INL/CON-24-79353-Revision-0

Infrastructure improvements in the National Reactor Innovation Center Virtual Test Bed

November 2024

Guillaume Louis Giudicelli, Lise Charlot, Logan H Harbour, Dempsey D Rogers, Casey T Icenhour, Ryan J Scott

Changing the World's Energy Future

Idaho National Laboratory

INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance, LLC

INL/CON-24-79353-Revision-0

Infrastructure improvements in the National Reactor Innovation Center Virtual Test Bed

Guillaume Louis Giudicelli, Lise Charlot, Logan H Harbour, Dempsey D Rogers, Casey T Icenhour, Ryan J Scott

November 2024

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

Infrastructure improvements in the National Reactor Innovation Center Virtual Test Bed

Guillaume L. Giudicelli, Logan Harbour, Ryan J. Scott, Dempsey D. Rogers, Casey Icenhour, Lise Charlot

Computational Frameworks, Idaho National Laboratory, P.O. Box 1625, MS 1343, Idaho Falls, ID,
guillaume.giudicelli@inl.gov
doi.org/10.13182/T131-46063

INTRODUCTION

The National Reactor Innovation Center's (NRIC) mission is to support deployment of novel reactor concepts. This is achieved by providing physical and virtual spaces for building and testing various components, systems, and complete pilot plants. The Virtual Test Bed (VTB) represents the virtual counterpart to the physical test bed. The VTB is being developed in collaboration with the Department of Energy's (DOE) Nuclear Energy Advanced Modeling and Simulation (NEAMS) program.

The mission of the VTB is to accelerate the deployment and licensing of advanced reactors by leveraging state-of-the-art modeling and simulation (M&S) tools developed by the DOE NEAMS program. This is accomplished via three primary means: (1) openly hosting simulations that showcase analysis capabilities, (2) continuously testing the models hosted against code updates to avoid deprecation, and (3) filling key M&S gaps that are relevant for the physical NRIC test beds. The VTB repository consists of two sub-entities:

- A documentation website detailing the models: https://mooseframework.inl.gov/virtual_test_bed
- A GitHub repository that hosts the corresponding files: https://github.com/idaholab/virtual_test_bed.

This paper presents the infrastructure added to the VTB in the last two fiscal years. Additional information about the VTB can be found in various publications [1, 2, 3, 4, 5, 6, 7, 8].

GITHUB REPOSITORY IMPROVEMENT

The models, their documentation, and auxiliary files such as meshes or group cross sections are stored on a GitHub repository at https://github.com/idaholab/virtual_test_bed. This repository is open to the public and may be downloaded by anyone. However, most models require access to controlled simulation codes, which can be requested at the INL Nuclear Computational Resource Center. In addition to the features described in [1], we highlight two additional techniques recently leveraged to improve our processes.

The first is the deployment of GitHub pull requests and issue templates. Issues are used to communicate with the VTB developer community. They can be used to report bugs (either in the test bed or in the models), to request new models or new model features, and to request features in the test bed. They are also used as announcements before contributing a new model. Pull requests are used to contribute models or to modify the repository and documentation. GitHub templates enable a pre-formatting of this user-generated content. This helps users and developers provide sufficient content on issues and pull requests. The pre-filled text can be seen in Figure 1.

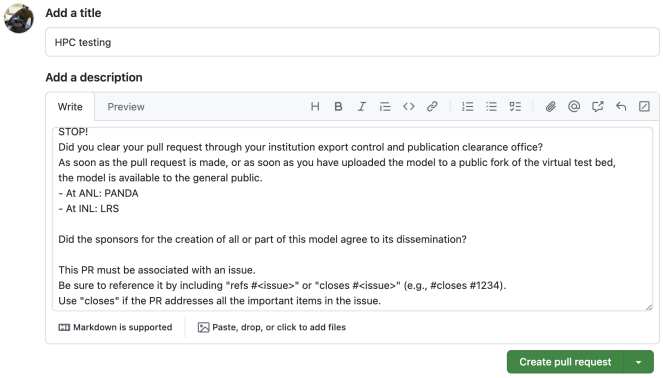

Fig. 1. Screenshot of the pull request template reminding model contributors that they have to get models cleared for export control before publishing them.

The second item is the use of the GitHub large file system (LFS). LFS is used to upload files such as meshes, tabulated group cross sections, or simulation result videos to the repository. These larger files slow down user downloads, and are only necessary if the user wants to use the model they are part of. The repository currently holds 250 MB of data, which most machines can download in under a minute. The large files, however, take up more than 6 GB of disk space, which would make downloading the VTB a lengthy process for many.

WEBSITE IMPROVEMENTS

With close to forty models published on the VTB, it became both more difficult to find models without a clear idea of what they reactor they pertained to, and more advantageous to group models that feature certain characteristics together. For this purpose we deployed a custom-made search engine on the VTB website. The search engine relies on contributors tagging their models with each of their characteristics. Models were already manually grouped by reactor types, application types, and simulation types. We can now also sort by geometry modeled, transient type, computing need, simulation features, contribution year, contributing entity, and development sponsor. New filters can be easily added in the documentation of each model.

This search engine uses a Javascript back-end that runs on the visitor's browser, as the website is static for simplicity and cybersecurity reasons. As shown in Fig. 2, users make their selections in the filters on the left of the screen. If two filters within the same category are selected, then the union of the sets of results is shown. Additional filters within other categories narrow down the results with an intersection. For example, selecting the molten salt reactor (MSR) and the high-temperature gas reactor (HTGR) reactor types will yield all

MSR and HTGR models. But selecting control rod transients for the simulation type will restrict all these models to the control rod transient type.

The filtering capability is widely extensible. Additional capabilities developed this year include greying out options that are no longer available after other filters have been selected, and displaying figures next to search results. Both features are shown in Fig. 2.

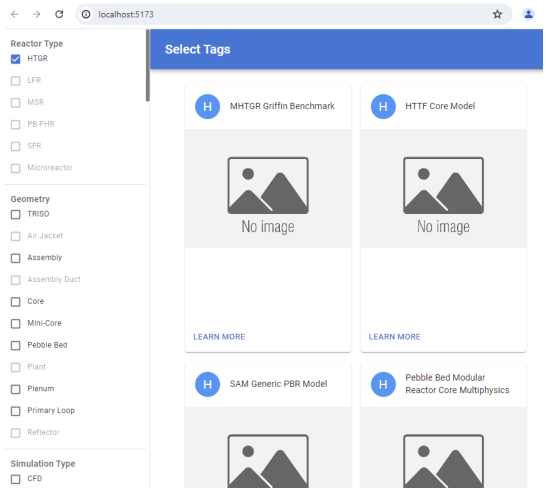

Fig. 2. Screenshot of the preliminary capabilities for figures accompanying results in the search engine.

Another feature is automated database generation from search engine data. The sorted data information can be output to CSV, which can then be examined using Microsoft Excel. This helps the VTB team keep track of contributions each fiscal year.

HIGH PERFORMANCE COMPUTING INTEGRATION

The VTB is leveraged to deliver tutorials for various capabilities of the NEAMS tools for advanced reactor modeling. For example, at the 2024 American Nuclear Society summer conference, a tutorial for group cross section generation for sodium fast reactors (SFR) was given by a team from Argonne National Laboratory. The tutorial was hosted on the VTB, which displayed tutorial content that could be downloaded by trainees with access to Griffin.

More details will be provided on the subject of using high-performance computing on the VTB for continuous integration purposes at the conference.

CONCLUSIONS

The Virtual Test Bed entered its fourth year of operation with significant infrastructure upgrades. We deployed a search engine to facilitate finding models, especially when looking for simulation features which may not yet have been deployed on the reactor type of interest, but were deployed on a model of a different reactor. To our knowledge it remains the only library of its genre, including continuous integration and fostering a vibrant community of modelers and developers. Contributions of advanced reactor models from the nuclear community are welcome.

ACKNOWLEDGMENTS

This manuscript was authored by Battelle Energy Alliance LLC, Operator of Idaho National Laboratory under Contract No. DE-AC07-05ID14517 with the U.S. Department of Energy (DOE). The work was prepared for the U.S. DOE, through the National Reactor Innovation Center (NRIC). The United States Government retains and the publisher, by accepting the article for publication, acknowledges that the United States Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.

REFERENCES

1. G. L. GIUDICELLI, A. ABOU-JAOUDE, A. J. NOVAK, A. ABDELHAMEED, P. BALESTRA, L. CHARLOT, J. FANG, B. FENG, T. FOLK, R. FREILE, T. FREYMAN, D. GASTON, L. HARBOUR, T. HUA, W. JIANG, N. MARTIN, Y. MIAO, J. MILLER, I. NAUPA, D. O'GRADY, D. REGER, E. SHEMON, N. STAUFF, M. TANO, S. TERLIZZI, S. WALKER, and C. PERMANN, "The Virtual Test Bed (VTB) Repository: A Library of Reference Reactor Models Using NEAMS Tools," *Nuclear Science and Engineering*, **0**, *0*, 1–17 (2023).
2. A. ABOU JAOUDE, D. R. GASTON, G. L. GIUDICELLI, C. J. PERMANN, and B. FENG, "Overview of Virtual Test Bed (VTB)," (12 2021).
3. E. SHEMON, J. FANG, T. HUA, Y. MIAO, N. STAUFF, A. ABOU-JAOUDE, G. GIUDICELLI, V. KYRIAKOPOULOUS, M. TANO, and S. WALKER, "NEAMS Model Contributions in 2023 to the National Reactor Innovation Center Virtual Test Bed for Use by Industry and Other Stakeholders," (12 2023).
4. E. SHEMON, G. GIUDICELLI, and A. ABOU-JAOUDE, "NEAMS Advanced Reactor Model Contributions to the NRIC Virtual Test Bed," (12 2022).
5. A. ABOU JAOUDE, S. A. WALKER, N. STAUFF, H. PARK, Y. YU, E. SHEMON, and G. L. GIUDICELLI, "Recent Advanced Reactor Multiphysics Model Highlights in the Virtual Test Bed (VTB)," (4 2024).
6. A. ABOU JAOUDE, G. L. GIUDICELLI, S. A. WALKER, M. E. TANO RETAMALES, L. C. MADELEINE CHARLOT, S. SCHUNERT, P. BALESTRA, D. D. ROGERS, L. H. HARBOUR, and D. R. GASTON, "Overview of Virtual Test Bed FY23 Activities," (7 2023).
7. A. ABOU-JAOUDE, E. SHEMON, G. GIUDICELLI, S. WALKER, L. CHARIOT, M. TANO, J. FANG, A. NOVAK, Z. OOI, H. PARK, N. WOZNIAK, Y. MIAO, A. ABDELHAMEED, N. STAUFF, and L. ZOUT, "Status of New Models Hosted on the Virtual Test Bed (VTB) in 2023," *Transactions of the American Nuclear Society*, **129**, 852–855 (2023), 2023 Transactions of the American Nuclear Society Winter Conference and Expo, ANS 2023 ; Conference date: 12-11-2023 Through 15-11-2023.
8. B. FENG, J. FANG, T. HUA, N. STAUFF, A. NOVAK,

L. ZOU, R. HU, P. BALESTRA, D. REGER, N. MARTIN, G. GIUDICELLI, and A. ABOU-JAOUDE, "Single- and Multi-Physics Models of Advanced Reactors in the Virtual Test Bed," *Transactions of the American Nuclear Society*, **125**, *1*, 1010–1013 (2021).