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Meeting Today's Planning Study Demands with Automation

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SUMMARY

Power system simulation has been highly computationally intensive, especially due to nonlinearity of the power network, the ever-expanding number of study scenarios due to evolving reliability standards and criteria, and the modeling of large-scale interconnections. Significant increase in the level of uncertainty as a result of high penetration of variable resources, demand response, distributed energy resources (DER), micro-grid and other Smart Grid technologies brings another level of challenges to power system planning and operations. For these reasons, new opportunities arose to explore new techniques of running larger planning studies and new methods to analyze the increasing amount of results quickly and efficiently. Today power system simulations needs both efficient solution algorithms and high performance computing environment

The study process has become much more automated by taking advantage of ever increasing computational power and new power system analysis tools that employ optimization techniques. This allows the planning engineer to focus on the issues instead of the process to obtain the study results. Web based tools store the current power flow model and all future projects and create a customized model for the planner based on their year of study and a set of future projects in a matter of hours. Databases are now used to store contingency information so files can now be created dynamically to match the power flow model and if errors are found, updates to the data are now streamlined and can be applied to the entire dataset and re-created within minutes. The previous process to start a regional planning study used to take three to six months.

After the power flow models and auxiliary data files are set, parallel processing servers can run tens of scenarios at a single time reducing computational time from days to just hours for a typical study. The number of scenarios is limited by the available computational resources. Scripts then take the results and filter out any extra information not needed by planners and create concise summaries of the results so decisions can be made quickly instead of taking weeks to review results.

In the future, studies will only become more complex and further ways to automate this process will be needed. The use of cloud computing for transmission planning study is on the horizon where thousands of scenarios can be studied at a single time. The use of cloud computing shifts the burden of internal Information Technology (IT) resources to the cloud computing service provider which can translate to large capital cost savings and make the latest computational infrastructure available to the planning engineer. This opens up an opportunity for engineers to run more detailed system models and more sophisticated scenarios that cannot be done today due to the internal resource, infrastructure and time constraints. Engineers can get a better overall picture of our evolving power grid so the right assets are constructed in time to meet criteria.

KEYWORDS

Automation, database, long-term transmission planning, N-1-1 testing, parallel processing, cloud computing

THE PAST – Few Scenarios, Hard to Update, and the Start of the Centralized Model

Since the start of the computer era, computers have been used to aid in the study and analysis of the power grid. Due to the enormous complexity of the physical power grid and the limitation of computational power of computers, compromises have traditionally been made on the scope and size of studies for the power system. Consequently, the size of the system model was reduced in order to solve a smaller set of complex non-linear equations. The number of generation dispatches was limited to only look at some of the most stressed scenarios, and the number of studied outages on the system was also reduced to only test some of the most serious conditions. In addition, only a single peak system load level was typically tested to evaluate the system's ability to serve customers thus system problems only appearing during shoulder load or light load level were not studied and identified.

When a transmission planner wanted to start a study, months of work would be involved to set up the network model. In New England, each company, whether a transmission owner, the Independent System Operator (ISO), or several consulting companies that ran studies in the region, they each had their own case to use for studies due to the enormous amount of time to review a model. It was far easier to take the model from the previous study performed and update it to start the next study. This process was still cumbersome, because when a future project was approved, the planner would need to track down the technical lead for the project and get the model to add to their case. Since each case was slightly different, projects would always need to be adjusted to match the model it was applied to.

This amount of work caused planners to only focus on their region of study to make sure the model was up-to-date and not the entire region. This was sufficient for local planning studies but for large scale regional studies, there was significant effort needed on the part of the planning engineers to update the model. This was sufficient due to the infrequency of large regional studies until the advent of the new Forward Capacity Market [1]. Since the market was for the entire region, a new network model that was up-to-date and covers the entire region was needed. The capacity market was run on a yearly basis, so it was not possible to spend six months updating the model each year and complete the work needed. A new centralized approach was needed that would be the basis for all studies in the region and new automation techniques were needed to keep that model up-to-date.

These new business needs led to the start of a web based program to store the existing system network model and a centralized repository of future projects on the system. When a planner needed to start a study, a request was made to the administrator of the system and a brand new network model was created based on their study criteria. The planners would now be confident that the case was ready for studies and did not need months of review and adjustments. If errors were found in the model, a single correction could be made to the centralized model and all future studies would reflect that correction. A new bridge program was created as well to match the Energy Management System (EMS) ratings and impedance data from the real-time operations model to the planning model to ensure that any adjustment to the current system would be regularly updated in the planning case.

This new system could not solve all the problems with the network model. The system did not have the ability to store the contingency information to model outages on the network. A single 'master' text file was used that contained only a subset of all possible contingency definitions. If a single change was made to the network model (e.g., a substation reconfiguration), it took a long time to find every location in the master contingency file where the old configuration was used and then replace it. Moreover, planners would update their individual study files but there was no established process to make sure all future studies reflected those changes.

THE PRESENT – Basecase Database, Parallel Processing and Automated Scripts

Due to the nature of contingency definitions being a combination of elements outaged for a given fault, this presented an opportunity to house this information in a database system. A new Basecase Database was created to house this contingency data in a central location. This allowed an administrator the ability to easily apply corrections and have it update all contingency definitions at the same time. It also allowed the planners to filter the master contingency list to only the contingencies needed for their study and ignore the ones that were outside of their local study area.

As time went on, new features were added to automate the creation of the network model for a study. Future project information was stored to allow the planner to easily create files that were customized to the type of study needed. Load information was stored in the database to enable the planner to create a specific load level that scaled uniformly according to a documented method ensuring consistency across all studies. Generation data was added to create unique profiles of generator capabilities. Each unit could has as many as eight different maximum capabilities depending on temperature and purpose of study, so the database easily stored all this information and help the planner apply the correct set for their study.

With the advent of the centralized network model and a database to customize all of the auxiliary files needed for analysis, the time to setup a planning study is significantly reduced from nearly three to six months down to several days. The role of automation allowed the planner to free up their time from preparing to run a study, to actually running the study and analyzing the results. This has led us to present day where with more time to run studies, the planner can increase the amount of scenarios to study. However, this leads to the next hurdle of computation power needed to run those scenarios and then analyzing a larger amount of results from those scenarios and filtering down the key findings that need to be solved on the power system to meet future demands.

With computational power becoming affordable, it is now possible to setup servers to run multiple scenarios in parallel. The use of job schedulers allows the setting up and running thousands of scenarios on tens of servers. At ISO New England, the servers that can handle up to 40 jobs in parallel have been setup. The first use of the servers was restricted to running transient stability assessments, but with growing number of basecases and dispatch scenarios being analyzed in steady-state testing, the servers are now being employed for steady-state analysis as well.

With expanded N-1-1 testing as mandated by NERC [2] in the new standards, the number of scenarios to analyze has increased substantially. A typical study with about 10-15 base dispatches to analyze may have up to 150-200 line out scenarios to be assessed. This results in a large number of jobs. Even though modern power system analysis tools have capabilities of running multiple N-1-1 scenarios, they are typically run in a serial manner. The use of servers allows the parallel processing of these scenarios.

To provide an example of the time saving available through parallel computing: one line out scenario could take 2-3 minutes to compute. With 3000 jobs in a study the whole study could take almost an entire week of computational time to complete if running sequentially. But with 40 jobs running in parallel, the study is completed in the course of four hours. Moreover, the reduced turnaround time allows the engineer to make any tweaks to the basecases and auxiliary files if needed and rerun the cases without requiring an extra week to run the assessment.

With the use of the parallel processing to run the N-1-1 assessment a large amount of data is created. When the results are run in a serial manner the results are all available in a single table that allows the easy perusal of the results. However, with parallel processing, the results are available in multiple files which need to be combined before the results can be analyzed. This can be done using scripts that combine the different text files from the individual runs. The use of scripts allows the addition of information such as direction of overloads, flagging for short-term emergency ratings violations, classification of violations based on the geographical location of the violation etc. The addition of this information makes the review of results easier and provides ways to filter out violations that may be external to the study area.

The use of scripts to process the results files has saved a considerable amount of time spent by the engineer to manually review and classify the results. The combination of parallel processing and the use of automation scripts have allowed the completion of the study in a much shorter timeframe. These techniques aid the transmission planner to keep up with ever changing assumptions and system conditions. These scripts also created a standard format for all study results making it easier to present to management during the study process.

The expanded use of these techniques has resulted in the available internal servers not being sufficient for all the transmission planners at the ISO to be able to run their studies in a timely manner. The information technology (IT) department is now faced with the dilemma of either buying more servers to meet the increasing needs or look towards the next advancement in power system analyses – the use of cloud computing.

THE FUTURE – Cloud Computing

On one hand, high performance computing (HPC) and super-computing capabilities require significant capital investments and comparatively high operating costs (including staff, electricity consumption, facilities, etc.). On the other hand, the hardware life cycle is too short due to rapid evolution of computational technique. Maintaining HPC environment in a company like ISO New England is becoming increasingly uneconomic from a cost-benefit perspective.

Cloud computing provides a new paradigm for easy access to larger scale computing resources over the Internet with relatively low cost, thus offering an alternative solution to maintaining and updating internal infrastructure. Cloud computing delivers infrastructure, platform, and software as services, which are made available as subscription-based services in a pay-as-you-go model to consumers. The technology is evolving fast with companies of all shapes and sizes adapting it. Industry experts believe that this trend will continue to grow and develop even further in the coming few years. The key features of cloud computing include:

Cost-Savings

Rather than over-purchasing costly infrastructure and adding in-house staffs to maintain it, companies can outsource that infrastructure to a third party providing cloud computing services. In the Cloud, the physical infrastructure is not owned by the companies. Instead, companies work on a pay-as-you-go plan for accessing resources and applications from a cloud service provider. Generally this is at a much lower cost because the total costs are spread across a large number of users.

One of the major cloud service providers uses three different types of cost structures: reserved instance pricing, on-demand instance pricing, and spot instance pricing. The spot instances enable the user to bid for unused cloud capability and get charged at spot price, which can significantly lower the computing costs further for time-flexible, interruption-tolerant tasks which is typical for regular long-term planning studies.

Scalability

Cloud computing offers flexibility in satisfying peak computational needs, without the need to invest in underutilized IT infrastructure. Scalability allows for quickly and easily to grow or shrink IT infrastructure depending on the business need at hand. Traditionally IT has to estimate the maximum capability based on business needs, then make purchase in advance to meet the peak demand because of long budget and procurement process.

With cloud computing, computing nodes, memory, space, and storage are quick and easy to be up- or downscaled. Company only pays for what is used, so the total capacity can be dynamically adjusted and be very closely matched to the demand in an economical fashion. Instead of taking months in the traditional way to purchase and deploy the infrastructure, a company's computational needs can be fulfilled in a matter of minutes or hours.

Flexibility to access

Cloud computing provides more flexible access to files and applications, both in and out of the workplace. The ability to simultaneously share data (i.e., documents) over the Internet can also help supporting both internal and external collaboration.

Privacy and Security Concerns

Despites the advantages, cloud computing continues to meet some resistance, mainly the concerns on privacy and security, giving the sensitivity of the data. With the use of comparable data protection measures, firewalls, security checkpoints, passwords, and encryptions, cloud computing services will become as secure as maintaining one's own infrastructure and comply with all current applicable cyber security standards.

ISO New England Pilot Project

ISO New England initiated a pilot project in 2012 to investigate the potential of using cloud computing technology to improve the computational efficiency of the existing planning studies. In this effort, a special licensing structure of the power system simulation software was created to allow easy installation and configuration at each computing nodes. Significant improvement in terms of the total execution time has been achieved during the project.

For example, a study consisting of 4,100 scenarios took about 1,700 hours on an engineer's desktop computer and about 40 hours over our internal parallel computing environment. When running the same study over 150 computing nodes with 8 cores each at cloud computing platform, the total execution time reduced to only 1.5 hours while the total cost was about $60 based on the bid-in spot price. To further addressing the data security issue, the AES-256 encryption was enabled for the data transfer from and to the cloud nodes. The test showed that the impact of additional encryption on the total execution time was insignificant.

CONCLUSION

This paper discusses some of the challenges that are being faced by transmission planning engineers in today's power industry with increasing needs for running larger and more complex simulations. The paper demonstrates methods in which the three-step procedure (i.e., setting up a study, executing a study and examining the results) has been automated to save both time and money.

First, a method of creating and maintaining consistent basecase models is introduced. This database is used as a central repository for contingency definitions, system loads, generation profiles and other auxiliary data of interest in running a planning study. This database is routinely maintained and has reduced the time to get an accurate representation of the system from a few months to a few hours.

Second, the use of parallel processing to employ a ‘divide-and-conquer’ approach is detailed. While modern power system analysis tools have become more adept at handling large-scale system models and employing optimization techniques for security constrained dispatch, the analysis of multiple scenarios is typically performed in a serial manner. By using multiple servers to run these jobs in parallel the processing time for the study has been reduced by multiple-fold and the techniques allow the planning engineer to evaluate more scenarios than in the past in a fast and efficient manner.

Finally, the use of automation scripts to combine the results from the parallel processing is included. The parallel processing of the study results in thousands of files allows engineers to examine the results in a comprehensive fashion with useful information gleaned and extraneous data filtered out.

In the last section, the paper discussed the use of cloud based computing for running planning studies. While running parallel processing within a company is restricted by the amount of computational resources, the world of cloud computing opens up virtually unlimited amount of processing power. Cloud computing provides several benefits over traditional in-house computer infrastructure in terms of cost savings, flexibility and ease of access. However, some security and privacy concerns remain over the use of sensitive data on the cloud networks.

Although cloud computing has been adopted in many other industries, power industry is relatively slow to embrace it. The pilot project that ISO New England is working on and the direction we are moving will surely motivate power system software vendors and other industry members to bring the technology forward. This will significantly improve the efficiency of power system analysis in both planning and operations with much lower cost as well.

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