
EMATEM
European Metrology Association
for Thermal Energy Measurement

Fast response thermal energy meters: Results on dynamic Modelling & Simulation, Proposal for test procedure

// Content

Fast Response Thermal Energy Meters: Goals and motivation / Field situation

Fast hot water tapping processes occur in heating systems with following features:

-> hot water systems without hot water storage, typical for systems without boilers

-> combined dynamic heating and fast hot water systems without hot water storage

-> district heating systems with small heating in-house substations without hot water storage

The EU market share of this systems is growing and is today in the range of around 10 … 15% for new installations.

Heat meters as ‚state of the art' work typically with sampling time >= 16 Seconds and with different types of temperature sensors (with low or high inertness). Some types of meters work with different adaption modes for sampling or integration, what is influencing the registration essentially.

We do not really know, what are the real requirements in relation to sensor inertness, sampling times, integration time and integration methods of heat meter calculator in fast metering appliances.

Fast Response Thermal Energy Meters: Goals and motivation (1)

Current Annex C in EN1434-1 (2015/A1:2018)

Annex C
(normative)

Fast response meters

A meter or sub-assembly defined as "Fast response meter" shall have at least the following additional specifications:

— Response time ($\tau_{0,5}$): max. 6 s for long temperature sensors; max. 2,5 s for short temperature sensors.

— For battery driven meters the time between measuring samples (flow and temperature) and as well as incremental energy calculations: for time interval based measurement 8 s are recommended. For volume quantum based measurement 8 s * q_p/q or by equivalent volume fraction are recommended.

— For meters driven by mains the time between measuring samples (flow and temperature) and as well as incremental energy calculations: for time interval based measurement 4 s are recommended. For volume quantum based measurement 4 s * q_p/q or by equivalent volume fraction are recommended.

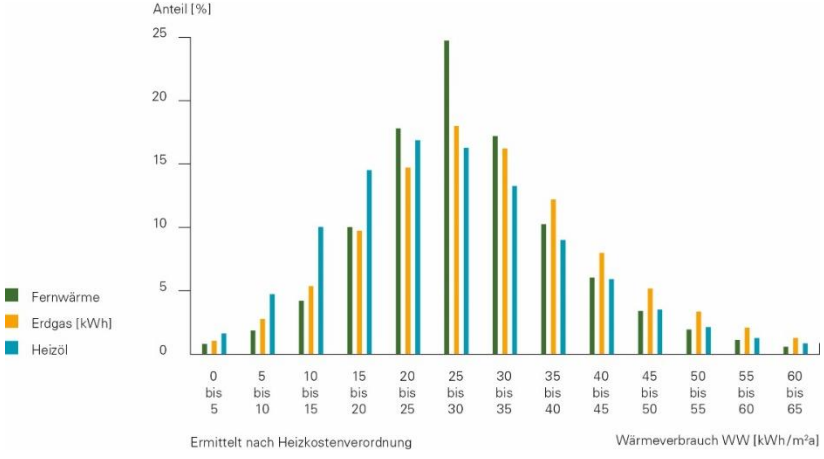
Do this requirements describe the real technical demands properly with respect to expected measurement deviations and resulting cost shifts?

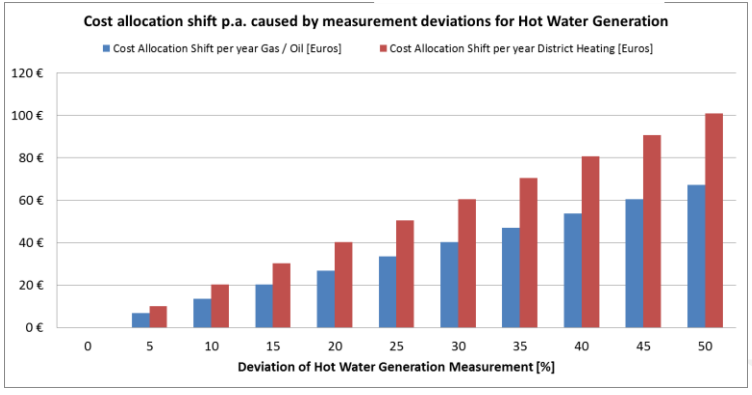
Fast Response Thermal Energy Meters: Goals and motivation (2)

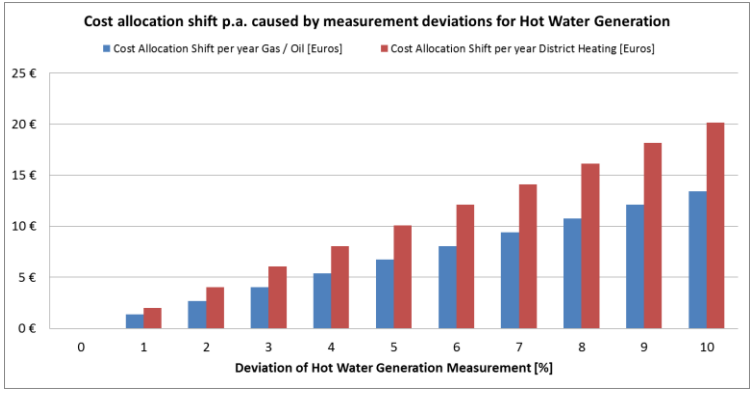
Expected cost allocation shifts per apartment resp. unit for hot water

Cost allocation shift is calculated with following assumptions:

- 6 EuroCent per kWh (Gas / Oil)
- 9 EuroCent per kWh (District Heating)
- Square per flat: 70 m^2
- Energy consumption for hot water p.a.: 32 kWh/m^2







Fast Response Thermal Energy Meters: Goals and motivation (3)

Investigation and definition of Fast Response Meters requirements / parameters is set as a Work Item in CEN TC 176 WG2 with following goals:

For fast hot water tapping processes

-> without hot water storage, typically without boilers

-> e.g. in district heating systems

clarify and quantize the impact on the calculation results of the heat meter calculator of:

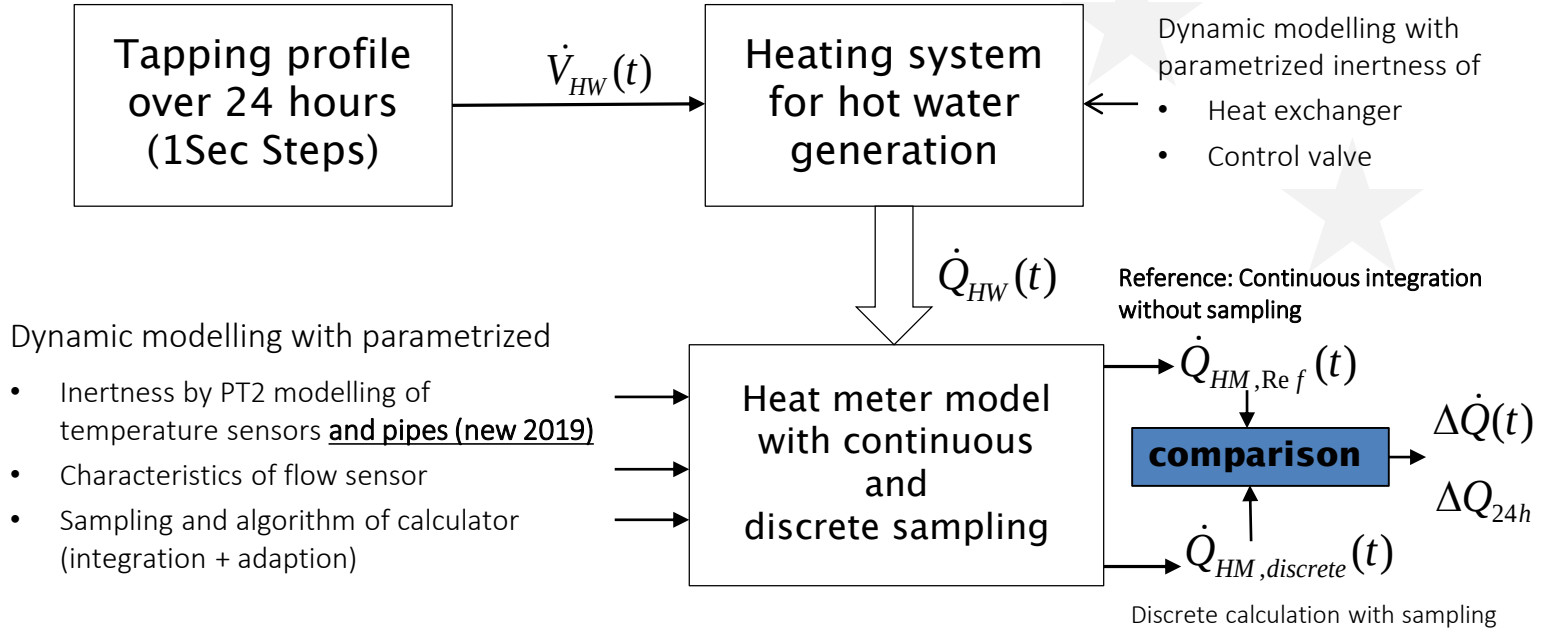
- Inertness (response time) of temperature sensors for measuring flow (inlet) temperature and back flow (outlet) temperature
- Sampling time and integration time interval of heat meter calculator
- Tapping profile type
- Inertness (response time) of pipes, heat exchanger and control valves

Normative goals:

- Definition of requirements in EN 1434 / rev. 2020 on Fast Response Thermal Meters
- Definition of appropriate test procedures

Fast Response Thermal Energy Meters: Investigation Methodology

Modularised Modelling and Simulation with Parameter Studies

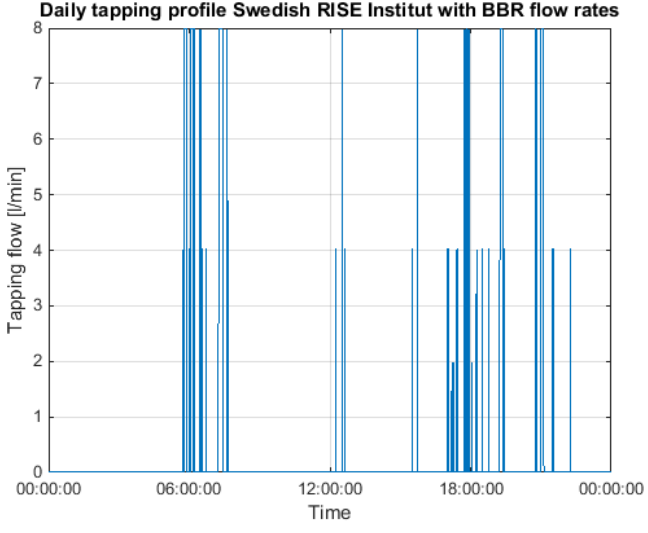


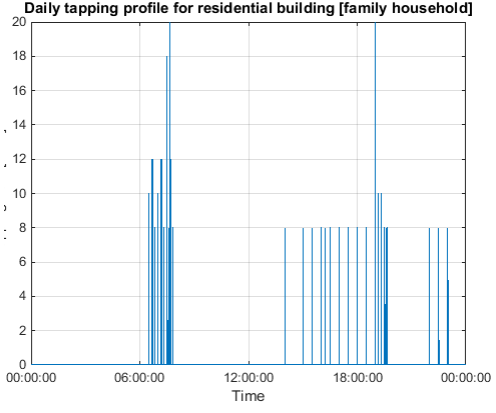
Fast Response Thermal Energy Meters: Achievements in 2018 / 2019

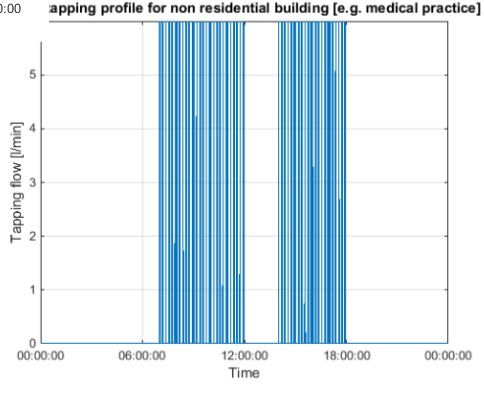
- Profiling and Modelling of HotWaterTapping(s) for apartments in residential buildings (family houses, multi apartment houses) and non residential buildings (for e.g. medical practice) defined and implemented
- Dynamic modelling of heating system and heat meter including sensors defined and implemented
- Simulation environment under Matlab/Simulink developed
- Simulations and parameter studies established and finished
- Recommendations for Heat Meter Sensors and Calculator derived
- New Wording for Annex C on Fast response meters proposed by German Mirror Committee CEN TC 176 at 22.03.2018
- Requirements on fast response heat meter sensors and calculators for EN 1434 rev. 2020 fixed by CEN TC 176 WG2 in Brondby, 13.02.2019
- Test environment for testing fast response flow meters with real hot water tapping realized (kamstrup)
- Proposal for testing fast response flow meters for en1434-4 rev. 2020 available (kamstrup and others)

Fast Response Thermal Energy Meters: Results in 2018 / 2019

Tapping profiles for residential (family) and non residential buildings





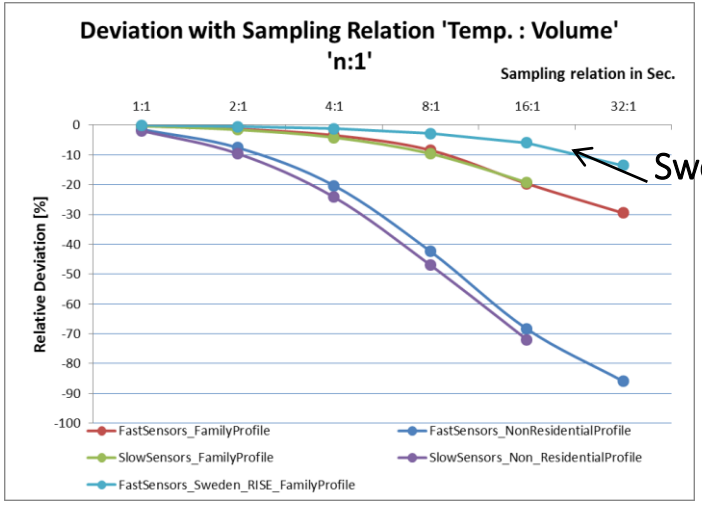


Swedish tapping profile provided by Mr. Franzen / Göteborg Energi.

Fast Response Thermal Energy Meters: Results in 2018 / 2019

Modelling, Simulation and Parameter Studies with different tapping profiles

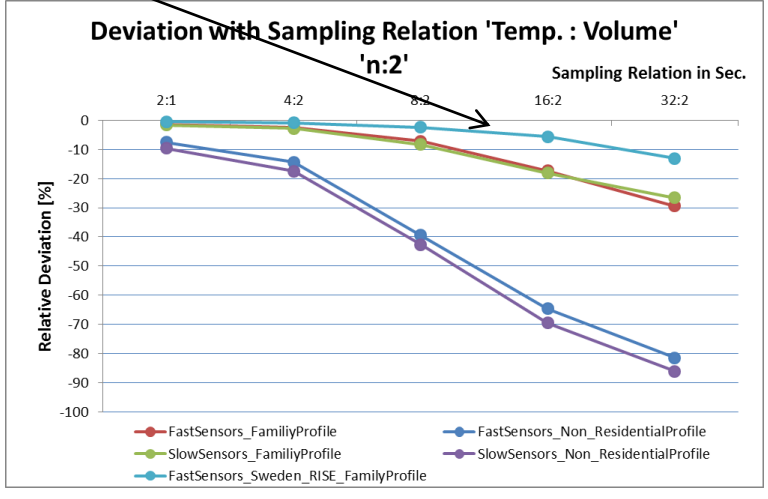
Reference: energy calculation without sampling (continuous measuring) and with continuous integration



Residential (family) tapping profiles lead to lower deviations. Non residential tapping profiles more sensitive in relation to the sampling rate.

Lowering the sampling rate leads to significant higher losses of the heat calculation. Influence of sensor inertness lower than sampling rate.

Swedish profile



Fast Response Thermal Energy Meters: New Recommendations

Recommendations for fast response heat meter sensors and calculators based on Modularised Modelling and Simulation and Parameter studies

- Temperature sampling time / sampling time interval:
  - <= 4 Seconds (non residential buildings, e.g. medical practice)
  - <= 8 Seconds (family houses, multi apartment / residential buildings)
- Volume sampling time: <= 2 Seconds (non residential buildings and family houses)
- Integration time = Volume sampling time
- Time constants (‚50% Value‘) of temperature sensors (DS): <= 3 Sec.

Fast Response Thermal Energy Meters: New wording proposal in Annex C

New Wording for Annex C on Fast response meters proposed by German Mirror Committee CEN TC 176 at 22.03.2018.

Annex C
(normative)

Fast response meters

A meter or sub-assembly defined as "Fast response meter" shall have at least the following additional specifications:

— Response time ($\tau_{0,5}$): max. ~~6~~ 3 s for ~~long~~ direct installed temperature sensors (temperature pockets shall not be used)~~; max. 2,5 s for short temperature sensors.~~

— Volume sampling times shall be equal or less than 2 s;

— Temperature sampling times shall be equal or less than 8 s for residential applications;

— Temperature sampling times shall be equal or less than 4 s for non-residential applications.

Fast Response Thermal Energy Meters: New Requirements

Requirements on fast response heat meter sensors and calculators
- Decision of CEN TC 176 WG2 in Brondby, 13.02.2019 -

- Temperature sampling time / sampling time interval:
  - <= 4 Seconds (non residential buildings, e.g. medical practice)
  - <= 8 Seconds (family houses, multi apartment/non residential buildings)
- Volume sampling time: <= 2 Seconds (non residential and family houses)
- Integration time = Volume sampling time
- Time constants (‚50% Value') of temperature sensors (DS): <= 3 Sec.

Decision of CEN TC 176 WG2 in Brondby , 13.02.2019:

This Requirements and the test procedure for fast response flow meters will be a part of the en 1434 revision 2020.

Fast Response Thermal Energy Meters: Test Proposal (Kamstrup and others)

Current Test of “Fast response flow sensors” does not reflect fast tapping / metering processes

Current Text in EN 1434 – 4: 2015, clause 7.4.2.4:

7.4.2.4 Fast response meters

For fast response meters the transient behaviour of the flow sensors of size $q_p \leq 2{,}5$ m³/h shall be investigated by measuring the total quantity of water delivered in 10 to 15 cycles, consisting of 10 s period at a flow rate of q_s and 30 s period at zero flow rate.

The duration of start and stop shall be (1 ± 0,2) s.

The water temperature shall be as a) in 7.4.2.2.

The error shall not exceed the MPE.

For a complete or combined meter, the water temperature specified above is the outlet temperature. The temperature difference shall be the maximum obtainable, but shall not exceed 42 K.

Fast Response Thermal Energy Meters: Test Proposal (Kamstrup and others)

Proposal for a new test “Fast response flow sensors / meters”

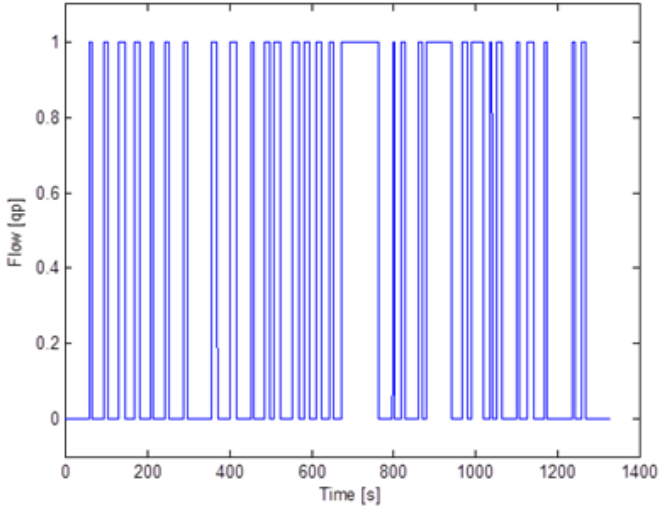
Proposal for new text (EN 1434-4:2020)

– presented and accepted at CEN TC 176 WG in Brondby, 13.02.2019 –

- WG2_N0706_Proposal_to_new_test_Fast_response_flow_sensors_meters_....pdf -

New Proposal:

Tapping profile: combination of periods with flow rate = qp or 0 (switching), start with q = 0



- the water temperature shall be in the range (15±5) °C
- opening & closing time of the utilized valve: < 1 Sec
- 6 samples of identical flow meters (15 repetitions with each)
- averaged deviation ($q - q_{Test}$) of 15 repetitions of all 6 samples shall not exceed the MPE
- only 5 out of 15 deviations determined for all 6 samples are allowed to exceed the MPE

Fast Response Thermal Energy Meters: Tasks for 2019 and 2020

Proposal for a test procedure for fast response meters

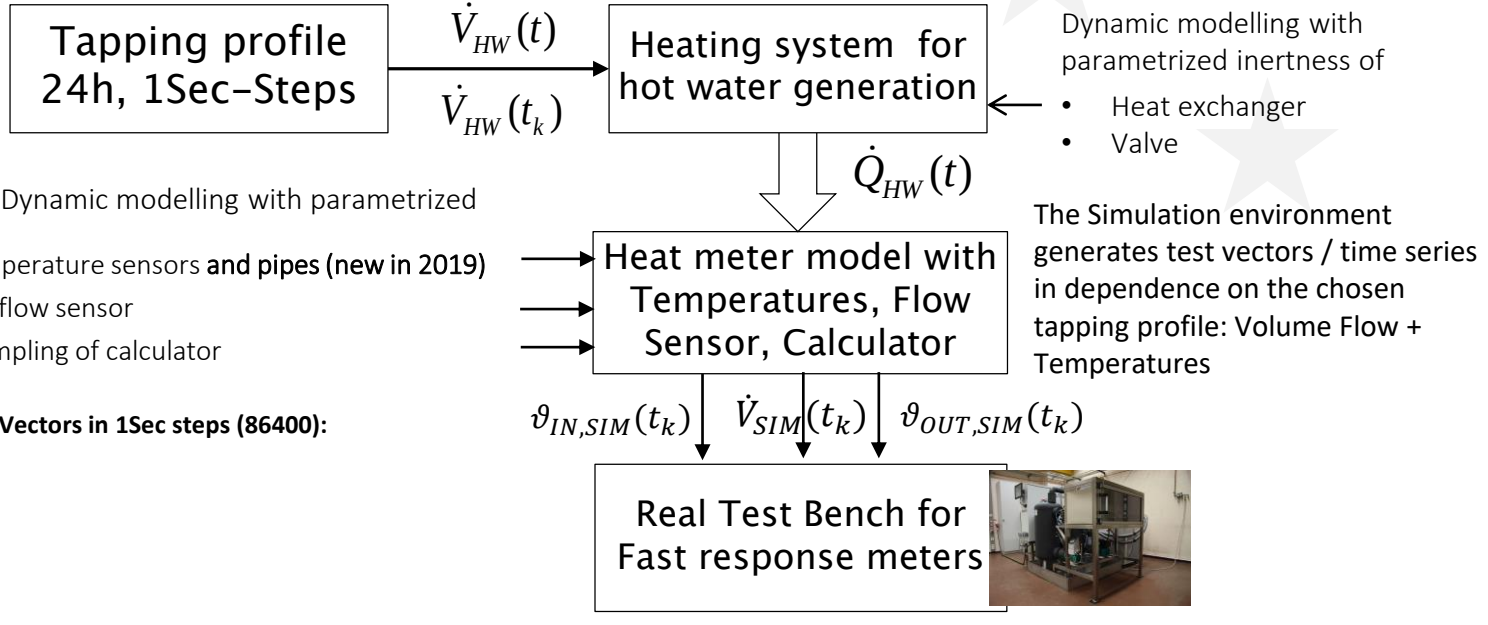
Decision of CEN TC 176 WG in Brondby, 13.02.2019 :

Definition and Release of new test / approval procedure(s) for fast response meters

- for fast response flow sensors: done
  (CEN-TC176-WG2_N0706_Proposal_to_new_test_Fast_response_flow_sensors__meters_Mr_Lang_replaces_N_698.pdf
  CEN-TC176-WG2_N0705_Updated_presentation_fast_response_meters_Dr_KaehlerMr_Lang_Mr_Bombis.pdf)
- for fast response calculator (sampling T, V and integration to heat energy): in progress (PTB)

Fast Response Thermal Energy Meters: Tasks for 2019 and 2020

Proposal for a test procedure on energy calculation for fast response thermal meters



Fast Response Thermal Energy Meters: Tasks for 2019 and 2020

Next steps on fast response heat meter sensors

- Decision of CEN TC 176 WG in Brondby, 13.02.2019 -

- In general: Definition [in EN1434 / 2020] of requirements on measurement dynamics of thermal meters with respect to state of the art combined dynamic heating and fast hot water systems without storages with defined tapping profile(s): done
- Fixing of reference tapping profile(s) for modelling and measurements/tests: done
- Definition and Release of new test / approval procedure(s) for fast response meters: Partly done, in progress
  - for fast response flow sensors: done
    (CEN-TC176-WG2_N0706_Proposal_to_new_test_Fast_response_flow_sensors__meters_Mr_Lang_replaces_N_698.pdf
    CEN-TC176-WG2_N0705_Updated_presentation_fast_response_meters_Dr_KaehlerMr_Lang_Mr_Bombis.pdf)
  - for fast response calculator (sampling T, V and integration to heat energy), Energy calculation: in progress (PTB)
- Clearing of deviations between modelling and measurements: in progress
  - ‚CEN-TC176-WG2_N0678_Fast_ResponseMeters_Mr_Kähler.pdf', / Techem (Kaehler), 2018 + 2019 (update: N705)
  - ‚Thermal Energy Meters with short integration times' / Energiforsk, Goeteborg Energy, Sweden, 2019
    (CEN-TC176-WG2_N0695_Thermal_energy_meters_with_short_integration_times_Mr_Franzén.pdf)
  - 'Fast response meters: Explorative experimental investigations' / kamstrup (Bombis), CEN TC 176, WG2, N677, 2018
- Investigation or measurements on impacts of calculators with adaptive integration mode
- Improvements on existing dynamic modelling of heating system (e.g. heat exchanger, temperatur level, pipes): in progress
- Modelling and Implementation of additional inertness caused by tubes resp. pipes, investigation of impact on dynamic temperature sensor behaviour (Jumo: Nau and Bott, Techem: Kähler): in progress

Fast Response Thermal Energy Meters: Tasks for 2019 and 2020

Clearing of deviations between modelling and measurements: current status

The following documents resp. studies are available:

(1) ‚CEN-TC176-WG2_N0678_Fast_ResponseMeters_Mr_Kähler.pdf', / Techem (Kaehler), 2018 + 2019 (update: N705)

(2) ‚Thermal Energy Meters with short integration times' / Energiforsk, Goeteborg Energy, Sweden, 2019
(CEN-TC176-WG2_N0695_Thermal_energy_meters_with_short_integration_times_Mr_Franzén.pdf)

(3)'Fast response meters: Explorative experimental investigations' / kamstrup (Bombis), CEN TC 176, WG2, N677, 2018

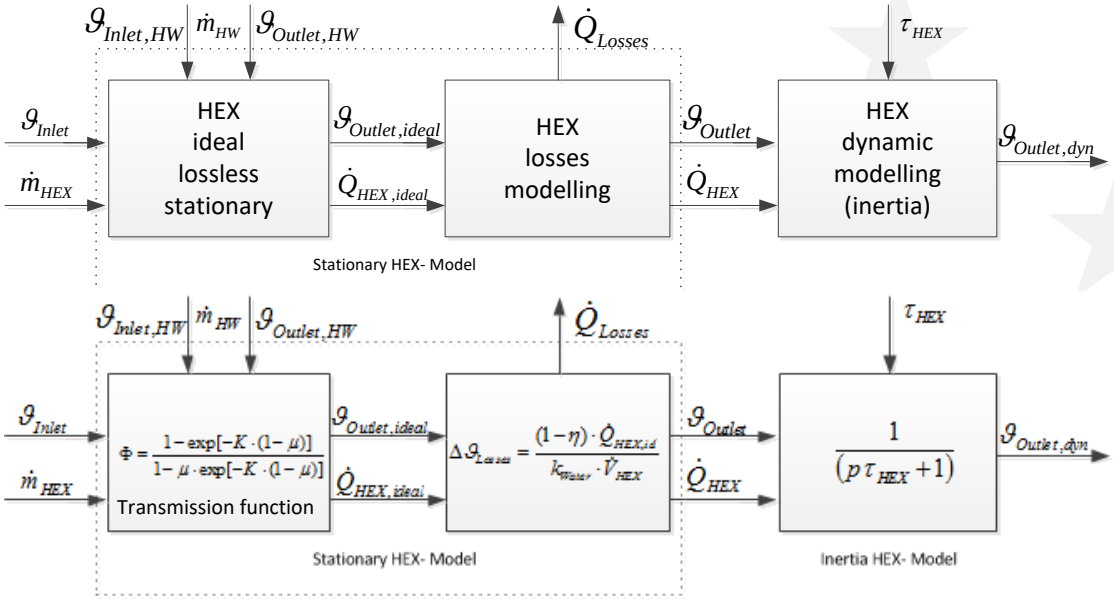
(1) Model-based and modularized simulation approach with changeable parameters, high stability of repeatabiltity:
- significant impact of sampling time and integration time if longer than 8 Seconds: 16, 32 Seconds critical
- improvements on temperature level (inlet/outlet) and on dynamic modelling of pipes / heat exchanger: model ready, validation with measurements from JUMO expected in September 2019.

(2) Study with field based ‚swedish' tapping profile and comparison of heat meters with integration time 2, 8, 32 Seconds.
- Deviation between heat meters around 1…2 % only, as a reference an US heat meter (same type) was used.
- Unknown: algorithm of heat meter calculator (influence of adaption mode?), different sampling time for temperature / flow?

(3) investigation of (low ~1%) impact of sampling/integration time on flow sensor measurements, impact on energy still open.

Fast Response Thermal Energy Meters: Tasks for 2019 and 2020

Improvements on dynamic modelling: Proposal for Modelling the Heat Exchanger



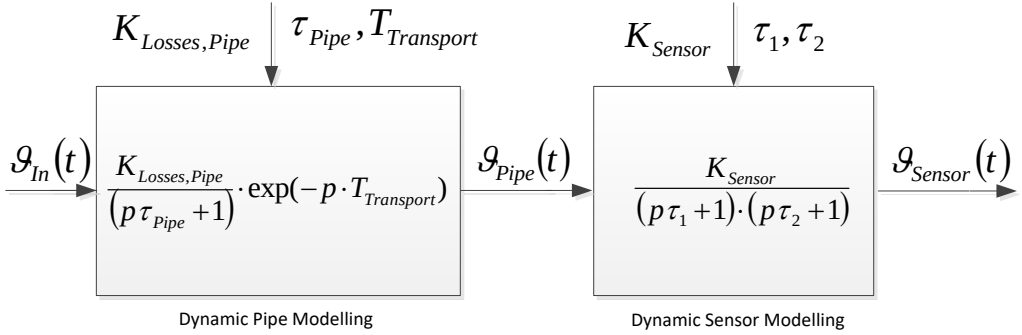
To be validated & parametrized in Matlab/Simulink Modelling.

-> Measurement data for adjustment needed …

Fast Response Thermal Energy Meters: Tasks for 2019 and 2020

Improvements on dynamic modelling:

Proposal for implementing pipe losses and pipe inertness



To be validated & parametrized in Matlab/Simulink Modelling.

-> Measurement data for adjustment needed … (JUMO?)

Many thanks for your kind attention.

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