Features & Benefits

• Flexible & Modular Hardware Platform
• Engineering Support
• Advanced Analytics
• Superior Sensor Designs
• Strategic Asset Management Software
Dynamic Ratings advanced design and precisely implemented transformer monitoring, control and communication systems provide users with many benefits.

- **Reliability Improvement**
  With improved on-line condition based data, users receive condition based alarms when problems first arise allowing problems to be detected early and appropriate actions to be taken before problems escalate.

- **Maintenance Savings**
  The advanced analytics within the monitoring system filters through the condition data to automatically identify issues requiring maintenance attention. This allows the Operations & Maintenance crews to focus on resolving problems rather than consuming resources to manually collect data for off-line condition assessment and provide an optimal platform for condition based maintenance.

- **Realizing True Capacity**
  The real-time measurement of operational parameters allows the dynamic rating of the transformer to be determined and optimal performance realized.
MONITORING, CONTROL, COMMUNICATION

Monitoring

- Temperature
- Partial Discharge
- LTC
- Alarms
- Cooling System
- DGA

Control Functions

- Cooling Control
- Voltage Control including the following paralleling methods:
  - Circulating Current
  - Master Follower
  - VAR Sharing
  - Reverse Reactance

Communication

Local or remote user display

- PCS, Fiber, RS-485, RS-232 or Wireless
- Modbus, DNP

- PCS, Fiber, Wire or Wireless
- Modbus, DNP or IEC61850

Ethernet

- LAN/WAN/HMI

RS-232, USB or TCP/IP

DGA Sensors

Any other IED’s

Local PC Connection

RS-232, USB or Ethernet

Data Download & Configuration

Remote PC

Data Download, Configuration & View Web Pages

SCADA

SCADA (RTU)
USER INTERFACE

Graphical Display

• Provides faster interpretation of data and reduces the chance of data entry errors.
• Historical data is presented in a graphical format to easily indicate trends.
• Voltage and control settings are drawn graphically for easier system testing.
• Adjustable font size allows the user to choose the optimum balance between easy visibility and quantity of content per screen.

Smart Menu Buttons

• F1, F2, F3 and F4 keys allow for dynamic system navigation.
• Fast and easy menu navigation provided through two hardcoded keys “0 and 1” and eight user defined smart keys “2 - 9.”
• Easy access to your programmable favorites.
• Customized maintenance inspection screen to simplify data entry for your crews.

Summary Status LEDs

Summary Status LEDs provide quick status indication.

Swing Panel Mounting

The display provided is connected to the main control via a single connection. The user display can be installed in a readily accessible location such as on a swing panel. This allows all control and monitoring connections to be made directly to the main control assembly typically installed on the back panel of the control cabinet. With this approach, the critical control and monitoring connections are not subject to stress when the swing panel is opened and closed.

Multi-Level Password Management

A multi-level password management system provides the appropriate level of access to different user groups. The responsibilities for each user group can be defined by the user.

Full Numerical Key Pad

Secure password entry and setting changes are made faster and easier with a full keypad. Audible feedback is provided following each key stroke to help prevent entry errors.

Weather Resistant Design

Since the swing panel of the transformer cabinet can extend out past the cover of the control cabinet, the installation of the main control on the cabinet’s back panel provides additional protection from rain, thus protecting both the main control and all the connections.

The user display will withstand ambient temperatures of -40°C to +85°C and its operating temperature range is -20°C to +70°C. For more extreme operating temperatures, the remote user display option is recommended.
USER INTERFACE

Recommended Operator Actions
Additional information is presented based on alarm or status conditions and provides:

- Safety warnings
- Diagnostic interpretation
- Troubleshooting tips

Remote User Display (Optional)
A rack mount LCD and keyboard combination provide a convenient way to view monitored hardware status in a control room. The remote hardware does not utilize a PC operating system. Therefore, it eliminates security and operating system maintenance issues. A dedicated communication line (PCS, fiber, wire or wireless) is used to display and navigate the graphical pages served by the Dynamic Ratings control.

A single remote screen may be used to view the information on one or more monitoring systems. The system can be specified to use a touch screen, trackball, touchpad, pressure sensitive pointer, or stand alone mouse.

For control rooms where rack space is limited, a folding LCD display is available.

Alarm Diagnostics
Easy access to alarm details provides:

- Alarm grouping
- Alarm status
- Last occurrence of the alarm
- Number of occurrences of the alarm
- Duration before it was acknowledged
Main Processor (CPU)

Quick and Easy Data Download
USB ports with auto-detect feature allows files to be easily downloaded directly to a USB drive.

Setup and Configuration
Connection for setup, configuration or downloading files can be made using either the USB ports, Serial, Copper Ethernet or Fiber Ethernet ports.

Links to other Peripherals
The USB type B ports allow the use of USB data connections to other smart sensors (IED’s).

Ethernet Link Via Copper or Fiber
Ethernet link supports simultaneous SCADA communications and multiple connections for the built-in web pages.

Self-Maintained Hardware Clock
Real-time hardware clock provides time and date stamped data storage and event recording. The clock can be synchronized via DNP, Modbus, NTP and is maintained when the SCADA link is down or the control is powered off.

System Health Alarm Contacts
A Status relay provides an indication of loss of power or monitoring system failure.

Non-Volatile Data Storage
1 gigabyte industrial flash card provides non-volatile data storage at user defined intervals.

Meets Industry Standards
Safety compliant to IEC 61010-1
EMC compliant to EN 60870-2-1
MULTI-PORT MODULE

Any combination of the option cards can be used to populate the eight port multi-port module.

**OLTC/LTC Motor Current Monitoring**
Provides early indication of OLTC/LTC drive or OLTC/LTC motor problems by monitoring the OLTC/LTC motor current and voltage and alarming on any unexpected deviation.

**Dual CT**
Two current inputs can monitor transformer load, fan current, pump current or other AC current signals.

**Dual PT100 RTDs**
Two, three-wire RTD inputs can monitor top oil, bottom oil, ambient, OLTC/LTC temp, main tank temp, cooler inlet/outlet or any other temperature.

**AC Input**
Measures AC Volts and AC Current and calculates Watts and VARS.

**RS-232**
Connection to a modem or other serial device can be made using this EIA232 compatible connection.

**RS-485**
Connection to SCADA or other serial devices can be either two-wire or four-wire with this EIA485 compatible connection.

**Serial Fiber Optic**
Serial connections to SCADA are supported using this port, compatible with multimode 50/100 & 62.5/125mm and ST Connectors.

**DC Analog**
Two DC analog signals can be monitored with ranges of 0-1mA, 4-20mA, & 0-10VDC.
Digital Input Modules
Each input module provides 12 digital inputs for monitoring the status of alarm contacts, switch positions, contactor status or other status points. The system can be expanded by adding any combination of modules.

Individually Isolated
Each input is isolated to 2.5kV AC for 60 seconds and 5kV impulse. Individual isolations allow the use of different AC or DC sources for wetting voltages up to 250 VAC or VDC.

Individual LED Status Indication
Status indication LEDs for each input provides a user friendly feature for field technicians.

Digital Output Modules
Each output module provides eight form C outputs for cooling control, voltage control, audible alarm or panel lights.

Form C Contact Design
Each relay output has both NO and NC contacts and is individually isolated to 2.5kV AC for 60 seconds and 5kV impulse. Each output can be configured for either continuous or pulse output with adjustable pulse duration. Contacts are rated for 6A @ 250 VAC / 6A @ 30 VDC and 0.4A @ 125V DC resistive / 0.15A @ 125V DC inductive.

Analog Input/Output or Input Only Modules
Each Analog Input module provides six inputs including two AC current inputs for monitoring transformer load, fan/pump current or other AC currents, two PT100 RTDs (three-wire) input for monitoring temperatures and two DC analog inputs for any DC sensor such as tap position, nitrogen pressure or other analog signals. DC analog inputs can be configured for 0-1mA, 4-20mA or 0-10VDC.

Analog Input/Output
Analog Input/Output modules include the above inputs plus eight analog outputs per module with a 4-20mA DC output supporting a burden of up to 400W. Accuracy +/- 0.2% of range (plus CT, RTD, sensor and transducer errors).

Individually Isolated
Isolation between circuits and to ground is 2.5kV AC for 60 seconds and 5kV impulse.

Universal Power Supply Module
The power supply module allows operation with DC or AC sources ranging from 48 to 275 V DC and from 60 to 275 VAC at 50 or 60Hz.

Minimal Power Consumption
Typical system consumption is only 50W providing minimal impact when powered by a DC station battery system.
Fiber Optic temperature probes provide direct winding temperature measurement. This modular add-on to the DR-E3 system provides an economical solution with the following advantages:

- Close monitoring of the winding hot spot on critical transformer applications including large Auto, GSU, mobile or other critical installations.
- Collection of precise winding hot spot data to develop an optimally refined winding hot spot model. This model is copied to the Dynamic Ratings control system on all thermal duplicates gaining the accuracy of fiber optics on multiple units with minimal expense.

Specifications

- Measurement Range: -30 to +200°C
- System Accuracy: ± 2°C or 1% of full scale
- Operating Range: -40°C to +70°C
- Probes: 4 temperature probes per module. The standard Dynamic Ratings system can accommodate up to 3 modules (12 probes).

Operational Description

The fiber optic temperature measurement system utilizes LumaSense patented Fluoroptic® technology.

![Fiber Optic Extension](image1)

![Transformer Tank Wall Penetrator](image2)

![Fiber Optic Probe](image3)

![Mounting Plate for Tank Wall Penetrator](image4)

![Ruggedized Transformer Probes](image5)
BUSHING HEALTH MONITOR

Unique Features
Continuous online monitoring of bushings provides asset owners with real-time information of bushing capacitance and power factor which can result in early detection of possible failure.

- Employs three levels of protection including a fail safe circuit.
- Unique bushing sensor design provides the signal for both bushing health and PD analysis.
- Calculates and reports capacitance and power factor of each bushing using data received from the Type BAU Bushing Sensors connected to the bushing capacitance tap.
- Reports both the magnitude of the sum of currents (severity of the defect) and vector information (provides the ability to determine which bushing has the defect).
- Utilizes dynamic operating parameters such as top oil temperature, humidity and load current from the DR-E3 system.
- Automatic behavior learning upon commissioning with load, humidity and temperature. Unit alarms when behavior is outside the learned responses.
- Available as a stand alone system or as a fully-integrated module for use with the E3 DRMCC system.

How it Works
Currents flowing through the bushing taps are proportional to the C1 capacitance and dielectric losses (Power Factor) of each bushing. By summing the currents from a bushing set, a signal proportional to the health of the bushings is provided. The system consists of four main components; Sensors installed in each bushing capacitance and/or voltage tap; Balancing Unit (K), Summation Unit (∑) and a Null Meter which measures the sum of the three currents.

During the commissioning of the system, the null meter is balanced to create a base line of zero (or null). If the capacitance and/or the power factor of a bushing changes, the null meter will no longer be null. The magnitude of the output represents the severity of the problem and the vector output indicates which bushing is deteriorating and whether the power factor and/or capacitance is changing.
PARTIAL DISCHARGE MONITOR

Partial Discharge (PD) Monitor

The Dynamic Ratings Partial Discharge Monitor (PDM) directly measures electrical partial discharges (PD) in power transformers and electrical power apparatus. Connection to the bushing capacitance taps provides a direct path for the PD signals and enables the system to see much further inside the transformer. Advanced noise cancellation technologies utilized in the Dynamic Ratings PDM enables the system to automatically differentiate between internal and external signal sources.

When PD occurs inside the core and coil assembly, detection via acoustic monitoring is more difficult. Use of the PDM directly measures the electrical signatures caused by a PD event.

Key Features Include:

• 15 PD channels with simultaneous data acquisition on all channels
• Each channel is fully configurable.
• Two levels of alarms
• Configurable alarm for PD magnitude (mV or pC)
• Stores up to 2 years of data with standard configuration.
• Records pulse magnitudes and pulse counts
• Tracks full phase resolved data.
• Available as a stand alone system or as a fully-integrated module for use with the DR-E3 system.
• Enhanced noise cancellation technology

Acoustic PD Measurement

Dynamic Ratings also has an acoustic PD module available that can be combined with the electrical PD monitor.

The main sensors used for monitoring partial discharge are the Type BAU Bushing sensors, Radio Frequency Current Transformers and Rogowski coils. All are installed externally on the transformer.
ON-LINE DISSOLVED GAS AND MOISTURE IN OIL ANALYSIS

Data Consolidation
The open architecture design of the DR-E3 product allows the system to be integrated with a wide array of different monitoring devices including DGA and Moisture Monitors. The communication link to these devices utilize a serial link to ensure information is sent in digital format preserving the precision of the measurements and providing access to additional diagnostic information. Shown below are several of the many Dissolved Gas Analysis devices we support.

Data Analysis and Diagnostics
Built-in diagnostics within the DR-E3 utilizes the data from the peripheral devices, converting the raw data into useful and actionable information.

Correlation of Data
The internal data logging feature archives all information including the information from the peripheral devices into one common storage file. With the information consolidated, it is much easier to identify cause-effect relationships and to take corrective action to prevent the escalation of problems.

Consolidated Display of Data
The built-in web pages within the DR-E3 enable asset managers and other utility personnel with access to monitor the transformer from their desktop PC.

SCADA Simplification
Data is consolidated from the DR-E3 to the peripheral monitoring devices into one SCADA file. The alarms and status points can be grouped with other transformer information to generate common, major, and minor alarm groupings.

Common Local Display
The DR-E3 display consolidates all transformer alarms and information into the one graphical display. Responding to a substation alarm, technicians will be able to conduct an analysis, determine when the issue arose, and then clear any common alarms from the DR-E3 display.

Pass-Thru Communication
The DR-E3 can be used to communicate with a wide array of IED’s. For a complete list of supported devices please contact Dynamic Ratings.
SYSTEM MONITORING, ALARMING AND DATA STORAGE

Transformer Health Systems
The DR-E3 product is used to consolidate all of the alarm and status monitoring data from the transformer. As new technology continues to develop smart transformer health products, the DR-E3 has also expanded the communication and user display screens to provide easy access to these new systems.

Auto-Recharging Breather
Some auto-recharging breathers have monitoring and self diagnostics to verify proper operation. The DR-E3 system can be used to interrogate the breather providing diagnostic details such as humidity, regeneration state, error code descriptions and other details. Our analysis of the data helps identify when the silica gel is aged and no longer capable of proper regeneration.

OLTC Oil Filtration System
Oil filtration system monitoring provides remote indication of flow and pressure to identify when the filter needs to be changed and to identify leaks that would generate a loss of system pressure.

OLTC Contact Wear Sensor
Vacuum bottle contact wear sensors are available to measure the physical travel of the contact. A kit, including the fiber optic sensors, penetrators, and control module is available to add this feature to any existing or new OLTC.

Inert Air or N₂ Generation System
Cylinder pressure, tank pressure and alarms provide indication when the bottle needs to be replaced. On N₂ generation systems, the monitoring provides indication of proper system operation.

Customized Alarm Groups
Alarms can be grouped into an unlimited number of customer defined alarm groups. This allows the choice of transmitting all items as discrete points, only select items in detail, or use of internal logic for transmitting grouped alarms.

Logic Calculator
The control provides a logic calculator to allow customers to customize the operation of the DR-E3. The logic can drive alarms, control operations or trigger events.

Data Storage
Data storage is maintained in archives to provide historical trending, alarm tracking, diagnostic interpretation and cause-effect investigation. The data is saved in a CSV file format allowing it to be imported into a number of common software products.

Chronological Data Log
Data can be stored at a user defined interval for up to five years. Data points recorded are user defined. Default settings provide one year of data storage at one minute intervals with up to 200 data points recorded each minute.

Alarm Log
The alarm history file provides a time and date stamped record of when alarms became active, when they were acknowledged and when they cleared. The DR-E3 also provides alarm diagnostics indicating the total number of alarm occurrences for each alarm, time since last alarm occurrence, and duration the alarm is active while unacknowledged.

Event Log
Users can define any number of event logs to capture cause-effect diagnostic information. An event is any status change defined by a user that will initiate a “snap shot” record of a user defined set of variables.
COMMUNICATIONS SOLUTIONS

Communication Link
The DR-E3 is the communication hub for all monitoring and control functions, providing a single communication link to the customer network. The single link back to the control building can be serial or Ethernet. It can use Fiber, Copper, Radio or Powerline Communication System (PCS).

Protocols Supported
The DR-E3 can support multiple simultaneous communications as either a Master or a Slave device with the following standard protocols:

- IEC 61850
- DNP 3.0
- Modbus
- TCP/IP
  - FTP/SFTP
  - HTTP/HTTPS
  - TELNET/SSH

Fiber Optics
The DR-E3 comes standard with a fiber ethernet port and can have serial fiber ports installed as needed. Both are compatible with 50, 62.5, 100 and 200 micrometer glass core multi-mode fiber. The connections are ST connectors.

Copper Connections
The DR-E3 comes standard with a wired Ethernet port and can have RS232 and / or RS485 ports installed as needed.

Radio Systems
Our standard serial radio is a frequency hopping spread spectrum system. The systems are customized for the installation and include radio’s, antennas, cables and connectors as needed.

Powerline Communication System (PCS)
All DR-E3 systems can use the DR Powerline Communication System. PCS is the industries secure, reliable and economical solution, whether communicating between devices or to a control building. PCS can be used to transmit serial or Ethernet data or both simultaneously.

PCS offers secure and reliable communications as an affordable alternative to installing new wire or fibre. PCS is a compact, substation hardened design with high data throughput over many physical configurations including:

- Peer to Peer
- Many to One

PCS transfers device(s) data via the native communications protocols, reliably and without interference. PCS installs rapidly. PCS power options include either a standard AC power cord or a Field Wiring plug as shown.

25% to 50% Less Cost Than Fiber
PCS installs in 15-30 minutes without the use of tools or specialized labor! At the transformer, an inductive coupler is installed onto an existing conductor. The transceiver encodes the data onto that conductor.

Inside the control building, an inductive coupler is used in conjunction with a second transceiver or a multiplexer to retrieve the signal and relay it onto the substation RTU or desired gateway.
COMMUNICATION AND DATA SECURITY

Web Pages

Built-in Graphical Pages
Our built-in web pages provide the ability to easily drill down through the data in a very user friendly format.

No Software Licenses Needed
Accessing the built-in web pages does not require the installation of special software. They can be accessed using any standard web browser software as the pages are hosted from a built-in server, that can only be accessed through a secure connection.

Security
Built in security features include password protection, HTTPS, SSH & SFTP encryption. The DR-E3 can be configured to only permit connecting from a list or range of IP addresses.

Auto-Generation of Web Pages and Graphics
Enabled features automatically populate providing an easy to navigate system.

Virtual User Interface
A fully interactive representation of the user interface is included in the graphical interface accessed with the web browser. This provides superior support to the field operations group because engineers can utilize the same user interface without traveling to the substation.

Easily Modified
A graphical configuration tool provides easy configuration and editing of the configuration as needed.
Dynamic Ratings provides a variety of sensors useful in measuring the physical property (ies) of interest related to electrical apparatus operation. These sensors are part of a complete monitoring solution and convert the measured properties into a signal readily used by an observer or an intelligent device, such as DR Monitoring, Control and Communication Systems.

DR sensors are designed to be highly sensitive and accurate to the property of interest. Where industry could not provide sensors with the quality, accuracy and performance required in our customer’s harsh demanding applications, DR has developed and patented its own sensors to exceed industry standards for quality and performance coupled with ease of installation.

Temperature
The DR-E3 uses the industry standard PT-100 RTD sensor input directly to the control. External RTD transducers are not needed, saving cost and complexity.

Thermal Well RTDs
Our thermal well RTDs are provided with a spring loaded sensor to insure positive contact with the thermal well. This contact improves accuracy and system response rate.

Magnetic Mount RTDs
Our magnetic mount RTDs also use a spring loaded sensor tip to insure positive contact with the tank wall.

Ambient RTDs – Radiation Shield Assembly
The ambient temperature assembly utilizes a weather shield to provide protection from the effects of solar radiation and precipitation.

Ambient RTDs – Std Enclosure Style
Retrofit cabinets can be supplied with the more economical RTD assembly which utilizes the main enclosure as the shield for solar radiation and precipitation.

OLTC/LTC Tap Position Sensor
DR LTC position sensors are patented to provide superior accuracy and noise immunity in new or retrofit applications.

DC Analog Sensors
DC analog signals of 0-1mA, 4-20mA or 0-10VDC can be provided by resistor board sensors, Selsyn type sensors with transducer or from our own sensor utilizing vacuum sealed reed switches.

BCD Sensors
The digital input modules on the DR-E3 system can be used to decode a BCD sensor input.

Current Monitoring (load/fan/pump)
The DR-E3 system is supplied with current sensors for monitoring of the transformer load, fan currents, pump currents, and OLTC/LTC motor current. These sensors can be supplied in one of three designs.

Split Core
The split core CTs allow installation without the need to lift any wires, making installation into energized cabinets easier.

Fixed Core
The fixed core CTs also offer an easy installation with the added benefit of protecting the CT core from potential oxidation problems.

PCB Design
The PCB sensor assembly offers added flexibility in tuning the ratio to provide higher resolution for monitoring pump and fan currents. The CTs also offer improved accuracy for measuring the transformer load power factor.
**Geomagnetic Induced Current Sensing (GIC)**

The Dynamic Ratings patented, GIC Sensors provide an easy and cost effective method of Monitoring a transformer’s DC neutral ground current produced by geomagnetic activity. DR GIC Sensors are engineered for the harsh utility environment with a rugged, industry accepted outdoor rated and UV stable housings.

Geomagnetic Induced Currents can occur when solar flares interact with the earth’s magnetic fields and can induce sudden, large flux changes in transformers which can cause core saturation, severe overheating in leads and structures, damage to insulation systems and increase combustible gases and has failed a number of transformers around the world.

DR sensors are designed to detect bidirectional DC currents and transmit this data in real time to the DR Monitoring Control and Communication products. The DR-E3 can monitor and alarm on DC neutral currents, which can be indicative of GIC, thus allowing customers to take preventative steps to protect transformers and the possibility of voltage collapse on systems.

GIC Sensors can be installed and communicating with the DR-E3 in a matter of minutes without the need to de-energize equipment and without making modifications to the transformer neutral ground connection.

**Conservator Membrane Integrity**

This sensor provides both a visual indication and a contact output indicating the failure of the membrane.

The sensor also proves useful in the transformer installation process as it provides a visual indication that the air has been properly purged.

**Control Cabinet Condensation Alarm**

Multiple methods are available to insure that the control cabinet heater system is operating as required. Dynamic Ratings application engineers will help select the most effective method for your application.

**Bushing Monitoring and Partial Discharge**

**Bushing Sensors (BAU)**

The type BAU bushing sensor provides both power frequency and high frequency signals. These signals are used for the monitoring of the bushing insulation as well as for partial discharges that may be occurring in the bushings or windings. BAU Bushing Sensors are installed in the bushing test/capacitance tap that are found on most bushings 69kV and above.

**Rogowski Coil (RC)**

For electrical partial discharge monitoring systems, Dynamic Ratings will typically provide Rogowski Coil (RC) sensors installed around the base of bushings rated 138kV or higher.

**Bushing Monitoring for Single Phase Transformers**

Installations where there is a fourth single phase transformer provided as a spare, we offer a switching kiosk. This NEMA 4 (IP65) enclosure provides connections to the bushings on all four transformers. A selector switch is provided to select any three of four transformers:

- Phase A / B / C
- Phase A / B / Spare
- Phase A / Spare / C
- Spare / C

The system automatically connects the proper sensors to the monitoring system and will safely ground the un-used sensor(s).

**Coupling Capacitor**

Coupling capacitors can be used for PD monitoring on transformers that don’t have bushing capacitive taps. Three voltage levels are available: 8, 16 and 28 kV.
Active Moisture Content

The Dynamic Ratings Transformer Moisture Monitor (DR-TMM) is a software application for the assessment of the moisture condition in the insulation system of a power transformer. Data from the moisture in oil (relative saturation) and temperature sensors is used to calculate the moisture content in the oil in units of ppm.

Using an intelligent fuzzy logic decision-making algorithm, DR-TMM calculates the ‘active’ moisture content in the solid insulation. DR-TMM uses the ‘Green Yellow Red’ (GYR) traffic light approach to identify and display the condition of the power transformer in terms of moisture.

MOISTURE MODELING

Fuzzy Logic ‘Smart Thinking’ Mechanism

Based on patented technology, DR-TMM uses neuro-fuzzy computing to evaluate the consistency of the moisture sensor output, to assess the water content in paper (WCP) and to alert the user when the insulation condition requires attention. The diagnostic window is divided in two sections. The moisture state is indicated by the red, yellow or green lights depending on the insulation condition in terms of moisture. The confidence level indicates the accuracy of the result. The confidence level takes the values of HIGH, MEDIUM and LOW. When the confidence level is HIGH the displayed value of WCP(%) becomes a true value, reflecting the percentage of water in paper available for exchange with the surrounding oil.

Water Activity - The Direct Indication of Moisture in the Oil/Paper Insulation System

A new parameter of water-in-paper activity reflects the free water available for exchange between oil and paper. Water-in-paper activity is the critical factor that determines the state of dryness in power transformers. By measuring the water-in-paper activity, it is possible to predict the degree of water contamination in an oil-paper system. Water-in-paper activity, not water content, determines the lower limit of available water for exchange with surrounding oil. The calculation of water-in-paper content is directly based on the correctly measured water-in-paper activity. In addition, water-in-paper activity can play a significant role in determining the breakdown risk of high voltage equipment and the probability of bubble formation. Therefore, controlling water-in-paper activity becomes an important method in maintaining the quality of electrical insulation.
Advanced Thermal Modeling

The thermal modeling analytic within the DR-E3 is designed in accordance with IEC 60076 Part 7 / IEEE C57. The thermal model requires transformer load, top oil temperature, tap position and cooling system status. This accounts for and enhances the precision with the following elements:

- Transformer design
- Cooling system
- Cooling system health
- Losses adjusted for each tap position
- Cooling efficiency adjusted based on cooling system performance

Precise Winding Temperature

Given the added detail included in the thermal modeling analytic, the system can calculate a more precise winding temperature. The modeling can calculate the winding temperature of the additional windings within a multi-winding transformer design.

Insulation Aging

Insulation loss of life model accumulates the thermal aging in each transformer winding.

Predictive Oil Temperature Model

Measured load currents and voltage is used to calculate relative load losses and no-load losses. By combining this with the ambient temperature, cooling status and cooling system health, an estimated top oil temperature is calculated.

The predictive oil temperature model may be used to provide a cross check of the thermal model variables.

Cooling Efficiency

The predictive top oil temperature is compared to the measured top oil temperature to verify that the cooling system is operating correctly and can help identify problems such as:

- Closed radiator valves or other obstructions to the oil flow
- Bird nests, tree debris or other external contamination

Cooling System Health

The thermal model adjusts the calculated winding temperature hot spot based on the health of the cooling system. The elements of the cooling health include:

- Loss of cooling power
- Loss of AC control power
- Contactor failure
- Oil flow sensors
- Fan currents
- Pump currents

Dynamic Rating

The dynamic rating provides:

- Time remaining at the current state
- Maximum Safe Load

The time remaining provides the amount of time before the temperature will exceed the maximum thermal limit.

The Maximum Safe Load indicates the maximum load the transformer can safely carry given the present health of the cooling system and the present environmental and operating conditions of the transformer without pushing the transformer beyond the thermal limit.

“What – If” Rating Calculations

Utilizing the Predictive Oil Temperature Model combined with the Dynamic Rating calculation, a “What – If” is used to allow additional calculations including:

- **Load for Time**: Given an assumed load, how long before the transformer would exceed a specified thermal limit.
- **Time for Load**: Given a specific time duration, what is the maximum load the transformer could sustain without exceeding a specified thermal limit.
Supported Cooling Systems

DR-E3 controls prior extensive cooling control function to support a wide variety of different cooling system designs and provide improved operational performance and reliability. Transformer factories will appreciate the flexibility and built-in features available in the Dynamic Ratings system:

- **Discrete Control**: The system can provide discrete control for more than 4 discrete stages of cooling control.
- **Dual Speed Fan Control**: For low noise applications, the system has dual speed fan control logic built in.
- **Parallel Pump Control**: For systems designed with parallel pumps, the system automatically manages the duty cycling of the pumps to ensure equal wear.
- **Variable Speed Control**: For coolers that operate with variable speed fans, the system provides the output to directly drive the VSD system.

Duty Cycle Control

Running hours are recorded for each stage of cooling and when the first stage of cooling is required, the duty cycle logic will automatically select the stage of cooling with fewer operational hours as the leading stage. This feature eliminates the need for a “Leading Bank” control switch in the control cabinet.

For retrofit applications which already have the “Leading Bank” switch, the input of this switch may be used in lieu of the automatic logic.

Cooling System Exercising

An automatic cooling system exercise feature may be used to operate the cooling system on a periodic schedule. Routine exercise will:

- Redistribute bearing lubricants extending bearing life
- Minimize bird nest problems
- Provide confirmation that the cooling system is operating properly.

Predictive SMART Cooling

Predictive cooling is a feature which, when enabled, proactively turns on the cooling system earlier to reduce insulation loss of life and to keep the transformer cooler, reserving more overload capacity for later in the day.

The predictive cooling uses the Ultimate Top Oil Temperature and the Ultimate Winding Hot Spot Temperature calculations to recognize when the transformer temperatures are increasing beyond a desired level. Discrete set points may be used to control the turn on and turn off temperatures for both ultimate top oil temperature and ultimate winding temperature.

SMART cooling versus conventional cooling

DRMCC SMART cooling keeps transformers running cooler than conventional systems thereby avoiding unnecessary “loss of life” and reserves more overload capacity for later use.

“Not In Auto” Alarming

SCADA and local alarms with user defined time delays may be configured to provide remote indication when the control switch has been left in the “Hand” or “Manual” position.

Low Temperature Pump Inhibit

A low temperature pump inhibit feature protects the transformer from static electrification which may occur when high velocity pumps are operated when the oil temperature is too cold.
**VOLTAGE CONTROL**

**Automatic Voltage Control**
The DR-E3 system can be configured to provide primary voltage control or can be used to provide backup control for an existing voltage control system. Voltage adjustment time delays can be configured in two standard methods:

- Definite with discrete settings for initial, inter-tap and fast tap time delays
- Inverse N where time delay used is determined by how far out of tolerance the voltage is.

**Visual Configuration**
The graphical display makes configuration, testing and troubleshooting easier.

**Reversing Switch Monitoring and Auto Cleaning**
Regular reversing switch operation is recommended by OLTC manufacturers to prevent problems with high resistive film build-up and coking problems. The DR-E3 continuously monitors the tap position and provides alerts when the number of days since the OLTC has passed through neutral exceeds the alarm set point. When the device is used as the primary voltage controller, an auto cleaning function is also available. Once the need to operate the reversing switch has been determined, the auto cleaning feature will begin looking for an opportunity to move through neutral. A user defined permission band ensures that the movement through neutral is achieved without generating unacceptable system voltages.

**Other Voltage Control Functions**
- Line drop compensation using R and X settings.
- Time delay configurable to Definite or Inverse.
- Inter-tap delay feature
VOLTAGE CONTROL

Paralleling

The DR-E3 product can be configured to provide paralleling using any of the following paralleling methods:

- Circulating Current
- Master Follower
- VAR Sharing
- Reverse Reactance

The hardware and sensors needed depends on the method used.

Circulating Current method requires the use of parallel balancing CT’s to separate the circulating current from the transformer load current. HV circuit breaker auxiliary contacts are used to configure the paralleling balancing circuit based on the status of the transformer and bus tie breakers.

Master Follower requires a form of communication between the transformers. Typically, a serial connection (fiber or PCS) would be used. However, the system can also be configured to exchange the data utilizing the SCADA link without needing a separate connection.

VAR Sharing also requires a form of communication between the transformers with the same options used by the Master Follower method.

Reverse Reactance does not require any communication between the transformers. This method operates on the same principle as line drop compensation but the polarity of the R component is reversed. Initial R and X compensation values are derived based on the transformer impedance and the typical load power for the system.

Operational Safety Features

- Undervoltage blocking of raise and lower operations should the control sense a low voltage or no voltage condition.
- Overvoltage blocking of raise operations should the measured voltage exceed a preset limit.
- Overcurrent blocking of raise and lower operations if the load current exceeds the rated current of the OLTC.
- Circulating current blocking of tap change operations if the measured circulating current exceeds preset limits.
- Out-of-step blocking prevents additional tap change operations should the controls get out of sync when using master follower schemes.
- No master and multi-master blocking to ensure one master is present when using master follower schemes.

Positive Feedback feature provides an added level of equipment and operator safety. After each tap command issued, the DR-E3 utilizes the tap in progress signal and the OLTC tap position to verify that the OLTC did take a step and that the step was in the proper direction. If the OLTC fails to make the operation, an alarm is raised and the OLTC operation is inhibited to prevent further operation attempts of stuck or broken contacts.

Recommended Operator Actions alert operators to the potential root cause of alarms, provide operational and safety warnings and/or diagnostic instructions.

Manual Switch Panel (Optional)

Optional mechanical switch panels provide large operator switches for manual operation.
On-Load Tap Changer

On-Load Tap Changer Monitoring analytics have been developed to catch a wide array of OLTC/LTC problems.

OLTC/LTC Counter

An individual OLTC counter is maintained for each tap position providing a summary of the historical operation of the OLTC/LTC. The summary provides an indication of the tap range used.

OLTC/LTC Contact Wear

An OLTC/LTC contact wear analytic model is used to calculate the amount of arcing wear accumulated on each individual tap. These calculations provide an accurate relative condition assessment of the contacts within the OLTC/LTC and can be used to improve the maintenance process by eliminating unnecessary maintenance and by indicating instances where additional maintenance may be needed.

OLTC/LTC Hunting

The hunting analytic indicates OLTC/LTC tuning or control problems that result in excessive tap changes. Transformers in parallel that are “chasing” each other, or instances where the line drop compensation is set too high can cause excessive OLTC/LTC contact wear.

Reversing Switch Exercise

Reversing switch problems can be avoided with the monitoring of the operation of the reversing switch. The time since last movement through neutral will provide visibility of the switch operation, confirming that the switch is operated on a periodic basis. If the switch has not operated through neutral in a time frame longer than deemed acceptable for that OLTC/LTC switch type, an alarm will be sent.

Auto-cleaning of the OLTC/LTC Reversing Switch System

The auto-cleaning feature provides the ability to automatically exercise the reversing switch. This feature is available when using the voltage control features in the E3 system. The auto-cleaning feature will exercise the reversing switch when the analytic indicates that a cleaning movement is needed and it will verify that it can be achieved without generating an unacceptable system voltage level. The time between cleaning and acceptable OLTC/LTC range before initiating cleaning are customizable.

OLTC/LTC Motor Current Monitoring

A dedicated module is available for monitoring the OLTC/LTC motor current and voltage. The information collected by this module uses analytics to compare the energy consumed during the tap change to an expected, preset value. An alarm will be triggered if the energy needed to make the tap change falls outside the acceptable range, indicating an unacceptable condition exists in the OLTC/LTC motor or drive mechanism.

OLTC/LTC Delta T Monitoring

A final line of defense is available for external tank OLTC/LTCs utilizing a Delta T analytic. The Delta T analytic compares the OLTC/LTC compartment temperature to the temperature on the opposite side of the barrier board in the main tank. To improve accuracy of the temperatures being compared, it is very important to monitor the temperatures at the same height. For this measurement and comparison, dedicated RTD’s are supplied for the main tank and OLTC/LTC compartment. Top oil temperature is not used in this comparison as it is typically not at the correct height to adequately support this comparison. The analytic utilizes filtering to prevent false alarms due to the heating and cooling profile of the OLTC/LTC.
System Engineering

Each DR-E3 system is engineered to order for an individual transformer and includes the following engineering services:

- Customized drawings for the specific project
- Pre-configured hardware
- Pre-tested configurations including pretesting of any interconnected devices
- Standardized hardware footprint to accommodate a variety of options
- Customized test guide
- Technical support

Control Configuration

Each DR-E3 system is configured by Dynamic Ratings to ensure that the functionality satisfies the technical specification and also meets the customer’s objectives. The configuration of the control incorporates specific details of the transformer including:

- Thermal design data or actual heat run data
- Cooling system
- Nameplate detail
- Wiring diagrams
- Outline drawing

These design criteria along with the monitoring hardware and customer objectives are combined to generate a custom configuration specifically suited to each application.

Detailed Testing

Each DR-E3 system is fully tested at the factory to verify correct configuration. All control, alarm and display functions are tested to verify that the setup is functioning as designed.
PACKAGING OPTIONS

Optimized Packaging
Each DR-E3 system can be assembled, configured, wired and tested in a variety of packaging options to provide the most cost effective and efficient manner for installation by the transformer factory or the end user.

Components Only
For new transformer applications, the Dynamic Ratings control and user display can be integrated into the main transformer control cabinet (shown to the right). The ability to install the main control on the back sub-panel within the control cabinet ensures that sensor and field wiring are not stressed during opening and closing of a swing panel. The user display is typically installed onto a swing panel to provide easy access by the customer and provide a clean cabinet look.

Sub-panel Assemblies
A second alternative available for new transformer applications is the sub-panel assembly. It typically contains all monitoring system hardware, transducers and sensors, reducing the amount of interconnection wiring. Terminal blocks are provided to make the interconnection of the system quicker and reduce wiring errors. Two standard cabinet sizes are available to accommodate any combination of options.

Cabinets for Retrofit or New Applications
Weather tight cabinets are also available for either new or retrofit applications. Two standard cabinet sizes are available to accommodate any combination of options. Retrofit systems include a swing panel for access to a user display and any needed control switches. Panel heaters are supplied to control condensation.

Custom Packaging Options
In addition to standard packaging alternatives, DR manufactures to OEM or customer defined specifications. Whether the scope is a minor variation to a standard sub-panel, or the need to manufacture a drop-in replacement replicating existing terminal arrangements and accommodating installed sensor and IED wiring, DR can provide a solution to fit the existing cabinet location to facilitate ease of field replacement.
**PACKAGING OPTIONS**

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<th>E3-7100</th>
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**Subject to change without notice.**

**KEY**

- Y: Included
- X: Optional
- #: Available
- #: Not Available
Strategic Asset Management

Easy access to asset status and asset health information is only useful if it is easily available to the right people and in an efficient and intuitive format. The Dynamic Ratings/Amulet Strategic Asset Management (SAM) software provides a powerful solution, insuring that utilities are able to truly benefit from the detailed information available to them.

Consolidation and Correlation of Data from Multiple Sources

Online monitoring data may be the foundation for the asset management system. The DR/SAM software package not only provides easy access to the online data from the assets, but also integrates this information with other data sources. This one system can provide efficient access to maintenance records, factory test results, inspection results, drawings and off-line test results. These data sources may reside within the utility or could include data held by third party companies such as DGA laboratories.

Calculation Engine and Predictive Tools

Raw data can feed analytic models to provide the foundation for driving asset management metrics. Asset condition, loading, history and brand specific data can produce reliability estimates. Installation criticality can be combined with the asset health information to provide a ranked priority of which assets or locations need attention.

Dashboards

User specific dashboards provide each individual with a customized view of relevant information.

Geospatial presentation

Custom views including geospatial maps and asset hierarchy charts allow users to see the total system, quickly locate alarms and to drill down into the data to evaluate/diagnose/respond and resolve issues quickly.

Reporting

Customized reporting further supports the ability to leverage the data.

Driving Performance

This powerful decision support tool has enabled many companies to optimize various aspects of their business with both reliability improvements and cost reductions.