Best of the Discussion Forum – Part II

# On MaxControlIterations ...

**From Roger Dugan:**

I see many scripts come by my inbox where users have set MaxIterations to 100 or 1000 thinking that will help with convergence problems. Likewise, I see MaxControlIterations set to very high numbers. This is seldom helpful.

The default MaxIterations is 15 and the default MaxControlIterations is 10. This is nearly always sufficient for reasonably-modeled distribution circuits.

The fixed point iteration solution technique essentially uses the Y matrix as the Jacobian. We don't update the Y matrix between iterations, or time steps, unless there has been a major change such as a regulator tap change or a capacitor switching. As long as the Y matrix is generally pointing in the right direction for the solution at which all currents at a node will sum to zero, the iterative process will usually get there eventually. It will take more iterations than a Newton method that updates Y at every iteration, but it will generally not take hundreds of iterations. The worst I have seen is 81 and that was for a circuit modeling error. The IEEE 8500-node Test Case takes 16 iterations on the first control iteration, but fewer on subsequent control iterations (there are 5 total control iterations -- see **Show Summary** after the solution). So in the script, we set MaxIterations=20.

It mostly has to do with how close the first guess at the voltages is to the final solution. The fixed-point iteration requires the first guess to be closer than other methods. The worst case is generally the first snapshot power flow. Thereafter, for a sequential-time power flow solution, the result for one time step is a really good starting point for the next time step. Thus, most solutions in a yearly or daily simulation take only 2 iterations -- one to get there and one to verify convergence.

So the method is not as good as other methods in terms of number of iterations for the initial solution, but it is not terrible either. So you should never have to set MaxIterations to a high value. In fact, if you are getting convergence only after 100 iterations, there is probably something wrong with your model such as a Load or Generator defined with the wrong voltage rating. Note that you can easily fix that if you've got the voltage base defined for each bus by using the **SetLoadandGenkV** command. This corrects the kV defined for Loads and Generators to match the kV base of the bus to which they are connected. Note that this mismatch could also happen for an incorrect definition of a Transformer object or Vsource object.

If OpenDSS reports that your solution did not converge, first try executing 'Solve' again. As with most things in OpenDSS, the program remains in the last state it was in when it stopped doing something. Hitting the Solve button again will continue the iterations from where it left off. If it still doesn't converge after two more Solves, there is likely something happening that will prevent convergence no matter how many iterations.

Users were recently having difficulties with convergence after opening Line objects. Part of this was due to the Load models not working well at near-zero voltages and part was due to tiny perturbations in the zero sequence, or ground, path. The model frequently loses connection to a strong ground source when a line is open, making it more difficult to figure out where the neutral should be. Build 7.6.3.26 corrected most of this but I wouldn't guarantee it for all cases. But doing more iterations will generally not help.

On **MaxControlIterations**, the program first achieves a converged power flow solution then queries all the control devices to see if they need to adjust something. If so, the adjustment is made and a new power flow solution is executed. This iteration process continues until all control actions for the present time are done.

The usual reason for exceeding MaxControlIterations is conflicting controls. One common one is where all the capacitor control time delays are set to the same value. Thus, they will all switch ON at the same time. That results in too much var support, so in the next control iteration they all switch OFF. This will continue forever if you let it. The value you set for MaxControlIterations will have no effect other than the stop the process when MaxControlIterations is reached.

Note that when you get the message that MaxControlIterations were exceeded, the power flow solution is likely OK. You can use it if you want to. It is often a reasonable solution.

The cure for the control oscillations is to **stagger the time delays**. For example, if all the CapControl objects have a delay of 60 s, set the one closer to the substation to 61 s. This will force the other one(s) to act first and will often fix the problem. In **STATIC control mode** (the default for Snapshot, Daily, and Yearly modes), OpenDSS will execute only the controls with the shortest time delay on each control iteration. In **TIME control mode** with a time step shorter than the delay time of the control, such as you would do in dutycycle mode for solar PV generation studies, this is usually not a problem because the control action waits until the solution time reaches the delay time. It is less likely that two capacitors in different parts of the circuit will arm to switch on exactly the same time step. When it comes time to switch, if the additional capacitor is no longer needed, the control action is popped off the control queue and discarded.

So the controls will generally sort themselves out when simulating in small time steps. The problem is generally when simulating in large time steps larger than the delay time in the control or in the standard Snapshot mode. In Snapshot mode, the control simulation strategy is to sort out the control actions in the order they would actually occur in real life. This is different than most other distribution system analysis tools, so it is common for OpenDSS to predict different regulator taps and capacitor switch positions. Of course, we think our method is better ;-)

There are legitimate reasons for increasing MaxControlIterations. You will see this in some of the IEEE Test Feeder scripts.

One reason is when you limit the max tap change of regulators to one tap per control iteration. This frequently gives the best simulation of an actual voltage regulator, but requires more control iterations. An example of this can be found here:

https://sourceforge.net/p/electricdss/code/HEAD/tree/trunk/Distrib/IEEETestCases/123Bus/Run\_IEEE123Bus.DSS

Another case would be if you are running InvControl on several PVSystems. Some of the control modes sneak up on the final answer slowly and require many passes through the control iteration loop.

**From Wes Sunderman:**

If you have the InvControl controlling several PVSystems, it is generally 'slow' in arriving at the final answer. One reason it was programmed this way, is to try to keep PVSystems that are electrically close to one another from interacting with each other, for instance in volt-var mode.

So we purposefully slow down the maximum reactive power change per control iteration to keep the PVSystems from interfering with each other and causing 'hunting' or oscillatory behavior.

The user-settable parameter *deltaQ*\_factor (and the corresponding *deltaP*\_factor for volt-watt control) can be used to either speed up the arrival at the solution on the volt-var curve (with the potential of introducing hunting or oscillatory behavior) or slow down the arrival at the solution, per control iteration.

The default for deltaQ\_factor is 0.7. That means that the change in reactive power will only be 70% of the desired change (target) in reactive power per control iteration.

It is not too unusual to have maxcontroliter equal to 300 or 500 for cases involving multiple PVSystems under InvControl. Once the user is getting good solutions, then they can turn off logging of these control entries to the event log by setting EventLog=No, and this will speed things up a bit

# Getting Access to CktElement data via User-Written DLLs

## Question

In my user-written DLL code how can I get access to currents in neighboring devices?

## Answer

In the New procedure of your DLL, which make a new instance of your user-defined model, you get a pointer to the CallBacks struct:

FNew: Function(Var GenVars:TGeneratorVars; Var DynaData:TDynamicsRec; Var CallBacks:TDSSCallBacks): Integer; Stdcall;// Make a new instance

This struct is defined as follows:

TDSSCallBacks = Packed Record

MsgCallBack: Procedure (S : pAnsiChar; Maxlen:Cardinal);Stdcall; {Make use of DSS Message handling}

{Routines for using DSS Parser. This allows you to write models that accept

syntax like other DSS scripts.}

GetIntValue: Procedure(var i : Integer);Stdcall; {Get next param as an integer}

GetDblValue: Procedure(var x : Double); Stdcall; {Get next param as a double}

GetStrValue: Procedure(s : pAnsiChar; maxlen : Cardinal); Stdcall;

{Get next param as a string <= maxlen characters (Cardinal = 32-bit unsigned)}

{caller must allocate space for s (Maxlen chars)}

LoadParser: Procedure(S : pAnsiChar; maxlen : Cardinal); Stdcall; // Copies a string into a special instance of the DSS parser

NextParam: Function (ParamName : pAnsiChar; Maxlen : Cardinal):Integer; Stdcall;

{Advance to the next parameter and

Get name of the param just retrieved, if one was given.

Returns length of parameter found. If 0, then end of string.

This is to handle the syntax "paramname=paramvalue" commonly used in DSS scripts

Copies the string to the location specified by s up to maxlen characters.

Caller must allocate space (Maxlen chars)}

DoDSSCommand: Procedure(S : pAnsiChar; Maxlen : Cardinal); StdCall;

GetActiveElementBusNames: Procedure(Name1 : pAnsiChar; Len1 : Cardinal; Name2 : pAnsiChar; Len2 : Cardinal); StdCall;

GetActiveElementVoltages: Procedure(Var NumVoltages : Integer; V : pComplexArray); StdCall;

GetActiveElementCurrents: Procedure(Var NumCurrents : Integer; Curr : pComplexArray); StdCall;

GetActiveElementLosses: Procedure(Var TotalLosses, LoadLosses, NoLoadLosses : Complex); StdCall;

GetActiveElementPower: Procedure(Terminal : Integer; Var TotalPower : Complex); StdCall;

GetActiveElementNumCust: Procedure(Var NumCust, TotalCust : Integer); StdCall;

GetActiveElementNodeRef: Procedure(Maxsize : Integer; NodeReferenceArray : pIntegerArray); StdCall;// calling program must allocate

GetActiveElementBusRef: Function(Terminal : Integer) : Integer; StdCall;

GetActiveElementTerminalInfo: Procedure(Var NumTerminals, NumConds, NumPhases : Integer); StdCall;

GetPtrToSystemVarray: Procedure(var V : Pointer; var iNumNodes : Integer); StdCall; // Returns pointer to Solution.V and size

GetActiveElementIndex: Function() : Integer; StdCall;

IsActiveElementEnabled: Function() : Boolean; StdCall;

IsBusCoordinateDefined: Function(BusRef : Integer) : Boolean; StdCall;

GetBusCoordinate: Procedure(BusRef : Integer; Var X, Y : Double); StdCall;

GetBuskVBase: Function(BusRef : Integer) : Double; StdCall;

GetBusDistFromMeter: Function(BusRef : Integer) : Double; StdCall;

GetDynamicsStruct: Procedure(var pDynamicsStruct : Pointer); StdCall; // Returns pointer to dynamics variables structure

GetStepSize: Function() : Double; StdCall; // Return just 'h' from dynamics record

GetTimeSec: Function() : Double; StdCall; // returns t in sec from top of hour

GetTimeHr: Function() : Double; StdCall; // returns time as a double in hours

GetPublicDataPtr: Procedure(var pPublicData : Pointer; Var PublicDataBytes : Integer); StdCall;

GetActiveElementName: Function(FullName : pAnsiChar; MaxNameLen : Cardinal) : Integer; StdCall;

GetActiveElementPtr: Function() : Pointer; StdCall; // Returns pointer to active circuit element

ControlQueuePush: Function(Const Hour:Integer; Const Sec:Double; Const Code, ProxyHdl:Integer; Owner:Pointer):Integer; StdCall;

GetResultStr: Procedure(S : pAnsiChar; Maxlen : Cardinal); StdCall;

From this you can access things in the OpenDSS data structures that you would not easily have access to otherwise, for example to use the simple error message mechanism, you could do something like:

CallBack^.MsgCallBack(pAnsichar(AnsiHelpStr), Length(HelpStr));

Where Callback is a local variable containing the pointer to the struct that is passed via the New procedure call. Note that strings passed between DLLs and OpenDSS are limited to ANSI strings for now. Also, note the string length argument. Delphi doesn't need this, but if you were writing your DLL in Fortran, it would push another argument, length, onto the stack.

I would use the DoDSSCommand procedure to select an element and then I can get access to that element's currents, losses, power, and voltages:

MyCmdString= 'Select Line.MyLine 1';

CallBack^.DoDSSCommand(pAnsiChar(MyCmdString), Length(MyCmdString));

CallBack^.GetActiveElementCurrents(NumCurrents, MyCurrents);

// where MyCurrents is a pointer to a complex array

You can also get access to the System V array, which is all the node voltages:

CallBack^.GetPtrToSystemVarray(MyVarray, NumberofNodes);

// then ...

Avoltage := MyVarray^[index]; // This is a complex number

There is not global current array. Currents are computed as needed by calling the device for which the currents are desired.

Keep in mind there is potential danger in tinkering with the global arrays. You can break your model if you aren't careful.

Also, let me remind you that the design philosophy of OpenDSS is that no circuit element knows anything about another circuit element. There are few exceptions (meters and control elements). If your model needs to know something like voltage or current from some other circuit element in order to function, you might want to reconsider the design.

# Getting the System Jacobian Matrix

## Question

I see there is a Newton solution methods. How can I get the Jacobian?

## Answer

The system Y matrix is used as the Jacobian in the Newton algorithm. It is the same Y matrix as in the "normal" fixed point solution. So you can get it from either solution algorithm.

Note that you get the Y matrix in different formats depending on whether you get it from "Show Y", "Export Y", or through the SystemY property of the Circuit interface when driving the program from COM.

One thing you will have to decide is whether you want Load and Generator equivalents in the Y matrix for your algorithm. If you define Load and Generator objects you will get the Norton equivalent admittances in the Y matrix. So if that messes up your algorithm (which it frequently does), do a Solve of some sort before you define Load and Generator objects, etc., and extract the Y matrix immediately after the Solve command.

The Y matrix is a common nodal admittance matrix in all formulations that we currently have implemented. You could form a different set of equations such as an augmented Y matrix like SuperHarm uses, but we just haven't done it. In fact, the "normal" fixed point solution using Y works just fine for nearly all the things we are doing.

Early on, when the system got a little ill-conditioned we used a Newton (technically a Newton-Raphson) method to get better convergence than the fixed-point method. Now, I don't know if there is really much difference between the two after implementing some tricks to get the fixed-point to work better.

The fixed-point solution might be written:

*Vn+1 = [Y]-1 \* Icomp(Vn)*

Where Icomp is the *compensation* current from the non-linear loads, etc. (See the User Manual; **OpenDSSManual.pdf**)

The Newton method in OpenDSS might be written:

*Vn+1 = Vn - [Y]-1 \* Iterm-n*

Where *Iterm*is the array of terminal current sums for all nodes. This formulation tries to force the current to sum to zero at each node. It will converge a little better for cases that are really nonlinear and/or ill-conditioned. However, we currently don't update Y between iterations, so it really isn't much of an advantage over the fixed point and takes twice as many arithmetic operations. So we prefer the fixed point for time-sequential simulations for the obvious reason that if you are running an 8760-hour simulation it is faster.

So the Y matrix is used as the Jacobian in this formulation. As long as the derivatives point in the right direction, the solution is likely to get there eventually. It would converge in fewer iterations if we updated the Y matrix for the nonlinear load derivatives at each iteration as my friends in Brazil (Sando Carneiro, Jr., Jose Luiz Pereira, et. al.) do, but iterations are cheap computationally. Rebuilding Y is more expensive. Besides, once you get a time series simulation going, there is frequently only 2 iterations between time steps -- one to get there and one to prove you got there -- because the solution at one time step is a real good starting point for the solution at the next.

The history is: we tried a crude fixed point in 1997 when it was in a much more primitive state than it is now and it worked for nearly all distribution systems we were simulating. We later ran into a transmission system that wouldn't converge and solved that with the Newton algorithm. But don't confuse that with the Newton-Raphson algorithm you find in most power system analysis text books. That uses a different formulation of the power flow problem. But it is still a system of non-linear equations solved by Newton's method.

Subsequently, we have evolved the power conversion models and the method of obtaining the first guess to the power flow solution so that the fixed-point can solve nearly everything we do. Getting a better first guess at the voltages was a key. That solved a lot of convergence problems.