ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-THPRB087

STUDY OF THE ENERGY SAVINGS RESULTING FROM THE EAST AREA RENOVATION

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Abstract

CERN's East Experimental Area, situated on the Swiss side of the Meyrin site, with its four beamlines, has served physics for more than 40 years. As the building and equipment are reaching their end of life, a thorough consolidation project has been initiated in order to provide many more years of reliable operation. This article addresses the different proposed solutions to reduce significantly the energy consumption of the East Area. It outlines the methodology applied to estimate as precisely as possible the future attained energy savings, which will result in an estimated reduction of approximately 80% in electricity usage (from 11 GWh to 2 GWh per year) and of approximately 65% in gas usage for heating purpose (from 3 GWh to 1 GWh per year).

INTRODUCTION

The East Area, with its main 4600 m^2 hall housing the beam lines [1] (T8/Irradiation facilities, T9, T10 and T11/CLOUD) as shown inFig.1, located next to the Proton Synchrotron PS accelerator, consumed 11 GWh in electricity in 2017. Even though this is only a small percentage (± 1%) of CERN's total electricity consumption, the experimental area has a high potential in energy savings.

The renovation project has the main objectives to provide a reliable working environment to the different users of the experimental area, which has not been the case for the last years. CERN's energy policy puts a high priority on energy efficiency for present and future projects. Already during the project study and preparation phase, the main energy consumers were identified as the magnet power supply chain (illustrated in Fig.2), composed of the magnets, cables, power converters and transformers, the air ventilation and the water-cooling systems.

THE MAGNET POWER SUPPLY CHAIN

The most substantial change induced by the renovation in terms of energy will be the modification of the powering mode of the magnets. The new power converters, called the SIRIUS, which have been conceived at CERN by the Electrical Power Converters Group, will be able to operate the new laminated magnets in cycled mode. Equipped with capacitor banks, the SIRIUS converters will also be able to recover temporarily the inductive energy stored in the magnetic field of the magnetic components as shown in Fig.2. Those recovering units reduce the RMS current requirements of equipment up-stream the electrical supply network and eliminate the voltage fluctuation of the CERN general electric grid, thus simplifying it and decreasing the losses within.

Today the magnets are turned on at the start of the physics' run and, if no major issue compels it, are never turned off, even when no beams are extracted towards the East Area. Bearing in mind that the beamlines, today, count 54

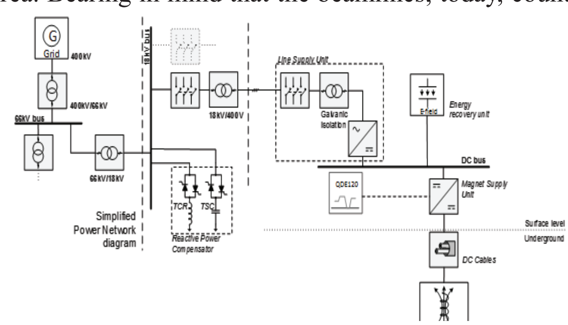

Figure 1: Overview of the magnet power supply chain.

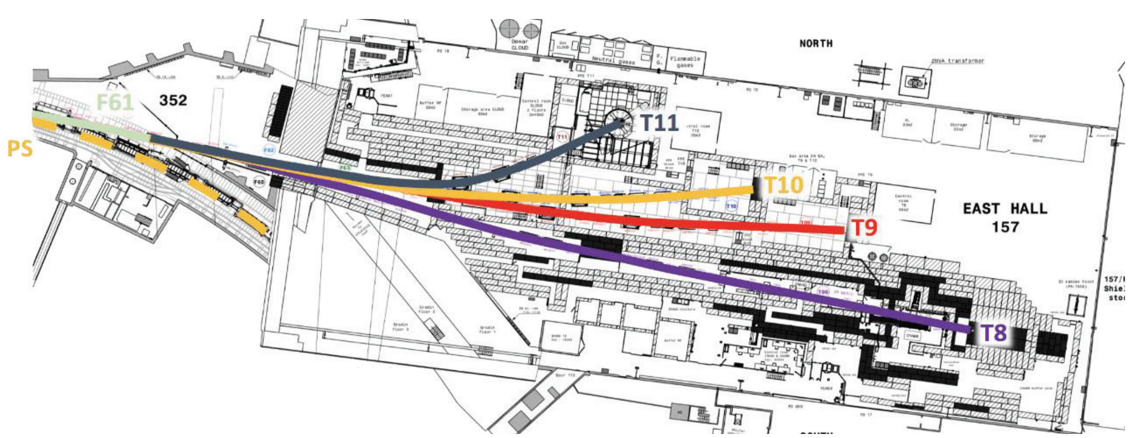

Figure 2: Layout of the Experimental area (Building 157) after renovation.

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magnets which in theory only require to be generating a magnetic field during 2,25 seconds (which equals to 5 extractions) per supercycle[1], significant energy saving can result from a compatible magnet and powering scheme. Such a cycled mode gives the opportunity to only feed the required magnets to extract and direct the particles towards one of the four experiments.

Furthermore, a lower electricity consumption will significantly decrease the power losses and thus the related dissipated heat, having consequently also a direct influence on the energy consumption needs for the water cooling and air ventilation systems.

To determine the power losses on the future supply chain, a bottom-up approach was applied. By retrieving the Root-Mean Square current value (I_{RMS}) (see Fig.3) for each magnet as a function of the magnetic field, one can retrieve the losses in the magnets, the cables, the power converters and the transformers. Knowing the specific characteristics of each component of the supply chain, the total power losses per extraction for each beam line were estimated.

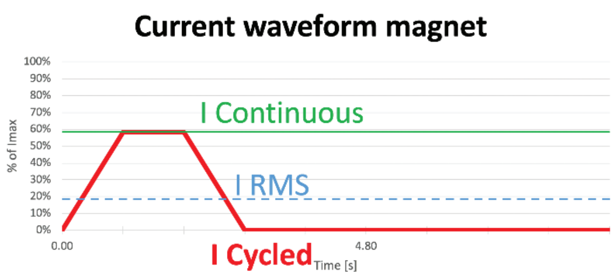

Figure 3: Magnet's current waveforms before and after renovation.

Even though it is impossible to predict the number of extractions occurring in a future physics' run, an estimated electricity consumption can be calculated based on the number of extractions which took place in 2017.

Based on retrieved current data of the 2017 physics' run, the electricity usage before renovation (6786 MWh) was calculated. Compared to the estimated consumption in cycled mode (1028 MWh), a potential saving of more than 80% can be demonstrated.

In addition, while power converters still consume electricity in maintaining stand-by mode, a future remote control by the operators allows to completely switch-off the equipment during long periods of inactivity.

AIR VENTILATION

Currently, air ventilation systems are present in the main experimental hall and the irradiation facilities[2] on beamline T8. Ensuring a thermal comfort and an adequate air quality inside the hall as well as a dynamic confinement (preventing the activated air to escape) for the highly radioactive areas. Building 251, adjacent to Building 157 hall and housing the power converters, is also equipped with a heating and ventilation system providing heating during winter and fresh air ventilation that partly removes the heat dissipated from the converters during warmer periods.

The air ventilation's energy consumption in the experimental hall is mainly due to the heating needs during cold months. During the hotter months, the heating is turned off and thermal comfort is uniquely assured by ventilation. Heating in the East Area and at CERN in general is provided by a central plant producing, by means of gas combustion, Super-Heated Water (SHW) which is distributed to the concerned infrastructures located on the various CERN premises.

The cladding of the main hall is currently not optimal when compared to today's environmental and safety standards, causing over the year an increase in air ventilation needs. Civil engineering works have therefore been introduced into the project. By refurbishing the cladding and the roofing with more modern and better performing insulated materials associated thermal losses significantly decrease.

Therefore, detailed thermal studies of today's and the post-renovation's situation have been conducted [2]. From this study, following results have been found; the peak losses occurring during the coldest month (January) will drop from 811 kW to 245 kW, the annual thermal energy consumption will decrease by 65% together with a 65% decrease of the related gas consumption.

The project also includes a modification in the disposition of the radioactive areas, similar to the one performed for IRRAD/CHARM in LS1. Thus, introducing new specific air handling units to the primary [3] and a new ventilation system to the mixed beam area (see Fig. 4), leads to a total of three dedicated ventilation systems for those areas. In addition to ensuring a dynamic confinement, they compensate the dissipated heat from the magnets, which will decrease due to above described cycled operation mode. Related thermal energy savings will amount to 75%. However, at the same time the electricity consumption for the primary areas must cover an increase of 42% (from 11MWh to 19 MWh) due to the required additional units.

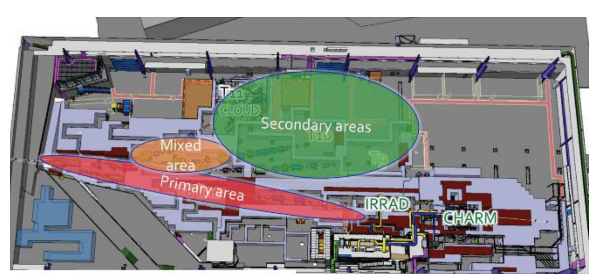

Figure 4: Layout of the new radioactive zones.

Finally, the power converter's building will see a 96% reduction in cooling needs (from 955MWh to 63 MWh). The substantial decrease is related to the fact that the new

[1] The supercycle of the PS accelerator lasts for 45,6 seconds and depicts the distribution of the particle's bunches from the accelerator towards the related experiments (nTof, AD, IRRAD, CHARM, …) and the Super Proton Synchrotron accelerator.

[2] Highly radioactive areas are covered with thick (up to 6 meters) concrete walls allowing presence of the users inside the hall during beam operation.

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power converters will be water-cooled after renovation. The ventilation will only have to compensate 15% of the total heat dissipated from the converters, while it is 100% today.

WATER COOLING

The last major energy consumer of the East Area is the water-cooling systems designed to compensate 85% of the magnets' and, after the renovation, the power converters' heat losses.

As mentioned previously, the cycled mode will significantly reduce the heat dissipation of the magnetic components and the power converters. Based on the power losses calculated for the electricity consumption of the magnets and the power converters, the cooling needs can be easily retrieved. The annual cooling needs will massively drop from 4162 MWh to a mesmerizing 369 MWh (91% decrease).

Heat of East Area magnets and power converters is mainly absorbed by the demineralised water circuit, passed to cooling tower water and ultimately released to the atmosphere. The cooling tower is a heat exchanger (air/water) of open wet type, meaning it partially evaporates and thus consumes the circuit's raw water to bring its temperature down.

Besides, miscellaneous liquids are used to keep the cooling functioning properly. Consumption of those liquids, being raw water as explained here above, demineralized water and water treatment fluids, are proportional to the cooling needs. All three liquids see their usage drop of 91%.

As for the electricity consumption, which is predominantly caused by the water pumps generating the required water flow inside the circuit, a corresponding decrease will be observed. Due to a careful pump selection the number of pumps in operation can be reduced from two to one. Combined with the fact that the new pump differential pressure will be reduced from 24 to 12 bar and the water flow will be of 220 m^3/h instead of 300 m^3/h, the corresponding electricity consumption will also drop from 4246 MWh to 1012 MWh, consequently saving 76% in energy consumption.

CONCLUSION AND OUTLOOK

To conclude, the total energy consumption will decrease of 81% after renovation and for the thermal energy consumption (heating and cooling needs combined), a saving of 82 % will be attained as illustrated in Fig. 5, which compares the energy flows by type (cooling, heating, electricity) before and after consolidation.

Additional operational improvements can be implemented. Firstly, switching off equipment such as power converters while not in use (e.g., during technical stops). Furthermore, replacing the water pumps of the water-cooling circuit can provide additional savings as they will be oversized after the renovation [4]. Finally, a renovation of the power converters' building which has been constructed around the same period as the main experimental hall and shows, today, the same insulation issues should be weighed.

ACKNOWLEDGEMENTS

The authors would like to thank all involved CERN equipment/service groups and are grateful for the continuous help and support provided.

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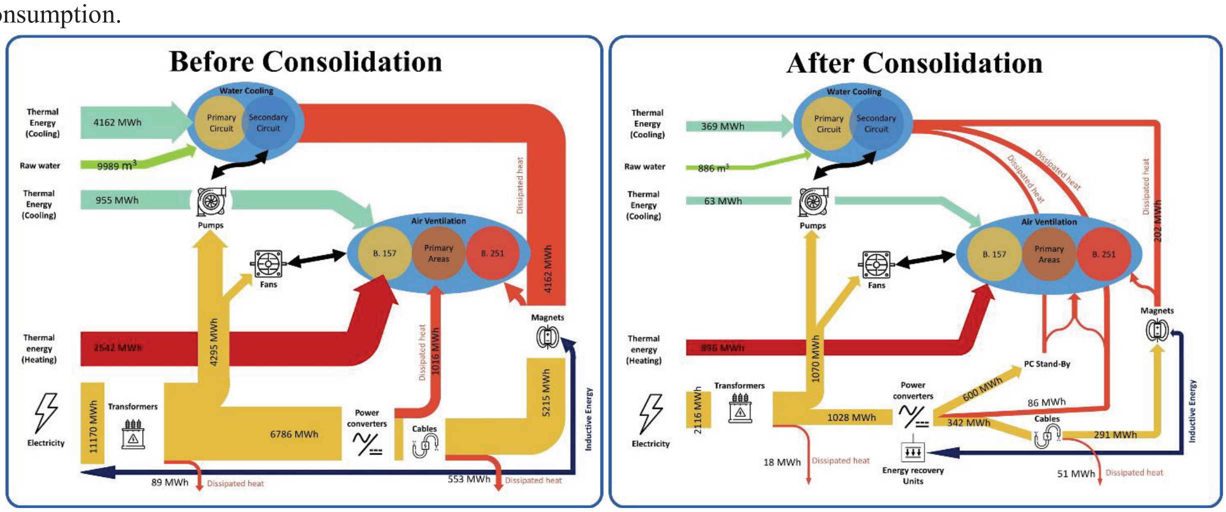

Figure 5: Summary diagrams of estimated energy consumption before and after renovation.