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Compression and Air Storage Systems for Small Size CAES Plants: Design and Off-Design Analysis

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Abstract : The use of renewable energy sources for electric power production leads to reduced CO2 emissions and contributes to improving the domestic energy security. On the other hand, the intermittency and unpredictability of their availability poses relevant problems in fulfilling safely and in a cost efficient way the load demand along the time. Significant benefits in terms of “grid system applications”, “end-use applications” and “renewable applications” can be achieved by introducing energy storage systems. Among the currently available solutions, CAES (Compressed Air Energy Storage) shows favorable features. Small-medium size plants equipped with artificial air reservoirs can constitute an interesting option to get efficient and cost-effective distributed energy storage systems. The present paper is addressed to the design and off-design analysis of the compression system of small size CAES plants suited to absorb electric power in the range of hundreds of kilowatt. The system of interest is constituted by an intercooled (in case aftercooled) multi-stage reciprocating compressor and a man-made reservoir obtained by connecting large diameter steel pipe sections. A specific methodology for the system preliminary sizing and off-design modeling has been developed. Since during the charging phase the electric power absorbed along the time has to change according to the peculiar CAES requirements and the pressure ratio increases continuously during the filling of the reservoir, the compressor has to work at variable mass flow rate. In order to ensure an appropriately wide range of operations, particular attention has been paid to the selection of the most suitable compressor capacity control device. Given the capacity regulation margin of the compressor and the actual level of charge of the reservoir, the proposed approach allows the instant-by-instant evaluation of minimum and maximum electric power absorbable from the grid. The developed tool gives useful information to appropriately size the compression system and to manage it in the most effective way. Various cases characterized by different system requirements are analysed. Results are given and widely discussed.

Keywords : artificial air storage reservoir, compressed air energy storage (CAES), compressor design, compression system management.
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