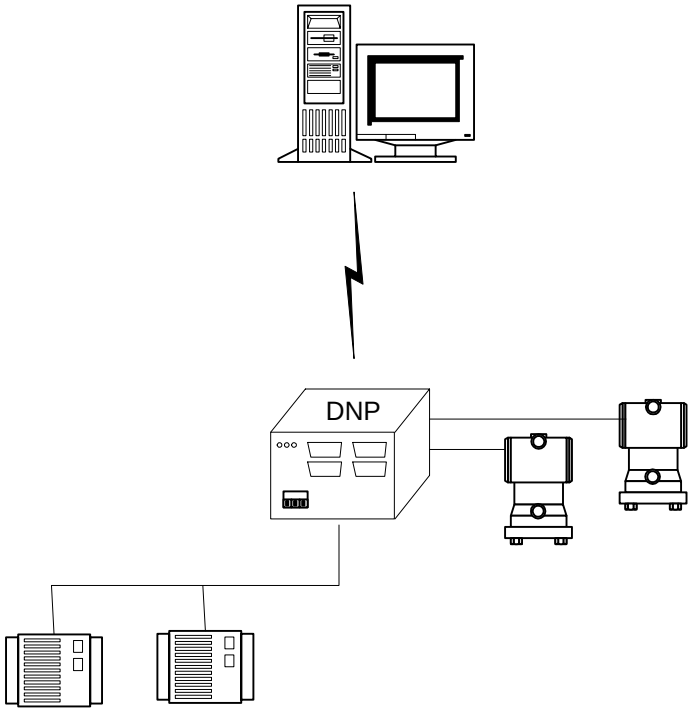
PJM DNP Specification



Release 1.6

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PJM DNP Specification

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Version Control

Version	Date	Approved	Description
1.0	10/13/00	J.P.T	Initial release of proposal for PJM review
1.1	11/20/00	J.P.T.	Update with comments from PJM
1.2	4/12/01	J.P.T.	Minor corrections, added configuration details
1.3	2/25/04	J.P.T.	Completely re-written for new software release
1.4	5/18/04	J.P.T.	Added state diagram
1.5	12/23/04	J.P.T.	Minor modifications, updates to ACE configuration objects
1.6	3/1/06	J.P.T.	Added copy&scale function, increased LoadStore rows to 10

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1 Introduction

This document describes the software functionality of an RTU (Remote Terminal Unit) Gateway device, provided by Arcom Control Systems Inc. to PJM. The RTU Gateway is one of Arcom's **Director** product line, which serves as a protocol interface, collects revenue and instantaneous data, and reports to one or more host systems. This section lists the functional requirements and basic system information, and later sections detail the product implementation and configuration.

1.1 Protocols

The Director includes support for DNP 3.0 protocol (Level 2), and Modbus protocol, including both master and slave implementations, and allow for either protocol to be transmitted over serial or Ethernet networks. It allows for simultaneous master and slave configurations in either protocol, configurable according to the requirements of a given project. DNP slave implementation also includes support for Object 23.5 (frozen counter events) to be generated by the Director. In addition to DNP and Modbus devices, local pulse input accumulators and digital inputs can be acquired.

1.2 Revenue Collection

Two forms of data may be collected by the Director: revenue information (MWH/MVARH); and instantaneous real-time data (MW, MVAR, Volts, Amps, Status, etc.). There are alternate methods of collecting revenue information, including pulse meters and intelligent meters supporting DNP 3.0 or Modbus protocol.

Revenue information collected from DNP or Modbus meters represents the energy used over a certain revenue interval (typically one hour, but can be configured). This may be a frozen counter from the previous period, or it may be a running counter. Revenue information collected from pulse inputs represents a running counter, with one pulse being equivalent to a certain quantity of energy.

The Director will freeze counter values obtained from meters as an Object 23.5 frozen counter event. Alternatively, it can perform delta calculations from interval to interval, and store the delta value as a frozen counter. All frozen counters will be stored in a queue to guard against data holes in the event of communication loss between the Director and the PJM SCADA system.

A Load Disconnect (LD) signal is used to indicate when to collect revenue data from each meter. The LD may be an external hardware input or a software point, or the Director may be configured to ignore the LD and continuously collect revenue data.

Revenue intervals may be triggered by an End of Interval (EOI) signal. This signal may be an external hardware input or a software point. This signal will be generated externally in order to indicate that counter values for this interval should be frozen, as long as the LD signal is active for the meter.

Revenue intervals may also be triggered by internal timers, causing revenue data to be collected starting from a number of seconds past the top of hour. After the top of hour (if configured) has been reached, revenue data will continue to be collected on a fixed time interval, as long as the LD signal is active for the meter.

1.3 Communication Networks

Serial communication utilizes the Director's RS-232 or RS-485 ports. Network communication uses the 10baseT Ethernet port.

Several options may be used for communication to PJM's host SCADA system and other network host equipment.

- Serial communication using either DNP or Modbus
- Network communication, via intranet or the Internet
- Encrypted communication via the Internet, using Comverge gateway equipment
- Direct dial-in from remote Director to a modem or ISP

When using IP, the typical port number assigned to DNP is 20,000, but this is configurable. Modbus IP port numbers are configurable. When the communication is via Ethernet, the Director has one or more fixed IP addresses defined in its configuration, which may be used by the host SCADA system(s). The SCADA host can request data from the Director upon demand at any time using the Director's IP address.

1.4 Encryption

The Director may connect to a Comverge Technologies' CCS (Comverge Communications Server), exchange security keys, and begin communicating using an encrypted IP session. This allows the Director to connect over a public Internet connection to a secure server, and to protect sensitive data using encryption technology. Since the Director will potentially be connecting through an ISP, its public IP address may be dynamically assigned.

The CCS, in addition to establishing the encrypted communication session, also provides IP address translation so that the DNP host computer inside PJM's network can use a fixed IP address for each remote Director. Aside from the fact that the public IP network traffic is encrypted, all the rest of the Director's functionality and network DNP communication remain unchanged.

1.5 PSTN Dial-up

An alternate method of communication is supported via PSTN telephone circuit. The Director can initiate a connection with PJM via a dial-up modem to a pre-determined phone number during each revenue interval. Once the connection is established, the PJM SCADA system will scan the Director, collecting the revenue and instantaneous information. At the end of the online period (configurable time), the Director breaks the connection automatically. This sequence continues for each revenue interval that the customer meter or Director has revenue information for PJM. If using a direct

modem connection, the communication is asynchronous serial, not IP, and is not encrypted. If using dial-up to an ISP, the Comverge encryption may be used.

2 Project Implementation

Arcom's **Director** products are the culmination of several man-years of software development, combining RTU and communications capabilities with network gateway and third-party protocol emulation. The Director is based on a standard software platform that is customizable to meet the requirements of this project.

2.1 Director Hardware

The Director series includes several products that are based on a common software platform. This project includes specific support for the following Director products:

- **DS2** - Four RS-232 serial ports (one configurable as RS-485), & Ethernet
- **DS3** - Four RS-232 serial ports (one configurable as RS-485, & Ethernet, on-board 8 DI and 6 AI, plus optional digital and pulse inputs or additional serial communication ports.
- **DS4** - Four RS-232 serial ports (one configurable as RS485), & Ethernet, plus optional digital and pulse inputs or additional serial communication ports

Each Director includes a microprocessor, Ethernet controller and optional I/O boards, housed in a metal or plastic enclosure. A battery is included, in order to maintain the system clock in the event of power loss. Unit firmware and configuration files are maintained in Flash memory.

Serial ports are supplied via DB-9 termination ports. Ethernet is supplied via a built-in RJ-45 socket. The DS3 is powered on either 9-24 VDC. The DS2 and DS4 typically require 18-30 VDC, but can be supplied with optional (factory fit) power supplies for a nominal 12 or 48 VDC system.

The DS3 and DS4 have space for three optional I/O boards (including Ethernet). Optional boards may consist of the following (MULTI/IO, SER4, and COM4 are available for use but not currently included in the default software configuration):

- AIM104-UPP -- 16 digital inputs, of which 4 may be frequency inputs or 10 may be accumulator. Inputs are 10-30 VDC, with maximum frequency of 100 KHz (for 30 VDC square wave signal).
- AIM104-IN16 -- 16 digital status inputs (10-30 VDC)
- AIM104-MULTI/IO -- 16 analog inputs, 8 digital inputs, 2 analog outputs
- AIM104-SER4 -- 4 RS-232 serial ports
- AIM104-COM4 -- 2 RS-232 and 2 RS-485/422 serial ports

2.2 Software Configuration

The Arcom Configuration Environment (ACE) program is used for setting up the basic configuration of each Director. This is an object-oriented configuration tool that runs under a Microsoft Windows environment. Configurations are created for each Director including DNP or Modbus master and slave parameters, internal databases, IP address, etc. The configurations are then downloaded to the Director using FTP or serial (using terminal program such as Windows HyperTerminal).

A standard set of libraries for ACE, and a default configuration are provided by Arcom. If different configurations are needed for individual Directors, typically these are configured by the customer using the default template; or Arcom can develop these based on standard engineering hourly rates.

The Director's application logic is performed by ISaGRAF, in conjunction with the protocol configuration defined in ACE. ISaGRAF is a third-party IEC61131 software development tool, that includes development, simulation, download, debugging, and project management features.

2.3 DNP Object Support

The DNP objects implemented in the Director include, but are not limited to:

- Object 1, variation 1 (Binary Input)
- Object 10, variation 1 (Binary Output)
- Object 12, variation 1 (Control Relay Output Block - Latch on/off only)
- Object 20, variation 6 (16-bit Binary Counter without Flag)
- Object 20, variation 1 (32-bit Binary Counter)
- Object 21, variation 1 (32-bit Frozen Counter)
- Object 22, variation 2 (16-bit Counter Change Event without Time - flags forced to 1)
- Object 23, variation 5 (32-bit Frozen Counter Event with Time)
- Object 30, variation 4 (16-bit Analog Input without Flag)
- Object 32, variation 2 (16-bit Analog Change Event without Time - flags forced to 1)
- Object 40, variation 2 (16-bit Analog Output Status - flags forced to 1)
- Object 41, variation 2 (16-bit Analog Output Block - Latch only)
- Object 50, variation 1 (Time and Date)

2.4 Basic Operation

Data obtained from external DNP or Modbus devices is stored into internal "real-time databases" (RTDB) in the Director's RAM memory, along with any local pulse or digital inputs on the DS4.

Data is acquired from slave devices into RTDB's using the Director's normal Master Channel configurations, or it may be placed there by an external DNP or Modbus host using a Slave Channel. Only the latest value of each point is stored in the RTDB. Once in the RTDB, the internal logic determines whether a revenue interval has been reached, examines the counter values, and freezes the quantity of points configured for the meter. The total number of frozen counter events (23.5) which may be stored in the Director is limited by available memory.

When configuring the Director, this document uses the term "meter configuration" to refer to one contiguous set of register values in an internal RTDB. If counters from the same physical meter are located in non-contiguous registers, each set of registers will be considered a separate "meter", unless the data is consolidated into the Director's RTDB using appropriate poll definitions. The total number of "meter configurations" in a Director is currently limited to eight.

In addition to freezing revenue data, the Director may also be configured to simply copy data from one RTDB location to another. This may be done in order to consolidate non-revenue data which is presented to a Modbus or DNP host. Each data copy operation uses one of the 8 "meter configuration" slots, and therefore reduces the total available number of revenue meters that can be accessed. For copy operations, most of the configuration parameters are ignored.

Configuration parameters for each meter include:

- Source of data (Channel and RTDB register)
- Quantity of counters to be frozen or copied
- Destination index to freeze data (Slave Channel and point number), or destination RTDB location for internal data copy operations
- Data type of counters
- Source of software LD signal (or disable)
- Source of software EOI signal (or disable)
- Type of EOI (KYZ input, rising-edge pulse, falling-edge pulse)
- Use hardware or software digital input for LD and EOI
- Whether to store counter value directly, or to calculate delta with previous value
- Time between freezes (if using time-based)
- Seconds past top of hour to begin time-based freeze (or start on power-up)
- Counter rollover value, for delta counters
- Scale factor (MWhr per pulse, for pulse inputs)

The Director's internal clock (RTC) may be synchronized with the PJM SCADA system by processing object 50.1 requests from the host. No time synchronization will be performed with DNP meters that are slaves to the Director.

2.5 Status Inputs

Each revenue meter may potentially have two status points. These are the *Load Disconnect* and *End of Interval* statuses. These may be digital inputs on the Director (read by Internal Channel into RTDB), or software RTDB registers from any external source. Some meters may not use one or both of the above status points.

- The *Load Disconnect* (LD) from each meter (hardware or software) is assumed to be true when the counters are operating (revenue data accumulating), and false when the counters are not operating. If the meter continuously collects revenue data, the Director can be configured to ignore this point and assume it to be true constantly.

- The *End of Interval* (EOI) from each meter (hardware or software) is a pulsed digital signal, which will transition upon reaching the end of a revenue interval. This is used by some meters to signal the end of the revenue interval (other meters use a time basis instead). The EOI is recommended to be a KYZ input, meaning it will transition true to false, or false to true, upon each revenue period. It can also be triggered only on the rising edge or falling edge of a pulse signal, but this may not be as reliable, depending on the duration of the pulse width. It is assumed that this value will never transition before the counter values are actually available from the meter.

For any meter, configuration settings determine the software RTDB register into which the LD or EOI inputs are read. In a Director, the LD or EOI points may be physical digital inputs. These will be read from the ISaGRAF RTU using normal Internal Channel poll definitions, making them into software RTDB points, just the same as if obtained from external sources.

When the RTDB register containing the LD status becomes true for a given meter, the Director begins checking the counter value for revenue periods. When the RTDB register containing the EOI status changes to an active state, the Director will trigger a freeze of event data, if configured to use EOI for revenue data collection.

2.6 Revenue Intervals

This section describes how the Director processes data in each revenue interval, including how it determines the beginning and end of the interval.

There are two methods that ISaGRAF uses to store the counter events, which is configurable for each meter configuration. In either case, the *Load Disconnect* indicates that revenue data should be processed. When *Load Disconnect* is true, the end of revenue period will be triggered either:

1) when the Director's clock reaches a configured number of seconds past the top of hour. This causes the Director to freeze counters and start an interval timer. Subsequently, counters are frozen on a configured interval number of seconds. This requires two configuration parameters -- *seconds past top of hour* for the first interval, and number of *seconds between freezes* for each following time interval; or,

2) when the *End of Interval* input for the meter makes an active transition (see Section 2.5); or,

3) the Director may be configured to freeze revenue data based on both time and EOI conditions.

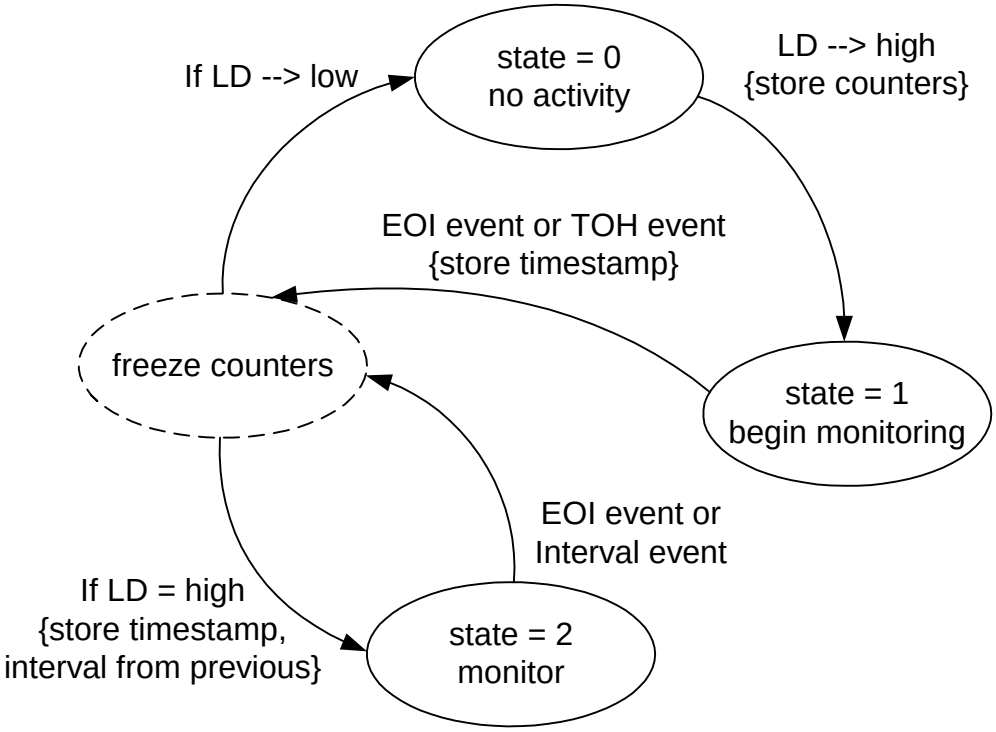
When the *Load Disconnect* signal changes from True to False, the Director will continue monitoring the counter until the next interval (based on time or *End of Interval* status), store that event and then cease checking its counters. Revenue data will not be frozen again until after the LD signal changes to True again.

For delta counters, upon reaching the end of an interval, the Director will subtract the difference between the previous counter values and the current values, and freeze the difference. A configured rollover value is necessary to detect counter rollover for delta counters. For non-delta counters, the Director simply freezes the actual counter value obtained.

On power-up or reset the Director will store previous values for all delta counters.

A state diagram of the revenue interval monitoring and freeze operations is shown below.

PJM Application State Diagram



3 Unit Configuration

This chapter describes the Director configuration, implementation details, and diagnostic information for the Directors as supplied to PJM for the latest phase of the DNP metering project.

The configuration details in this section supplement the full set of Director documentation in order to give the project-specific information to configure the PJM Director, and does not cover the configuration process in every detail. For further reference, see the *APEX/Director Manual Set*, in particular the *ACE Operation Manual* for use of the ACE program, and the *APEX Configuration Manual* for detailed information on each configuration object.

3.1 Configuration Overview

In order to create a configuration for the Director, it is necessary to first identify what needs to be done. The configuration is divided into logical groups, based on these functional requirements. The following suggestions are intended to guide the configuration process.

1. Identify which meters need to polled by the Director. In this context, the meters are the "slaves" and the Director is the "master." Identify the protocol to be used (DNP or Modbus), and the network characteristics (serial port baud rate, etc.) List the location of all data needed from the meter by object or register number. This information is used in creating the "Master Channel" and "Network" configurations.

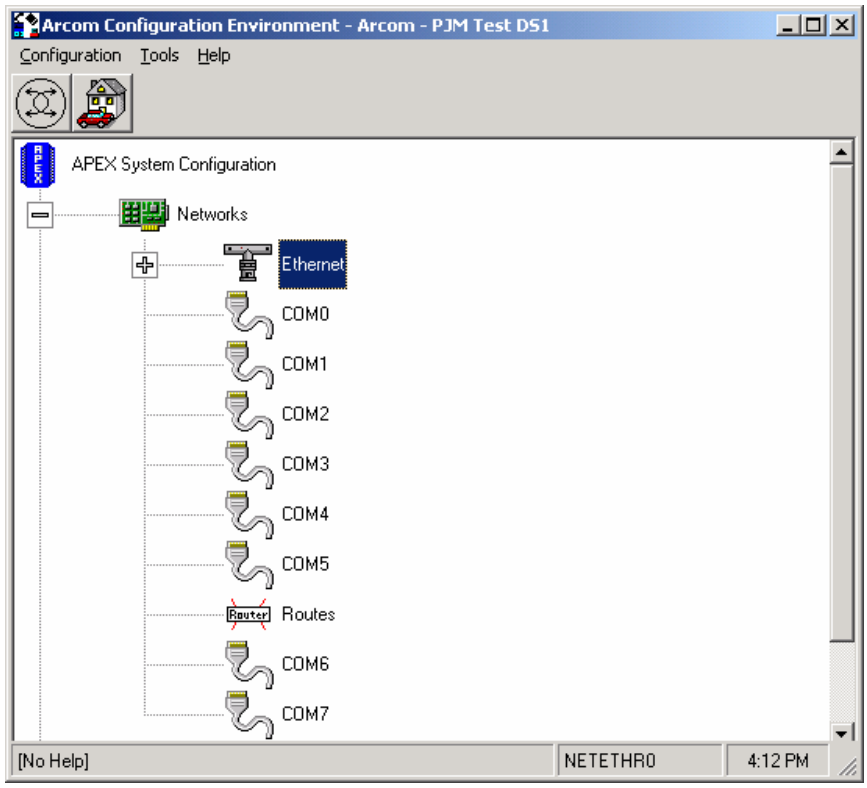
2. If a host system is writing revenue data into a Director, this will require a "Slave Channel" and also a "Virtual RTU" configuration to be set up. In this case, the host system is the "master" and the Director is the "slave" for this data.

3. Identify what host systems (DNP or Modbus) need access to the data, and the network characteristics required (serial port, dial-up, network, encryption, etc.). This will be used to configure "Slave Channel" and "Network" settings.

4. Determine revenue interval type for each meter, whether EOI based or time-based, locations of EOI and LD signal values, etc. Note the quantity of registers to be frozen from each meter. If configuring data copy operations, determine the source and destination RTDB locations. This information will be used to define meter configuration parameters.

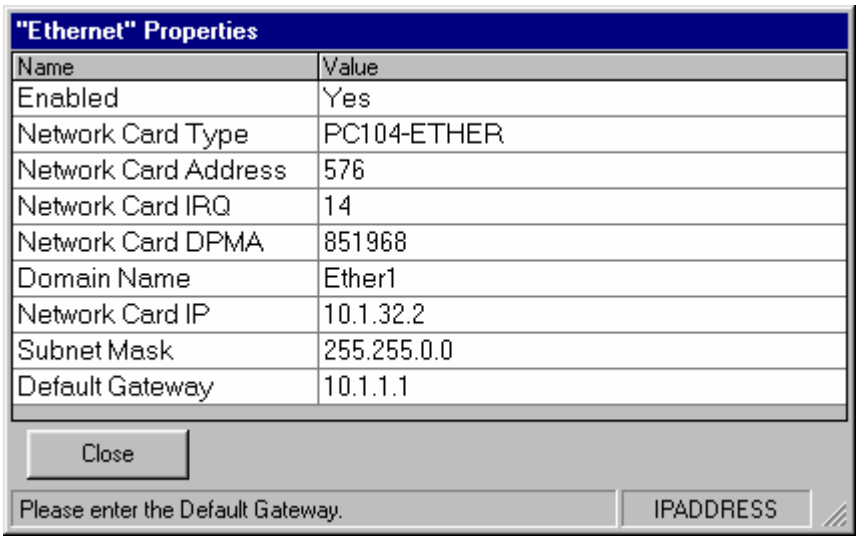
3.2 Networks

The Networks section of the ACE configuration defines the serial and IP network properties for the Director unit. These objects are briefly described in this section.

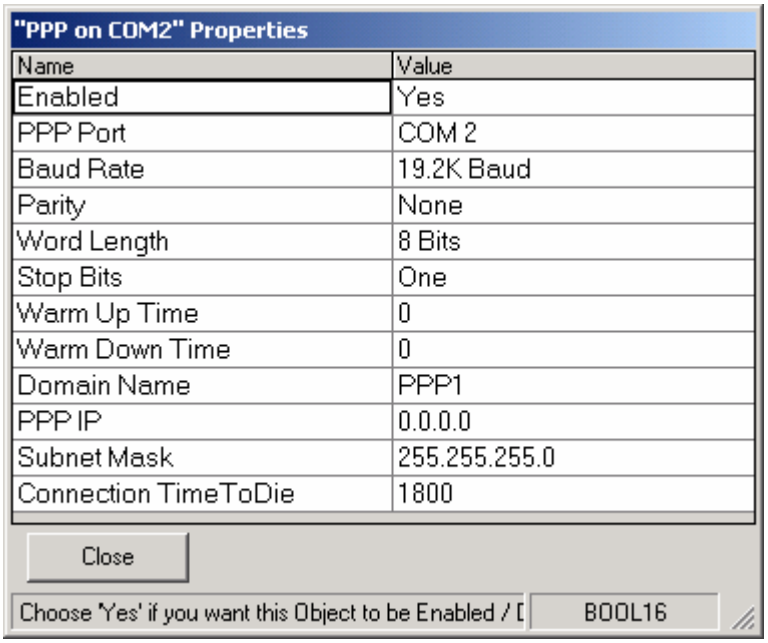


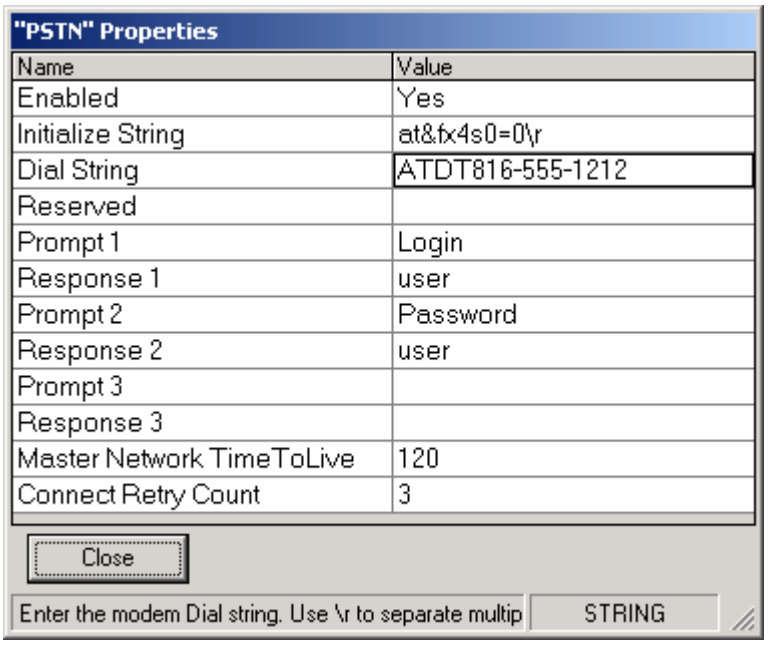
3.2.1 Ethernet and PPP

The TCP/IP settings for Ethernet must be configured for the network on which the Director is to be connected. Consult your network administrator for how to set the **Network Card IP, Subnet Mask,** and **Default Gateway**. Ethernet has an optional Multi-Home child object, which defines additional IP addresses, if necessary.

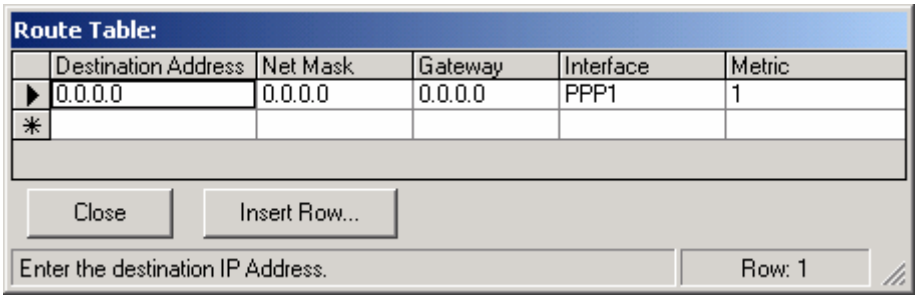


The PPP object can also be configured under Networks. This is only needed if the Director connects to a network via a serial IP dialup using PPP protocol, such as to an Internet Service Provider. PPP includes a Dialer child object.



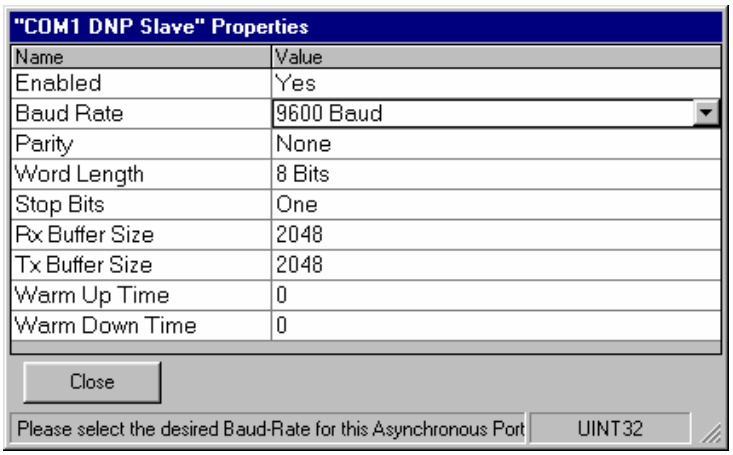


The Routes object is optional, and is necessary only if using PPP or if a custom route table has to be defined. If Ethernet is the only IP network (i.e. there is no PPP network configured), typically the Routes object can be omitted.



3.2.2 Asynch Serial

Asynch serial ports include the configuration of any serial port that is not configured as PPP. Set the **Baud Rate** and other properties to match the device being used, and set the **Warm-up Time** and **Warm-down Time** for appropriate handshaking (see *APEX/Director Configuration Manual* for details). COM3 on the Director DS2, DS3, or DS4 is configurable for RS-485 using link settings.

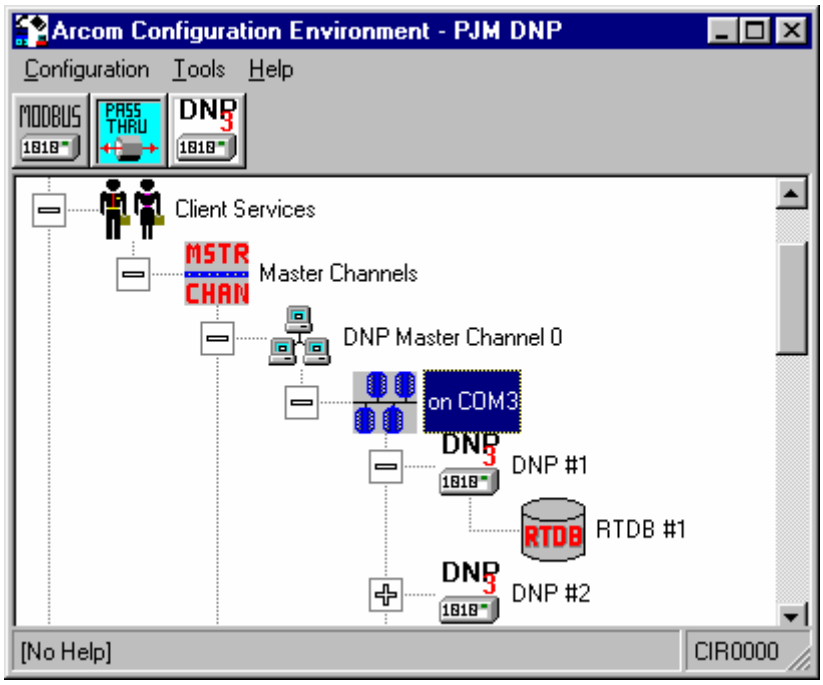


COM ports that are numbered above the available physical ports are considered “virtual COM port pairs”, and are used for internal connections between two tasks. The highest numbered physical port is COM3, so ports COM4 and COM5 are a virtual pair. Data sent into COM4 automatically appears on COM5, and vice versa.

3.3 Master & Slave Channels

3.3.1 DNP Master Configuration

The Director's DNP Master Channel is used to poll the external DNP meters. This section describes the configuration of a DNP master, but nearly the same structure is used for Modbus master channels as well. The main difference is in the Poll Table definition for Modbus type data addresses.



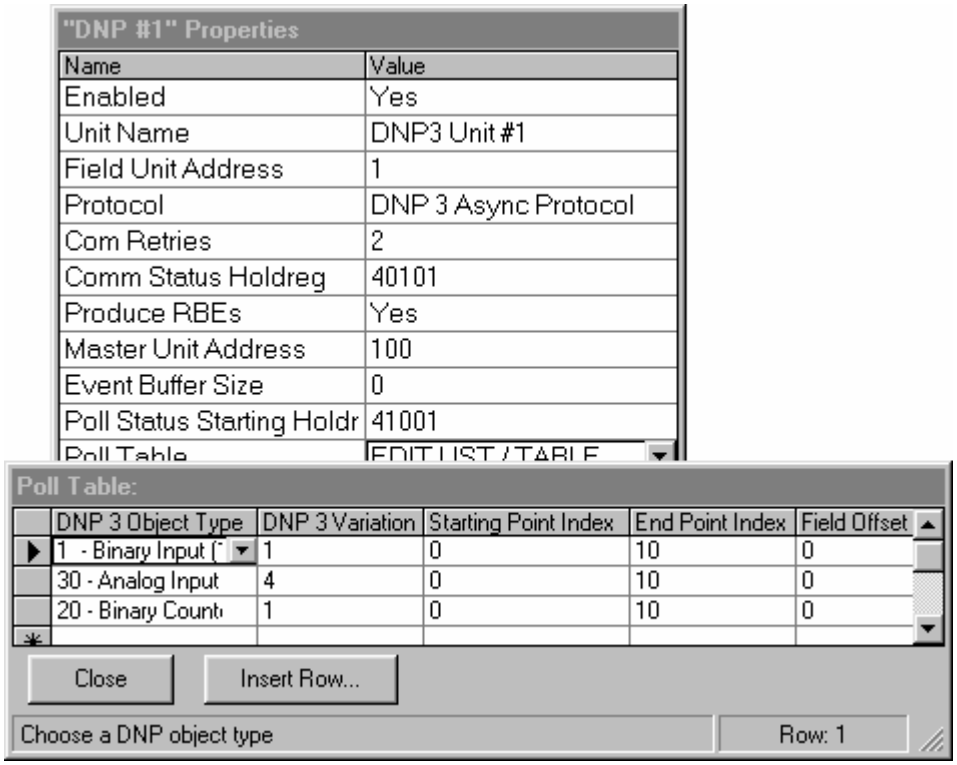
All the data obtained from the DNP meters is stored in a Real-time Database (RTDB) for each meter. Each meter must have its RTDB configured **with the 8 fields defined <u>in the order shown below</u>**, with the quantities of each register type large enough for the number of points being polled by the Director. The RTDB address ranges used for DNP are as follows:

Starting Address	Data Format	DNP Object(s)	Description
1	Boolean	10 (r), 12 (w)	Binary Output
10,001	Boolean	1	Binary Input
30,001	SINT16, SINT32	30	Analog Input
40,001	SINT16, SINT32	40 (r), 41 (w)	Analog Output
31,001	SINT16	31	Frozen Analogs
35,001	SINT32	20.1	Binary (running) Counter
36,001	SINT32	21.1 (23.5 event)	Frozen Counter
41,001	SINT16	N/A	poll counter

Under the DNP outstation icon  you will configure the polling properties of a DNP slave device.

The **Unit Name** is the unit name displayed in the Director diagnostics.
Set the **Field Unit Address** to the slave address of the DNP meter.
The **Master Unit Address** is the address of the Director when talking to this slave meter.
Configure the **Poll Table** to read the appropriate data from the meter. The order of polls is not important, but the polls of specific types will always be stored in the RTDB address ranges defined above.

DNP Object Type/ DNP Variation	Use Object 1.x to read Load Disconnect, End of Interval, and any Instantaneous binary data. Use Object 30.x for any Instantaneous analog data. Use either Object 20.1 or 21.1 to read the running or frozen counters from the meter.
Starting Point Index	Starting index of points in slave device. 0 = first point.
End Point Index	Ending index of points in slave device. Using 0 for Start and End will request all points from the slave device. If this is used, make sure the RTDB is large enough to store all the points that are returned.
Field Offset	Offset into the RTDB to store data, 0=first point in the specified data range. For instance, using an offset of 2 for Object 1.1 will store the resulting data beginning at RTDB register 10,003.



Note that the Analog Input and Output data types may be 16-bit or 32-bit. In order to make this work correctly, the following three things must be configured to match each other:

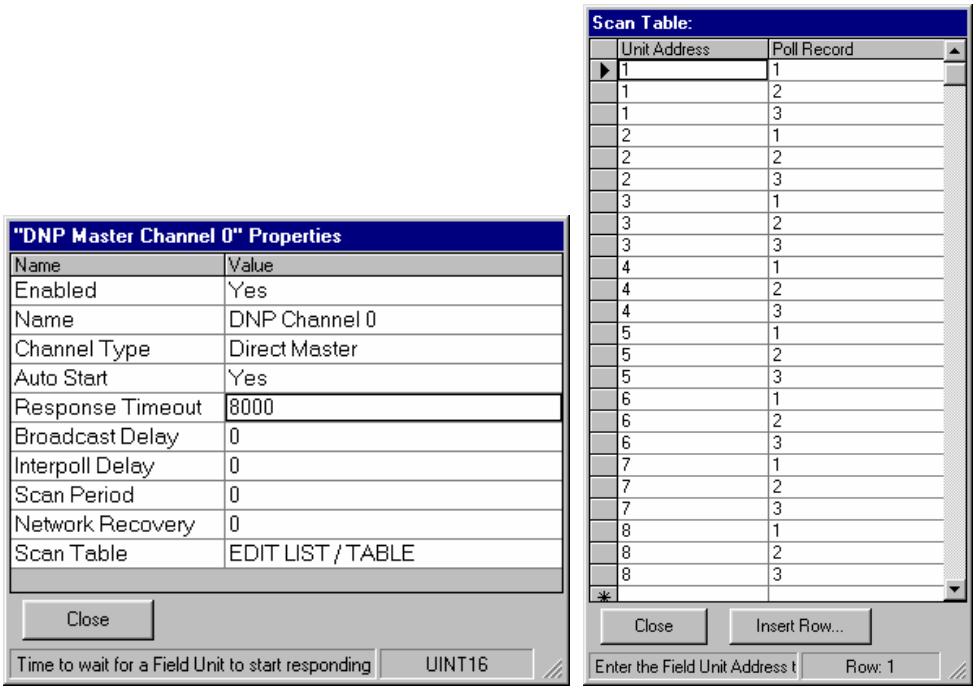
RTDB data type (SINT16 or SINT32)
Poll Table with correct **Object** and **Variation** for the analog type (16- or 32-bit)

DNP Server must also match data type for Analog Inputs and Outputs (see Section 3.3.5).

The **Master Channel** properties must also be set similar to the example below.

The **Response Timeout** should be set for at least several seconds (value is configured in milliseconds). All the other timing parameters can be left at zero.

The **Scan Table** is the list of which polls are sent to each individual meter. The example shows 8 meters, with three polls being used for each. The **Poll Record** correlates with the row number in the meter's Poll Table (see above). If one or more meters is not configured in ACE, or if a meter doesn't have three polls in its Poll Table, those items should be omitted from the Master Channel **Scan Table**.



3.3.2 DNP/Modbus ComSlave

The DNP ComSlave Channel configuration defines how the Director responds to a DNP host. A Modbus ComSlave channel is similar, but using the Modbus slave object rather than the DNP slave.

☞ The **Port** is the COM port that will be used for connection to the master system. If using over a physical serial port (including dial-up modem), set this to the appropriate COM port. If using with DNP over an Ethernet connection, see section 3.3.4, *DNP Network Slave*.

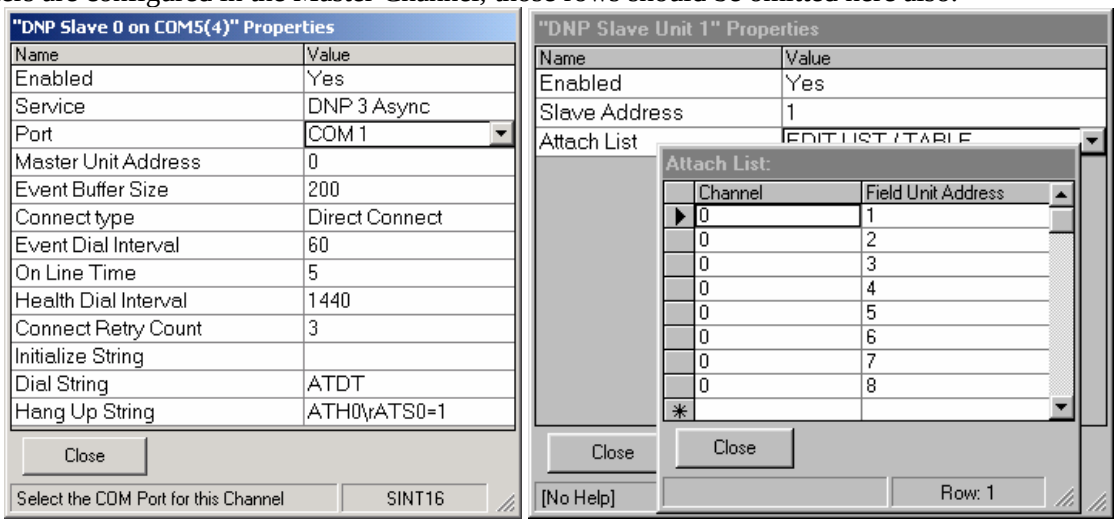
☞ The **Master Unit Address** is the address of the DNP host that is polling the Director. The Director will only respond to the host address specified in this parameter.

☞ The **Event Buffer Size** is the number of object 23.5 events that the Director will store for the connected meters.

☞ Set **Connect Type** to "Direct Connect" to be a slave on hard-wired serial connection, or "Master Dial" to allow the DNP Slave to dial out over a serial modem connection. If set to "Master Dial", the **Event Dial Interval, On Line Time, Connect Retry Count, Initialize String,** and **Dial String** appropriately.

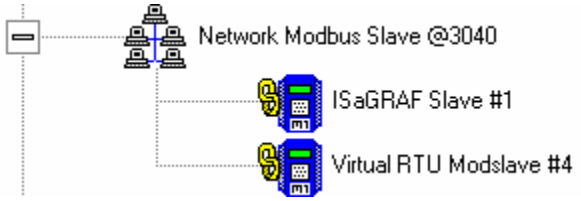
☞ The **Health Dial Interval** is the time interval between dial attempts if there are no stored events. Use this to allow the Director to dial at a much longer interval so the host can ensure it is still communicating, or enter -1 to never dial if there are no unreported events.

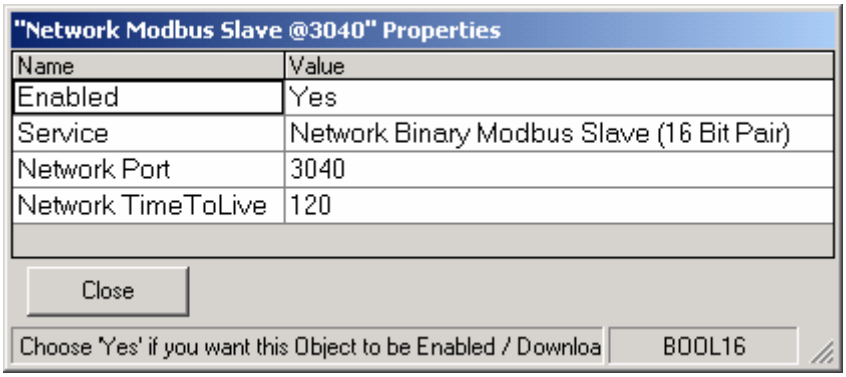
☞ Under the **Slave Unit**, its **Slave Address** is the address of the Director when responding as a slave to a DNP host software. The **Attach List** is the Master Channel number and Unit Address of the individual RTDB's (DNP or Modbus unit data) to present to the DNP host. If less than eight meters are configured in the Master Channel, those rows should be omitted here also.



3.3.3 Modbus Network Slave

In order to poll the Director from a Modbus host over TCP/IP, use a Network Modbus Slave object. The Network Modbus Slave includes an IP port configuration, which can be set to any unique IP port greater than 1000 in the Director. Its Slave Attach object is configured similar to the Slave Attach described in Section 3.3.2.



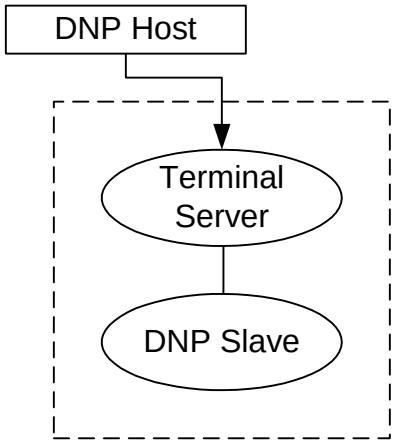


3.3.4 DNP Network Slave

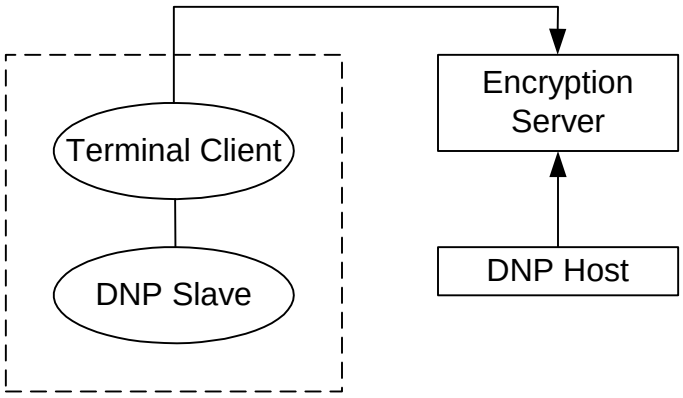
In order to poll the Director from a DNP host over TCP/IP, the standard serial slave channel (described above in Section 3.3.2) is used in conjunction with a network client or server object to convert the serial DNP data to IP. (Note that the ACE configuration also includes a DNP NetSlave object, but this should not be used in cases where archived event data is required.)

The client/server object should be chosen as follows:

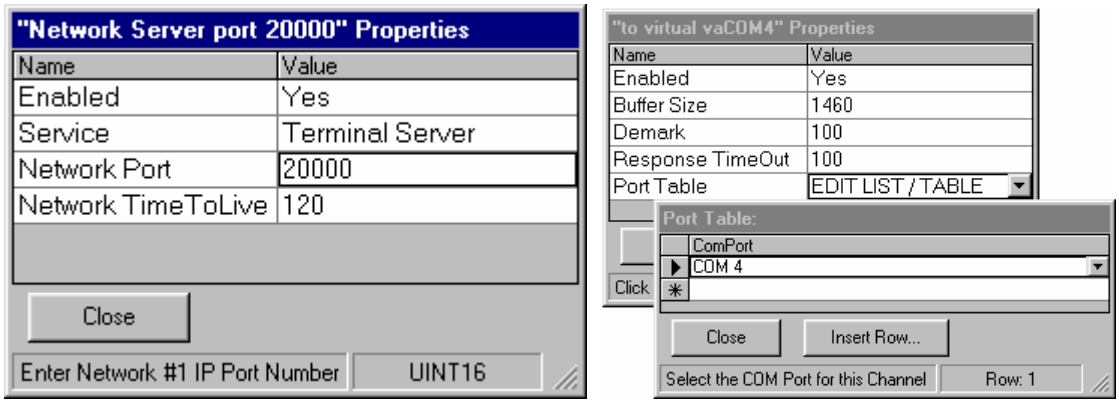
- **Terminal Server** - Use this when the host DNP computer initiates connections to the Director. This would be on a permanent TCP/IP network, where data is not required to be encrypted.



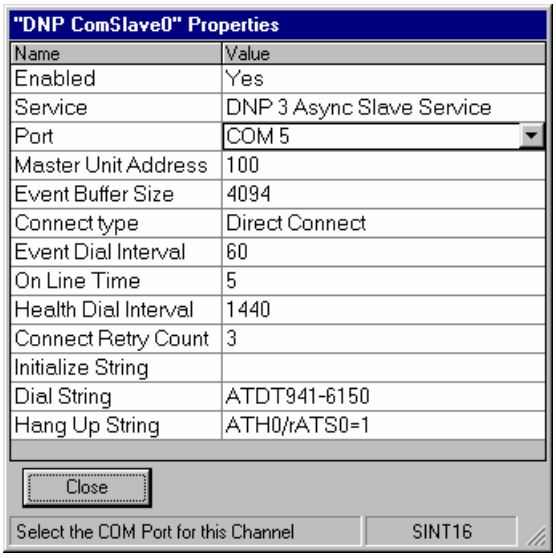
- **Terminal Client** - Use this when the Director initiates connections to a host computer, and/or when Comverge encryption is required. Typically this would be over dial-up to the Internet, but it may also be used over Ethernet.



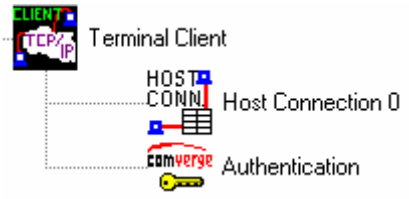
The Terminal Server object is configured underneath Servers.



☞ The Terminal Server is linked to the Serial DNP Slave Channel by use of an internal (virtual) COM port pair, COM ports 4 and 5. Any data that appears on either COM4 or COM5 is automatically transferred to the other port.

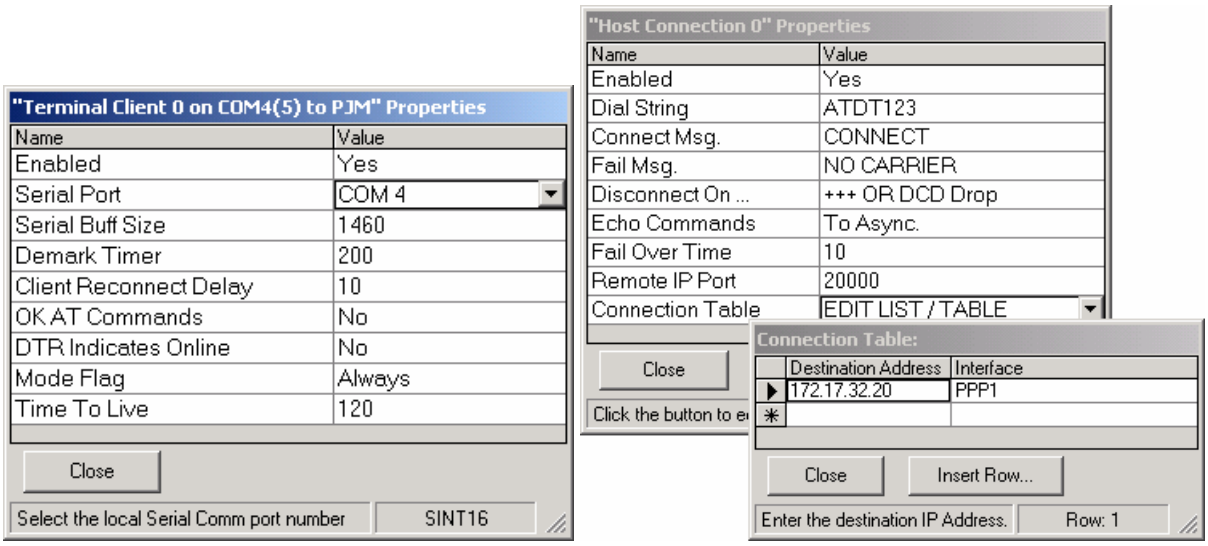


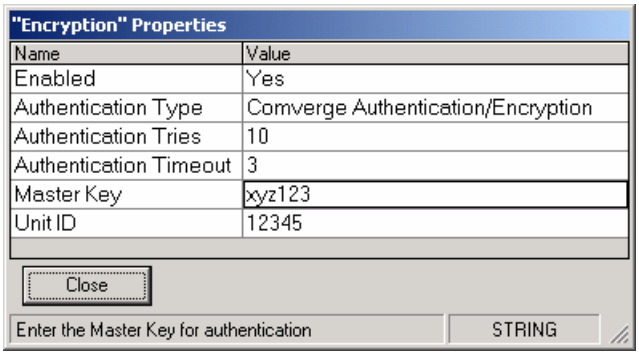
The Terminal Client is configured under Client Services.



☞ Configure the **Remote IP Port** to be the IP port at which to connect to the Comverge encryption server, the **Destination Address** is the IP address of the server, and the **Interface** is the name assigned in the properties of either the Ethernet or PPP object (depending on whether dial-up PPP or Ethernet is used for the connection). All the other properties are used to allow the DNP Slave Channel to initiate the Terminal Client connection

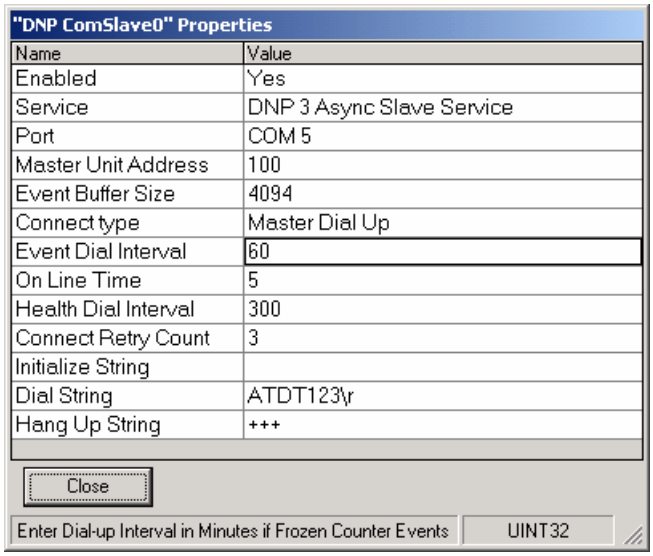
The **Authentication** object is used to define the authentication parameters into the Comverge server. **Master Key** and **Unit ID** will be assigned prior to commissioning.





In this case, the Serial DNP Slave Channel uses internal (virtual) COM port pairs to connect to the Terminal Client task. The "Master Dial Up" option would normally be used to dial a physical modem, but in this case it is used to "dial" the virtual modem presented by the Terminal Client. When the DNP Slave "dials," it uses an AT string of "ATDT123." The Terminal Client (above) is configured that whenever it sees the "ATDT123" string coming from its (virtual) serial port, it will make an IP connection to the configured IP address and port number. After connecting to the server, the Director will be authenticated. If authentication is successful, all subsequent communication between the DNP host and the Director's DNP slave will be encrypted.

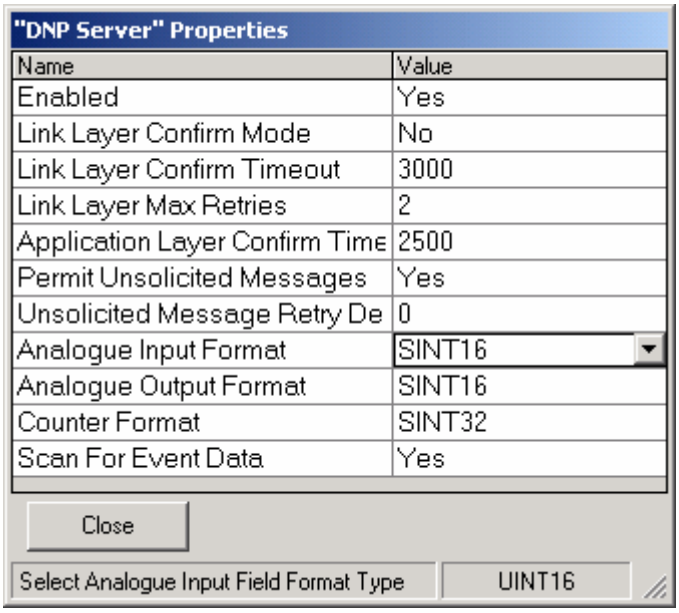
☞ **Event Dial Interval** determines how long in between dial-out attempts, if there are events to be reported to the host. If there are no events for period of time longer than the Event Dial Interval, the Director will still connect out at the **Health Dial Interval**. Once connected, the Director will disconnect after the **On Line Time** interval. All three timers are expressed in minutes.



3.3.5 DNP Server object

The DNP Server task controls DNP protocol handling on both the master and slave channels of the Director.

☞ For this application, the important things to configure are: **Analogue Input Format** (for instantaneous analog values), **Counter Format** (must be SINT32 to support object 20.1 and 21.1), and **Scan For Event Data** must be set to "Yes" to store frozen counter events.



3.4 Internal (ISaGRAF) Channel

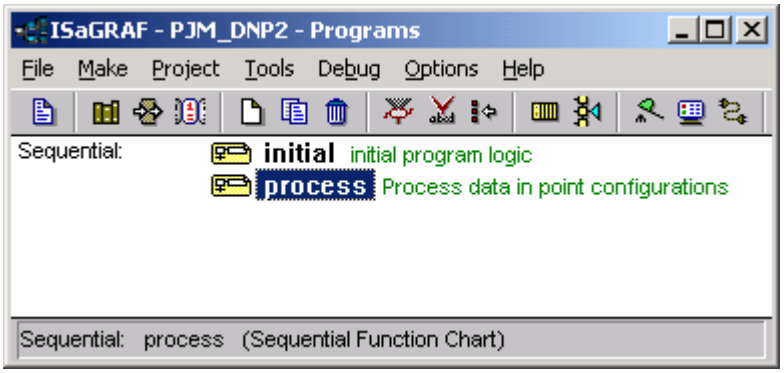
The internal Director logic and I/O are treated as a separate RTU called “ISaGRAF”. This RTU essentially runs stand-alone inside the Director, and I/O transactions between the Director system and the ISaGRAF RTU are handled in a parallel manner to the way in which external RTUs are polled. This section describes the unique configurations necessary for the Internal Channel.

3.4.1 ISaGRAF RTU

The ISaGRAF RTU contains the three elements contained in a typical RTU: I/O points, memory registers, and logic. The RTU logic and setup are defined in the ISaGRAF Workbench, and downloaded to the Director system. When combined with the Director operating system, it adds much functionality and power to the capabilities of the Director product.

The I/O of the ISaGRAF RTU represents internal Modbus holding register space, as well as any external analog or digital signals that may be present on the DS3 or DS4. The logic of the ISaGRAF RTU handles not only this I/O, but can interact with RTDB databases throughout the Director system (other Master Channels), and also provides the logic to trigger frozen counters and counter events on each revenue interval.

The ISaGRAF project name is ‘PJM_DNP2,’ and it contains the functional program blocks shown below. The ‘process’ program is the main logic routine which controls the data copy and freeze operations in this project.



The I/O boards and Modbus registers built into the ISaGRAF project are given in the following table. These addresses will be necessary in determining the Poll Table of the ISaGRAF RTU definition in ACE.

aimpsu	Only used in DS3 for built-in AI and DI signals
aimupp	Optional AIM104-Pulse (DI/pulse input board for DS3/DS4)
aimrelay	Optional AIM104-Relay8/IN8 (DO/DI board for DS3/DS4)

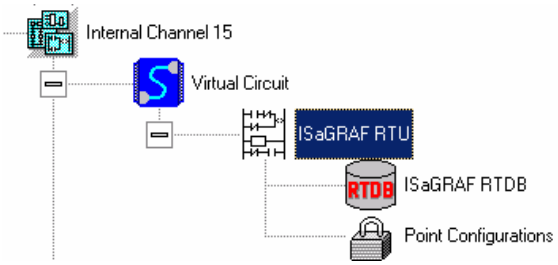
Board	Type	Modbus	Description
aimrelay/ rly8out	DO	00,001 - 00,008	DO's from Relay8/IN8 board
coil32	Coil	00,009	LD read from a given meter
		00,010	EOI read from a given meter
		00,011	"Single Loop" flag for troubleshooting
		00,012 - 00,017	*These registers contain flags calculated based on configured meter parameters for the meter data currently being processed.*
		00,012	True if the "meter configuration" defines a copy operation, as opposed to a revenue data freeze operation.
		00,013	True if EOI is checked for freezing data of this meter.
		00,014	True if time is checked for freezing data of this meter.
		00,015	LD source: True if LD is obtained from Director DI's, False if from a different RTDB.
		00,016	EOI source: True if EOI is obtained from Director DI's, False if from a different RTDB.
		00,017	Delta counter: True if counter is delta counter (Director will freeze difference), False if running counter (Director freezes actual value).
		00,018 - 00,023	*These registers contain diagnostic bits set during each scan of a given meter. They are included for diag purposes.*
		00,018	Array success - 0 if internal arrays are initialized successfully on startup.
		00,019	EOI Event: True during a given meter cycle, if a valid transition is received on EOI for this meter.
		00,020	TOH Event: True during a given meter cycle, if the "Seconds past top of hour" is reached for this meter.
		00,021	Interval Event: True during a given meter cycle, if the interval timer is exceeded for this meter.
		00,022	Store Counters: True during a given meter cycle, if the counters are to begin to be stored for delta counters.
		00,023	Freeze Counters: True during a given meter cycle, if the counters are frozen for this meter.
		00,024 - 00,040	Unused
coil32	Coil	00,033 - 00,064	Unused
aimpsu/ aimpsudi	DI	10,001 - 10,008	DS3 digital inputs
aimupp/ aimuppstat	DI	10,009 - 10,024	DI's from AIM104-Pulse board

aimrelay/ rly8in	DI	10,025 - 10,032	DI's from AIM104-Relay8/IN8 board
aimpsu	AI	30,001 - 30,008	DS3 analog inputs
hold32	HoldReg	40,001	Current meter config being processed.
		40,002	Manual loop number, used to troubleshoot a specific meter config.
		40,003 - 40,017	*These registers contain the parameters configured for the meter data currently being processed, descriptions below in Section 3.4.3.*
		40,003	Quantity of RTDB registers.
		40,004	Source channel of data.
		40,005	Source unit.
		40,006	Starting source RTDB register.
		40,007	Destination channel (Master or Slave) for copy/freeze.
		40,008	Destination unit number.
		40,009	Starting destination register (for copy) or slave channel point # (freeze).
		40,010	Type of register.
		40,011	EOI type.
		40,012	LD register.
		40,013	EOI register.
		40,014	Seconds between freezes.
		40,015	Seconds past top of hour for freeze.
		40,016	Counter rollover value.
		40,017	Scale value for pulse inputs.
		40,018 - 40,019	unused
		40,020 - 40,027	*These registers are included for troubleshooting purposes.*
		40,020	Internal pointer to last stored counter value.
		40,021	Result of reading LD signal from RTDB
		40,022	Result of reading EOI signal from RTDB
		40,023	Result of reading counter from RTDB
		40,024	Result of a DMOV (internal data copy)
		40,025	Index number used when looping through multiple freeze points in a given meter config.
		40,026	Total number of counters frozen in Director since last reset.
		40,027	Total number of errors in freezing counters since last reset.
		40,028 - 40,032	unused
hold32	HoldReg	40,033 - 40,064	unused
rtc	System Clock	40,065	Milliseconds
		40,066	Seconds
		40,067	Minutes
		40,068	Hours
		40,069	Day
		40,070	Month
		40,071	Year

		40,072	Clock status (1=running from hardware)
hold32	HoldReg	40,101 - 40,132	Storage of current counter values (UINT16)
hold32	HoldReg	40,133 - 40,164	Storage of current counter values (UINT16)
		40,165 - 40,260	reserved
hold32	HoldReg	40,301 - 40,332	Storage of previous current values (UINT16)
hold32	HoldReg	40,333 - 40,364	Storage of previous current values (UINT16)
		40,365 - 40,460	reserved
store16 (total of 8)	Flash	40,461 - 40,620	Meter configuration values, defined in ACE 'LoadStore' board (16 registers defined per meter config). These values are stored in Flash memory, and are read from the 'ls15000000' file upon Director startup.
		40,621 - 40,972	Reserved
aimupp/ uppfreq	Frequency	41,001 - 41,004	Frequency counter (Hz) of first 4 inputs on AIM104-Pulse board.
aimupp/ uppaccum	Accumulator	41,005 - 41,014	Accumulator (pulse counter) of first 10 inputs in AIM104-Pulse board.
long32	HoldReg	41,015 - 41,046	unused long integers
hold32	HoldReg	41,101 - 41,132	Temporary storage of registers for scaling short integers.
long32	HoldReg	41,301 - 41,332	Temporary storage of registers for scaling long integers.
long32	HoldReg	42,101 - 42,132	Storage of current counter values (UINT32)
long32	HoldReg	42,133 - 42,164	Storage of current counter values (UINT32)
		42,165 - 42,260	reserved
long32	HoldReg	42,301 - 42,364	Storage of previous counter values (UINT32)
long32	HoldReg	42,301 - 42,364	Storage of previous counter values (UINT32)
		42,365 - 42,460	reserved

3.4.2 ISaGRAF RTU & Channel

The ISaGRAF RTU should be defined as shown, in order to poll for the correct set of ISaGRAF data as described in the table in Section 3.4.1. Not all RTU data is polled for, as some is not necessary to bring into the ISaGRAF RTDB. The Internal Channel **must** be configured as channel 15, and the ISaGRAF RTU must be unit address 1.



"ISaGRAF RTU" Properties

Name	Value
Enabled	Yes
Unit Name	ISaGRAF RTU
Unit Address	1
Protocol	IsaGraf Logic Unit
Com Retries	3
Comm Status Holdreg	0
Produce RBEs	No

Poll Table:

Source Register	Source Format	Count	Destination Register
1	Boolean	32	1
10001	Boolean	32	10001
30001	16 bit register (HL)	8	30001
40001	16 bit register (HL)	72	40001
41005	32 bit register (hlHL)	10	35001

Close | Insert Row... | Choose a Source register from 1 to 65535. | Row: 1

The ISaGRAF RTDB and Internal Channel must be defined as shown:

"ISaGRAF RTDB" Properties

Name	Value
Enabled	Yes
Database Definition	EDIT LIST / TABLE

Database Definition:

Point Count	Field Format	Data Address
100	Boolean	1
100	Boolean	10001
100	UINT16	30001
100	UINT16	40001
0	UINT16	31001
20	UINT32	35001
10	UINT32	36001
10	REAL32	41001

Close | Insert Row... | Enter number of points | Row: 1

"Internal Channel 15" Properties

Name	Value
Enabled	Yes
Name	Internal Chan
Channel Type	Internal Channel
Auto Start	Yes
Response Timeout	32767
Broadcast Delay	0
Interpoll Delay	0
Scan Period	0
Network Recovery	0
Scan Table	EDIT LIST / TABLE

Scan Table:

Unit Address	Poll Record
1	1
1	2
1	3
1	4
1	5

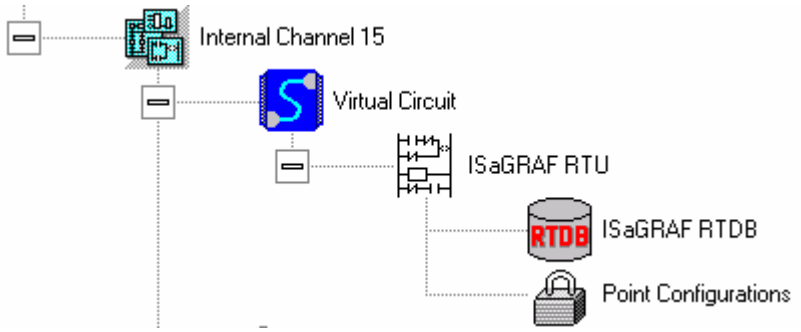
Close | Insert Row... | Enter the Field Unit Address to Poll. | Row: 1

3.4.3 User-defined Configuration Parameters

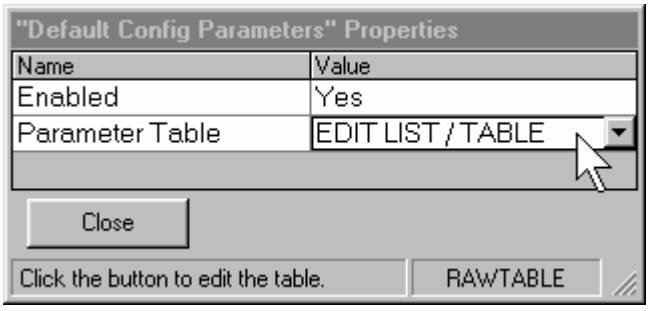
In the PJM ISaGRAF application, there are configuration parameters necessary to make the Director act according to the requirements described in Section 1 of this document.

These parameters cause the ISaGRAF program to know how to handle meter data, how and when to freeze counters, and how to copy data between RTDB registers. They are defined in the ACE configuration using a "LoadStore" board, and appear in the Director in non-volatile memory registers.

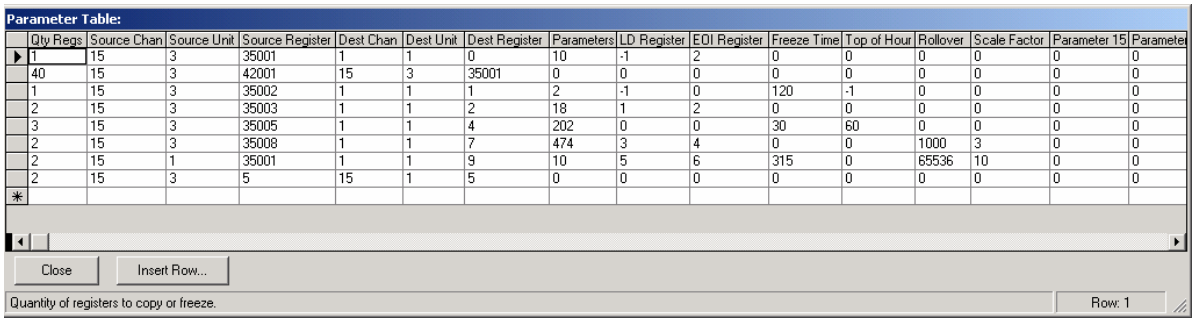
The ACE object is a child to the ISaGRAF unit, and displays with the  icon, below.



Open the LoadStore properties, and click on the "Parameter Table".



The parameters are listed in groups of 16 on each row of the table, with each column labeled with a heading. Each row in the LoadStore table defines one “meter configuration”, or one discrete set of operational characteristics for handing a group of data registers. Only the first 10 rows are used, and any further rows will be ignored.



Qty Regs	Source Chan	Source Unit	Source Register	Dest Chan	Dest Unit	Dest Register	Parameters	LD Register	EOI Register	Freeze Time	Top of Hour	Rollover	Scale Factor	Parameter 15	Parameter
1	15	3	35001	1	1	0	10	-1	2	0	0	0	0	0	0
40	15	3	42001	15	3	35001	0	0	0	0	0	0	0	0	0
1	15	3	35002	1	1	1	2	-1	0	120	-1	0	0	0	0
2	15	3	35003	1	1	2	18	1	2	0	0	0	0	0	0
3	15	3	35005	1	1	4	202	0	0	30	60	0	0	0	0
2	15	3	35008	1	1	7	474	3	4	0	0	1000	3	0	0
2	15	1	35001	1	1	9	10	5	6	315	0	65536	10	0	0
2	15	3	5	15	1	5	0	0	0	0	0	0	0	0	0

Below is a description of each configuration parameter and how it affects the operation of the Director ISaGRAF logic program.

Field	Name	Description
1	Qty Registers	Number of registers in meter RTDB to freeze or copy. 0 = ignore this meter config (row in LoadStore object).
2	Source Channel	Master channel number of RTDB which is the source of data. Data is placed into RTDB either through DNP or Modbus master polling, or it may be from the ISaGRAF or other internal channel RTDB.
3	Source Unit	Unit address for RTDB which is the source of data.
4	Starting Register	First register address of source of data within RTDB. Copy/Scale: For copy operations, this may be any valid RTDB address. Freeze: For freeze operations, this will typically be a 35,xxx or 36,xxx address for running or frozen counters.
5	Destination Channel	Copy/Scale: Master Channel number of RTDB into which data will be copied. Freeze: Slave Channel number for DNP slave unit into which frozen counter values are to be stored.
6	Destination Unit	Copy/Scale: Unit address in Destination Master Channel into which RTDB data will be copied. Freeze: Slave Channel unit address into which frozen counter values are to be stored.
7	Destination Register	Copy/Scale: Starting register address in RTDB to which data will be copied. Freeze: Starting point number into which to freeze counters for this meter configuration. Point number is an offset, with zero being the first counter.
8	Parameters	Bit-weighted configuration register, containing parameters determining how to freeze data. Following this table is a complete description of these parameter bits. Copy: For copy operations with no scaling, this and all subsequent LoadStore fields may be set to 0. Scale: Set data type of source and destination data in bits 0-2 and 9-11. Decimal values are: 513 (16->16 bit), 514 (32 ->16 bit), 1025 (16->32 bit), 1026 (32->32 bit). Source type of zero is assumed 32-bit, destination type of zero is assumed same as source. The following bits are used. Bits 0-2: Source data type Bits 3-8: unused Bits 9-11: Destination data type Freeze: The following bits are used. Bits 0-2: Counter data type Bits 3-5: EOI type Bit 6: Use Hardware LD (local input) Bit 7: Use Hardware EOI (local input) Bit 8: Delta counter
9	Load Disconnect register	Copy/Scale: Unused. Freeze: Register number to acquire *Load Disconnect* status. If

		"Use Hardware LD" is True, the register is taken from Channel 15, Unit 1 (ISaGRAF) RTDB. If False, the register is taken from the configured "Source Channel/Source Unit" RTDB. In order to enable LD constantly (always freeze), set this value to zero. In this case, the "Use Hardware LD" is ignored.
10	End of Interval register	Copy/Scale: Unused. Freeze: Register number to acquire *End of Interval* status. If "Use Hardware EOI" is True, the register is taken from Channel 15, Unit 1 (ISaGRAF) RTDB. If False, the register is taken from the configured "Source Channel/Source Unit" RTDB. If there is no End of Interval signal to indicate revenue intervals, leave this field zero.
11	Seconds between Freezes	Copy/Scale: Unused. Freeze: For time-based meters, interval number of seconds to freeze counters. *Load Disconnect* must be true or disabled before counters will be frozen. If this field is set to 0, no time-based freeze will occur. If "Seconds past top of hour" is enabled, the data will be frozen periodically beginning from the time that the Director's clock reaches the starting time past the top of a given hour until the LD signal changes to False.
12	Seconds past top of hour	Copy/Scale: Unused. Freeze: For time-based meters, number of seconds past top of hour to store first frozen counter event, if *Load Disconnect* is True. If this field is set to -1, time-based freezes won't wait for the seconds past top of hour, but will begin as soon as LD becomes true. If "Seconds between Freezes" is set to 0 (disabled), this parameter is ignored.
13	DNP Rollover value	Copy: Unused. Scale: Set this parameter to '1' to scale analogs as signed integers. Otherwise, they will be scaled as unsigned integers. Freeze: Rollover value to use for delta counters. Local pulse inputs should use 65536 as the rollover. If this parameter is set to 0, it will be assumed as 65536 for 16-bit counters, or 2,147,483,647 for 32-bit counters.
14	Multiplication factor	Copy/Freeze: Unused. Scale: Multiplicative scaling factor for values. See below for example of scaling. If factor is left at zero, it is assumed to be 1. Unused for copy-only operation.
15	Division factor	Copy/Freeze: Unused. Scale: Division scaling factor for values. If factor is left at zero, it is assumed to be 1. Unused for copy-only operation.
16	Scaling offset	Copy/Freeze: Unused. Scale: Offset added to scaled value after multiplication and division. Unused for freeze and copy-only operations.

Scaling parameters (14-16) are used to scale counters prior to freezing and for scaled copy operations. This will allow counter values to be scaled to engineering units, and analog values may be scaled

and/or copied to different data type registers (16/32 bit). Some important notes on this feature are listed below:

1) Leaving parameters 14-16 as zero values will always result in a simple copy operation. Simple copy operations must use the same datatype for both source and destination (parameter 8, bits 0-2 and 9-11 will be ignored).
2) Setting any one of the parameters 14-16 on a copy operation will result in a copy&scale. Any time scaling is done for copy&scale or freeze operations, a multiplication or division factor configured to zero is assumed to be 1.
3) To copy data between different data types, the copy&scale feature must be used (set bits 0-2 and 9-11 to specify source and destination data types).
4) For a copy&scale operation where either source or destination data type is not set (zero value), data type is assumed to be 32-bit.
5) Copy&scale operations are limited to max of 32 registers. Simple copy operations are limited to 1024 (Booleans), 124 (16-bit values), or 62 (32-bit values).

Description of Parameters field

The Parameters field (item #8 above) is a bit-weighted value describing various options for the counter. A given meter configuration must be defined by its functional characteristics, and then this field is calculated as the sum of the various components, as described below.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Desc	xxx	xxx	xxx	xxx	d2	d1	d0	delt	eoi	ld	e2	e1	e0	c2	c1	c0

c2 c1 c0	**Counter/Source Register type**
0 0 0	reserved (Bool)
0 0 1	16-bit integer
0 1 0	32-bit integer
0 1 1	reserved (Float)
1 0 0	unused
. . .	
1 1 1	unused

e2 e1 e0	**EOI type**
0 0 0	No EOI (only time-based freeze)
0 0 1	KYZ - both transitions trigger freeze
0 1 0	Rising edge of pulse is trigger
0 1 1	Falling edge of pulse is trigger
1 0 0	unused
. . .	
1 1 1	Unused

ld	Use hardware Load Disconnect input (0=get LD from Source Channel RTDB, 1=get LD from ISaGRAF RTDB channel 15)

eoi	Use hardware End of Interval input (0=get EOI from Source Channel RTDB, 1=get EOI from ISaGRAF RTDB channel 15)

delt	Counter is a delta counter. Instead of freezing the RTDB value, the Director will calculate the difference in counter value from previous revenue interval. (1=delta, 0=normal)

d2 d1 d0	**Destination Register type** (Scale)
0 0 1	16-bit
0 1 0	32-bit
others	unused

The "Parameters" value entered in the LoadStore object is an integer, calculated from the values of all bits which are turned on.

Example of Parameter 8 bits:

Counter values for a meter configuration are 32-bit integer, non-delta counter. The EOI signal is a KYZ type. Both the LD and EOI inputs are taken from hardware digital inputs on the Director. The Parameters field is calculated below for this example. The fourth row in the table below shows the relative value of each bit position, and these values are added together.

Bit#	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Desc								delt	eoi	ld	KYZ EOI			32-bit int		
On/off	0	0	0	0	0	0	0	0	**1**	**1**	0	0	**1**	0	**1**	0
Value								256	**128**	**64**	32	16	**8**	4	**2**	1

Parameters field = 128 + 64 + 8 + 2 = 202

Example of Scaling Factors:
If scaling is used (any of parameters 14-16 set to non-zero, operation is as follows:

Freeze operations:
frozen_value = original * mult factor / div factor
(or delta of frozen_value, if delta counter type selected)

Copy&scale operations:
scaled_value = (original * mult factor / div factor) + offset

3.5 I/O Setup

This section describes briefly how the I/O configuration must be set up for the Director.

3.5.1 Hardware Revenue Inputs

Hardwired *Load Disconnect* and *End of Interval* status inputs are connected to the Director's optional AIM104-Relay8/IN8 digital I/O board, or from built-in digital inputs on the DS3. These signals are polled internally from the ISaGRAF RTU at the Modbus addresses listed in Section 3.4.1, and are stored into the ISaGRAF RTDB.

For a given meter configuration, if the hardwired LD or EOI inputs are used, then the "Use hardware Load Disconnect" (or Use hardware End of Interval) flag is set. This tells the program logic to take the LD or EOI value from ISaGRAF's RTDB register, rather than the Source Chan/Unit that is configured.

A closed contact *Load Disconnect* input means the revenue data will be collected, and open contact means that revenue data will not be collected.

Pulse meters should be connected to the AIM104-Pulse input board. The pulse values will be read from the appropriate ISaGRAF RTDB field locations for accumulators, as UINT32 data type.

3.5.2 Software Revenue Inputs

Software *Load Disconnect* and *End of Interval* signals are acquired using the Master Channel (see Section 3.3.1, above). Use the Master Channel number and Field Unit address as the "Source" of the data in the meter configuration.

Running counters or Frozen counters from DNP meters are obtained by configuring the DNP Master Channel to poll either an Object 20.1 or an Object 21.1 for the appropriate points in the slave meter's database. As above, user-defined parameters must be set so that ISaGRAF knows where in the RTDB to find the revenue meter value, and whether to store the actual counter value or the delta.

3.5.3 Software Instantaneous Inputs

Any analog or digital instantaneous values are configured by including polls in the DNP or Modbus Master Channel to request the appropriate points. These are passed through to the DNP Slave Channel, where the RTDB's may be concatenated to each other to make one large DNP slave database. The host software requests data from the Director via the Slave Channel using the Modbus or DNP protocol.