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14. ABSTRACT
We derived methods for a simulation environment to automatically select the level of detail necessary for the design of the sub-system of interest without excessive detail and consequent slowing down in other parts. The approach comprises a preliminary simulation phase to determine the differences between model levels in a stochastic sense using the Collocation approach. The results of the preliminary analysis are then synthesized in a sensitivity function; the mean and variance of the sensitivity function are than transformed via discrete wavelet transform. The description of the differences in accuracy between levels is used to allow for the use of a rule-based approach to the selection of the component levels.

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FINAL REPORT

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UNCERTAINTY-BASED SELF CONFIGURING SIMULATION FOR DESIGN SUPPORT

1 September 2011

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ABSTRACT

The authors introduce the idea of using a criterion based on uncertainty propagation for appropriate detail for a model given a simulation task. A guideline to achieve this goal is proposed. A process to synthesize the differences in accuracy between the levels of the model of a component is developed so that the proposed guideline can be implemented in a solver. This approach comprises a preliminary simulation of the components, performed once for all, to determine the differences between model levels in a stochastic sense using the Collocation approach. The results of the preliminary analysis are then synthesized in a sensitivity function that we use in a rule-based selection of the levels for all the models in a simulation scheme. The efficacy of this method is demonstrated using case studies.

OBJECTIVES

Many simulation scenarios require analyzing the same topology with different level of details. As result, it is becoming more and more important to define automatic procedures able to select the appropriate detail for a model given a simulation task. Our objectives are to develop a method for selecting the appropriate detail for a model given a simulation task using a criterion based on uncertainty propagation.

BACKGROUND

During the design of systems (for example power systems, but this is also true for many other types of systems), two kinds of simulation-based analyses are traditionally performed. The first, at the system level, is usually a power flow analysis that is intended to develop sizing criteria and to ensure sufficiency of power to all loads. The second, at the component level, is a transient analysis that is intended to ensure correct dynamic performance, especially under expected adverse or rapidly-changing operating conditions. In the first case, models are generally formulated to represent steady-state behavior, and transient behavior is neglected. In the second case, models are formulated with great attention to detail and correct representation of dynamic behavior. Models appropriate for one form of analysis are not appropriate for the other. Further confounding the problem is that modern power electronic systems may require analysis at intermediate levels of detail, thereby introducing finer-grain detail in the ranking of model resolutions.

For the new generation of complex power systems, most of the challenges in the design are at system level rather than at component level. Furthermore, due to the growing complexity, the design of the individual subsystem cannot be done without considering its global effect. Coherently with many definitions of complexity, in fact, the behavior of the overall system cannot be easily deduced from the behavior of its individual parts.

Additionally, from the operational point of view, the interdisciplinary nature of the design problem calls for experts from different fields to work on different aspects of the system while preserving a coherent unifying picture. Thus, the simulation environment should guarantee the level of detail necessary for the design of the sub-system of interest without excessive detail and consequent slowing down in other parts. This different granularity should be automatically set, since the individual designer cannot be expected to manually choose it for the models outside his/her area of expertise. For these reasons, a systematic approach to automatic selection of model detail is needed to facilitate the design process.

ACCOMPLISMENTS

A pathway to realize automatic selection of appropriate models was reported in [2][6]; four issues were addressed:

- Definition of specifications for how the different levels of detail of models should be organized.
- Definition of a method to choose the right level of model detail for each system component, given the objectives of the analysis that is to be executed.
- Definition of an ontology for meta-models.
- Definition of a way to incorporate information about the differences between models at various levels of detail so that the automatic model selection method can always choose the right level of detail.

Publications [1][3] define a method for select the right levels of model detail for the various system components, given the specifications of some desired analysis, .

The approach comprises a preliminary simulation phase, performed once for all levels of model detail, to determine the differences between model levels in a stochastic sense using the Collocation approach. The results of the preliminary analysis are then synthesized into a sensitivity function; the mean and variance of the sensitivity function are than transformed via discrete wavelet transform so that significant coefficients can be isolated. This new and final step in the description of the differences in accuracy between levels was introduced to allow for the use of a rule-based approach to the automatic selection of the components levels.

A rule-based approach is the solution of choice as it emulates common reasoning. Although it may not produce the absolute optimal combination of model levels of detail, nonetheless it accomplishes a suitable result with satisfactory tradeoffs. In fact, the possibility of automatically selecting the appropriate model levels of detail by using some precise analytic calculation of desired accuracy of the output variables has now been discarded since it is poorly scalable and may easily cause an excessive computational overhead that would nullify the advantage of the automatic set-up.

The method was demonstrated for a test case where the problem was to specify the circuit breaker trip points for the circuit protection system for an induction motor that drives a water pump. The variable of interest is the motor current. We want the circuit breaker to disconnect the motor during any serious fault such as a line-to-line fault, but not during the brief period of overcurrent during motor start up. For each component models at several different levels of detail were provided. Our method successfully selected the least complex set of models that gave the correct protection solution. [4]

The final goal of our work was to develop a rule for automatic selection of model levels of detail, where the rule is conceptually based on the requirements of the design function, and it is numerically based on the requirement of the wavelets transformation results. In this method the wavelet transformation results are lumped into indices that allow classification of the available models of each component. These classifications can then be used to automatically select which levels of model should be used when composing the system model from component models. [5]

We tested two indices: one for the mean of the sensitivity function, and one for the variance of the sensitivity function. The test system consisted of an induction machine and several components of a cooling system for the room in which the machine was located. The objectives were twofold – to select the trip settings of the circuit protection device on the circuit feeding the induction machine, and to size the cooling system. This example is interesting because it underlines how the proposed approach can apply to multidisciplinary systems that require concurrent work by engineers in different disciplines..

Here the power system voltage and the torque of the motor load were set as the uncertain input variables. The sensitivity function is the difference of the phase A currents computed by the two models. Once the mean and variance of the sensitivity functions are calculated by using Collocation, each is transformed to produce matrices of wavelet coefficients of the wavelets to . Two different dynamic situations were considered:

- Startup of the machine from standstill
- Doubling of the torque load while the machine was running at the nominal operating point

Both of these cases were tested. Current to the motor was selected as the sensitivity variable, the variable used for comparison of the differences in model level accuracy. Both of the test cases were simulated using different levels of models and the simulation results were compared to a set of baseline results coming from yet-more-detailed models that were taken as the "truth models". The indices that 'selected' the best model level, the models with the lowest level of detail that gave acceptable results, were then examined to see if the selected models gave the same results as the baseline models. For each case the indices provided the same answer as the simulation results directly.

CONCLUSIONS

The authors introduce the idea of using a criterion based on uncertainty propagation for appropriate detail for a model given a simulation task. A process to synthesize the differences in accuracy between the levels of the model of a component in a sensitivity function was developed and implemented in a solver. The choice of model levels for target accuracy and minimum computational cost can be based on this function. The proposed approach has been initially validated with a simple case study consisting of the selection of commercial protection devices.

A rule-based approach was chosen for selecting the model level of detail, where the rule is conceptually based on the requirements of the design function, and it is numerically based on the requirement of wavelet transformation of the sensitivity function mean and variances. In this method the wavelet transformation results are lumped into indices that allow classification of the available models of each component. These classifications are then be used to automatically select which levels of model should be used when composing the system model from component models. This approach was tested by a second multidiscipline case study the method selected component models having the lowest level of detail that gave acceptable results, demonstrating the efficacy of this method.

Journal Papers:

1. A. Benigni, F. Ponci, A. Monti "Towards an Uncertainty-based Model Level Selection for the Simulation of Complex Power Systems" Submitted to IEEE System Journal

Conference Papers:

2. F. Ponci, "Challenges in Uncertainty-based, Self-configuring Simulation for Design Support", Summer Simulation Multi-conference of the Society for Modeling and Simulation International, Grand Challenges in Modeling and Simulation, Edinburgh, Scotland June 16-19, 2008

3. A.Benigni, F. Ponci, A. Monti, "Towards an Uncertainty-based Model Level Selection for the Simulation of Complex Power Systems", Complexity in Engineering, 2010. COMPENG '10, Rome. Page 46-48.

4. A. Benigni, F. Ponci, A. Monti, "Sthocastic Based Sensitivity function for Model Level Selection In System Simulation", International Simulation Multiconference of the Society for Modeling and Simulation International, Grand Challenges in Modeling and Simulation, Ottawa, ON, Canada 12-14 July 2010.

5. A. Benigni, F. Ponci, A. Monti "Model Level Selection for the Simulation of Complex Power Systems: A Test Case" ISMC 2011, International Simulation Multiconference, 27-29 July 2011, The Hague, Netherlands.

Masters Thesis:

6. Yongjie Huang "Automated Level Selection For Design-Aimed Simulation"2009

Publications

Publications or Reports (May 2011 – August 2011).

Journals: 1

Book or Chapters: none

Technical Reports / Presentations: 1

Workshops: none

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Honors and Invitations: none

Personnel Statistics: (May 2011 – August 2011)

Total Number of Co-PIs: 0

Number of Woman Co-PIs: 0

Number of Minority Co-PIs 0

Total No of research faculty working on the grant: 0

Number of Woman Co-PIs: 0

Number of Minority Co-PIs 0

Total No of students working on the grant: 2

Number of Graduate Students: 0

Number of Woman Grad Students: 0

Number of Minority Grad Students: 0

Number of Under Graduate Students: 3

Number of Woman Under Grad Students: 5

Number of Minority Under Grad Students 0

Total Post Docs: 1

Number of Woman Post Docs: 0

Number of Minority Post Docs 0

No of degrees Granted during this report Period: 0