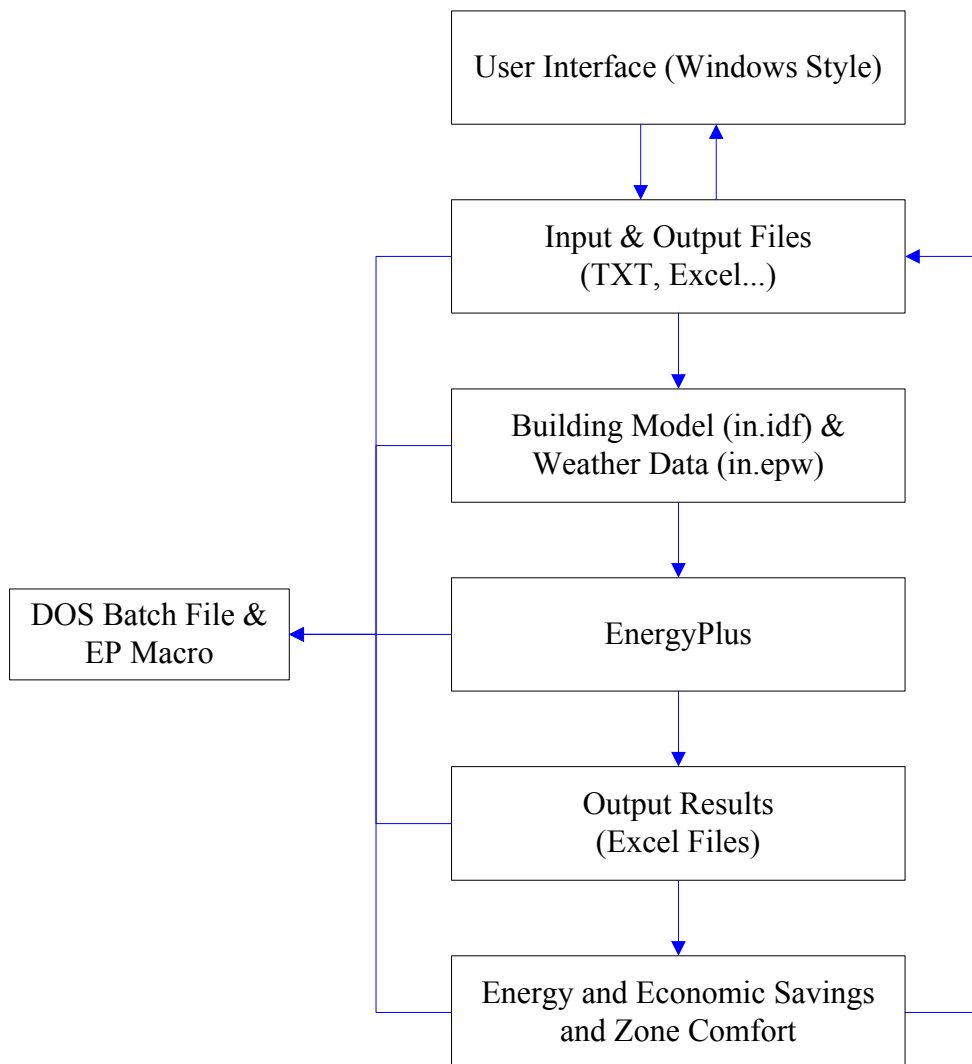


Figure 1 Flow chart – Structure of DRQAT

The elements of the program shown in Figure 1 are as follows:

User Interface

Developed by Delphi, User Interface shows the input building model parameters and output on simulation results (Energy consumption, Energy savings, and zone comfort). It transfers the input and output data between the user and internal programs such as DOS

and Input Macros.

Input and Output files

Most of these “Input & Output” files are Excel or Txt files, used to save input parameters defined by users and output simulation results by running EnergyPlus.

Internal (DOS)

DOS program reads the flexibly input data that user supply and translates it into EnergyPlus file (.idf). Then this program call EnergyPlus and run this file, finally, there is a post process program to calculate the energy cost, energy cost savings, and so on.

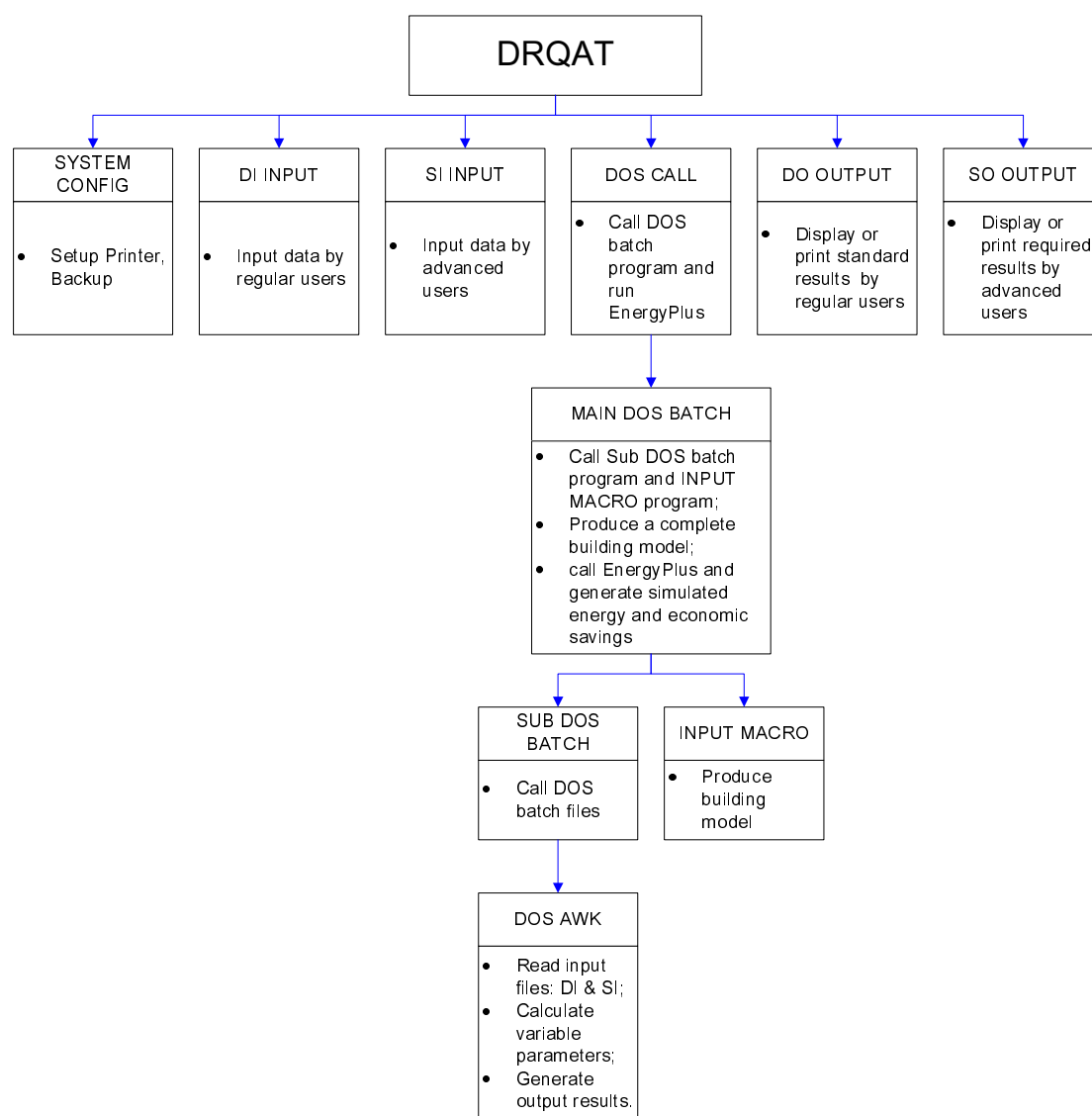


Figure 2 Detailed Structure of DRQAT

Figure 2 shows the basic structure of this tool. The elements of the detailed information

shown in Figure 2 are as follows:

System Configuration

It is used to print the output reports which are shown to users.

DI Input

It includes those building model parameters and utility parameters, which are changed by users. Users input these parameters into DI files, and then this file will be used for developing building model by calling DOS batch file.

SI Input

It includes some special building model parameters which can be changed by advanced users, engineers. These files are used for debugging the model.

DOS Call

The main DOS batch file is called to run the EnergyPlus. There are many sub batch file for developing the building model.

DO Output

It contains the simulation results about energy saving, economic saving, zone temperature and zone comfort.

SO Output

It contains the output reports from EnergyPlus, used to debug DOS batch command file. The results of these files will not be presented to users except for advanced users or engineers.

3 The DQRAT Files and Folders

There are two methods to install the DRQAT program. First is to use the latest DRQAT installation program located on the website (<http://drrc.lbl.gov/tools-guides.html>). The second method is to copy the DRQAT folder and its subfolders from another computer which has DRQAT installed. The folder name on the destination computer should not contain any spaces. There is no limitation for user to install this tool in "C:\\" and other disk partitions, or the subfolders of this disk partitions. However, users must ensure that there is no space for the installation path. After installation, the DRQAT folder should contain 8 files and 21 subfolders. The list of files and folders is as follows.

Table 3-1 Summary of the DRQAT files and folders

| No. | Name | Attribute | Files included | Note |
|-----|-----------------|-----------|--|---|
| 1 | run.bat | file | - | It can be constructed automatically or manually |
| 2 | Main.bat | file | - | Main DOS batch file to run the office model |
| 3 | Main_Retail.bat | file | | Main DOS batch file to run the retail model |
| 4 | cppday.bat | | | Selects the 12 hottest days in the weather file |
| 5 | city.dat | | | Cities in 16 climate zones |
| 6 | zip.dat | | | Zip code of cities in 16 climate zones |
| 7 | Awk2006.exe | file | | AWK program |
| 8 | log.err | file | | This is an output file. It is the log of the DOS programs running. It will be created once the DOS program starts to run. |
| 9 | airflow | folder | airflowX.lom airflow_retail.lom airflow.bat airflow_retail.bat airflow.awk airflow_retail.awk | X equals the number of stories in the office building |
| 10 | analysis | folder | analysis.bat analysis.awk | These files are programs |
| 11 | construc | folder | construc.awk construc.bat | Two types of these files: office and retail |

The DRQAT Files and Folders

| | | | | |
|----|------------|--------|--|--|
| | | | construc.lom | |
| 12 | dataproc | folder | dataproc.bat Dataproc.awk | These files are post process programs, which are used to calculate the simulation results from EnergyPlus. |
| 13 | design | folder | design.bat designX.lom | Two types of HVAC systems for office building model |
| 14 | EnergyPlus | folder | DElight2.dll Energy+.idd Energy+.ini EnergyPlus.exe Energyplus.ini EPMACRO.EXE ReadVarsESO.exe libsparkeplus.dll libsparksolver.dll | EnergyPlus version 4.0.0 |
| 15 | imf | folder | airflow.imf construc.imf design.imf integain.imf location.imf nodebran.imf plantsys.imf report.imf simulate.imf schedule.imf zonesurf.imf | These files are output files created when running DOS program via the user interface. There are also two types of output files for the office and retail models |
| 16 | Input | folder | DI.csv DIOriginal.csv InputSchedules.csv InputSchedulesOriginal.csv InputSchedulesSimulation.csv RateDaySchedule.csv RateMonthSchedule.csv RateMonthScheduleOriginal.csv SI.csv SIOriginal.csv climate_zones_zipcode.csv climate_zones_construction.csv Buildingtype.txt hvac.txt | These files are input files. The contents of DI.csv, InputSchedules.csv, RateDaySchedule.csv, RateMonthSchedule.csv, and SI.csv can be changed by users. The other two can be named by developers. The hvac.txt file includes the type of HVAC system in the building. Buildingtype.txt contains the type of the building model. |
| 17 | integain | folder | integain.bat people.awk light.awk | Two types of these files: office and retail. |

The DRQAT Files and Folders

| | | | | |
|----|----------|--------|---|---|
| | | | equipment.awk integain.lom | |
| 18 | location | folder | location.bat location.awk location.lom | These files are programs |
| 19 | nodebran | folder | nodebran.bat nodebran.lom | Two types of building models. Two types of HVAC systems for the office building model. |
| 20 | output | folder | TempComfTStepYYY.csv EnergyTStepYYY.csv EnergyHourlyYYY.csv EnergyDailyYYY.csv EnergyMonthlyYYY.csv EnergySeasonalYYY.csv EnergyCostMonthlyYYY.csv EnergyCostSeasonalYYY.csv in.epw in.imf in.idf eplusout.eso eplusout.csv CurrentClimateZone.csv BasicOutput.csv Queue.csv Original | There is a separated folder named "Original" which includes the simulation results of the baseline model. The simulation results of DR models are stored in "Output" folder. |
| 21 | plantsys | folder | plantsys.bat plantsys.lom | Two types of building model. Two types of HVAC system for office building model. |
| 22 | report | folder | report.bat report.lom | There are two types of reports for the office building model and one type of report for retail building model. |
| 23 | schedule | folder | schedule.bat schedule.awk schedule.lom | These files are programs |
| 24 | simulate | folder | simulate.bat simulate.awk simulate.lom | These files are programs |
| 25 | weather | folder | weather.bat weather.awk ClimateZone01_CA.epw ClimateZone02_CA.epw ClimateZone03_CA.epw ClimateZone04_CA.epw | Weather.* are two programs. The other are 16 weather data files for California that are compliant with EnergyPlus |

The DRQAT Files and Folders

| | | | | |
|----|----------|--------|--|---|
| | | | ClimateZone05_CA.epw ClimateZone06_CA.epw ClimateZone07_CA.epw ClimateZone08_CA.epw ClimateZone09_CA.epw ClimateZone10_CA.epw ClimateZone11_CA.epw ClimateZone12_CA.epw ClimateZone13_CA.epw ClimateZone14_CA.epw ClimateZone15_CA.epw ClimateZone16_CA.epw | |
| 26 | zonesurf | folder | zonesurf.bat zonepara.awk surfcoor.awk surfcons.awk surfarea.awk zonesurf.lom | These files are programs |
| 27 | Original | folder | BasicOutputOriginal.csv EnergyCostMonthlyOriginal.csv EnergyCostSeasonalOriginal.csv EnergyDailyOriginal.csv EnergyHourlyOriginal.csv EnergyMonthlyOriginal.csv EnergySeasonalOriginal.csv EnergyTStepOriginal.csv queueOriginal.csv TempComfTStepOriginal.csv | This folder is under “output” folder. These files are output files from simulation of original building parameters, which are used for comparison to changed building model parameters. |
| 28 | Output | folder | BasicOutput.csv BasicOutputCPP.csv BasicOutputOriginal.csv EnergyCostMonthlyYYY.csv EnergyCostSeasonalYYY.csv EnergyDailyYYY.csv EnergyHourlyYYY.csv EnergyMonthlyYYY.csv EnergySeasonalYYY.csv EnergyTStepYYY.csv TempComfTStepYYY.csv | This folder is under “output” folder, which is produced by running specifically changed building parameters. These files are output files |

Figure 3-1 shows the screen capture of the DRQAT folder and its sub folders. The installation path is “C:\DRQAT-V-3-0-0”. Users can install this tool in other disk partitions, and ensure that there is no space for the installation path due to the main batch file called by DOS.

The DRQAT Files and Folders

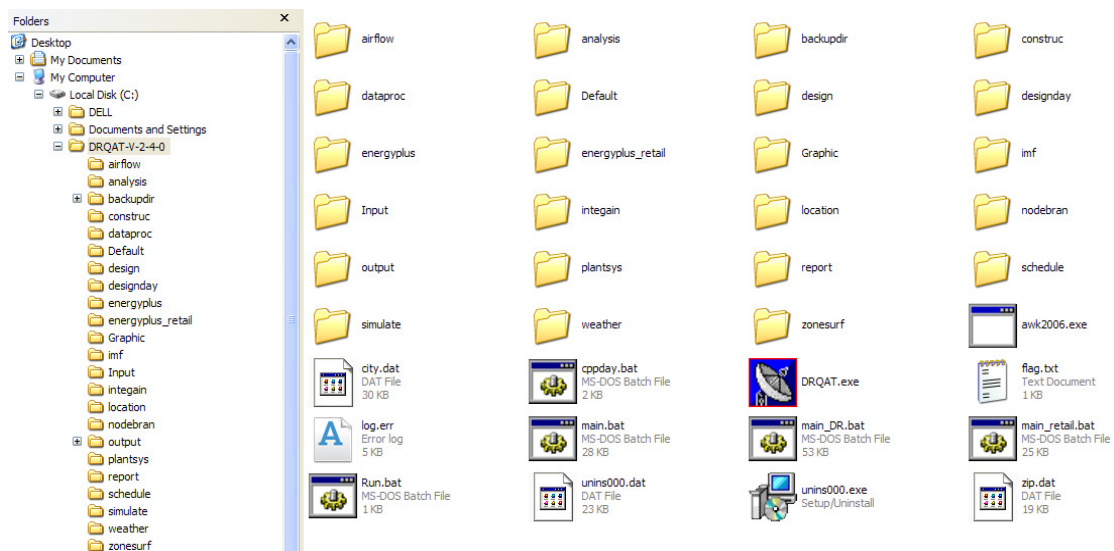


Figure 3-1 Detailed Structure of DRQAT

4 The DOS programs

4.1 Structure of the DOS programs

Building model is composed of all kinds of classes: construction, zone surface, schedules, internal load, etc. For each part of model, there is a DOS batch file to produce corresponding part of EnergyPlus input file. Then the main DOS batch file is built to call all the sub batch files together and develop a completed EnergyPlus input file. The DOS programs of DRQAT are designed for constructing the building model using the MACRO INPUT and obtaining simulation results using EnergyPlus. The key to the DOS programs is that they create a building model according to the data input by users. In order to debug and extend easily, we divide the whole building model into several parts according to parameters' changeability of CLASS GROUP of building model (see "Structure of Building Model for EnergyPlus.doc"). If there are changeable parameters in a CLASS GROUP, a set of programs for changing the parameters of the CLASS GROUP will be created. If there are no changeable parameters in a CLASS GROUP, a set of programs for one group or more groups will be created according to the size of a group or its future changeability. If the size of a group is large or its future changeability is likely, a set of programs for this group will be created. The SUB DOS BATCH program and the DOS AWK program are used to automatically construct the building model. The SUB DOS BATCH program is used to check if the input files for the AWK program exist, call the AWK program to produce the parameters' definition for the INPUT MACROS program, and check if the results produced by AWK are correct.

The building model is a text file composed of various kinds of classes. A class comprises several fields. Some classes have different objects (instances). A building model is constructed by selecting which classes to use, which objects (the instances of classes) to define, and specifying the values of the objects. Figure 4-1 shows the structure of the building model.

The structure of the Main Batch file is shown in Figure 4-2. A Main DOS Batch file named "main.bat" collects all local "Input Macro" models of a building model into a whole "Input Macro" model, and then produces a completed building model for EnergyPlus simulation. Based on the simulation results produced by Energy Plus, "Main DOS Batch" program will call post-processing program to produce zone comfort predictions as well as predictions of energy and economic savings.

For the sake of easy installation, there is a DOS Batch program passing the path of all DOS programs to Main DOS Batch program, which can be edited manually or automatically.

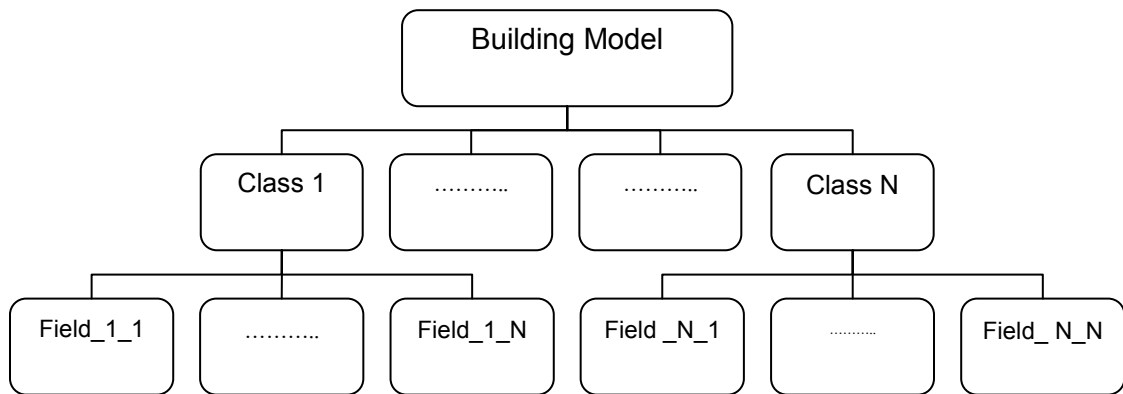
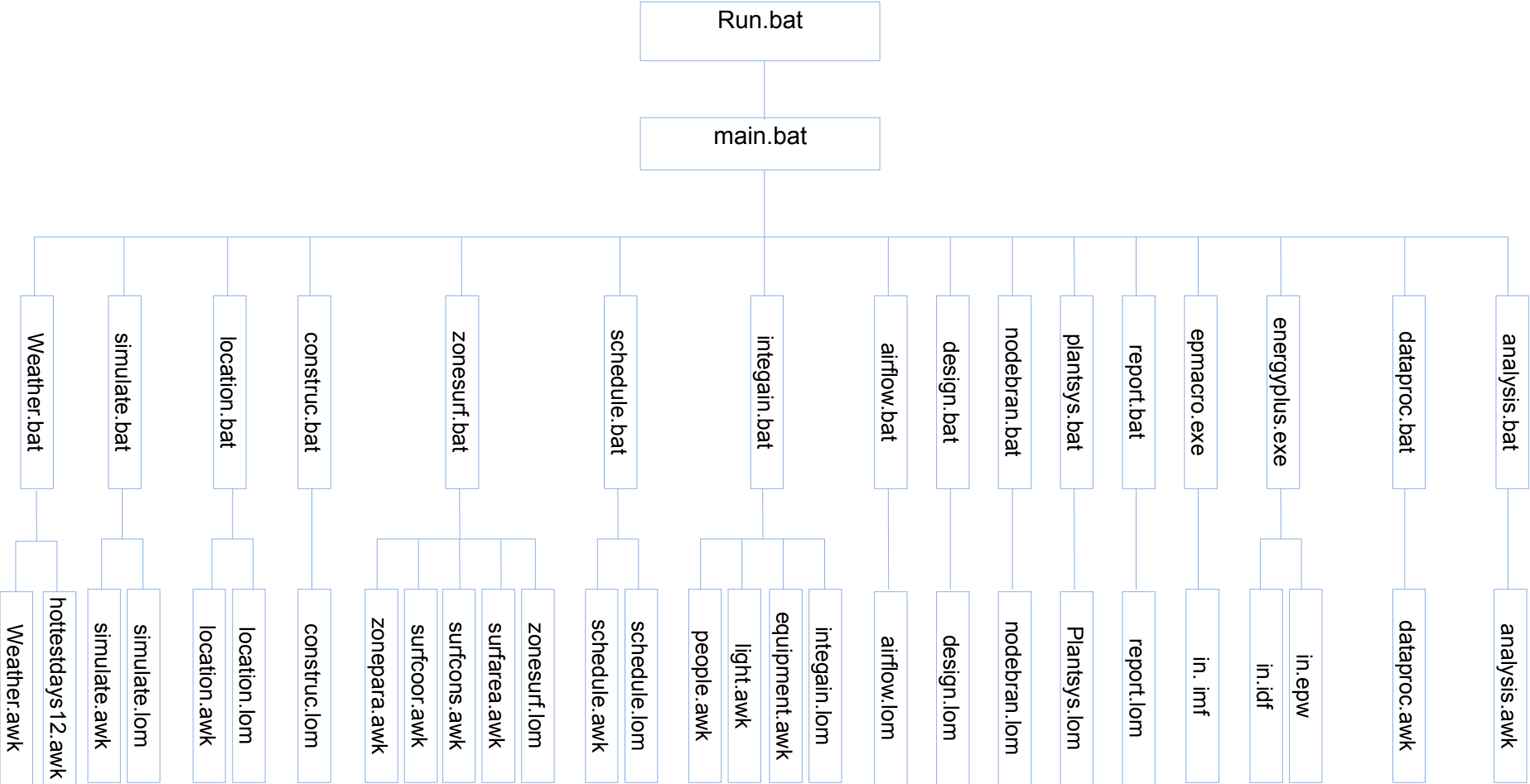


Figure 4-1 Simple Structure of the Building Model

Figure 4-2 Detailed Structure of Main batch file



4.2 Running the DOS Program

Run.bat is the top batch program that runs the DOS programs. It calls the Main batch file which includes all of the sub DOS batch files and also the AWK files to produce a whole building model. It then calls EnergyPlus to run the completed building model.

The content should be checked before running the batch file run.bat. Here is an example. Suppose the second batch file "main.bat" is contained in the folder of "C:\DRQAT", and then the run.bat should contain "call C:\DRQAT\main.bat C:\DRQAT". The following is the steps of running DOS programs.

- 1) Check simulation parameters of EnergyPlus in the file "SI.csv". The meaning of all variables is explained in "input data files" below.
- 2) Check building parameters in the file "DI.csv". The meanings of its all variables are explained in "input data files" below.
- 3) Check schedules and temperature set points in the "InputSchedules.csv". If it is the original building parameters, please write the string "Original" into the second field of the file "input/InputSchedules.csv" with the first field being "Output Filename". If it is not the original building parameters are the original values, string, such as "Pre-cooling" will be written into the second field of the file "input/InputSchedules.csv" with the first field being "Output Filename". Remember that you must run original building parameter first. If it is the CPP program, please write the string "CPP" into the second field of the file "input/InputSchedules.csv" with the first field being "Program". The meanings of its all variables are explained in "input data files" below. Notation: The string "Original" and "CPP" is sensitive of letter case.
- 4) Check charge rate in the file "RateDaySchedule.csv" and "RateMonthSchedule.csv". The meanings of its all variables are explained in "input data files" below.
- 5) Check climate zone files CLIMATE_ZONES_ZIPCODE.csv and CLIMATE_ZONES_CONSTRUCTION.csv. The meanings of its all variables are explained in "input & output files" below.
- 6) Run the batch file "run.bat" for getting simulation results. If it is the original building parameters, that is, "Original" is the string of the second field of the file "input/InputSchedules.csv" with the first field being "Output Filename", the outputs will be saved in the folder "\output\original". If it is not original, for example, if you run the DR simulation, the outputs will be saved in the folder "\output\" directly.
- 7) Open the proper output file to view the results. All output files are explained in "output data files" below.
- 8) Another run.

4.3 Detailed information about production of building model

In order to produce a local building model, we divide the global building model into groups. Each group has its own folder, which contains files to produce a class model. If a group has no changeable parameters, its folder only contains two files: GROUP.bat and GROUP.lom. If a group has changeable parameters, its folder contains three files: GROUP.bat, GROUP.awk and GROUP.lom. GROUP.lom is composed of INPUT MACROS of a group of classes of building model with variant parameters. Its changeable parameters will be replaced with variables' values, which are defined in GROUP.def, which is produced by GROUP.awk. The GROUP.bat is used to produce INPUT MACROS with the definition of parameters via calling GROUP.awk. Finally, we emerge all INPUT MACROS models into a complete building model by order with a DOS BATCH file (main.bat), and then run EnergyPlus.exe to simulate the completed building model. We will introduce Input Macros to users and developers. It would be helpful for users or developers to understand the procedure for production of building model.

4.3.1 Simulation parameters

4.3.1.1 Description

- *Changeability*
Changeable
- *Input files*
di.csv, si.csv
- *Output files*
simulate.def, simulate.imf
- *Program*
simulate.bat, simulate.awk, simulate.lom
- *Groups (Classes)*
Simulation Parameters (Version, Run control, System Convergence Limits, Building, Time step in hour, Inside Convection Algorithm, Outside Convection Algorithm, Zone Volume Capacitance Multiplier, Solution Algorithm, Run Period)

4.3.1.2 Functional allocation

4.3.1.2.1 Simulate.bat

- Check if the input files for "simulate.awk" exists or not
- Call "simulate.awk" to produce proper climate zone number
- Check if the definition files "simulate.def" produced by "simulate.awk" exists

- Build the Input Macro model (“simulate.imf”) by combining “simulate.def” with “simulate.lom”.

4.3.1.2.2 Simulate.awk

- Get input data from “DI.csv” and “SI.csv”. These data include "North Axis" and "Terrain" from “DI.csv”, and “TimeStep”, “BeginMonth”, “EndMonth”, “BeginDay”, “EndDay”, “WeekDay”, “MinTimeStep”, “Iterations”, “LoadTolerance”, “TemperatureTolerance”, “WarmupDay” from “SI.csv”
- Produce an INPUT MACRO definition file with these input data. The definition include: "North Axis", "Terrain", “LoadTolerance”, “TemperatureTolerance” and “WarmupDay” for class “BUILDING”, “TimeStep” for class “TIMESTEP IN HOUR”, “BeginMonth”, “EndMonth”, “BeginDay”, “EndDay” and “WeekDay” for class “RunPeriod”, “MinTimeStep” and “Iterations” for class “System Convergence Limits”.

4.3.1.2.3 Simulate.lom

- Provide an Input Macros of groups of “Simulation parameters (Version, Run Control, System Convergence Limits, Building, Timestep in hour, Inside Convection Algorithm, Outside Convection Algorithm, Zone Volume Capacitance Multiplier, Solution Algorithm, RunPeriod)” of building model with variant parameters, which are listed in simulate.awk above.

4.3.2 Location – Climate – Weather files

4.3.2.1 Description

- *Changeability*
Changeable
- *Input files*
in.epw
- *Output files*
location.def, location.imf
- *Program*
location.bat, location.awk, location.lom
- *Groups (Classes)*
Location Climate Weather File Access (DesignDay, Location, Ground Temperatures)

4.3.2.2 Functional allocation

4.3.2.2.1 Location.bat

- Check if “location.lom” and the input files for “location.awk” exist or not
- Call “location.awk” to produce “location.def”
- Check if the definition file “location.def” exists
- Build the INPUT MACRO model “location.imf” by combining “location.def” with “location.lom”.

4.3.2.2.2 Location.awk

- Get input data from “in.epw”. These data include: Latitude, Longitude, GMT and Elevation
- Produce an INPUT MACRO definition file “location.def” with these input data. The definition include: Latitude, Longitude, GMT and Elevation for class “Location”.

4.3.2.2.3 Location.lom

- Provide an INPUT MACROS of a group of “Location – Climate – Weather File Access (DesignDay, Location, GROUNDTEMPERATURES,)” of building model with variant parameters, which are listed in simulate.awk.

4.3.3 Surface construction elements

4.3.3.1 Description

- *Changeability*
Unchangeable
- *Input files*
None
- *Output files*
construc.imf
- *Program*
construc.bat; construc.lom
- *Groups (Classes)*
Surface Construction Elements (Material: Regular, Material: Regular-R, Material: Air, MATERIAL: WindowGlass, Material: WindowGas, Construction)

4.3.3.2 Functional allocation

4.3.3.2.1 Construc.bat

- Check if “construc.lom” exists
- Build the INPUT MACRO model “construc.imf” by copying “location.lom”.

4.3.3.2.2 Construc.lom

- Provide an INPUT MACROS of a group of “Surface Construction Elements (Material: Regular, Material: Regular-R, Material: Air, MATERIAL: WindowGlass, Material: WindowGas, Construction)

4.3.4 Thermal zone description/Geometry

4.3.4.1 Description

- *Changeability*
Changeable
- *Input files*
di.csv, si.csv, CLIMATE_ZONES_CONSTRUCTION.csv
- *Output files*
zonepara.def, surfcoor.def, surfcons.def, surfarea.def, zonesurf.imf
- *Program*
zonesurf.bat; zonepara.awk; surfcoor.awk; surfcons.awk; surfarea.awk;
zonesurf.lom
- *Group (Classes)*
Thermal Zone Description/Geometry (Zone, SurfaceGeometry, Surface:
HeatTransfer, Surface: HeatTransfer: Sub, Surface: HeatTransfer: InternalMass)

4.3.4.2 Functional allocation

4.3.4.2.1 Zonesurf.bat

- Check if “zonesurf.lom” and the input files for “zonepara.awk”, “surfcoor.awk”, “surfcons.awk” and “surfarea.awk” exist
- Call “zonepara.awk” to produce “zonepara.def”
- Call “surfcoor.awk” to produce “surfcoor.def”
- Call “surfcons.awk” to produce “surfcons.def”
- Call “surfarea.awk” to produce “surfarea.def”
- Check if all definition files exist

- Build the INPUT MACRO model “zonesurf.imf” by combining “zonepara.def”, “surfcoor.def”, “surfcons.def” and “surfarea.def” with “zonesurf.lom”.

4.3.4.2.2 Zonepara.awk

- Get input data from “DI.csv”. These data include: Conditioned stories, Floor length, Floor width, Floor Height and Depth of perimeter zone
- Calculate the parameters of X, Y and Z of zone coordinate, Multiplier, Height of ceiling and Volume of zone for all zones in class “ZONE”, and produce an INPUT MACRO definition file “zonepara.def” with these parameters.

4.3.4.2.3 Surfcoor.awk

- Get input data from “DI.csv”. These data include: Conditioned stories, Floor length, Floor width, Floor Height, Ratio of window to wall and Depth of perimeter zone
- Calculate the parameters of X, Y and Z of surface coordinate of all surfaces for class “Surface: HeatTransfer and Surface: HeatTransfer: Sub”, and produce an INPUT MACRO definition file “surfcoor.def” with these parameters.

4.3.4.2.4 Surfcon.awk

- Get “climate zone number” from “CurrentClimateZone.csv”, and get construction name of external wall, window and roof under the climate zone from “Climate_Zones_Constructionin.csv”
- Calculate and produce an INPUT MACRO definition file “surfcons.def” for class “Surface: HeatTransfer and Surface: HeatTransfer: Sub” with parameter of “Construction Name of the Surface”.

4.3.4.2.5 Surarea.awk

- Get “Mass Level” from “DI.csv”. Get “High Mass Level”, “Medium Mass Level” and “Low Mass Level” from “SI.csv”
- Calculate and produce an INPUT MACRO definition file “surfarea.def” for class “Surface: HeatTransfer: InternalMass” with parameter of “Surface area”.

4.3.4.2.6 Zonesurf.lom

- Provide an INPUT MACROS of a group of “Thermal Zone Description/Geometry (Zone, SurfaceGeometry, Surface: HeatTransfer, Surface: HeatTransfer: Sub, Surface: HeatTransfer: InternalMass)

4.3.5 Schedules

4.3.5.1 Description

- *Changeability*
Changeable
- *Input files*
InputSchedules.csv
- *Output files*
schedule.def, schedule.imf
- *Program*
schedule.bat, schedule.awk, schedule.lom
- *Group (Classes)*
Schedules (DaySchedule, WeekSchedule, Schedule)

4.3.5.2 Functional allocation

4.3.5.2.1 Schedule.bat

- Check if “schedule.lom” and the input files for “schedule.awk” exist
- Call “schedule.awk” to produce “schedule.def”
- Check if the definition file “schedule.def” exists
- Build the INPUT MACRO model “schedule.imf” by combining “schedule.def” with “schedule.lom”.

4.3.5.2.2 Schedule.awk

- Get daily schedule from “InputSchedules.csv”. These daily schedule include: work days and holiday schedule, and set points of zone cooling temperature, chiller water loop outlet temperature, chiller water condenser loop outlet temperature and summer supply air temperature
- Calculate the daily schedule of OCCDAY-1 and OCCDAY-2 for class “PEOPLE”, LITDAY-1 and LITDAY-2 for class “LIGHTS”, INFIL-1 and INFIL-2 for class “INFILTRATION”, EQPDAY-1 and EQPDAY-2 for class “ELECTRIC EQUIPMENT” for class “DAYSCHEDULE”, and produce an INPUT MACRO definition file “schedule.def” with these parameters.

4.3.5.2.3 Schedule.lom

- Provide an INPUT MACROS of a group of “Schedules (DaySchedule, WeekSchedule, Schedule)

4.3.6 Internal gains

4.3.6.1 Description

- *Changeability*
Changeable
- *Input files*
di.csv, si.csv
- *Output files*
people.def, light.def, equipment.def, integain.imf
- *Program*
integain.bat, people.awk, light.awk, equipment.awk, integain.lom
- *Group (Classes)*
Internal Gains (People, Lighting, Electric Equipment)

4.3.6.2 Functional allocation

4.3.6.2.1 Integain.bat

- Check if “integain.lom” and the input files for “people.awk”, “light.awk” and “equipment.awk” exist
- Call “people.awk” to produce “people.def”
- Call “light.awk” to produce “light.def”
- Call “equipment.awk” to produce “equipment.def”
- Check if all definition files exists
- Build the INPUT MACRO model “integain.imf” by combining “people.def”, “light.def” and “equipment.def” with “zonesurf.lom”.

4.3.6.2.2 People.awk

- Get Conditioned stories, Floor length, Floor width and Number of total people in a building from “DI.csv”, and get Depth of perimeter zone from “SI.csv”
- Calculate the parameters of “Number of People” for class “PEOPLE”, and produce an INPUT MACRO definition file “people.def” with these parameters.

4.3.6.2.3 Light.awk

- Get Conditioned stories, Floor length, Floor width and Electric energy per square foot for all lights in the building from “DI.csv”, and get Depth of perimeter zone from “SI.csv”
- Calculate the parameters of “Design Level” for class “LIGHTS”, and produce an

INPUT MACRO definition file “people.def” with these parameters.

4.3.6.2.4 Equipment.awk

- Get Conditioned stories, Floor length, Floor width and Electric energy per square foot for all electric equipment in the building from “DI.csv”, and get Deep of perimeter zone from “SI.csv”
- Calculate the parameters of “Design Level” for class “ELECTRIC EQUIPMENT”, and produce an INPUT MACRO definition file “equipment.def” with these parameters.

4.3.6.2.5 Integain.lom

- Provide an INPUT MACROS of a group of “Internal Gains (PEOPLE, LIGHTS, ELECTRIC EQUIPMENT)” for building model with variant parameters.

4.3.7 Air flow

4.3.7.1 Description

- *Changeability*
Changeable
- *Input files*
di.csv, si.csv
- *Output files*
airflow.def, airflow.imf
- *Program*
airflow.bat, airflow.awk, airflow.lom
- *Group (Classes)*
Air Flow (Infiltration)

4.3.7.2 Functional allocation

4.3.7.2.1 Airflow.bat

- Check if “airflow.lom” and the input files for “airflow.awk” exist
- Build the INPUT MACRO model “airflow.imf” by combining “airflow.def” with “zonesurf.lom”.

4.3.7.2.2 Airflow.awk

- Get Floor length, Floor width in the building from “DI.csv”
- Calculate the parameters of “infiltration” for class “AIRFLOW”, and produce an INPUT MACRO definition file “airflow.def” with these parameters.

4.3.7.2.3 Airflow.lom

- Provide an INPUT MACROS of a group of “Airflow” for building model with variant parameters.

4.3.8 Design objects

4.3.8.1 Description

- *Changeability*
Changeable
- *Input files*
si.csv
- *Output files*
design.def, design.imf
- *Program*
design.bat, design.awk, design.lom
- *Group (Classes)*
Design objects (Zone Sizing Factor)

4.3.8.2 Functional allocation

4.3.8.2.1 Design.bat

- Check if “design.lom” and the input files for “design.awk” exist
- Build the INPUT MACRO model “design.imf” by combining “design.def” with “zonesurf.lom”.

4.3.8.2.2 Design.awk

- Get Zone Sizing Factor for the building model from “DI.csv”
- Calculate the parameters of “Zone Sizing Factor” for class “DESIGN”, and produce an INPUT MACRO definition file “design.def” with these parameters.

4.3.8.2.3 Design.lom

- Provide an INPUT MACROS of a group of “design” for building model with variant parameters.

4.3.9 Node – branch Management

4.3.9.1 Description

- *Changeability*
Unchangeable
- *Input files*
None
- *Output files*
nodebran.imf
- *Program*
nodebran.bat, nodebran.lom
- *Group (Classes)*
Node-Branch Managements (Node List, Branch List, Connector List, Branch, Pipe)

4.3.9.2 Functional allocation

4.3.9.2.1 Nodebran.bat

- Check if “nodebran.lom” exist
- Build the INPUT MACRO model “nodebran.imf” by just copying “nodebran.lom”.

4.3.9.2.2 Nodebran.lom

- Provide an INPUT MACROS of a group of “Node-Branch Managements (Node List, Branch List, Connector List, Branch, Pipe)”

4.3.10 Plant and system

4.3.10.1 Description

- *Changeability*
Unchangeable
- *Input files*

None

- **Output files**
plantsys.imf
- **Program**
plantsys.bat, plantsys.lom
- **Group (Classes)**
Plant and system

4.3.10.2 Functional allocation

4.3.10.2.1 Plantsys.bat

- Check if “plantsys.lom” exists
- Build the INPUT MACRO model “plantsys.imf” by just copying “plantsys.lom”.

4.3.10.2.2 Plantsys.lom

- Provide an INPUT MACROS of a group of “plantsys”

4.3.11 Report

4.3.11.1 Description

- **Changeability**
Unchangeable
- **Input files**
None
- **Output files**
report.imf
- **Program**
report.bat, report.lom
- **Group (Classes)**
Report (Report Variable)

4.3.11.2 Functional allocation

4.3.11.2.1 Report.bat

- Check if “report.lom” exists
- Build the INPUT MACRO model “report.imf” by just copying “report.lom”.

4.3.11.2 Report.lom

- Provide an INPUT MACROS of a group of “Report (Report Variable,)” of building model without variant parameters.

4.3.12 Dataproc

4.3.12.1 Functional allocation

4.3.12.1.1 Dataproc.bat

- Check if the simulation results are for original building parameters or changed building parameters. If for original building parameters, do not copy original output files. Otherwise, copy original output files.
- Check if the input files for “dataproc.awk” exist
- Call “dataproc.awk” to produce output file “*.csv”
- Check if all output files exist

4.3.12.1.2 Dataproc.awk

- Get average zone temperature and zone comfort of all zones in time step from EnergyPlus simulation result “BasicOutput.csv” and save them into “TempComfTStepXXX.csv”
- Get energy consumption and maximum instantaneous power in time step of chiller and condenser loop, fan, lights of all zones, electric equipment of all zones and total building from EnergyPlus simulation result “eplusout.csv” and save them into “EnergyTStepXXX.csv”
- Calculate hourly energy consumption and maximum instantaneous power of chiller and condenser loop, fan, lights of all zones, electric equipment of all zones and total building based on “EnergyTStepXXX.csv” and save them into “EnergyHourlyXXX.csv”
- Calculate monthly energy consumption and maximum instantaneous power of chiller and condenser loop, fan, lights of all zones, electric equipment of all zones and total building based on “EnergyHourlyXXX.csv” and save them into “EnergyMonthlyXXX.csv”
- Calculate seasonal energy consumption and maximum instantaneous power of chiller and condenser loop, fan, lights of all zones, electric equipment of all zones and total building based on “EnergyMonthlyXXX.csv” and save them into “EnergyseasonalXXX.csv”
- Calculate monthly and seasonal energy cost of chiller and condenser loop, fan, lights of all zones, electric equipment of all zones and total building based on “EnergyHourlyXXX.csv”, “EnergyMonthlyXXX.csv”, and energy and demand

charge from "RateDaySchedule.csv" and "RateMonthSchedule.csv", and save them into "EnergyCostMonthlyXXX.csv" "EnergyCostSeasonalXXX.csv"

4.3.13 Weather

4.3.13.1 Weather.bat

- Check if the input files for "weather.awk" and "hottestdays12.awk" exist
- Call "weather.awk" to produce proper climate zone number
- Check if the output files produced by "weather.awk" exist
- Choose proper weather data file as "in.epw"
- Call "hottestdays12.awk" to produce 12 hottest days in a season, and save them to "hottestdays.csv" and "queue.csv". 12 hottest days defined here are based on the outside temperature through the whole year.
- Check if the output files produced by "hottestdays12.awk" exist

4.3.13.2 Weather.awk

- Get "zip code" input by users from "DI.csv"
- Get "climate zone number" according to zip code from "Climate_Zones_Zipcode.csv"
- Get weather data file according to climate zone number from "Climate_Zones_Construction.csv"
- Save climate zone number to "CurrentClimateZone.csv" for choosing of building constructions

4.3.13.3 Hottestdays.awk

- Find 12 hottest days from "in.epw", and save them into "hottestdays.csv", in which line ranks by temperature
- Reorder the lines of "hottestdays.csv" by date, and save them into "queue.csv"

4.3.14 Functional allocation of Main DOS Modules

4.3.14.1 Main.bat

- Accept program path from DOS CALL in windows module (Run)
- Setup the paths of sub level programs for these input and output files
- Check if the application programs of AWK, Input Macros, and EnergyPlus exist or not
- Clear all old output files
- Call "weather.bat" to produce proper weather data file (in.epw) and determine

- CPP days: 12 hottest days saved as "hottestdays.csv"
- Call its sublevel programs "simulate.bat", "location.bat", "construc.bat", "zonesurf.bat", "schedule.bat", "integain.bat", "airflow.bat", "design.bat", "nodebran.bat", "plantsys.bat", "report.bat" by order to produce proper input macros file "in.imf"
 - Call "epmacro.exe" to produce true building model "out.idf"
 - Change "out.idf" into "in.idf"
 - Call "EnergyPlus.exe" to produce zone temperature, zone comfort, energy consumption and energy cost at a time step, which are included in the file "eplusout.eso".
 - Call "ReadVarsESO.exe" for post processing of "eplusout.eso" to "eplusout.csv".
 - Produce "BasicOutput.csv" with adding a line "End of Data" at the bottom of "eplusout.csv".
 - Call "dataproc.bat" to calculate of average zone temperature, zone comfort, energy consumption, energy charge, then to produce "TempComfTStepXXX.csv", "EnergyTStepXXX.csv", "EnergyHourlyXXX.csv", "EnergyDailyXXX.csv", "EnergyMonthlyXXX.csv", "EnergySeasonalXXX.csv", "EnergyCostMonthlyXXX.csv", "EnergyCostSeasonalXXX.csv".
 - Log the running period of the software.

5 Input Macros ^[1]

5.1 Introduction

The Input Macros feature increases the flexibility of the EnergyPlus Input file. For the building model in DRQAT, users simulate a building model with a specific climate zone, and building geometry, internal load, occupancy pattern, building operation schedule and HVAC system characteristic would be different between each other. Input macros would be the input values of these variable parameters.

The basic capabilities are:

- Incorporating external files containing pieces of IDF into the main EnergyPlus input stream.
- Selectively accepting or skipping portions of the input.
- Defining a block of input with parameters and later referencing this block.
- Performing arithmetic and logical operations on the input.
- Input macro debugging and listing control.

These capabilities are invoked in the EP-Macro program by using macro commands. Macro commands are preceded by ## to distinguish them from regular EnergyPlus input commands. After execution by the EP-Macro processor, macro commands produce regular lines of EnergyPlus input that are shown in the resulting IDF file (out.idf) and, subsequently, in the EnergyPlus echo print (audit.out). Descriptions of input macros are given at the end of this section; they should be reviewed before reading the macro command description.

The EP-Macro allows users and developers to change the input parameters of the building model, such as building geometry, building location, building operation and so on. A block input with parameters is defined first and then an AWK program is used to read the value of these parameters from input files. External files are then incorporated into the main EnergyPlus input file.

5.2 Example

An Input Macro example for one building parameter is shown below. Input Macros are similar for other building model parameters.

```

!
VERSION,
  1.2.3;      !- Version Identifier
!
RUN CONTROL,
  Yes,        !- Do the zone sizing calculation
  Yes,        !- Do the system sizing calculation
  Yes,        !- Do the plant sizing calculation
  No,         !- Do the design day simulations
  Yes;       !- Do the weather file simulation
!
System Convergence Limits,
  MinTimeStep[], !- Minimum System Time Step (0=same as zone time step, 1~60 minutes)
  Iterations[],  !- Maximum HVAC Iterations (>=1, default:20)
!
Blocks of Input Parameters
BUILDING,
  Building,     !- Building Name
  NorthAxis[], !- North Axis {deg}
  Terrain[],    !- Terrain
  LoadTolerance[], !- Loads Convergence Tolerance Value {W}
  TemperatureTolerance[], !- Temperature Convergence Tolerance Value {deltaC}
  MinimalShadowing, !- Solar Distribution
  WarmupDay[],  !- Maximum Number of Warmup Days
!
TIMESTEP IN HOUR,
  TimeStep[];  !- Time Step in Hour
!
INSIDE CONVECTION ALGORITHM,
  Simple;      !- InsideConvectionValue
!
OUTSIDE CONVECTION ALGORITHM,
  Simple;      !- OutsideConvectionValue
!

```

Figure 5-1 Input parameters for the building model

As shown in Figure 5-1, these blocks of input parameters need to be given a value or name. DRQAT would call the AWK program to produce the ##def file, which allows the block of input text to be defined and given a name. The block of text can then be inserted anywhere in the EnergyPlus input stream referencing the name of the block. This process applies EP-Macro to give Input parameter values to these blocks of input parameters which are referred.

```

## INPUT MACROS FILE OF BUILDING MODEL |
##
!

##set1 NorthAxis = 0
##set1 Terrain = Urban
##set1 TimeStep = 4
##set1 BeginMonth = 6
##set1 EndMonth = 9
##set1 BeginDay = 1
##set1 EndDay = 30
##set1 WeekDay = Thursday
##set1 MinTimeStep = 0
##set1 Iterations = 10
##set1 LoadTolerance = 0.1
##set1 TemperatureTolerance = 0.5
##set1 WarmupDay = 3
## The file name is "simulate.lom"
## This file is a class instance with variables, which being together with
## simulate.def produce by simulate.awk will produce a INPUT MACROS.

```

Figure 5-2 Simulation variables for Input Macros file of the building model

Figure 5-2 shows the input macro of simulation variable parameters of the building model. The “simulate.bat” batch file calls the AWK program to produce ##def file and then incorporate the def file into the EnergyPlus model to define the value of blocks.

6 Interface between the Windows and DOS programs

6.1 Input & Output files

There are 7 input files, which are all of data format *.csv. These 7 input files are divided into two classes: regular user input files and advanced user input files. The former includes 4 files: DI.csv, InputSchedules.csv, RateDaySchedule.csv and RateMonthSchedule.csv. The latter comprises 3 files: SI.csv, Climate_Zones_Zipcode.csv and Climate_Zones_Construction.csv. Names of these input files can not be changed. DIOriginal.csv has the same structure as DI.csv. SIOriginal.csv has the same structure as SI.csv. InputSchedulesOriginal.csv has the same structure as InputSchedules.csv.

6.1.1 Input files

6.1.1.1 DI.csv

The "DI.csv" is used for recording users' input about building parameters. It has three fields: CLASS NAME, FIELD NAME and FIELD VALUE. Only FIELD VALUE can be changed by user. The other two fields are not allowed to be changed. The structure of the DI.csv with default values is shown below.

| CLASS NAME | FIELD NAME | FIELD VALUE |
|----------------|----------------------------------|----------------|
| AREA | Zip Code | 94702 |
| BUILDING | Building Name | Large Building |
| BUILDING | North Axis | 0 |
| BUILDING | Terrain | urban |
| ZONE & SURFACE | Conditioned Stories | 3 |
| ZONE & SURFACE | Floor Length | 45.72 |
| ZONE & SURFACE | Floor Wide | 30.48 |
| ZONE & SURFACE | Floor Height | 3.048 |
| ZONE & SURFACE | Northern Ratio of Window to Wall | 0.5 |
| ZONE & SURFACE | Southern Ratio of Window to Wall | 0.5 |
| ZONE & SURFACE | Western Ratio of Window to Wall | 0.5 |
| ZONE & SURFACE | Eastern Ratio of Window to Wall | 0.5 |
| ZONE & SURFACE | Mass Level | Medium |
| PEOPLE | Occupancy | 200 |
| LIGHTS | Lighting | 10 |
| ELECTRIC | Equipment | 20 |

Interface between the Windows and DOS programs

| | | |
|-------------|--|--|
| EQUIPMENT | | |
| End of Data | | |

6.1.1.2 InputSchedule.csv

The "InputSchedules.csv" is composed of schedules input by users. It has 25 fields.

The first one consists of schedule names, which are not allowed to be changed. The other 24 fields represent set points of 24 hours, which can be changed by users. The structure is as follows. When the value (Field 2) of "Output Filename" is "Original", the simulation results will be saved to the folder "..\output\original" as original simulation results, and all output file names contain "Original" string. When the value (Field 2) of "Output Filename" is not "Original", such as "Urban", the simulation results will be saved to the folder "..\output" as compared simulation results, and all output file names contain "Urban" string. When the value (Field 2) of "Program" is "CPP", the simulation results used for statistic of energy consumption and cost calculations will be produced based on original simulation results "BasicOutputOriginal.csv" with data for 12 hottest days replacing original data for corresponding days of current simulation results "BasicOutput.csv" of EnergyPlus.

| | | | | |
|--------------------------------|------|------|-------|------|
| HOUR | 1 | 2 | ..... | 24 |
| PEOPLE-SCHED-1-1 | 0 | 0 | ..... | 0 |
| PEOPLE-SCHED-1-2 | 0 | 0 | ..... | 0 |
| LIGHT-SCHED-1-1 | 0 | 0 | ..... | 0 |
| LIGHT-SCHED-1-2 | 0 | 0 | ..... | 0 |
| EQUIPMENT-SCHED-1-1 | 0 | 0 | ..... | 0 |
| EQUIPMENT-SCHED-1-2 | 0 | 0 | ..... | 0 |
| FAN-SCHED-1-1 | 0 | 0 | ..... | 0 |
| FAN-SCHED-1-2 | 0 | 0 | ..... | 0 |
| CLG-SCHED-1-1 | 32.2 | 32.2 | ..... | 32.2 |
| CLG-SCHED-1-2 | 32.2 | 32.2 | ..... | 32.2 |
| Chilled Water Loop Daily | 6.67 | 6.67 | ..... | 6.67 |
| Condenser Loop Daily | 29.5 | 29.5 | ..... | 29.5 |
| Summer Supply Air Temp Day Sch | 16.0 | 16.0 | ..... | 16.0 |
| Output Filename | | | | |
| Program | CPP | | | |
| End of Data | | | | |

6.1.1.3 RateDaySchedule.csv

The "RateDaySchedule.csv" and "RateMonthSchedule.csv" are used for

Interface between the Windows and DOS programs

calculating energy cost. "RateDaySchedule.csv" includes energy charges and demand charges of day types. "RateMonthSchedule.csv" is composed of day type schedules.

The first field of "RateDaySchedule.csv" can not be changed. The other 24 fields represent hourly set points for 24 hours, which can be changed by users. Its structure is as follows.

| HOURL | 1 | 2 | ..... | 24 |
|--------------|---------|---------|-------|---------|
| DAY-1-ENERGY | 0.051 | 0.051 | ..... | 0.051 |
| DAY-1-DEMAND | 2.55 | 2.55 | ..... | 2.55 |
| DAY-2-ENERGY | 0.01815 | 0.01815 | ..... | 0.01815 |
| DAY-2-DEMAND | 9.68 | 9.68 | ..... | 9.68 |
| DAY-3-ENERGY |  |  | ..... |  |
| DAY-3-DEMAND |  |  | ..... |  |
| End of Data | | | | |

6.1.1.4 RateMonthSchedule.csv

The first field of "RateMonthSchedule.csv" is not allowed to be changed. The other 24 fields represent hourly set points for 24 hours, which can be changed by users. Its structure is as follows.

| MONTH | 1 | 2 | ..... | 31 |
|-------------|-------|-------|-------|-------|
| 1 |  |  | ..... |  |
| 2 |  |  | ..... |  |
| 3 |  |  | ..... |  |
| 4 |  |  | ..... |  |
| 5 |  |  | ..... |  |
| 6 | DAY-1 | DAY-1 | ..... | DAY-1 |
| 7 | DAY-2 | DAY-2 | ..... | DAY-2 |
| 8 | DAY-2 | DAY-2 | ..... | DAY-2 |
| 9 | DAY-2 | DAY-2 | ..... | DAY-2 |
| 10 | DAY-1 | DAY-1 | ..... | DAY-1 |
| 11 |  |  | ..... |  |
| 12 |  |  | ..... |  |
| End of Data | | | | |

Interface between the Windows and DOS programs

6.1.1.5 SI.csv

The “SI.csv” is used for advanced users, which is invisible for regular users. The following is its structure.

| CLASS NAME | FIELD NAME | FIELD VALUE |
|---------------------------|---|-------------|
| VERSION | Version | 4.0.0 |
| TIME STEP IN HOUR | Time Step | 4 |
| ZONE | Zone Deep | 4.57 |
| SURFACE | High Mass Level | 0.8 |
| SURFACE | Medium Mass Level | 0.5 |
| SURFACE | Low Mass Level | 0.2 |
| RUNPERIOD | Begin Month | 8 |
| RUNPERIOD | Begin Day of Month | 1 |
| RUNPERIOD | End Month | 8 |
| RUNPERIOD | End Day of Month | 31 |
| RUNPERIOD | Day of Week for Start Day | Sunday |
| SYSTEM CONVERGENCE LIMITS | Minimum System Time Step | 0 |
| SYSTEM CONVERGENCE LIMITS | Maximum HVAC Iterations | 10 |
| BUILDING | Loads Convergence Tolerance Value | 0.4 |
| BUILDING | Temperature Convergence Tolerance Value | 0.5 |
| BUILDING | Maximum Number of Warm-up Days | 3 |
| End of Data | | |

6.1.1.6 Climate Zones Zipcode.csv

The “Climate_Zones_Zipcode.csv” is used to find climate zone according to zip code input by users. Its original data can be obtained from government website (<http://www.energy.ca.gov/maps/>). Then it should be processed to have the structure as follows.

| ZIP CODE | CITY NAME | CLIMATE ZONE |
|----------|---------------------|--------------|
| 94922 | BODEGA | 1 |
| 94923 | BODEGA BAY | 1 |
| | | |
| 96158 | SOUTH LAKE TAHOE | 16 |

Interface between the Windows and DOS programs

| | | |
|-------------|---------|----|
| 96160 | TRUCKEE | 16 |
| 96161 | TRUCKEE | 16 |
| End of Data | | |

6.1.1.7 Climate_Zones_Construction.csv

The “Climate_Zones_Construction.csv” is used to find the proper weather data file and construction of surfaces according to zip code or climate zone. These constructions meet the requirement of Title 24. Its structure is as follows:

| CLIMATE ZONE | WEATHER DADA FILE | WALL | WINDOW_NN_1 | WINDOW | ROOF | DDY |
|--------------|----------------------|---------|----------------|--------|---------|-----------|
| 1 | ClimateZone01_CA.epw | WALL-1 | WINDOW_NN_1_1 | ..... | ROOF-1 | CZ_01_DDY |
| 2 | ClimateZone02_CA.epw | WALL-2 | WINDOW_NN_1_2 | ..... | ROOF-2 | CZ_02_DDY |
| 3 | ClimateZone03_CA.epw | WALL-3 | WINDOW_NN_1_3 | ..... | ROOF-3 | CZ_03_DDY |
| 4 | ClimateZone04_CA.epw | WALL-4 | WINDOW_NN_1_4 | ..... | ROOF-4 | CZ_04_DDY |
| 5 | ClimateZone05_CA.epw | WALL-5 | WINDOW_NN_1_5 | ..... | ROOF-5 | CZ_05_DDY |
| 6 | ClimateZone06_CA.epw | WALL-6 | WINDOW_NN_1_6 | ..... | ROOF-6 | CZ_06_DDY |
| 7 | ClimateZone07_CA.epw | WALL-7 | WINDOW_NN_1_7 | ..... | ROOF-7 | CZ_07_DDY |
| 8 | ClimateZone08_CA.epw | WALL-8 | WINDOW_NN_1_8 | ..... | ROOF-8 | CZ_08_DDY |
| 9 | ClimateZone09_CA.epw | WALL-9 | WINDOW_NN_1_9 | ..... | ROOF-9 | CZ_09_DDY |
| 10 | ClimateZone10_CA.epw | WALL-10 | WINDOW_NN_1_10 | ..... | ROOF-10 | CZ_10_DDY |
| 11 | ClimateZone11_CA.epw | WALL-11 | WINDOW_NN_1_11 | ..... | ROOF-11 | CZ_11_DDY |
| 12 | ClimateZone12_CA.epw | WALL-12 | WINDOW_NN_1_12 | ..... | ROOF-12 | CZ_12_DDY |
| 13 | ClimateZone13_CA.epw | WALL-13 | WINDOW_NN_1_13 | ..... | ROOF-13 | CZ_13_DDY |
| 14 | ClimateZone14_CA.epw | WALL-14 | WINDOW_NN_1_14 | ..... | ROOF-14 | CZ_14_DDY |
| 15 | ClimateZone15_CA.epw | WALL-15 | WINDOW_NN_1_15 | ..... | ROOF-15 | CZ_15_DDY |
| 16 | ClimateZone16_CA.epw | WALL-16 | WINDOW_NN_1_16 | ..... | ROOF-16 | CZ_16_DDY |
| End of Data | | | | | | |

6.1.2 Output files

6.1.2.1 TempCompTStep.csv

There are two TempCompTstep.csv files in the output folder:

TempCompTstepOriginal.csv for the baseline model and

TempCompTstepSimulation.csv for the demand response model.

TempCompTstepSimulation.csv will not appear in the Output folder unless users select DR simulation.

| | | | | | |
|----------|-------|---------|---------|---------|---------|
| DATETIME | | WEEKDAY | AVERAGE | AVERAGE | AVERAGE |
|----------|-------|---------|---------|---------|---------|

Interface between the Windows and DOS programs

| | | | TEMP | PPD | PMV |
|----------------|-------|----------|----------|---------|----------|
| 06/01 00:15:00 | ..... | Thursday | 25.4747 | 4.98198 | 0.0295 |
| 06/01 00:30:00 | ..... | Thursday | 25.46355 | 4.98714 | 0.02492 |
| 06/01 00:45:00 | ..... | Thursday | 25.43194 | 4.99348 | 0.01775 |
| 06/01 01:00:00 | ..... | Thursday | 25.39076 | 4.99838 | 0.00884 |
| | | | | | |
| 09/01 23:15:00 | ..... | Thursday | 25.30526 | 4.99983 | -0.00289 |
| 09/01 23:30:00 | ..... | Thursday | 25.24375 | 4.99654 | -0.01294 |
| 09/01 23:45:00 | ..... | Thursday | 25.21052 | 4.99214 | -0.01948 |
| End of Data | | | | | |

6.1.2.2 EnergyTStep.csv & EnergyHourly.csv & EnergyDaily.csv & EnergyMonthly.csv & EnergySeasonal.csv

The “EnergyTStep.csv” records the output results of the original and the DR simulation electric instantaneous power and energy consumption of the HVAC system (including chiller, condenser, chiller pump and condenser pump), fans, lights, electric equipment for each time step. “EnergyHourly.csv”, “EnergyDaily.csv”, “EnergyMonthly.csv” and “EnergySeasonal.csv” record the hourly, daily, monthly and seasonal energy consumption respectively. There are also two types of EnergyHourly.csv files: EnergyHourlyOriginal.csv for the baseline model and EnergyHourlySimulation.csv for the demand response model. Its structure is as follows.

| DATETIME | ..... | WEEKDAY | CHILLERPOWER [kW](TimeStep) | ..... | TOTAL POWER [KW](TimeStep) |
|----------------|-------|----------|-----------------------------|-------|----------------------------|
| 06/01 00:15:00 | ..... | Thursday | 101.37547 | ..... | 328.1225 |
| 06/01 00:30:00 | ..... | Thursday | 104.26447 | ..... | 331.3433 |
| 06/01 00:45:00 | ..... | Thursday | 106.16317 | ..... | 333.3837 |
| 06/01 01:00:00 | ..... | Thursday | 107.92569 | ..... | 335.2492 |
| | | | | | |
| 09/01 23:15:00 | ..... | Thursday | 0 | ..... | 93.56601 |
| 09/01 23:30:00 | ..... | Thursday | 0 | ..... | 93.56601 |
| 09/01 23:45:00 | ..... | Thursday | 0 | ..... | 93.56601 |
| End of Data | | | | | |

Interface between the Windows and DOS programs

6.1.2.3 EnergyCostMonthly.csv & EnergyCostSeasonal.csv

The “EnergyCostMonthly.csv” contains the monthly demand charge, energy charge and total charge. The “EnergyCostSeasonal.csv” contains the seasonal demand charge, energy charge and total charge. Its structure is as follows.

| MONTH | DAY OF MAX POWER | HOUR OF MAX POWER | DEMAND CHARGE RATE | DEMAND CHARGE [US\$](Monthly) | ENERGY CHARGE [US\$](Monthly) | TOTAL CHARGE [US\$](Monthly) |
|----------------|------------------------|-------------------------|--------------------------|-------------------------------------|-------------------------------------|------------------------------------|
| 6 | 26 | 14 | 7.25 | 3859.8289 | 16306.98 | 20166.81 |
| 7 | 24 | 14 | 7.25 | 4846.08596 | 18076.98 | 22923.06 |
| 8 | 9 | 14 | 7.25 | 3131.80231 | 16673.73 | 19805.53 |
| 9 | 12 | 14 | 7.25 | 3375.37129 | 15626.14 | 19001.51 |
| End of Data | | | | | | |

6.1.2.4 BasicOutput.csv

The “BasicOutput.csv” includes all the output results. It is transferred from the eplusout.csv which is the output file in the EnergyPlus folder.

6.1.2.5 CurrentClimateZone.csv

“CurrentClimateZone.csv” is used to store the climate zone number, which is determined by searching the input file “climate_Zones_Zipcode.csv”. It has only one record and two fields. Its structure is as follows.

6.1.2.6 queue.csv

The queue.csv file contains the 12 hottest days in the summer season, which are used for CPP program (Demand response, its demand charge and energy charge are different from regular charge). Its structure is as follows. It ranks by date order.

| MONTH | DAY | HOUR | TEMPERATURE |
|-------|-----|------|-------------|
| 6 | 15 | 16 | 38 |
| 6 | 16 | 16 | 38.6 |
| 6 | 21 | 16 | 37.5 |
| 7 | 11 | 15 | 39.1 |
| 7 | 12 | 15 | 37.5 |
| 7 | 23 | 16 | 38.5 |
| 7 | 24 | 16 | 39.7 |

Interface between the Windows and DOS programs

| | | | |
|-------------|----|----|------|
| 8 | 5 | 16 | 38.6 |
| 8 | 6 | 15 | 39.3 |
| 8 | 7 | 15 | 39.4 |
| 8 | 9 | 17 | 37.6 |
| 8 | 20 | 15 | 39.4 |
| End of Data | | | |

6.1.2.7 in.epw

The in.epw file is a weather data file, which is necessary for running EnergyPlus. The weather data file in.epw varies with climate zone, which is determined by the building's location.

6.1.2.8 in.imf

The in.imf is a macro building model, in which parameters of some fields will be calculated according to users and developers input. It will be used to produce the "true" building model in.idf for EnergyPlus simulation. Basically it is made of fields of variables and their definitions. Below is an example of a class LOCATION, which has 5 variables. The definitions (##set1) are produced by the program automatically.

```
##set1 Name = Climate_Zone_3_CA_USA_WYEC2-C-00003
##set1 Latitude = 37.70
##set1 Longitude = -122.20
##set1 GMT = -8.0
##set1 Elevation = 2.0
```

Location,

```
Name [],      !- Location Name
Latitude [],   !- Latitude {N+ S-}
Longitude [],  !- Longitude {W- E+}
GMT [],       !- Time Zone Relative to GMT {GMT+/-}
Elevation []; !- Elevation {m}
```

6.1.2.9 in.idf

"in.idf" is a building model for EnergyPlus simulation, which is composed of classes and their fields. It is produced by "in.imf".

7 Windows Interface of DRQAT

The top layer of the Windows interface is produced by the windows program automatically or by the developer manually. The batch file name can be determined arbitrarily. Its purpose is to call the second layer batch program with specified program path created in section 5. For example, suppose that the top batch file name is RUN.bat, and the second batch file "main.bat" is contained in the folder of "d:\building\simulation", then it should contain "call main.bat d:\building\simulation" only.

Windows are used to input building parameters and schedules. All the variables are contained in four input files: DI.csv, InputSchedules.csv, RateDaySchedule.csv and RateMonthSchedule.csv. Each variable has its default value so as to be convenient for input by the user.

Windows must recognize and read the original input data of buildings and changed input data so as to calculate energy saving and economic saving.

7.1 Introduction to Delphi

Delphi is a high-level, compiled, strongly typed language that supports structure and object-oriented design. Based on Object Pascal, its benefits include easy-to-read code, quickly compilation, and the use of multiple units files for modular programming. Delphi has special features that support Code Gear's component framework and RAD environment. Therefore Delphi could make function-strongly, friendly interface which meets the requirement of DRQAT.

7.2 Data transfer using Delphi

The purpose of using Delphi is to achieve the data transfer between the interface and the main DOS batch file. The interface made by using Delphi is so friendly for users that they could easily evaluate energy consumption, demand reduction and cost saving for individual buildings when applying different demand response strategies into the building. Users don't need so much experience in energy simulation by using EnergyPlus. This software can meet the need of users to analyze the effect of different demand response strategies.

Here we introduce the general process of making the interface for DRQAT. There are seven buttons on the main interface of DRQAT, when clicked a sub interface appears that shows detailed information about the building model.

7.2.1 Building basic input

The Building basic input DRQAT shows the building basic input information of the building model. There are two main functions in this form: one for loading from CSV files and another one for checking input information. User could load default input information when clicking the “Load default” button, then the function of the interface would read hvac.txt, building type.txt and DI.csv in the Input folder as following.

```
function tform10.loadfromcsv(loadstyle:string):boolean;
var
temp:textfile;
tempstr,valuestr:string;
kk,aa,bb:tstrings;
begin
  if loadstyle='Default'then
  begin
    if not(fileexists(filedir+'\Default\DI.csv'))then
    begin
      showmessage('Can not load data');
      result:=false;
      exit;
    end;
    if not (fileexists(filedir+'\Default\hvac.txt')) then
    begin
      showmessage('Can not load data');
      result:=false;
      exit;
    end;
    if not (fileexists(filedir+'\Default\BuildingType.txt')) then
    begin
      showmessage('Can not load data');
      result:=false;
      exit;
    end;
    assignfile(temp,filedir+'\Default\DI.csv');
  reset(temp);
  try
```

Figure 7-1 Load building basic input information from CSV files in Input folder

Since there are two different building models with different HVAC systems for DRQAT: Office building model and Retail building model, the variable parameters are stored in “hvac.txt” and building type.txt, respectively.

```
function TForm10.checkbuildingbasic:boolean;
var
  kk:string;
begin
  result:=true;
  if pos('.',edit10.Text)=length(edit10.Text) then
  begin
    kk:=copy(edit10.Text,1,length(edit10.Text)-1);
    edit10.Text:=kk;
  end;
  if pos('.',edit2.Text)=length(edit2.Text) then
  begin
    kk:=copy(edit2.Text,1,length(edit2.Text)-1);
    edit2.Text:=kk;
  end;
  if pos('.',edit3.Text)=length(edit3.Text) then
  begin
    kk:=copy(edit3.Text,1,length(edit3.Text)-1);
    edit3.Text:=kk;
  end;
  if pos('.',edit5.Text)=length(edit5.Text) then
  begin
    kk:=copy(edit5.Text,1,length(edit5.Text)-1);
    edit5.Text:=kk;
  end;
  if pos('.',edit6.Text)=length(edit6.Text) then
  begin
    kk:=copy(edit6.Text,1,length(edit6.Text)-1);
    edit6.Text:=kk;
  end;
end;
```

Figure 7-2 Check building basic input information from CSV files in Input folder

Once users input the basic building information into building model, click the “save” button and the “Done” button in turn, the information is saved as “diOriginal.csv” into Input folder. When running the simulation, the Main batch file will read the building basic information data from corresponding input files.

7.2.2 Utility input

For the utility input of the building model, there are some main functions and procedures to input the utility information for the simulation period; check the utility input, load the default utility values, find the CPP days for the building model and so on.

Users can click “Load Default” button to load the default utility values from RateDaySchedule.csv and RateMonthlySchedule.csv which are stored in the “Input” folder.

```
function TForm11.loadfromcsv(style:string):boolean;
var
  temp:textfile;
  tempstr,valuestr:string;
  i,j,rownum:integer;

begin
  assignfile(temp,filedir+'\input\RateDaySchedule.csv');
  reset(temp);
  readln(temp);
  rownum:=0;
  while(true)do
  begin
    rownum:=rownum+1;
    readln(temp,tempstr);
    readvalue.readcellvalue(valuestr,1,tempstr);
    if valuestr='CUSTOMER CHARGE' then
      break;
  end;
  rownum:=rownum-1;
  stringgrid6.RowCount:=rownum+1;
  reset(temp);
  readln(temp);
  for i:=1 to rownum do
  begin
    readln(temp,tempstr);
```

Figure 7-3 Load default utility values from CSV files in Input folder

Users can input custom utility values themselves and save these utility values in RateDayScheduleOriginal.csv and RateMonthlyScheduleOriginal.csv. On running the building baseline model, the main DOS batch file will read the utility values and insert them into the report of the baseline model or DR model.

If the building model applies different utility rates on CPP days, this interface also provides a function for finding the CPP days. Clicking “find CPP days” button will run the “cppday.bat” batch file and show the 12 CPP days in the form. Users can input different utility values for the 12 CPP days.

```
procedure TForm1.Button4Click(Sender: TObject);
var
  i:integer;
  kk:tstrings;
begin
  kk:=tstringlist.Create;
  kk.LoadFromFile(filedir+'\input\runpara.txt');
  if kk.Strings[7]='NO' then
  begin
    showmessage('Please complete the building basic input first');
    exit;
  end;
  setlength(cppday,12);
  for i:=0 to 11 do
  setlength(cppday[i],2);

  if fileexists(filedir+'\output\queue.csv') then
  deletefile(filedir+'\output\queue.csv');
  shellexecute(self.Handle,'open',pansichar(filedir+'\cppday.bat'),pansichar(filedi:
  timer1.Enabled:=true;
end;
```

Figure 7-4 Find CPP days and show it in the form

7.2.3 Baseline schedules

For the baseline schedules input, users can load default baseline schedules from “InputSchedules.csv” stored in Input folder. And also users can input custom baseline schedules in this page of the interface. These baseline schedules are saved as “InputSchedulesOriginal.csv” to the Input folder. The detailed functions and procedures are not presented here. Engineers or developers are referred to the source code about it.

7.2.4 Run baseline simulation

Clicking the “Run” button in the baseline simulation will begin running the EnergyPlus simulation of the building baseline model. There are two building models for DRQAT: Office building model and Retail building model. The corresponding “main.bat” file specified by the variable parameter in “building type.txt” is run.

```
label1.Caption:='Calculation is in process';
label1.Visible:=true;
form7.Label3.Caption:='0 seconds';
unit7.secondnum:=0;
assignfile(temp,filedir+'\input\di.csv');
reset(temp);
readln(temp);
readln(temp);
readln(temp);
readln(temp);
readln(temp);
readln(temp);
readln(temp,tempstr);
closefile(temp);
readcellvalue(kk,3,tempstr);
if strtoint(kk)>=3 then
kk:='3';
tempkk:=tstringlist.Create;
tempkk.LoadFromFile(filedir+'\input\hvac.txt');
kk1:=tempkk.Strings[0];
bb:=tstringlist.Create;
bb.LoadFromFile(filedir+'\input\buildingtype.txt');
if bb.Strings[0]='Office' then
if checkbox1.Checked then
shellexecute(self.Handle,'open',Pchar(extractfiledir(application.ExeName)+'\'+main.bat
else
shellexecute(self.Handle,'open',pchar(extractfiledir(application.ExeName)+'\'+main.bat
if bb.Strings[0]='Retail' then
if checkbox1.Checked then
shellexecute(self.Handle,'open',Pchar(extractfiledir(application.ExeName)+'\'+main_ret
else
shellexecute(self.Handle,'open',pchar(extractfiledir(application.ExeName)+'\'+main_ret
```

Figure 7-5 Run the main batch file

7.2.5 DR strategies

Users can apply different demand response strategies to the building model. Users can load the baseline schedules and then input the DR simulation schedules based on the baseline schedules. The DR strategies schedules are saved as “InputSchedulesSimulation.csv” to the Input folder. The other functions and procedures in this page of the interface are almost the same as that of the baseline schedules.

For the DR strategies, users can change operation of the HVAC system and then do demand response analysis. For example, reset zone temperature set-point, run HVAC system earlier than normal operation to pre-cooling building, and so on.

7.2.6 Run DR simulation

The function of this interface is the same as that for running the baseline simulation.

7.2.7 Report

This part of the DRQAT interface has four sub pages to show the detailed report

about simulation results: average zone temperature and comfort, energy consumption and power, energy cost and CPP days report. There are so many procedures to show the simulation results. These procedures read the output results from the Output folder and show it to users in the form of figures, graphs, and so on.

8 Prototypical Large Office and Retail Buildings

The prototypical large office and retail building were developed by Joe Huang which addressed the load pattern and characteristics for the office and retail building [2]. These two building model describe the zone size, internal gains, operation schedules, and HVAC systems. For DRQAT, users can define an office building model or a retail building model with different size, operation schedules, internal loads, and HVAC types. The characteristics of the prototypical large office building are described as follows. Based on the prototypical building model, DRQAT defines variable parameters as EnergyPlus macros for the office and retail building and then develops a model to simulate the actual buildings.

8.1 Prototypical Office Model

8.1.1 Size

The prototype large office buildings vary significantly in size from less than 150,000 in the Western U.S to over 500,000 ft² in the Eastern U.S. Although the average floor area varies by a factor of three, the average number of floors is fairly constant in the range of 7 to 9. As shown in the *Dodge Project Detail* data summarized in the top part of Table 8-1, the size variations between the *Stock* and *Current* vintages are fairly insignificant.

8.1.2 Shell Characteristics

The offices are modeled with steel frame construction with light-weight curtain walls. The window-to-wall ratios of the prototypes vary from 0.41 in the Northeast to 0.50 in the South. For the Stock vintage, the windows are assumed to be single pane in all cities.

Prototypical Large Office and Retail Buildings

| Building Parameter | North-east | North Central | South | West |
|---|-------------------------------------|---------------|------------|------------|
| Floor Areas (1000 ft²) | | | | |
| <i>Stock</i> Vintage | Bos: 186 | Chi: 349 | Mia: 149 | LA: 196 |
| | NY: 557 | Det: 226 | NO: 272 | SF: 267 |
| | Phi: 271 | StL: 321 | Hou: 204 | SD: 148 |
| <i>Current</i> Vintage | Bos: 197 | Chi: 352 | Mia: 159 | LA: 197 |
| | NY: 419 | Det: 150 | NO: 342 | SF: 197 |
| | Phi: 203 | StL: 198 | Hou: 253 | SD: 146 |
| | | | | Phx: 142 |
| No. of floors | 8 | 9 | 7 | 9 |
| Shell characteristics | | | | |
| <i>Stock</i> vintage: | | | | |
| Ceiling R-value | 6.2 | 9.1 | 7.9 | 7.1 |
| Wall R-value | 1.1 | 1.5 | 1.1 | 1.0 |
| Window glass | 1-pane | 1-pane | 1-pane | 1-pane |
| <i>Current</i> vintage: | | | | |
| ASHRAE-90.1 (see Table 4.1) | | | | |
| Window shad. coeff | 0.6 | 0.6 | 0.6 | 0.6 |
| Window/wall ratio | 0.41 | 0.45 | 0.50 | 0.47 |
| Internal loads | | | | |
| Ft ² /person | 420 | 380 | 360 | 390 |
| Lights W/ft ² (<i>Stock</i>) | 1.8 | 1.9 | 2.0 | 2.0 |
| Lights W/ft ² (<i>Current</i>) | 1.57 | 1.57 | 1.57 | 1.57 |
| Equip W/ft ² (12-hr Off.) | 0.75 | 0.75 | 0.75 | 0.75 |
| Equip W/ft ² (24-hr Off.) | 1.2 | 1.2 | 1.2 | 1.2 |
| Hot Water Btu/ft ² | 175 | 175 | 175 | 175 |
| Process Btu/ft ² | N/A | N/A | N/A | N/A |
| Process W/ft ² | N/A | N/A | N/A | N/A |
| System Type | | | | |
| 2 systems; one for perimeter and one for core zone. | | | | |
| <i>Old</i> equipment | Constant volume for all regions | | | |
| <i>New</i> equipment | Variable-air-volume for all regions | | | |
| Heat Sched | 74 F day, 65 F night | | | |
| Cool Sched | 78 F day, 85 F night | | | |
| Heating plant | gas boiler | gas boiler | gas boiler | gas boiler |
| Chiller type | hermetic | hermetic | hermetic | hermetic |
| | centrif. | centrif. | centrif. | centrif. |
| Hot water plant | gas boiler | gas boiler | gas boiler | gas boiler |

Table 8-1 Building Descriptions for Large Office Prototypes

8.1.3 Zone Conditions

For simulation, we assumed that the aspect ratio (length to width) of the building is 0.67. Each floor is divided into five zones—four perimeter zones and one core zone. The wall height is 10 feet and the depth of the perimeter zone is 15 feet. The design internal loads and occupancy intensities have been assumed constant throughout the buildings. The lighting intensity is assumed to be 2 W/ft² in the South and the West, 1.8 W/ft² in the Northeast, and 1.9 W/ft² in the North Central regions. The equipment energy intensity is 0.75 W/ft², the hot water usage is 175 Btu/person per day, and the peak power usage for elevators is 57 kW for all cities.

8.1.4 Schedules

The prototype large office buildings have been simulated with both a 12-hour normal operating schedule and a 24-hour schedule for data centers. The occupancy, equipment, hot water and elevator schedules are summarized in Table 8-2.

The offices with normal 12-hour operations are unoccupied between 7 p.m. and 6 a.m. on week days, and between 1 p.m. and 7 a.m. on weekends and holidays. As shown in Figure 8-1, the week day occupancy is 1.0 (100%) from 9 a.m. to 5 p.m. on week days and 0.2 (20% of max occupancy) from 10 to 11 a.m. on weekends. For the transition hours from 7 to 8 a.m. and from 5 to 6 p.m. on weekdays, and from 8 to 9 a.m. and 11 a.m. to noon on weekends, a linear transition is assumed from the occupied to the unoccupied schedules. The domestic hot water usage is assumed to closely follow the occupancy schedule.

Figure 8-2 shows the lighting and equipment schedules, which assumed to be 90% of the peak lighting intensity from 7 a.m. to 5 p.m. during normal week days. For the other week day hours, as well as weekends and holidays, the lighting schedule is 20%. The schedules for lighting, equipment, and elevator are all modeled as simple square waves with no ramping. For example, the equipment intensity is 100% from 7 a.m. to 5 p.m. on week days and 17% for all other week day hours, weekends, and holidays.

The occupancy and lighting schedules for the 24-hour offices differ from those for the 12-hour offices during the off hours. Instead of 0% or 20%, these schedules never fall below 33% of the peak levels. The equipment and elevator schedules are the same as in the 12-hour office. These schedules are shown in the bottom part of Table 8-2.

Prototypical Large Office and Retail Buildings

Table 8-2 Occupancy and Equipment Schedules for Large Offices

A. 12-hour Office

| Zone | Parameter | Day type* | Hour of Day | | | | | | | |
|------|----------------------|-----------|-------------|------|------|------|------|------|------|------|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Bldg | People, Hot Water | WD | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.67 |
| | | WEH | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 |
| Bldg | Lights | WD | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.90 | 0.90 |
| | | WEH | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Bldg | Equipment, Elevators | WD | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 1.00 |
| | | WEH | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| Zone | Parameter | Day type* | Hour of Day | | | | | | | |
| | | | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Bldg | People, Hot Water | WD | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | | WEH | 0.13 | 0.20 | 0.20 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bldg | Lights | WD | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | | WEH | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Bldg | Equipment, Elevators | WD | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | | WEH | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| Zone | Parameter | Day type* | Hour of Day | | | | | | | |
| | | | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Bldg | People, Hot Water | WD | 1.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | WEH | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bldg | Lights | WD | 0.90 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| | | WEH | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Bldg | Equipment, Elevators | WD | 1.00 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| | | WEH | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |

B. 24-hour Office

| Zone | Parameter | Day type* | Hour of Day | | | | | | | |
|------|----------------------|-----------|-------------|------|------|------|------|------|------|------|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Bldg | People, Hot Water | WD | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.67 |
| | | WEH | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| Bldg | Lights | WD | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.90 | 0.90 |
| | | WEH | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| Bldg | Equipment, Elevators | WD | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 1.00 |
| | | WEH | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| Zone | Parameter | Day type* | Hour of Day | | | | | | | |
| | | | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Bldg | People, Hot Water | WD | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | | WEH | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| Bldg | Lights | WD | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | | WEH | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| Bldg | Equipment, Elevators | WD | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | | WEH | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| Zone | Parameter | Day type* | Hour of Day | | | | | | | |
| | | | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Bldg | People, Hot Water | WD | 1.00 | 0.50 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| | | WEH | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| Bldg | Lights | WD | 0.90 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| | | WEH | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| Bldg | Equipment, Elevators | WD | 1.00 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| | | WEH | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |

* WD = weekdays, WEH = weekends and holidays

Prototypical Large Office and Retail Buildings

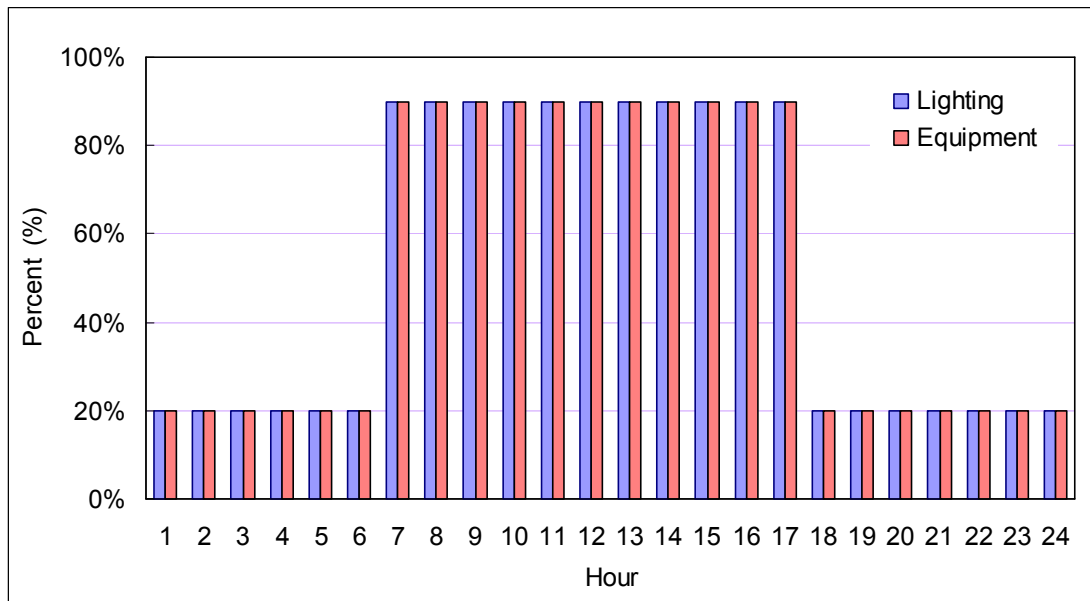


Figure 8-1 lighting and equipment schedules on weekdays for 12-hour office

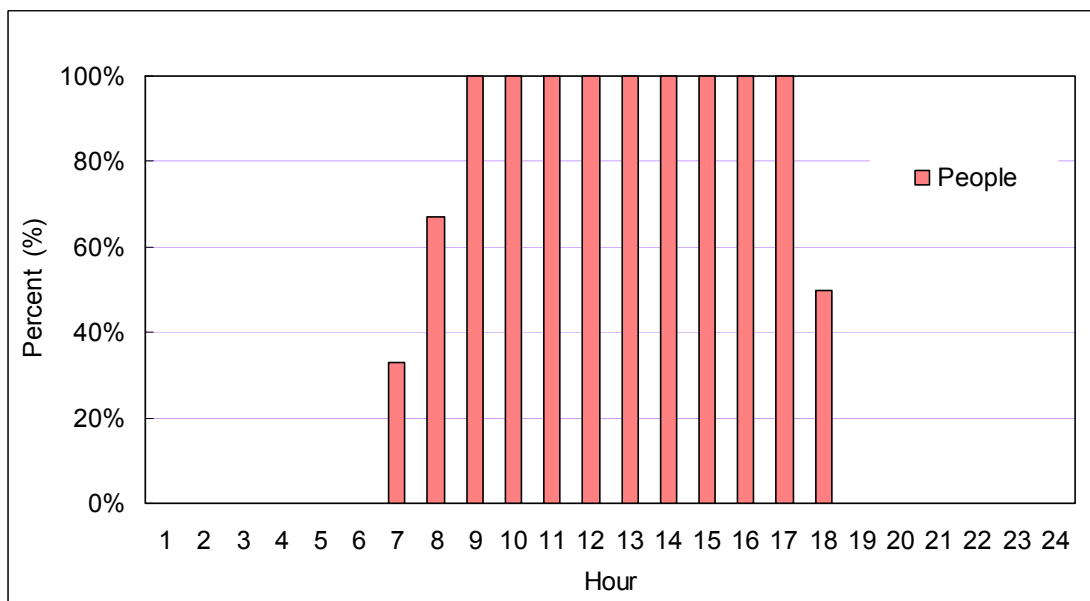


Figure 8-2 occupancy schedule on weekdays for 12-hour office

8.1.5 HVAC Systems

The heating is done with gas boilers, and the cooling with central centrifugal chillers with cooling towers in all cities. Two systems are modeled for the building, one for the perimeter zones and the other for the central zone. The systems are reheat-fan with constant volume for the Old vintage equipment, and variable-air-volume with variable volume for the new vintage equipment.

8.2 Prototypical Retail Model

8.2.1 Size

The size of the prototype large retail store varies significantly from less than 27,000 in the San Francisco to 140,000 ft² in New York, based on analysis of the detailed Dodge Building Start data. The majority of stores are in the range of 60,000 to 100,000 ft². Although the prototype floor areas vary by a factor of five (only two, excluding San Francisco), the average floors are fairly constant in the range of 2 to 3.

8.2.2 Shell Characteristics

Large retail stores have three modes of occupancy: peak sales period, normal weekday operation, normal weekend operation. During the peak sale periods, the peak time occupancy of the entire store may increase so that the average occupancy is around 20 to 50 ft² per person. In normal daily operation, average occupancy is around 100 to 120 ft² per person. The prototypes are modeled with average weekday occupancy densities. For weekends, the same occupancy density is assumed, but with shorter hours of operation. Although we are aware of the existence of peak sales periods (e.g., Christmas), no attempt has been made to incorporate these periods into the prototype modeling.

8.2.3 Zone Conditions

The prototype retail stores are assumed to be rectangular in shape with aspect ratios (length to width) of 0.5. Because of the assumed low window/wall ratio, each floor of the building has been simulated as a single zone, so that the prototype stores have two to three zones. The walls heights are taken to be 15 ft.

8.2.4 Schedules

For all but the West region, the prototype stores are assumed to be open from 8 a.m. to 6 p.m. on weekdays and from 10 a.m. to 6 p.m. on weekends and holidays. In the West, the stores are assumed to stay open until 9 p.m. on weekdays. 100% occupancy is assumed from 11 a.m. to 6 p.m. on weekdays and from 1 p.m. to 5 p.m. on weekends. For the transition hours of 9 a.m., 10 a.m., and 7 p.m. (10 p.m. in the West) 4-76 assumed from the day schedule to night schedule. The domestic hot water schedules are assumed to closely follow those for occupancy. The lighting schedule is assumed to be 90 percent of the peak lighting intensity for hours 9 a.m. to 9 p.m. during the normal weekday operations and 20% for hours 10 p.m. to 8 a.m. For weekends and holidays lighting schedule is 90 per cent during hours 11 a.m. to 5 p.m.

Prototypical Large Office and Retail Buildings

and 20% for hours 6 p.m. to 10 a.m. Equipment, escalators, and elevator schedules, like lighting, are also simple square waves, 100 per cent for 9 a.m. to 9 p.m. of weekdays and 17 per cent for all other hours. For weekends and holidays, equipment schedule is 100% from 11 a.m. to 5 p.m. and 17% for other hours.

8.2.5 HVAC Systems

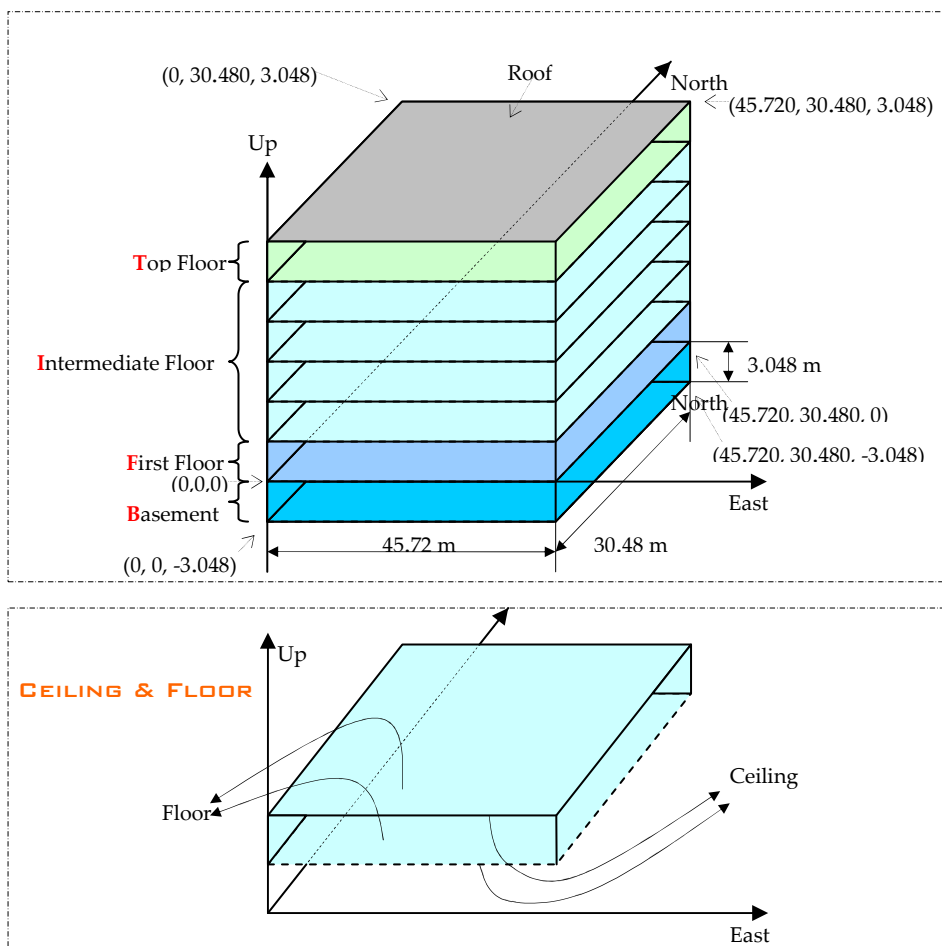
Large retail stores in all regions are heated with gas. The cooling is with central centrifugal chillers and cooling towers. The systems are all Single-zone Reheat (SZRH), with Constant-air Volume for the old and Variable-air Volume for the new systems. One system for each floor is considered.

9 Building Models of DRQAT

9.1 Building Type

9.1.1 Office Building Model

For the size of the office building models defined in DRQAT, the length, width and height of the floor can be specified according to the actual building by using Input Macros. The following figures show the detailed information about the building models in DRQAT.



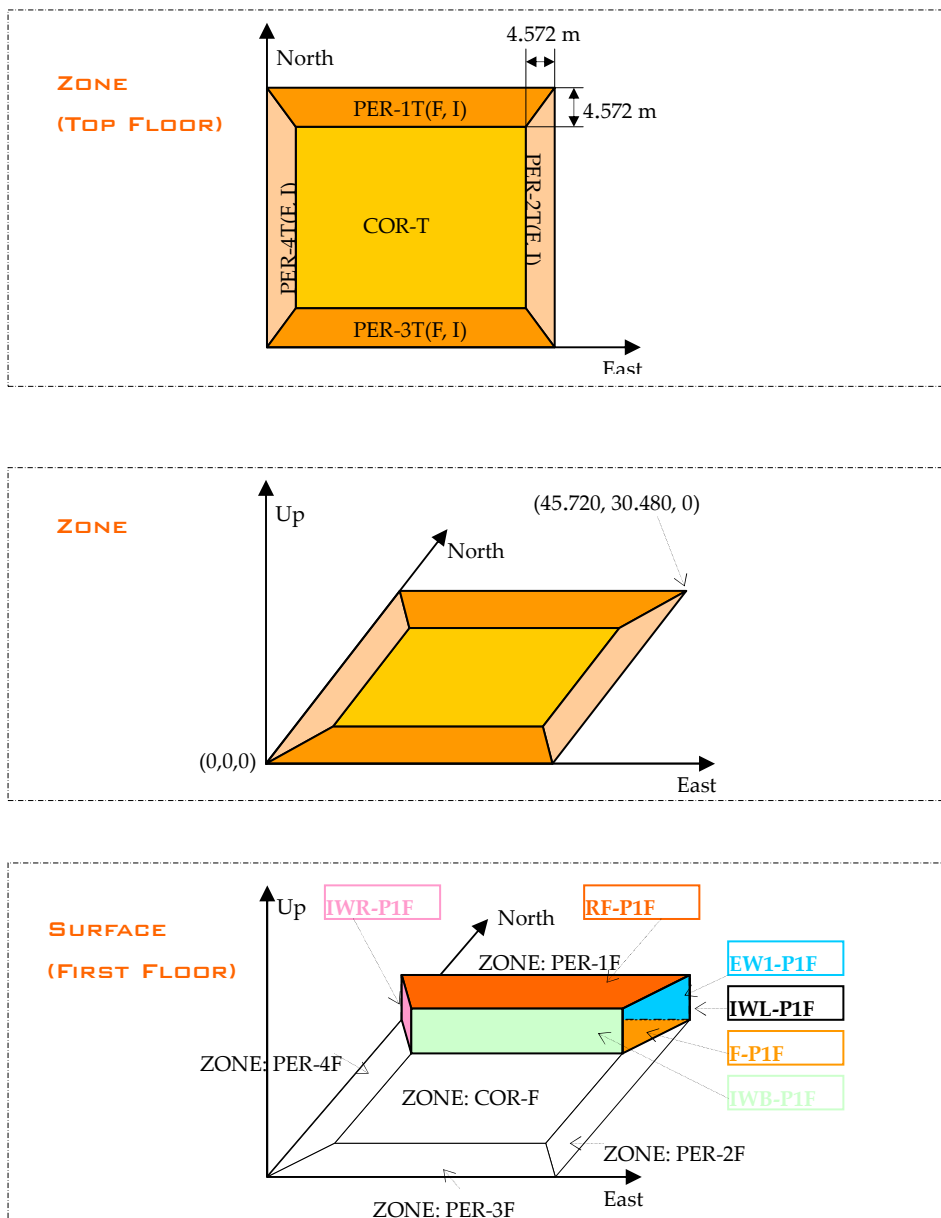


Figure 9-1~5 Office Building Model

9.1.2 Retail Building

For the retail building model defined in DRQAT, it is a single story building model with five functional zones as shown in Figure 9-6.



Figure 9-6 Retail Building Model

9.2 Constructions

9.2.1 Walls

The wall constructions used in the building models for DRQAT depend on climate zones and meet the minimum prescriptive requirements of California Title 24 Standards.

9.2.2 Windows

The window constructions are also based on requirements of California Title 24. Based on the window-to-wall ratio, orientation and climate zones, the windows constructions would be selected from "CLIMATE_ZONES_CONSTRUCTION.CSV" stored in Input folder. If users or developers want to change the constructions of the building models, they can go to "Construc" folder and change the "construc.lom" file. Table 9-3 shows the building envelope requirements of Title 24 - 2005.

Table 9-1 Building envelope requirements in Title 24

| | CLIMATE ZONES | | | | | | | | | |
|--|----------------|-------|-----------|-------|-----------|-------|-----------|-------|-----------|-------|
| | 1, 16 | | 3-5 | | 6-9 | | 2, 10-13 | | 14, 15 | |
| Roof/Ceiling | | | | | | | | | | |
| U-factor | 0.051 | | 0.051 | | 0.076 | | 0.051 | | 0.051 | |
| R-value ¹ | 19 | | 19 | | 11 | | 19 | | 19 | |
| Wall | | | | | | | | | | |
| R-value or U-factor | 13 | | 11 | | 11 | | 13 | | 13 | |
| Wood frame | 0.102 | | 0.110 | | 0.110 | | 0.1024 | | 0.102 | |
| Metal frame | 0.217 | | 0.224 | | 0.224 | | 0.217 | | 0.217 | |
| Metal building | 0.113 | | 0.123 | | 0.123 | | 0.113 | | 0.113 | |
| Mass/7.0≤HC<15.0 | 0.330 | | 0.430 | | 0.430 | | 0.430 | | 0.430 | |
| Mass/15.0≤HC | 0.360 | | 0.650 | | 0.690 | | 0.650 | | 0.410 | |
| Other | 0.102 | | 0.110 | | 0.110 | | 0.102 | | 0.102 | |
| Floor/Soffit | | | | | | | | | | |
| R-value or U-factor | 19 | | 11 | | 11 | | 11 | | 11 | |
| Mass/7.0≤HC | 0.090 | | 0.139 | | 0.139 | | 0.090 | | 0.139 | |
| Other | 0.048 | | 0.071 | | 0.071 | | 0.071 | | 0.071 | |
| Windows | | | | | | | | | | |
| U-factor ² | 0.47 | | 0.77 | | 0.77 | | 0.47 | | 0.47 | |
| Relative solar heat gain | Non-North | North | Non-North | North | Non-North | North | Non-North | North | Non-North | North |
| 0-10% WWR | 0.49 | 0.72 | 0.61 | 0.61 | 0.61 | 0.61 | 0.47 | 0.61 | 0.46 | 0.61 |
| 11-20% WWR | 0.43 | 0.49 | 0.55 | 0.61 | 0.61 | 0.61 | 0.36 | 0.51 | 0.36 | 0.51 |
| 21-30% WWR | 0.43 | 0.47 | 0.41 | 0.61 | 0.39 | 0.61 | 0.36 | 0.47 | 0.36 | 0.47 |
| 31-40% WWR | 0.43 | 0.47 | 0.41 | 0.61 | 0.34 | 0.61 | 0.31 | 0.47 | 0.31 | 0.40 |
| Skylights | | | | | | | | | | |
| U-factor ² | Glass w/Curb | 1.18 | 1.42 | 1.42 | 1.42 | 1.18 | 1.18 | 1.18 | 1.18 | 1.18 |
| | Glass wo/Curb | 0.68 | 0.82 | 0.82 | 0.82 | 0.68 | 0.68 | 0.68 | 0.68 | 0.68 |
| | Plastic w/Curb | 1.04 | 1.56 | 1.56 | 1.56 | 1.32 | 1.32 | 1.32 | 1.32 | 1.32 |
| SHGC Glass | 0-2% | 0.68 | 0.79 | 0.79 | 0.79 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |
| | 2.1-5% | 0.46 | 0.40 | 0.40 | 0.40 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |
| SHGC Plastic | 0-2% | 0.77 | 0.79 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 |
| | 2.1-5% | 0.58 | 0.65 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 |
| Note: Construction assembly U-factors shall be calculated in accordance with Appendix IV. | | | | | | | | | | |
| ¹ R-value cannot be used for compliance when roof has metal framing members or a metal deck unless additional rigid insulation is installed. See Section 143 (a) 1 C. | | | | | | | | | | |
| ² U-factor adjustments are made to make the criteria consistent with revised NFRC rating procedures. | | | | | | | | | | |

9.3 Zone Conditions

The flexibility of the model defined in DRQAT is increased compared to other models (e.g. those by Joe Huang). For the office building model, each floor is divided into five zones: four perimeter zones and one core zone. The default depth of the perimeter zone is 15 feet. For the retail building model, it is divided into five zones; however there are no perimeter zones and core zones, users don't need to define the depth of the perimeter zone. There is one special feature for DRQAT models, user can define the size of the building model, and internal load and occupancy intensities can be input by users based on the actual building.

9.4 Schedules

The schedules defined in the model include internal load schedules and HVAC operation schedules. For the former, it includes occupant schedule, lighting and equipment schedules on work days and weekend days. The HVAC system operation schedules include fan & chiller schedules, zone temperature set-point schedules, condenser water set-point & chilled water set-point, and supply air temperature set-point on weekday and weekend. Users could input custom baseline schedules and DR schedules in the building models.

9.5 Systems

There are two types of building models in DRQAT: Office and Retail. The office building model has two types of HVAC systems: Water-cooled chiller with VAV systems and DX cooling with VAV systems. Both of these HVAC systems are auto-sized. For the retail building model, it has one types of HVAC system: DX cooling with VAV systems. We will add new types of HVAC system for the later version.

10 Reference

- [1] Input/Output Reference, “EnergyPlus Documentation”, Version 4.0 Documentation, October 2009.
- [2] Joe Huang, Hashem Akbari, Leo Rainer, and Ron Ritschard. Lawrence Berkeley Laboratory, Applied Science Division. “481 Prototypical Commercial Buildings For 20 Urban Market Areas”. Technical documentation of building loads data base developed for the GRI Cogeneration Market Assessment Model. April 1991.
- [3] California Energy Commission. California’s Energy Efficiency Standards for Residential and Nonresidential Buildings, 2005.

11 Glossary

| | |
|----------|---|
| IDF | EnergyPlus input file |
| LOM | Pieces of IDF files |
| AWK | Program language that is designed for processing text-based data |
| Title 24 | California's Energy Efficiency Standards for Residential and Nonresidential Buildings |
| CPP | Critical peak pricing |
| DR | Demand response |
| DRRC | Demand Response Research Center |
| DRQAT | Demand Response Quick Assessment Tool |
| HVAC | Heating, ventilating, and air conditioning |
| LBNL | Lawrence Berkeley National Laboratory |
| PMV | Predicted mean vote |
| VAV | Variable air volume |