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Bio-HyPP

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D4.5	Lessons learned for development, set-up and installation of a hybrid power plant demonstrator	31.12.2019	WP4 / DLR
Short Summary	This deliverable was originally planned to briefly describe the technology demonstrator of a hybrid power plant of a micro gas turbine (MGT) and a solid oxide fuel cell (SOFC). As the technology demonstrator could not be built within the project frame, this report describes organizational lessons learned for future projects.		
Author/Corresponding author(s)	DLR: Melanie Herbst, Martina Hohloch, Matthias Metten		
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Dissemination Level		
PU	Public / Demonstrator	X
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Acronyms

DLR	German Aerospace Center
HyPP	Hybrid power plant
MGT	Micro gas turbine
MGT test rig	Hybrid power plant test rig consisting of a real MGT and an emulated SOFC
SOFC	Solid Oxide Fuel Cell
SOFC test rig	Hybrid power plant test rig consisting of a real SOFC and an emulated MGT
WP	Work package
PLC	Programmable Logic Controller

1 Introduction

The aim of the Bio-HyPP project has been the development of a hybrid power plant [1] – a combination of a solid oxide fuel cell (SOFC) and a micro gas turbine (MGT). For this development, the understanding of both, the characteristics of the MGT system and its components as well as the characteristics of the SOFC system and its components are essential. Therefore, two separate test rigs have been set up for the characterization of both subsystems under hybrid conditions, as a part of WP4: the MGT hybrid power plant test rig (real MGT with emulated SOFC) [2] and the SOFC hybrid power plant test rig (real SOFC with emulated MGT), ([3],[4]).

In the beginning of the project, the aim was to build a technology demonstrator of a real coupled hybrid power plant consisting of MGT and SOFC. This deliverable was originally planned to describe the operation of the technology demonstrator of the hybrid power plant of MGT and SOFC.

In the course of the project, various issues occurred with components and their interactions while setting-up and while running experiments with the separate test rigs MGT hybrid power plant test rig and SOFC hybrid power plant test rig. These issues on the one hand cost a lot of extra resources (time and manpower). Therefore, the experiments on both the separate test rigs had to be extended to cope with the occurred issues: a surge and backflow-issue at the MGT hybrid power plant test rig destroying the engine had to be solved [6], control issues had to be fixed and the layout of the SOFC hybrid power plant test rig had to be revised. On the other hand, auxiliary components being standard products procured from the market - such as electronic load and the recirculation blower- failed iteratively and caused delays with the experimental results that had not been planned. It has been found that the components and also the auxiliary components need to be characterised even more deeply to be taken into account for the real coupling.

So, the assumption that the set-up of two separate emulation test rigs and their experimental characterisation is needed as one step before coupling has been proven to be essential.

Due to these reasons the technology demonstrator could not be built within the project frame and the focus has been moved towards separate test rig characterization, their components and interactions. This has led to the insight that the coupling concept needs some conceptual changes to allow for real coupling.

So, this report of D4.5 describes now the lessons learned about planning the set-up and commissioning for future set-ups, and commissioning of first-of-its-kind test rigs. The technically necessary modifications and the revised coupling concept are reported in [5].

It is structured in 3 chapters:

In chapter 2, the lessons learned from issues that occurred while setting-up, commissioning and experimental runs with the test rig are described.

Finally, Chapter 3 draws the conclusions.

2 Lessons learned for set-up, commissioning and running of hybrid power plant test rigs in lab infrastructure

Within the project, one main focus has been to gain experimental data for the analysis of a hybrid power plant. Therefore, two separate test rigs have been built ([2],[3],[4]) to investigate the components and the whole system characteristics under hybrid conditions using emulators for the corresponding subsystem. The test rigs have been designed by using models and simulations, and the experimental data are used for analysis as well as for the validation of the models.

In the course of the project, a lot of difficulties had to be solved concerning the construction, set-up and experiments. Using risk analyses are a basis to identify possible bottlenecks as early as possible. However, while most of the issues occurring in the project could not be foreseen and planned, there have been a few insights that should have been done differently or could be optimized in future projects. These lessons learned are described in the following sub-chapters.

2.1 Project communication should be started with personal meeting in an early project phase

Partly, the communication has gone very well: starting the project with a kick-off meeting that included a full day of interactive work and discussions has been proven as an effective project start. The project partners have been very much involved, they have known each other personally and the collaboration has worked well. So it has proven to be very useful to have personal meetings especially in the beginning of the project.

Project management meetings took place every 3 months together by personal meetings and online meetings alternately. This time interval has held the consortium connected and informed.

2.2 Planning of the project needs to be particularized after project has been accepted

The conflict of planning a project in detail already for the proposal versus planning the details after a project has been accepted is an obvious and well-known conflict. The particularization of the planning after the project acceptation has gone well and proven to be suitable.

Yet, the detailed planning phase, or particularization, needs to be included as work in the project plan. The planning phase actually never ends and needs to be taken into account. The particularization of the work can be done more often within a project, at every new step within the project. Our retrospection has shown that especially for the set-up of the test rigs the planning phase of the test rig could have been done more detailed in earlier project steps.

For these detailed planning it makes sense to start with meetings with people of different expertise: experts about components - their thermodynamic characteristics as well as their controls – should be planning the details together with electrical experts, control experts and also safety system experts. Some of the topics have been in the focus – usually the objects of investigation. Other topics like electrical wiring or safety sometimes seem to be a side-topic in the eyes of scientists. Nevertheless, these aspects need to be focused earlier in the project.

The topics electrical planning, safety planning, measuring instrumentation and communication protocols of components could already be better addressed in the conceptual phase. Reviews of the project phases could be done with external reviewers more often and at earlier steps within the project course. For this, also the stakeholders of the project could be included more in earlier project phases (while being aware that it is less motivating for stakeholders as not having many insights are there to offer to them).

Also, the consecutive dependency of tasks and results needs to be planned. The dependency of the tasks following each other has been planned on project management level and proven to be functional. Yet, the dependency of experimental boundary conditions from other experimental data could have been planned more detailed. For this it is recommended to include knowledge and experiences of all experts involved (such as technicians and experimenters as well).

2.3 System analysis of each coupling component is essential

For coupling two systems, as in this project a MGT and a SOFC, the approach to build two separate test rigs with emulation of the other system, has proven to be very important and necessary. These separate test rigs bring additional work with them as for the emulation extra components are needed. Nevertheless these emulation test rigs are needed to be able to run experiments at the operation limit of the components without the danger of causing much side-damage. Yet, the component needs to be studied in correlation to the components with which it interacts.

It is necessary to investigate and analyse the boundary conditions of each component. The components do all have their specific characteristics that cannot be generalized to the type of component, e.g. the compressor. Each compressor brings its unique characteristics that influence the system.

2.4 Requirements of purchased parts need to be specified in more detail

For future projects, purchasing management can be done with more focus. Although it is time-consuming to discuss the requirements, the necessity cannot be neglected: discussions with suppliers should include an explanation of the planned application (so not only buying "a valve", but "a valve in a certain test rig configuration"). By doing so, the expert knowledge of the supplier about their component can help to indicate possible complications that were not obvious from researchers' point of view. Also, implicit requirements can be identified more easily. In such discussions the functionality of the required parts shall be discussed as well as the interface on electrical and control sides.

Also the written requirements should always include every minor detail, even if it seems very implicit. Furthermore, the boundary conditions should be checked with each supplier before purchasing. Boundary conditions like support for commissioning at the lab site should be included in the requirements as well.

It could help to address the use and goal of the test rig and the time-frame of the project with the supplier to check for possible replacement parts in the same version as the originally purchased part. In case of planned technology adaptions, it should be checked whether a different supplier can be chosen. Replacing a broken part with a newer version (as the technology has moved forward) results often in additional construction work to adapt the test rig according to new boundary conditions of a component.

2.5 Purchased parts should be checked by quality inspection

In the course of the set-up and commissioning of the two separate test rigs, many of the purchased parts/components have shown failures. Within the project, the main focus has been towards the parts that have been developed by the consortium and with a specific hybrid power plant objective.

Reality showed that many of the purchased standard parts failed and their removal and repair cost the project a lot of time and resources. Some of these parts are listed to give an example of possible failures:

- Some pipe parts were wrongly welded (angle of a flange, angle of a pipe, etc.)
- Parts of the PLC were damaged by incorrect wiring within the power electronics
- Electrical heaters have not been parametrized for European standards when delivered
- Heating insulation that has been customized for the test rig by measuring on-site was not fitting to the test rig and had to be re-manufactured
- The high-temperature blower of anode recirculation broke down a few times -> removal from the test rig and repair at the producer in Japan

For future projects, more quality inspections, not only an optical quality control, but also a functional testing needs to be planned and budgeted from the beginning: functional testing by the supplier shall be ordered with every purchasing. Yet, it has proven to be not enough. So, a functional test of each purchased component should be done in-house right after delivery. Sometimes this brings the need of an extra test rig. It might not be possible with every component, but the planning of component-checking should be included in the project. In case it cannot be tested in-house, inspection of the components should be done at the supplier's site together with a project member.

If possible, checks should be expanded to tests of component combinations in case a component cannot act and be tested independently.

Quality inspection does not only concern mechanical components like valves, mass flow measurements, pressure measurements, temperature measurements, electronic parts, blower, water pumps etc., but also the inspection of software.

Additional to the functional testing right after delivery, the supplier shall be present for the commissioning of the component after installation in the final test rig. Supplier knowledge can help in any case of insecurity or open questions and the understanding of the component interactions increases a lot.

2.6 The given lab/site infrastructure needs to be validated and checked regarding the project requirements

The test rig installations have been based on the existing site infrastructure. Interfaces like electricity, gas supply, water supply, lab cooling, etc. are often taken for granted.

In reality the site infrastructure caused quite a lot of problems as for example the following issues occurred:

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- The gas compressor for the gas supply of the whole building stopped many times and set itself into a failure mode.
- The cooling of the lab failed with one test rig running experiments for long-term or with more than one test rig running at the same time
- The cooling water seemed to be insufficient for running both test rig simultaneously
- The grid connection's fail safety has not fulfilled the needed standard for the hybrid power plant
- The power electronics failed due to possible external/grid over-currents

The learning of these incidents has been that effort needs to be planned for detailed checking of the infrastructure in regard to the boundary conditions relevant for the test rig and its components.

2.7 Buffer for unforeseen events and additional work needs to be scheduled and planned in the project

It has shown that more effort than planned in the proposal has been needed for the "side-work" that has not been the main focus of research. Some of these issues cannot be foreseen in all detail before starting a project. Therefore, more buffer time should be included in a project plan.

3 Conclusion

As described in the previous chapters, some improvements can be done to better achieve the goal of the project.

These improvements, more detailed planning in earlier project steps (chapter 2.2), requirement management and discussions with suppliers (chapters 2.4 and 2.6) as well as quality checks (chapter 2.5) do all require resources. These resources should all be planned for the project.

Planning more buffering time in a project is always connected to the conflict between realistic planning to fulfil the project goals and the optimistic view which is necessary for motivation and the increased possibility to get funding for a project. To minimize the amount of resources needed it is recommended to analyse the risks for the project to prioritize counteractions.

Also, the planning of a project in the proposal phase could on the one hand be more detailed, but this also conflicts with the situation that this work is usually not funded.

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