Open Source Software for Simulating Active Distribution Systems

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Prague, 8-11 June 2009

OpenDSS

- EPRI has released its Distribution System Simulator (DSS) program as open source
- Called “OpenDSS”
- Can be found at:
  - **WWW.SOURCEFORGE.NET**
  - (Search for OpenDSS)

Why was DSS Developed?

- DSS was developed to provide a very flexible research platform and a foundation for special distribution analysis applications such as DG analysis
- Fills gaps left by other distribution system analysis tools.
- Study new approaches to distribution system analysis.

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Why OpenDSS?

- EPRI has made the DSS open source to:
  - Cooperate with other open source efforts in the USA in Smart Grid research
  - To encourage new advancements in distribution system analysis
  - To provide Smart Grid researchers a tool for testing algorithms

Current Related EPRI Activities

- Intelligrid
  - Distribution Fast Simulation & Modeling
  - DSE – Distribution State Estimator
- CIM/DCIM
- OpenDSS – Distribution System Simulator
  - Multipurpose distribution system analysis tool
  - Open source version released – 5 Sept 2008
  - Official release – November 2008

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DSS Background

- Under development for more than 10 Years
  - Started at Electrotek Concepts in 1997
  - Purchased by EPRI in 2004
- Objectives in 1997
  - Tool to support all distribution planning aspects of distributed generation
  - Implement a flexible research platform
  - Incorporate object-oriented data ideas
- Key Future work
  - Platform for DSE for North American Systems
  - Research platform for reliability tools

Distribution System Simulator (DSS)

The DSS is designed to simulate utility distribution systems in arbitrary detail for most types of analyses related to distribution planning.

- It performs its analysis types in the *frequency domain*,
  - Power flow,
  - Harmonics, and
  - Dynamics.
- It does NOT perform electromagnetic transients (*time domain*) studies.

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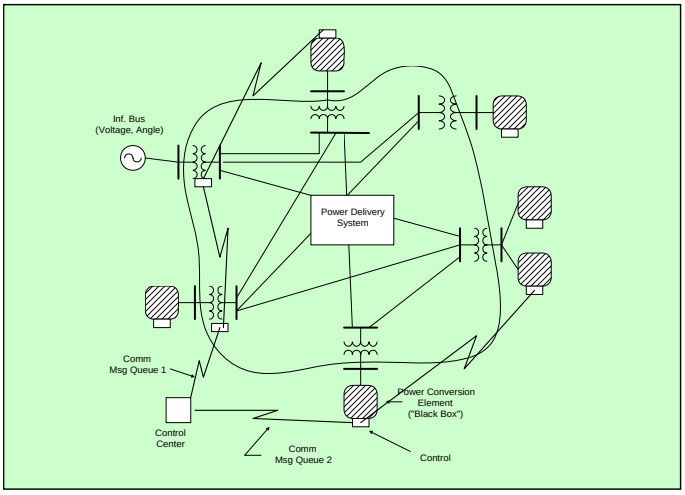
Overall Model Concept



Example DSS Applications

- Neutral-to-earth (stray) voltage simulations.
- Loss evaluations due to unbalanced loading.
- Development of DG models for the IEEE Radial Test Feeders.
- High-frequency harmonic and interharmonic interference.
- Losses, impedance, and circulating currents in unusual transformer bank configurations.
- Transformer frequency response analysis.
- Distribution automation control algorithm assessment.
- Impact of tankless water heaters on flicker and distribution transformers.
- Wind farm collector simulation.
- Wind farm impact on local transmission.
- Wind generation and other DG impact on switched capacitors and voltage regulators.
- Open-conductor fault conditions with a variety of single-phase and three-phase transformer connections.

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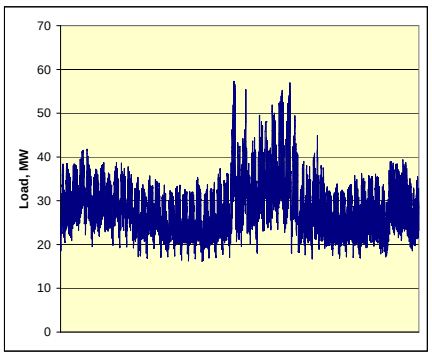
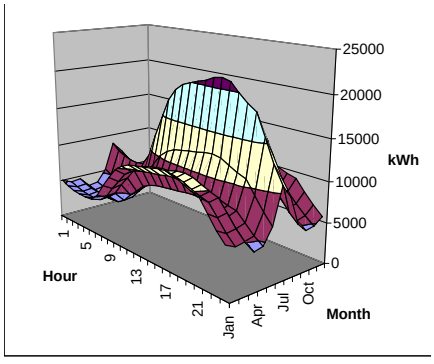
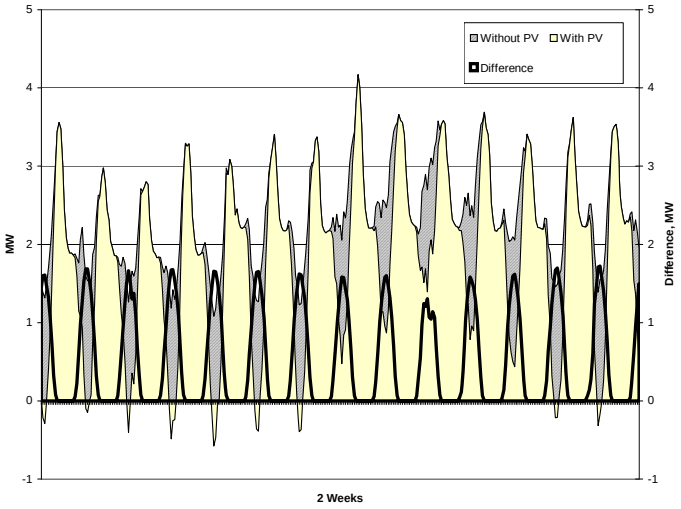
Annual Losses

Peak load losses are not necessarily indicative of annual losses





Solar PV Simulation



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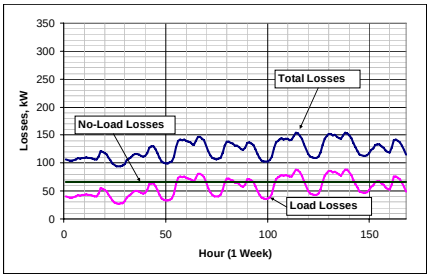
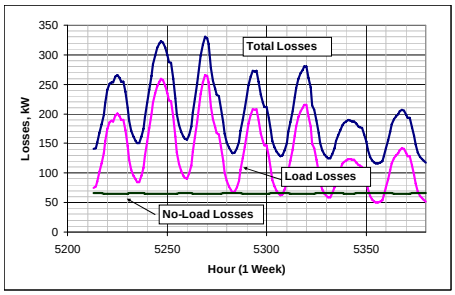
Power Distribution Efficiency

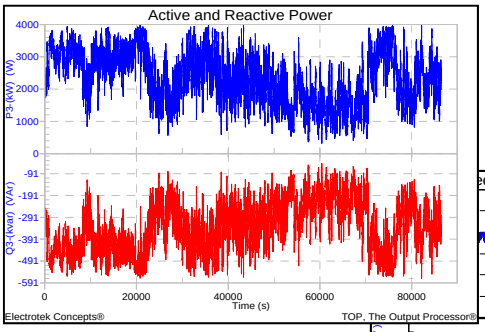


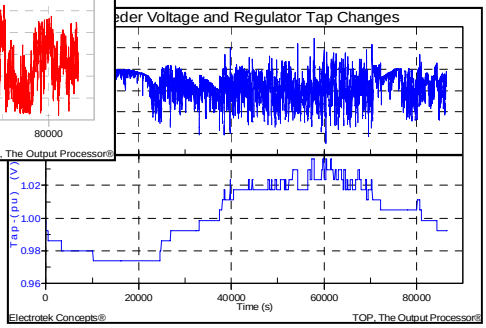
Light Load Week

Peak Load Week



Wind Plant 1-s Simulation





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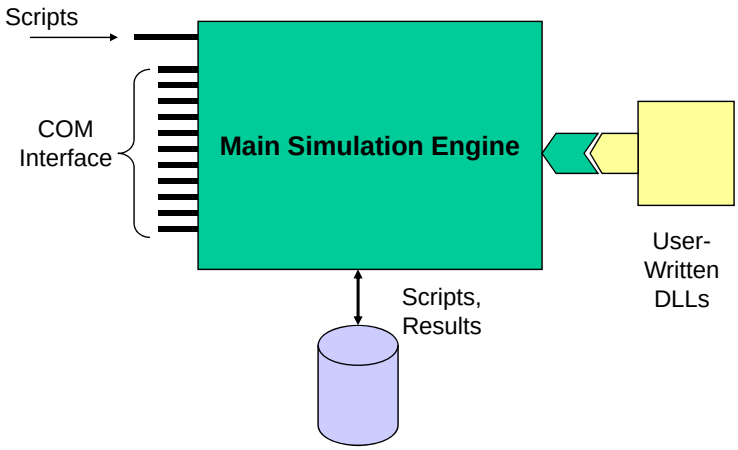
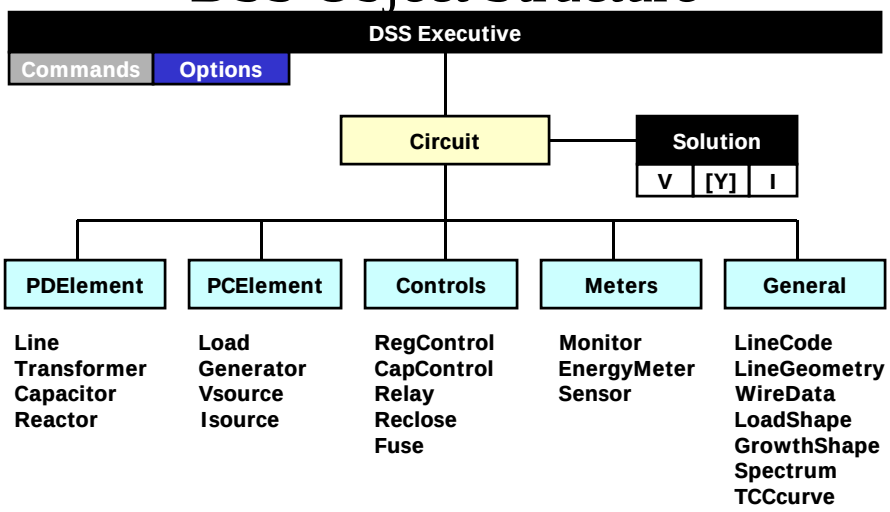
Architecture

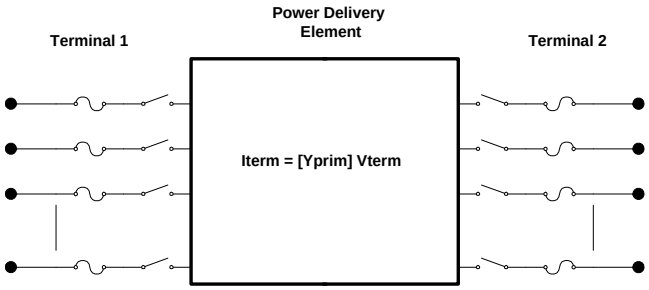
DSS Structure



DSS Object Structure

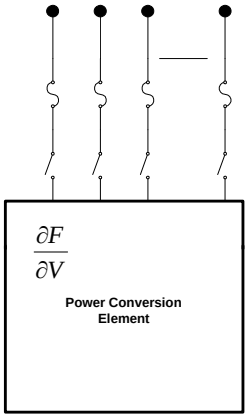


Power Delivery Elements

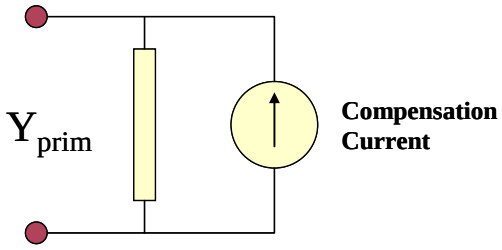


Power Conversion Elements

$I_{Term}(t) = F(V_{Term}, [State], t)$

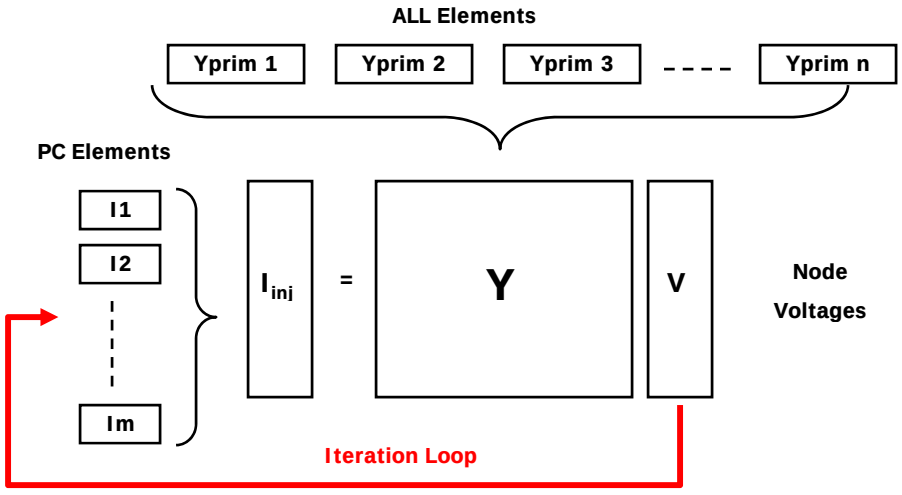


Load (a PC Element)



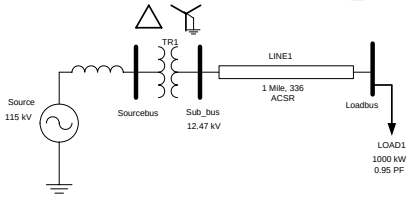
(One-Line Diagram)

Putting it All Together



Scripting Basics

A Basic Script




```
New Circuit.Simple     ! Creates voltage source  (Vsource.Source)
Edit Vsource.Source BasekV=115 pu=1.05  ISC3=3000  ISC1=2500  !Define source V and Z
New Transformer.TR1 Buses=[SourceBus, Sub_Bus] Conns=[Delta Wye] kVs= [115 12.47]
~ kVAs=[20000 20000] XHL=10
New Linecode.336ACSR R1=0.058 X1=.1206 R0=.1784 X0=.4047 C1=3.4 C0=1.6 Units=kft
New Line.LINE1 Bus1=Sub_Bus Bus2=LoadBus Linecode=336ACSR Length=1 Units=Mi
New Load.LOAD1 Bus1=LoadBus kV=12.47 kW=1000 PF=.95
Solve
Show Voltages
Show Currents
Show Powers kVA elements
```

Solution Modes

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Distribution System Analysis Tools

- DSS has the basic tools for Planning built in:
  - Power Flow
  - Short Circuit Calculations
- In Addition, it has Several Advanced Capabilities
  - “Dynamic” Power Flow
  - Other power flow modes
  - Dynamics
  - Harmonics
- If it is not built in, you can drive it from another program such as Matlab
  - For example: Reliability Analysis

Classes of Solution Modes

- Power Flow
  - Snapshot
  - Direct
- Dynamic Power Flow
  - Daily
  - Yearly
  - DutyCycle
  - Peakday
- Dynamics
- Harmonics
- Other Power Flow
  - LD1
  - LD2
  - Monte Carlo
    - M1
    - M2
    - M3
- Short Circuit
  - Faultstudy
  - MF - Monte Carlo Fault

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Introduction to Driving the COM Server from another Application

Active objects concept

- There is one registered In-Process COM interface:
  - *OpenDSSEngine.DSS*
    - That is, the DSS interface is the one you instantiate
    - The DSS interface creates all the others.
- The interfaces generally employ the idea of an **ACTIVE object**
  - Active circuit,
  - Active circuit element,
  - Active bus, etc.
  - The interfaces generally point to the active object
    - To work with another object, change the active object.

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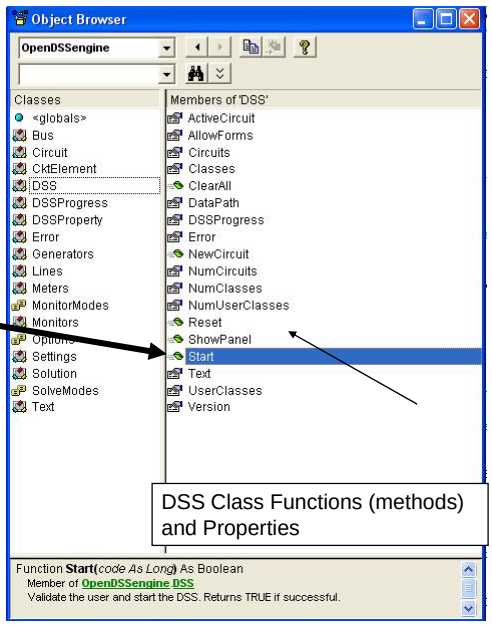
DSS Interface

This interface is instantiated upon loading OpenDSSEngine.DSS and then instantiates all other interfaces

Call the Start(0) method to initialize the DSS



Instantiate the DSS Interface and Attempt Start

```
Public Sub StartDSS()

' Create a new instance of the DSS
    Set DSSobj = New OpenDSSengine.DSS
' Start the DSS
    If Not DSSobj.Start(0) Then
        MsgBox "DSS Failed to Start"
    Else
        MsgBox "DSS Started successfully“
      ' Assign a variable to the Text interface for easier access
        Set DSSText = DSSobj.Text
    End If


End Sub
```

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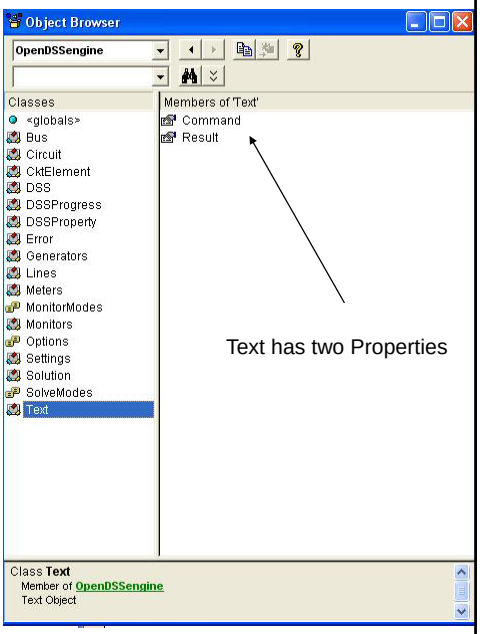
Accessing the COM Server

- In MATLAB:
  - `DSSobj = actxserver('OpenDSSEngine.DSS');`
- In VBA:
  - `Public DSSobj As OpenDSSEngine.DSS`
    `Set DSSobj = New OpenDSSEngine.DSS`
- In PYTHON:
  - `self.engine = win32com.client.Dispatch("OpenDSSEngine.DSS")`

TEXT Interface

Interfaces as Exposed by VBA Object Browser in MS Excel

Text interface is simplest



Text has two Properties

Assign a Variable to the Text Interface

```
Public Sub StartDSS()

' Create a new instance of the DSS
    Set DSSobj = New OpenDSSengine.DSS
' Start the DSS
    If Not DSSobj.Start(0) Then
        MsgBox "DSS Failed to Start"
    Else
        MsgBox "DSS Started successfully"
        ' Assign a variable to the Text interface for easier access
        Set DSSText = DSSobj.Text
    End If


End Sub
```

Now Use the Text Interface …

- You can issue any of the DSS script commands from the Text interface

```
‘ Always a good idea to clear the DSS when loading a new circuit
    DSSText.Command = "clear"
' Compile the script in the file listed under "fname" cell on the main form
    DSSText.Command = "compile " + fname
‘ Set regulator tap change limits for IEEE 123 bus test case
With DSSText
    .Command = "RegControl.creg1a.maxtapchange=1  Delay=15  !Allow only one tap change per solution.
   This one moves first"
    .Command = "RegControl.creg2a.maxtapchange=1  Delay=30  !Allow only one tap change per solution"
    .Command = "RegControl.creg3a.maxtapchange=1  Delay=30  !Allow only one tap change per solution"
    .Command = "RegControl.creg4a.maxtapchange=1  Delay=30  !Allow only one tap change per solution"
    .Command = "RegControl.creg3c.maxtapchange=1  Delay=30  !Allow only one tap change per solution"
    .Command = "RegControl.creg4b.maxtapchange=1  Delay=30  !Allow only one tap change per solution"
    .Command = "RegControl.creg4c.maxtapchange=1  Delay=30  !Allow only one tap change per solution"
    .Command = "Set MaxControlIter=30"
  End With
```

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Result Property

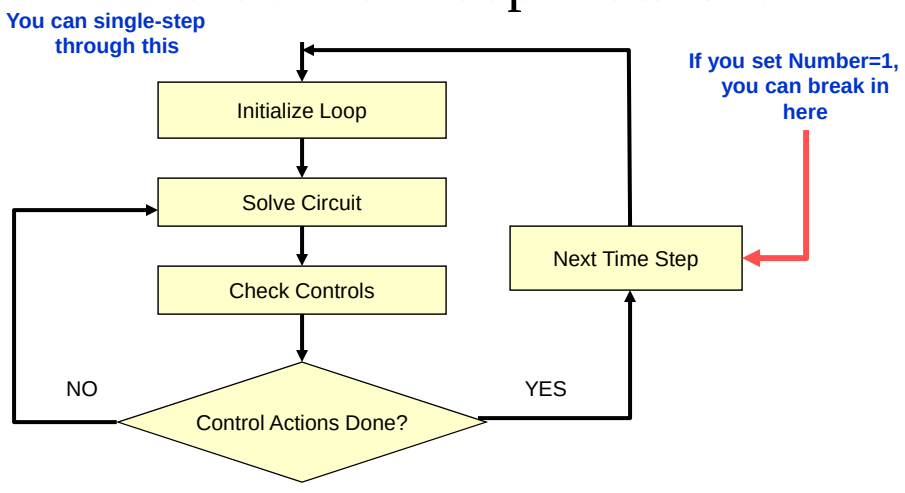
- The Result property is a Read Only property that contains any result messages the most recent command may have issued.
  - Error messages
  - Requested values

```
‘ Example: Query line length
DSSText.Command = “? Line.L1.Length”
S = DSSText.Result      ‘ Get the answer
MsgBox S          ‘ Display the answer
```

User-Written Controls

From the COM Interface

Basic Control Loop Flow Chart



Control Loop (Actual Pascal Code)

```
FUNCTION TSolutionObj.SolveSnap:Integer;  // solve for now once
VAR
   TotalIterations  :Integer;
Begin
   SnapShotInit;
   TotalIterations    := 0;
   REPEAT
       Inc(ControlIteration);
       Result := SolveCircuit;  // Do circuit solution w/o checking controls
       {Now Check controls}
       CheckControls;
       {For reporting max iterations per control iteration}
       If Iteration > MostIterationsDone  THEN MostIterationsDone := Iteration;
       TotalIterations := TotalIterations + Iteration;
   UNTIL ControlActionsDone or (ControlIteration >= MaxControlIterations);
   If Not ControlActionsDone and (ControlIteration >= MaxControlIterations) then  Begin
       DoSimpleMsg('Warning Max Control Iterations Exceeded. ' + CRLF + 'Tip: Show
  Eventlog to debug control settings.', 485);
       SolutionAbort := TRUE;   // this will stop this message in dynamic power flow modes
   End;
   If ActiveCircuit.LogEvents Then LogThisEvent('Solution Done');
   Iteration := TotalIterations;  { so that it reports a more interesting number }
End;
```

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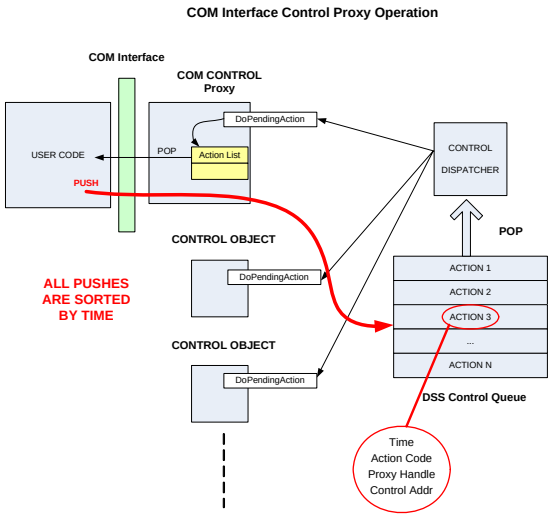
External Script and COM Interface Options

- Take Immediate action or keep track of time yourself
  - Set Number=1
  - Sample after solution step
  - Execute command to change element state
- Use the DSS Control Queue through COM Proxy
  - Set Number=1
  - Step through solution
  - Push control commands onto DSS control queue
    - (Allows DSS to keep track of when control actions happen)
  - Write routines to handle pending actions

Control Proxy in COM Interface



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For More Information