1) Introduction

Due to special circumstances in my personal life, I undertake this brief description of a very simple basic concept, as well as its implementation in a narrow band of applications, in a somewhat unusual way: Even though I have performed a detailed quantitative analysis and developed design formulae and description of this class of applications, I feel that a well informed reader benefits right now most from an elucidation of the basic ideas, with the quantitative mathematical details relegated to a later report. A highly motivated reader can find the basis for the fairly simple quantitative analysis in ref. 2.

2) Genesis

Bill Barletta, Alan Jackson, Kern Robinson and I met in August 1999 at my home away from home to discuss options on how to design and build 1700 dipole magnets of 10 meters length with a field range of 30 to 300 Gauss. The purpose of this study was to find out whether Bill Barletta’s idea of a “cheap” high energy accelerator was as cheap as it had to be in order to be practical. It turned out later that for reasons not related to the magnets this accelerator was too expensive to justify further exploration of this concept. However the magnet problem represented all by itself a very interesting problem. Not having been able to find a satisfactory solution for the magnet problem at this point, but stimulated by our discussion of magnet systems, I came up with a rather interesting general concept that is easily applied to a large class of magnet problems.

3) A generic concept about changing the performance characteristics of some systems.

It is quite common that changing essential characteristics of a system entails also a change of the stored energy in at least that part of the system which determines the performance characteristics, the region that I call the business region. In case of an accelerator magnet, the business region would be that part of the magnet where the particle beam is located and affected by the field. When the method used to change the stored energy in the business region consists of “simply” exchanging energy between the system and the outside environment, this exchange of energy with the environment can be very difficult and costly. This problem can be greatly reduced if one can add to the “normal” system a region that satisfies the following conditions: 3.1) One must be able to store energy in this region. 3.2) One must be able to exchange energy (in both directions) with minimal effort between this region and the business region. 3.3) The total stored energy in the complete system has to remain constant during the interchange of energy between this region and the business region, i.e., while changing the performance characteristics.

4) A specific application: A variable field permanent magnet with fixed field energy

Fig. 1 shows schematically an ideal permanent dipole magnet that allows changing the field level in the business region without exchanging energy with the outside environment. What makes the magnet ideal are the assumptions that the iron has infinite permeability and that the permanent magnet cylinder has isotropic differential permeability. In addition it is assumed that the system is sufficiently long, that the resistivity of all materials is large enough that eddy currents can be ignored, and that the
bearings have no friction. It is easy to show that the respective maximum and minimum total system energy are achieved for either $\beta=0$ and $\pi/2$, or $\beta=\pi/2$ and $0$, depending on the relative gap geometries. By adjusting just one parameter in the energy storage region (e.g., the gap width), the total stored energy can be made entirely independent of $\beta$, meaning that moving the stored magnetic field energy from one region to the other by changing $\beta$ becomes effortless. Since the material properties of the system will not be as perfect as assumed above, and since there will be some friction in the bearings of the PM cylinder, a very small effort will be required to change the field level. It is clear from the general concept that the topography of the dipole shown in Fig. 1 can be modified to apply to virtually any magnet type of interest, e.g., a quadrupole or higher-order multipole, a combined function magnet, etc. One can, in fact, consider the configuration shown in Fig. 1 as a generic driver, allowing one to design virtually any kind of a magnet by combining appropriate drivers with corresponding poles and pole configurations.

1) Chemotherapy under Hospice care
2) Handbook of Accelerator Physics and Engineering, A.W. Chao, M. Tigner Editors
World Scientific (1999), Sect. 7.2.7