Entellisys™
Low Voltage Switchgear
Entellisys Presentation Topics

✓ Concept – *A different approach to the problems*

✓ Architecture – *Reliability, redundancy, robustness, simplified wiring, installation & maintenance*

✓ Advanced Protection – *Improvements not possible before*

✓ Minimizing Arc Flash Energy – *Clearing faults without compromising system performance*

✓ Keeping Away From Arc Flash Energy – *Making the obvious solution easier*

✓ Control and Digital I/O – *Flexibility & capability without wiring hassles*

✓ Metering, Diagnostics, Maintenance – *Measure what, how and where you need, report it usefully*
Each evolution & enhancement = More Complexity

More complexity may mean less reliability

Multiple trips with different information ... all independent

Let’s not add more of the same, Let’s change the way we do it completely
A different concept

Each trip is independent & ignorant of what other trips see

• All information is processed simultaneously in one place.
• All information is considered.
• All trip commands issued simultaneously

From this

To this
From intelligent CB to intelligent & educated equipment

Change from . . . 1 circuit . . . 1 breaker . . . 1 trip
To ➔ 1 system . . . Process all information simultaneously
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**Entellisys**: streamlined design for enhanced functionality
One standard set of hardware provides all functions
Simplified breakers…no trip units, no integral CTs
Simple switching devices
EntelliGuard Power Circuit Breakers

- Built from proven WavePro design, Real ANSI design
- Electrical, manual and fusible available
- Less components = simplified maintenance, increased reliability
Current sensors... in equipment cubicle
When circuit breakers swapped for maintenance the settings stay with the circuit
Potential Transformers
System keeps track of which source is connected, which voltage signal is needed . . . Less PTs needed
Messengers
Provide communications, A/D, D/A and self powered back-up protection
EntelliGuard Messenger

- Located above CB
- Digitizes sensor signals & sends data to CPUs
- Receives CB commands from CPU
- Powered by 120v ac control power
- Self powered from CTs for back-up protection
EntelliGuard Messenger

- Com 1 & 2 OK
- LT Setting
- CB Open/Closed
- Locator LED controlled from HMI
- AC Power
- Test Kit connection
- Ampere Rating

Front panel settings and indication
Messengers
Provide communications, A/D, D/A and self powered back-up protection
Central Processing Unit (CPU)
Redundant CPUs, self monitoring
Central Processing Units

Redundant industrial computers
• Rack mounted
• Real time operating system
• Run simultaneously
Human Machine Interface
Easy access to system and information
Human Machine Interface (HMI)

• Intuitive system interface via Touch Screen
• Individual password protection
• Independent of system operation
• Located in lineup or “near gear”
Control Power

Redundant Control Power

• 2 CPT or separate AC control power sources
  - 5KVA switchgear CPT’s
• 2 control power throwover relays
  - Throwover relay on each source
• 2 UPS
  - GE Digital Energy GT Series
  - 3000VA
• ALL control power is 120VAC
Ethernet Hub ... interface to external communication
Fewer Spare Breakers Needed

Circuit specific information remains in equipment

Messenger – Single catalog number

Current sensors moved from the breaker to the cubicle

Universal Spares

✓ Every 800A CB = any other 800A CB . . .
✓ 2000A can replace 800, 1600 and 2000A
✓ 4000A can replace 3200A or 4000A

Simpler, Increased Flexibility
REMEMBER THIS??????
Simplicity

Simplified components and subsystems

- Less wiring, less peripheral devices, simpler CB

Before Entellisys

After

Reduced

- Installation time
- Start up time
- Maintenance time
Reliable Components

Hardened components

- Less size restrictions on components
  Not stuck inside the CB
- Broad/tough qualifying test criteria
  Toughest global standards we could find
- Tougher packaging and enclosures (case, size)
  Optimized for performance not small size

Moving key components from the CB allows making components larger, stronger, simpler, more accessible & . . . More reliable

- Tested for EMI, surges & fault withstand.
- Associated with the circuit, not the CB, for faster maintenance
Redundancy
All system wide components, wiring & power sources are redundant

Redundancy
- Dual CPU
- Dual UPS - With dual control power input sources
- Dual communication networks

Where \( R_x \) = reliability of component \( x \) & \( P_Y \) = probability of failure for system \( Y \)

\[
P_S = R_{1S} \times R_{2S}
\]

For a series system with 90% reliability for each component. Two components in series yields 81% reliability, three yields 72.9%, etc.

\[
P_P = 1-[(1-R_{1P}) \times (1-R_{2P})]
\]

The same components in parallel at 90% reliability yield 99% system reliability.
Entellisys – Designed for State of the Art Performance
Reliability through **redundancy** and **continuous self monitoring**

Functionality for all 30 circuit breakers
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From intelligent CB to intelligent & educated equipment

Change from . . . 1 circuit . . . 1 breaker . . . 1 trip
To ➔ 1 system . . . Process all information simultaneously

Enables more accurate and faster protection
All the information in one place. Process system wide algorithms that identify fault magnitude & location
Switchgear Yesterday (Traditional Switchgear)

• Selectivity depends on time delays and lowered sensitivity

• Back up and primary protection is the same for mains and ties

• Clearing speed depends on fault magnitude and fault location . . .

Therefore -- arc flash risk, equipment damage varies
Switchgear Yesterday

The right way to protect?

Back up and primary protection is the same for the buses protected by the main with traditional trips!

• Traditional Breaker Trip Units have 1 setting. Back up and primary protection are the same.
Zone based protection
The right way to protect

Entellisys today

- Selective protection depends on fault location, not fault magnitude
- Nested delays are unnecessary
- Primary protection is always fast
- Back up protection minimally slowed
- Arc flash risk & equipment damage minimized regardless fault magnitude or location
- Improved Energy reduction for branch circuits
System sets “above zone” CB as back up if needed

“In zone” CB trips as fast as you set it to protect

- “Through fault” on feeder CB cleared in fastest possible time
- ZSI forces main and tie to act as back up if set up as separate tiers . . . or both would act together if defined as the same tier
- ZSI forces system to act as coordinated CB regardless of protective settings
Automatically adjust curve to match situation

As set

Feeder fault

Tie fault

Main fault
Add bus differential to cover High Z faults that main breaker ST P/U may miss

System coordinates all protection modes and back up modes simultaneously

- Bus differential adds protection for bus faults down to 20% of largest CT on bus. . .
  - Arcing faults 60-43% bolted and normal main device only responds to main’s contribution

Bus differential . . Down to 20% of bus size & 10X largest CB contribution
Arcing currents can be small . . . Lower magnitude faults may be most dangerous

- Consider a 2500kVA, 5.75% Z transformer, 50% motor load, 480V
- Base $A_{AA} = 3,007$, extended $A_{FA} = 3,759 \rightarrow LTPU = 4,000A$
- $SCA = 56,218A$. Motor Contrib. = 6,015A. $\rightarrow$ Total $SCA = 62,233A$
- Total arcing current $\sim 28.9 – 24.6kA \ldots$ (100-85% calculated)
- Arcing current through main $26.1 – 22.2kA$ (no motor contribution)
- Nominal main picks up at 20-24kA (Short Time setting of 5-6X)

Bus differential eliminates risk -- sensitive to lower magnitude faults

Arcing current through main right on top of ST PU . . . Too much risk
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How is arc flash hazard determined

Perform a study and determine values

- Spreadsheet approach can be used for small systems
- Arc Flash calculation modules can be obtained with commercially available comprehensive power system modeling software.

1. Short-Circuit Study
2. Protective Device Coordination Analysis
3. Arc Flash analysis
## Arc Flash Categories & Protective Clothing

<table>
<thead>
<tr>
<th>ATPV cal/cm$^2$</th>
<th>Hazard Risk Category</th>
<th>Description of Clothing</th>
<th>Weight Oz/yd$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 2</td>
<td>Class 0</td>
<td>Untreated Cotton</td>
<td>4.5 - 7.0</td>
</tr>
<tr>
<td>&gt;2 – 5</td>
<td>Class 1</td>
<td>FR Shirt &amp; FR Pants or FR coverall</td>
<td>4.5 - 8.0</td>
</tr>
<tr>
<td>&gt;5 – 8</td>
<td>Class 2</td>
<td>FR Underwear + FR Shirt &amp; FR Pants</td>
<td>9 - 12</td>
</tr>
<tr>
<td>&gt;8 – 25</td>
<td>Class 3</td>
<td>Cotton Underwear + FR Shirt &amp; FR Pants + FR Coverall</td>
<td>16 - 20</td>
</tr>
<tr>
<td>&gt;25 – 40</td>
<td>Class 4</td>
<td>Cotton Underwear + FR Shirt &amp; FR Pants + Multi-layer Flash Suit</td>
<td>24 - 30</td>
</tr>
<tr>
<td>&gt; 40</td>
<td>Extreme Danger</td>
<td>No PPE class applies</td>
<td>-</td>
</tr>
</tbody>
</table>
So how is Entellisys different

Since

Arc Flash energy is a function of:

- Voltage – Fixed for the systems
- Available short circuit current – Fixed by system design and source
- Working distance – Arms are only so long
- Arc gap – determined by equipment type
- Arcing fault clearing time (not short circuit clearing time) A function of the protective device acting upon arcing current

Short Circuit current is fixed, can’t change voltage, arms or the hot stick are only so long . . . Clearing time is the only parameter than can be modified. So . . .

Arcing fault clearing time becomes the critical factor
Even for very simple system where the main is set selectively at a second time delay the bus is > level 4 and the feeder reaches level 4.
Main bus protection

- Incident Energy with Long Time protection
- Incident Energy with Short Time protection
- HRC Class 4 boundary

“Cascaded” time delays provide inferior bus and arc flash protection

Add ZSI and it gets faster . . .
But only above ST PU!

> HRC4

> HRC4 @ low fault A

HRC3 Max – high A
Main bus protection Improved

Complete range protection

Bus differential and ZSI offer fast protection across the complete potential fault range
Bus differential protection

- Optimal protection with no sacrifice in selectivity, no need for nested time delays
- CT saturation does not affect ability to provide zone protection, works with ZSI to provide fault zone identification across full fault range.
- Back-up tripping can be configured to provide redundant protection of zones
- Alarm notification (no trip) at user defined set points
Dynamic Zone Selective Interlocking

- Up to 4 zones and 4 tiers
- Short time and ground fault
- Control of tripping – time bands as fast as 1.5 cycles
- No extra wiring or devices
- Change ZSI circuit relationships depending on main and tie positions at any one moment
- Selectivity with time delays as fast as 25 milliseconds...

Works with 87B for complete zone based protection
Multiple Source Ground Fault and HRG

**MSGF**
- Up to 4 zones
- Identify fault within a zone, trips all source breakers
- No extra CTs, interlocking or wiring
- No extra wiring or devices

**HRG**
- Alarm only function
- Independently monitors multiple ground resistors
- Ground CT connected to messenger
- System identifies faulted phase
- Next generation will identify faulted feeder
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✓ Control and Digital I/O – Flexibility & capability without wiring hassles
✓ Metering, Diagnostics, Maintenance – Measure what, how and where you need, report it usefully
Comprehensive safety & complete system visibility. Keep staff away from live gear - complete remote monitoring and control capability
Personnel safety: Remote racking mechanism . . .
Combined with remote monitoring & control capability No excuse for “ever” getting near an energized circuit breaker
Entellisys Remote Racking

Motor-operated racking device for EntelliGuard breakers

- One motor unit & two attachment plates
  - Small frame (800-2000A)
  - Large frame (3200-5000A)
- Start / Stop PB on 30FT cord
- 120VAC Control Power
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Control schemes and remote operation

- Digital I/O – 128 configurable points
- Flex logic programming
- System conditions available as output
- Redundant I/O available
- Preprogrammed logic such as ATO- 3 CB M-T-M
Digital I/O

Interface blocks
• 64-pin connector to terminal block points

Cables to 64-point digital I/O cards in CPU’s
Digital I/O

- Relay Blocks
  - 16-point blocks for input and output points
Flex Logic™

Purpose

1. **Control** functions within Entellisys, such as Automatic Transfer

2. **Digital I/O interface** with Entellisys
Flex Logic™

Operands

Breaker status – open, closed, locked out, charged, drawout position

Overcurrent – LT, ST, INST, GF, High Current, HRG
  • Operated, in pick-up, dropped out

Single-point relays – over / under voltage, phase loss, over / under frequency, power reversal, sync check
  • Alarm or trip, operated, in pick-up, dropped out

Breaker Control
  • Open, close, trip, lockout

Digital Inputs and Outputs

Virtual Inputs and Outputs
Structured Auto Transfer Scheme for Main-Tie-Main

- Uses Entellisys internal protective relay functions and Flex Logic programming
- Under/overvoltage, under/overfrequency, phase loss, sync check on each main breaker
- Manual or Auto Return to Normal
- Open Transition (Break-before-Make) or Closed Transition (Make-before-Break) on Return to Normal
Automatic Transfer

HMI Screen for Auto Transfer (Control & Status)
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# Metering

**Standard – All breakers**

<table>
<thead>
<tr>
<th>Package</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expanded Meter Package</td>
<td>kW, kvar, KVA, Power Factor, kWh, varh, frequency</td>
</tr>
<tr>
<td>Demand Package</td>
<td>Block demand, Rolling Demand, Demand logging</td>
</tr>
<tr>
<td>Harmonics Package</td>
<td>K Factor, Harmonic Distortion</td>
</tr>
<tr>
<td>Standard for each meter package</td>
<td>Dynamic Locations, meters can be moved from circuit to circuit at any time</td>
</tr>
</tbody>
</table>

Amps and Volts
# Protective Relaying

<table>
<thead>
<tr>
<th>Voltage Package</th>
<th>Undervoltage, Overvoltage, Phase Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency and Power Package</strong></td>
<td>Over Frequency, Under Frequency, Reverse Power</td>
</tr>
<tr>
<td><strong>High current</strong></td>
<td>High Current Alarm</td>
</tr>
<tr>
<td><strong>Early notice of possible trip conditions</strong></td>
<td>Alarm and / or Trip Settings</td>
</tr>
</tbody>
</table>
Event Recording
~ 600 different kinds of events possible

<table>
<thead>
<tr>
<th>Date &amp; Time</th>
<th>True sequence due to synchronization across lineup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source of event, Cause and Description</td>
<td>Ease of analysis</td>
</tr>
<tr>
<td>Fault Data</td>
<td>Magnitude of current levels, Waveform capture</td>
</tr>
<tr>
<td>Notification</td>
<td>Email messages, Local screen, Remote, Email</td>
</tr>
</tbody>
</table>
Advanced diagnostics...system wide waveform capture & event recording – synchronized across system
CB MAINTENANCE – LOAD LIFE

\[ \% \text{of Load Life} = \sum \left( \frac{I_{rms}}{I_{frame}} \right)^2 / K_{frame} \]

\[ \% \text{of Mechanical Life} = \frac{\text{Operations}_{Total}}{\text{Operations}_{Rated}} \]

- \( I_{rms} \) calculated when open/trip command is sent.
- \( I_{frame} \) is the CB frame rating
- \( K \) value related to frame rating
- If current \( \neq \) saturation point of CT, 45% life used added to \% load life
- Algorithm conservatively tracks CB usage-no load, load & fault conditions
- CCPU activate alarm & logs event when CB reaches 12.5, 25, 37.5, 50, 62.5, 75, 87.5 & 100% mechanical life
- \# of operations varies with frame size

---

**Breaker:** Panel G & Shop

<table>
<thead>
<tr>
<th>MAINTENANCE DATA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Operations</td>
<td>8</td>
</tr>
<tr>
<td>Total No Load Operations</td>
<td>8</td>
</tr>
<tr>
<td>Total Load Operations</td>
<td>1</td>
</tr>
<tr>
<td>Total Fault Operations</td>
<td>0</td>
</tr>
<tr>
<td>Percent Load Life</td>
<td>5.00</td>
</tr>
<tr>
<td>Percent Mechanical Life</td>
<td>0.53</td>
</tr>
<tr>
<td>Last Breaker Operation</td>
<td>02/21/2005 10:37:44</td>
</tr>
<tr>
<td>Initial Energization</td>
<td>10/05/2004 00:00:00</td>
</tr>
</tbody>
</table>

Conservative estimation of real CB usage with alarm thresholds to advise when maintenance may be needed -- reduces maintenance hours and downtime.
SYSTEM TEST KIT

- Connected via Messenger
- Signal injected into A/D converters . . . tests entire system excluding instrument transformers
- Test overcurrent functions and voltage functions
- Checks trip circuits
- Injects single & 3 φ current signals
- Saves test results for record keeping
- Any one circuit may be tested while rest of system is operational

Reduce start up & maintenance time
Entellisys Version 4.0 features

**Reduced Energy Let-Thru** – Local or remote initiation, can reduce arc fault energy for maintenance operations.

**Control Stack** – Entellisys redundant components located in a section remote from the swgr.

**E-Stop** – Remote shunt trip capability without using FlexLogic.

**HRGF Location** – Faulted feeder identified by Entellisys via pulsing system, without 0-seq CT.

**GF Priority Tripping** – Trip feeder on occurrence of 2nd GF on HRG system. Every breaker has its own priority trip assignment.

**Frequency Meter (part of Expanded Metering)** – Frequency meter added.

**Color-coded Event Log** – Events can be color coded for quick identification of important events.

**Waveform Capture on High Current Trigger** – Capture waveforms of non-fault conditions such as during start-up, commissioning, or normal operation of equipment.

**Expanded Flex Logic Resources** – Additional resources permit larger control schemes (auto transfer with multiple main and tie breakers – greater than 4 breaker transfer).

**Multiple Line-up Access from Remote HMI (up to 25 line-ups)** – User Interactive HMI Software will allow access to multiple line-ups from one PC.

**CSA, IBC2003** – Canadian Standards approval, Seismic certification to IBC standards.
Entellisys Current Sensors & Potential Transformers
Provide Protection & Metering Data

**Current Transformers**
- 150A – 5000A

Freed from size restrictions imposed by CB
All CT’s have –
- Integral open circuit protection
- Plug connection to Messenger
  - Cannot be wired incorrectly
  - Cannot be faulted by open ckt

**Potential Transformers**
18V, system keeps track of what V signal represents voltage used
Differential protection

Kirchoff’s node law: All the currents into a node equal all the currents out of the node

\[ I_1 + I_2 + I_3 + I_4 = 0 \]

- Zone = node
- Differential protection is Kirchoff’s node law implemented
You set CB to protect circuit

Entellisys coordinates

- All CB set to provide optimized protection for their zone
  - sustain loads & detect overloads
- Overlapping devices selective → protection is location based.
- Cascaded time delays not required
- Each CB set for faults or overloads in its protection zone
Variables in the IEEE 1584 Calculations

Despite complexity, at a given location there are only three significant inputs:

• $I_{bf} =$ Three phase bolted RMS symmetrical fault (kA)
  (Function of system configuration, fault sources in service)

• $t =$ Arcing time, (seconds)
  (Function of the type and settings of protective devices, arcing fault current clearing time)

• $D =$ Working distance
  (Set based on energized equipment work practices and may vary with equipment type/voltage or activity) Typically 18 inches
Reduced incident energy
Still selective, feeder and main bus equally protected
Entellisys “Near Gear” HMI

• Stand-alone stack or Wall Mount
• Maximum 300 cable feet from CPUs
• Can be in addition to HMI in lineup
• Can replace HMI in lineup for the safety conscious
Entellisys Control Using Flex Logic

1. ISEC FLASHER ON (VO12)
2. TIMER 32
3. = FLASHER END (VO14)

4. AUTO ON (V11)
5. MANUAL ON (V12)
6. NOT
7. AND(2)
8. = AUTO ON (VO1)

9. MANUAL ON (V12)
10. AUTO ON (V11)
11. NOT
12. AND(2)
13. = MANUAL ON (VO2)
Flex Logic™

Operators
• Provides a defined function
• Logic gates – AND, OR, NAND, NOR, XOR, NOT, LATCH
• Timers (up to 64)

Other Flex Logic Statistics
• Virtual Inputs – up to 32
• Virtual outputs – up to 128
• Program steps – up to 2048