IED Object Models

Dr. Alexander Apostolov
Objects

• An object is ".. a thing that can be seen and touched; material thing that occupies space .. ".

  Webster New World Dictionary of the American Language

• In object-oriented design (OOD) an object is an abstraction of real world entities and functions in a problem domain.
Objects

• Problem Domain is the application or process that is being modeled by Object Oriented representation (Classes and Objects) – power system protection and control.

• Objects are encapsulated — that is, they contain both their code and their data, making them more easier to maintain
Classes and Objects

• A class is a template for the creation of objects, the description of one or more objects with the same definitions for information and behavior.
• An object is defined as an instance of a class
• Objects represent information and behavior:
  – properties (or components, attributes)
    • Data that describe an object
  – services (or methods, and events)
    • Methods are things you can tell the object to do
    • Events are things the object does
Class Example
Class Example

Click to add title

- Click to add text
Class Instance Example

Classes and Objects

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  - properties (or components, attributes)
    - Data that describe an object
  - services (or methods, and events)
    - Methods are things you can tell the object to do
    - Events are things the object does
Classes and Objects

Properties - cmdCalc

- (Name) cmdCalc
- Appearance 1 - 3D
- BackColor #80000000
- Cancel False
- Caption &Calculate
- Default False
- DisabledPicture (None)
- DownPicture (None)
- DragIcon (None)
- DragMode 0 - Manual
- Enabled False
- Font MS Sans Serif
- Height 400
- HelpContextID 0
- Index
- Left 240
- MaskColor #000000
- MouseIcon (None)
- MousePointer 0 - Default
- OLEDropMode 0 - None
- Picture (None)
- RightToLeft False
- Style 0 - Standard
- TabIndex 15
- TabStop True
- Tag
- ToolTipText
- Top 195
- UseMaskColor False
- Visible True
- WhatThisHelpID 0

Caption

Returns/sets the text displayed in an object’s title bar or below an object’s icon.
Substation Communications Architecture

Substation HMI  Substation Computer  SCADA Master

Switch  Router  Switch

IED  IED  IED  IED  IED  IED  IED  IED
System Communications Architecture

- **EMS**
  - Substation Gateway
    - Switch
      - IED
      - IED
      - IED
    - SCADA Server
      - ISD
  - WAN
    - Substation 1
    - Traders
    - Analysts
    - Substation j
    - Substation i
    - Substation 2
Function Definitions

• Functions in the substation are performed by the protection, control, monitoring and recording system.

• A function can be divided into sub-functions and functional elements.

• The functional elements are the smallest parts of a function that can exchange data.

• These functional elements in IEC 61850 are called Logical Nodes.
Logical Node Groups

• System Logical Nodes LN Group: L
• Logical Nodes for protection functions LN Group: P
• Logical Nodes for protection related functions LN Group: R
• Logical Nodes for control LN Group: C
• Logical Nodes for interfacing and archiving LN Group: I
• Logical Nodes for automatic control LN Group: A
Logical Node Groups

- Logical Nodes for metering and measurement LN Group: M
- Logical Nodes for sensors and monitoring LN Group: S
- Logical Nodes for switchgear LN Group: X
- Logical Nodes for instrument transformers LN Group: T
- Logical Nodes for power transformers LN Group: Y
Object Models
Device Functional Hierarchy

- Protection IED
  - Device Identity
    - Over-current
      - Function
      - Function Control
        - Ground
          - Phase
          - Negat. Seq.
      - Definite time #1
        - Inverse time
        - Instant.
    - Pickup
      - Time delay
      - Directionality
  - Sub-Function Control
    - Value
      - Minimum
      - Maximum
      - Step
# IEC 61850 Server Class

<table>
<thead>
<tr>
<th>Attribute name</th>
<th>Attribute type</th>
<th>Value/value range/explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ServiceAccessPoint [1..n]</td>
<td>(*)</td>
<td>(*) Type is SCSM specific</td>
</tr>
<tr>
<td>LogicalDevice [1..n]</td>
<td>LOGICAL-DEVICE</td>
<td></td>
</tr>
<tr>
<td>File [0..n]</td>
<td>FILE</td>
<td></td>
</tr>
<tr>
<td>TPAppAssociation [0..n]</td>
<td>TWO-PARTY-APPLICATION-ASSOCIATION</td>
<td></td>
</tr>
<tr>
<td>MCAppAssociation [0..n]</td>
<td>MULTICAST-APPLICATION-ASSOCIATION</td>
<td></td>
</tr>
<tr>
<td>Services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GetServerDirectory</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IEC 61850 Server Class

- GetServerDirectory (LD or File) → Server
  - response (LDNames or FileNames) ←

- GetLDDirectory (LDName) → LD
  - response (LNNames) ←

- GetLNDirectory (LNNName) → LN
  - response (DataNames) ←

- GetDataDirectory (DataName) → Data
  - resp. (DAAttrNames) ←

- GetDataDefinition (DataName) → Data
  - or (DName_attr)

- response (all DAAttr Definitions)
  - or (one DAAttr Definition)
### IEC 61850

#### Logical Device Class

<table>
<thead>
<tr>
<th>Attribute name</th>
<th>Attribute type</th>
<th>Value/value range/explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDName</td>
<td>ObjectName</td>
<td>Instance name of an instance of LOGICAL-DEVICE</td>
</tr>
<tr>
<td>LDRef</td>
<td>ObjectReference</td>
<td>Path-name of an instance of LOGICAL-DEVICE</td>
</tr>
<tr>
<td>LogicalNode [3..n]</td>
<td>LOGICAL-NODE</td>
<td>IEC 61850-7-4 specifies specialized classes of LOGICAL-NODE</td>
</tr>
<tr>
<td>Services</td>
<td></td>
<td>GetLogicalDeviceDirectory</td>
</tr>
</tbody>
</table>

---
# IEC 61850 Logical Node Class

<table>
<thead>
<tr>
<th>Attribute name</th>
<th>Attribute type</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNName</td>
<td>ObjectName</td>
<td>Instance name of an instance of LOGICAL-NODE</td>
</tr>
<tr>
<td>LNRef</td>
<td>ObjectReference</td>
<td>Path-name of an instance of LOGICAL-NODE</td>
</tr>
<tr>
<td>Data [1..n]</td>
<td>DATA</td>
<td></td>
</tr>
<tr>
<td>DataSet [0..n]</td>
<td>DATA-SET</td>
<td></td>
</tr>
<tr>
<td>BufferedReportControlBlock [0..n]</td>
<td>BRCB</td>
<td></td>
</tr>
<tr>
<td>UnbufferedReportControlBlock [0..n]</td>
<td>URCB</td>
<td></td>
</tr>
<tr>
<td>LogControlBlock [0..n]</td>
<td>LCB</td>
<td></td>
</tr>
</tbody>
</table>

IF compatible LN class defined in IEC 61850-7-4 equals LLN0

<table>
<thead>
<tr>
<th>Attribute name</th>
<th>Attribute type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SettingGroupControlBlock [0..1]</td>
<td>SGCB</td>
</tr>
<tr>
<td>Log [0..1]</td>
<td>LOG</td>
</tr>
<tr>
<td>GOOSEControlBlock [0..n]</td>
<td>GoCB</td>
</tr>
<tr>
<td>GSSEControlBlock [0..n]</td>
<td>GsCB</td>
</tr>
<tr>
<td>MulticastSampledValueControlBlock [0..n]</td>
<td>MSVCB</td>
</tr>
<tr>
<td>UnicastSampledValueControlBlock [0..n]</td>
<td>USVCB</td>
</tr>
</tbody>
</table>

**Services**

GetLogicalNodeDirectory
GetAllDataValues

**NOTE 1**  
IEC 61850-7-4 defines specialized logical node classes – the compatible logical node classes, for example, XCBR representing circuit-breakers.
IED 61850 Logical Nodes
IED 61850 Logical Nodes

Physical Device

Logical Device

- LLN0
- LPHD
- PIOC1
- PTOC1
- PTOC2
- RDIR1
- PIOC1
- PTOC1
- PTOC2
- RDIR1
- RREC1

- Ocp
- Gnd
- Phs

**External Functional Group Name (Overcurrent Protection function)**

**Internal Functional Group Name (Phase Overcurrent Protection sub-function)**
Logical Nodes Information

Categories

Logical node

Logical node information

Common logical node information
Information independent from the dedicated function represented by the LN, e.g., mode, health, name plate, ...

Status information
Information representing either the status of the process or of the function allocated to the LN, e.g., switch type, switch operating capability, ...

Settings
Information needed for the function of a logical node, e.g., first, second, and third reclose time, close pulse time, and reclaim time of an autoreclosing function.

Measured values
Are analogue data measured from the process or calculated in the functions like currents, voltages, power, etc., e.g., total active power, total reactive power, frequency, net real energy since last reset, ...

Controls
Are data, which are changed by commands like switchgear state (ON/OFF), tap changer position or resetable counters, e.g., position, block opening, ...
Functional Constraints

• The property of DataAttribute that shows its use is a Functional Constraint (FC).

• Some more commonly used are:
  • CO – control
  • SP – set point
  • CF – configuration
  • DC – description
  • SG – setting group
  • MX – measurements
Object Hierarchy

- Server
  - Logical Device
    - Logical Node
      - Data
        - Data Attribute
      - Logical Node
      - Data
        - Data Attribute
    - Logical Node
      - Data
        - Data Attribute
  - Logical Device
  - Logical Device
Nested DataAttributes

DATA
Instance

DataAttr

DAComp

DataAttr

DAComp

DAComp
Data path example

MMXU1.A.phsB.cVal.mag.f

– MMXU1: instance of LN class MMXU defined in Part 7-4
– A: instantiation of the Composite DATA class WYE (defined in 7-3)
– phsB: value of the current in phase B as a Simple Common DATA class of type CMV (defined in 7-3)
Data path example

MMXU1.A.phsB.cVal.mag.f

–cVal: is the complex value of the current in phase B (of the Common DataAttribute type Vector)

–mag: this object represents the magnitude of the complex value (type AnalogValue - defined in 7-3)

–f is a DataAttributeComponent which is of the basic type FLOATING POINT (defined in 7-2)
Common data classes for measurand information

- Measured value (MV)
- Complex measured value (CMV)
- Sampled value (SAV)
- WYE
- Delta (DEL)
- Sequence (SEQ)
- Harmonic value (HMV)
- Harmonic value for WYE (HWYE)
Metering and Measurement Logical Nodes

• Differential measurements Name: MDIF
• Harmonics or interharmonics Name: MHAI
• Metering Name: MMTR
• Non phase related Measurement Name: MMXN
• Measurement Name: MMXU
• Sequence & imbalance Name: MSQI
• Metering Statistics Name: MSTA
<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPV</td>
<td>DEL</td>
<td>Phase to phase voltages</td>
</tr>
<tr>
<td>PhV</td>
<td>WYE</td>
<td>Phase to ground voltages</td>
</tr>
<tr>
<td>A</td>
<td>WYE</td>
<td>Phase currents</td>
</tr>
<tr>
<td>W</td>
<td>WYE</td>
<td>Phase active power (P)</td>
</tr>
<tr>
<td>VAr</td>
<td>WYE</td>
<td>Phase reactive power (Q)</td>
</tr>
<tr>
<td>VA</td>
<td>WYE</td>
<td>Phase apparent power (S)</td>
</tr>
<tr>
<td>TotW</td>
<td>MV</td>
<td>Total Active Power (Total P)</td>
</tr>
<tr>
<td>TotVAr</td>
<td>MV</td>
<td>Total Reactive Power (Total Q)</td>
</tr>
<tr>
<td>TotVA</td>
<td>MV</td>
<td>Total Apparent Power (Total S)</td>
</tr>
<tr>
<td>TotPF</td>
<td>MV</td>
<td>Average Power factor (Total PF)</td>
</tr>
<tr>
<td>Hz</td>
<td>MV</td>
<td>Frequency</td>
</tr>
<tr>
<td>PF</td>
<td>WYE</td>
<td>Phase power factor</td>
</tr>
<tr>
<td>Z</td>
<td>WYE</td>
<td>Phase Impedance</td>
</tr>
</tbody>
</table>
## Protection Logical Nodes

<table>
<thead>
<tr>
<th>Functionality</th>
<th>IEEE C37.2 reference</th>
<th>Defined in IEC 61850-5</th>
<th>Modelled in IEC 61850-7-4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transient earthfault</td>
<td></td>
<td>PTEF</td>
<td>PTEF</td>
<td>Use shown in Annex B.1</td>
</tr>
<tr>
<td>Zero speed and underspeed</td>
<td>14</td>
<td>PZSU</td>
<td>PZSU</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>21</td>
<td>PDIS</td>
<td>PDIS PDCH</td>
<td>Use one instance per zone. To build line protection schemes</td>
</tr>
<tr>
<td>Volt per Hz</td>
<td>24</td>
<td>PVPH</td>
<td>PVPH</td>
<td></td>
</tr>
<tr>
<td>(Time) Undervoltage</td>
<td>27</td>
<td>PTUV</td>
<td>PTUV</td>
<td></td>
</tr>
<tr>
<td>Directional power/reverse power</td>
<td>32</td>
<td>PDPR</td>
<td>PDOP PDUP</td>
<td>Directional over power. Directional under power. Reverse power modelled by PDOP plus directional mode “reverse”</td>
</tr>
<tr>
<td>Undercurrent/underpower</td>
<td>37</td>
<td>PUCP</td>
<td>PTUC PDUP</td>
<td>Undercurrent. Underpower</td>
</tr>
<tr>
<td>Loss of field/Underexcitation</td>
<td>40</td>
<td>PUEX</td>
<td>PDUP</td>
<td>Directional under power</td>
</tr>
<tr>
<td>Reverse phase or phase balance current</td>
<td>46</td>
<td>PPBR</td>
<td>PTOC</td>
<td>Time overcurrent (PTOC) with three-phase information with sequence current as an input or even ratio of negative and positive sequence currents</td>
</tr>
<tr>
<td>Phase sequence voltage</td>
<td>47</td>
<td>PPBV</td>
<td>PTOV</td>
<td>Three-phase information and processing</td>
</tr>
<tr>
<td>Thermal overload</td>
<td>49</td>
<td>PTTQ</td>
<td>PTTQ</td>
<td></td>
</tr>
<tr>
<td>Rotor thermal overload</td>
<td>49R</td>
<td>PROL</td>
<td>PTTQ</td>
<td>Thermal overload</td>
</tr>
<tr>
<td>Stator thermal overload</td>
<td>49S</td>
<td>PSOL</td>
<td>PTTQ</td>
<td>Thermal overload</td>
</tr>
<tr>
<td>Instantaneous overcurrent or rate of rise</td>
<td>50</td>
<td>PIQC</td>
<td>PIQC</td>
<td></td>
</tr>
<tr>
<td>AC time overcurrent</td>
<td>51</td>
<td>PTOC</td>
<td>PTOC</td>
<td></td>
</tr>
<tr>
<td>Voltage controlled/dependent time overcurrent</td>
<td>51V</td>
<td>PVOC</td>
<td>PVOC</td>
<td></td>
</tr>
<tr>
<td>Power factor</td>
<td>55</td>
<td>PPFF</td>
<td>POPF PUFFF</td>
<td>Over power factor. Under power factor</td>
</tr>
<tr>
<td>(Time) Overvoltage</td>
<td>59</td>
<td>PTOV</td>
<td>PTOV</td>
<td></td>
</tr>
<tr>
<td>DC-overvoltage</td>
<td>59DC</td>
<td>PDOV</td>
<td>PTOV</td>
<td>Both for DC and AC</td>
</tr>
<tr>
<td>Voltage or current balance</td>
<td>60</td>
<td>PVOC</td>
<td>PTOV PTUV</td>
<td>Over voltage or Under voltage</td>
</tr>
<tr>
<td>Earth fault / Ground detection</td>
<td>64</td>
<td>PHIZ</td>
<td>PHIZ</td>
<td></td>
</tr>
</tbody>
</table>
# Protection Logical Nodes

<table>
<thead>
<tr>
<th>Functionality</th>
<th>IEEE C37.2 reference</th>
<th>Defined in IEC 61850-5</th>
<th>Modelled in IEC 61850-7-4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor earth fault</td>
<td>64R</td>
<td>PREF</td>
<td>PTOC</td>
<td>Time overcurrent</td>
</tr>
<tr>
<td>Stator earth fault</td>
<td>64S</td>
<td>PSDE</td>
<td>PTOC</td>
<td>Time overcurrent</td>
</tr>
<tr>
<td>Interturn fault</td>
<td>64W</td>
<td>PITF</td>
<td>PTOC</td>
<td>Time overcurrent</td>
</tr>
<tr>
<td>AC directional overcurrent</td>
<td>67</td>
<td>PDOC</td>
<td>PTOC</td>
<td>Time overcurrent</td>
</tr>
<tr>
<td>Directional earth fault</td>
<td>67N</td>
<td>PDEF</td>
<td>PTOC</td>
<td>Time overcurrent</td>
</tr>
<tr>
<td>DC time overcurrent</td>
<td>76</td>
<td>PDGO</td>
<td>PTOC</td>
<td>Time overcurrent; for AC and DC</td>
</tr>
<tr>
<td>Phase angle or out-of-step</td>
<td>78</td>
<td>PPAM</td>
<td>PPAM</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>81</td>
<td>PFRQ</td>
<td>PTOF; PTUF; PFRC</td>
<td>Over frequency; Under frequency; Rate of change of frequency</td>
</tr>
<tr>
<td>Differential</td>
<td>87</td>
<td>PDIF</td>
<td>PDIF</td>
<td></td>
</tr>
<tr>
<td>Phase comparison</td>
<td>87P</td>
<td>PPDF</td>
<td>PDIF</td>
<td></td>
</tr>
<tr>
<td>Differential line</td>
<td>87L</td>
<td>PLDF</td>
<td>PDIF</td>
<td></td>
</tr>
<tr>
<td>Restricted earth fault</td>
<td>87N</td>
<td>PNDF</td>
<td>PDIF</td>
<td></td>
</tr>
<tr>
<td>Differential transformer</td>
<td>87T</td>
<td>PTDF</td>
<td>PDIF; PHAR</td>
<td>Differential transformer; Harmonic restraint</td>
</tr>
<tr>
<td>Busbar</td>
<td>87B</td>
<td>PBDF</td>
<td>PDIF or PDIR</td>
<td>Busbar differential or Fault direction comparison</td>
</tr>
<tr>
<td>Motor differential</td>
<td>87M</td>
<td>PMDF</td>
<td>PDIF</td>
<td></td>
</tr>
<tr>
<td>Generator differential</td>
<td>87G</td>
<td>PGDF</td>
<td>PDIF</td>
<td></td>
</tr>
<tr>
<td>Motor Startup</td>
<td>49R, 48, 51LR</td>
<td>PMSU</td>
<td>PMRI; PMSS</td>
<td>Motor Restart Inhibition; Motor Starting Time Supervision</td>
</tr>
</tbody>
</table>
Logical Nodes Data

- **Logical node**: XCBR
- **Data**:
  - Control value “ctlVal”
  - Operate time
  - Originator
  - Control number
  - Status value “stVal”
  - Quality
  - Time stamp
  - Substit. enable
  - Substit. value
  - Pulse configuration
  - Control model
  - SBO timeout
  - SBO class
  - B1kOpn
- **Data-Attributes**: controllable, control, status value, status, substitution, configuration, description, and extension
- **Controls**: controllable
Setting Data

Logical node

Active buffer (active setting group)

Each setting group contains a consistent set of values

Each DATA, e.g., "RsDITmms" is more complex than the depicted value (43). The CDC of this data is "ING" = Integer status setting:
- setVal
- minVal
- maxVal
- stepSize
- d

LN PVOC

Status information...

Settings
- Operating Curve Type (volt.)
- Operating Curve Type (amp)
- Time Multiplier
- Minimum Operate Time
- Max Operate Time
- Operate Delay Time
- Type of Reset Curve
- Reset Delay Time

Settings data

LN PDIF

Settings
- Restraint Mode

Setting groups
Overcurrent Protection LN PTOC
## Setting Attributes

### Analogue Setting (ASG)

<table>
<thead>
<tr>
<th>Attr. Name</th>
<th>Attr. Type</th>
<th>FC</th>
<th>TrgOp</th>
<th>Value Range</th>
<th>M/O/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>setMag</td>
<td>AnalogueValue</td>
<td>SP</td>
<td></td>
<td></td>
<td>AC NSG M</td>
</tr>
<tr>
<td>setMag</td>
<td>AnalogueValue</td>
<td>SG, SE</td>
<td></td>
<td></td>
<td>AC SG M</td>
</tr>
<tr>
<td>units</td>
<td>Unit</td>
<td>CF</td>
<td></td>
<td>see Annex A</td>
<td>O</td>
</tr>
<tr>
<td>sVC</td>
<td>ScaledValueConf</td>
<td>CF</td>
<td></td>
<td></td>
<td>AC SCAV</td>
</tr>
<tr>
<td>minVal</td>
<td>AnalogueValue</td>
<td>CF</td>
<td></td>
<td></td>
<td>O</td>
</tr>
<tr>
<td>maxVal</td>
<td>AnalogueValue</td>
<td>CF</td>
<td></td>
<td></td>
<td>O</td>
</tr>
<tr>
<td>stepSize</td>
<td>AnalogueValue</td>
<td>CF</td>
<td></td>
<td>1 ... (maxVal - minVal)</td>
<td>O</td>
</tr>
<tr>
<td>d</td>
<td>VISIBLE STRING255</td>
<td>DC</td>
<td>Text</td>
<td></td>
<td>O</td>
</tr>
<tr>
<td>dU</td>
<td>UNICODE STRING255</td>
<td>DC</td>
<td></td>
<td></td>
<td>O</td>
</tr>
<tr>
<td>cdcNs</td>
<td>VISIBLE STRING255</td>
<td>EX</td>
<td></td>
<td>AC DLNDA M</td>
<td></td>
</tr>
<tr>
<td>cdcName</td>
<td>VISIBLE STRING255</td>
<td>EX</td>
<td></td>
<td>AC DLNDA M</td>
<td></td>
</tr>
<tr>
<td>dataNs</td>
<td>VISIBLE STRING255</td>
<td>EX</td>
<td></td>
<td>AC DLN M</td>
<td></td>
</tr>
</tbody>
</table>

### I>1 Current Set

- Current Value: 1.000
- Minimum: 80.00m
- Maximum: 4.000
- Step Size: 10.00m
- New Value: 1.000
Services

1. Operate <ON>
2. Trip <OFF>
3. Report <ON>
4. Log
5. Substitute
6. Configure...
7. Selfdescription

XCBR

Controls

- Control value
- Operate time
- Originator
- Control number
- Status value "stVal"
- Quality
- Time stamp...
- Substit. enable
- Substit. value...
- Pulse configuration
- Control model
- SBO timeout
- SBO class
-...

BlkOpn

configuration, description, and extension
Distributed Applications

Diagram showing distributed applications with nodes labeled PD1, LN1, LN2, LN3, LN4, LD1, LNn, F1, F2, and F3. The diagram illustrates the connections and relationships between these nodes in a distributed application context.
Measuring Functions Decomposition

Substation Level
- IARC
- IHMI

Bay Level
- MMTR
- MMXU

Process Level
- TVTR
- TCTR
Multifunctional IED Object Model
Multifunctional IED Object Model
Multifunctional IED Object Model

PQM IED

DG1

LN(i)

MMXU1

MMTR1

MMHI1

MSTA1

MMXU2

MMHI2

MSTA2
IED Object Model

BiTRONICS M871

HV

MV

LLNO

LPHD

DIAG1

RWRE1

RDRE1

RDRE2

dmd

prs

MMXU1

MMXU2

AMXU1

MMXU1

MMXU2

AMXU1

min

mmxu1

mmxu2

max

mmxu1

mmxu2

Recorder Controls