TRNSYS 17: NEUERUNGEN UND ANWENDUNG DER IEA BESTEST MULTI-ZONE NON-AIRFLOW IN-DEPTH DIAGNOSTIC CASES MZ320 – MZ360

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KURZFASSUNG

In der neuen Version TR NSYS 17 wurde das bestehende Mehrzonengebäudemodell durch die detaillierte Modellierung von 3-dimensionalem Energietransport durch Strahlung und thermische Schichtung erweitert (Aschaber, J. et. al , 2009). Dabei werden die Genauigkeit, der Benutzeraufwand und die Fehlerquellenanfälligkeit hinsichtlich der Einbindung einer externen Verschattung und der Solarstrahlungsverteilung innerhalb des Gebäude-modells wesentlich verbessert.

Zur Validierung werden standardisierte qualitativ hochwertige Testfälle angewendet. Die Validierungs-verfahren dienen dazu verschiedene Probleme in der Simulationssoftware zu identifizieren, wie zu m Beispiel: Modell- und Programmierungsfehler, fehlende Features und Unklarheiten für den Anwender. Gleichzeitig dienen frühere Untersuchungen und Nutzerberichte als Bewertungs-grundlage um den aktuellen Stand der Entwicklung zu überprüfen und zu vergleichen.

In dem folgenden Beitrag wird das neue detaillierte Strahlungsmodell in TRNSYS 17 kurz beschrieben. Zur Überprüfung von TR NSYS 17 wenden die Autoren die Validierungsprozeduren der IEA BESTEST Multi-Zone Non-Airflow In-Depth Diagnostic Cases: MZ320-MZ360 (Neymark, J. et. al, 2008) an. Die Testfälle konzentrieren sich auf interzonale Wärmeleitung, Mehrzonenverschattung inkl. der Gebäudeeigenverschattung und interne Fenster. Die ermittelten Ergebnisse werden mit den Ergebnissen der ursprünglich getesteten Simulations-programme verglichen, unter anderem der vorherigen Version TRNSYS 16. Die Modellierungsunterschiede in Bezug auf TRNSYS 16, die Erfahrungen mit dem neuen Release und ausgewählte Ergebnisse werden in diesem Beitrag vorgestellt.

Die Ergebnisse von TR NSYS 17 zeigen eine gute Übereinstimmung mit den Ergebnissen der anderen Programme. Berichtete Fehler sowie die meisten Modellierungsschwierigkeiten bei vorherigen Programmversionen wurden durch di e neuen detaillierten Modelle gelöst.

ABSTRACT

In the new release of TRNSYS 17, the existing multi-zone building model has been extended to include the detailed modeling of 3-dimensional energy transport by radiation and thermal stratification (Aschaber, J. et. al, 2009). Thereby, the accuracy to model external shading and solar radiation distribution within zones is significantly improved while errors and user effort are notably reduced.

Particularly, the new release of TRNSYS 17 has been validated with a high quality test suite. These published validation procedures can serve to identify different problems in simulation software: modeling and coding errors, missing features and frequent sources of user confusion. Comparative reviews of previous tests serve as the basis to assess the current state of development.

This paper briefly describes the new detailed radiation model of TRNSYS 17. The authors applied the test suite of IEA BESTEST multi-zone non-airflow in-depth diagnostic cases (Neymark, J. et. al., 2008) to TRNSYS 17. The tests focus on interzonal conduction heat transfer, multi-zone shading including building self shading and internal windows. The results are compared to the originally tested simulation programs, including the previous version TRNSYS 16.

The modeling differences with respect to TRNSYS 16, the experiences with the new release, and selected results are presented in this paper.

The results of TR NSYS 17 simulations agree very well to results of other participants. Reported modelling errors and most modelling difficulties of previous versions are solved by the new detailed models.

INTRODUCTION

In the new release of TRNSYS 17, the multi-zone building model so-called Type 56 has been extended to a detailed modeling of 3-dimensional energy transport by radiation and thermal stratification. Figure 1 provides an overview of the newly integrated features. These new features are optional such that the user can adapt the level of detail according to the needs of the project. A detailed description of the models is given by Aschaber (Aschaber, J. et al. 2009) and the TRNSYS 17 manual (Klein et al., 2009).

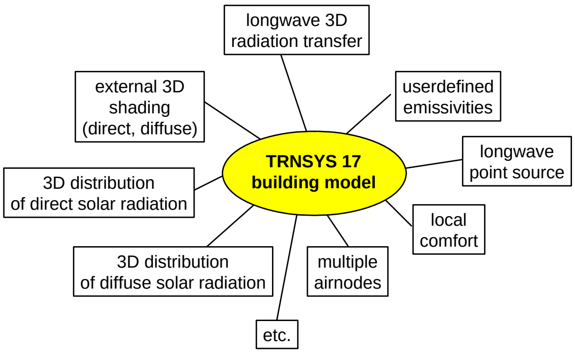

Figure 1: New features of the multi-zone building model

For validating the detailed radiation models implemented in TRNSYS 17 the multi-zone non-airflow test cases developed in IEA SHC Task 34/ ECBCS Annex43 are conducted by the authors.

METHODOLOGY

The multi-zone non-airflow test cases are developed in IEA SHC Task 34/ ECBCS Annex43 and represent an extention to the original IEA BESTEST (Judkoff, R. et al., 1995). The suite consits of five in-depth diagnostic cases MZ320 - MZ360 covering modeling of (Judkoff, R. et al., 2008):

- Interzonal conduction heat transfer, assuming one-dimensional conduction
- Multi-zone shading, including building selfshading
- Internal windows between zones

For each case specific output reporting requirements are given. The key Figures in assessing tool capability are: annual and peak cooling load for the whole building and the specific zones, annual average air temperature for each zone, annual peak air temperature for each zone and its first time of occurrence, annual incident un-shaded total solar radiation on the exterior façade, disaggregated solar radiation on the exterior façade into beam and diffuse radiation, total and disaggregated radiation through each window and for specific zones a daily analysis of radiation and sensible cooling for the 14th of august and the 15th of march.

There are no formal criteria given when results of a program agree or disagree. However, the test suite allows software developers to compare their programs with the simulation tools originally tested, as well as with more recent results if they are publicly available. TRNSYS Version 16.01.0002 as well as TRNSYS-TUD (a modified version based on TRNSYS 14.2 created by the university of Dresden) are two of the originally tested programs.

Case MZ320: 3-Zone Steady-State Conduction Analytical Verification Test

The multi-zone non-airflow test cases start with MZ 320 a relatively simple steady state analytical verification test for multi-zone conduction (see Figure 2).

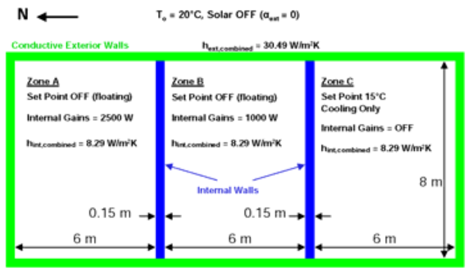

Figure 2: Case MZ320 3-Zone Steady-State Conduction Analytical Verification Test

Case MZ340–MZ355: In-Depth Multi-Zone Shading Test Cases

Cases MZ340-MZ355 are based upon the same geometry while the type of shading geometry is changing from no shading, to fin shading, and finally to automated building self-shading (see Figure 3). The building geometry is composed by 6 rectangular zones. The external windows are west orientated and there are no internal windows between the zones. The idealized window has solar transmittance of 1 and a thermal conductance of 0.

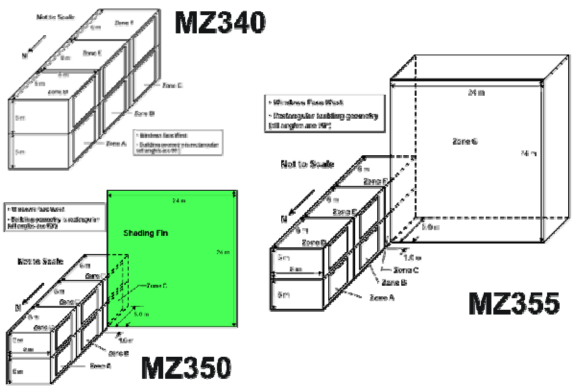

Figure 3: Case MZ340–MZ355 In-Depth Multi-Zone Shading Test Cases

MZ355 differs to the test cases MZ340 and MZ350 by an additional Zone G that is attached to two existing zones and replaces their glazing plus a certain part of wall by adjacent opaque wall elements. The new Zone G has no windows.

Infiltration, ventilation, and internal gains are set to 0. The solar absorptance of the interior wall surfaces, the exterior wall surface of zone G, and the shading fin is 100% such that no reflection is considered.

In addition to standard results, the differences between the results of the non-shaded case MZ340 (base case) and the shaded cases are evaluated.

Case MZ360: In-Depth Internal Window Calorimeter

In contrast to the previous test cases the three zones of test case MZ360 are placed in series (see Figure 4). Besides one external window, two internal windows are defined. The building orientation is set to 45° west of south. This test offers the ability to track transmitted beam and diffuse radiation and its distribution through multiple zones.

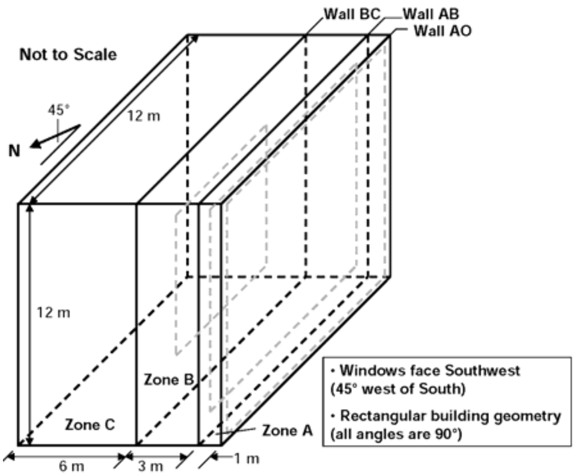

Figure 4: Case MZ360 In-Depth Internal Window Calorimeter

MODELLING ASSUMPTIONS DIFFERING TO TRNSYS 16

Since a previous version of TRNSYS is one of the originally tested simulation programs, this paper focuses on the differing modelling assumption applying the new TRNSYS 17 features.

Geometry input

For TRNSYS 17, the standard building description file is extended by the addition of 3D geometric information required by the new detailed radiation modes. For all tests cases MZ340, MZ350, MZ355, and MZ360 the geometry of the building as well as the shading devices have been created by using the GoogleSketchup™ plugin Trnsys3d (Transsolar, 2010). Afterwards the model is imported to TRNBuild for adding further data like properties, materials, and outputs.

In TRNSYS 16, no 3D geometric information of the thermal model was included in the building description file.

Weather data reader and radiation processor

In TRNSYS 17 Type 109 is replaced by Type 15 and Type 99 as the standard weather data reader and radiation processor. For these Types including Type 16 the curving algorithm of the direct normal radiation is improved. Radiation spikes as reported by Type 109 (L'Hoest et al., 2008) on March 15th, hour 19 where the sun is partially down during the time step are avoided. Therefore, Type 15 is applied.

Exterior combined surface coefficients

Compared to TRNSYS 16.x the exterior surface infrared emittance is a direct user input. According to the test specification it is set to 0 and the convective surface coefficient is set to the combined value of 30.4872 W/(m² K).

In the previous TRNSYS versions, it wasn't possible to turn off the automatic long-wave radiation exchange of exterior surfaces. Setting the view factor to the sky of an exterior surface to 0 only avoids long-wave radiation exchange with the specified sky temperature. However, the long-wave radiation exchange with the ambient temperature of the surroundings, except the sky, is still calculated.

Interior combined surface coefficients

For defining the given interior combined surface coefficients the simple long-wave radiation mode of the building model is selected. In addition the convective surface coefficient is set to the combined value of 8.29 W/(m² K).

The simple long-wave radiation mode already existed in previous versions, but it was much more complicated for the user to activate.

Exterior shading model

For modelling shading effects by fixed external shading devices and building self-shading the new detailed external shading model integrated into the multi-zone building model is applied. The geometry of the shading fin and the building itself is defined once, and the model checks automatically which windows are effected by the shading. The integrated model accounts for beam and isotropic diffuse sky radiation shading. Although TRNSYS offers more sophisticated sky models like the Perez model (Klein et al., 2009) an isotropic diffuse sky model is applied in order to obtain consistent results. The shading matrix is generated with a high resolution (2305 patches).

In TRNSYS 16.x the shading fin was modeled by Type34 (wingwall and overhang shading). The geometry of this component has to be defined for each window separately and is limited to perpendicular external shading of a vertical window. In addition TRNSYS 16.x didn't include building self-shading due to the lack of 3D geometric building description.

Direct radiation distribution model

The new detailed direct radiation distribution mode of the building model is activated during these tests. The insolation matrix is generated with high resolution. For each external window the sunlit fraction of the window that strikes each inside surface of a zone is calculated. Due to the fact that the automatic direct radiation distribution is restricted to external windows, user-defined distribution factors, so-called Geosurf's, are applied for zones with internal windows.

For determining the time-depending Geosurf values of zone B the new detailed direct radiation model is applied. As shown in Figure 5 two additional zones B2 and C2 are simulated. The zone B2 is similar to Zone B, but the internal window AB is now an external window. The geometry of Zone A is defined as a shading for Zone B 2. The resulting distribution factors of the external window of Zone B 2 are used as the Geosurf values for Zone B.

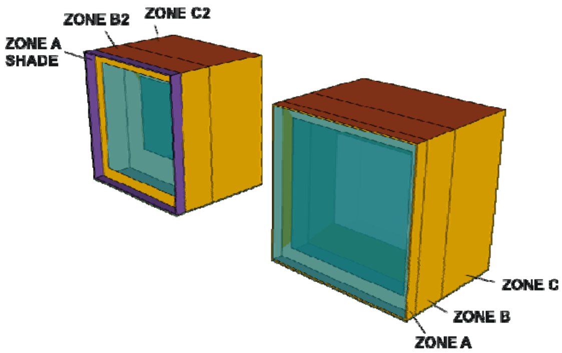

Figure 5: Case MZ360 – additional zones B2 and C2

For determing the internal radiation distribution after window BC constant Geosurf values were calculated according to the ratio between each surface and the total of the surfaces of the zone, excluding the window by which the solar radiation entered a zone.

For TRNSYS 16.x Geosurf values for all zones have been calculated according to the ratio between each surface and the total of the surfaces of the zone, excluding the window by which the solar radiation entered a zone. (L'Hoest et al., 2008)

Diffuse radiation distribution model

The new detailed diffuse radiation distribution mode of the building model is activated during these tests. Thereby, so-called Gebhart factors are applied, which are based on view factors. The short-wave diffuse radiation exchange between all surfaces of a thermal zone is calculated explicitly, including all possible paths.

In TRNSYS 16.x a simple non-geometric method is implemented which may cause significant deviations for shallow zones with large unshaded windows in combination with high absorptive interior walls (see MZ 360). The incoming diffuse and reflected solar radiation is distributed according to absorptance-weighted area ratios. Thereby, an amount of the incoming diffuse radiation through a window is distributed back to that window and falling out of the zone even if there is no reflected solar radiation (walls solar absorptance = 1; window solar transmittance = 1). To avoid this problem the modelers of the university of Liège decided to add the diffuse radiation to the direct radiation and then distribute it by userdefined distribution factors (L'Hoest et al., 2008).

RESULTS AND ANALYSIS

The intent of this paper is not to present the complete results of applying IEA BESTEST Diagnostic Cases of TRNSYS 17. Rather it is to show the effects of the new detailed modelling approach compared to previous TRNSYS versions and to other simulation software. Based on the different capabilities and calculation methods of the several programs it is expected that there are differences in results throughout the case.

Case MZ320: 3-Zone Steady-State Conduction Analytical Verification Test

As result a the air temperature of each zone and the sensible cooling load for Zone C is obtained. The results show a good agreement with maximum deviation of 0.09 %

Case MZ340–MZ355: In-Depth Multi-Zone Shading Test Cases

In general, the results of TRNSYS 17 simulations agree very well to the results of other participants.

Figure 6 shows the annual transmitted total solar radiation of the different zones for the programs orginally tested, as well as TRNSYS 17. The annual hourly integrated peak cooling load is shown in Figure 7.

The results show that the new modelling approach of external shading based on a discretisation of the half hemisphere in combination with bilinear interpolation for direct shading and integration for sky diffuse shading gives correct results. If instead of a high resolution of the discretisation (2305 patches) a medium resolution (577 patches) is selected, the annual transmitted total solar radiation of the different zones is reduced by a maximum of 0.6 %.

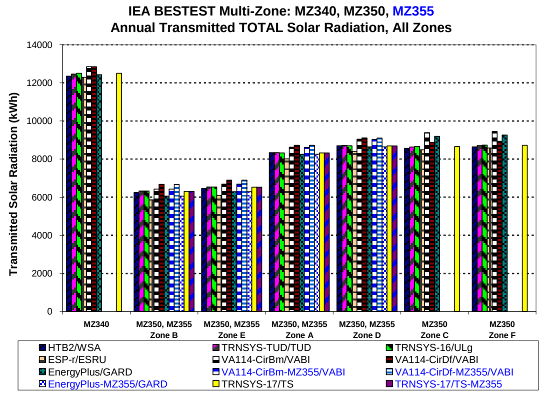

Figure 6: Multi-Zone Shading - Annual Transmitted Solar Radiation

In contrast to previous verisons, TRNSYS 17 is able to run test case MZ 355 (automated building self shading). Since the effective shading geometry with respect to zones A,B,E and D of test case MZ350 and MZ355 are the same the results are equivalent too. For zone C and F the results differ due to the fact that these zones have no window in test case MZ355.

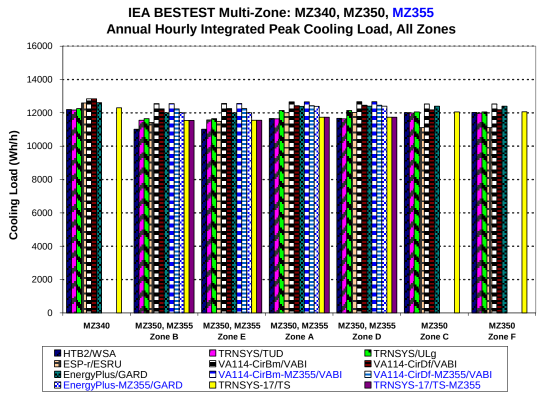

Figure 7: Multi-Zone Shading - Annual Hourly Integrated Peak Cooling Load

Case MZ360: In-Depth Internal Window Calorimeter

This case tests the ability to track transmitted beam and diffuse solar radiation though mulitple zones.

The following Figure 8 - 10 show the hourly transmitted solar radiation on March , 15th of the external window OA, the first internal window AB and the second internal window BC, respectively.

The differences for external window OA are very small (see Figure 8). It can be seen that after 11 am the solar radiation is dominated by direct radiation.

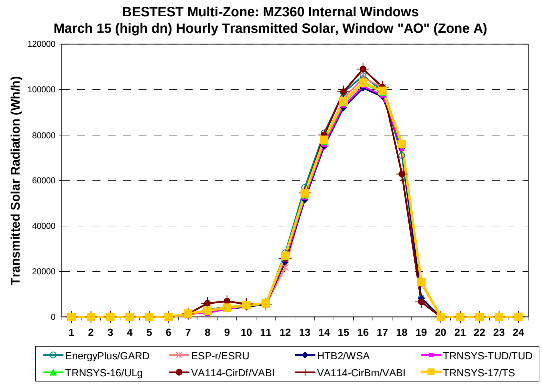

Figure 8: MZ360 Transmitted Solar, March 15th, WINDOW OA

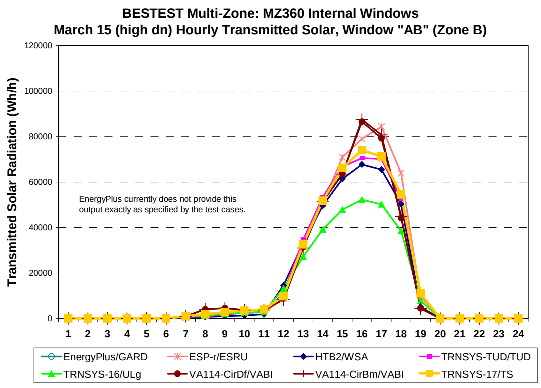

Figure 9: MZ360 Transmitted Solar, March 15th, WINDOW AB

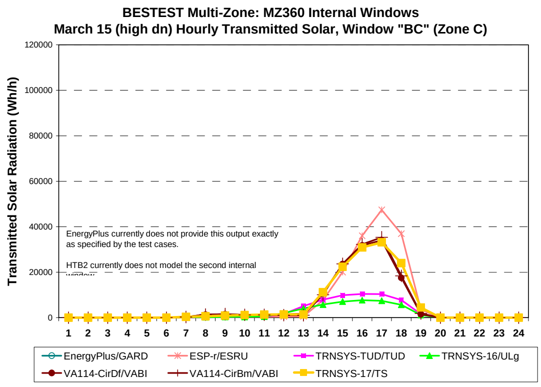

Figure 10: MZ360 Transmitted Solar, March 15th, WINDOW BC

For the first internal window AB, significant differences exist compared to the previously performed TRNSYS 16 calculations by the University of Liège (TRNSYS-16). These differences may be caused by the assumption of constant distribution factors for beam radiation where as TRNSYS17 and TRNSYS-TUD used factors depending on the sun's position. TRNSYS-TUD (Felsmann, 2008) applied a ray-tracing method and TRNSYS17 an insolation matrix combined with bilinear interpolation. Both methods lead to similar results.

For the transmitted solar radiation of the second internal window B C a significant deviation of the TRNSYS 17 calculation compared to both other program versions exists (see Figure 10). Both, TRNSYS-16 and TRNSYS-TUD use constant distribution factors. In contrast TRNSYS 17 applied factors depending on the sun's position. The results are similar to other programs using a detailed approach like VA114.

The resulting annual incident and transmitted solar radiation including the direct (Itrb) and the diffuse (Itrd) part is presented in Figure 11. Besides the previously discussed differences in direct radiation distribution, the impact of the different diffuse radiation models of TRNSYS 17 and TRNSYS 16 is shown. The detailed model TRNSYS 17 is based on Gebhart-factors which are equivalent to view factors due to the absence of reflection. The improved approach used in TRNSYS 16 still yields to considerable deviation for schallow zones with large unshaded windows in combination with high absorption of interior wall surfaces.

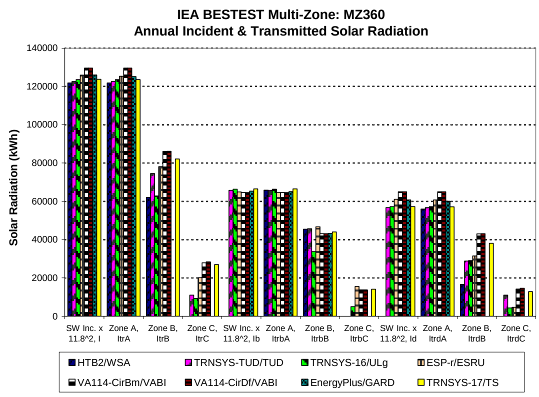

Figure 11: MZ360 Annual Incident and Transmitted Solar Radiation

The influence of the chosen resolution for generating the insulation matrices is rather small. If instead of a high resolution of the discretisation (2305 patches) a medium resolution (577 patches) is selected, the annual transmitted total solar radiation of the window AB is increased by 0.18 %.

The resulting annual sensible cooling load of the building and disagregated zones are shown in Figure 12. Whereas the results for the whole building show a good agreement for all programs, significant differences occur for each zone. As discussed previously these differences are mainly due to different modelling approaches of radiation distribution. Programs with a detailed approach have a higher cooling load in zone C and lower cooling load in zone A.

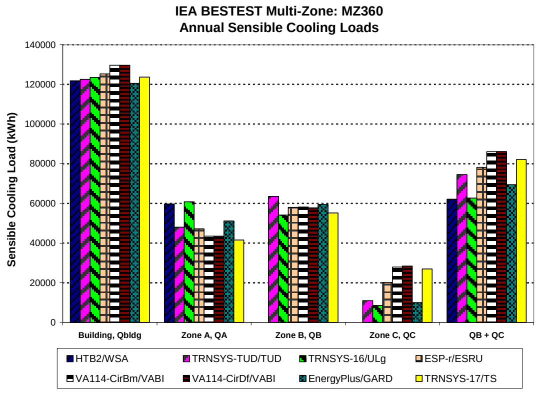

Figure 12: MZ360 Annual Sensible Cooling Loads

The tests show that the results of the new detailed distribution models are in good agreement with other simulation tools using a detailed approach like VA114.

Case MZ360: In-Depth Internal Window Calorimeter – additional results

Since the effort for determining time-dependent distribution factors for internal windows is relatively high the impact compared to a simplified approach is investigated. Therefore, additional runs are conducted where in zone B the distribution factor for direct radiation (Geosurf) are set according to the window area ratio. Thus, for window BC it is set to 0.49 and the remaing 51% are area distributed to the wall surfaces.

The results are shown in Figure 13 – 16. Due to the simplified assumption the transmitted solar radiation of window BC is higher. The increase of the total annual transmitted solar radiation into zone C is increased by 29 %. Consequently, the annual cooling load of zone B is reduced by 14 % and the one of zone C increased by 29 %. Compared to the annual load the influence of the peak load is smaller. For zone B the hourly integrated peak cooling load is reduced by 10 % whereas for zone C it is increased by 3 %.

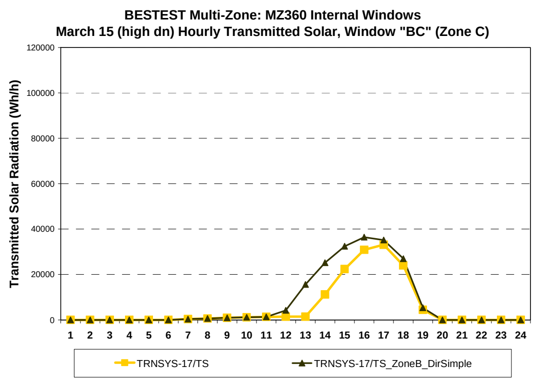

Figure 13: MZ360 Transmitted Solar, March 15th, WINDOW BC

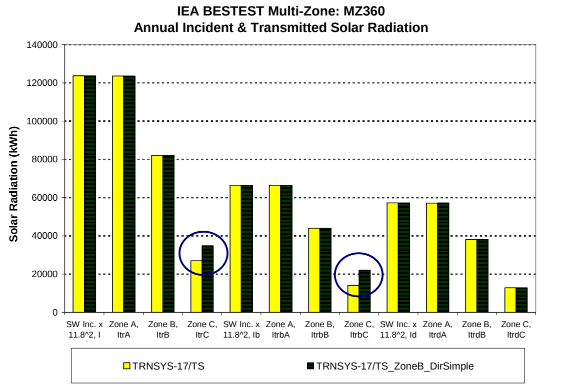

Figure 14: MZ360 Annual Incident and Transmitted Solar Radiation

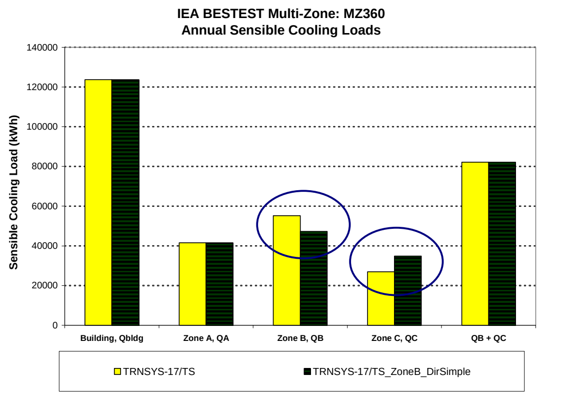

Figure 15: MZ360 Annual Sensible Cooling Loads

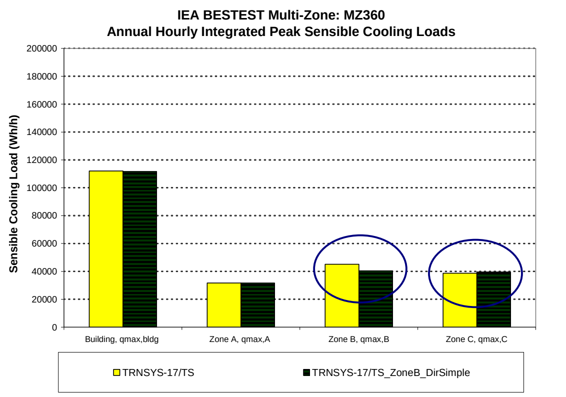

Figure 16: MZ 360 - Annual Hourly Integrated Peak Cooling Load

CONCLUSIONS AND OUTLOOK

The multi-zone non-airflow test cases developed in IEA SHC Task 34/ ECBCS Annex43 offer a very useful procedure to validate the detailed radiation models implemented in TRNSYS 17. The accomplishment of the test suite demonstrate that the new features are an improvent with respect to accuracy, user effort and error-proneness.

The results of TRNSYS 17 simulations agree very well to results of other participants. Reported modelling errors and some modelling difficulties of previous versions are fixed.

The automatic external shading calculation reduces the input effort for the user significantly compared to previous versions. In addition, test case MZ355, automated self-shading, can now be conducted successfully.

The results of test case MZ 360 demonstrate the need of detailed direct and diffuse radiation distribution models for shallow zones with large windows.

The influence of the resolution (high or medium) for generating the shading and insolation matrices is very small.

Further work of TRNSYS development should include an extension of the automatic detailed solar radiation distribution to internal windows. Also, the shading model should be extended to more sophisticated diffuse sky models like the Perez model. In addition, the standard diffuse distribution model should be improved.

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