# USING GENOPT WITH TRNSYS 16 AND TYPE 56

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**Quick instructions to run the example (if you are an advanced user or just in a hurry)**

- Unzip GenOpt and copy the contents of go_prog into "C:\Program Files\GenOpt". This means that the full path to the "WinGenOpt.class" should read as "C:\Program Files\GenOpt\genopt\WinGenOpt.class"

- Add the path to GenOpt to your CLASSPATH environment variable as explained in section 2.2.1. **Do not skip this step!**

- Unzip the example into "C:\Program Files\Trnsys16\Examples". It should create the "Genopt-Type56" folder, i.e. the full path to the project file, "Genopt-Type56.tpf", should read "C:\Program Files\Trnsys16\Examples\Genopt-Type56\Genopt-Type56.tpf".

  - You can open the project and look at the starting point in the Simulation Studio. If you want to know what the example is doing, please read Section 3.

- To perform an optimisation study, browse to "C:\Program Files\Trnsys16\Examples\Genopt-Type56" in Windows Explorer and launch "StartOptimisation.bat". This should start the GenOpt interface. In the interface, click on the green arrow (or go to File/Start). Select the GenOpt.ini file and click "Open". This should launch the TRNSYS simulations. If it does not, make sure you are opening the "Genopt.ini" file that is located in "C:\Program Files\Trnsys16\Examples\Genopt-Type56".

If this does not work, you might have to actually read this document (and check the "troubleshooting" section)

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## 1. Introduction

### 1.1. About this document

This document assumes that you are reasonably comfortable with the TRNSYS jargon, such as what is the TRNSYS input file (deck, or .DCK) and what is the building description file (Building file, or .BUI, created by TRNBuild). Please refer to the TRNSYS Manual [1] for more details.

**This document briefly describes how to use GenOpt [2] with TRNSYS, including some features that are currently not available from the dedicated TRNSYS interface for GenOpt, TRNOPT [3].**

The document comes with a working example. In order to run the example "out of the box", you will have to install the different programs and the example itself in the directories listed below. This is necessary because absolute paths are hard-coded in some of the configuration files provided with the example.

### 1.2. About GenOpt

GenOpt [2] is an optimisation program for the minimization of a cost function that is evaluated by an external simulation program. It can be used with any simulation program that reads inputs from and write outputs to text files. GenOpt and its user manual can be downloaded free of charge (after registration) from the Lawrence Berkeley National Lab website, http://gundog.lbl.gov/GO.

### 1.3. About TRNOPT

TRNOPT is a dedicated TRNSYS interface for GenOpt. It has been created by TESS (http://www.tess-inc.com) in order to streamline the optimisation process and it is being distributed as part of the TESS libraries Version 2. With TRNOPT, the entire process of optimizing the results from a TRNSYS simulation

reduces to choosing the TRNSYS input file, choosing the variables which will be varied to optimize the results, and choosing the simulation result to be optimized. In this respect TRNOPT is highly recommended to any TRNSYS user wishing to experiment with GenOpt.

This document is intended to demonstrate the use of some GenOpt features that are currently not available from within TRNOPT: equations implementing relationships between optimisation variables, and direct modification of building parameters located within the BUI file (created by TRNBuild) and not in the DCK file.

## 1.4. Program versions

This document relies on settings, default directories, etc., which were tested for the following program versions:

- TRNSYS
  - Tested with TRNSYS 16.01.0002
  - TRNSYS 16 is required (TRNSYS 15 will not work), TRNSYS 16.01.0000 or above is strongly recommended
- GenOpt
  - Tested with GenOpt 2.0.0
  - Any subsequent version of GenOpt 2 (if any) should work, GenOpt 1 will not work
- Java
  - Tested with Java 2 Runtime Environment, Standard Edition, Version 1.5.0 Update 11
  - Any Java 2 version compatible with GenOpt should work, i.e. Java 2 Runtime Environment Version 1.4.2 or higher.

# 2. Setting up the programs

## 2.1. TRNSYS 16

This document assumes that you have installed TRNSYS 16 in the default directory (C:\Program Files\Trnsys16). If you have installed it in a different directory, you will need to make the appropriate changes in pathnames that appear in the configuration files for the example (see below).

## 2.2. GenOpt

This document assumes that you have unzipped the downloaded version of GenOpt into its own directory and moved that directory into "C:\Program Files\GenOpt".

**In other words, the full path to the main program, "WinGenOpt.class" should read as "C:\Program Files\GenOpt\genopt\WinGenOpt.class".** You will have to create the directory "C:\Program Files\GenOpt" and move there the content of the "go_prog" directory created when unzipping the downloaded version of GenOpt. If you wish to install GenOpt in a different directory, you will need to make the appropriate changes in pathnames that appear in the configuration files for the example (see below).

### 2.2.1. Setting CLASSPATH in the environment variables (IMPORTANT STEP!)

You **must** add the path to GenOpt to the CLASSPATH environment variable. Failing to do so will result in a java error in if you attempt to run the example as it is.

In order to do so:

- Right-click on "My Computer" and select "Properties" (or go to Start/Settings/Control Panel/System)
- Go to the "Advanced" tab
- Click on "Environment variables" (see screenshot below)
- If you can see a CLASSPATH variable, select it, click on "Edit" and add ";C:\Program Files\GenOpt" (without the quotes) to the variable value. It is important to type the string **without surrounding quotes**!

- If you cannot see a CLASSPATH variable, click on "New" under "System variables" (see screenshot below). Enter "CLASSPATH" (without the quotes) for the variable name and "C:\Program Files\GenOpt" (without the quotes) for the variable value. It is important to type both strings **without surrounding quotes**!
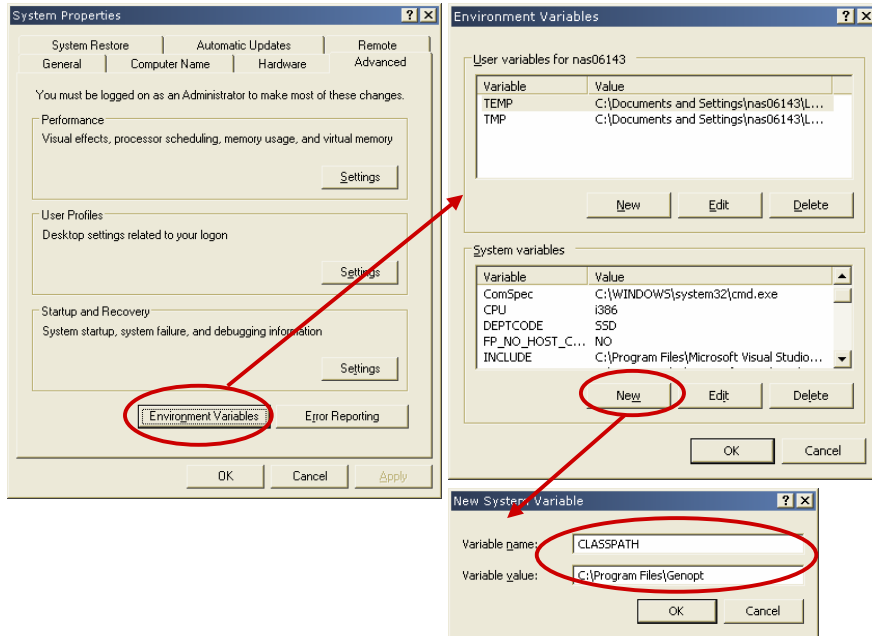


## 2.3. Java

You should install a Java version that is compatible with GenOpt. If you want to test your Java installation, open a command prompt and type "java –version". You should get a message with the java version installed on your machine. If you don't then chances are GenOpt will not work and you should reinstall a recent version of the Java Runtime Environment which you can download from http://www.java.com.

# 3. The example

The example models a very simple square building (10 x 10 m, 3 m height). It only has one window, oriented due south. The two optimized variables are the window height (h, measured from the top) and the overhang projection, p.
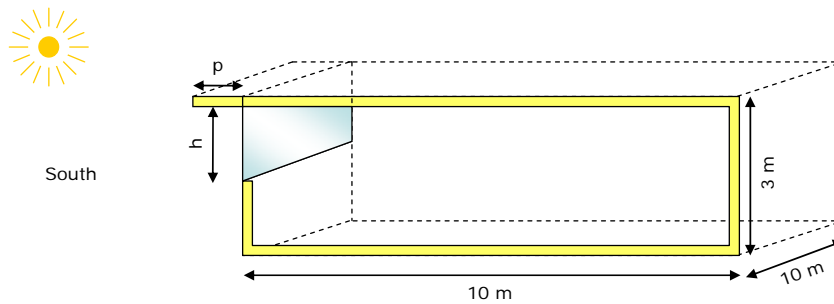


A Studio screenshot is given here below. The total heating and cooling load is calculated by Type 28 and written to an external file (***.sum where *** is the project name, i.e. GenOpt-Type56 here).

In order for GenOpt to find the cost function to minimize, it is important to leave QTot as the first printed variable in Type 28. It would also possible to use an integrator (Type 24) and a printer (Type 25), as long as you make sure you tell GenOpt where and how to find the cost function.
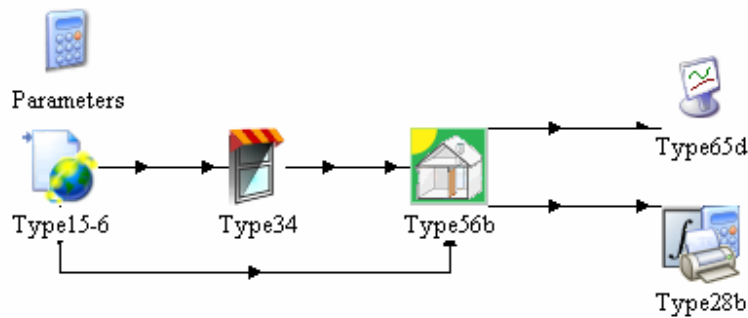


The project will create the GenOpt-Type56.dck TRNSYS input file (DCK file, or deck file). The building description is located in "Building.bui". Those two files will be used to generate templates for GenOpt (see below).

One particularity of the project is that the two optimisation variables, the overhang projection and the window height, have been defined in an equation block ("Parameters"). This is not strictly necessary but it makes your life easier when creating the GenOpt templates.

> **A list of all files used in the example is provided for reference at the end of this document (section 9)**

# 4. How to generate templates for GenOpt

GenOpt works by replacing variable names in the input files (DCK and BUI) with different values selected by the optimisation algorithm. In order to do that, it reads so-called "Template" files (that are left unchanged) and writes new input files at each optimisation run.

As a starting point, make a copy of the DCK file created by the Simulation Studio (GenOpt-Type56.dck) and rename it to GenOpt-DeckTemplate.dck. Then make a copy of the BUI file (GenOpt-Type56.bui) and rename it to GenOpt-BuildingTemplate.bui.

## 4.1. Editing the Deck file (DCK) template

Open GenOpt-Type56.dck in a text editor such as Notepad.

Look for the section with the 2 equations defining the optimization parameters at the beginning and edit it to replace numerical values with variable names %h% and %p%.

```
* EQUATIONS "Parameters"
*
EQUATIONS 2
windowHeight = %h%
overhangProjection = %p%
```

Look for the section providing the Type 56 parameters and edit the filename to replace "Building.bui" with "GenOptRun.bui". This is not strictly necessary but it will ensure that your original BUI file is left as it is during the optimisation. This filename (GenOptRun.bui) must be provided to GenOpt in the project initialization file (see below).

```
UNIT 5 TYPE 56      Type56b
*$UNIT_NAME Type56b
*$MODEL .\Loads and Structures\Multi-Zone Building\Without Standard Output Files\Type56b.tmf
…
(edited for clarity)
…
3,47              ! Type15-6:Angle of incidence for surface-4 -> 21- AI_WEST
*** INITIAL INPUT VALUES
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
*** External files
ASSIGN "GenOptRun.bui" 32
```

Optionally, you might also disable the online plotter to speed up simulations and make TRNSYS runs less intrusive. Look for the online plotter (Type 65) section and change the 9th parameter to -1:

```
UNIT 6 TYPE 65      Type65d
*$UNIT_NAME Type65d
*$MODEL .\Output\Online Plotter\Online Plotter Without File\Type65d.tmf
*$POSITION 407 64
*$LAYER Main #
PARAMETERS 12
1          ! 1 Nb. of left-axis variables
2          ! 2 Nb. of right-axis variables
-30        ! 3 Left axis minimum
30         ! 4 Left axis maximum
0.0        ! 5 Right axis minimum
50000      ! 6 Right axis maximum
1          ! 7 Number of plots per simulation
12         ! 8 X-axis gridpoints
-1         ! 9 Shut off Online w/o removing
-1         ! 10 Logical unit for output file
0          ! 11 Output file units
0          ! 12 Output file delimiter
…
```

## 4.2. Editing the Bulding file (BUI) template

Open GenOpt-BuildingTemplate.bui in a text editor such as Notepad.

Look for the section describing the zone "ROOM" and edit the file to replace numerical values for the south window and wall areas by variable names (resp. %aWindow% and %aWall%) name to replace "Building.bui"

with "GenOptRun.bui". This is not strictly necessary but it will ensure that your original BUI file is left as it is during the optimisation. This filename (GenOptRun.bui) must be provided to GenOpt in the project initialization file (see below).

```
*---------------------------------------------------------------------------------------------------
* Z o n e  ROOM  /  A i r n o d e  ROOM
*---------------------------------------------------------------------------------------------------
ZONE ROOM
AIRNODE ROOM
WINDOW=DOUBLE     : SURF=  1 : AREA= %aWindow% : EXTERNAL : ORI=SOUTHSHADED : FSKY=0.5
WALL  =BST_H_EXT  : SURF=  2 : AREA=   %aWall% : EXTERNAL : ORI=SOUTH : FSKY=0.5
WALL  =BST_H_EXT  : SURF=  3 : AREA=        30 : EXTERNAL : ORI=NORTH : FSKY=0.5
WALL  =BST_H_EXT  : SURF=  4 : AREA=        30 : EXTERNAL : ORI=EAST : FSKY=0.5
```

# 5. Creating the project files for GenOpt

## 5.1. GenOpt configuration file for TRNSYS 16 (GenOpt-Trnsys16.cfg)

This file includes settings that should be used by GenOpt for all TRNSYS optimisation projects. For that reason, it should be located in the main GenOpt directory or in a directory within the TRNSYS 16 installation. However, for this example, we will use a local copy located in the project directory (C:\Program Files\Trnsys16\Examples\GenOpt-Type56).

Please check the file itself and comments inside the file for more information. Two items are worth noting: special characters and TRNExe switches.

### 5.1.1. Special characters

Any special character passed to the GenOpt string interpreter must be preceded by a backslash (\). Two special characters that are often used are the backslash itself (in pathnames) and the quotes. So the path TRNSYS 16 looks like:

```
C:\\Program Files\\Trnsys16\\Exe\\TRNExe.exe
```

And the input file name sent to TRNSYS (deck filename, which must be enclosed between quotes in case there are spaces in it) looks like:

```
\"%Simulation.Files.Input.Path1%\\%Simulation.Files.Input.File1%\"
```

### 5.1.2. TRNExe switches

TRNExe must be called with special switches so that it does not stop at the end of the simulation and wait for a user action. Please check the "Running TRNSYS in batch mode" section in the TRNSYS Manual [1] for more details. The "/h" switch is used here, which means that TRNExe should run completely hidden in the background if there is no active online plotter in the simulation. At the time of writing, TRNBuild does not comply with this behaviour and you will still see its window popping up at each optimisation run, but the TRNSYS progress bar will not be displayed. Change to "/n" if you want to display the progress bar.

## 5.2. GenOpt project initialization file (GenOpt.ini)

This file is typically located in the project directory. It tells GenOpt where to find the files to run for the current optimisation project. Please check the file itself and comments inside the file for more information.

The warning about special characters in the GenOpt configuration file also applies here. In particular, any "\" in pathnames must be converted to "\\".

A few other points are worth noting:

### 5.2.1. Project path

If all input and output files are in the same directory, you only need to specify it once, at the first occurrence of "Path1". You can then refer to the previously defined path, by having instructions such as:

```
Path2 = Simulation.Files.Template.Path1;
```

includes settings that should be used by GenOpt for all TRNSYS optimisation projects. For that

### 5.2.2. Templates

Templates must be provided to GenOpt for the optimisation. You should provide the filenames for the two template files (DCK and BUI) described in section 4.

### 5.2.3. Input files

The "input" section provides filenames for the files created by GenOpt at each optimisation run, "GenOptRun.dck" and "GenoptRun.bui". You should remember that the template for the DCK file should refer to the correct BUI file, as explained in section 4.1.

### 5.2.4. Finding the value of the objective function

GenOpt must know in which file to look for the numerical value of the cost function after each run and how to find that numerical value.

The output filename and path are provided in the Simulation.Files.Output section:

```
Output {
    File1 = "GenOptRun.sum";
    Path1 = Simulation.Files.Template.Path1;
}
```

The place where to find the cost function is defined in the Simulation.ObjectiveFunctionLocation section:

```
ObjectiveFunctionLocation {
        Name1     = "QTot";
        Delimiter1 = "Sum   0.8760000000000000E+0004" ;
    }
```

GenOpt always proceeds by looking for the **last occurrence of a delimiter string** and reading the numerical value **after that string**. What this section says is that the cost function named "QTot" should be read after the last occurrence of "Sum   0.8760000000000000E+0004". This is adapted to the output of Type 28 in mode "2", which is used in the example (note that mode 2 is **not** the default for Type 28), assuming that the cost function is the first output variable of Type 28 (the first column):

```
SUMMARY FOR UNIT   7
 Simulation Summary in intervals of          1.000000 month
 --------------------------------------------------------------------------------------------------------
Month   Time            QTot                   QHeat                  QCool
    Jan 0.7440000000000E+0003  0.7323671099231E+0003  0.7323671099231890E+0003  0.0000000000000E+0000
    Feb 0.1416000000000E+0004  0.4932822976986E+0003  0.4928614184750621E+0003  0.4208792235762E+0000
...
(Edited for clarity. Note that the actual Type28 output also has more significant digits)
...
    Nov 0.8016000000000E+0004  0.3654354259556E+0003  0.3653657006425123E+0003  0.6972531304370E-0001
    Dec 0.8760000000000E+0004  0.7735996173125E+0003  0.7735996173502123E+0003  0.0000000000000E+0000
    Sum 0.8760000000000E+0004  0.5114417241175E+0004  0.2959722064493123E+0004  0.2154695177090E+0004
```

(The value of the cost function, which is the yearly sum of QTot, is shown in bold).

## 5.3. GenOpt optimisation commands (GenOpt-OptimizationCommands.txt)

This file tells GenOpt what parameters to optimise and what algorithm to use.

Continuous parameters are defined by specifying a name, min/max/initial values and a step size for the first iterations (see [2] for more details and for information on how to define discrete variables).

```
Parameter {
    Name    = h;
    Min     = 0.01;
    Ini     = 2.00;
    Max     = 2.99;
    Step    = 0.50;
    Type    = CONTINUOUS;
}
```

Derived variables are defined using "functions". The window area, for example, is defined as the result of multiplying the window height (optimisation parameter "h") by the window width (fixed at 10 m in this example). See [2] for more details and for available functions.

```
Function {
    Name = aWindow;
    Function = "multiply( %h%, 10 )";
}
```

The "OptimizationSettings" section sets the maximum number of iterations and some other settings [2].

```
OptimizationSettings {
    MaxIte = 100;
    MaxEqualResults = 5;
    WriteStepNumber = false;
}
```

Finally, the "Algorithm" section tells GenOpt which algorithm to use. The selected algorithm for this example was just the result of a very crude trial and error process and its parameters have not been optimised in any way. It should definitely not be seen as a recommendation of a good algorithm to use in similar projects. You should refer to GenOpt user's guide for an in-depth description of the available algorithms.

# 6. *Running the example*

- Setup the programs correctly (see section 2)
- Unzip the example into "C:\Program Files\Trnsys16\Examples". It should create the "Genopt-Type56" folder, i.e. the full path to the project file, "Genopt-Type56.tpf", should read "C:\Program Files\Trnsys16\Examples\Genopt-Type56\Genopt-Type56.tpf".
  - You can open the project and look at the starting point in the Simulation Studio. If you want to know what the example is doing, please read Section 3.
- To perform an optimisation study, browse to "C:\Program Files\Trnsys16\Examples\Genopt-Type56" in Windows Explorer and launch "StartOptimisation.bat". This should start the GenOpt interface.
- In the GenOpt interface, **click on the green arrow** (or go to File/Start). Select the **GenOpt.ini** file and click "Open". **Make sure you are opening the "Genopt.ini" file that is located in "C:\Program Files\Trnsys16\Examples\Genopt-Type56"**.

This will launch the optimisation. GenOpt will display a plot of the optimisation parameters and the objective function. It should converge after a few minutes. You can analyse results in the GenOpt output files, e.g. OutputListingAll.txt.

At the end of the optimisation process, the main GenOpt window should look like this:
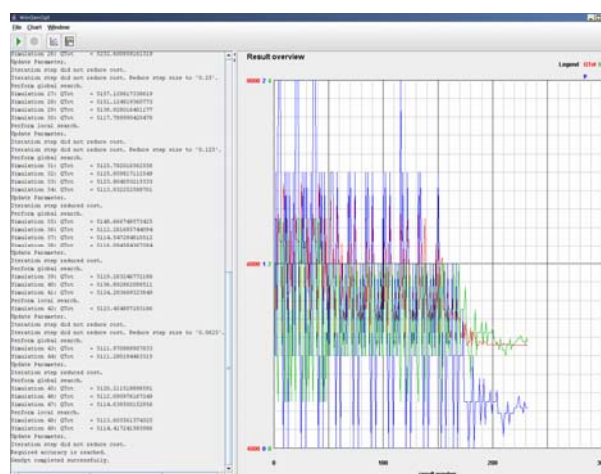
# *7. Troubleshooting*

## *7.1. GenOpt does not start*

Launch a command prompt window, change the directory to "C:\Program Files\Trnsys16\Examples\Genopt-Type56" and type in the following command:

```
java -version
```

You should get something like this:

```
java version "1.5.0_11"
Java(TM) 2 Runtime Environment, Standard Edition (build 1.5.0_11-b03)
Java HotSpot(TM) Client VM (build 1.5.0_11-b03, mixed mode)
```

If not, reinstall the java runtime environment (see section 2)

If java seems to be working properly, type in the following command:

```
java genopt.WinGenOpt GenOpt.ini
```

This should open the main GenOpt window. If it does not, you are likely getting the following error:

```
Exception in thread "main" java.lang.NoClassDefFoundError: genopt/WinGenOpt
```

Did you set the CLASSPATH environment variable correctly? Repeat the steps in section 2.2.1. As a quick fix, you may try to type in the following instructions:

```
set CLASSPATH=%CLASSPATH%;C:\Program Files\GenOpt
java genopt.WinGenOpt GenOpt.ini
```

Note that you will have to type in those instructions each time you run the program unless you set the environment variables correctly and save them as explained in section 2.2.1.

Another possible cause of that problem is that you did not install GenOpt correctly or that you installed it in a different directory. Check that the file "C:\Program Files\GenOpt\genopt\WinGenOpt.class" exists. It is easy to get confused with the GenOpt directory structure and to have a go_prog directory somewhere in the way. Just move your directories around until you get the following structure:

```
C:\Program Files\GenOpt

 cfg
 example
 genopt
 jdoc

 readme.html

C:\Program Files\GenOpt\genopt

 algorithm
 db
 gui
 img
 io
 lang
 simulation
 util

 GenOpt.class
 WinGenOpt$1.class
 WinGenOpt$2.class
 WinGenOpt$3.class
 WinGenOpt$4.class
 WinGenOpt.class
```

## 7.2. GenOpt is launched correctly but the optimisation does not start

Are you opening the correct initialisation file after pressing the green arrow? You should open the GenOpt.ini file that is in the current directory (C:\Program Files\Trnsys16\Examples\Genopt-Type56\GenOpt.ini).

If you are getting an error message similar to the following:

```
Error message:
**************
genopt.simulation.SimulationInputException:
Variable was not found in any simulation input template file,
or in any function objects:
    Searching for String: '%overhangProjection%'. Cannot find string.
    '%overhangProjection%' must occur in at least one simulation
    input template file, or in at least one function object.

GenOpt terminated with error.
```

You may have forgotten to edit the template files (DCK and BUI) and replace numerical values with their variable names, or you may have typos in the variable names. It is a good idea to start with only one variable and then refine the project.

# 8. References

[1] Klein et al., 2004. TRNSYS 16 – A TRaNsient SYstem Simulation program, User manual. Volume 1: Getting Started. Solar Energy Laboratory, University of Wisconsin-Madison.
More information on TRNSYS at http://sel.me.wisc.edu or http://www.trnsys.com

[2] Wetter M. GenOpt, generic optimisation program, user manual, version 2.0.0. Technical report LBNL-54199, Lawrence Berkeley National Laboratory; 2004.
Manual and program downloadable free of charge from http://gundog.lbl.gov/GO

[3] TESS, 2004. TRNOPT v16 Installation, Run-Time Instructions, and License Agreement. Thermal Energy Systems Specialists, Madison, WI. http://www.tess-inc.com

# 9.  Overview of example files (for reference)

| File name | Role |
|---|---|
| **Original TRNSYS project file (starting point)** | |
| GenOpt-Type56.tpf | TRNSYS Studio project used as a starting point. It creates the TRNSYS input file (DCK) and several output files (LST, LOG, SUM) with the same name. In the project, Type 56 reads the building data from Building.bui |
| GenOpt-Type56.dck | TRNSYS input file (DCK, or deck) created by the project |
| GenOpt-Type56.log | TRNSYS LOG file created by the project |
| GenOpt-Type56.lst | TRNSYS LST file created by the project |
| GenOpt-Type56.sum | Output file created by Type 28. It includes QTot, the objective function (Total heating+cooling load) |
| GenOpt-Type56.pti | TRNSYS file with online plotter options (background color, etc.) |
| **Original Building files (starting point)** | |
| Building.bui | Building description file created with TRNBuild and used in the Studio project |
| Building.bld | Building data file automatically created by TRNBuild (from information in the BUI) |
| Building.trn | Building transfer function file automatically created by TRNBuild (from information in the BUI) |
| Building.inf | Building information file automatically created by TRNBuild (from information in the BUI) |
| Summary.bal | Output file automatically created by Type 56 (not used) |
| **GenOpt configuration files** | |
| GenOpt-TRNSYS16.cfg | GenOpt configuration file for TRNSYS 16 |
| GenOpt.ini | GenOpt initialisation file for this optimisation project |
| GenOpt-OptimizationCommands.txt | GenOpt optimisation commands for this project |
| StartOptimization.bat | Batch file used to start the optimization project (optional) |
| **GenOpt template files** | |
| GenOpt-DeckTemplate.dck | GenOpt Template for the TRNSYS input (DCK) file |
| GenOpt-BuildingTemplate.bui | GenOpt Template for the building (BUI) file |
| **Files created by GenOpt and TRNSYS at each optimisation run** | |
| GenOptRun.dck | TRNSYS input file (DCK) for current run |
| GenOptRun.bui | TRNSYS building file (BUI) for current run. **Note that the DCK file must refer to the correct BUI file!** |
| GenOpt.log | TRNSYS LOG file for the current run |
| GenOpt.lst | TRNSYS LST file for the current run |
| GenOpt.sum | TRNSYS output file (with the objective function) for the current run |
| **Files created by GenOpt during the optimisation process** | |
| GenOpt.log | GenOpt log file with optimisation start / end time, error messages etc. |
| OutputListingMain.txt | Short version of the GenOpt output file (Main iterations only) |
| OutputListingAll.txt | Long version of the GenOpt output file |