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TURNKEY SYSTEMS COST OPTIMIZATION BY ITERATIVE DESIGN OF MAGNETS AND POWER SUPPLIES

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Abstract

For more than 30 years, Sigmaphi has been manufacturing magnets and power supplies. Its teams are now able to supply a complete particle beamline, from beam optics calculation to on-site installation and alignment. These combined skills allow design optimization for turnkey systems in order to reduce their purchasing and running costs. A common though widespread in scientific community is that savings are possible by making the complete (and optimized) design of a magnet before asking an industrial company to manufacture it. At first glance, only looking at the design cost, it may be true. But in most cases, considering the complete system and running costs, this hypothesis is false. Based on the average cost breakdown between material and workmanship in a magnet and the related power supply, it is highlighted how an iterative design can reduce the total cost of the system. Two examples of successful iterative designs are presented: a tunable kicker magnet with its pulser, and a 70 meters beamline designed, manufactured and installed by Sigmaphi.

INTRODUCTION

A common though widespread in scientific and accelerator's engineering community is that savings are possible by making the complete (and optimized) design of a magnet before asking an industrial company to manufacture it. At first glance, only looking at magnet costs, this may be true. But in most cases, considering the complete system and running costs, this hypothesis is false. Power supplies are the first "victims" of magnets size optimization, and the consequences on running costs can be dramatic.

The best practice is to adapt magnet design to standard power supplies, and mutualize magnets design as much as possible through what we call here "iterative design".

An example of successful iterative design is presented here.

GUIDELINE FOR ITERATIVE DESIGN

The entry point for designing a cost-adapted solution is functional needs. The one who designed his magnet without considering the task of his colleague from power supply can be sure that his system will not be optimized. The main steps for iterative and cost-optimized design are:

- Beam optics.
- Magnets design, which give main parameters: bore or gap, effective length, field or gradient.
- Electrical parameters of magnets, through coils design.
- Determining if a standard "on-shelf" power supply is close to what is required. If not, all the possibilities must be explored to change coils and magnet design to fit standard power supply, keeping in mind the objective of using the device with the lowest power.
- Verifying that power consumption is lower than the initial target. If not, a new iteration starting from one of the stages above is necessary.
- In case of a beam line where several pairs of magnet/power supply are to be designed, check if there are possibilities to group magnet design: same bore diameter/length to use same coils, even if magnet is used at 70 or 80% of its full capacity.
  Of course, this last step is strongly limited by the space constrains you may have.

EXAMPLE

An example of successful iterative design led by Sigmaphi is given here. Sigmaphi was in charge of designing, manufacturing, installing and aligning a 70m beam line for JINR in Dubna, Russia: Acculina-2. Beam optics responsibility was held by JINR, but teams from both sides worked together to adapt it in order to reduce significantly running costs.

For this beam line, the necessary quantities of magnets are presented in Table 1, and part of the layout in Fig. 1.

Starting from the initial specification, seven iterations were necessary to come up with an optimized design of both magnets and power supplies.

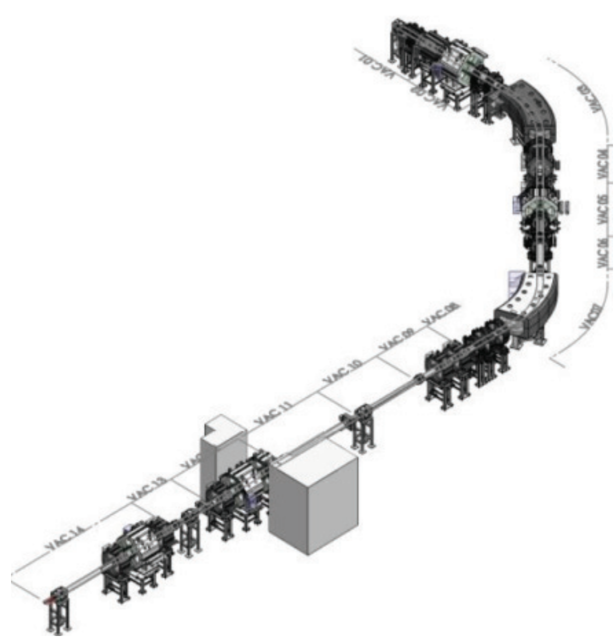

Figure 1: Partial layout of Acculina-2 beam line.

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Table 1: Types and Quantities of Magnets

Type	Number of different designs (final)	Total quantity needed
Dipole	2	2
Quadrupole	5	14
Sextupole	2	5
Octupole	1	3
Steerer	1	4

As the quadrupoles represent the major part of energy consumption for this beam line, we will focus only on these magnets. The main parameters for quadrupole after iterative design are presented in Table 2.

Table 2: Quadrupoles Parameters

Bore diameter	Magnetic length	Gradient (T/m)			
94 mm	543 mm	9.2			
160 mm	476 mm	3.8	4.6	5.5	7.8
		8.6	8.7	9.75	
	871 mm	7.1			
240 mm	518 mm	6.3	6.3		
	859 mm	3.8	6.2	7.21	

For each bore/length pair, a single design was made, and gradient is adjusted only by current in coils. Even if some coils may be oversized, the time and costs saved on coils manufacturing tools worth it, and finally only five quadrupoles designs cover all the needs (Table 1 & 2).

Thanks to this iterative design method, the total power consumption for the 14 quadrupoles decreased from 283 kW to 262 kW, which represents a drop of 7.5%.

CONCLUSION

Iterative beam line design can lead to significant savings on initial purchasing and running costs. However, it is only possible to achieve such goal by dialogue between industrial companies and buyer's technical and scientific team. By requiring only functional needs, not over-specifying, and leaving industrial companies responsible for the design and manufacture of turnkey systems, scientific teams from accelerator labs can save time, taxpayer money, and keep working on highly innovative accelerators and components.

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