PLANNING AND CONTROLLING OF THE COLD ACCELERATOR SECTIONS INSTALLATION IN XFEL

M. Bousonville*, F. Eints, S. Choroba, DESY, Hamburg, Germany

Abstract

The installation of the main linear accelerator in the 2 km European XFEL (X-Ray Free-Electron Laser) tunnel is currently under way. The accelerator consists of nine so-called cryo-strings. A typical cryo-string comprises 12 accelerator modules, which will be fed by three RF stations. Furthermore, the installation of electronic racks, cables, power and water supply etc. takes place.

To enable a most effective installation of the accelerator components, planning and controlling methods, which had first been developed for the RF system work package, were adapted for the entire main linear accelerator. As a first step, a process plan was developed in cooperation with the work package leaders. On the basis of this plan, the installation process is promoted by several measures: The status of the installation is precisely registered by weekly queries which enable monitoring of the progress and feedback to everyone involved. With this information at hand, the installation process can be controlled and plan deviations can be corrected. Furthermore, the experience gained at one cryo-string is used to optimise the plan for the next cryo-string installation.

INTRODUCTION

Figure 1 shows part of the main linear accelerator in the European XFEL tunnel as installed. On top, yellow accelerator modules can be seen, stretching above a pulse transformer (red), a klystron (blue) and some racks (grey, in the background). Details of the machine can be found in [1]. 13 work packages (WPs) are involved in the installation process†:

WP 01 – RF System
WP 02 – LLRF System
WP 03 – Accelerator Modules
WP 05 – Power Couplers
WP 08 – Cold Vacuum
WP 13 – Cryogenics
WP 28 – Accelerator Controls
WP 32 – Survey & Alignment
WP 33 – Tunnel Installation
WP 34 – Utilities
WP 36 – General Safety
MDI – Cabling for WPs
IT – Fibre Optics and Ethernet

Early in 2015, the installation speed was unsatisfactory. The reason for that was the high number of working packages involved and their complex interactions, which caused coordination problems. A solution had to be found to handle these complex interactions. The application of a suitable planning method marked the turning point. This planning method enables a fast gathering and visualisation of the dependencies between all process steps. On the basis of the information gained, a new process oriented plan for installation controlling was created in cooperation with the WP leaders. The management methods applied are based on [2, 3] and were adapted to the organisational culture of DESY.

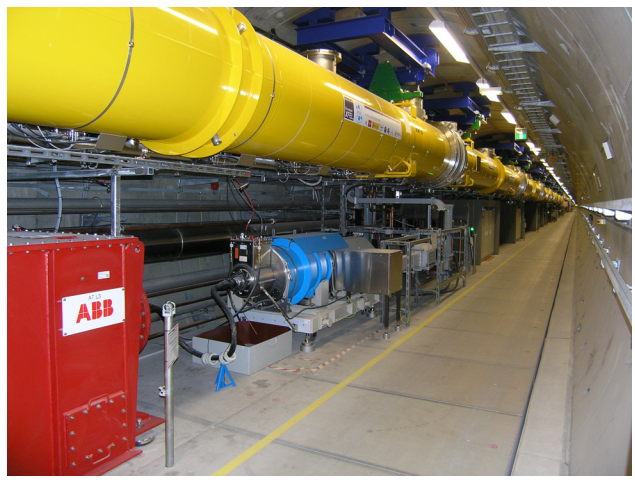

Figure 1: Part of the main linear accelerator in the European XFEL.

INSTALLATION MANAGEMENT

Plan Development

To arrive at the first installation plan, six one-hour meetings with the most important WP leaders were necessary. Two DESY employees trained in management methods prepared the meetings, followed up on them and carry out the operative installation management.

1st Meeting

At the time of the first meeting, cryo-string #1 had already been assembled. In the meeting, this assembly process was analysed. To this end, all WP leaders were asked to note down their process steps on cards. These cards were arranged on a magnetic board exactly in the sequence of the first installation process. Visualized in this way, the installation process became transparent for everyone involved. A discussion about the sequence of process steps started immediately. All ideas for optimization, which came up, were recorded for the next meeting.

2nd Meeting

Before the 2nd meeting, all WP leaders had enough time to think about sequence optimization of their process steps. In the meeting, all ideas were listed and discussed.

* Michael.bousonville@desy.de
† For the sake of simplification contributing DESY groups, which are not assigned to an XFEL work package, will be called work package, too.

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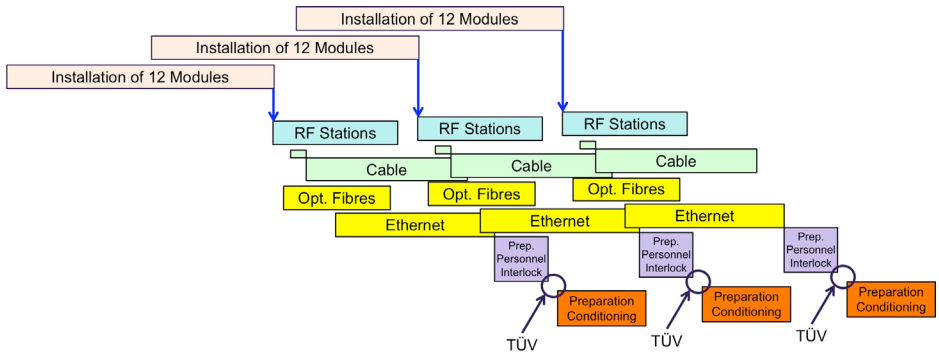

Figure 2: Installation sequence of several accelerator sections (so called cryo-strings including 12 modules) in a Gantt diagram. Each block represents 4 to 24 installation steps.

Those ideas all WP leaders agreed to were used to optimize the installation sequence. As a result, a new installation plan of about 100 process steps was created (at this point, without parallelization of process steps) and the WP leaders gained an understanding of the mutual interdependencies of the different WPs. At the end of this meeting, process steps, which could be parallelized, were marked in the plan.

3rd Meeting

Before the 3rd meeting, the WP leaders were interviewed how long each process step takes to be carried out and which other process steps must be finished before they can start. By means of this information, reasonable parallelization of process steps was proposed. The resulting plan (process map and Gantt diagram) was presented to and accepted by the WP leaders in the meeting.

4th and 5th Meeting

Up to now, only the installation of one cryo-string was considered. In the 4th meeting, the efficient sequencing of the installation of several cryo-strings was the subject. The result was visualised afterwards and presented to the WP leaders in the 5th meeting. Furthermore, optimization options for reduction of the overall installation time were shown.

6th Meeting

One of these optimization options was the partial parallelization of module installation work at several cryo-strings at a time. In the 6th meeting, this proposal was accepted by the European XFEL linear accelerator project management (DESY). The resulting Gantt diagram is shown in Fig. 2.

Controlling in the XFEL Tunnel

The installation plan is now being implemented in the tunnel. To make sure that everyone involved knows when to start his process steps, a schedule is derived from the installation plan. This information is given to the WP leaders four weeks before the starting dates. If they foresee that any of these dates cannot be met, then the schedule is revised and again given to the WP leaders until all starting dates are agreed. This approach yields a schedule in which all deviations from the installation plan are already considered. Consequently, the WP leaders get mid-term (i.e. 4 weeks) reliability to do their resource planning. In long-term (> 4 weeks), only rough estimates are given because the forecast is not precise enough.

For short-term (1 week) controlling of the installation process, weekly tunnel meetings take place (Fig. 3). Essential component of this meeting is the setup of a weekly schedule where everyone can see who works at the main linear accelerator where and when. This helps to avoid interferences between installation teams in the tunnel. Most of the weekly schedule is already agreed with the WP leaders before the tunnel meeting. Thus the meeting is primarily an information event, where typically only small deviations from the planning are discussed. Furthermore, the status of the installation work is visualised by means of several posters (one poster for each cryo-string). Thanks to the preparatory work, the meeting normally lasts only 20 minutes. The meeting takes place right at the centre of gravity of the current installation work. This permits a close look at any occurring installation problems right after the meeting, with the relevant people, in order to discuss and solve the problems. After the tunnel meeting is finished, the installation status is summarized in a progress matrix and sent to the project management the same day as weekly report.

Problems that may occur in-between the meetings are detected by daily tunnel inspections and tackled immediately with a small group of the involved.

Figure 3: Weekly tunnel meeting at the installation front next to the main linear accelerator. Posters visualising the installation status are seen on the right.

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Results

Naturally, unexpected deviations occurred during the first installation process according to the new installation plan. But these deviations were compensated by operative countermeasures. It was thus not only possible to meet the planned installation time of 15 weeks, but to even reduce it by two weeks to 13 weeks (Fig. 4). This was due to robust planning and an effective operative controlling of the process.

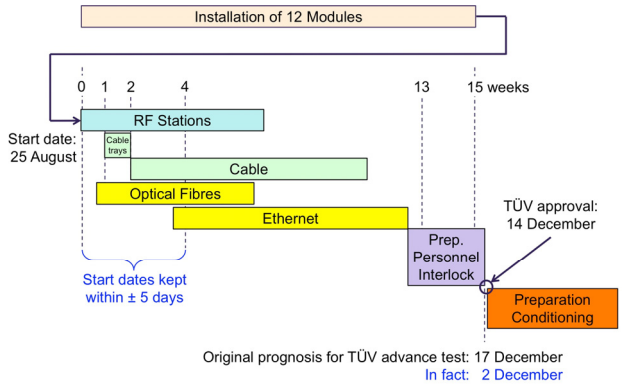

Figure 4: First installation process, according to the newly developed plan, finishes two weeks earlier than expected.

Construction is on-going not only at one cryo-string, but on several at a time (Fig. 2). In Fig. 5 the status changes are plotted over time, in order to illustrate the increase in installation activity in the overall main linear accelerator. The number of status changes indicates how many process steps per weeks are started or finished. After a start-up period of 15 weeks, an average of 30 to 50 status changes per week was achieved.

The application of these management methods sped up the installation process by a factor of 6, as compared to cryo-string #1.

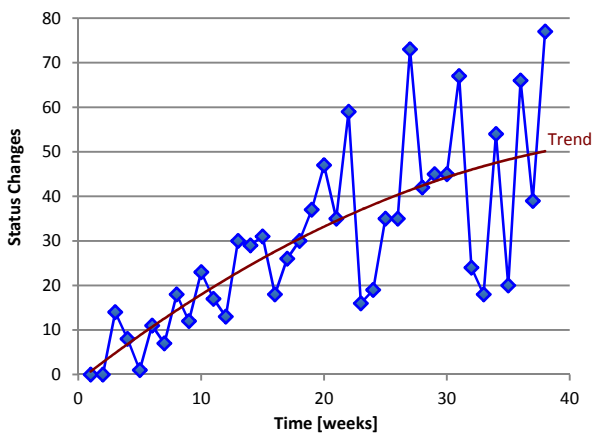

Figure 5: Installation activity in the overall main linear accelerator.

Continual Improvement Process

The increase in installation activity is caused by the fact that since the application of the new installation plan, more and more cryo-strings were assembled at the same time (see Fig. 2). But the process plan optimization did not stop when the first installation plan was released (after the 6th meeting, see above). Instead, it has been and will be reviewed after completion of each cryo-string. In each review, the installation plan is optimized on the basis of gained experience and the suggestions for improvements made by the involved.

OUTLOOK

The methods presented can also be used for accelerator commissioning, rebuilding, and shutdown. In the case of the European XFEL main linear accelerator installation, the repetition of the installation process (i.e. the installation of several cryo-strings identical in construction) is used for further optimizations. But such a repetition is not a precondition for applying these methods, as proven by the success of the first installation process (Fig. 4).

SUMMARY

The methods described facilitated the identification of the interactions and dependencies of the 13 WPs, which contribute to the construction of the main linear accelerator of the European XFEL. The resulting transparency enabled the development of a practice-oriented installation plan in cooperation with the WP leaders. This installation plan has proved reliable in practice and is permanently subject to further optimization on the basis of experience gained in the on-going installation processes. The realisation of the installation plan is accompanied by an operative management in the tunnel in order to correct deviations from the planning and make use of any occurring potential for acceleration of the installation process. This combination of solid planning and close controlling of the assembly sped up the installation process in the main linear accelerator by a factor of 6.

ACKNOWLEDGEMENT

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