RWTH Aachen University
E.ON ERC EBC

LOCAL4GLOBAL

Building control issues

Consortium meeting

Eibar, Spain

9th October 2014

General items:

Concrete core activation (CCA)

CCA basically is a simple method to temper the rooms ceiling for heating or cooling effects for the space. Therefore, pipes are cemented in the core of the ceiling acting as a heat exchanger between the concrete mass outside and a fluid inside the pipe. Thereby, the streaming fluid within the pipes heats or cools the concrete mass, depending on the temperature relations of concrete and fluid. Because the concrete ceiling`s mass, the thermal inertia is characteristic for CCA, wherefore this system usually is controlled for covering the base load and for compensating long-term influences as far as they are predictable (e.g. the weather changing along the seasons).

Air treatment - after cooler (AC)

In series with the central air handling unit (AHU) that provides pre-conditioned air depending on the overall weather conditions, the supply air to the spaces can be cooled more by the after cooler. That is an air-water-heat-exchanger in the supply air duct, streamed by cool water to reduce the supply air temperature and likewise to increase the cooling load for the room. The AC is a fast reacting system and meant to cover the cooling peak load within the room.

Air treatment - volume flow controller (VFC)

In series with the central air handling unit (AHU) that contains fans for generating pressure differences in the air ducts, forcing an air stream through the duct-net, flaps are installed in the supply and the exhaust air duct for each particular room. Changing the position of these flaps influences the pressure conditions in the air duct-net of the particular path and therewith the air volume flow through the room can be modified. Two effects are coupled with that: firstly, the air flow determines the change of e.g. CO_2-concentration or VOC-substances within the room by rarefaction. Secondly, the air volume flow is directly related to the (potential) cooling load of the AC unit, so an interrelation to AC-capability has to be attended!

Air treatment – façade ventilation unit (FVU)

The FVU is a small air handling unit supplying one single room with air. Therefore, fans are integrated for supply and exhaust air controllable with a frequency converter. The integrated flaps control the streaming through the components of the FVU. For thermal air treatment, heat-exchangers for heating and cooling and a heat-recovery is integrated, thus outdoor air is threatened to supply air as needed to condition the air in the supplied room. Filters clean the supply air. Because the FVU is a complex system, an own controller is integrated and facilitates to reduce the effort of controlling the FVU block by defining set points for supply temperature and air volume flow through the room.

Conference constituent system

The conference rooms face the challenge to hold the target dimensions in a small threshold against disturbances due to infrequent occupancy of different intensity of thermal loads and emissions. In addition, the weather, especially the fast alternating direct insolation, determines the thermal load within a space that has to be dissipated. The target dimensions are not interrelated directly, so it is possible to control them independently.

Table 1: Target dimensions and threshold of conference constituent systems

Dimension	Unit	Lower bound	Upper bound
Room temperature	°C	20	26
CO2-concentration	ppm	- (0)	800

Figure 1 illustrates the technical equipment of the conference constituent system, Figure 2 represents the control task with in- and output values. Data points are marked with a circle (actuator=green, sensor=red) if they already exist and with filled circles if they will be expanded. See

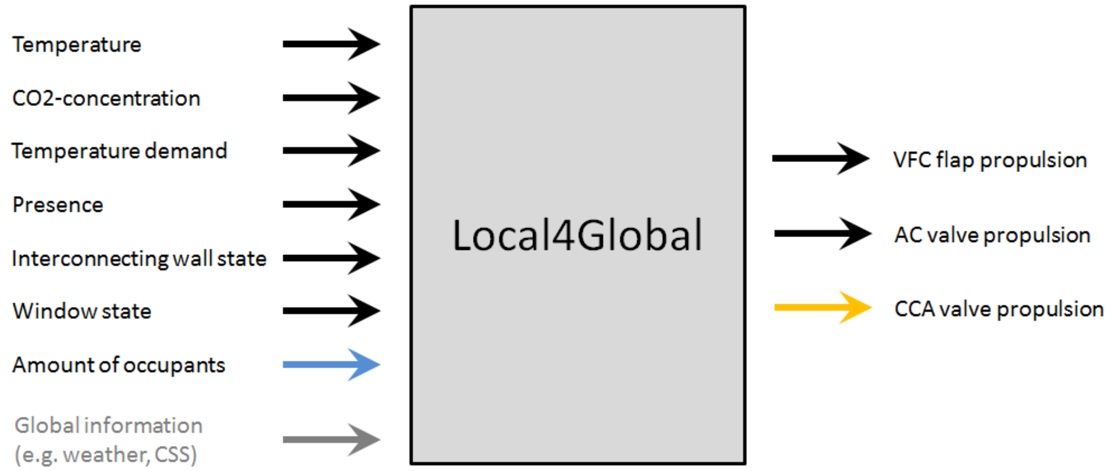

Figure 2: Local4Global control block for conference constituent systems

Table 2 and Table 3 for further information (regard the term designations on the last page).

The conference rooms are all equipped with concrete core activation (CCA), own volume flow controllers in the supply and exhaust air ducts (VFC) and own after coolers (AC). Not regarding the control issues of the central supply systems (CSS) that influence some pre-conditions like supply temperatures, supply pressure and system operations at the TSoS boundary, the VFC flap propulsions and the AC valve propulsion are the available actuators to control the target dimensions.

As an option, the CCA valve propulsion could also be taken into account to achieve control on all cooling devices with the Local4Global algorithm. One control output value is expected to be generated for this propulsion by Local4Global algorithm.

Local information is given by the input values of the sensors. The base measurements are the room temperature (T) and the CO_2-concentration (CO_2) as the rated values of the control purpose. The air volume flows are measured by sensors within the VFC units. The current control strategy regards presence information of the user by a presence sensor (PS) that initiates the control mode for 2 hours. Before and after this period, a kind of stand-by-mode is active. The user interface contains the PS and a temperature demand sensor (TD) that allows shifting the temperature set point between -3 to +3 °C from a pre-defined parameter. Further information is given by two binary values. One contact observes the state of the interconnecting wall (IS), another one of the state of the windows (WS). If two rooms are interconnected, they have to be controlled as a single room and the device capabilities can be managed this way. If one window is opened, the air flow has to be set to minimal and the AC valve has to be closed for energy saving reasons. Further depicted sensors are necessary only for evaluation reasons.

A further sensor can optionally be integrated in the control task. A people counter system (PC) measures the amount of occupants within the room as a major disturbance for control. The use of such a sensor for control reasons is not yet usual, although it allows a prediction of internal loads and emissions.

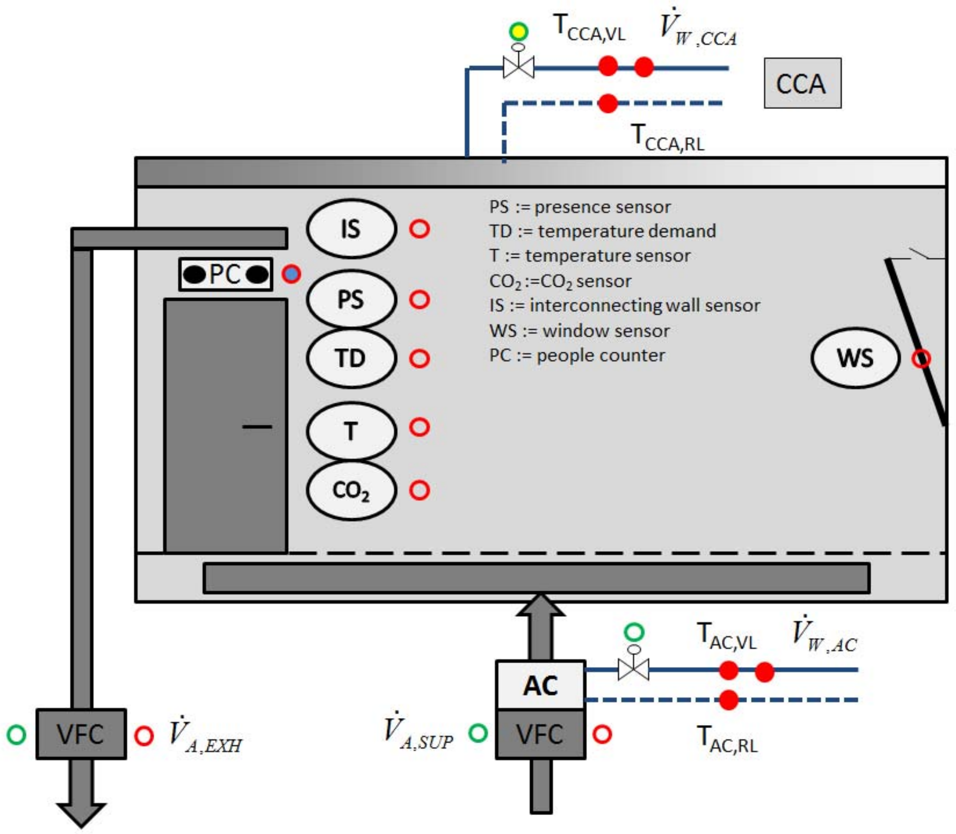

Figure 1: equipment and data point overview of conference constituent systems

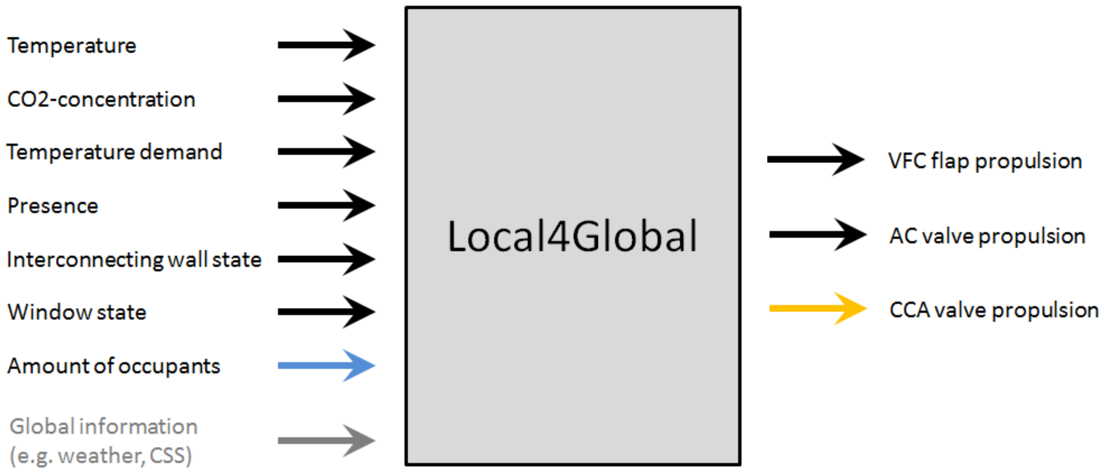

Figure 2: Local4Global control block for conference constituent systems

Table 2: list of actuators in conference constituent systems

Package	Actuator	Rated value	Allocation	State
Base	VFC propulsion supply air	% air flow (of control range)	Local	Existent
Base	VFC propulsion exhaust air	% air flow (of control range)	Local	Existent
Base	AC valve propulsion	% valve travel	Local	Existent
Opt. A	CCA valve propulsion	% valve travel or open/closed	Local	New

Table 3: list of sensors in conference constituent systems

Package	Sensor	Measured value	Allocation	State
Base	Room temperature	Abs. Value (°C)	Local	Existent
Base	CO2-concentration / VOC	Abs. Value (ppm)	Local	Existent
Base	Temperature demand	Abs. Value (Δ°C)	Local	Existent
Base	Presence sensor	Binary value (1/0)	Local	Existent
Base	Window sensor	Binary value (1/0)	Local	Existent
Base	Interconnecting wall sensor	Binary value (1/0)	Local	Existent
Base	VFC supply air flow	Abs. Value (m^3/h)	Local	Existent
Base	VFC exhaust air flow	Abs. Value (m^3/h)	Local	Existent
Opt.B	People counter	Abs. value (number of occupants)	Local	New
Eval.	CCA volume flow water	Abs. Value (m^3/h)	Local	New
Eval.	CCA temperature water supply line	Abs. Value (°C)	Local	New
Eval.	CCA temperature water return line	Abs. Value (°C)	Local	New
Eval.	AC volume flow water	Abs. Value (m^3/h)	Local	New
Eval.	AC temperature water supply line	Abs. Value (°C)	Local	New
Eval.	AC temperature water return line	Abs. Value (°C)	Local	New
Eval.	Weather temperature	Abs. Value (°C)	Global	Existent
Eval.	Weather global radiation	Abs. Value (W/m^2)	Global	Existent
Eval.	Weather direct radiation	Abs. Value (W/m^2)	Global	Existent
Eval.	Weather wind direction	Abs. Value (ang.deg.)	Global	Existent
Eval.	Weather wind speed	Abs. Value (m/s)	Global	Existent
Eval.	AHU supply air temperature	Abs. Value (°C)	Global	Existent
Eval.	AHU supply air humidity	Abs. Value (% rel.)	Global	Existent
Eval.	AHU supply air CO2-concentration	Abs. Value (ppm)	Global	Existent

Office constituent system

The offices face the challenge to hold the target dimensions in a small threshold against disturbances (thermal loads, emissions) due to occupancy and equipment operations. Depending on the thermal relation of room and outdoor temperature, loads have to be identified either they are useful or not for deriving control decisions. The target dimensions are not interrelated directly, so it is possible to control them independently.

Dimension	Unit	Lower bound	Upper bound
Room temperature	°C	20	26
CO2-concentration	ppm	- (0)	800

Figure 3 illustrates the technical equipment of the conference constituent system, Figure 4 represents the control task with in- and output values. Data points are marked with a circle (actuator=green, sensor=red) if they already exist and with filled circles if they will be expanded. See Table 4 and Table 5 for further information (regard the term designations on the last page).

The offices are all equipped with concrete core activation (CCA) and an own façade ventilation unit (FVU) with heating and cooling heat-exchangers, heat-recovery, filters, fans and flaps. Aggregating the FVU`s devices, the FVU block is an independently operating and controlled subsystem, that only needs one set point for supply temperature and one set point for air flow.

As a option, the CCA valve propulsion could also be taken into account to achieve control on all cooling devices with the Local4Global algorithm. One control output value is expected to be generated for this propulsion by Local4Global algorithm.

As another option, the FVU block could be decomposed and each actuator and sensor could be controlled by Local4Global algorithm independently.

Local information is given by the input values of the sensors. The base measurements are the room temperature (T) and the CO_2-concentration (CO_2) as the rated values of the control purpose. The air handling completely is encapsulated in the FVU block. The current control strategy regards presence information of the user by a presence sensor (PS), thus presence depending operations are possible. The user interface contains the PS and a temperature demand sensor (TD) that allows shifting the temperature set point between -3 to +3 °C from a pre-defined parameter. Further information is given a contact that observes the state of the windows (WS). If a window is opened, the FVU block has to be set to a minimal mode. Further depicted sensors are necessary only for evaluation reasons.

A further sensor can optionally be integrated in the control task. A people counter system (PC) measures the amount of occupants within the room as a major disturbance for control. The use of such a sensor for control reasons is not yet usual, although it allows a prediction of internal loads and emissions.

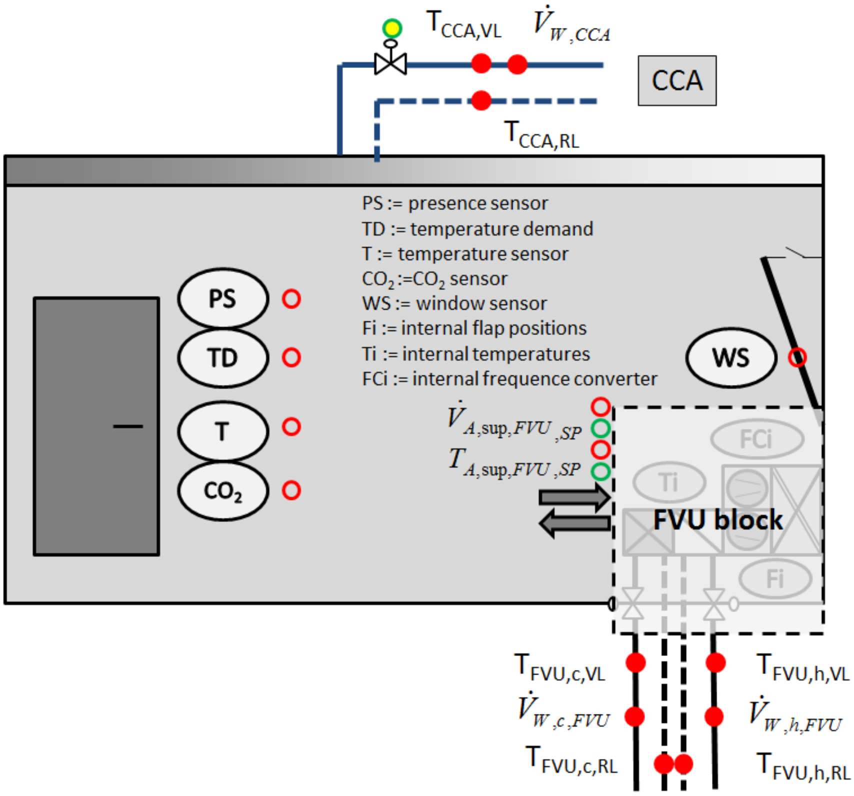

Figure 3: equipment and data point overview of office constituent systems

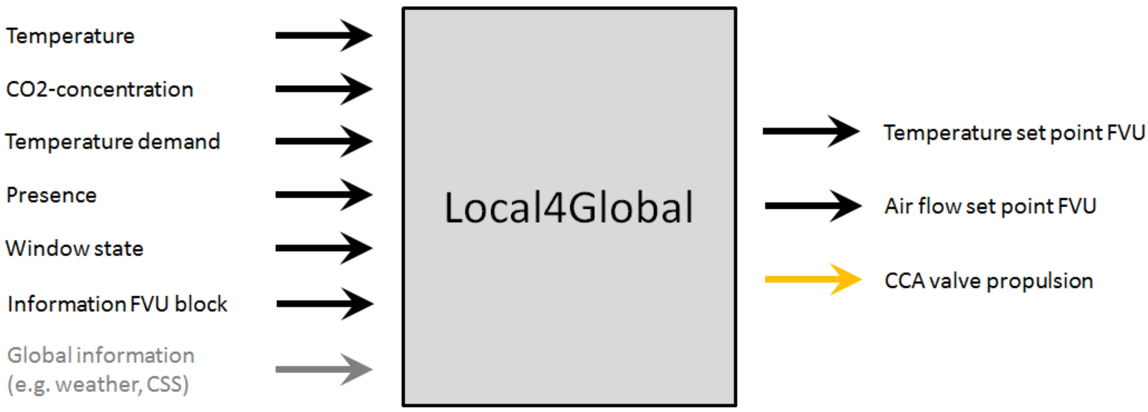

Figure 4: Local4Global control block for office constituent systems

Table 4: list of actuators in office constituent systems

Package	Actuator	Rated value	Allocation	State
Base	FVU-Block set point air flow	value (m^3/h)	Local	Existent
Base	FVU-Block set point supply air temperature	value (°C)	Local	Existent
Opt.A	CCA valve propulsion	% valve travel or open/closed	Local	New
Opt.C	Probably decomposition of FVU-Block	Multiple	Local	New

Table 5: list of sensors in office constituent systems

Package	Sensor	Measured value	Allocation	State
Base	Room temperature	Abs. Value (°C)	Local	Existent
Base	CO2-concentration / VOC	Abs. Value (ppm)	Local	Existent
Base	Temperature demand	Abs. Value (Δ°C)	Local	Existent
Base	Presence sensor	Binary value (1/0)	Local	Existent
Base	Window sensor	Binary value (1/0)	Local	Existent
Base	FVU supply air flow	Abs. Value (m^3/h)	Local	Existent
Base	FVU exhaust air flow	Abs. Value (m^3/h)	Local	Existent
Opt.C	Probably decomposition of FVU-Block	Multiple	Local	New
Eval.	CCA volume flow water	Abs. Value (m^3/h)	Local	New
Eval.	CCA temperature water supply line	Abs. Value (°C)	Local	New
Eval.	CCA temperature water return line	Abs. Value (°C)	Local	New
Eval.	FVU volume flow water hot	Abs. Value (m^3/h)	Local	New
Eval.	FVU temp. water supply hot	Abs. Value (°C)	Local	New
Eval.	FVU temp. water return hot	Abs. Value (°C)	Local	New
Eval.	FVU volume flow water cold	Abs. Value (m^3/h)	Local	New
Eval.	FVU temp. water supply cold	Abs. Value (°C)	Local	New
Eval.	FVU temp. water return cold	Abs. Value (°C)	Local	New
Eval.	Weather temperature	Abs. Value (°C)	Global	Existent
Eval.	Weather global radiation	Abs. Value (W/m^2)	Global	Existent
Eval.	Weather direct radiation	Abs. Value (W/m^2)	Global	Existent
Eval.	Weather wind direction	Abs. Value (ang.deg.)	Global	Existent
Eval.	Weather wind speed	Abs. Value (m/s)	Global	Existent

Term designation:

- Package “Base” has to be controlled by Local4Global at least
- Package “Opt. # “ offers an interesting option for the building control purposes
- Package “Eval.” represents all sensor values that are necessary for evaluation task
- State “Existent” marks positions that are already available and used for current control strategy
- State “New” marks positions that will be expanded for project reasons as far as unavailable yet (e.g. evaluation, verification or artificial circumstances)
- Allocation “local” marks positions that contain information of the local level
- Allocation “global” marks positions that contain (the most essential) information of the global level

Simulation – code transfer

```
model Pipe
  extends Interfaces.TwoPort;

  import Modelica.Math;

  parameter Modelica.SIunits.Length D=0.05 "Diameter";
  parameter Modelica.SIunits.Length l=1 "Length";
  parameter Modelica.SIunits.Length e=2.5e-5 "Roughness";

  parameter Modelica.SIunits.Temperature T0=baseParameters.T0
    "Initial temperature" a;

  Modelica.SIunits.Temperature T "Temperature inside the CV";

protected
  Modelica.SIunits.ReynoldsNumber Re(nominal=1e5) "Reynolds number";
  Real lambda2 "Modified fanning friction factor";

  parameter Modelica.SIunits.Temperature T_ref=baseParameters.T_ref;
  parameter Modelica.SIunits.Mass m=Modelica.Constants.pi*D^2/4*l*rho
    "Mass of the fluid in CV";
  Modelica.SIunits.Energy U(start=m*cp*(T0 - T_ref)) "Internal energy";
  Modelica.SIunits.EnthalpyFlowRate H_flow_a "Enthalpy at port a";
  Modelica.SIunits.EnthalpyFlowRate H_flow_b "Enthalpy at port b";

equation
  port_a.h_outflow = cp*(T-T_ref);
  port_b.h_outflow = cp*(T-T_ref);
  H_flow_a = port_a.m_flow*actualStream(port_a.h_outflow);
  H_flow_b = port_b.m_flow*actualStream(port_b.h_outflow);

  U = m * cp * (T-T_ref);
  der(U) = heatport.Q_flow + H_flow_a + H_flow_b;
  heatport.T = T;

  lambda2 =  abs(p)*2*D^3*rho/(l*mu*mu);
  Re = -2*sqrt(lambda2)*Math.log10(2.51/sqrt(lambda2+1e-10) + 0.27*(e/D));
  m_flow =  sign(p)*Modelica.Constants.pi/4*D*mu*Re;

  a
end Pipe;
```