

# TRNFLOW: Integration of the airflow model COMIS into the multizone building model of TRNSYS

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## Introduction

In the thermal building model TRNSYS Type 56 the air flows between the zones and from the outside are defined by the user as input values. In natural ventilation systems these values depend on external wind pressures and the inside and outside temperatures. To account for this situation, a coupling with an air flow model is absolutely necessary. TRNFLOW integrates the multi-zone air flow model COMIS into the type 56. An internal solver, optimized for this task, iterates in each time step between the two models until their solutions are consistent. The existing user surface TRNBuild was extended in such a way that data for the air flow model can be entered. Thus a user-friendly handling of the coupling is assured. With TRNFLOW, a immense step forward has been made for building simulation with TRNSYS.

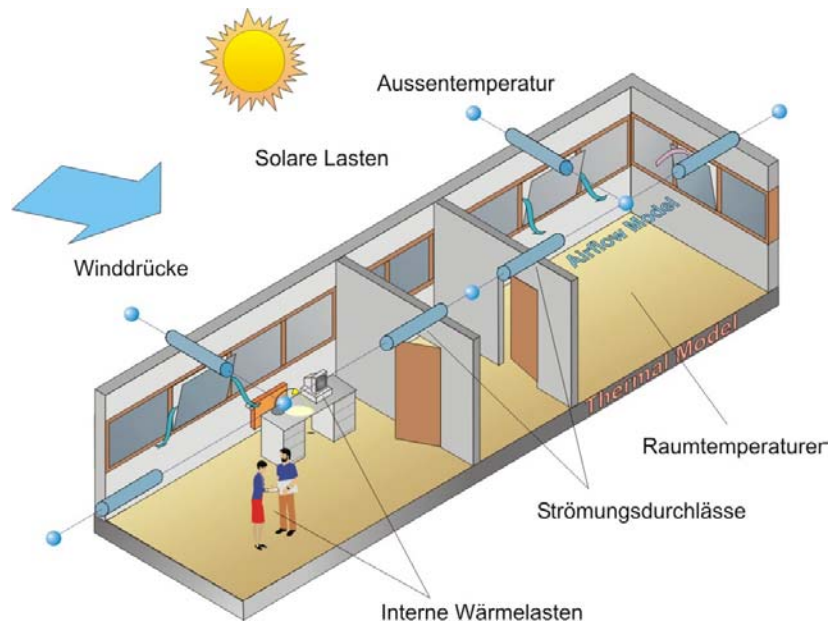


Fig. 1: Interaction of the thermal and the airflow model

## Coupling of TRNSYS and COMIS in the Past

In order to achieve sustainable buildings new energy systems have been generated using natural effects to renew the air and lead away the heat. Examples are passive night cooling, double facades, solar chimneys, inside courtyards and so on. In these systems the mutual impacts of thermal and air flow behavior are very distinctive. Thus for numerical building simulation programs an integral approach is inevitable.

Already in 1993 in the frame of the IEA project Annex 23 the EMPA has developed a coupling of the multizone air flow model COMIS with the thermal building and system simulation program TRNSYS which was presented at the TRNSYS Userday 1994. The self-contained program COMIS was modified to TRNSYS Type 157 which can be linked to the thermal building model Type 56 within the TRNSYS-Deck via in- and outputs. The input information of the air flow model are read in by Type 157 from the standard COMIS Input File (CIF). The TRNSYS solver iterates the results of the two models until they match (Fig. 2).

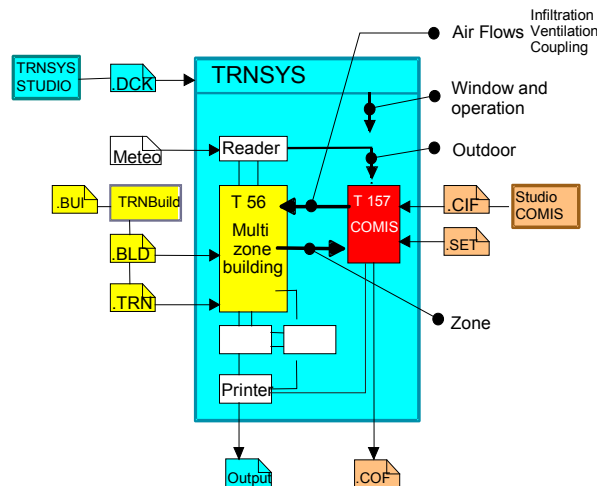


Fig. 2: Former solution of the integration of COMIS as TYPE 157 into TRNSYS Type 56

This coupling has been successfully applied by several projects and simulation tasks. However the coupling wasn't very user-friendly and required a laborious handling. As the mutual classification of the data is made by hand the inputs tend to be incorrect. This susceptibility is also increased by the redundancies of the two input files. Furthermore it was proven that the TRNSYS solver is not always the perfect solution for such a system. The solver possibly has to be supported by additional convergence promoting Types what makes the handling again more difficult. Yet the need of an integral approach concerning thermal building dynamics and natural air exchange is clearly necessary. Therefore with TRNFLOW an improved version including a deepened integration of the two models is available now.

### Multizone Air Flow Model COMIS

Multizone air flow models idealize the building as a network of nodes and airflow links. A node represents a room volume which a set of state variables can be assigned to. Cracks, window joints and openings, shafts as well as ventilation components like inlets and outlets, ducts and fans represent the links. Boundary conditions and thereby also input factors are:

- State variables of the air in the zones
- Local wind pressures

The pressure  $p_Z$  is a free parameter in the node which is evaluated according to the continuity equation (mass flow balance in the node = 0). This results in  $n_Z$  equations where  $n_Z$  represents the number of zones.

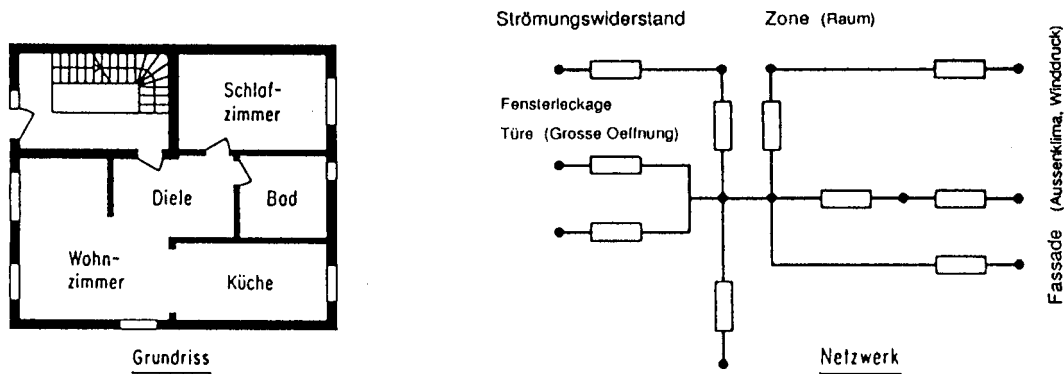


Fig. 3: Modeling of a building with zones and current outlets

The relation between mass flow rate  $m$  and pressure difference  $dp$  and thus the zone pressure  $p_Z$  is not linear. Therefore an iterative process is used to solve the system of equations. The mass flow rates per link and all dependent factors such as air exchange rates, air age etc. are calculated of the resulting zone pressures  $p_{Zi}$ . The calculation is static without an explicit consideration of the timestep. In principle calculating a condition based on a new time is independent of the previous timestep.

### Coupling Concept of TRNFlow

The indoor temperatures are important boundary conditions of a multi zone air flow model which mostly can only be defined on the basis of the user's guess. The indoor air temperatures calculated by the thermal model strongly depend on the exchange of air between the zones as well as the outside. To link the two models and mutually use the results is the obvious consequence. Thus the multi zone air flow model COMIS is completely integrated into Type 56. This means that the exchange of data between the thermal and the air flow model is made internally and no longer by inputs and outputs. The proper classification of air flows (infiltration, ventilation, couplings) and temperatures to the air flow node resp. the thermal zones and the appropriate other model is automatically carried out by the program.

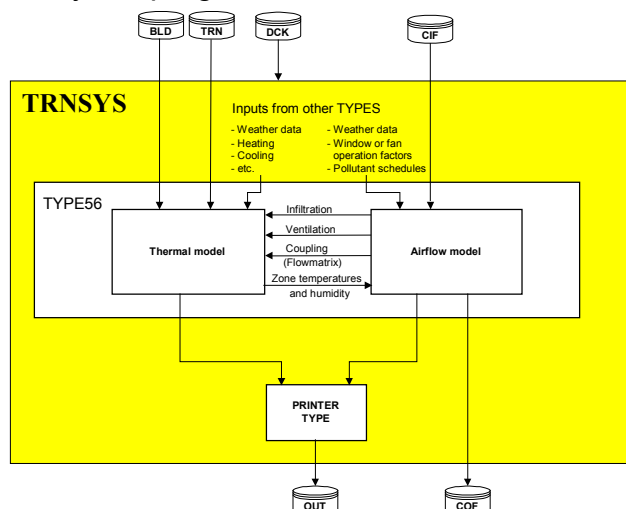


Fig. 4: Coupling concept of TRNFlow: the air flow model is fully integrated in Type 56

The input files of both models are kept in the existing formats (BUI, CIF) but can be created by the common user interface TRNBuild. Air flow model data depending on time like wind velocity or window opening factors are defined as inputs or schedules. Outputs like air flows or zone pressures are declared as outputs by means of new NTYPES and can be written into an output file using a printer type or processed otherwise. The standard COMIS Output File (COF) is optionally also available.

### User Interface TRNBuild for TRNFlow

The functionality of the existing user interface TRNBuild has been enlarged. Beneath traditional data of the thermal model also the required input information of the air flow model will be entered (see figure 5). This data is also stored in the BUI file and can be read in from it. Analog to the Standard Type 56 files (BUI, TRN, BLD) TRNBuild also creates a COMIS Input File (CIF) which is read by TRNFlow. The CIF created this way is - with few additions – completely equivalent to the format described in the COMIS 3.1 User's Guide [2].

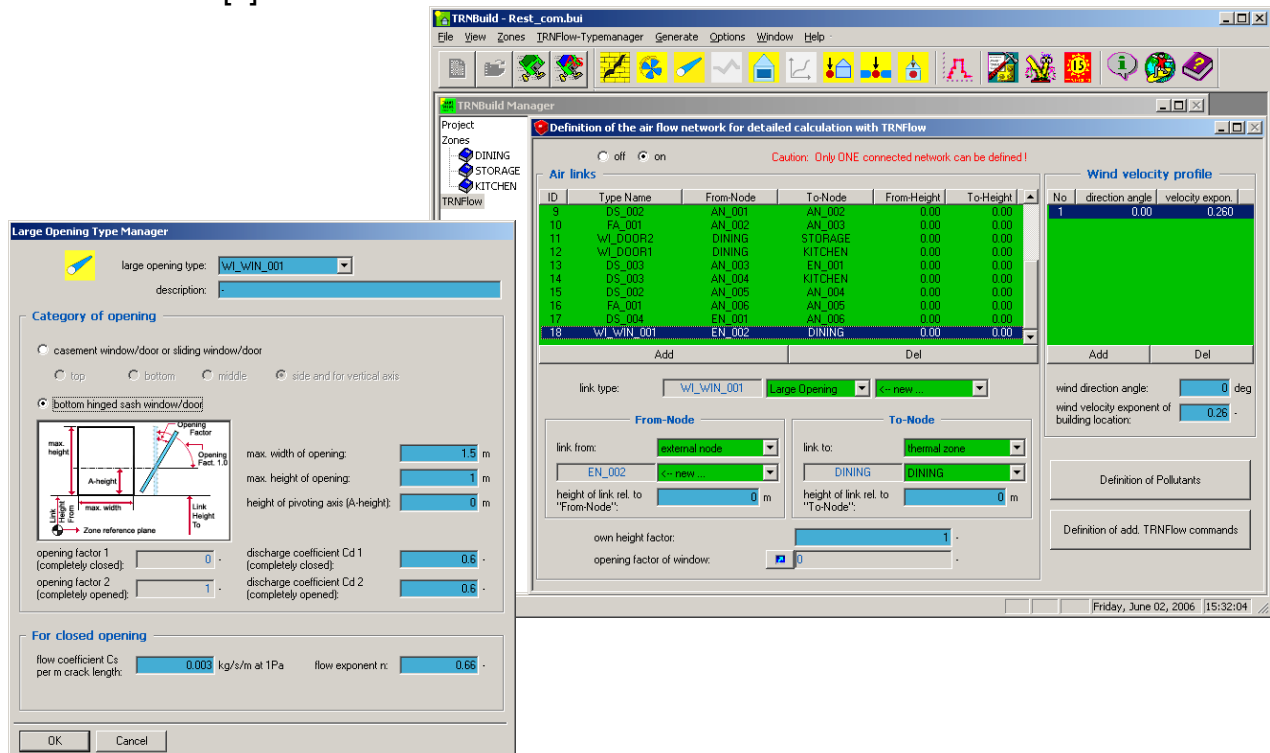


Fig. 5: User interface TRNBuild for TRNFlow

### Internal Solver of TRNFlow

Due to the integration of the air flow model into Type 56 the TRNSYS Solver can no longer be used for the iteration process between the two models. I.e. the solutions have to reach convergence using a solver integrated into Type 56. Depending on the boundary conditions the coupling of the two models forms a recursive flow of information with negative feedback. E.g. at cold outdoor air an increasing indoor temperature imposes an increasing exchange of air. This counters another increase of the indoor temperature so that a balance will appear (Fig. 6). If the negative feed back gets too strong there will be the risk of getting an unstable system. A solver algorithm with a successive substitution method (TRNSYS solver 0) then also becomes unstable. Therefore the new solver

integrated into Type 56 automatically dampens individually every recursive flow of information according to the iteration process so that an optimum of stability and convergence is achieved.

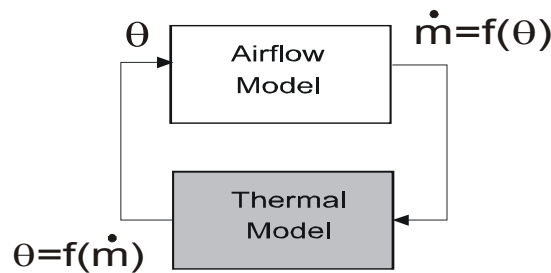


Fig. 6: Recursive flow of information between air flow and thermal model

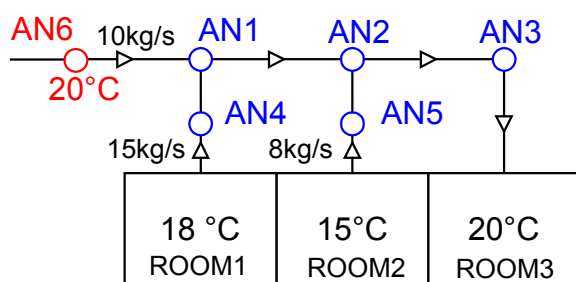
### Duct Network System

Beneath the room nodes (thermal zones) the air flow model needs additional auxiliary nodes for the ventilation duct network as junctions of the individual parts of the duct system. In order to keep the thermal model small these nodes are not modeled as thermal zones in Type 56.

The temperatures of the auxiliary nodes are directly calculated from the temperatures of the joining air flows. Thermal capacitance or other heat gains or losses of these nodes are not considered. In the thermal model air flows of the auxiliary nodes into the space zones are interpreted as ventilations.

To model an air heater or cooler, resp. a humidifier or dehumidifier, temperature as well as humidity can be defined for an auxiliary node by means of a constant, input or schedule variable. The power necessary to reach this set point for the air can be obtained by an output.

Figure 7 shows an example for the illustration of a duct network. The reference temperature of 20°C is defined for the auxiliary node AN6. For Room3 a ventilation of 33kg/s with 17.9°C results. Room1 and Room2 have zero ventilation.



Resulting temperature of aux. nodes:

Aux. nodes	Temperature [°C]
AN1	18.8
AN2	17.9
AN3	17.9
AN4	18.0
AN5	15.0

Fig. 7: Example duct network system

## Example: Double Facade

The development of TRNFLOW was finished in March 2003. Since that date it has already proved its strength in various projects like in the simulation of cross ventilation of offices, natural ventilation of double facades and atria, the pressure difference at doors of high-rise buildings or pollutant concentration in a building. Figures 8 and 9 show a multi storey building with double facade as an example.

TRNFLOW demonstrates its suitability for large building models by an example with more than 60 thermal zones and lots of auxiliary nodes. No numerical or other difficulties have been obtained in those runs.

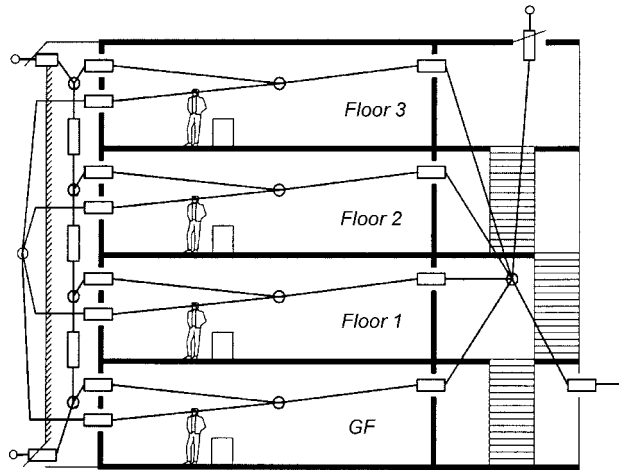


Fig. 8: Air flow network model of a multi story building with double facade

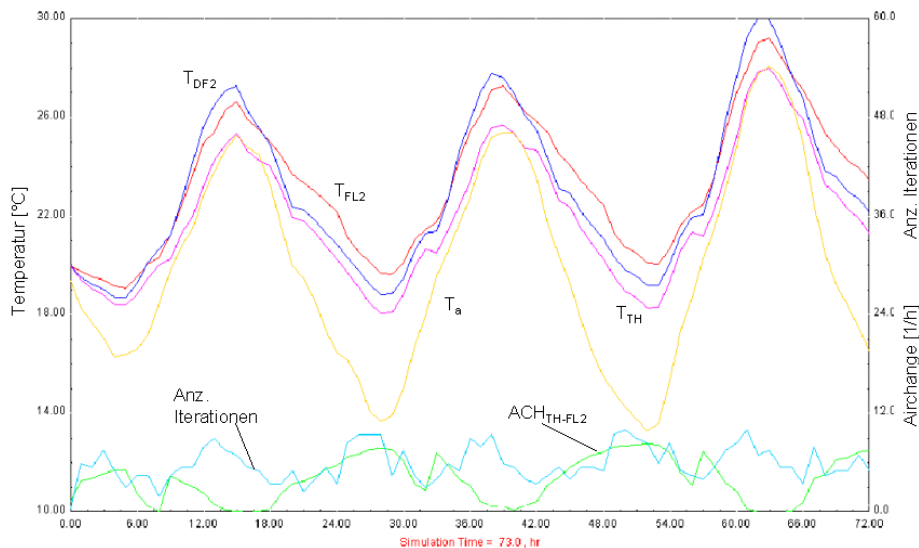


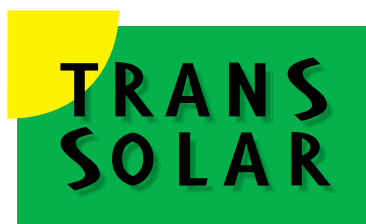
Fig. 9: ONLINE Plot of the zone temperatures: floor 2, double facade 2, staircase and outside temperature as well as the air flow referring to the room volume between floor2 and the staircase and the number of internal iterations

## Conclusions

- TRNFLOW is a tool which allows an easy calculation of natural ventilation, passive night cooling, double facades and exhaust air shafts quite fast.
- No new input file structure or user interface has to be learned. Simply the known user-friendly TRNBuild has been expanded. Due to the full integration the required input data is greatly reduced and less error-prone.
- The newly-developed internal solver is featured with high stability. Due to the integrated automatical optimization of convergence the user is no longer bothered with numerical questions.

## Further Information

If you have further questions, please do not hesitate to contact your TRNSYS distributor:



K l i m a E n g i n e e r i n g

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## References

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- [2] H. Feustel, B. Smith, V. Dorer, A. Haas A. Weber et al.: *COMIS 3.1 – User's Guide*, 2001 EMPA Dübendorf, Switzerland
- [3] Klein, S.A. et al.. 2006. TRNSYS 16.1: a Transient System Simulation Program, SEL, University of Wisconsin, Madison, USA