Kaplan turbine flow simulation using OpenFOAM in the Advania Cloud

An UberCloud Experiment

With Support From:

UberCloud Case Study 198

http://www.TheUberCloud.com

January 30, 2018
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.

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 and more powerful computing resources in the cloud, their major benefits became clear: 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 obviously increase a company’s innovation and competitiveness.

Tangible benefits like these make computing - and more specifically technical computing as a service in the cloud - very attractive. But how far are we from an ideal cloud model for engineers and scientists? At first we didn’t know. We were facing challenges like security, privacy, and trust; traditional software licensing models; slow data transfer; uncertain cost & ROI; lack of standardization, transparency, cloud expertise. However, in the course of this experiment, as we followed each of the 197 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 cloud experiment deals with an application in the hydropower and renewable energy sector. There are still many opportunities with usable hydro potential: existing hydropower plants with old obsolete turbines, new hydropower plants at an existing weir, or new hydropower plants for new locations. Kaplan water turbines are used for locations with small head. The flow simulation inside the turbine is calculated using the Turbomachinery CFD module from CFD Support for OpenFOAM. The flow simulation and its analysis are important for verification of turbine energy parameters, turbine shape optimization and turbine geometry changes.

We want to thank all team members for their continuous commitment and contribution to this project. And we want to thank our main UberCloud Experiment sponsors Hewlett Packard Enterprise and INTEL for generously supporting these 198 UberCloud experiments. A big Thank You also to the HPCwire Team which regularly published our UberCloud Experiments.

Now, enjoy reading!

Wolfgang Gentzsch and Burak Yenier

*) UberCloud is the online community & marketplace where engineers and scientists discover, try, and buy Computing 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.

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MEET THE TEAM

**End User** – Martin Kantor, GROFFENG, a GRoup OF Freelance ENGineers.

**Software Provider** – Turbomachinery CFD based on OpenFOAM, Luboš Pirkl, Co-founder & Technical Director, CFD Support ltd.

**Resource Provider** – Advania Cloud in Iceland (represented by Aegir Magnusson and Jon Tor Kristinsson), with access and support for the HPC server from HPE.

**HPC Cloud Experts** – Fethican Coskuner and Wolfgang Gentzsch, UberCloud, with providing novel HPC container technology for ease of OpenFOAM cloud access and use.

About CFD Support

CFD Support supports manufacturers around the world with numerical simulations based on OpenFOAM. One of the main CFD Support’s businesses is providing full support for virtual prototyping of rotating machines: compressors, turbines, fans and many other turbomachinery. All the rotating machines need to be simulated to test, confirm or improve its efficiency, which has a major effect on its energy consumption. Each machine design is tested many times and is optimized to find the best efficiency point. In practice these CFD simulations are very demanding, because of complexity and number of simulations to run.

About GROFFENG

GROFFENG – GRoup OF Freelance ENGineers - is an open group of experienced Czech engineers focusing on Data analysis, Measurement, Data Acquisition and verification, Simulation and 3D Design. Not only do their engineers have experience and knowledge but they are also well equipped with hardware and software. This allow GROFFENG to provide quality and non-standard services to optimize technical processes.
USE CASE
This application can be found in the area of hydropower and the renewable energy sector. There are still many opportunities with usable hydro potential: existing hydropower plants with old obsolete turbines, new hydropower plants at an existing weir, or new hydropower plants for new locations. Kaplan water turbines are used for locations with small head. For turbines with runner diameter 0.3–1 meters we can expect power 1 – 300 kW.

The flow simulation inside the turbine is calculated using the Turbomachinery CFD module (software by CFD Support) for OpenFOAM. The flow simulation and its analysis are important for the verification of turbine energy parameters, turbine shape optimization, and turbine geometry changes. Realistic application of the Kaplan turbine can be seen in the next picture.

Figure 1: Intake part of the turbine with guide vane and runner (left), two turbines during the installation (right).

Description of the turbine and simulation
Kaplan turbine for the low-head application includes the following: the inlet part with elbow and shaft, fixed guide wanes (blue color), runner with adjustable blades (red color) and conical draft tube.

Figure 2: Intake part of the turbine with guide vane and runner (left), two turbines during the installation (right).

The following turbomachinery settings are applied for these simulations:
- Turbomachinery CFD solver (software by CFD Support) includes MRF approach for rotation modeling;
steady-state RANS simulations with k-omega SST turbulence models and incompressible water;
- time saving of the simulation is created by using periodic segment, each segment contains only one guide wane or runner blade;
- the boundary conditions are: volumetric flow rate for inlet, mixing plane for internal interface, cyclicAMI for periodic boundaries and fixed static pressure for outlet.

The computational mesh is created using snappy hex mesh algorithms (the mesh you can see in the following picture). For correct simulation flow inside the Kaplan turbine the following is important: uniform computational mesh of draft tube (for example in this case with inflation layers) and fine mesh in the gap between runner blade and runner camber (which you can see in the red cross section in the following picture). Our computational mesh with periodical segment has approximately 800k elements.

Figure 3: Computational mesh for the Kaplan turbine with periodical segment with approximately 800k elements.

The main task of this simulation is the calculation of energy parameters: i.e. the head and volumetric flow rate for defined runner speed of rotation and positioning of the runner blade. The task contained approximately 30 operating conditions, from minimal power output through best efficiency point to maximal power output.

Post processing is done with:
- global energy parameters using OpenFOAM scripts;
- flow visualization and analysis using ParaView (you can see velocity field and streamlines inside the turbine in the following picture).

**CLOUD APPLICATION AND BENEFITS**

The flow simulation is calculated using UberCloud’s Turbomachinery CFD container from CFD Support on up to 20 CPU cores on Advania’s HPC as a Service (HPCaaS) hardware configuration built upon HPE ProLiant servers XL230 Gen9 with 2x Intel Broadwell E5-2683 v4 with Intel OmniPath interconnect. Firstly,
Martin Kantor had to prepare a geometry of turbine in local computer, the next step was the data transfer to cloud. The calculation settings were made from the previous calculation in local computer.

Turbomachinery CFD (TCFD) is a powerful tool for turbomachinery simulation with the computing mesh creation tool, the computation and evaluation process. You can see the TCFD GUI in the following picture: process bar is on the left, visualization of complete geometry is on the top in the middle, computational mesh with segments is on the bottom in the middle and convergence report is on the right.

<table>
<thead>
<tr>
<th>Platform</th>
<th>Time duration of 1000 iteration [minutes]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local computer (1 core)</td>
<td>90</td>
</tr>
<tr>
<td>Cloud application (2 cores)</td>
<td>80</td>
</tr>
<tr>
<td>Cloud application (4 cores)</td>
<td>34</td>
</tr>
<tr>
<td>Cloud application (20 cores)</td>
<td>20</td>
</tr>
</tbody>
</table>

The most effective strategy is to make several simultaneous simulations using 4 cores. Using the cloud (24 cores available) allows up to 10 times faster calculations than the local computer.

**BENEFITS OF USING CLOUD SIMULATIONS**
- high performance computing available at your fingertips;
- HW usage and all support are included in the cost for using the cloud service;
- simple and user-friendly operation of the cloud solution through the browser;
- possibility to perform postprocessing on the cloud or on the local computer.

*Case Study Author — Martin Kantor from GROFFENG, a GRoup OF Freelance ENGineers in Czech Republic.*
Thank you for your interest in the free and voluntary UberCloud Experiment. If you, as an end-user, would like to participate in an UberCloud 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 building a SaaS solution and promoting your services on the UberCloud Marketplace then please send us a message at https://www.theubercloud.com/help/.


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