OpenFOAM Modelling and Product Optimization of Dry-type Transformers in the Cloud

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UberCloud Case Study 182:

OpenFOAM Modelling and Product Optimization of Dry-type Transformers in the Cloud

http://www.TheUberCloud.com

November 26, 2015

Welcome!

The UberCloud* Experiment started in July 2012, with a discussion about cloud adoption in technical computing and a list of technical and cloud computing challenges and potential solutions. We decided to explore these challenges further, hands-on, and the idea of the UberCloud Experiment was born, also due to the excellent support from INTEL generously sponsoring these experiments!

We found that especially small and medium enterprises in digital manufacturing would strongly benefit from technical computing in HPC centers and in the cloud. By gaining access on demand from their desktop workstations to additional compute resources, their major benefits are: the agility gained by shortening product design cycles through shorter simulation times; the superior quality achieved by simulating more sophisticated geometries and physics and by running many more iterations to look for the best product design; and the cost benefit by only paying for what is really used. These are benefits that increase a company's innovation and competitiveness.

Tangible benefits like these make technical computing - and more specifically technical computing as a service in the cloud - very attractive. But how far away are we from an ideal cloud model for engineers and scientists? In the beginning, we didn't know. We were just facing challenges like security, privacy, and trust; conservative software licensing models; slow data transfer; uncertain cost & ROI; availability of best suited resources; and lack of standardization, transparency, and cloud expertise. However, in the course of this experiment, as we followed each of the 175 teams closely and monitored their challenges and progress, we've got an excellent insight into these roadblocks, how our teams have tackled them, and how we are now able to reduce or even fully resolve them.

This case study is about optimizing dry-type transformers which have growing applications in the transformer market because the technology is non-flammable, safer and environmental friendly. We use the OpenFOAM CFD package to simulate the heat transfer of a dry-type transformer unit with different dimensions. In this way, the temperature rises can be evaluated and compared, directing a way to optimize the transformer design in terms of thermal performance. As the 3D CFD model is built, only one quarter of the geometry is taken into account considering the geometry symmetry, still a number of millions of computation cells will be generated. This is why a cloud based computational platform has been considered as an option to speed up the entire evaluation cycle.

We want to thank the team members for their continuous commitment and voluntary contribution to this experiment, and thus to our technical computing community. And we want to thank our main Compendium sponsor **INTEL** for generously supporting the 181 UberCloud experiments.

Now, enjoy reading!

Wei Wu, ABB, and Wolfgang Gentzsch & Burak Yenier
The UberCloud, November 2015

**) UberCloud is the online community and marketplace where engineers and scientists discover, try, and buy Computing Power as a Service, on demand. Engineers and scientists can explore and discuss how to use this computing power to solve their demanding problems, and to identify the roadblocks and solutions, with a crowd-sourcing approach, jointly with our engineering and scientific community. Learn more about the UberCloud at: http://www.TheUberCloud.com.*

Team 182:
OpenFOAM Modelling and Product Optimization of Dry-type Transformers in the Cloud

"Cloud based computing extends our potential to design/develop better products. By utilizing this potential the products can be optimized with a much faster pace and higher quality."

MEET THE TEAM

End user and Team Expert – Wei Wu, Senior R&D Design/Development Engineer, ABB
Software Provider – ESI – OpenCFD providing OpenFOAM
Resource Provider – Microsoft Azure with UberCloud OpenFOAM Container
Technology Experts – Fethican Coskuner, Hilal Zitouni, and Baris Inaloz, UberCloud Inc.

USE CASE

Dry-type transformer has growing applications in transformer market because the technology is non-flammable, safer and environmental friendly. On the other hand, dry-type transformers typically have bigger dimensions compared to the liquid-immersed units to have sufficient dielectric insulation and cooling capacity. Therefore, how to manage to design dry-type transformers with smaller sizes in order for lower material cost, while still satisfying dielectric and thermal performance, is one of the high priority tasks of a transformer manufacturer.

In this project, we aim at using OpenFOAM open-source CFD package to simulate the heat transfer of a same dry-type transformer unit with a group of different dimensions. In this way, the temperature rises can be evaluated and compared, directing a way to optimize the transformer design in terms of thermal performance. As the CFD model is built as 3D, even though only one quarter of the geometry is taken into account considering the geometry symmetry, still a number of millions of computation cells will be generated. This is why a cloud based computational platform has been considered as an option to speed up the entire evaluation cycle.

TECHNOLOGY: UBERCLOUD CONTAINERS

UberCloud Containers are ready-to-execute packages of software. These packages are designed to deliver the tools that an engineer needs to complete the task in hand. The ISV (Independent Software Vendor) or Open Source tools are pre-installed, configured, and tested, and are running on bare metal, without loss of performance. They are ready to execute, literally in an instant with no need to install software, deal with complex OS commands, or configure. The UberCloud Container technology allows a wide variety and selection for the engineers because they are portable from

server to server, Cloud to Cloud. The Cloud operators or IT departments no longer need to limit the variety, since they no longer have to install, tune and maintain the underlying software. They can rely on the UberCloud Containers to cut through this complexity. This technology also provides hardware abstraction, where the container is not tightly coupled with the server (the container and the software inside isn't installed on the server in the traditional sense). Abstraction between the hardware and software stacks provides the ease of use and agility that bare metal environments lack.

CHALLENGES

Overall, the computation speed is the bottleneck of the simulation project. On a modern desktop workstation computer with 4 to 6 cores (8 to 12 threads), the iterative steady-state computation of a single case can take 1.5 to 3 hours, which is actually bearable. However as in design optimization one single case is certainly not enough. Geometry dimensions and physic properties can all be changeable and the combination of the changed parameters can be a large number of simulation cases. Furthermore, for special cases, time-transient models may be necessary which takes even more computational effort to accomplish.

PROCESS AND BENCHMARK RESULTS

The computations were performed on a 10 node class "medium" cluster, where eight compute nodes were equipped with dual socket Intel(R) Xeon(R) CPU E5-2670 @ 2.60GHz and 112 GB of RAM, giving a total count of 128 cores and 1TB of RAM. The nodes were connected with 40Gbit/s InfiniBand network with remote direct memory access (RDMA) technology. This hardware setup was chosen since it is suitable for a first test of the capabilities of HPC computing in the cloud. The hardware was supplied by Microsoft Azure, and OpenFOAM CFD package was running on UberCloud Containers.

The benchmarks were performed with two cases with different height dimensions, as Fig. 1 shows. The simulation took 7 and 8 minutes respectively for these two cases to accomplish 500 iteration steps; the results are illustrated in Fig. 2. However the same simulation cases will need 77 and 82 minutes respectively on a local workstation with 11 core threads, which demonstrates the speed-up linearly proportional to the number of processor core threads. The computational time comparison is summarized in Fig. 3.

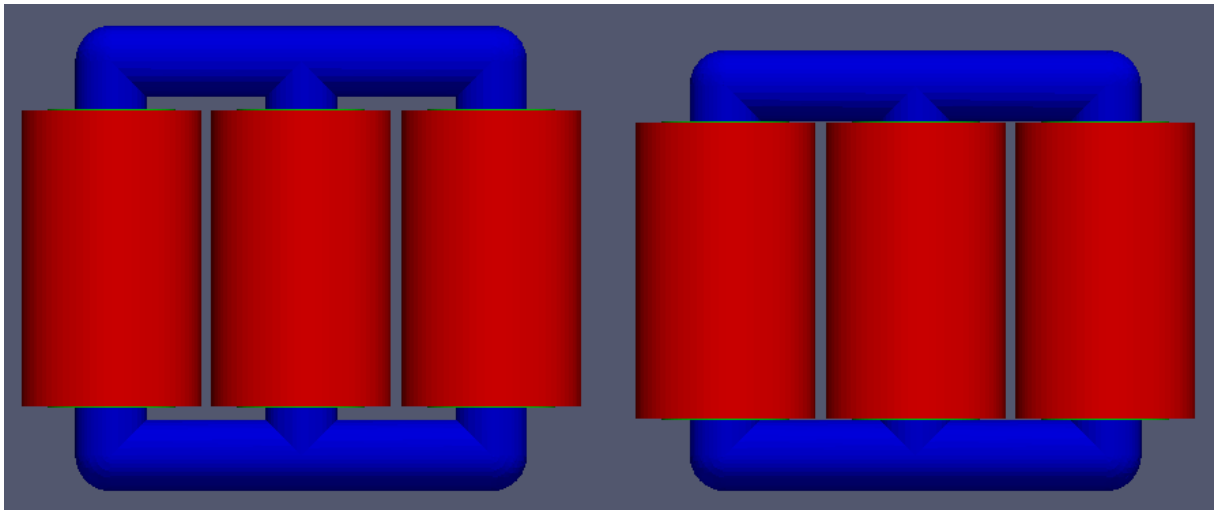

Figure 1: The two cases simulated. The right-hand size case has lower dimension than the left-hand side one. The blue color part is iron core and the red color part is high-voltage coils.

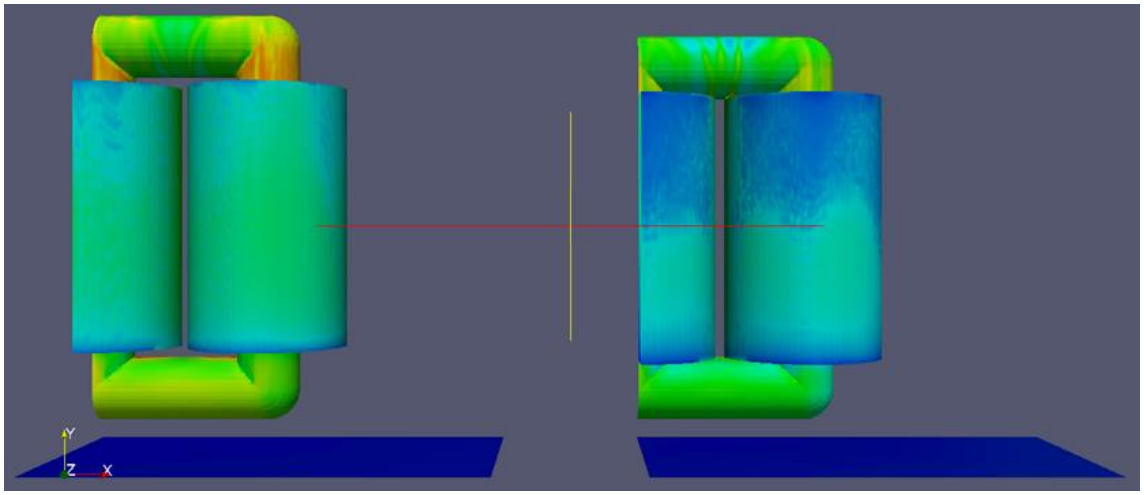

Figure 2: Temperature distribution example of both cases in Fig. 1. Due to geometry symmetry only a quarter of the full domain was simulated.

Figure 3: Computational time comparison between the two cases in Fig. 1. With the cloud cluster computational time is reduced to only 10%.

BENEFITS

The cloud based technology has significantly higher computational speed, which made parametric study or optimization of transformer designs much faster. On the other hand, the technology costs relatively lower compared to owning in-house HPC equipment with equivalent computational power.

CONCLUSIONS

- We showed that the Microsoft Azure based UberCloud cloud solution is a beneficial solution for OpenFOAM users who have the need to deliver their simulation results in a much faster time manner.
- To use the cloud based cluster computing, there is no investment in in-house HPC equipment or expertise needed, since UberCloud offers customized and handy cloud cluster solutions with all requisite software packages pre-installed.

Case Study Author – Wei Wu, ABB

Thank you for your interest in the free and voluntary UberCloud Experiment.

If you, as an end-user, would like to participate in this Experiment to explore hands-on the end-to-end process of on-demand Technical Computing as a Service, in the Cloud, for your business then please register at: http://www.theubercloud.com/hpc-experiment/

If you, as a service provider, are interested in promoting your services on the UberCloud Marketplace then please send us a message at https://www.theubercloud.com/help/

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In any case, if you wish to be informed about the latest developments in technical computing in the cloud, then please register at http://www.theubercloud.com/. It's free.