Centrum för solenergiforskning
Solar Energy Research Center

PARAMETER IDENTIFICATION MANUAL FOR TRNSYS MODELS AT SERC

Chris Bales

SERC

Department of Mathematics, Natural Sciences and Engineering
Högskolan Dalarna
SE 781 88 Borlänge

Tel: +46 23 778000
Fax: +46 23 778701

Besöksadressadress/
Street address:
Forskargatan 6

HÖGSKOLAN
Dalarna

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Parameter Identification Manual

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Chris Bales
SERC
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Abstract

This manual describes the use of the programs Fittrn, DF and Trnsys for use with parameter identification. The same programs can be used for optimisation of systems modelled in Trnsys. The emphasis is placed on the identification requirements at the Solar Energy Research Center SERC at Dalarna University, Sweden. Here, the majority of parameter identification is for water based heat stores used in solar heating systems and their associated components. A brief review of alternative identification routines is given before the detailed description of the mentioned programs is started. A detailed practical guide is given to all stages of the process of identification, from creating data files to analysing the results.

It is assumed that the reader has a basic knowledge of Trnsys and the store model type 140.

Sammanfattning

Denna manual beskriver användningen av programvarorna Fittrn, DF och Trnsys då de används för parameteridentifiering. Samma programvaror kan användas för systemoptimering för system som modellerats i Trnsys. Betoningen är på behoven vid centrum för solenergiforskning SERC vid Högskolan Dalarna, Sverige. Vid SERC används programvarorna för identifiering av parametrar för vattenbaserade tankar för solvärmesystem och relaterade komponenter. Manualen redogör för ett par alternativa metoder för optimering innan den beskriver i detalj hur programmen används vid SERC. Det är en praktisk guide till bruket av programvarorna, från skapande av datafilerna till analysen av resultaten.

Det förutsätts att man har viss kunskap om Trnsys och tankmodellen type 140.

Contents

1 Introduction

When using computer tools to simulate the behaviour of a component or system of components it is necessary to specify the values of the models parameters. If it is desired to simulate a real component then realistic values are required. If the model is a physical one, where the parameters are physical entities it is sometimes possible to calculate or estimate the values with reasonable precision. However, with an empirical model, or where it is difficult to accurately estimate the parameter values of a physical model, some sort of parameter identification process using measured data is required. Parameter identification means here the finding of parameter values that make the model calculate most closely to the measured data – the best fit, which is why this process is also called fitting.

In a simple procedure for a simple model this would involve initial estimates followed by trial an error until the desired degree of matching of the calculated to the measured data. In more complex models this is very difficult, which is why automatic methods have been developed. They are in fact optimisation tools, where the value that is to be optimised (minimised) is the difference between calculated and measured results. SERC has chosen to use one such tool together with Trnsys for the work with simulation of solar heating systems and more specifically of stores used in these systems. This tool is called DF (Dynamic Fitting) and was developed for parameter identification of solar domestic hot water (SDHW) systems (Spirkl 1995). It uses a gradient based method for achieving best fit. The actual algorithm is the Levenberg-Marquardt algorithm (see the DF manual for more details). It is a DOS based program and contains a simple model for such systems. When used with other models, an extra program is required in order to pass information to and from DF from the simulating program. In this case the program Fittrn, a program developed at SPF, Rapperswil (and available free of charge there) is used to communicate between Trnsys and DF.

This manual explains how to use the tools of Trnsys (Klein et al. 1996), Fittrn (Hüber 1998) and DF (Spirkl 1995) together. It is not intended as a manual for each of these tools as they all have their own manuals, although the one for Fittrn is very basic. The manual gives first some information on basic concepts and then goes on to give details about the special features of Fittrn and DF followed by a short description of other methods (not used at SERC) and a simple comparison with them. The main section describes the application of the method to store testing. Finally the appendices give ideas about how to use the tools effectively, hints when troubleshooting and finally how to prepare the measured data files so that they can be used with Trnsys.

The manual covers part of the work involved in store testing at SERC. The major section, the actual testing of the stores in the test stand and the measurement program used, is covered in Combitest Program Manual (Bales 2000).

It is assumed that the reader has some knowledge of simulations and of Trnsys in particular.

1.1 Overview of Store Testing Procedure at SERC

Store testing at SERC comprises the following stages, only some of which are covered by this manual. Other components would be treated in a similar manner.

1.1.1 Initial Study of Store

First you have to get the documentation from the manufacturer and study it. Next you make a calculation of the geometric heights (equivalent relative heights for store model) for all connections and calculate theoretical volume. This is done in an Excel sheet.

1.1.2 Calibration Checks of Test Stand

All the flow and temperature sensors are checked against one another. See Combitest Program Manual.

1.1.3 Connection to Test Stand

Connect the store to the test stand. Normally the conditioning and full charge circuit will be connected as high/low as possible so that the whole store can be charged/discharged. Special air release mechanisms might be required. All extra pipes other than the ones normally used should be drawn down inside the insulation for connection at the bottom of the store.

1.1.4 Definition of Tests to be Performed and Quantities to Measure

Based on the manufacturers documentation and a simple analysis of the function of the store, a list of all the ports, heat exchangers that need to be identified is made up. Based on this list, the list of tests required is made up based on experience from previous tests. Once this list is made, the programming of the individual test sequences is made – see Combitest Program Manual. A decision as to what parameters should be identified will be required here as this affects which test sequences need to be applied.

1.1.5 Application of Tests to Store

Run the measurement program with the command files for each test sequence, including the verification sequence if used. After each test sequence it is important to make an energy balance check to make sure that the test stand is operating correctly.

1.1.6 Creation of Trnsys Model for Parameter Identification

Make a model of the store together with: the data reader for the measurement files; equations to calculate the measured heat transfer rates and instantaneous difference between measured and simulate rates; online output of the rates; and simulation summaries for the transferred energies and difference in heat transfer rates. See sections 3.2.1 and 3.2.3 for more details.

1.1.7 Modification of Datafiles to use for Parameter Identification

Convert the raw measurement file to ones that can be used with the model created above. See Appendix A for more details.

1.1.8 Parameter Identification

Use DF and Fittrn to identify the parameters. See sections 3.2.3 and 3.2.4 for more details.

1.1.9 Verification of Identification Results

After the parameters have been identified, a verification of the resulting parameter values should be performed. This involves simulating a special test sequence, one not used for identifying the parameters, and calculating the relative errors energy and power. See section 3.2.6 for more details.

1.1.10 Documentation

The results of the tests, the identification and verification should be documented. See section 3.2.8 for more details.

2 Background

2.1 Parameter Identification Process

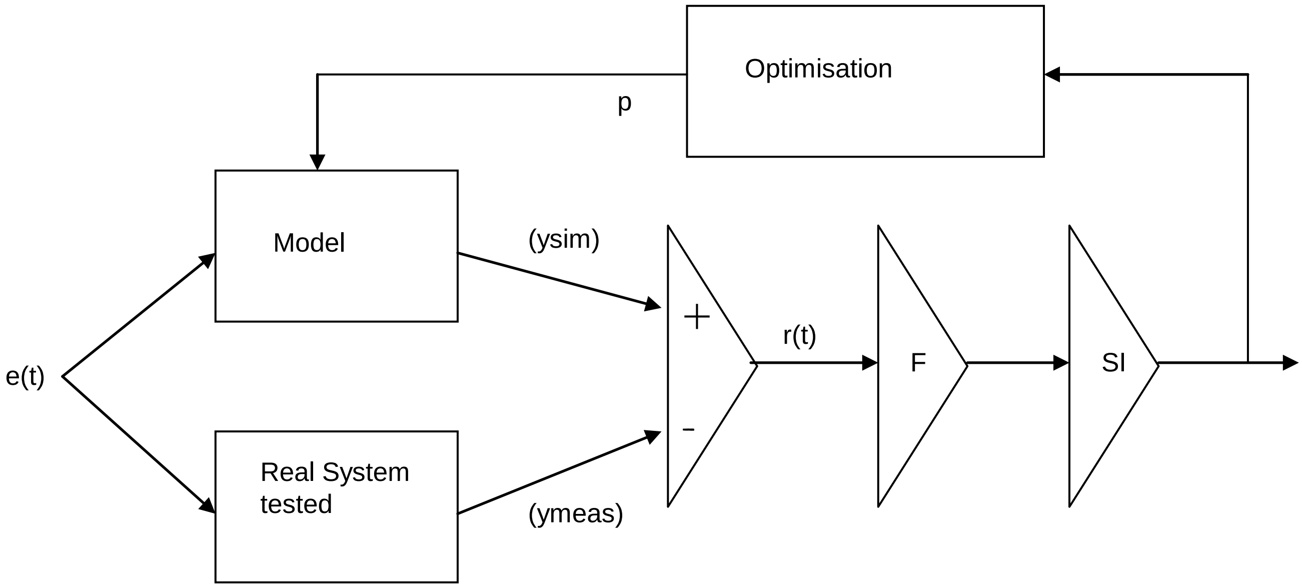


Figure 1. The dynamic fitting procedure (after Spirkl).

The fitting procedure is applied as follows:

- The input e(t) is applied to the system under test. In store testing this signal is input temperatures and flows, as well as electrical power to electrical heaters. These values are measured and stored by the measurement program, which also controls the test stand in order to apply realistic or fixed values. It measures and stores the output temperatures as well so that the heat transfer rates can be calculated. See Combitest Program Manual (2000). The input is in the form of several different test sequences applied to the test object.
- The same signal is applied to the model. Measured data for input temperatures and flows are read from a data file created by the measurement program.
- The measured output (y^{meas}) is compared to the simulated output (y^{sim}), which is dependent on the parameters set **p**. The measured output, heat transfer rates for stores, can either be read directly, if present, from the same data file as the input data, or be calculated by using the measured input and output temperatures and flow in the data file. At SERC, these measured heat transfer rates are calculated by the simulation

program using simple equations. The simulated values come directly form the simulation models themselves.

- The deviation (r(t)) is first filtered (F) to remove “noise” in the data, then squared and integrated (SI). The resulting signal gives a measure of the goodness of fit.
- An optimisation procedure is used to derive the best parameter set **p** – i.e. To minimise r(t) and hence C(**p**)

The values for y^{meas} and y^{sim} can be based on anything but it is usual to have it based on power (heat transfer rate). For an optimisation problem there is not a real system, and the filter is not required. The function for y^{sim} can be of any form and is dependent on what is intended to be opitimised.

2.2 Concepts

The following concepts are integral to the process of parameter identification/optimisation using DF. For many of them a deeper understanding can be gained by reading the manual for DF.

Parameters
These are variables used in the simulation model to specify features of the component. They are constant during the whole simulation. It is the values of certain of these that are to be identified by DF. In general there are several parameters that can be easily and accurately determined by the user. DF need not identify these. The more parameters to be identified the, more measured data that is required and the longer it takes to identify the values reliably.

Objective (Residual)
This is the value that is to be minimised by DF. DF requires two values, or more accurately time series, the measured value and the calculated value. The comparison between these two is only one dimensional, so if several different quantities are to be used for optimising they must be combined with relevant weighting into a single value. This is to be done in the same way for both measured and calculated values. DF uses not just a single value in fact, it uses the objective for every time step of the simulation, which can in fact be split into several different simulations using different measured data. Both measured and calculated values have to be written out to a file by the simulation program.

Measured Data and Inputs to the Model
For solar heating systems the measured data consists of inlet and outlet temperatures, flows and electrical power (or if relevant fuel usage). The simulation model uses the measured data as input values and in effect then calculates its own output values. For a fluid circuit the inputs are thus flow and inlet temperature.

Local Minima
The results produced by a model are dependent on its parameter values. When several parameters are varied, the resulting objective can be considered to be a multidimensional field. DF tries to find the lowest point (absolute minimum) in this field. However, there are often other minima that are not as low as the absolute minimum – these are called local minima. Most optimisation routines find local minima and require special routines to “hop” away from these minima so that new ones can be located.

Cross Correlation Matrix
DF calculates the gradient in the objective with respect to each parameter and file. Information from this and other changes in the objective from parameter changes are used to derive a cross correlation matrix where it can clearly be seen how closely parameters are correlated. High correlation implies it is difficult to identify the absolute values of those parameters accurately as an increase in one results in a corresponding increase/decrease of the other. With very high correlations (over 0.95) it can be necessary to fix the value of one parameter and the other be identified.

Standard Deviation
The variation in identified value for each parameter is multiplied by a weighted factor dependent on cross correlation with other parameters to get a "Standard deviation" for the identified value – this is a measure of confidence for the identified value and is given under the identified value in the results file. Note that it does not represent maximum deviations.

Data files
More than one set of measured data can be used and DF combines the results for each into a single objective value. These have to be such that the simulation program can read them.

Time Constant
This is used to filter the results in order to remove "noise" in the data due to sensor uncertainties amongst other things. For a more detailed description read the DF manual.

DDP file
This is a data definition file used by Fittrn. It defines what is unique to a particular data file. Normally this is just the start, stop, step and data step times. However, it can also include different starting conditions, or even different components, other parameter values etc as it is inserted directly into the deck before the deck is run.

Run
A run is a single simulation during the course of the identification process. Up to 50 000 runs maybe required for large numbers of parameters (up to 20) and files (around 20).

2.3 Special Features of Fittrn and DF

Figure 2 shows how the programs communicate with each other. Fittrn acts as the organiser initially before handing over control to DF for the actual identification. Fittrn is also used as a link to Trnsys by modifying the deck before each run and the results after it. The most powerful features of Fittrn are that it gives a simple graphical interface to choosing and adjusting parameters and files and also that the user can define what is special to each data file in a so called DDP file. This gives great flexibility.

DF is itself a DOS program that can cause some problems in certain cases, but usually does not. With the latest version of Fittrn it is possible to do identifications and still work on the computer with other tasks.

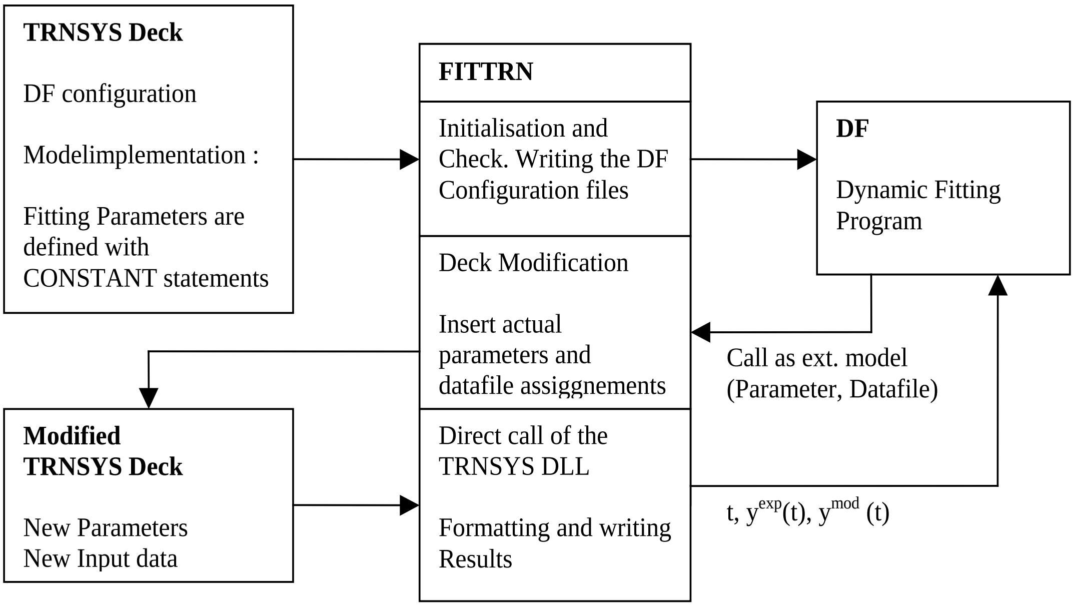

TRNSYS Deck
DF configuration
Modelimplementation :
Fitting Parameters are defined with CONSTANT statements
FITTRN
Initialisation and Check. Writing the DF Configuration files
Deck Modification
Insert actual parameters and datafile assiggnements
Direct call of the TRNSYS DLL
Formatting and writing Results
DF
Dynamic Fitting Program
Call as ext. model (Parameter, Datafile)
t, y^exp(t), y^mod (t)
Modified TRNSYS Deck
New Parameters
New Input data

Figure 2. Communication between the programs Trnsys, DF and Fittrn. Figure taken from Fittrn manual, courtesy of SPF, Rapperswil.

2.3.1 Requirements

The following programs are required:
Trnsys 14.2
Fittrn has not yet been developed for Trnsys 15
DF v2.8 (and above)
This is the only version with minimal parameter steps working properly. DF.exe and RTM.exe only are required.
Fittrn v2.3

If large numbers of parameters are to be identified together (10 or more) and 20+ local minima then it is necessary to Windows NT as the operating system.

2.3.2 Limitations

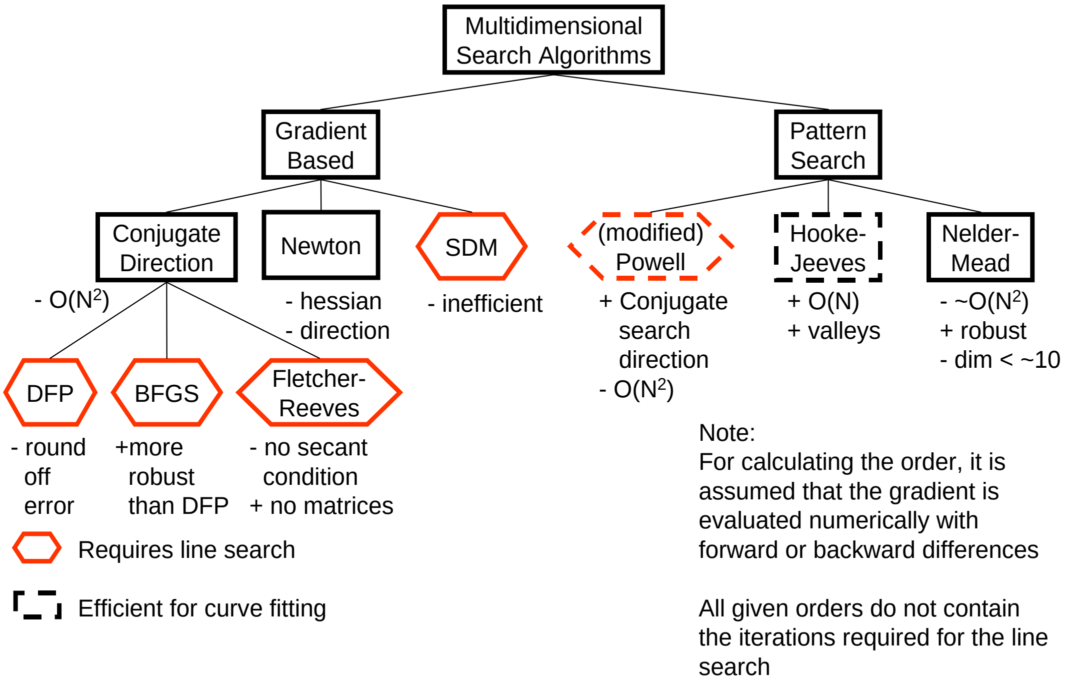
DF allows up to 20 parameters to be identified simultaneously. If more parameters need to be identified then the process has to be split into different parts.

Windows 95 and 98 cause problems with large numbers of runs. Fittrn crashes after approx. 10000 runs.

DF has reportedly problems with identifying parameters with very different values (orders of magnitude different). It is therefore necessary sometimes to add multiplication values to the identified values to give the used parameter values in the model. Type 140 can do this internally for the relevant values (see section 3.1).

2.4 Alternative Optimisation/Identification Methods

There are many optimisation methods and it is not within the scope of this manual to describe them all. However, it is worth mentioning two that have been used together with Trnsys or for optimising solar heating systems.



Note:
For calculating the order, it is assumed that the gradient is evaluated numerically with forward or backward differences

All given orders do not contain the iterations required for the line search

Figure 3. Some of the many optimisation algorithms available. (From GenOpt 1.0 manual, courtesy of LBNL, Berkeley Univ.)

2.4.1 GenOpt (Generic Optimisation Tool)

This is a generic optimisation tool that is available for free from the following website http://gundog.lbl.gov/GO/index.html. There is very good documentation here and a good summary of different optimisation methods. GenOpt is not specifically written for a particular optimisation method or simulation tool instead it has a relatively easy command structure that handles interfacing to any program. However, four different optimisation routines do come with the program. GenOpt has been used with Trnsys at ITW, Univ. Stuttgart and at other sites for both optimisation and parameter identification. It has not been used at SERC. It gives a good graphical indication of how the identification is proceeding and how the objective function has become. No cross correlation information is available.

Figure 4. Interface between GenOpt and the simulation program (From GenOpt Manual, courtesy of LBNL, Berkeley Univ.).

GenOpt is written in java, which means that this environment has to be installed on the computer. This is however, free. Because of this GenOpt can be used with virtually any operating system.

2.4.2 Genetic Algorithm

This is a particular optimisation algorithm that has been implemented in a program at TNO for optimising large-scale SDHW systems (Loomans and Visser 2000). The search algorithm was very efficient for this process but has not been implemented in GenOpt or used with Trnsys as yet. It would thus take some effort to use with Trnsys.

“The standard Genetic Algorithm uses a *population* (i.e. a group of possible solutions) of *individuals* (i.e. parameter sets) that are represented in a binary format. Each parameter is encoded in a binary string. The strings for the separate parameters then are grouped into one long string. For the first population, the individuals are randomly determined from the search space. The ‘fitness’ of the separate solutions is determined subsequently from the fitness function. The individual that generates the best fitness within the population has the highest chance to return in the next *generation* (population of individuals), i.e. *reproductio*n. As appears in chromosomes in real life, in this new population also *recombination* is possible at a given probability. For example, *crossove*r, the exchange of data (in binary format) between two randomly chosen individuals in the population, and *mutatio*n, the transposition of a 0 in a 1 and vice versa. This new generation is calculated and the process is repeated until a given number of generations is reached or until convergence has been obtained.” Extract from Loomans and Visser (2000). More details of the algorithm can be found in a book by Goldberg (1989).

2.5 Simple Comparison of Methods

DF was designed for parameter identification of solar heating systems and has proven to work efficiently for them. However, the majority of the work has been done with smaller numbers of free parameters (<10) whereas combistores often require up to 20 or more. It has been successfully applied. It is slightly slower than the algorithms used in GenOpt but it does give a cross correlation matrix that can be used to check whether the results are reasonable and whether it is better to fix a parameter instead of having it free (variable). This decision is however difficult and requires experience.

3 Application of DF to Store Testing at SERC

3.1 Introduction to Multiport Store Model (Type 140)

This is the model used in the Trnsys work at SERC. The standard version (v1.95) has 5 double ports and up to 3 heat exchangers. The extended, as yet not released, version (v1.98) has up to 10 double ports, 4 heat exchangers and the possibility of calculating the flow on the tank side of natural convection in encapsulated heat exchangers with attached pipe. The manual to v1.95 is very thorough and good. However, there is a limited amount of information about the extended version where the method for calculating the effective UA-value of the heat exchangers is different when working with natural convection. These equations are given here. For the standard equations see the user manual for type 140.

$$UA_{hx} = \frac{1}{\frac{1}{UA_{pri}} + \frac{1}{UA_{sec}}}$$

$$UA_{pri} = UA_0 \cdot \dot{m}_{hx,p}^{b_1} \cdot \left[T_{p,in} - T_{p,out}\right]^{b_2} \cdot T_{p,in}^{b_3}$$

$$UA_{sec} = UA_0 \cdot \dot{m}_{hx,s}^{b_1} \cdot \left[T_{s,in} - T_{s,out}\right]^{b_2} \cdot T_{s,in}^{b_3}$$

where,

UA_{hx} Effective UA-value for the whole heat exchanger [kJ/h.K].
UA_{pri} Effective UA-value for the primary side of the heat exchanger [kJ/h.K].
UA_{seci} Effective UA-value for the secondary side of the heat exchanger [kJ/h.K].
$\dot{m}_{hx,p}$ Flow on primary side [kg/s].
$\dot{m}_{hx,s}$ Flow on secondary side [kg/s].
$T_{p,in}/T_{p,out}$ Inlet and outlet temperatures on primary side. [°C].
$T_{s,in}/T_{s,out}$ Inlet and outlet temperatures on secondary side. [°C].
b_1,b_2,b_3 Empirical constants for the equations. Dependencies on flow, temperature difference and inlet temperature respectively.

In addition, because of the difficulty that DF has in identifying parameters with widely differing values, type 140 has a built-in function for internally multiplying the supplied parameters to model to the correct parameter values for the model. This occurs when the last parameter is given –7. The parameters that are affected are the base UA-values, the number of nodes in the model and the time constant for the heat exchangers. This can sometimes be confusing, so check the type 140 manual thoroughly.

Only two heat loss components can generally be identified whereas it is best (standard practice at ITW) to have three values. Generally one identifies the UA-value for the bottom separately and for the top and sides combined. This combined value is multiplied by the proportion of the side area (with respect to the area of sides and top) to get the UA-value for the sides. The value for the top is calculated in the same manner.

3.2 Practical Guide

3.2.1 Create the New Trnsys Deck

- Format the Data Reader so that it can read the data files that you have. It is best if all the data files that will be used with this deck have the same format (i.e. same order for the columns) so that this data reader can read all of them). Have the time step for the data as a constant (define in SimCtrl), egg Dstep. This is useful if you have different time steps for the different data files. Check that the data reader works correctly before proceeding.
- Define the start, stop and step times for the simulation as constants, egg Sstart, Sstop, Sstep.
- Define also a constant called SKIP, which is used to define how much of the output results are to be ”skipped” by DF. See DF manual.
- Remember to check whether mass or volume flows are required by the Trnsys components to be used and convert if necessary.
- Create the values used to calculate the relative errors in energy and power and connect them to simulation summaries. These are defined below.
- Create a sum of the relative errors in power for all connection and connect this to the special DF printer. This should have the title **Printer DF**. The first value in the DF printer should be a constant 0.
- Make all the parameters that are of interest to constants and define them in SimCtrl. These constants are read by Fittrn and you can choose which of them to use in the DF runs.
- Check that the deck works properly by looking at the results in the DF printer file and by using online.
- The online plotter and any other printers and simulation summary components should be at the end of the deck so that they can easily be removed while running Fittrn.

3.2.2 Equations to Use (Defined in prEN 12977-3)

The following equations are given in prEN12977-3 and should be used in the decks. They are different to those used at SERC up until the start of 2001.

For each connection x (double port or heat exchanger) the calculated and measured heat transfer rates ($P_{x,c}$ and $P_{x,m}$) shall be calculated according to:

$$P_{x,c} = \overline{\rho} \cdot \overline{C}_P \cdot \dot{V} \cdot \left(T_{x,i} - T_{x,o,c}\right)$$
$$P_{x,m} = \overline{\rho} \cdot \overline{C}_P \cdot \dot{V} \cdot \left(T_{x,i} - T_{x,o,m}\right)$$

Where for heat exchanger or double port x, $T_{x,i}$ is the measured input temperature (used also as input to the simulation model), $T_{x,o,c}$ is the calculated (simulated) output temperature and $T_{x,o,m}$ is the measured output temperature. $\dot{V}$ is the volume flow rate into the port or heat exchanger, and $\overline{C}_P$ and $\overline{\rho}$ are the average heat capacity and density for the heat transfer.

The average density and heat capacity should be for the normal operating conditions of the port/heat exchanger. This should be 992 kg/m3 and 4.18 kJ/kg.K for water (valid for 15-60°C) and values based on the glycol properties for the water/glycol mixture.

From this the absolute difference between measured and calculated heat transfer rate should be calculated according to:

$$\Delta P_x = \left| P_{x,c} - P_{x,m} \right|$$

This value, and the measured and calculated heat transfer rates should be summed in a simulation summary so that can be used to calculate the relative errors in energy and heat transfer rate (see section 3.2.6).

The value to be used as the objective for the identification by DF is the sum of the differences for all ports:

$$\text{objective} = \sum_x \Delta P_x$$

3.2.3 Steps to Run Fittrn with a New Deck

1. Create a new directory and copy the 4 Fittrn files (cnfgtr.trn, dfstart.bat, fittrn.exe, gofit.exe) to it.
2. Copy your own Trnlib32.dll and cnfgtr.trn and your deck to the same directory.
3. Modify your deck to run with Fittrn:
   - If you are going to use more than one data file then you have to remove the Assign statement(s) for the data file(s) in the deck, and remove the following constants (Sstart, Sstop, Sstep, Dstep, and SKIP) - these will be defined individually in the DDP file for each data file (see below).
   - Check that the path to the data files specified in the Assign statement is correct. It is often best to have the data files in a separate directory under the working directory called data - this whole directory can then easily be moved when the next fit is done.
   - “Remove” the (for DF) unnecessary output components (online, printers etc) by writing END on its own line before them – Trnsys will ignore everything after this line. When results are to be checked this line can be commented to re-include the output components.
4. First time using Fittrn with the deck:
   - Start Fittrn.
   - Check that Fittrn knows where to find DF (menu options – DF path).
   - Open the deck with Fittrn and use the command ”Create DF Config” (bottom right). This creates the header information at the start of the deck for parameters, data files and DF configuration.
   - Choose DF Config (from the list on the left) and enter the values for the number of minima and the time constant to be used. It is suggested that 20 minima be chosen as default and that the time constant is twice that of the time step of the data files. The number of minima depends on the number of parameters to be identified – the fewer the parameters the fewer the number of minima required. See the DF manual for information about the time constant.
   - Choose Parameters. Nothing comes up. You now have to add a list of parameters that will be able to be identified by DF and Fittrn. Use the menu command Edit/Add Parameter to add new parameters to the list. You can choose from all of the constants defined in the deck. Add as many as you want.
   - Open up the Parameters folder and for each parameter in the list, fill in the allowed min and max for the identification process as well as the units. Heights for the type

140 store model should use the minimal parameter step option, specifying the size for a single node (egg. 0.01 if 100 nodes are used).

- If there is more than one data file to be used, then use the menu command Edit/Add Data File to create a list of these data files. (If you use only one data file, then do not define a data file in Fittrn - otherwise you have to remove the 5 constants and data file assign statement in the deck as for multi-file runs.)
- Open up the data files folder and for each data file define a DDP file and put there the Assign statement(s) for the data file(s) and the following 5 constants (Sstart, Sstop, Sstep, Dstep, and SKIP), entering the relevant values for each of the constants.

5. Save the deck!
6. Choose which parameters and data files that are to be used and mark them.
7. Specify the start values for the parameters to be identified by creating a new DFP f ile. This file normally contains the current best parameter set. However, when starting, DF uses the values as start values, otherwise it uses the minimum values for each parameter. Look at a previous DFP file for the correct format. The parameters have to be in capital letters, separated from the value by an equal sign with no spaces. They also have to be in the correct order.
8. Start the fitting process.
    - Choose which parameters that are initially going to be identified.
    - Make initial identification of the store volume and the heat loss coefficients
    - Do identifications separately of any circuits where the model is uncertain or new so that experience can be gained with what parameters are required in the model.

3.2.4 Checks During an Identification

The main thing to check for is whether there is a singular matrix (zero Hesse matrix) and whether there are very high cross correlations. To get current values press the s key. WAIT until a menu comes up in the DOS window before choosing the list option (l key). This brings up the best parameter values and the cross correlation matrix and the identification proceeds automatically. Note! If you do not wait for the menu to appear and press the s key again, DF will stop!

3.2.5 After an Identification Run

Two files that DF produces are of interest. They are the:

<filename>.dfr	Results file where all information that might be needed is written. See Appendix B for more details and comments on the example. More details can also be found in the DF manual.
<filename>.dfp	Best fitted parameters from the identification.

The following procedure should be followed after an identification run has been completed.

1. Copy the *.dfr and *.dfp files and give them an appropriate identification tag with the identification run number.
2. Copy the results at the end of the dfr file into the documentation file for the store being tested stating what the new files are called.
3. Analyse the results in the dfr file. Are there any very high cross correlations and do they give very high uncertainties to the identified parameter values? Correlations of over 0.90 should be looked at more thoroughly. Uncertainties of over 20% for normal

parameters, 0.05 for store heights and 0.2 in exponent values for the internal heat exchangers should also be analysed in more detail and it should be decided whether a parameter should be fixed or not.

4. Copy the identified parameter values into the deck that was used for the identification and run for all files used. Check in the online window how well the calculated and measured powers agree for the different circuits. The values in the simulation summaries give also an indication of how well the match is. Anything above 3% difference in energy input/output for a circuit is not good. If the results are not good then the model is normally to be blame. Either there are too few of the available parameters chosen to be identified, or the model is not detailed enough for the particular heat exchanger or component.
5. Write any comments and decisions about how to proceed in the identification document.

3.2.6 Verification

Make a deck for simulating the verification sequence and run the verification sequence. The verification should be two to three days of realistic conditions for summer, winter and inbetween conditions. A suitable sequence has already been designed for use at SERC (see Combitest Program Manual). It is best to measure and store the same values for the verification sequences as for the test sequences, as this allows the same deck to be used as that in the identification process. The verification sequence is simulated in the same way as the normal test sequences, but simulation summary components should record:

- Energy, both simulated and measured, for each port.
- Time integral of absolute difference between simulated and measured heat transfer rates.

In prENV 12977-3 relative errors are defined for making a benchmark test and validation of the evaluation procedure. These quantities are a useful measure for comparison of the simulation results of the verification sequence with the measured ones. They are defined as follows. For each port or heat exchanger, *x*, the relative error in transferred energy is defined according to $\varepsilon_{x,Q}$ and the relative error in mean transferred heat power by ε_P. The subscript $_m$ refers to measured values and $_c$ to calculated (simulated) values. The integrals are what the simulation summaries calculate.

$$\varepsilon_{x,Q} = \frac{Q_{x,c} - Q_{x,m}}{Q_{x,m}} \cdot 100\%$$

$$\varepsilon_P = \frac{\Delta \overline{P}}{\overline{P}} \cdot 100\%$$

where:

$Q_{x,c}$	Calculated heat energy transferred to port/heat exchanger x.
$Q_{x,m}$	Measured heat energy transferred to port/heat exchanger x.

The quantities for the calculation of the relative error in transferred power, are calculated as follows:

$$\Delta P_x = \left| P_{x,c} - P_{x,m} \right|$$

$$\overline{P} = \frac{\int_t \sum_x P_x dt}{\sum_x t_{x,t}}$$

$$\Delta\overline{P} = \frac{\int_t \sum_x \Delta P_x dt}{\sum_x t_{x,t}}$$

In previous work at SERC, a modified definition of the relative error for transferred power has been used, $\varepsilon_{X,P}$. This is in effect the same measure, but applied to each port/heat exchanger separately. ε_P is a measure for all ports combined. The equations used for this are as follows.

$$\varepsilon_{x,P} = \frac{\Delta\overline{P}_x}{\overline{P}_x} \cdot 100\%$$

$$\overline{P} = \frac{\int_t P_x dt}{\sum_t t_{x,t}}$$

$$\Delta\overline{P} = \frac{\int_t \Delta P_x dt}{\sum_t t_{x,t}}$$

3.2.7 Guidelines for Determining Whether to Fix a Parameter Value

As stated in section 3.2.5 part 3, it is necessary to look for results that could be unreliable. Generally correlations above 0.90 and especially above 0.95 are suspect. Also suspect are uncertainties of over 20% for continuously variable parameters, 0.05 for store heights and 0.2 in exponent values for the internal heat exchangers.

The first step is to check whether the parameters are realistic. This is an engineering judgement requiring some experience with the method. For the heat exchangers one should calculate the effective UA-value at potential operating conditions and see how that compares with results from previous tests and from estimates of what is to be expected. There is a special Excel sheet for this purpose. Low values of exponents (<0.3) are not generally a problem, as they do not make the results vary much for typical operating conditions. Higher values (above 0.8) are much more suspect. If it is unsure whether the result is good or not, redo the identification for that heat exchanger only with the exponent fixed at 0.0. Check the results of this not only in online but also in the simulation summaries to check whether the energy balance for the circuit is under 3%. If it is then use these values.

Heights should be checked against the geometric heights. The geometric height is defined as the equivalent relative height in the model that has the same volume under it that the real tank has under the relevant position.

3.2.8 Documentation and Administrative Routines

3.2.8.1 Before the Identification

- Make an excel sheet to calculate the geometric heights of all inlets and outlets
- Prepare the data files to be used in the identification process. Decide what time step to use for the simulations (and data files). Usually a time step of 0.025 is used. If there are dynamic effects with shorter time steps that are important for the model then a shorter time step is required. Document what has been done.
- Prepare the deck for use with Fittrn as described in sections 3.2.1 and 3.2.3.
- Create a directory on the computer where all the identifications are to be made. One subdirectory for each identification run.

3.2.8.2 During the Identification Process

- Make a document where all the steps of the identification are recorded. This should include a brief description of the model used for the different circuits. A short description of each run and the conclusions from them should be made.

3.2.8.3 After the Whole Identification Process

- Create an Excel sheet with the results of the verification sequence and calculate the relative energy error and relative power error for each port as defined in prEN 12977-3 for validation.
- Copy the parameter values to the Excel sheet with all the values for the stores tested.
- Write a document describing the best identified parameters and the models used. See Appendix C. Put a printed copy of this in the file with the other reports.

3.3 Creation of Data files and DDP Files

Data files are created from the measured data files. First it has to be decided what the time step of the data is going to be. Generally we have used 0.025 hr for both data and simulation time step. If more detailed dynamic effects are to be studied then a shorter time step is required. The time step of the measured data has to be the same or shorter than that used in the simulations.

DDP-files are files that allow customising of simulations dependent on the data file. The contents of the data file are inserted into the deck before it is run. Generally the contents are just the start, stop and time step as well as the assign statement for the data file. However, it is in principal possible to have completely different system for each data file in the DDP-file as any contents that are Trnsys input commands can be there. Often all that is required above the normal is reallocation of ports that may be used for different purposes in different test sequences.

More details of the creation of data files and their associated DDP-files are given in Appendix A.

3.4 Choice of Parameters to Identify

This is the most important but also the most difficult of the choices. There are no fixed rules, but the following guidelines can be given. These guidelines will need to get updated with time. It is intended that IEA SHCP Task 26 Solar Combisystems will create a guideline document about this.

The following refer to the parameters in type 140 v1.95.

N^o	Description	Guide
1	storage height	Fix to measured height of cylindrical part of store
2	storage volume	Identify
3	Specific heat of fluid	Fixed (4.18)
4	Density of fluid	Fixed (992)
5	effective vert. therm cond. in storage	Identify – if time limited then fix to 4.5 kJ/h.m.K
6	not used	-
7	initial temp. of the whole system	Fixed to measured value for start of test sequence. Usually 20°C but could vary – maybe need to have this in DDP file if it varies from test to test.
8	heat loss through bottom	Identify as own parameter
9	heat loss through top	Identify as combined parameter (UA_{ls1}) with parameter 11, $UA_{lstop} = UA_{ls1}*A_{top}/(A_{top}+A_{sides})$
10	rel length 1st zone	1
11	heat loss through 1st zone	Identify as combined parameter (UA_{ls1}) with parameter 9, $UA_{lstop} = UA_{ls1}*A_{sides}/(A_{top}+A_{sides})$
12	rel. length 2nd zone	0
13	heat loss through 2nd zone	0
14	rel. length 3rd zone	0
15	heat loss through 3rd zone	0
16	heat loss through 4th zone	0
17	rel. height inlet 1st doubleport	Identify if used – might be difficult if near top or bottom
18	rel. height outlet 1st doubleport	Identify if used – might be difficult if near top or bottom
19	stratified charge 1st dp? yes=1	Fixed – dependent on store
20-31	parameters for double ports 2-5	As for double port 1
32-36	Positions of temperature sensors 1-5. Used for control sensors and general information	Positions for control sensors should be identified. This is done after the other parameters have been identified. Match measured and simulated temps.
37	aux heater mode (0=no,1=Pvar,2=Pconst)	Store dependent
38	aux heater installed from top? yes=1	Store dependent
39	absolute length aux heater (if 38=1)	Store dependent
40	rel. pos. aux heater (if 38 not 1)	Identify
41	rel. pos. of temp. controller to aux heatr	Identify separately using EiA and EiB sequence when the electrically auxiliary is enabled.
42	set temp. for aux heater	As for param 41.

43	dead band temp. of the controller	As for param 41.
44	rel. inlet pos. 1st hx	Fixed to geometric height – can try identifying but it is normally not possible
45	rel. outlet pos. 1st hx	Identify
46	Volume of 1st hx	Fix to estimated equivalent volume (included metal)
47	specific heat of fluid in 1st hx	Fixed
48	density of fluid in 1st hx	Fixed
49	UA- number from 1st hx ; *1/1000	Identify
50	b1.1 – flow dependency	Identify if there are test sequences with different flows
51	b1.2 – temperature difference dependency	Fix to 0. Can try identifying with separately but usually is 0.0
52	b1.3 – temperature level dependency	Identify
53	Time constant for hx 1 * 1 / 1000	Identify if it is thought there is a time constant associated with the UA-value. Usually only DHW discharge heat exchangers
54	stratified charging with 1st hx?	Store dependent
55-76	parameters for heat exchangers 2 & 3	Same guide as for heat exchanger 1
77	accuracy for calculating temperat.	0.001 or 0.0001
78	accuracy for UA when using b*.*	10
79	precision of mixing process in the tank	10000
80	flag if temp. dependence timestep control	0
81	Number of nodes / *1/10000	Usually 0.01 but could be 0.005 or 0.004 or even 0.002 if less accurate model was desired
82	0 = normal mode; -7 = fit mode	-7

For other components a choice will have to be made based on previous experience and knowledge of the model.

3.4.1 Note on Parameters for Heat Exchangers

The above guidelines are for heat exchangers that are placed in the store without any covering. They produce mixed charging and discharging. If these are covered (encapsulated) then it is more accurate to treat them as a counter flow heat exchanger with natural convection on the store side. They can either be modelled using a separate heat exchanger component (type 5 or type 105) along with equations to define the natural convection flow, or with v1.98+ and above of type 140.

In the latter case there are extra parameters for defining how to calculate the flow. These are defined in the notes on the changes to type 140. Suggested values for these are:
sc_{hx} = 2 for heat exchangers with stratifier unit (with holes/flaps), -2 for heat exchangers with simple pipes.
sm_{hx} is the flow factor for the natural convection. A positive value is suggested, when the flow calculation is based on the average store density over the height of the pipe. A negative value uses the density of the store at the pipe outlet. A test should be performed to see which

one works best for a given device. Sometimes this parameter can be quite high (over 100) in which case it is suggested that a multiplying factor is used so that the identified value is between 0 and 10.

In addition the equations used for calculating the effective UA-value are not the same for enclosed heat exchangers. See section 3.1.

4 Suggestions To Aid Efficient Identification

4.1 Use of RAM Memory

The identification process can use the hard disk repeatedly. This is dependent on how the operating system is set up and the other programs used on your computer. If you notice that this is the case for your computer then it might be good to use a RAM disk. This helps in two ways. One the retrieval of data is much faster. Two the load on the hard disk is much smaller. Disks have been known to crash with continued use for identification.

A size of 8 Mbytes is suggested, although this is very dependent on the size of the data files used. The easiest method is to copy the whole working directory to the RAM disk, including data files and programs (Fittrn.exe, fittrn.ini, gofit.exe, dfstart.bat and trnlib32.dll). The two parts of DF, DF.exe and RTM.exe can usually be left on the hard disk, as they are not repeatedly run.

RAM disks can easily be installed on Win95 and Win98, as it is part of the operating system. For NT a separate program (NTRAMDSK) must be downloaded from the following website http://www.ntfaq.com.

4.2 Maximum and Minimum Parameter Values

These affect how DF calculates the derivatives (gradients) for the individual parameters. Too small a value and sometimes DF can have problems in calculating a gradient, in which case a singular matrix will result. On the other hand a too large value can result in crashes or system instability (for certain models). Care has also to be taken with heights for inlets and outlets as if the values are too large, then it is possible to get heat exchangers 2 and 3 overlapping – something not allowed in the model.

Generally speaking it is best to give quite large ranges of the order of one magnitude. If the value cannot be estimated, then a wider range is required. Exponents for the heat exchangers should be in the range 0-1 but a range for the identification of 0-2 is suggested. Parameters that influence the results significantly can usually have smaller ranges. These are often certain inlets/outlets and the volume.

4.3 Use of DF /Q

It is possible to get an objective function value for the model for a given parameter set using the following command in the DOS window:
DF <filename> /Q
where <filename> is the name of the deck but without the extension.
DF takes the values in the DFP file for use in the calculation. A DF file is also required. This defines which data files to use and the ranges for the parameters and is created when Fittrn

starts an identification run. It is therefore necessary to have previously started a proper run with DF with the same parameter set.

This option is useful sometimes if DF has problems identifying a value, often a height near 0 or 1. With good parameter values for the other parameters, one can manually change the value for the relevant parameter in the DFP file and make a note of the objective value. Other times when it is useful are when you would like to get a "feel" for how parameter changes influence the objective function.

5 Troubleshooting

The following is a list of common problems and their solutions.

Fittrn does not configure the deck

Check that the DF printer in the deck has the correct format.

DF or Fittrn does not work

- Check that the path to DF is correct (menu command Options).
- Check that you have the latest version of Fittrn (older ones have had some bugs).
- If you get ”runtime error 200” when the program DF itself is run, then get the latest version of DF. (This occurs only on Pentium II computers).
- Check the path name for where you are working. DF does not seem to be able to handle long path names (longer than 8 letters) that are allowed in Windows 95.
- Check that fittrn has not corrupted the deck – sometimes it duplicates some of the information at the start of the deck.

Fittrn ”loses” the data files when started again

Have the data files in a subdirectory to the one where Fittrn is located.

Fittrn stops after many runs with a message saying that its run out of memory

This is an unsolved bug in Fittrn (as of end of 2000). The only solution (work around) found so far is to run the whole process on a computer using Windows NT.

Zero Hesse (Singular) Matrix Found

This occurs when there is no change in the objective function when the derivatives are calculated, i.e. the second derivative matrix of the objective function is zero. This can be due to several reasons. See DF manual (section on error messages for more details).

- It is at the start of the identification process and DF does not have enough information to evaluate the matrix properly. Let it run a bit longer before acting.
- The range (min- max) allocated for the parameter is too small - increase the range.
- The parameter is not possible to identify, as there is too little information in the data files (a change in parameter value does not change the objective). This cannot be fixed without making more tests.
- The real value is very close to the real maximum possible. This can occur for the relative heights near 0 and 1, more often near 1. To overcome this you can identify the value manually using DF /Q (see section 4.3) or construct equations that limit the

height to the range 0-1 but allow the identification process to “use” values beyond this. Useheight = MAX(MIN(identheight, 1.0), 0.0)

Trnsys does not complete a simulation (various messages in German can occur with this)
First look in the listing file for any information on why it did not work. If this gives too little information then you should simulate the deck with the correct parameter values chosen by DF (the ones which caused the crash). The deck used for the current simulation has an extension of *.TRA. Copy it and give it a temporary name with the file extension .DCK. Simulate it including online. Often the system is unstable with certain extreme parameter values. In this case just change the maximum and minimum values of the parameters causing the problem. The “problem” parameter(s) can often be identified by manually changing the values and rerunning the deck to see whether it crashes.

6 References

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Appendix A Making Trnsys Data Reader Files From Measured Data

A.1 The program CTS

CTS is a program developed by SPF in Switzerland. It can average the raw data to equal length time steps. The following is the way it should be used with the measured data from SERC.

A.2 Format of Trnsys Data Files

These are the files read in by Trnsys – one for each test sequence. First decide what the format of the data files is to be. All data files including the verification sequence should have the same structure (i.e. same columns) in order to be able to use the same data reader in all cases. The alternative to this is to have several different data readers and therefore decks for identifying parameters.
Things to watch out for:

- the measured boiler flow (Vb) is used both for full charge (Vfc) and for the boiler (Vob) in the Presim model and deck. There are no test sequences where both Vfc and Vob are used. To deal with this you can either:
    - Use a switch in the DDP file to say whether the Vb is for Vfc of Vob in this data, egg Vfcon = 1 (for full charge tests and Vfcon = 0 for oil boiler tests) in the DDP file, and in the equations calculating the mass flows in the main deck, Vob = (1-Vfcon)*Vb and Vfc = Vb*Vfcon. Preferable option.
    - create two separate columns in the data files and manually copy the Vb to the Vob column for the few tests where the boiler ports are used
    - Identify the boiler ports separately using different decks.
- If you have more than 18 columns in the Trnsys data file (including the time column), then 2 data readers are required. These need not be the same as each other, rather can be created separately from Excel (see below).

A.3 Creation of the Trnsys Data Files

A.3.1 Removing Unwanted Data

- Load a measurement data file into Excel – make sure that the column titles are ok using the text import guide.
- Remove the columns that are not to be used in the Trnsys data files. Generally these are Ts1-7, Tbc, Tcc, Tc, Thc and often Tcxi.
- Remove the comment lines at the bottom of the measured file with all the energy balance information.
- Remove the top two rows (lines) of the file leaving just the column titles and the data.
- Remove bad data points. These are denoted as –9.99. This is normally only for flows. Use the replace function (CTRL+H) and replace –9.99 with a relevant value based on the values before and after – often 0.
- Regularly the measured flow is 0.001 to 0.005 due to extra pulses coming into the flow sensors. These make no difference to the energy balance but can be a nuisance in the Trnsys simulations. If you have time it is worth editing these to zero – using the replace function (CTRL+H) changing 0.005 to 0, 0.004 to 0 etc. NOTE – do not change all values at once as this might change some of the time values!

A.3.2 Splitting into separate test sequences

- Create separate excel books for each test sequence by copying sections from the measurement data file. These can be found by seeing where the flow in conditioning (Vdx) changes from 0 to non-zero. Each test sequence should start with roughly 0.05 hr of conditioning. The end of the test sequence can be when the outlet from the store has gone below 20.5°C if the test sequence is going to be used separately. If the test sequence is to be joined to another test sequence to form a larger data file than the whole conditioning period is required.
- Save each test sequence file as a TAB separated file with the relevant test sequence name and extension of .tab.

A.3.3 Creating the Trnsys data files with CTS

- Start CTS
- Load an existing configuration file (.CFG) and save it with a suitable name for the store being tested. This file should be nearly the same as that used for previous stores, except possibly for the flow coupling (see below).
- Edit the CFG file. The only thing to check is the flow links. This links temperature sensors to flow sensors so that the temperatures calculated for longer time steps give the correct energy output. If the flow is zero then the flow-linked temperatures in the output file will also be zero. Tci&Tco linked to Vc, Tbi&Tbo to Vb, Tdhwi&Tdhwo&Tdhw1&Tdhwt to Vdhw. Thi and Tho should NOT be linked to Vh or to Vdx as they are used with both these flows.
- The following are the standard settings to be used in the CFG file (in the order going down):
    - Inoptions: Tab, 1, tbHour, Header exist, special data offset yes – 1.
    - OutOptions: no header, no automatic…, Tab, ffFixed, 6,3,dfd.
    - CTSOptions: 0.025, tbHour, smNextFit.
- Convert the test sequence data files. Note that it is possible to append files together to create a longer file – this could be useful to reduce the number of files, but implies that the individual test sequences in the larger file always get run together.

A.3.4 Create the DDP files for each Trnsys data file

This should have the form shown in the example below. Note that in the data reader in Trnsys, the first parameter should be set to 2 so that the first data line is for the start of the simulation.

```
CONSTANTS 6
Sstart = 16.525   * Sstart is the start for the simulation – the same value as the first time in the data file
Sstop = 8.35      * Sstop is end of simulation – should be two time steps less than the time at the end of
                  the measurement data file
Sstep = 0.025     * Sstep is Trnsys simulation time step – should be same as Dstep
Dstep = 0.025     * Dstep is the time step for the data file – set in CTS – usually 0.025
SKIP = 0.0        * skip is time to skip at start of data file – always 0.
Vfcon = 1         * Vfcon controls whether the flow Vb is for full charge (Vfcon=1)
                  or for oil boiler (Vfcon=0).
ASSIGN data\CIS-sl2.dfd 21   * name of the data file normally in subdirectory data.
```

Appendix B   Example DF Results File

This appendix gives an example DF results file (*.dfr) and describes the various sections and gives comments on the results shown.

The start of the file lists the basic identification constraints for DF for the identification such as parameters, max/min values, and data files.

```
*** DF 2.7 Oct 97 @Copyright InSitu running 31.05.1999 08:05:12
> TimeBase,1
> FilterConst,1
> Precision,1.0
> TimeBase,3600
> FileName,F:\c500c2\c500all1
> Model,Extprog,GOFIT.EXE
> Model,Dimension,4
> Model,OutputUnits,-
> Model,ParSpec,1,DHXUA,KJ/HK
> Model,ParSpec,2,DHXB1,-
> Model,ParSpec,3,DHXB3,-
> Model,ParSpec,4,DSMDOT,-
> Model,Range,1, 1.00000000000000E-0001, 2.00000000000000E+0002
> Model,Range,2, 0.00000000000000E+0000, 2.00000000000000E+0000
> Model,Range,3, 0.00000000000000E+0000, 2.00000000000000E+0000
> Model,Range,4, 1.00000000000000E+0000, 5.00000000000000E+0002
> Read,C5PT01\DHW-HF.DAT,Skip=0.000000
> Read,C5PT01\DHW-HIF.DAT,Skip=0.000000
> Read,C5PT01\DHW-HIP.DAT,Skip=0.000000
> Read,C5PT01\DHW-HP.DAT,Skip=0.000000
> Read,C5PT01\DHW-LF.DAT,Skip=0.000000
> Read,C5PT01\DHW-LP.DAT,Skip=0.000000
> FilterConst, 2.00000000000000E-0002
> NumOfLocMin,20
> Fit
Reading parameters from file F:\C500C2\C500ALL1.DFP
```

The middle part lists the local minima found after each attempt at finding a new one.

```
Search local minimum, trial No 1 of 20

Search local minimum, trial No 2 of 20

Search local minimum, trial No 3 of 20

* summary of potential local minima (3 trials, 2 found)
 42.669   0.728   0.000 145.801 | 1982
 65.919   1.023   0.000 159.768 | 2333



Final search

* summary of potential local minima (20 trials, 18 found)
 41.783   0.726   0.000 150.375 | 1971
 42.334   0.735   0.000 150.371 | 1971
 42.017   0.730   0.000 149.865 | 1971
 39.361   0.722   0.015 150.537 | 1973
 43.073   0.741   0.000 147.938 | 1974
 44.034   0.753   0.000 146.801 | 1978
 42.669   0.728   0.000 145.801 | 1982
 49.748   0.834   0.000 149.565 | 2005
 12.281   0.708   0.424 149.617 | 2023
 51.102   0.838   0.000 143.357 | 2023
 11.870   0.689   0.425 150.506 | 2024
 23.219   0.667   0.159 161.993 | 2026
 53.938   0.894   0.000 155.894 | 2087
  1.822   0.769   1.270 150.472 | 2128
  1.026   0.694   1.476 157.356 | 2157
 65.919   1.023   0.000 159.768 | 2333
108.014   1.261   0.000 136.928 | 2879
 91.301   1.223   0.000 163.186 | 2897
```

The final section gives a summary of the results.

```
\NumOfData,432
\NumOfDataCorr,427
\SumTime,109476[s]
\SpectralError,9.96E8[s]

* analysis of variability and intercorrelation of data
\EigenValues of normalized Hesse Hn[i,j]=H[i,j]/Sqrt(H[i,i]*H[j,j])
            3.376410030  0.593126404  0.029943105  0.000520461
\EigenVectors of Hn (each column one eigenvector)
     DHXUA  0.536077606 -0.204063538  0.397195619  0.716389917
     DHXB1 -0.527858381  0.258481754  0.808792107  0.020199999
     DHXB3  0.536088516 -0.200425221  0.431350264 -0.697406470
    DSMDOT  0.382877831  0.922699835 -0.045032399  0.001289568
```

Measure of variability of parameter values with and without the influence of the intercorrelation

```
\ErrorNoCorr (parameter error ignoring intercorrelation, = 1 / variability)
       0.3866      0.00589     0.003069        1.793
\ErrFactorCorr (error increase/factor due to intercorrelation)
        31.49        4.778        30.67        1.245



\Parameters
Param,DHXUA,KJ/HK,0.1,200,0
Param,DHXB1,-,0,2,0
Param,DHXB3,-,0,2,0
Param,DSMDOT,-,1,500,0



\Results DF 2.7 Oct 97 @Copyright InSitu running 31.05.1999 10:37:30
\Value,Parameters,"DHXUA=42 DHXB1=0.729 DHXB3=0 DSMDOT=150 Obj=1970"
* External model GOFIT.EXE
frequency transform method............... Cosine
initial state value...................... 0
numerical precision...................... 1
time base................................ 3600
filter type.............................. Gaussian, tf=0.02
                Name   mode  tvf  t_start   t_skip    t_end    N*        Size
   C5PT01\DHW-HF.DAT   Mean    1        0        0      6.1  86.5      1..610
  C5PT01\DHW-HIF.DAT   Mean    1        0        0     5.45  77.4      1..545
  C5PT01\DHW-HIP.DAT   Mean    1        0        0     4.13  58.8      1..413
```

```
   C5PT01\DHW-HP.DAT   Mean    1        0        0     3.53  50.3      1..353
   C5PT01\DHW-LF.DAT   Mean    1        0        0     6.46  91.6      1..646
   C5PT01\DHW-LP.DAT   Mean    1        0        0     4.74  67.4      1..474
     DHXUA      DHXB1      DHXB3     DSMDOT  objective
   [KJ/HK]        [-]        [-]        [-]        [-]
     41.65     0.7247   2.508E-4      150.3     1971.3
      11.8     0.0276     0.0913       2.21
```

The above line gives a measure of uncertainty of the result (absolute value), including the effects of intercorrelation – a standard deviation value.

```
Cross correlation matrix:
 1.0000000  0.2368541 -0.9874529  0.0258676
 0.2368541  1.0000000 -0.0856613 -0.1383960
-0.9874529 -0.0856613  1.0000000 -0.0720066
 0.0258676 -0.1383960 -0.0720066  1.0000000
```

Note that in this example the cross correlation matrix shows very high correlation between the base UA-value (DhxUA and the temperature exponent b3). This is quite common but in this case it causes a very high uncertainty for these two values. In this case the identification should be redone with b3 fixed to 0.

Appendix C Example Identification Report – SERC2

Model Parameters for Type 140, Multiport Type 140, v1.98F
Chris Bales
SERC. 990615

C.1 General Parameters

Height:	1.42 m	{fixed}
Heat Loss Coefficient: CEN	UA_{s1} = 1.89 W/K (6.80 kJ/h.K)	{fit}
	UA_{bot} = 0.41 W/K (1.48 kJ/h.K)	{fit}
Effective Vertical Conduction:	1.28 W/m.K (4.62 kJ/h.m.K)	{fit}
Number of nodes	100	{fixed}
Water Volume	465 litres	{fit}
	(+ 10 litres water and 1 litre antifreeze in heat exchangers.)	

C.2 Collector Loop

The collector loop was modelled using an internal heat exchanger with natural convection based on the temperature difference between average tank temperature over the height of the pipe and the outlet temperature from the heat exchanger. Perfect stratification is assumed. Tests were made using antifreeze mixture with 41% P44 glycol.

C.2.1 Heat Exchanger

Volume	1 litre antifreeze	{fixed}
Inlet	0.83 [relative height]	{fit}
Outlet	0.04 [relative height]	{fit}
Heat Transfer Coefficient (UA)	UAh1 = 1096 kJ/h.K	{fit}
	b_{h1}=0.738, b_{h2}=0.0, b_{h3}=0.726	{fit}

	UA is dependent on both the primary and secondary conditions (and thus temperature distribution in the store).
	UA = 190-360 W/K @ 3 kW charging
	UA = 250-420 W/K @ 6 kW charging
	(UA-value calculated using log. temp. diff.)	

Option for Stratified Charging	On	
Natural Convection Mode	Average tank temperature over heat exch.	
Natural Convection Factor	59.1	{fit}

C.3 Boiler Heat Exchanger

This was modelled as an internal heat exchanger. It operates at high flows (600 l/h or more).

Volume	4 litres water	{fixed}
Inlet	0.80 [relative height]	{fixed}
Outlet	0.43 [relative height]	{fit}
Heat Transfer Coefficient (UA)	UAh1 = 7.77 kJ/h.K	{fit}
	b_{h1}=0.0, b_{h2}=0.0	{fixed}
	b_{h3}=1.510	{fit}
	This gives a UA-value at T_m=70°C and flow of 600 l/h: $UA_{70,600}$ = 1315 W/K (4736 kJ/h.K)	
Option for Stratified Charging	Off	
Natural Convection Mode	None	

C.4 Heating System Heat Exchanger

This was modelled as an encapsulated internal heat exchanger. It operates at low flows (<120 l/h).

Volume	4 litres water	{fixed}
Inlet	0.42 [relative height]	{fit}
Outlet	0.81 [relative height]	{fit}
Heat Transfer Coefficient (UA)	UAh1 = 38590 kJ/h.K	{fit}
	b_{h2}=0.0	{fixed}
	b_{h1}=0.946, b_{h3}=0.0	{fit}
	This value is dependent on both primary and secondary flows.	
Option for Stratified Charging	Off	
Natural Convection Mode	Average tank temperature over heat exch.	
Natural Convection Factor	60.2	{fit}

C.5 Hot Water Preparation

This was modelled using an internal heat exchanger with down pipe.

Volume	2.4 litres water	{fixed}
Inlet	0.00 [relative height]	{fixed}
Outlet	1.00 [relative height]	{fixed}
Heat Transfer Coefficient (UA)	UAh1 = 42670 kJ/h.K	{fit}
	b_{h2}=0.0	{fixed}
	b_{h1}=0.726, b_{h3}=0.0	{fit}

	UA is dependent on both the primary and secondary flows (and thus temperature distribution in the store). For 60°C in store.
	UA = 800-1400 W/K @ 300 l/h draw off
	UA = 1900-2500 W/K @ 900 l/h draw off
	(UA-value calculated using log. temp. diff.)	

Option for Stratified Charging	Off	
Natural Convection Mode	Average tank temperature over heat exch.	
Natural Convection Factor	145.8	{fit}

C.6 Temperature Sensors

Not yet identified.

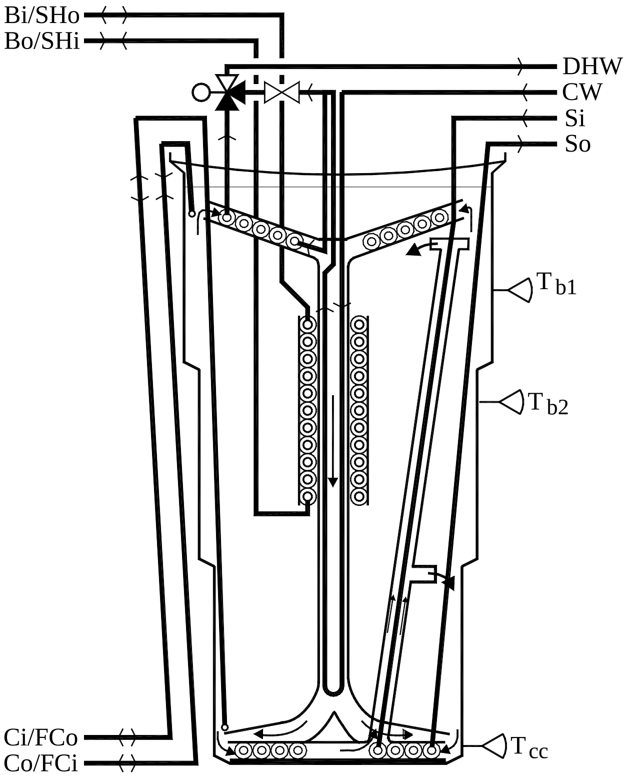
C.7 Verification Results

The following is a summary of the results from the verification sequence which comprised 3 days of realistic conditions and a fourth day of standby. It was not possible to measure the outlet temperature of the DHW before the mixing valve and so the DHW port was verified with a separate test sequence not used for parameter identification.

The heat exchanger for space heating was connected as in a real system as a preheater on the return from the radiator circuit. The flow was calculated to be that for a circuit with a boiler with outlet temperature of 80°C.

	Heating	Collector	Final	DHW	Boiler
	System	Loop	Disch.		Port
	kWh	kWh	kWh	kWh	kWh
Energy Totals- meas	-31.8	22.8	-11.8	-28.8	47.8
Energy Totals-sim	-32.6	21.5	-12.9	-28.3	48.4
Differences between measured and simulated according to CEN.					
Energy Difference	2.5%	-5.6%	9.4%	-1.7%	1.2%
Mean Power Diff.	7.3%	17.7%	13.4%	1.7%	6.3%

C.8 Schematic of Tank



Appendix D FITTRN MANUAL

Courtesy of SPF, Rapperswil, Switzerland.

FITTRN / DF
TRNSYS Parameter identification with DF for Windows 95 / NT

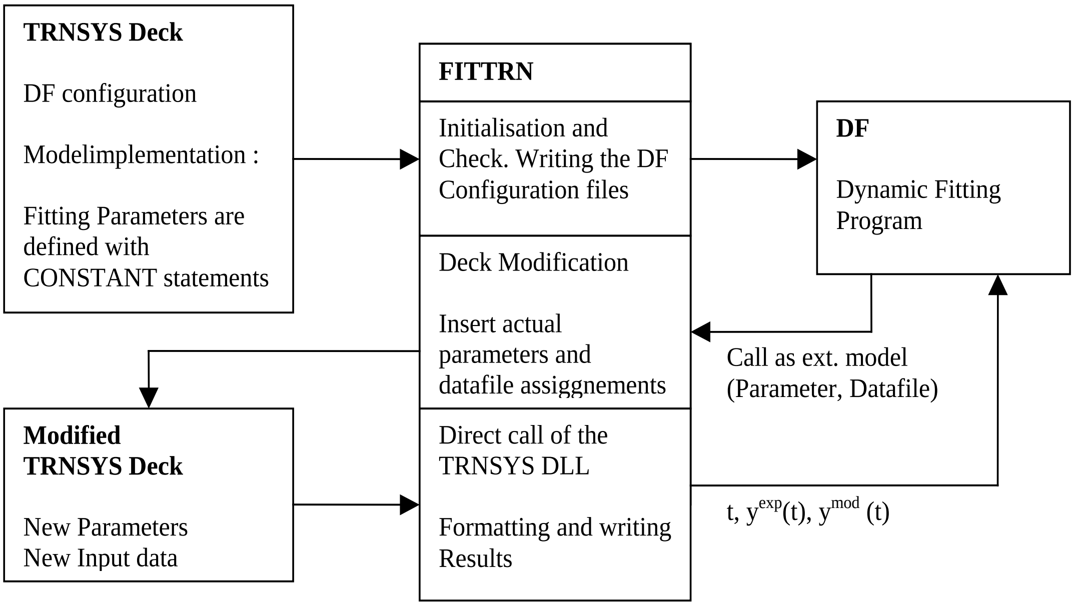
Christof Huber, SPF Solar Energy Laboratory, ITR School of Engineering, CH-8640
Rapperswil
6.3.98

Intro

The Parameter identification program DF from Scientific Software, Munich is used by several Institutes within their solar collector test and SDHW test activities. DF is a DOS program which calls external model implementations trough a textfile based interface. This article describes the program FITTRN, which enables the parameter identification of TRNSYS models by DF. An advantage thereby is the use of the efficient Windows 95 / NT version of TRNSYS.

Architecture

The diagram shows the parameter identification information flow. The user only needs to call the FITTRN program. The DF configuration, thus the specification of the parameters as well as the used input data files are defined in the deck.


TRNSYS Deck
DF configuration
Modelimplementation :
Fitting Parameters are defined with CONSTANT statements
FITTRN
Initialisation and Check. Writing the DF Configuration files
Deck Modification
Insert actual parameters and datafile assiggnements
Direct call of the TRNSYS DLL
Formatting and writing Results
DF
Dynamic Fitting Program
Call as ext. model (Parameter, Datafile)
t, $y^{exp}(t)$, $y^{mod}(t)$
Modified TRNSYS Deck
New Parameters
New Input data

- **Initialisation:**

  The deck is read and the DF configuration file is written. Subsequently, the DF program is started.

- **Deck modification :**

DF calls FITTRN as external model. FITTRN modifies the original deck with the parameters and input data of the current Fit run. Dependent-dependent TRNSYS blocks are also inserted.

- **TRNSYS Simulation Call:**

  FITTRN calls directly the TRNLIB32 DLL. After the end of the TRNSYS simulation the output data are written on the DF format. The control of the process is transferred back to DF.

Deck extensions recommended to run with FITTRN / DF

The DF configuration is written as comment block directly into the TRNSYS deck. Some conventions must be kept. The configuration block is marked with the keywords ”BEGIN DF CONFIG” and ”END DF CONFIG”. This Block is automatically written by the FITTRN program. Changes of the configuration should be made trough FITTRN. The following paragraph shows a typical configuration block.

```
** BEGIN DF CONFIG
* PARAMETER        MIN          MAX          UNIT                 SWITCH  MINSTEP
* CAP              0.1          5            KJ/K/M2              OFF     OFF
* C0               0.7          0.9          -                    ON      OFF
* C1               10           20           KJ/H/K/M2            ON      OFF
* CPA2             0.05         10           0.01KJ/H/K2/M2       ON      OFF
* IAM              0.2          0.5          -                    OFF     OFF
* VOL              0.0002       0.005        -                    OFF     OFF
* DATA FILE                                                        SWITCH
* DATA\DATA01.DAT                                                 ON
* DATA\DATA02.DAT                                                 ON
*
* FILTERCONST = 0.1
* NUMOFLOCMIN = 20
*
* DATA DEPENDENT BLOCK

** END DF CONFIG
```

After the keyword " PARAMETER " follows the listing of the parameter names, their certified variation area as well as a switch. This switch serves switching a Fit parameter on and off, without deleting equal the appropriate line. The parameters are defined in the deck by normal CONSTANTS statements. FITTRN detects these definitions and exchanges the values during the identification process. The keyword DATA FILE marks the data files used for the identification. Also here a switch can be set. In the further two DF configuration instructions, the time constant for the low-pass filter as well as the number of local Minima can be set.

The lines between the keyword ”DATA DEPENDENT BLOCK” are used to insert TRNSYS statements which depends on the specified data file. This statements must be defined in a text file which has the same name as the corresponding data file but with extension ”.DDP” The convention for this file is the ASSIGN statement of the data file and the Constant SKIP which are needed for each data file. The simulation times also must be defined in this file. At each TRNSYS run, the lines of the DDP file are copied and inserted in the deck. This enables full flexibility for example the use of more than one physical data file as input or data file dependent Units.

The measured and simulated functions $y^{mod}(t)$ and $y^{exp}(t)$ must be written to a text file. The convention you have to look for is that the printer unit is marked with the keyword „PRINTER DF”. FITTRN detects this and reads the result file which is assigned to this printer unit. This modification is **not** automatically inserted by the FITTRN program.

```
UNIT 53 TYPE 25 Printer DF
PARAMETERS 4
STIMEST
SIMSTART
SIMEND
46
INPUTS 3
 0,0  Pmeas  Pcalc
 0.   0.     0.
```

The result file must contain at least 3 columns. The columns are described in the DF Manual.

Files coming up with the FITTRN package

FITTRN.EXE : Main program
FITTRN.INI : Configuration File
GOFIT.EXE : DOS Interface which is called by DF as external model.
DFSTART.BAT : DOS batch file used by FITTRN to start DF. Must contain the path to DF.

The TRNSYS DLL TRNLIB32.DLL the configuration File CNFGTR.TRN and the deck file are supplied by the user and need to be located in the same directory as the FITTRN files.

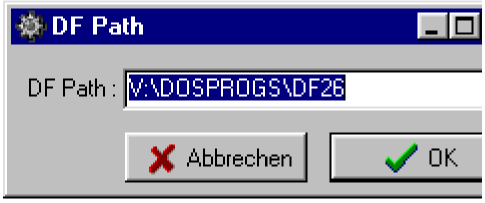
FITTRN can be obtained from Christof Huber, email christof.huber@solarenergy.ch

Quick start with the DEMO Application

These steps explain the installation of FITTRN and a first parameter identification process with the example deck.

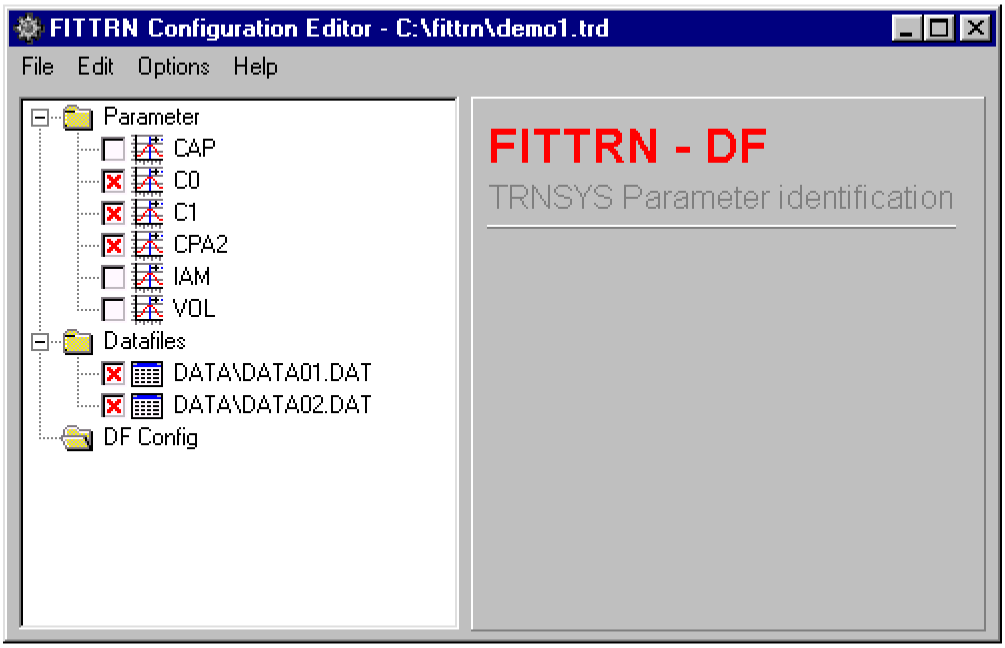
1. Copy the 4 Files located on the Disk in the directory \PROGRAM on your Harddisk.
2. Copy the example files located on the Disk in the directory \PROGRAM inclusive the DATA subdirectory into the same directory on the Harddisk.
3. Start FITTRN.EXE

   First, we need to configure the Path, where the DF program is located.
   Choose Menu Options->DF Path.. Insert the correct Path here.



DF Path : V:\DOSPROGS\DF26

4. Menu File->Open... Choose the demo deck called "demo.trd". The following Window comes on your screen :


FITTRN Configuration Editor - C:\fittrn\demo1.trd
File
Edit
Options
Help
FITTRN - DF
TRNSYS Parameter identification

- Parameter
  - ☐ CAP
  - ☒ C0
  - ☒ C1
  - ☒ CPA2
  - ☐ IAM
  - ☐ VOL
- Datafiles
  - ☒ DATA\DATA01.DAT
  - ☒ DATA\DATA02.DAT
- DF Config

You have just loaded a TRNSYS Deck with all needed extensions to work with FITTRN. Now the Tree on the left side contains the parameters configured to identify, the used Input data files and the DF configuration. Click on a icon to show the corresponding settings. The Box with the red cross is used to switch a parameter on or off.

5. Start fitting. Choose Menu File-> Start fitting to start the identification process.

If all is successful, a DOS Window with DF appears on the screen. Then the FITTRN is started for each run. The FAST! flag on this Window sets the TRNSYS process to a high operating system priority. Thus it is not possible to identify in the Background. On Windows NT it is possible that the mouse is not yet responding until the parameter identification Process is terminated.

To terminate FITTRN you have to terminate DF with typing ”escape” on the DOS Window. !

Steps to modify a deck to run with FITTRN

1. Create a new subdirectory and copy the 4 FITTRN files to it.
2. Copy your TRNLIB32.DLL, CNFGTR.TRN and your deck to this directory.
3. Modify your Deck : Insert the Residual File Printer and mark it with the keyword ”DF PRINTER” If you use more than one data file, set the SIMULATION times to variables, which you can defin in the DDP.
4. Start FITTRN.EXE
5. When no DF configuration is found in the Deck, you can create a new configuration. Then you can add data files and Parameters trough Edit Menu. Set up the DF configuration too.
6. Save the Deck
7. Start fitting