IEA ECES Annex 30 Subtask 1

Process Analysis Guidelines

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1. Document summary and goals

The goal of the subtask is the development of process analysis guidelines and the testing of these analysis steps with work conducted by researchers in Annex 30.

The goals of the guidelines are twofold. One the one hand, these guidelines can serve as guidance for researchers developing thermal energy storages for industrial processes and upscaling from the laboratory setting. On the other hand, the process analysis guidelines can assist process customers or partners in assessing the necessary information and depth of information at the various steps of the evaluation and design.

The combination of the process analysis conducted here in Subtask 1 and the storage unit analyses conducted in Subtask 2 *Technical Parameters* and Subtask 3 *Economic Parameters* results in a combination of factors that can be used for evaluating the integration of a storage unit. This is analyzed in Subtask 5 *Key Performance Indicators*.

These guidelines have been developed with a focus on industrial processes and power plants. In addition, the focus has been on integrating storage units into already existing processes. These guidelines can be used for other processes or greenfield applications, but some adjustment may be necessary.

2. Process analysis guidelines

For designing thermal energy storage units, various aspects must be considered. Some of the considerations are only relevant if the storage is to be physically integrated and not solely theoretically evaluated for integration.

The main step in this procedure is the collection and analysis of process information. Following that, a storage concept can be evaluated, roughly planned and thereafter, the aspects of detailed engineering become relevant. Realistically, the concept and integration are evaluated in parallel.

For the process analysis, different types of information are necessary and/or beneficial. Sometimes, however, the optimum information is not available and secondary sources have to be used. The information *sources* discussed within the subtask are listed in Table 2-1.

Measured transient data
Average system values
Database information
Fuel use extrapolation
PID analysis
Commercial information
Extrapolation from CO_2 emissions
Company experts
Industry experts

Table 2-1: Information sources for process data.

The process analysis guidelines can be broken down into six steps:

- Step 1: Define process and boundaries
- Step 2: Identify thermal sources
- Step 3: Identify thermal sinks
- Step 4: Quantify the source and sink
    - Step 4.1: Thermodynamics
    - Step 4.2: Physical properties
- Step 5: Analyze general factors
- Step 6: Summarize analysis

Step 1: Define process and boundaries

In order to analyze a process for storage integration, the process has to be defined or selected and the process boundaries for analysis clarified. Currently, process definition is a part of project research work, and typically entails a partner discussing process aspects with research institutions. If only parts of the process are analyzed, it helps to clarify this limitation.

Questions

1. What is the process or part of the process being analyzed?
2. What is the overall goal of the possible storage integration?

Step 2: Identify thermal sources

As a first step, thermal sources have to be identified. This can be done via discussion with (industry) specialists, analysis of PIDs, process database analysis, estimation via extrapolation of fuel usage or measurement. In this analysis, the terms thermal source and thermal sink are referring to energy from the perspective of a possible thermal energy storage integration.

This information can (and probably should) be gathered in two steps – an initial estimation to preliminarily determine the benefit of pursuing more detailed information, followed by the more detailed information itself. Some of this information may be confidential.

Typical sources can be waste heat or part of the process. Sources collected within this subtask are listed in Table 2-2. If there is no heat source found within a process, there is no need for a storage system. However, when also considering Power-to-Heat systems, excess electricity can also be seen as a heat source.

Waste heat
Heat provided directly for charging – i.e. steam from HRSG
Electricity
Direct combustion
HTF from solar field in CSP plants
HTF from solar field for solar process heating / cooling
Cooling water / exhaust gas
Lake water, ambient air

Table 2-2: Analyzed thermal energy sources.

<u>Questions</u>

1. What thermal source(s) was/were selected?
2. Why was/were this/these selected?
3. What sources were considered?

Step 3: Identify thermal sinks

As a second step, thermal sinks have to be identified. As with the sources, this can be done via discussion with (industry) specialists, analysis of PIDs, process database analysis, estimation via extrapolation of fuel usage or measurement.

This information again can (and probably should) be gathered in two steps – an initial estimation to preliminarily determine the benefit of pursuing more detailed information, followed by the more detailed information itself. Some of this information may be confidential.

Typical sinks can be preheating or electricity generation and as such can be external to original process boundaries. Sinks collected within this subtask are listed in Table 2-3.

ORC Process
Steam turbine
Steam main
Heat pump
Process heat (direct integration)
Water main
Space heating
Upgraded heat at a higher temperature by heat transformation
Thermal Electric Generator
Environment (esp. cold storage)
Back to source

Table 2-3: Analyzed thermal energy sinks.

<u>Questions</u>

1. What thermal sink(s) was/were selected?
2. Why was/were this/these selected?
3. What sinks were considered?

Step 4: Quantify the source and sink

The source and a sink must first be quantified in order to evaluate their potential applicability for TES integration. There are two major groups of parameters in this quantification – thermodynamics and physical properties.

1. Thermodynamics

These data can be analyzed independently of the physical factory or environment, though without consideration of the physical properties, a full analysis is not possible. These data are, however, most critical for the storage concept development.

The following distinctions are clarified for liquid energy sources. If electricity is used as the energy source, the transient supply characteristics must be determined. The other parameters detailed here are then only necessary for the sink.

a) Medium

The medium of the source or sink influences the heat transfer rate, types of containment and materials used and applicable storage concepts. In some cases, an additional heat transfer fluid will need to be introduced into the system as a heat transfer medium. Media collected within this subtask are listed in Table 2-4.

Fluid	Source?	Sink?	Additional?
Thermal oil	X	X	X
Water (and water mixtures)	X	X	X
Air (Ambient)	X	X	X
Air (Flue gas)	X		
Steam	X	X	X
Molten salt	X	X	X
Molten metal	X	X	X
Refrigerants			X
Emulsions and slurries			X
Helium and CO_2	X	X	X

Table 2-4: Heat transfer fluids

<u>Questions</u>

1. Which medium(s) is/are used as the thermal source?
2. Which medium(s) is/are used as the thermal sink?
3. Is there a closed loop involved?

b) Temperature levels and transient profiles

The temperature levels and transient profiles of the source and/or the sink are key for the development of a thermal energy storage concept, its power level and its capacity (in combination with further characteristics). Information about the temperature level or temperature range can help establish the motivation and usefulness of storage integration. For detailed development, access to the transient temperature profiles is necessary.

If electricity is used as the energy source, then the transient profiles of this availability are necessary as well.

The mass flow rates and the transient character of the source and sink are critical for the power level and capacity determination.

The pressure, as well as the transient profile thereof, determines the phase of the heat transfer medium and therefore also the heat transfer characteristics. In addition, the material and containment aspects are directly affected by the pressure levels of the source, sink and possible intermediate heat transfer fluids.

For a better understanding of the depth of the information available, it is helpful to know if this information is available solely for this process analysis or is known for this specific process or this type of process.

Questions

1. How were temperature levels, transient profiles, mass flow rates, pressure levels determined?
2. Were measurements needed especially for this analysis or are these values known in the process anyway?

c) General Thermodynamics

The following questions regarding the heat transfer fluid, temperature gradients and cycle characteristics need to be clarified for the analysis of the given process for thermal energy storage integration.

Questions

1. Is the heat transfer fluid between the source and the sink the same?
   a. If yes – are the in the same phase state (liquid, gaseous)?
2. Are temperature gradients, profiles or levels currently used in the process adjustable in any way?

In some systems, cycle length, as in the length of time energy is available for charging and needed for discharging a storage, and cycle frequency, as in the rate or interval during which a storage is cycled, are directly coupled to one another. In others, these characteristics are more independent of one another, depending on the source(s) and sink(s). There are also systems in which several sources or sinks are considered, resulting in a combination of cycle lengths and frequencies. If the sources and sinks operate independently, an evaluation of fully regular or irregular cycles is necessary – are full charging and discharging cycles likely, or is some kind of bypass and partial charge or discharge likely? The following questions address this potential combination of sources and sinks.

Questions

3. When the source and sink are connected via a storage system, what is the resulting cycle length? The cycle length here refers to the length of time energy is available for charging a storage and for discharging a storage if charging and discharging are conducted directly back-to-back. For example, in a CSP integration, consider 12hcharge and 6h discharge: 18h length.

4. Do multiple cycle lengths need to be considered (i.e. seasonal and daily)?
5. Are the source and sink operating in a regular or full cycle, and independently? This means:
    a. Are full discharging and charging cycles possible? and
    b. Is the source sometimes available at the same time that the sink has a demand? This would require either a closed loop or bypass over a possible storage, two storages or some other system solution.
6. When the source and sink are connected via a storage system, do multiple cycle frequencies need to the considered? How often would a theoretical charging and/or discharging of the storage occur? The cycle frequency in a continuously charging and discharging system is related to the cycle length. Taking the CSP storage above, the cycle frequency is 1/day.
7. When the source and sink are connected via a storage system, what is the maximum energy that can theoretically be transferred and/or saved?
8. What is the required response time of a storage system for charging? How quickly does a theoretical storage unit need to respond to charging requirements?
9. What is the required response time of a storage system for discharging? How quickly does a theoretical storage unit need to respond to discharging requirements?
10. Are charging/discharging times controlled by the system or result from less foreseeable factors?

2. Physical plant/process properties

Some processes are very large so that physical distance can be a critical factor. In very small processes or integrating a storage system in an existing site, the same can be true. When analyzing a mobile storage system, the source and sink may not even be in the same area. The physical distance between the source, the sink and a possible location for the storage system can therefore directly affect the feasibility of the integration.

Questions

1. Has the storage been physically integrated?
2. If no, is planning for a physical integration being or been conducted?
3. What physical is space available for a storage system?
4. What physical distance and hindrances are between the source, sink and space for a storage system?
5. What integration infrastructure exists and what needs to be considered? This includes basics such as necessary foundations or fork-lifts to various control technologies.
6. Do regularly scheduled shut-down times need to be incorporated into the planning?

Step 5: Analyze general factors

In this step, the overall process is considered. These questions and their answers are related to the process and process type, regardless of the storage system that may or may not be developed for integration. These questions are somewhat related to the research nature of the integration of storage units and the continuing development and changes in the policies and economics in different countries regarding energy efficiency. The questions can be grouped into two basic categories: company/type and legal/specific.

<u>Company/process type questions:</u>

1. How often does this process exist? With these conditions?
2. What is the life cycle/-span of the analyzed process? Here, the life cycle or life span denotes how long the process is expected to exist for.
3. Are company goals related to the following being pursued?
    a. CO2 reductions?
    b. Greenwashing?
    c. Policy changes?
    d. Energy reliability or flexibility?

<u>Specific/legal questions</u>

1. Would the storage be integral to the process?
2. What developmental grade of research is acceptable?
3. What environmental/health restrictions exist at the site or in the process? These can relate to safety issues such as legionnaires or dioxins specific to the process or to factors such as critical permits regarding noise or emissions during commissioning.

Step 6: Summarize analysis

In this step, the guideline summarizes the answers with some basic questions.

Questions

1. Is this process considered suitable for a TES in general?
2. If yes, why? If no, why not?
3. If yes: Are there clear indications which storage concepts or types are better suited to the process? Why?
4. If yes: Are there clear indications which storage concepts or types are NOT suited to the process? Why? What is the process or part of the process being analyzed?