A COMPONENT BASED APPROACH TO POWER SYSTEM APPLICATIONS DEVELOPMENT

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Abstract - This paper addresses issues of reusability of component models. Once a component model is designed, implemented and tested, it should be possible to use it as many times as necessary for a variety of purposes. The main idea of this paper is to introduce a new way for building flexible power system applications. In order to obtain code reusability a "general" non-linear equation handler and solver is implemented. The general-purpose solver does not need to know in advance what kind of problem is going to be solved. Instead, the solver is based on symbolic model handling and evaluation. In order to use the model, each specific application of interest has a converter that transforms input data to the realm of the general purpose solver. Both the application-specific converter and the general purpose equation handler and solver are designed as components. Thus, there is no need to change, or to recode the solver each time when new specific problem of interest arises. It is only necessary to create a new "converter." The result is that the complete development process is less error prone. In addition to describing code reusability, this paper also presents a unique way of collecting input data and model descriptions that make it possible to reuse symbolic models in an effective manner.

Keywords: Software Design and Development, Object-orientation, Code Reusability, COM, Symbolic Computation

1 INTRODUCTION

Previous approaches to power system modeling and application development vary from traditional procedural programming to modern object-oriented approaches. Speeding up the programming process, improving the quality of the source code organization and the ability to manipulate the code are the main features of current object-oriented methods. Traditional procedural programming gives very good results in terms of final application computational speed. Lack of quality of source code is the main reason in the move toward object-oriented programming. Object-oriented modeling of power systems to date has been based on physical objects. Physically based objects are a natural way of representing the system. Using these approaches the developer of a power system application are faced with the problem of understanding the physical principles of objects. Previous analyses of object-oriented application development were based on comparisons of computational speed between applications developed using object-oriented and procedural languages [1,2,3,4].

Several symbolic tools have been developed to speed up the software development cycle [7,11,12,13]. ADIFOR [8] and ADIC [9] are tools for automatic code differentiation. These tools can be used to achieve faster programming. However, modifying applications developed using these tools requires two steps. First, new differentiation information must be generated. This step includes entering a new mathematical model directly into source code and using these tools regenerating needed derivative information. Second, the regenerated code has to be recompiled. Furthermore, these tools are dependent on the use of a specific underlying programming language (Fortran, C).

Another modern approach to software development can be based on component modeling using COM/DCOM or CORBA. These frameworks are programming language independent. A developed component can be used in any programming language as long as that programming language provides support for component communication. Additionally, components are used as binary objects and there is no possibility of accidentally changing their behavior. In this paper COM is used as a case-study for component development.

Object-oriented design and component software development have several advantages. Maintaining source code and its reusability are the most important. This paper presents a new approach to power system software application development with the following goals:

- Code reusability,
- Speeding up programming,
- Easier maintenance of large power system models,
- Independence from programming languages.

2 FRAMEWORK DESIGN

For a large power system, problems of maintaining source code and making changes to models can be quite difficult. In order to solve this problem, the process of modeling and applications development is divided into three layers: a model design layer (editor layer), a database layer, and an application layer. The database layer collects information on the current system state. This includes information about the mathematical model of the system, its symbolic Jacobian, and initial guesses. Thus, time needed for parsing and symbolical differentiation is removed from the application layer. Information on the current system state is entered using editor and input format converters. The application layer can use this data via component models.

2.1 Code reusability

Once designed, implemented and tested application (component) should be re-used whenever possible. Implementation of applications with code reusability intentions requires that the design process be dominant in the software development cycle. It is natural for an object-orientated approach to go from the general (even abstract) toward the specific. The paper uses this approach to achieve code reusability.

A general-purpose solver that solves non-linear sets of equations is implemented as the main part of this approach. Since a general-purpose solver cannot know in advance what kind of problem is going to be solved, the solver must be able to perform symbolic evaluations. The symbolic module is responsible for evaluating functions, gradients, Jacobians, and Hessians of the specific problem.

The solver component is based on a well-tested and documented SolverQ implementation [5,6]. Since this solver makes extensive use of symbolic computation, its native format is used as input to the solver. For power systems, on the other hand, there are specific data input formats (e.g. CDF, PTI) that are frequently used. In order to reuse these power system file formats, converters for each format type are implemented. These converters generate the same input format for the solver. Developers can use these modules as part of the solution process, or can use them as independent stand-alone modules. Furthermore, these converters help in seamlessly integrating component models and the proposed framework into existing power system model organizations.

Since components are used and distributed in binary formats there is no need for recompilation of application. Future applications can be developed with additional flexible features.

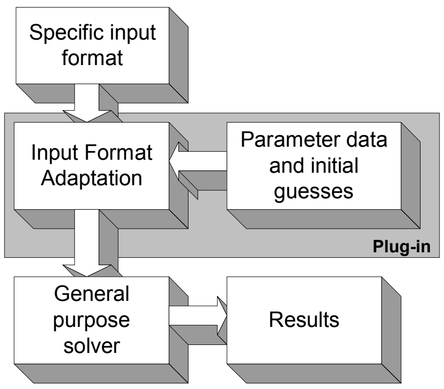

Figure 1: Input data adaptation for general purpose solver

To be robust, future applications have to implement a plug-in loader module. This module collects all available plug-ins for different problems. Using this approach, a main application does not need to be recompiled or even changed to accommodate additional requirements. From a developer’s point of view there is only a need for a new plug-in (converter) implementation. A plug-in contains descriptions that are required by the user interface. Thus, plug-ins must “expose” all information necessary for dynamic menu construction and information on required file format extensions.

2.2 Application robustness and input data reusability

Introducing symbolic evaluation and having application based on a general solver results in reduced computational speed. In order to speed up the solving process, a prepared Jacobian and parsed input data are used. This is implemented using formula (module) pool, which contains unique formula (system) names and information needed by the solver. Thus, unnecessary parsing for repetitive solving of the same problem is skipped. For on-line adjustment, parameter variables are included. Figure 2. contains the design of the proposed framework. New components are emphasized in yellow.

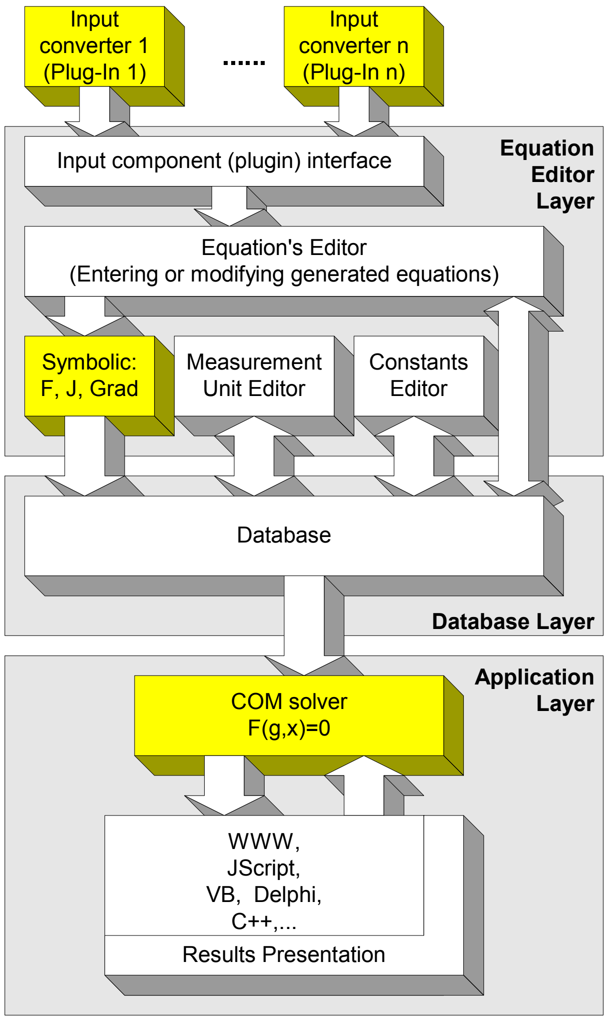
Input converter 1 (Plug-In 1)
......
Input converter n (Plug-In n)
Input component (plugin) interface
Equation Editor Layer
Equation's Editor (Entering or modifying generated equations)
Symbolic: F, J, Grad
Measurement Unit Editor
Constants Editor
Database
Database Layer
Application Layer
COM solver F(g,x)=0
WWW, JScript, VB, Delphi, C++,...
Results Presentation

Figure 2: Framework for using COM modules

In order to obtain input data model reusability three layers are introduced. An Equation Editor Layer contains all plug-ins and an editor for manually entering and changing models. This layer also includes an editor for constants and an editor for unit conversion.

The database layer is used for storing models for future use. The database is organized as a tree.

The application layer contains specific user's code and results presentation obtained from the COM solver.

The Equation Editor prepares set of equations, parses them, and stores them in an appropriate format into the database. This process can require either manual typing or using available plug-ins for converting data from other input formats. The Equation Editor produces postfix notation for faster formula evaluation. The Measurement Unit Editor stores information needed for unit conversion. This information is used by the application layer for unit conversions. The Constants editor enters values for the most useful constants and stores information into the database. The Appendix contains screenshots of these parts of framework.

Once every has been organized, the COM solver requires very short overhead time. The COM solver exposes its interface to the Application Layer for setting parameter variables (g) and for taking solutions (x).

2.3 Generic approach for future development

Three different components are developed: converters, component for parsing and symbolic derivation, and a non-linear solver. These three components are taken directly from SolverQ code. The flexibility of this framework is illustrated on the following Figure, where components are used without a database layer.

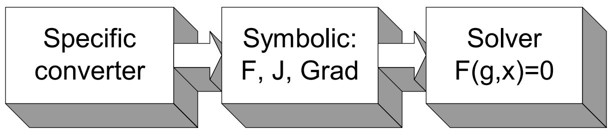

Figure 3: Component piping

Figure 3 shows in a simple and generic way how to obtain a solution on a specific problem in power system. However, greater robustness of application can be obtained if database layer is included, as described next.

3 COM SOLVER USAGE

The COM Solver is developed using C++ and ATL. This leads to small memory requirements for executable components. Components can be used and controlled by external clients (e.g. VBScript, JScript, VBA, VB, VC++, etc.), even on web pages.

There are three different ways of using the COM solver. These differences are caused by the way in which parameters and variable values are passed. Parameter and variable values passing can be done using names or indices. The Appendix contains a partial listing of the solver component interface.

3.1 Passing Value by Name

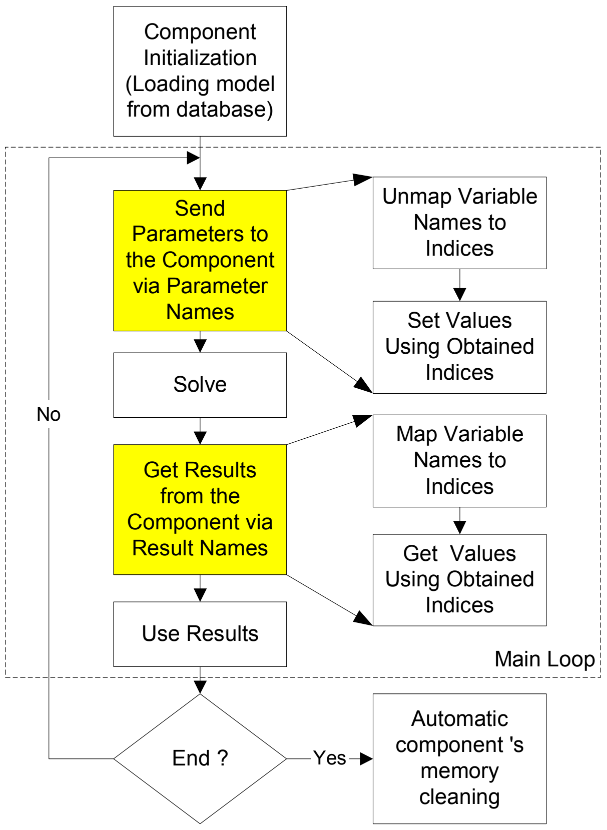
Component Initialization (Loading model from database)
Send Parameters to the Component via Parameter Names
Unmap Variable Names to Indices
Set Values Using Obtained Indices
Solve
No
Get Results from the Component via Result Names
Map Variable Names to Indices
Get Values Using Obtained Indices
Use Results
Main Loop
End ?
Yes
Automatic component 's memory cleaning

Figure 4: Passing values by variable names

The highlighted part of the example shows lines of code that pass parameter values by names. Named parameter passing is very flexible from a developers' point of view. The code is more flexible in case the model is modified. However, this method incurs some overhead time needed for mapping names to actual memory locations. Using this method of passing values into solver component should be avoided inside of loops.

3.2 Passing Value by Index

This is the fastest approach for passing parameters inside and outside of COM modules. From a developers' point of view this method is less clear. There is a need for using comments for each index. Problems can arise when models are changed or when the order of variables is reorganized.

In order to use fast data access of passing values by index and flexibility of passing values by names, a combination of these two methods is used.

3.3 Combination of Passing Values by Name and Index

Combination of passing values by name and by index solves the problem of potential variables reordering with the same time response. To obtain this, developer should use GetParamIndex and GetOutputIndex in initializating part of application code. Thus, an application will obtain indices at run time and can use them in loops.

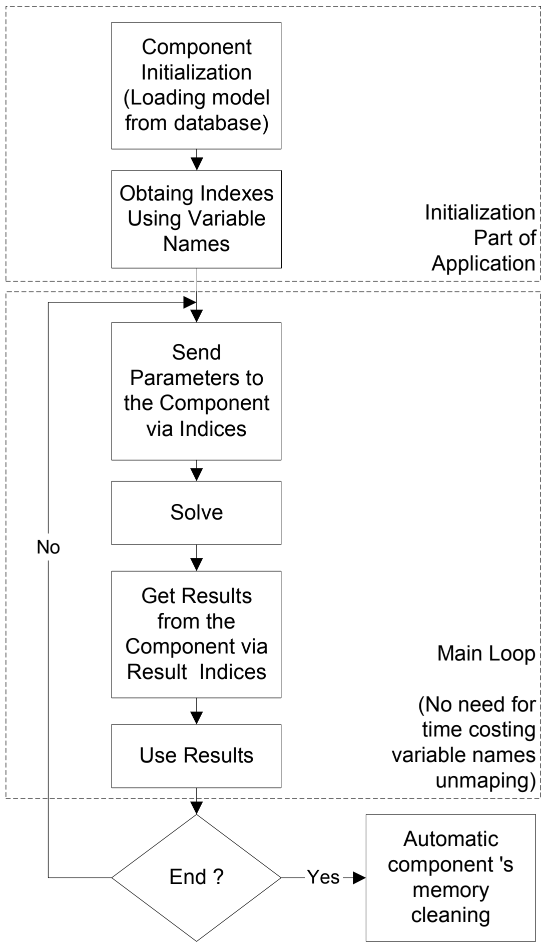
Component Initialization (Loading model from database)
Obtaing Indexes Using Variable Names
Initialization Part of Application
Send Parameters to the Component via Indices
Solve
Get Results from the Component via Result Indices
Use Results
Main Loop
(No need for time costing variable names unmaping)
No
End ?
Yes
Automatic component 's memory cleaning

Figure 5: Combined way of passing values

4 RESULTS

Components are tested on power flow and economic dispatch problem. Timing results are given for power flow compared to MatPower [14].

4.1 Power Flow problem

As a demonstration of the modeling process, a 6-bus system is chosen. Listing 1 shows output from the converter, which uses common data format file (CDF) and transforms data into form that can be solved using COM solver. These data are used as an input for the symbolic COM solver.

```
{Generated from CF File}
{Problem: Power Flow}
k=1.0;
a1=0.0;
v1=1.05;

0.5· k=v2· (+v6· (-1.559020)· COS(a2-a6)+v6· 4.454343·  SIN(a2-a6)
+ v5· (-1)· COS(a2-a5)+v5· 3· SIN(a2-a5)+  v4· (-4)·  COS(a2-a4)
+v4· 8· SIN(a2-a4)+v3· (-0.769231)· COS(a2-a3) + v3· 3.846154·
SIN(a2-a3)+ v2· 9.328251+ v1· (-2)· COS(a2-a1)+ v1· 4· SIN(a2-a1));

v2=1.05;

0.6· k=v3· (+v6· (-1.923077)· COS(a3-a6)+v6· 9.615385· SIN(a3-a6)
+v5· (-1.463415)· COS(a3-a5)+v5· 3.170732· SIN(a3-a5)+ v3·
4.155722+v2· (-0.769231)· COS(a3-a2)+v2· 3.846154· SIN(a3-a2));

v3=1.07;
(-0.7)· k=v4· (+v5· (-1)· COS(a4-a5)+v5· 2· SIN(a4-a5) +v2· (-4)·
COS(a4-a2)+v2· 8· SIN(a4-a2)+v4· 6.176471+v1· (-1.176471)·
COS(a4-a1)+v1· 4.705882· SIN(a4-a1));

(-0.7)· k=-v4· (+v5· 2· COS(a4-a5)-v5· (-1)· SIN(a4-a5)+v2· 8·
COS(a4-a2)-v2· (-4)· SIN(a4-a2)+v4· (-14.670882)-v4· 6.176471 ·
SIN(a4-a4)+v1· 4.705882· COS(a4-a1)-v1· (-1.176471)· SIN(a4-a1));

(-0.7)· k=v5· (+v6· (-1)· COS(a5-a6)+v6· 3· SIN(a5-a6)+v4· (-1)·
COS(a5-a4)+v4· 2· SIN(a5-a4)+v3· (-1.463415)· COS(a5-a3)+v3·
3.170732· SIN(a5-a3)+v2· (-1)· COS(a5-a2)+v2· 3· SIN(a5-a2)+v5·
5.293290+v1· (-0.829876)· COS(a5-a1)+v1· 3.112033· SIN(a5-a1));

(-0.7)· k=-v5· (+v6· 3· COS(a5-a6)-v6· (-1)· SIN(a5-a6)+v4· 2·
COS(a5-a4)-v4· (-1)· SIN(a5-a4)+v3· 3.170732· COS(a5-a3)-v3·
(-1.463415)· SIN(a5-a3)+v2· 3.000000· COS(a5-a2)-v2· (-1)·
SIN(a5-a2)+v5· (-14.210265)-v5· 5.293290· SIN(a5-a5)+v1·
3.112033· COS(a5-a1)-v1· (-0.829876)· SIN(a5-a1));

(-0.7)· k=v6· (+v5· (-1)· COS(a6-a5)+v5· 3· SIN(a6-a5)+v3·
(-1.923077) ·  COS(a6-a3)+v3· 9.615385· SIN(a6-a3)+v6· 4.482097+
v2· (-1.559020)· COS(a6-a2)+v2· 4.454343· SIN(a6-a2));

(-0.7)· k=-v6· (+v5· 3· COS(a6-a5)-v5· (-1)· SIN(a6-a5)+v3·
9.615385 ·  COS(a6-a3)-v3· (-1.923077)· SIN(a6-a3)+v6·
(-17.037228)-v6· 4.482097· SIN(a6-a6)+v2· 4.454343· COS(a6-a2)-
v2· (-1.559020)· SIN(a6-a2));

{Initial values:}
v1≈1.000000;   a1≈0.000000;   v2≈1.000000;   a2≈0.000000;
v3≈1.000000;   a3≈0.000000;   v4≈1.000000;   a4≈0.000000;
v5≈1.000000;   a5≈0.000000;   v6≈1.000000;   a6≈0.000000;
```

Listing 1. Output from CF converter module (6-bus)

Last output lines contain symbol "≈", which denotes initial values. Symbol ";" is used as separator between equations. Symbols "{" and "}" denote start and end of a comment section, respectively.

Prepared data are sent to the symbolical differentiator, which constructs symbolical Jacobian. Both, symbolical Jacobian and function equations are transformed into postfix evaluators, which will be used by Newton-Raphson solver.

Listing 2. contains solution obtained after solving 6 bus problem. Solution is obtained in 2 iterations and tolerance = 1e-3.

```
v1=1.050000   a1=0.000000    v2=1.050000   a2=-0.065010
v3=1.070000   a3=-0.075642   v4=0.986423   a4=-0.072934
v5=0.979665   a5=-0.091175   v6=1.014433   a6=-0.104205
```

Listing 2. Solution of 6-bus power system

In presented example, components are "piped" forming the following chain: problem formulation (CDF file) → power flow converter → symbolical differentiator → Newton-Raphson solver. Data transferred through components, are available for examination. Listing 1. contains data transferred from converter component into symbolical differentiator. In case when data are accessed from database, complete solver construction process is much faster since database contains prepared postfix evaluators, which are loaded directly into the solver.

Authors cannot show data passed from symbolical evaluator into the solver, due to paper's space restriction. However, an example of output from a symbolical differentiator is shown on the following example.

4.2 Economic Dispatch problem

For clarity reasons, Wood-Wollenberg's economic dispatch example will be examined. In order to solve this problem, augmented Lagrangian converter will be put in front of symbolical differentiator and solver components chain. Economic dispatch problem solution is obtained via four "piped" components. Original problem formulation is passed through the following component chain: problem formulation → Lagrangian converter → symbolical differentiator → (Hessian) symbolical differentiator → Newton-Raphson solver.

Problem formulation is shown on the following listing.

```
{Minimize:}
1.1· (510+7.2· p1+0.00142· p1^2)+0.00194· p2^2+7.85· p2+0.00482·
p3^2+7.97· p3+388;

{Subject to:}
p1 + p2 + p3 = 850 + ploss; {and}
ploss = 0.00003 ·  p1^2 + 0.00009 ·  p2^2 + 0.00012 ·  p3^2;

{Inequality constraints:}
p1 ≤ 400;   p2 ≤ 300;   p3 ≤ 300
```

Listing 3. Economic dispatch problem formulation

Lagrangian converter converts inequality constraints into equality constrains and constructs augmented Lagrangian. Listing 4. contains output from Lagrangian converter for economic dispatch problem.

```
{Augmented Lagrangian:}
{L=}µ6· (SQUARE(δ6)+p3-300)+µ5· (SQUARE(δ5)+p2-
300)+µ4· (SQUARE(δ4)+p1-400)+µ3· (ploss-(0.00003· p1^2+
0.00009· p2^2+0.00012· p3^2))+µ2· (p1+p2+p3-(850+ploss))+
1.1· (510+7.2· p1+0.00142· p1^2)+0.00194· p2^2+7.85· p2+0.00482·
p3^2+7.97· p3+388;
```

Listing 4. Output from Lagrangian converter

Output from Lagrangian converter is sent to the symbolical differentiator, which finds derivatives with respect to each variable.

```
{d(L)/d(p3)=} µ6+µ3· (-0.00012· p3· 2)+µ2+0.00482· p3· 2+7.97;
{d(L)/d(p2)=} µ5+µ3· (-0.00009· p2· 2)+µ2+0.00194· p2· 2+7.85;
{d(L)/d(p1)=} µ4+µ3· (-0.00003· p1· 2) + µ2+
              1.1·  (7.2+0.00142· p1· 2);
{d(L)/d(ploss)=} µ3+(-µ2);
{d(L)/d(µ2)=} p1+p2+p3-(850+ploss);
{d(L)/d(µ3)=} ploss-(0.00003· p1^2+0.00009· p2^2+0.00012· p3^2);
{d(L)/d(δ4)=} µ4· δ4· 2;
{d(L)/d(µ4)=} SQUARE(δ4)+p1-400;
{d(L)/d(δ5)=} µ5· δ5· 2;
{d(L)/d(µ5)=} SQUARE(δ5)+p2-300;
{d(L)/d(δ6)=} µ6· δ6· 2;
{d(L)/d(µ6)=} SQUARE(δ6)+p3-300;
```

Listing 5. Output from symbolical differentiator

From this point on, situation is the same as previously described power flow problem. Symbolical data, shown on Listing 5, are sent to the Hessian differentiator. Hessian differentiator evaluates symbolical Hessian of given problem. During solving, Hessian will play role of Jacobian in Newton-Raphson solver. The following listing contains solution of stated problem. Solution is obtained in 5 iterations, and tolerance = 1e-3.

```
p1=334.2882655      p2=234.8271323      p3=300.0000000
ploss=19.1153997    µ2=-9.1477966       µ3=-9.1477966
µ4=-1.19*10^-9      µ5=0.0000002        µ6=-2.3728448
δ4=8.1062776        δ5=8.0729727        δ6=6.44*10^-9
```

Listing 6. Economic dispatch solution

4.3 Timing results

Table 1 shows results of the COM power flow solver module computation as compared to MatPower [14] execution times.

Input model	Toler-ance	COM solver		MatPower	
		No. Iter.	Time	No.Iter.	Time
IEEE118	10^{-6}	3	0.210	3	0.05
IEEE300	10^{-6}	4	1.580	5	0.16

Table 1. Testing platform: Win2000, Pentium III, 750 MHz

The execution time is bigger for COM due to the use of a general nonlinear solver for the set of equations. Furthermore, symbolic evaluation requires extensive stack usage and parsing time. However, despite the fact that symbolical evaluation is used inside of components, computational speed is still quite tolerable, about 10 times slower than the "hard coded" approach. In other larger examples this same ratio seems to hold

5 CONCLUSIONS AND FUTURE WORK

A new approach for component based application development in power system has been explored. A generic framework for power system models organization and software development has been proposed. Using code reusability as one of its main guidelines, components for future software development has been developed and tested.

Fast technological development was taken into consideration, so that computational speed of future applications was not the main goal. Instead of speed of execution, speed of development is the paramount. Examples shown in this paper emphasize simplicity and efficiency of development. Developers are not bounded by a programming language. Proposed COM modules enable future software development using different programming languages. Even developers with limited power system knowledge can use these components very efficiently.

Since COM modules are created using C/C++ and ATL (and thus, they are very "light" in terms of memory consumption) they can be used on web pages, and embedded within script languages that support COM.

The problem of model redesign and the need for complete application recompilation has been removed using a centralized database for model collection. Applications developed within this framework only need to be restarted to re-initialize needed COM modules. Collecting updates on model changes is much easier using this framework.

There is a sacrifice in speed for this flexibility. A slowdown of a factor of 10 is seen in those applications illustrated as well as a few others. Computing power, however, is making such considerations less relevant.

Future work will try to add more robust optimization composers, such as Interior-Point solver.

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APPENDIX

Appendix contains component solver interface, screenshot of Equation Editor Module – SolverQ, and screenshots of additional tools previously mentioned in the paper.

5.1 COM Solver Module Interface

COM Newton-Raphson solver module is done using dual interface automation server. All COM-aware programming languages like VB, VBA, VC++, etc. can use the automation server.

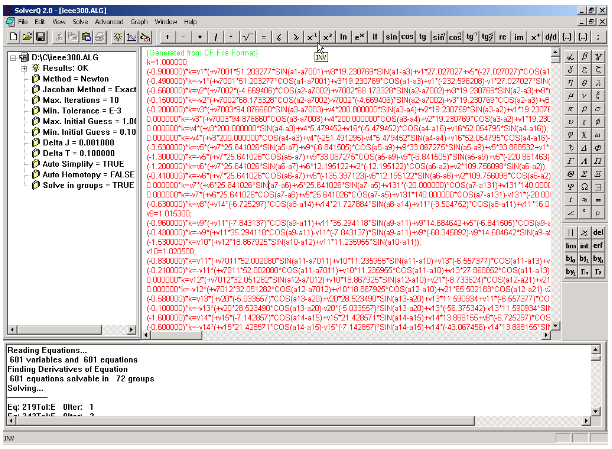
```
HRESULT InitByStr([in] BSTR
strEquationName)

HRESULT InitByID([in] long nID)

HRESULT GetOutputName([in] long
nIndex,[out, retval]BSTR *strVarName)

HRESULT GetOutputIndex([in]  BSTR
strVarName,[out, retval]long *nIndex)

HRESULT GetAllOutputNames([out, retval]
SafeArray(BSTR) *strVarNames)

HRESULT GetOutputValueByName([in]BSTR
strVarName, [out, retval] double
*dblVarValue)

HRESULT GetOutputValueByIndex([in]long
nIndex, [out, retval] double *dblVarValue)

HRESULT GetAllOutputValues([out, retval]
SafeArray(double) *dblVarValues)

HRESULT GetParamName([in] long nIndex,
[out, retval] BSTR *strParamName)

HRESULT GetParamIndex([in] BSTR
strParamName, [out, retval] long *nIndex)

HRESULT GetAllParamNames([out, retval]
SafeArray(BSTR) *strParamNames)
```

```
HRESULT SetParamValueByName([in] BSTR
strParamName, [in] double dblParamValue)

HRESULT SetParamValueByIndex([in] long
nIndex, [in] double dblParamValue)

HRESULT SetAllParamValues([in]
SafeArray(double) *dblParamValues)

HRESULT SetOutputUnit([in] long
nIndex,[in] BSTR strUnitName)

HRESULT Solve()
```

Listing 7. A part of COM solver interface (MS IDL)

5.2 *Equation Editor Module*

Using Equation Editor module, models can be edited and stored into database. This module is small modification of SolverQ. The module implements container for plug-ins and enable model designer to test the model. After testing, model can be saved into database. Saved model contains symbolical information needed in solving process.


SolverQ 2.0 - [ieee300.ALG]
File Edit View Solve Advanced Graph Window Help
INV

D:\C\ieee300.ALG
Results: OK
Method = Newton
Jacoban Method = Exact
Max. Iterations = 10
Min. Tolerance = E-3
Max. Initial Guess = 1.0(
Min. Initial Guess = 0.10
Delta J = 0.001000
Delta T = 0.100000
Auto Simplify = TRUE
Auto Homotopy = FALSE
Solve in groups = TRUE

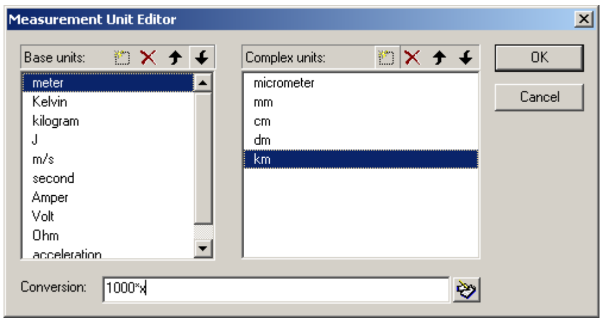
```
{Generated from CF File Format}
k=1.000000;
(-0.900000)*k=v1*(+v7001*51.203277*SIN(a1-a7001)+v3*19.230769*SIN(a1-a3)+v1*27.027027+v5*(-27.027027)*COS(a1
(-0.490000)*k=-v1*(+v7001*51.203277*COS(a1-a7001)+v3*19.230769*COS(a1-a3)+v1*(-232.596208)-v1*27.027027*SIN(
(-0.560000)*k=v2*(+v7002*(-4.669406)*COS(a2-a7002)+v7002*68.173328*SIN(a2-a7002)+v3*19.230769*SIN(a2-a3)+v8*(
(-0.150000)*k=-v2*(+v7002*68.173328*COS(a2-a7002)-v7002*(-4.669406)*SIN(a2-a7002)+v3*19.230769*COS(a2-a3)+v8
(-0.200000)*k=v3*(+v7003*94.876660*SIN(a3-a7003)+v4*200.000000*SIN(a3-a4)+v2*19.230769*SIN(a3-a2)+v1*19.23076
0.000000*k=-v3*(+v7003*94.876660*COS(a3-a7003)+v4*200.000000*COS(a3-a4)+v2*19.230769*COS(a3-a2)+v1*19.230
0.000000*k=v4*(+v3*200.000000*SIN(a4-a3)+v4*5.479452+v16*(-5.479452)*COS(a4-a16)+v16*52.054795*SIN(a4-a16));
0.000000*k=-v4*(+v3*200.000000*COS(a4-a3)+v4*(-251.491295)-v4*5.479452*SIN(a4-a4)+v16*52.054795*COS(a4-a16)-
(-3.530000)*k=v5*(+v7*25.641026*SIN(a5-a7)+v9*(-6.841505)*COS(a5-a9)+v9*33.067275*SIN(a5-a9)+v5*33.868532+v1*
(-1.300000)*k=-v5*(+v7*25.641026*COS(a5-a7)+v9*33.067275*COS(a5-a9)-v9*(-6.841505)*SIN(a5-a9)+v5*(-220.861463)
(-1.200000)*k=v6*(+v7*25.641026*SIN(a6-a7)+v6*12.195122+v2*(-12.195122)*COS(a6-a2)+v2*109.756098*SIN(a6-a2));
(-0.410000)*k=-v6*(+v7*25.641026*COS(a6-a7)+v6*(-135.397123)-v6*12.195122*SIN(a6-a6)+v2*109.756098*COS(a6-a2)
0.000000*k=v7*(+v6*25.641026*SIN(a7-a6)+v5*25.641026*SIN(a7-a5)+v131*(-20.000000)*COS(a7-a131)+v131*140.0000
0.000000*k=-v7*(+v6*25.641026*COS(a7-a6)+v5*25.641026*COS(a7-a5)+v131*140.000000*COS(a7-a131)-v131*(-20.000
(-0.630000)*k=v8*(+v14*(-6.725297)*COS(a8-a14)+v14*21.727884*SIN(a8-a14)+v11*(-3.504752)*COS(a8-a11)+v11*16.0
v8=1.015300;
(-0.960000)*k=v9*(+v11*(-7.843137)*COS(a9-a11)+v11*35.294118*SIN(a9-a11)+v9*14.684642+v5*(-6.841505)*COS(a9-a
(-0.430000)*k=-v9*(+v11*35.294118*COS(a9-a11)-v11*(-7.843137)*SIN(a9-a11)+v9*(-68.345892)-v9*14.684642*SIN(a9-a
(-1.530000)*k=v10*(+v12*18.867925*SIN(a10-a12)+v11*11.235955*SIN(a10-a11));
v10=1.020500;
(-0.830000)*k=v11*(+v7011*52.002080*SIN(a11-a7011)+v10*11.235955*SIN(a11-a10)+v13*(-6.557377)*COS(a11-a13)+v
(-0.210000)*k=-v11*(+v7011*52.002080*COS(a11-a7011)+v10*11.235955*COS(a11-a10)+v13*27.868852*COS(a11-a13)
0.000000*k=v12*(+v7012*32.051282*SIN(a12-a7012)+v10*18.867925*SIN(a12-a10)+v21*(-8.733624)*COS(a12-a21)+v21
0.000000*k=-v12*(+v7012*32.051282*COS(a12-a7012)+v10*18.867925*COS(a12-a10)+v21*65.502183*COS(a12-a21)-v2
(-0.580000)*k=v13*(+v20*(-5.033557)*COS(a13-a20)+v20*28.523490*SIN(a13-a20)+v13*11.590934+v11*(-6.557377)*CO
(-0.100000)*k=-v13*(+v20*28.523490*COS(a13-a20)-v20*(-5.033557)*SIN(a13-a20)+v13*(-56.375342)-v13*11.590934*SIN
(-1.600000)*k=v14*(+v15*(-7.142857)*COS(a14-a15)+v15*21.428571*SIN(a14-a15)+v14*13.868155+v8*(-6.725297)*COS
(-0.600000)*k=-v14*(+v15*21.428571*COS(a14-a15)-v15*(-7.142857)*SIN(a14-a15)+v14*(-43.067456)-v14*13.868155*SIN
```

```
Reading Equations...
 601 variables and  601 equations
Finding Derivatives of Equation
 601 equations solvable in   72 groups
Solving...

Eq: 219Tol:E   0Iter:  1
```

Figure 6: Equation Editor Module

5.3 *Measurement Unit Module*

This module is used for data measurement unit conversion. In fact this is a very simple dialog with possibility to enter conversion equation. Information about units together with their belonging conversions are stored in database.



Base units: meter, Kelvin, kilogram, J, m/s, second, Amper, Volt, Ohm, acceleration

Complex units: micrometer, mm, cm, dm, km

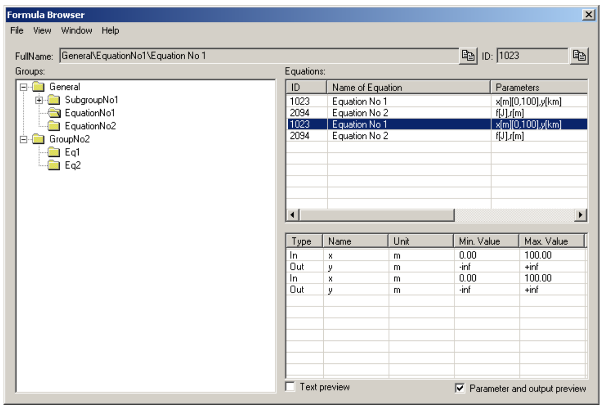
Conversion: 1000*x

Figure 7: Measurement Unit Module

This information can be used with method SetOutputUnit. COM based solver will automatically convert measurement unit into desired one.

5.4 *Model Browser Module*

The following picture contains screenshot of Model Browser module.



FullName: General\EquationNo1\Equation No 1 ID: 1023

Groups:
- General
  - SubgroupNo1
  - EquationNo1
  - EquationNo2
- GroupNo2
  - Eq1
  - Eq2

Equations:

ID	Name of Equation	Parameters
1023	Equation No 1	x[m][0,100],y[km]
2094	Equation No 2	f[J],r[m]
1023	Equation No 1	x[m][0,100],y[km]
2094	Equation No 2	f[J],r[m]

Type	Name	Unit	Min. Value	Max. Value
In	x	m	0.00	100.00
Out	y	m	-inf	+inf
In	x	m	0.00	100.00
Out	y	m	-inf	+inf

☐ Text preview ☑ Parameter and output preview

Figure 8: Model Browser module

This module is a helping tool for finding appropriate module inside database. The tool should help developers while making new power system applications using stored power system models.