Workshop on Special Compact and Low Consumption Magnet Design

Report of Contributions

https://indico.cern.ch/e/321880

Contribution ID: **0** Type: **not specified**

CERN Welcome

Wednesday 26 November 2014 09:00 (10 minutes)

Presenter: BORDRY, Frederick (CERN)

Session Classification: Introduction

Contribution ID: **1** Type: **not specified**

Introduction to EuCard2

Wednesday 26 November 2014 09:10 (10 minutes)

Presenter: VRETENAR, Maurizio (CERN)

Session Classification: Introduction

Contribution ID: **2** Type: **not specified**

Introduction to ”EnEfficient’ Work Package of EuCard2

Wednesday 26 November 2014 09:20 (10 minutes)

Presenter: SEIDEL, Mike

Session Classification: Introduction

Contribution ID: **3** Type: **not specified**

The outlook for electricity in Western Europe

Wednesday 26 November 2014 09:30 (30 minutes)

Presenter: WITTENSTEIN, Matthew (IEA)

Session Classification: 1st Session

Contribution ID: **4** Type: **not specified**

Why are particle accelerators so inefficient?

Wednesday 26 November 2014 10:00 (30 minutes)

High-energy accelerators/colliders have developed into large machines consuming high electrical power up to the 100 MW range, thus making the energy bill a major component of their operating costs and eventually of their acceptability by society. With several new projects under study beyond the Large Hadron Collider (LHC), and projections of rising electricity prices by energy agencies, this trend is expected to grow into a critical issue for future machines. While a minimum power duty can be estimated from the beam parameters of both circular and linear accelerators/colliders, they all share low grid-to-beam efficiency entailing much higher power requirements from the electrical networks. We analyse the sources of energy dissipation, from the closest to the farthest from the beams, and discuss the power efficiency of some existing machines and future projects. This methodology also enables to identify possible paths for improvement.

Presenter: LEBRUN, Philippe (CERN)

Session Classification: 1st Session

Contribution ID: **5** Type: **not specified**

CERN plans towards energy efficiency

Wednesday 26 November 2014 11:00 (30 minutes)

High energy accelerators are usually great energy consumers and could not escape from being concerned by energy efficiency aspects. After recalling the context, major actions towards energy efficiency will be presented, with plans for the future.

Presenter: CLAUDET, Serge (CERN)

Session Classification: 2nd Session: Opportunities of Energy Saving in Accelerators - Part 1

Contribution ID: **6** Type: **not specified**

Magnet Energy Recovery: a way towards more compact and efficient systems

Wednesday 26 November 2014 11:30 (30 minutes)

Magnet energy recovery on a cycle-by-cycle basis shows potential for great energy savings and improvement of the grid power quality. Reducing the magnet duty cycle allows more compact mechanical layout and greater efficiency. To achieve such a benefit a system integration study is essential before starting the parallel development of magnets and power conversion/energy recovery systems.

Presenter: PAPASTERGIOU, Konstantinos (CERN)

Session Classification: 2nd Session: Opportunities of Energy Saving in Accelerators - Part 1

Contribution ID: **7** Type: **not specified**

Saving opportunities in accelerator magnets

Wednesday 26 November 2014 12:00 (30 minutes)

An accelerator magnet is usually excited either by water cooled copper coils powered with an effective current density in the range of 3-6 A/mm2 or by using superconducting coils, depending on the required field amplitude. Exceptions are often due to technical reasons (special constraints, easier construction, more reliability). Up to now, only in rare cases (in particular in experimental magnets) the energy consumption is an important design factor. The situation is however rapidly evolving and many research institutes are either revising the existing installations or planning the new ones with special attention towards energy consumption. This talk will review several “saving opportunities”presently considered in this domain.

Presenter: TOMMASINI, Davide (CERN)

Session Classification: 2nd Session: Opportunities of Energy Saving in Accelerators - Part 1

Contribution ID: **8** Type: **not specified**

Power Converters design optimization: need for an integrated approach with the magnet design

Wednesday 26 November 2014 14:00 (30 minutes)

This talk presents the basics of the design of a power converter for DC and pulsed magnet. Particularly the impact of the magnet design (inductance, voltage and current adaptation given by the number of turns, etc.) on the converter design is illustrated. Compromises between efficiency, cost and technologies are presented. Finally, the need and benefits of an integrated approach which considers the magnet design variables is demonstrated via a simplified example.

Presenter: AGUGLIA, Davide (CERN)

Session Classification: 2nd Session: Opportunities of Energy Saving in accelerators - Part 2

Contribution ID: **9** Type: **not specified**

Iron-dominated cycled SC magnets for energy efficiency

Wednesday 26 November 2014 14:30 (30 minutes)

Presenter: BOTTURA, Luca (CERN)

Session Classification: 2nd Session: Opportunities of Energy Saving in accelerators - Part 2

Contribution ID: **10** Type: **not specified**

In-vacuum magnet design and challenges

Wednesday 26 November 2014 15:00 (30 minutes)

Synchrotron light sources can extend their wavelength reach significantly by putting the undulator arrays into the beam vacuum system. The advantages are such than many light sources now utilise in-vacuum undulators when required. However, there are a number of extra physics and engineering challenges which have to be dealt with when putting magnets in-vacuum. In this talk I will explain the motivation, the additional challenges, and the realisation of in-vacuum undulators.

Presenter: CLARKE, Jim (STFC)

Session Classification: 2nd Session: Opportunities of Energy Saving in accelerators - Part 2

Contribution ID: **11** Type: **not specified**

The CEA-Saclay experience

Wednesday 26 November 2014 16:00 (30 minutes)

Presenter: VEDRINE, Pierre (CEA/IRFU,Centre d'etude de Saclay Gif-sur-Yvette (FR))

Session Classification: 3rd Session: The saving prospects in European Labs, projects and machine upgrades - Part 1

Contribution ID: **12** Type: **not specified**

Compact and low consumption magnet design - The DESY experience

Wednesday 26 November 2014 16:30 (30 minutes)

During the last ten years a variety of electromagnets has been ordered to upgrade the PETRA accelerator into a synchrotron light source, to build up a new branch at the FLASH accelerator facility and to install the new European XFEL.
The talk will give an overview of the ingredients which are necessary for developing and manufacturing magnets. Two septum designs will be presented to discuss how electricity costs can be reduced without losing machine performance. Furthermore design studies of combined function magnets and a permanent magnet design that could replace a quadrupole electromagnet to save energy costs will be shown.

Presenter: KRAUSE, Bernward (DESY)

Session Classification: 3rd Session: The saving prospects in European Labs, projects and machine upgrades - Part 1

Contribution ID: **13** Type: **not specified**

Energy management at GSI and FAIR strategy on energy management

Wednesday 26 November 2014 17:30 (30 minutes)

GSI Helmholtzzentrum für Schwerionenforschung GmbH operates a unique large-scale accelerator for heavy ions. In the coming years the new international accelerator facility FAIR, one of the largest research projects worldwide, will be built at GSI. In the final extension FAIR consists of several heavy ion accelerator rings, experiment storage rings with up to 1,100 meters in circumference, two linear accelerators and about 3.5 kilometers high energy beam transfer lines as well as several experiment caves. In the context of rising energy prices and the responsible use of resources, GSI has taken the task to develop concepts for efficient use of energy. Actual work includes the introduction of a broad collection and analysis of energy consumption data and the development of the high efficient data center "Green IT Cube" and technologies such as load based cooling of accelerator components. The final intention of this work is to provide a modern and efficient research facility at reasonable energy costs and sustainable use of energy.

Presenter: GARDLOWSKI, Philipp (urn:Facebook)

Session Classification: 3rd Session: The saving prospects in European Labs, projects and machine upgrades - Part 1

Contribution ID: **14** Type: **not specified**

Magnet designs for the ESRF-SR2

Wednesday 26 November 2014 17:00 (30 minutes)

Magnets for the ESRF storage ring upgrade (SR2) are being developed. The power consumption of the new ring should be lower than the present ESRF consumption, with much more magnets installed. On top of that, the new lattice must preserve the existing source points in the ID straight sections: longitudinal compactness is a strong constraint. Permanent magnet (PM) and electromagnet (EM) devices are being developed for this purpose. It is foreseen to install PM dipoles with longitudinal gradient. The other magnets will be normal conducting, with optimized power consumption and length. These technological choices have been driven by the magnet tuning ranges, the ESRF experience and the limited development time. For EM magnets, low power consumption goes against compactness. A compromise can be reach with longitudinally compact magnets with increased transverse dimensions. A brief review of the ESRF-SR2 magnet designs and an estimation of the energy saving (as compared to standard J=5 A/mm2 designs) will be presented.

Presenter: LE BEC, Gael (ESRF)

Session Classification: 3rd Session: The saving prospects in European Labs, projects and machine upgrades - Part 1

Contribution ID: **15** Type: **not specified**

The PSI experience: A theory of evolution

Thursday 27 November 2014 09:00 (30 minutes)

From the beginning, operating costs have been a factor in the design of accelerators and beamlines at PSI. However, limited funds and increasing power costs have made this aspect even more important nowadays. Through the history of PSI, we will present the initial prerogatives for magnet design at our institute and their evolution over time, resulting in the current compact design of the magnets for the SwissFEL project and the first design concepts for the SLS 2.0 upgrade.

Presenter: GABARD, Alexander (PSI)

Session Classification: 3rd Session: The saving prospects in European Labs, projects and machine upgrades - Part 2

Contribution ID: **16** Type: **not specified**

CERN experience on PM based magnet design and procurement

Thursday 27 November 2014 09:30 (30 minutes)

Presenter: THONET, Pierre Alexandre (CERN)

Session Classification: 3rd Session: The saving prospects in European Labs, projects and machine upgrades - Part 2

Contribution ID: **17** Type: **not specified**

Energy efficient magnets for FCC

Contribution ID: **18** Type: **not specified**

Compact superconducting magnets for linear accelerators

Thursday 27 November 2014 10:30 (30 minutes)

New Linear Accelerators based on SCRF cavities need compact and efficient superconducting magnet packages to focus and steer electron or proton beams. These magnets should be combined with SCRF cryomodules and installed inside or between them. A recent activity in this area was directed by FNAL-KEK collaboration to splittable conduction cooled magnets. Several magnet prototypes were built and successfully tested. These magnets were designed for high energy beams used in ILC, and Project-X. Nevertheless, there is an interest to explore splittable conduction cooled magnets for new accelerators: FNAL ASTA and PIP-II, KEK STF, SLAC LCLS II. Presented results of various magnets design, fabrication, and tests. Most magnet packages combine the quadrupole magnet and two dipole correctors. The presented magnetic measurement results confirm the specified magnet package parameters.

Summary

The splittable conduction cooled superconducting magnets provide the efficient way of integration SCRF caviries and magnets in the common cryomodule. The main advantages of the proposed approach are:
• Splittable configuration allows to install the magnet out of a very clean room;
• Conduction cooling, and cryogen-free magnet design (no LHe vessels for the magnet and current leads);
• Iron dominated magnetic design is less sensitive to the coil geometry and position.
• Coils placed far away from the magnet aperture reduce influence of superconductor magnetization
effects.
• The simple magnet configuration is very efficient for serial magnet fabrication.

Presenter: KASHIKHIN, Vladimir (Fermilab)

Session Classification: 4th Session: Efficient and compact magnet design examples - Part 1

Contribution ID: **19** Type: **not specified**

Electromagnetic and hybrid design experience for CLIC magnet R&D

Thursday 27 November 2014 11:00 (30 minutes)

Since 2009 CERN started R&D activities in order to identified and investigate the most challenging cases among the magnets needed for CLIC the Compact Linear Collider one of the possible Future Linear Colliders. In some specific cases the work is mainly done by our colleagues of STFC-Daresbury Lab (UK) part of the CLIC International Collaboration. In the last four years several theoretical studies, models and prototypes were realized mainly focusing two sub-system of the CLIC complex: the "2-beam Modules", the modular elements that are composing the backbone of the two linacs of CLIC, and the Machine Detector Interface (MDI) that include the final focus elements as QD0 and SD0 and the antisolenoid. In this talk we revise the status of the studied and procured magnets. Among them the Drive Beam Quadrupoles, the Main Beam Quadrupoles, the main beam Steering Correctors all challenging for the required compactness, performances and production size, and the final quadrupole QD0 and the sextupole SD0, challenging for the high performances required in terms of gradients and stability.

Presenter: MODENA, Michele (CERN)

Session Classification: 4th Session: Efficient and compact magnet design examples - Part 1

Contribution ID: **20** Type: **not specified**

ZEPTO: Tunable permanent magnet dipoles and quadrupoles

Thursday 27 November 2014 11:30 (30 minutes)

Within the framework of the CLIC-UK collaboration between CERN and STFC, two types of permanent magnet based quadrupoles have been developed and built. These magnets have a very large tuning range (15-60 T/m and 4-43 T/m respectively). The parameters were specified for the challenging requirements of the CLIC Drive Beam Decelerator. Two prototypes have been built and successfully tested, demonstrating the tuning range, stability and field quality of these magnets. A study is also under way to develop a PM-based dipole with a tuning range of 0.8-1.6T, in line with requirements for the CLIC Drive Beam Turnaround Loop.

Presenter: SHEPHERD, Ben (STFC)

Session Classification: 4th Session: Efficient and compact magnet design examples - Part 1

Contribution ID: **21** Type: **not specified**

Development and operation of a superconducting combined-function magnet system for J-PARC neutrino beam line

Thursday 27 November 2014 14:00 (30 minutes)

Presenters: YAMAMOTO, Akira (High Energy Accelerator Research Organization (JP)); OGITSU, Toru (KEK)

Session Classification: 4th Session: Efficient and compact magnet design examples - Part 2

Contribution ID: **22** Type: **not specified**

Integrated magnet block design and production for MAX IV

Thursday 27 November 2014 14:30 (30 minutes)

The magnet design of the MAX IV 3 GeV storage ring replaces the conventional support girder + discrete magnets scheme of previous 3rd gen. light sources with a compact integrated design having several consecutive magnet elements precision-machined out of a common solid iron block. This presentation consists of a brief description of the design, and mechanical + magnetic field measurement results from the magnet production series.

Presenter: JOHANSSON, Martin (MaxLab)

Session Classification: 4th Session: Efficient and compact magnet design examples - Part 2

Contribution ID: **23** Type: **not specified**

PM materials for accelerator magnets application

Contribution ID: **24** Type: **not specified**

News from electrical steel producers to enable higher efficiency

Contribution ID: **25** Type: **not specified**

Development of energy efficient power supplies/power electronics

Contribution ID: **26** Type: **not specified**

Permanent (and soft) magnet materials for use in accelerators

Thursday 27 November 2014 15:00 (30 minutes)

Permanent magnets and soft magnetic materials with specific properties have been frequently used in various assemblies at accelerators and colliders. Among these are undulators, wigglers as well as dipoles (PM based and specific electromagnets), PM-quadrupoles and higher multipoles. From energy consumption aspects, the PM-solutions may provide a contribution to long term energy savings combined with high long term stability. New PM-materials with enhanced properties at cryogenic temperatures may open new aspects for devices at low temperatures. Actual improvements in the properties of soft magnetic materials will contribute to more effective flux guidance elements. We will present some of the recent developments in these material classes which contribute to further enhancements of such units in future accelerator and collider projects.

Presenter: BÖRGERMANN, Franz-Josef (Vacuumschmelze GmbH & Co KG)

Session Classification: 5th Session: Industrial perspective

Contribution ID: **27** Type: **not specified**

Industrial challenges of compact magnet production

Thursday 27 November 2014 16:00 (30 minutes)

The CLIC-UK collaboration between CERN and STFC produced two prototypes of permanent magnet based quadrupoles to cover the large tuning range (15 - 60 T/m and 4 - 43 T/m respectively) required for the CLIC Drive Beam Decelerator. The space envelope and accuracies to achieve the demanding parameter challenges have been addressed during the production of the prototypes. Assembly sequencing, accuracy analysis and an investigation into industrial capabilities in both metrology and manufacture/assembly led to a proposal in the efficient and specification meeting "mass-production". Manufacture and assembly of the prototypes provided the identification and foundation of techniques and methodologies essential for large scale industrial manufacture.

Presenter: COLLOMB, Norbert (STFC Daresbury Laboratory)

Session Classification: 5th Session: Industrial perspective

Contribution ID: **28** Type: **not specified**

Beam dynamics requirements for future accelerators

Friday 28 November 2014 09:00 (20 minutes)

Presenter: PAPAPHILIPPOU, Yannis (CERN)

Session Classification: 7th Session: Beam dynamics, alignment, magnetic measurement requirements

Contribution ID: **29** Type: **not specified**

Magnet alignment challenges for future accelerators

Friday 28 November 2014 09:20 (20 minutes)

Presenter: MAINAUD DURAND, Helene (CERN)

Session Classification: 7th Session: Beam dynamics, alignment, magnetic measurement requirements

Contribution ID: **30** Type: **not specified**

Magnetic measurements challenges for very compact magnets

Friday 28 November 2014 09:40 (20 minutes)

Presenter: BUZIO, Marco (CERN)

Session Classification: 7th Session: Beam dynamics, alignment, magnetic measurement requirements

Contribution ID: **31** Type: **not specified**

Summary of 6 sessions

Contribution ID: **32** Type: **not specified**

Summary

Contribution ID: **33** Type: **not specified**

General discussion

Contribution ID: **34** Type: **not specified**

Energy efficient beam transport by means of high current pulsed magnets

Wednesday 26 November 2014 18:00 (30 minutes)

In order to raise the focusing gradient in case of bunched beam lines, an alternative, iron free, pulsed quadrupole was designed. The transfer channels between synchrotrons as well as the final focusing for the production of secondary beams are possible applications. The construction of this quadrupole is about to be finished and thus it is almost ready to be tested. The quadrupole is running in a pulsed mode, which means an immense saving of energy by avoiding standby operation. Still the high gradients demand high currents. Hence a circuit had to be developed which is able to reclaim a significant amount of the pulsing energy for following shots. The basic design of the pulsed quadrupole is introduced also considering its differences according to common technologies. Furthermore the energy efficient circuit is explicated and the limits of adaptability are considered.

Presenter: TENHOLT, Carmen (GSI)

Session Classification: 3rd Session: The saving prospects in European Labs, projects and machine upgrades - Part 1

Contribution ID: **35** Type: **not specified**

The experience at FERMILAB: recycler ring and beam lines based on PM technology

Thursday 27 November 2014 12:00 (30 minutes)

Various permanent magnets were built and successfully operated at FERMILAB Accelerator Complex. The Recycler Ring and 8 Gev beam transfer line includes nearby 500 permanent magnet gradient dipoles and quadrupoles based on strontium ferrite bricks. For NLC were built and tested 6 adjustable permanent magnet quadrupoles with gradients up to 100 T/m, and wide range of integrated gradient changes. The NOVA beamline and the Main Injector ionization profile monitor permanent magnets were recently commissioned. They based on SmCo5 permanent magnets. In the presentation briefly discussed the FERMILAB experience in the area of permanent magnets design, fabrication, and operation.

Presenter: KASHIKHIN, Vladimir (Fermilab)

Session Classification: 4th Session: Efficient and compact magnet design examples - Part 1

Contribution ID: **36** Type: **not specified**

Development of electrical steel for highest efficiency applications

Thursday 27 November 2014 15:30 (30 minutes)

Voestalpine is a producer of highest quality electrical steel. In recent years voestalpine proofed to be a reliable partner regarding the supply of electrical steel for the construction of magnets. From the point of the electrical steel producer the requirements of the magnet construction industry are very demanding. This contribution tries to show the difficulties that arise by the example of the MedAustron project. With the startup of the new continuous annealing line 2 voestalpine is now able to supply electrical steel for applications that require the highest efficiency available on the market. In this presentation an overview of the technical capabilities of the production of electrical steel is given. Possibilities to produce electrical steel with tailored properties concerning the coercitivity and the permeability are discussed. At the same time the physical limitations of electrical steel are discussed. Also the newest developments regarding electrical steel for higher frequency applications are discussed.

Presenter: KEPPERT, Tim (VoestAlpine)

Session Classification: 5th Session: Industrial perspective

Contribution ID: **37** Type: **not specified**

6th Session: Short communication from participants; Chair:

Contribution ID: **38** Type: **not specified**

Energy efficient magents for FCC Injector Complex

Presenter: MILANESE, Attilio (CERN)

Contribution ID: **39** Type: **not specified**

Discussion

Thursday 27 November 2014 18:00 (15 minutes)

Session Classification: 6th Session: Short communication from participants

Contribution ID: **40** Type: **not specified**

Nano-positioning possibilities for future accelerator magnets

Friday 28 November 2014 10:00 (30 minutes)

A subject common to several future high-energy physics R&D programs is the generation of beams with very small emittance and beam size and concomitantly the alignment and stabilization of accelerator components with ultimate precision. To reach e.g. the design luminosity at the CLIC interaction point, the beam size at the interaction point (IP) shall be only one nanometre in vertical direction and 45 nanometre in horizontal direction. About 4000 Main Beam Quadrupoles (MBQ) are needed to conserve such a small beam along the accelerator and final focus (FF) magnets will focus the two beams to collide at the IP. In addition to a very stringent alignment, the quadrupole positions should be stable to sub nanometre level and this for frequencies as low as 1 Hz. An active mechanical stabilization and positioning system based on very stiff piezo electric actuators and inertial reference masses is under study for the Main Beam Quadrupoles (MBQ). The stiff support was selected for robustness against direct forces and for the option of incrementally repositioning the magnet with sub nanometre resolution. The technical feasibility and the required stability level was demonstrated on several test benches, including a type 1 MBQ prototype (100 kg) with nominal magnetic field and nominal water flow. Technical issues were however identified and the development of the actuating support, sensors, and controller is still ongoing to increase the performance, integrate the system in the overall controller, adapt to the accelerator environment, and reduce costs. This presentation will show the type of components that can be used for actuating accelerator magnets with sub nanometer resolution and the technical parameters to be dealt with. Some R&D possibilities will also be indicated.

Presenter: ARTOOS, Kurt (CERN)

Session Classification: 7th Session: Beam dynamics, alignment, magnetic measurement requirements

Contribution ID: **41** Type: **not specified**

Summary of sessions 3&4

Friday 28 November 2014 11:10 (10 minutes)

Presenter: SCHOERLING, Daniel (CERN)

Session Classification: 8th Session: Summary and final discussions

Contribution ID: **42** Type: **not specified**

Summary of sessions 5&6

Friday 28 November 2014 11:20 (10 minutes)

Presenter: CLARKE, Jim (STFC)

Session Classification: 8th Session: Summary and final discussions

Contribution ID: **43** Type: **not specified**

General discussions

Friday 28 November 2014 11:30 (1 hour)

Session Classification: 8th Session: Summary and final discussions

Contribution ID: **44** Type: **not specified**

Summary of sessions 1&2

Friday 28 November 2014 11:00 (10 minutes)

Presenter: YAMAMOTO, Akira (High Energy Accelerator Research Organization (JP))

Session Classification: 8th Session: Summary and final discussions

Contribution ID: **45** Type: **not specified**

ZEPTO: Tunable Permanent Magnet Dipoles and Quadrupoles

Within the framework of the CLIC-UK collaboration between CERN and STFC, two types of permanent magnet based quadrupoles have been developed and built. These magnets have a very large tuning range (15-60 T/m and 4-43 T/m respectively). The parameters were specified for the challenging requirements of the CLIC Drive Beam Decelerator. Two prototypes have been built and successfully tested, demonstrating the tuning range, stability and field quality of these magnets. A study is also under way to develop a PM-based dipole with a tuning range of 0.8-1.6T, in line with requirements for the CLIC Drive Beam Turnaround Loop.

Author: Mr SHEPHERD, Ben (STFC)

Co-authors: PETRONE, Carlo (CERN); CLARKE, Jim (STFC); STRUIK, Michael (CERN); MODENA, Michele (CERN); MARKS, Neil (STFC); Mr COLLOMB, Norbert (STFC Daresbury Laboratory)

Presenter: Mr SHEPHERD, Ben (STFC)

Contribution ID: **46** Type: **not specified**

Development of a hybrid permanent magnet quadrupole

The ESRF Insertion Devices laboratory is developing high gradient permanent magnet (PM) quadrupoles for potential use in a storage ring. This paper presents the development of a hybrid quadrupole with strong gradient (100T/m). The performance of a few PM and resistive structures are compared. One hybrid structure, composed of iron parts and rectangular PM blocks, appears to offer a good compromise between performance and technological complexity. This structure has an aperture in the horizontal plane for the X-ray beam port. It introduces field quality deterioration because of the structure asymmetry. Field quality repair work can be achieved in particular on the pole shape by optimization. Furthermore, the arrangement of the quadrupole elements allows a number of simple methods to correct the errors during the assembly.

Summary

ESRF-II high gradient quadrupole is specified at 90 T/m which is close to the limit of conventional resistive technology. This paper introduces the development of a high gradient PM hybrid quadrupole

Author: Mr NGOTTA, patrick (esrf)

Co-authors: Dr LE BEC, gael (esrf); Dr CHAVANNE, joel (esrf)

Presenter: Mr NGOTTA, patrick (esrf)

Contribution ID: **47** Type: **not specified**

Magnet designs for the ESRF-SR2

Magnets for the ESRF storage ring upgrade (SR2) are being developed. The power consumption of the new ring should be lower than the present ESRF consumption, with much more magnets installed. On top of that, the new lattice must preserve the existing source points in the ID straight sections: longitudinal compactness is a strong constraint. Permanent magnet (PM) and electromagnet (EM) devices are being developed for this purpose. It is foreseen to install PM dipoles with longitudinal gradient. The other magnets will be normal conducting, with optimized power consumption and length. These technological choices have been driven by the magnet tuning ranges, the ESRF experience and the limited development time. For EM magnets, low power consumption goes against compactness. A compromise can be reach with longitudinally compact magnets with increased transverse dimensions. A brief review of the ESRF-SR2 magnet designs and an estimation of the energy saving (as compared to standard J=5 A/mm2 designs) will be presented.

Author: LE BEC, Gael (ESRF)

Co-author: Dr CHAVANNE, Joel (ESRF)

Presenter: LE BEC, Gael (ESRF)

Contribution ID: **48** Type: **not specified**

A capital-cost and energy reducing configuration for dipoles in multi-stacked race-track bends.

Some existing facilities (1) and the recent proposal for the LHeC collider (2,3), have utilised a race-track configuration, with 180 degree bends, to circulate beam for a small number of turns (typically 3 revolutions) through superconducting energy-recovery linacs. Particles of differing energies are defected in these bends and this is accomplished by positioning the beams at different vertical positions, with different strength dipole magnets stacked vertically at the appropriate height for each beam. Conventionally, these dipoles are separately, individually, powered. However, the paper will present a revised geometry that allows coils to be shared between two adjacent vertically stacked dipoles, so contributing to the required Ampere-turns in both magnets. The resulting configuration reduces the total coil volume and hence the energy losses of the complete assembly. As an example, such a modified structure for the LHeC, configured according to the linac-ring option, would reduce the dipole coil volume and power loss by circa one third.

(1) CEBAF: see https://www.jlab.org/12-gev-upgrade

(2) A. Bogacz, Thomas Jefferson National Accelerator Facility, CERN-ECFA-NuPECC Workshop, June 2012.

(3) LHec; A Large Hadron Electron Collider at CERN; sections 8.1.2, Fig 8.5; and 9.2.1 p335.

Author: Prof. MARKS, Neil (STFC, Daresbury Laboratory; U. of Liverpool.)

Presenter: Prof. MARKS, Neil (STFC, Daresbury Laboratory; U. of Liverpool.)

Contribution ID: **49** Type: **not specified**

Compact Superconducting Magnets for Linear Accelerators

New Linear Accelerators based on SCRF cavities need compact and efficient superconducting magnet packages to focus and steer electron or proton beams. These magnets should be combined with SCRF cryomodules and installed inside or between them. A recent activity in this area was directed by FNAL-KEK collaboration to splittable conduction cooled magnets. Several magnet prototypes were built and successfully tested. These magnets were designed for high energy beams used in ILC, and Project-X. Nevertheless, there is an interest to explore splittable conduction cooled magnets for new accelerators: FNAL ASTA and PIP-II, KEK STF, SLAC LCLS II. Presented results of various magnets design, fabrication, and tests. Most magnet packages combine the quadrupole magnet and two dipole correctors. The presented magnetic measurement results confirm the specified magnet package parameters.

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The splittable conduction cooled superconducting magnets provide the efficient way of integration SCRF caviries and magnets in the common cryomodule. The main advantages of the proposed approach are:

- Splittable configuration allows to install the magnet out of a very clean room;
- Conduction cooling, and cryogen-free magnet design (no LHe vessels for the magnet and current leads);
- Iron dominated magnetic design is less sensitive to the coil geometry and position.
- Coils placed far away from the magnet aperture reduce influence of superconductor magnetization effects.
- The simple magnet configuration is very efficient for serial magnet fabrication.

Author: Dr KASHIKHIN, Vladimir (Fermilab)

Co-authors: Prof. YAMAMOTO, Akira (High Energy Accelerator Research Organization (JP)); Dr TARTAGLIA, Michael (Fermilab); Mr ANDREEV, Nikolai (Fermilab); Prof. KIMURA, Nobuhiro (KEK); Mr ORLOV, Yuriy (Fermilab)

Presenter: Dr KASHIKHIN, Vladimir (Fermilab)

Contribution ID: **50** Type: **not specified**

Industrial challenges of compact magnet production

The CLIC-UK collaboration between CERN and STFC produced two prototypes of permanent magnet based quadrupoles to cover the large tuning range (15 - 60 T/m and 4 - 43 T/m respectively) required for the CLIC Drive Beam Decelerator. The space envelope and accuracies to achieve the demanding parameter challenges have been addressed during the production of the prototypes. Assembly sequencing, accuracy analysis and an investigation into industrial capabilities in both metrology and manufacture/assembly led to a proposal in the efficient and specification meeting "mass-production". Manufacture and assembly of the prototypes provided the identification and foundation of techniques and methodologies essential for large scale industrial manufacture.

Author: Mr COLLOMB, Norbert (STFC Daresbury Laboratory)

Co-authors: Mr SHEPHERD, Ben (STFC); CLARKE, Jim (STFC); MARKS, Neil (STFC)

Presenter: Mr COLLOMB, Norbert (STFC Daresbury Laboratory)

Contribution ID: **51** Type: **not specified**

The Loss Budget of the SIS100 Fast Ramped Superferric Magnets

The superconducting magnets of the SIS100 heavy ion accelerator are to be built based on a compact window-frame design. Beside the optimisation of the magnetic field characteristics the minimisation of the AC losses was a central part during the R&D phase. Now the first dipole was built and tested. We presend the obtained loss results for typical operation modes and compare them with previous estimations and extrapolate these to the expected power consumption required for thequadrupole and corrector magnet. This will allow estimating the expected total energy consumption.

Author: FISCHER, Egbert (GSI)

Co-authors: BLEILE, Alexander (GSI); Dr MIERAU, Anna (GSI Helmholtzzentrum für Schwerionenforschunb mbH); SCHNIZER, Pierre (GSI Helmholtzzentrum für Schwerionenforschung mbH)

Presenter: FISCHER, Egbert (GSI)

Contribution ID: **52** Type: **not specified**

Integrated magnet block design and production for MAX IV

The magnet design of the MAX IV 3 GeV storage ring replaces the conventional support girder + discrete magnets scheme of previous 3rd gen. light sources with a compact integrated design having several consecutive magnet elements precision-machined out of a common solid iron block. This presentation consists of a brief description of the design, and mechanical + magnetic field measurement results from the magnet production series.

Author: Mr JOHANSSON, Martin (MAX IV Laboratory)

Presenter: Mr JOHANSSON, Martin (MAX IV Laboratory)

Contribution ID: **53** Type: **not specified**

Permanent (and soft) magnet materials for use in accelerators

F.-J. Boergermann, C. Brombacher, K. Uestuener, F. Fohr, Vacuumschmelze GmbH & Co KG, Hanau, Germany

"Permanent magnets and soft magnetic materials with specific properties have been frequently used in various assemblies at accelerators and colliders.
Among these are undulators, wigglers as well as dipoles (PM based and specific electromagnets), PM-quadrupoles and higher multipoles.
From energy consumption aspects, the PM-solutions may provide a contribution to long term energy savings combined with high long term stability.
New PM-materials with enhanced properties at cryogenic temperatures may open new aspects for devices at low temperatures.
Actual improvements in the properties of soft magnetic materials will contribute to more effective flux guidance elements.
We will present some of the recent developments in these material classes which contribute to further enhancements of such units in future accelerator and collider projects."

Author: Dr BÖRGERMANN, Franz-Josef (Vacuumschmelze GmbH & Co KG)

Presenter: Dr BÖRGERMANN, Franz-Josef (Vacuumschmelze GmbH & Co KG)

Contribution ID: **54** Type: **not specified**

Saving opportunities in accelerator magnets

An accelerator magnet is usually excited either by water cooled copper coils powered with an effective current density in the range of 3-6 A/mm2 or by using superconducting coils, depending on the required field amplitude. Exceptions are often due to technical reasons (special constraints, easier construction, more reliability). Up to now, only in rare cases (in particular in experimental magnets) the energy consumption is an important design factor. The situation is however rapidly evolving and many research institutes are either revising the existing installations or planning the new ones with special attention towards energy consumption.
This talk will review several "saving opportunities"presently considered in this domain.

Author: Dr TOMMASINI, Davide (CERN)

Presenter: Dr TOMMASINI, Davide (CERN)

Contribution ID: **55** Type: **not specified**

Power converters design optimization - need for an integrated approach with the magnet designer

This talks presents the basics of the design of a power converter for DC and pulsed magnet. Particularly the impact of the magnet design (inductance, voltage and current adaptation given by the number of turns, etc.) on the converter design is illustrated. Compromises between efficiency, cost and technologies are presented. Finally, the need and benefits of an integrated approach which considers the magnet design variables is demonstrated via a simplified example.

Author: AGUGLIA, Davide (CERN)

Presenter: AGUGLIA, Davide (CERN)

Contribution ID: **56** Type: **not specified**

Magnet Energy Recovery; a way towards more compact and efficient systems

Magnet energy recovery on a cycle-by-cycle basis shows potential for great energy savings and improvement of the grid power quality. Reducing the magnet duty cycle allows more compact mechanical layout and greater efficiency. To achieve such a benefit a system integration study is essential before starting the parallel development of magnets and power conversion/energy recovery systems.

Author: Dr PAPASTERGIOU, Konstantinos (CERN)

Presenter: Dr PAPASTERGIOU, Konstantinos (CERN)

Contribution ID: **57** Type: **not specified**

Energy management at GSI and FAIR, strategy on energy management,

GSI Helmholtzzentrum für Schwerionenforschung GmbH operates a unique large-scale accelerator for heavy ions. In the coming years the new international accelerator facility FAIR, one of the largest research projects worldwide, will be built at GSI. In the final extension FAIR consists of several heavy ion accelerator rings, experiment storage rings with up to 1,100 meters in circumference, two linear accelerators and about 3.5 kilometers high energy beam transfer lines as well as several experiment caves.
In the context of rising energy prices and the responsible use of resources, GSI has taken the task to develop concepts for efficient use of energy. Actual work includes the introduction of a broad collection and analysis of energy consumption data and the development of the high efficient data center "Green IT Cube"and technologies such as load based cooling of accelerator components.
The final intention of this work is to provide a modern and efficient research facility at reasonable energy costs and sustainable use of energy.

Author: LINDENBERG, Jan (G)

Presenter: LINDENBERG, Jan (G)

Contribution ID: **58** Type: **not specified**

The GSI experience: Energy efficient beam transport by means of high current pulsed magnets

In order to raise the focusing gradient in case of bunched beam lines, an alternative, iron free, pulsed quadrupole was designed. The transfer channels between synchrotrons as well as the final focusing for the production of secondary beams are possible applications. The construction of this quadrupole is about to be finished and thus it is almost ready to be tested. The quadrupole is running in a pulsed mode, which means an immense saving of energy by avoiding standby operation. Still the high gradients demand high currents. Hence a circuit had to be developed which is able to reclaim a significant amount of the pulsing energy for following shots. The basic design of the pulsed quadrupole is introduced also considering its differences according to common technologies. Furthermore the energy efficient circuit is explicated and the limits of adaptability are considered.

Author: TENHOLT, Carmen (GSI Helmholtzzentrum für Schwerionenforschung GmbH)

Presenter: TENHOLT, Carmen (GSI Helmholtzzentrum für Schwerionenforschung GmbH)

Contribution ID: **59** Type: **not specified**

CERN plans towards energy efficiency

High energy accelerators are usually great energy consumers and could not escape from being concerned by energy efficiency aspects. After recalling the context, major actions towards energy efficiency will be presented, with plans for the future.

Author: Mr CLAUDET, Serge (CERN)

Presenter: Mr CLAUDET, Serge (CERN)

Contribution ID: **60** Type: **not specified**

In-vacuum magnet design and challenges

Synchrotron light sources can extend their wavelength reach significantly by putting the undulator arrays into the beam vacuum system. The advantages are such than many light sources now utilise in-vacuum undulators when required. However, there are a number of extra physics and engineering challenges which have to be dealt with when putting magnets in-vacuum. In this talk I will explain the motivation, the additional challenges, and the realisation of in-vacuum undulators.

Author: CLARKE, Jim (STFC)

Presenter: CLARKE, Jim (STFC)

Contribution ID: **61** Type: **not specified**

Electro-magnetic and hybrid design experience for CLIC magnet R&D

Since 2009 CERN started R&D activities in order to identified and investigate the most challenging cases among the magnets needed for CLIC the Compact Linear Collider one of the possible Future Linear Colliders. In some specific cases the work is mainly done by our colleagues of STFC-Daresbury Lab (UK) part of the CLIC International Collaboration.
In the last four years several theoretical studies, models and prototypes were realized mainly focusing two sub-system of the CLIC complex: the "2-beam Modules", the modular elements that are composing the backbone of the two linacs of CLIC, and the Machine Detector Interface (MDI) that include the final focus elements as QD0 and SD0 and the antisolenoid.
In this talk we revise the status of the studied and procured magnets. Among them the Drive Beam Quadrupoles, the Main Beam Quadrupoles, the main beam Steering Correctors all challenging for the required compactness, performances and production size, and the final quadrupole QD0 and the sextupole SD0, challenging for the high performances required in terms of gradients and stability.

Author: MODENA, Michele (CERN)

Presenter: MODENA, Michele (CERN)

Contribution ID: **62** Type: **not specified**

Nano-positioning possibilities for future accelerator magnets

A subject common to several future high-energy physics R&D programs is the generation of beams with very small emittance and beam size and concomitantly the alignment and stabilization of accelerator components with ultimate precision. To reach e.g. the design luminosity at the CLIC interaction point, the beam size at the interaction point (IP) shall be only one nanometre in vertical direction and 45 nanometre in horizontal direction. About 4000 Main Beam Quadrupoles (MBQ) are needed to conserve such a small beam along the accelerator and final focus (FF) magnets will focus the two beams to collide at the IP. In addition to a very stringent alignment, the quadrupole positions should be stable to sub nanometre level and this for frequencies as low as 1 Hz. An active mechanical stabilization and positioning system based on very stiff piezo electric actuators and inertial reference masses is under study for the Main Beam Quadrupoles (MBQ). The stiff support was selected for robustness against direct forces and for the option of incrementally repositioning the magnet with sub nanometre resolution. The technical feasibility and the required stability level was demonstrated on several test benches, including a type 1 MBQ prototype (100 kg) with nominal magnetic field and nominal water flow. Technical issues were however identified and the development of the actuating support, sensors, and controller is still ongoing to increase the performance, integrate the system in the overall controller, adapt to the accelerator environment, and reduce costs.
This presentation will show the type of components that can be used for actuating accelerator magnets with sub nanometer resolution and the technical parameters to be dealt with. Some R&D possibilities will also be indicated.

Author: ARTOOS, Kurt (CERN)

Co-author: JANSSENS, Stef (CERN)

Presenter: ARTOOS, Kurt (CERN)

Contribution ID: **63** Type: **not specified**

The experience at FERMILAB: recycler ring and beam lines based on PM technology

Various permanent magnets were built and successfully operated at FERMILAB Accelerator Complex. The Recycler Ring and 8 Gev beam transfer line includes nearby 500 permanent magnet gradient dipoles and quadrupoles based on strontium ferrite bricks. For NLC were built and tested 6 adjustable permanent magnet quadrupoles with gradients up to 100 T/m, and wide range of integrated gradient changes. The NOVA beamline and the Main Injector ionization profile monitor permanent magnets were recently commissioned. They based on SmCo5 permanent magnets. In the presentation briefly discussed the FERMILAB experience in the area of permanent magnets design, fabrication, and operation.

Author: KASHIKHIN, VLADIMIR (Fermilab)

Co-authors: Dr BROWN, Bruce (Fermilab); Dr HARDING, David (Fermilab); Dr VELEV, George (Fermilab); Dr KOURBANIS, Ioanis (Fermilab); Dr KIEMSCHIES, Oliver (Fermilab)

Presenter: KASHIKHIN, VLADIMIR (Fermilab)

Contribution ID: **64** Type: **not specified**

Compact and Low Consumption Magnet Design – The DESY Experience

During the last ten years a variety of electromagnets has been ordered to upgrade the PETRA accelerator into a synchrotron light source, to build up a new branch at the FLASH accelerator facility and to install the new European XFEL.

The talk will give an overview of the ingredients which are necessary for developing and manufacturing magnets. Two septum designs will be presented to discuss how electricity costs can be reduced without losing machine performance. Furthermore design studies of combined function magnets and a permanent magnet design that could replace a quadrupole electromagnet to save energy costs will be shown.

Author: Mr KRAUSE, Bernward (DESY)

Presenter: Mr KRAUSE, Bernward (DESY)

Contribution ID: **65** Type: **not specified**

Development of electrical steel for highest efficiency applications

Voestalpine is a producer of highest quality electrical steel. In recent years voestalpine proofed to be a reliable partner regarding the supply of electrical steel for the construction of magnets. From the point of the electrical steel producer the requirements of the magnet construction industry are very demanding. This contribution tries to show the difficulties that arise by the example of the MedAustron project. With the startup of the new continuous annealing line 2 voestalpine is now able to supply electrical steel for applications that require the highest efficiency available on the market. In this presentation an overview of the technical capabilities of the production of electrical steel is given. Possibilities to produce electrical steel with tailored properties concerning the coercitivity and the permeability are discussed. At the same time the physical limitations of electrical steel are discussed. Also the newest developments regarding electrical steel for higher frequency applications are discussed.

Author: Dr KEPPERT, Timothy (Voestalpine Stahl GmbH)

Presenter: Dr KEPPERT, Timothy (Voestalpine Stahl GmbH)

Contribution ID: **66** Type: **not specified**

A capital-cost and energy reducing configuration for dipoles in multi-stack race-track bends

Thursday 27 November 2014 17:00 (20 minutes)

Some existing facilities (1) and the recent proposal for the LHeC collider (2,3), have utilised a racetrack configuration, with 180 degree bends, to circulate beam for a small number of turns (typically 3 revolutions) through superconducting energy-recovery linacs. Particles of differing energies are defected in these bends and this is accomplished by positioning the beams at different vertical positions, with different strength dipole magnets stacked vertically at the appropriate height for each beam. Conventionally, these dipoles are separately, individually, powered. However, the paper will present a revised geometry that allows coils to be shared between two adjacent vertically stacked dipoles, so contributing to the required Ampere-turns in both magnets. The resulting configuration reduces the total coil volume and hence the energy losses of the complete assembly. As an example, such a modified structure for the LHeC, configured according to the linac-ring option, would reduce the dipole coil volume and power loss by circa one third.

Summary

(1) CEBAF: see https://www.jlab.org/12-gev-upgrade
(2) A. Bogacz, Thomas Jefferson National Accelerator Facility, CERN-ECFA-NuPECC Workshop, June 2012.
(3) LHec; A Large Hadron Electron Collider at CERN; sections 8.1.2, Fig 8.5; and 9.2.1 p335.

Presenter: MARKS, Neil (STFC)

Session Classification: 6th Session: Short communication from participants

Contribution ID: **67** Type: **not specified**

Development of a hybrid permanent magnets quadrupole

Thursday 27 November 2014 17:20 (20 minutes)

The ESRF Insertion Devices laboratory is developing high gradient permanent magnet (PM) quadrupoles for potential use in a storage ring. This paper presents the development of a hybrid quadrupole with strong gradient (100T/m). The performance of a few PM and resistive structures are compared. One hybrid structure, composed of iron parts and rectangular PM blocks, appears to offer a good compromise between performance and technological complexity. This structure has an aperture in the horizontal plane for the X-ray beam port. It introduces field quality deterioration because of the structure asymmetry. Field quality repair work can be achieved in particular on the pole shape by optimization. Furthermore, the arrangement of the quadrupole elements allows a number of simple methods to correct the errors during the assembly.

Summary

ESRF-II high gradient quadrupole is specified at 90 T/m which is close to the limit of conventional resistive technology. This paper introduces the development of a high gradient PM hybrid quadrupole

Presenter: NGOTTA, Patrick (ESRF)

Session Classification: 6th Session: Short communication from participants

Contribution ID: **68** Type: **not specified**

The loss budget of the SIS100 fast ramped superferric magnets

Thursday 27 November 2014 17:40 (20 minutes)

The superconducting magnets of the SIS100 heavy ion accelerator are to be built based on a compact window-frame design. Beside the optimisation of the magnetic field characteristics the minimisation of the AC losses was a central part during the R&D phase. Now the first dipole was built and tested. We presend the obtained loss results for typical operation modes and compare them with previous estimations and extrapolate these to the expected power consumption required for the quadrupole and corrector magnet. This will allow estimating the expected total energy consumption.

Presenter: MIERAU, Anna (GSI)

Session Classification: 6th Session: Short communication from participants

Contribution ID: **69** Type: **not specified**

The PSI Experience: A Theory Of Evolution

From the beginning, operating costs have been a factor in the design of accelerators and beamlines at PSI. However, limited funds and increasing power costs have made this aspect even more important nowadays. Through the history of PSI, we will present the initial prerogatives for magnet design at our institute and their evolution over time, resulting in the current compact design of the magnets for the SwissFEL project and the first design concepts for the SLS 2.0 upgrade.

Author: GABARD, Alexander (Paul Scherrer Institute)

Presenter: GABARD, Alexander (Paul Scherrer Institute)

Contribution ID: **70** Type: **not specified**

Why are particle accelerators so inefficient?

High-energy accelerators/colliders have developed into large machines consuming high electrical power up to the 100 MW range, thus making the energy bill a major component of their operating costs and eventually of their acceptability by society. With several new projects under study beyond the Large Hadron Collider (LHC), and projections of rising electricity prices by energy agencies, this trend is expected to grow into a critical issue for future machines. While a minimum power duty can be estimated from the beam parameters of both circular and linear accelerators/colliders, they all share low grid-to-beam efficiency entailing much higher power requirements from the electrical networks. We analyse the sources of energy dissipation, from the closest to the farthest from the beams, and discuss the power efficiency of some existing machines and future projects. This methodology also enables to identify possible paths for improvement.

Author: LEBRUN, Philippe (CERN)

Presenter: LEBRUN, Philippe (CERN)