The Electrical Grid and Supercomputer Centers: An Investigative Analysis of Emerging Opportunities and Challenges

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Abstract. Some of the largest supercomputer centers in the United States are developing new relationships with their electricity service providers. These relationships, similar to other commercial and industrial facilities, are driven by mutual interest to save energy costs and improve electricity grid reliability. Supercomputer centers are concerned about electricity price, quality, environmental impact and availability. Electricity service providers are concerned about supercomputer center's impact on the electrical grid reliability; for energy consumption, peak power and fluctuations in power. Supercomputer center power demand can be greater than 20 megawatts (MW) or more - the theoretical peak power requirements are greater than 45MW - and re-occurring intra-hour variability can exceed 8MW. As a consequence, there are some supercomputer centers whose electricity service providers are asking for hourly forecasts of power demand, a day in advance. This paper explores today's relationships, potential partnerships and possible integration between supercomputer centers and their electricity service providers, and its value. It evinces the challenges for this possible HPC-Grid integration, and then cites opportunities to overcome the barriers using feedback from a questionnaire of Top 100 List sized supercomputer centers in the United States.

1 Introduction

Supercomputer centers(SCs) with petascale systems for high-performance computing(HPC) are realizing the large impact they will be putting on their electricity service providers(ESPs) with peak power demands of 20MW and instantaneous power fluctuations of 8MW. Today, with the impetus for moving towards Exascale computing, the need to address challenges thrown by even larger peak power demands and instantaneous power fluctuations is extremely relevant, and bears prime importance in improving electric grid reliability.

The electric grid reliability has always been an extremely important aspect to optimally manage and link electric supply with demand. This has motivated

the notion of Demand Response. Demand Response investigates the change in electric usage by end-users from normal consumption patterns to understand their effects on reliable supply, as well as propose solution to handle discrepancies arising out of abnormal patterns. The change in usage patterns of the end-user is influenced by several factors that are either in response to physical, operational or monetary demand. In HPC, the change is predominantly operational in the present. The instantaneous power fluctuations in SC mainly arise from changes in computational workloads that use variable amounts of resources during their execution lifetime; this also affects the peak power demand. Fluctuating number of workloads scheduled during the day, maintenance are among the other factors that affect peak power demands.

It is evident that SC wants energy efficiency to lower costs, but it is important to understand if this need finds a key interest in ESP. Likewise, it is important to understand the significance of electric grid reliability - a priority for ESP - from the perspective of SC. Only a mutual understanding of concerns between the SC and ESP could lead to evolution of a symbiotic relation and fathom beyond the current producer-consumer paradigm, paving the way for possible integration of HPC with the Electric Grid.

Effective Demand Response(DR) requires real-time monitoring of usage, determination of change, followed by response to moderate the effect of this change. The efficient implementation of the DR process needs the linking of supply-side and demand-side systems, and is the basis of this work which emphasizes on the integration of the HPC with Electric Grid. Leveraging prior work on data center and grid integration opportunities done by Lawrence Berkeley National Laboratory's (LBNL) Demand Response Research Center(cite LBNL DR datacenter integration paper), we attempt to understand the existing infrastructure from the ESP that is available for DR. The existing infrastructure for DR can be used by SC to manage their electricity requirements in a tightly coupled manner, facilitating energy efficiency.

The Energy Efficient HPC Working Group (EE HPC WG) has been investigating opportunities for large supercomputing sites to more closely integrate with their electricity service providers. The objectives of this investigation are to understand the willingness of SC to co-operate with their ESP, their expectations from ESP, and the feasible measures that the SC could employ to help ESP with demand-response. To achieve our objectives a questionnaire was deployed whose respondents were Top100 List class supercomputer centers in the United States, the results of which are documented in subsequent sections.

The second section of this paper brings forth the goals and challenges of the supercomputing community. The third section gives the electric service providers' view of the world. The fourth section of this paper presents the results of the questionnaire. The fifth section of the paper describes opportunities, solutions and barriers. A sixth section concludes and suggests future work. Finally, the last section recognizes additional authors.