Performance Study of Distributed State Estimation Algorithms on the HiPerDNO HPC Platform

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1. INTRODUCTION

Distribution State Estimation (DSE) functions can be used to determine a distribution network voltage profiles in near to real-time. Large networks and the required DSE refresh rate pose considerable computational challenges, thus requiring HPC (High Performance Computing) technologies.

We present here two new DSE algorithms, their implementation in the HiPerDNO HPC platform and their performance. These algorithms aim to reduce the dimensionality of the problem by decomposing the network into sub-trees or "zones" that can then be solved concurrently. Both algorithms have been implemented on the HiPerDNO HPC platform and their performance and scalability are reported.

2. THE HIPERDNO PROJECT

The EU-funded HiPerDNO project [1] aims to develop new applications to enhance the operational capabilities of Distributed Network Operators (DNOs). Novel applications include Distributed State Estimation (the subject of this paper), Condition Monitoring, Data Mining, Power Restoration, voltage control.

Given the extent of distribution network and the rate at which processing is required, all these applications pose considerable computing challenges, requiring the development of appropriate HPC strategies. HiPerDNO has proposed, developed and implemented an HPC platform suitable for the DNOs' requirements [2].

In this paper we present the implementation of two DSE algorithms on the HiPerDNO HPC platform and report on their performance and scalability. Both algorithms decompose the network tree into "zones", i.e. sub-domain or sub-trees and allow the concurrent processing of zones.

Within HiPerDNO, Oxford and Brunel Universities and EDF R&D have collaborated closely to implement these algorithms on the HPC platform and to study their performance. Next sections describe the two "Zonal Algorithms"; the following section reports on their implementation on the HiPerDNO HPC platform, followed by the results of initial benchmarks. Finally, we present our conclusions and outline our work plan which we intend to carry out and present in the final version of this paper and at UPEC2012.

3. THE "ZONAL" ALGORITHMS FOR DSE

The first approach, proposed by EDF R&D [3], splits the network into zones by means of measuring devices at specific nodes of the network (switchable elements) ("Disjoint Zones").

The second algorithm originating from Brunel University [4], makes no such requirements, but allows for neighbouring zones to share common nodes ("Overlapping Zones"). Solution can be achieved by iteration reaching convergence when the matching of common nodes properties is reached.

For both algorithms, each zone can be treated independently and in parallel, by employing standard techniques, e.g. WLS or WEM.

However, while "disjoint zones" provide a single-pass solution, "overlapping zones" require iteration until convergence in the matching nodes. The algorithms present a trade-off between flexibility and performance, also in view of the extra costs involved in instrumenting selected nodes.

4. DSE IMPLEMENTATION

Both DSE algorithms were implemented in MATLAB and have been compiled in order to be integrated in appropriate frameworks suitable for processing within the HiPerDNO HPC platform [2].

The Disjoint Zone Algorithm has been implemented using the Pelican framework [2]. Developed at Oxford University within a radio astronomy context, Pelican allows the concurrent and balanced processing of a data stream that can be divided into "chunks" suitable for independent computation (Pelican server). Each chunk is then processed by a different Pelican pipeline and the results are collated. This approach is very suitable for disjoint zones as it leads to good load balancing and scalability when the number of zones is larger than the number of Pelican pipelines and zones are of comparable sizes. The MATLAB code is invoked by the Pelican framework (written in C++).

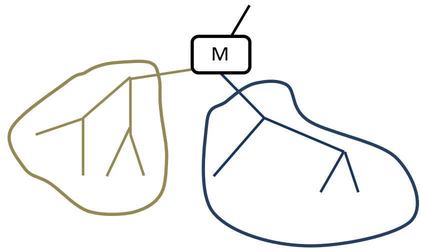

Figure 1. DSE zonal approach in a Pelican framework.

The Pelican framework is not suitable for the Overlapping ones" approach as at the end of each iteration, information needs to be exchanged between neighbouring zones. The algorithm was implemented using a parallel, MPI based framework that allows for independent processing of zones as well as implementation of the gather-scatter procedure to process the matching data at shared nodes. Convergence is achieved when data on matching nodes, as obtained from neighbouring zones, coincide within a given tolerance.

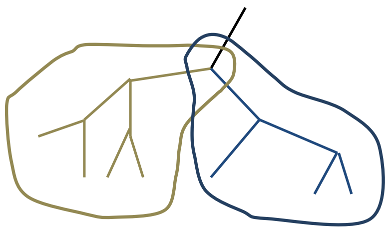

Figure 2. DSE zonal with overlap data in an MPI framework.

5. INITIAL BENCHMARKS

The first implementation of both algorithms has been ported to the HPC platform. Our initial tests employed test network models from EDF R&D and Brunel University.

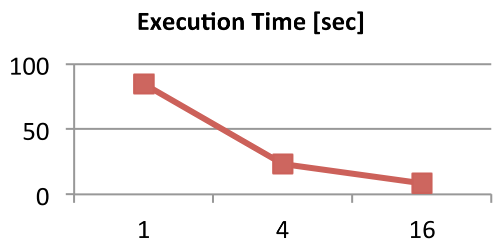

Figure 3. Scalability – DSE zonal: 32-zone network.

Figure 3 presents the results obtained for the Disjoint Zone algorithm implementation in Pelican. The network consisted of 32 zones and was run with one, four and sixteen pipelines. Scalability is very good and shows the validity of using Pelican for this approach.

The Overlapping Zones algorithm is still under development and has been implemented for a simple two-zone network only, so that we cannot provide, at this time, estimates of its scalability. The implementation and testing effort is ongoing.

6. FUTURE WORK AND CONCLUSIONS

Both algorithms show considerable promise, within already discussed trade-offs between them. We are planning to complete the implementation and carry out a full study of both algorithms.

We intend to produce results and a more detailed discussion in the full paper to be presented at UPEC2012.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

1. http//:www.hiperdno.eu, *HiPerDNO: High Performance Computing Technologies for Smart Distribution Network Operation*, EU FP7/2007-2013 ICT Energy Funded Research Project

2. Stefano Salvini, Piotr Lopatka, and David Wallom. 2011. A hardware and software computational platform for the HiPerDNO (high performance distribution network operation) project. In *Proceedings of the first international workshop on High performance computing, networking and analytics for the power grid* (HiPCNA-PG '11). ACM, New York, NY, USA, 75-82. DOI=10.1145/2096123.2096139

3. Letitia De-Alvaro, Sebastien Grenard. Scalable Distribution State Estimation approach for Distribution Management Systems, HiPerDNO report or "Scalable Distribution State Estimation approach for Distribution Management Systems" IEEE PES Manchester 2011

4. Nazia Nusrat, Malcolm Irving, Gareth Taylor, Development of Scalable Ditribution System State Estimation, HiPerDNO deliverable report