APPLICATION AND FIELD EXPERIENCE OF A DIGITAL SUBSTATION SWITCH AT SAVANNAH ELECTRIC AND POWER COMPANY

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Richard Spain

Savannah Electric and Power Company
Savannah GA

and

Kenneth Fodero
Gary Hoffman

RFL Electronics Inc.
Boonton NJ

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INTRODUCTION

There has been an increase in the use of solid-state, microprocessor-based relays, fault recorders, meters, and programmable controllers in transmission and distribution substations. These devices can be remotely interrogated or programmed, and can send reports back to a host computer through their RS-232 communications ports. These devices use a wide variety of communications software and protocols. Because these devices can be located in the substation yard, induced surges and voltages can be present on the communication lines. This can impair the ability to communicate over RS-232 lines, and even cause equipment damage. In addition, the distance from the control house to the substation yard can limit the use of standard RS-232 protocol.

For greater system economy, several devices must use the same communications channel. This requires a means of reliably connecting several devices to the incoming and outgoing communications circuits. This paper describes a digital substation switch (DSS) that was designed for this application, and its initial installation and field experience at Savannah Electric. The DSS connects various meters, transmission relays, and distribution relays to PC's in remote locations through a voice-grade telephone circuit. In this application, the DSS uses a fiber loop to communicate with the devices in the substation yard.

DESIGN CONSIDERATIONS

There are several approaches that can be taken to communicate with several RS-232 device ports. The first is running individual communication circuits to each device. Although this is the easiest method, it is also the most expensive. The value of the information that can be retrieved does not justify the leasing cost of the telephone circuits required for this method. (See Figure 1.)

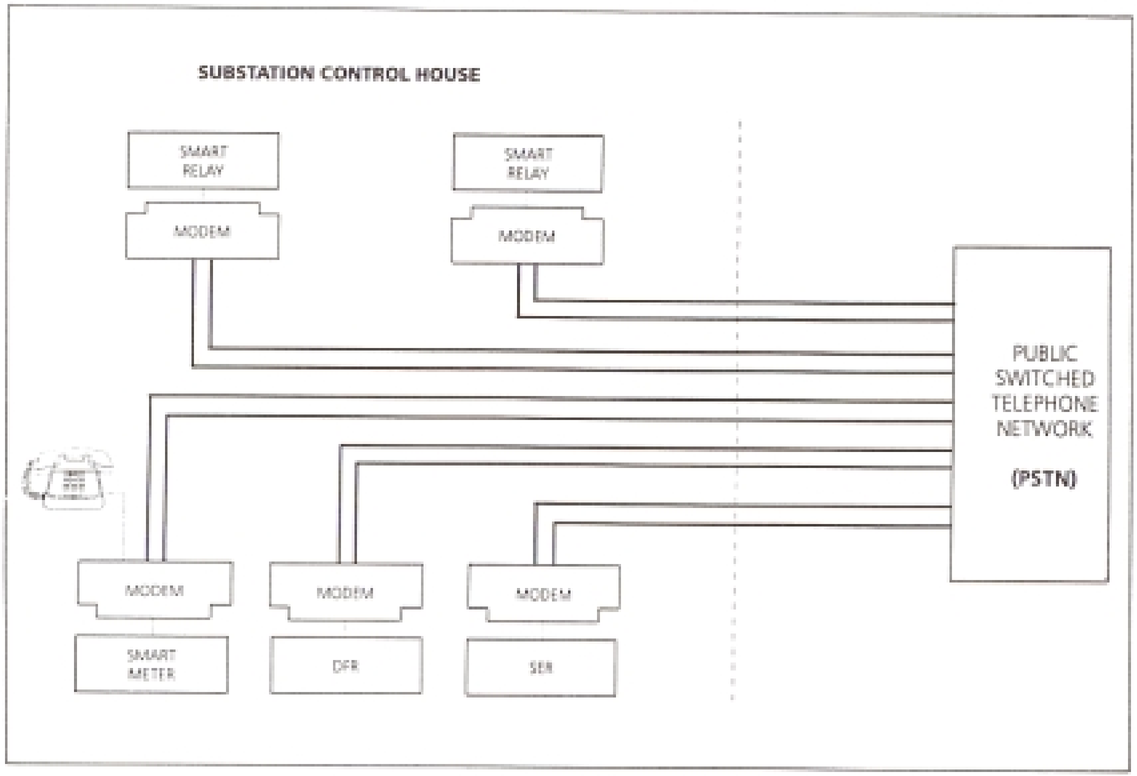

Figure 1. Running individual communication circuits to each device

The next logical approach to this problem is to adapt current telephony practice. In telephony, a private automatic business exchange (PABX) connects many telephones to a few trunk lines. The PABX (as used in this application) is an analog device that switches the tip and ring connections from a trunk circuit to one of many extensions. It also supports the required loop currents and ringing functions. (See Figure 2.) While this method successfully connects many devices to a single telephone circuit, it requires a dial-up modem at each connected device. It also usually requires the user to terminate the modem connection to switch between devices.

To reduce the number of modems required, the switching device can be moved between the modem and the RS-232 device connections. (See Figure 3.) This eliminates the need for the switch to support the loop currents and ringing functions between the individual modems. In addition, once a user establishes a connection with a remote PC, the modem output is data. This allows the user to switch connections from one device to another by issuing ASCII commands instead of DTMF tone signals.

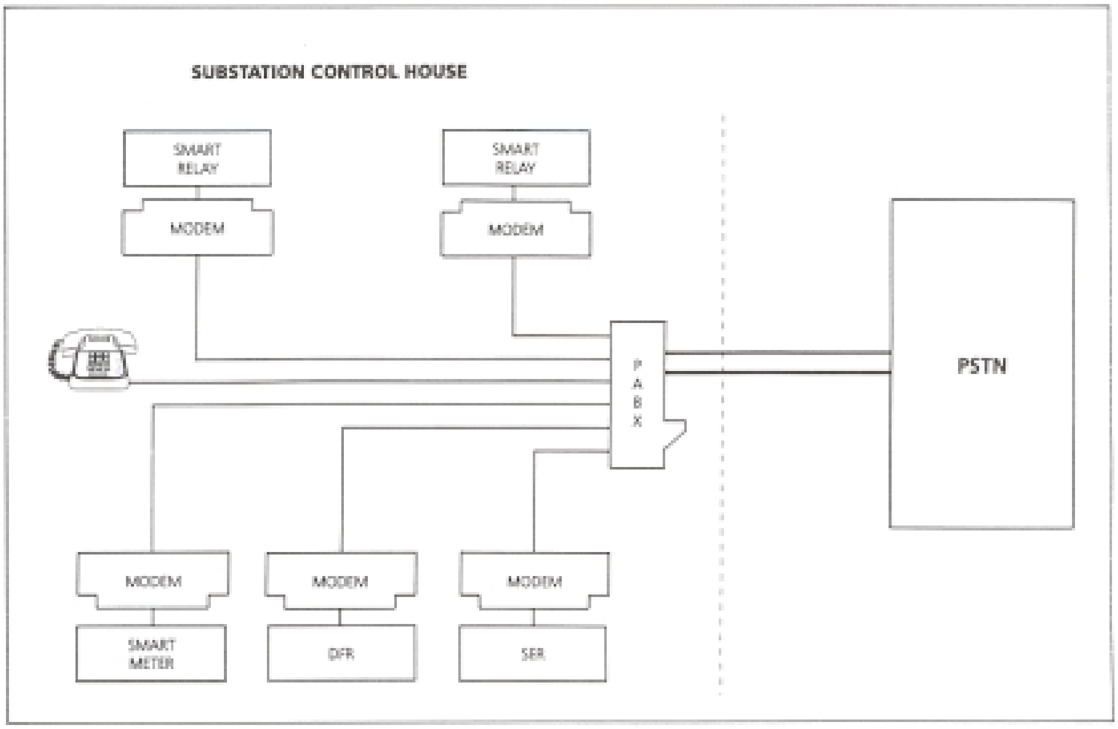

Figure 2. Connecting the devices with a PABX

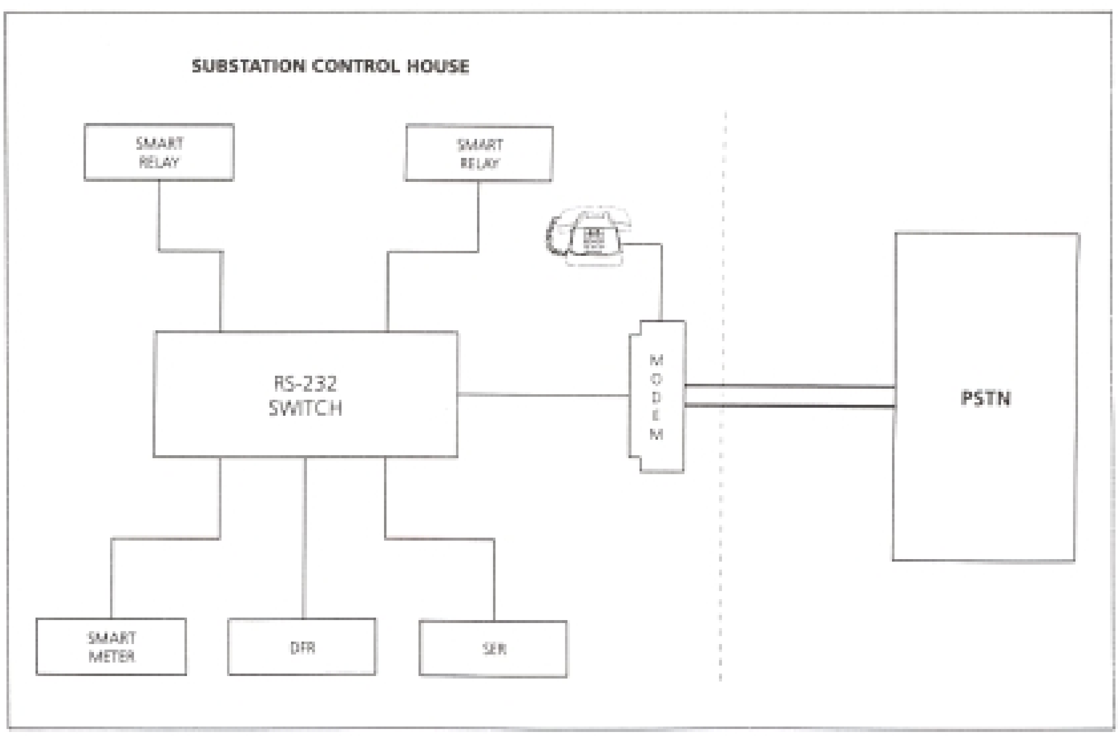

Figure 3. Moving the switching device between the modem and the RS-232 connections

One limitation of traditional RS-232 switches is that different end-device protocols (and sometimes different baud rates) are not supported between the device output ports. This limited their application to devices with identical protocols.

DESIRED FEATURES

The performance goals identified by the Savannah/RFL team were to provide a device that on a single modem connection could re-configure itself by port selection. This would allow devices with a wide range of communications protocols to be accommodated without having to re-establish the initial modem connection.

At the PC initiating the call, an off-the-shelf software solution was desired. This program had to be able to to provide ASCII commands to the switch, and a simple means of switching between DOS-based application programs without disturbing an established modem connection. Microsoft Windows Version 3.1, which is supplied with most new PC's, was found to support our requirements. One thing most people agreed to was that no one was interested in another proprietary software package.

Although many of these features are available individually in different products, a single product solution with all the following features was not available:

* A single product with an integral modem and CPU. (See Figure 4.)
* Modular construction to allow for future RS-232 port expansion.
* Protocol transparency.
* Remote callout.
* Remote disconnect feature.
* Security.
* Substation hardening.
* The ability to convert the electrical RS-232 data for use with a fiber optic loop. (See Figure 4.)

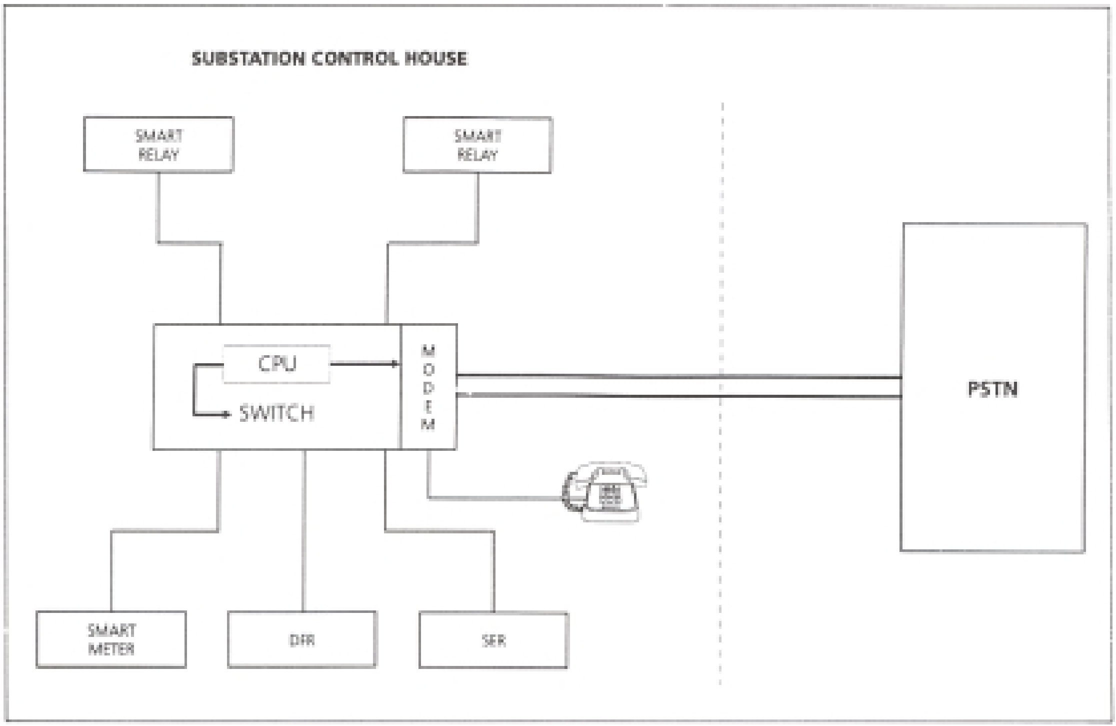

Figure 4. Digital Substation Switch (DSS) with integral modem and CPU

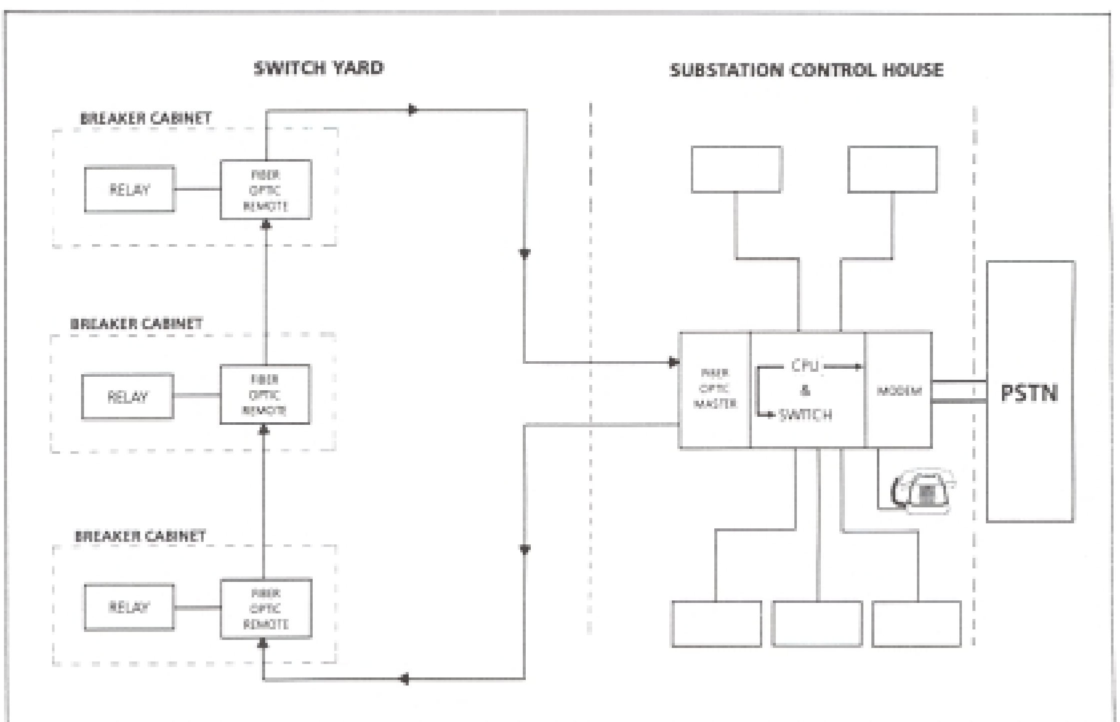

Figure 5. Fiber optic loop communications

In the lab, successful connection to a few simple devices was encouraging, but then real-world reality struck. With each new device connected to the system, another combination of data formats was required. The variables in asynchronous data communications are as follows:

Data:	Hexadecimal, octal, binary, and ASCII
Baud Rates:	300 bps to 19.2 Kbps
Data Bits:	Seven or eight
Stop Bits:	One or two
Parity:	Odd, even, or none
Flow Control:	XON/XOFF, RTS/CTS, DSR/DTR, or none

The system baud rate is established when a modem connection is made. The data format and flow control is usually established by the device interrogation software. To be able to communicate with multiple devices using any possible combination of the variables listed above, the data at each port is programmed. This means that regardless of connection speed or format, the data is always presented to the port in a fixed format. Changes that were required included the addition of a modem string to re-configure the modem output selection.

The following describes the application of this device and its performance in the substation environment.

GRANGE ROAD SUBSTATION

Savannah Electric installed the RFL Digital Substation Switch in its Grange Road Substation during a station upgrade. The station was converted from a radial feed to a loop station with the addition of three new 46-kV transmission lines. General Electric DLP and GEC Optimho relays are used for protection on each of these lines.

Each of the station's five feeders was retrofitted with a General Electric DDP relay. These relays were mounted in the feeder breaker cabinets located in the switchyard. All of these relays are capable of remote interrogation and reconfiguration through an RS-232 communications port. The DSS is mounted in the station's communication rack, along with the fiber optic T1 system. (See Figures 6 and 7.)

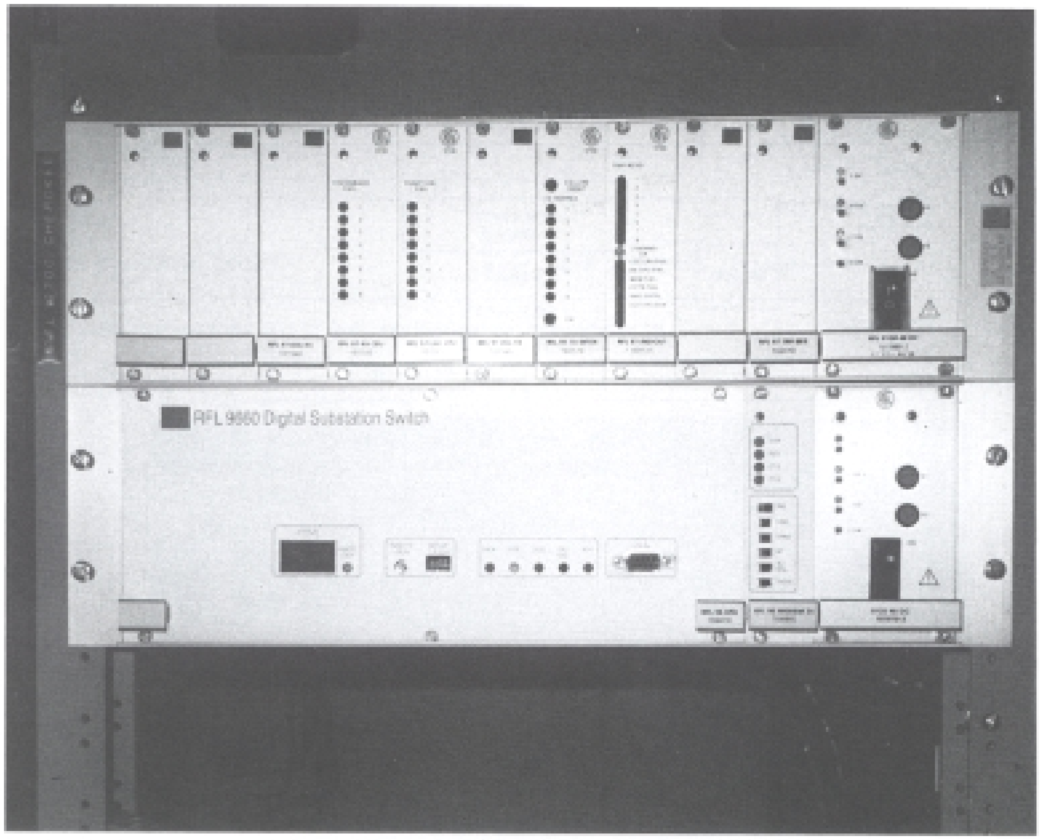

Figure 6. The digital substation switch, as installed at Grange Road Substation

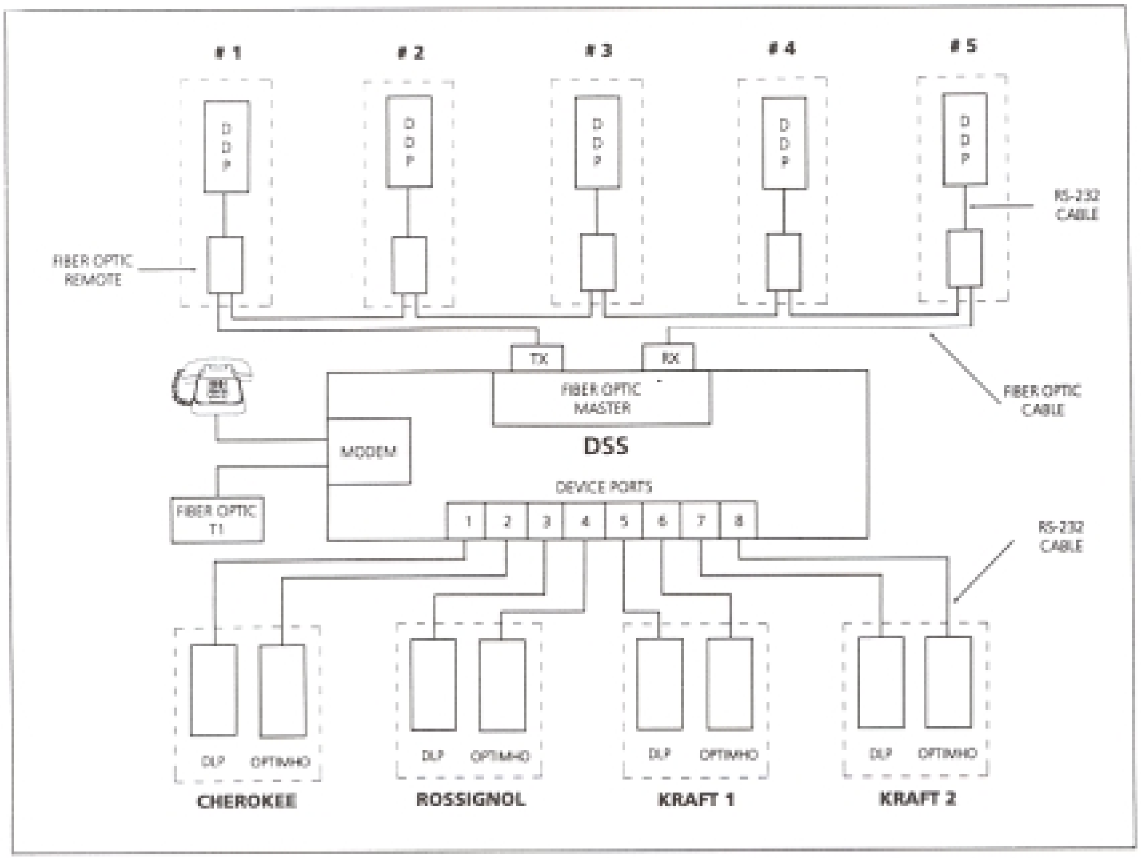

Figure 7. Block diagram, Grange Road Substation

Relay Communications

Data is transferred between the DSS and the eight line relays using the relay's RS-232 interfaces. The pin configuration for the RS-232 cables is specified by the relay manufacturers. The DLP and Optimho relays use the same cable configuration, as shown in Figure 8.

Data is transferred between the DDP relays in the breaker cabinets and the DSS by a 850-nm multimode fiber optic loop. The DSS has a fiber optic master, containing a transmitter and a receiver. A fiber optic remote is installed at each feeder breaker, for transmitting and receiving data between the relay and the DSS. Serial data is passed around the loop, with each fiber optic remote acting as a repeater. The fiber optic remotes are connected directly to the relay, and are configured through the DSS. (See Figure 9).

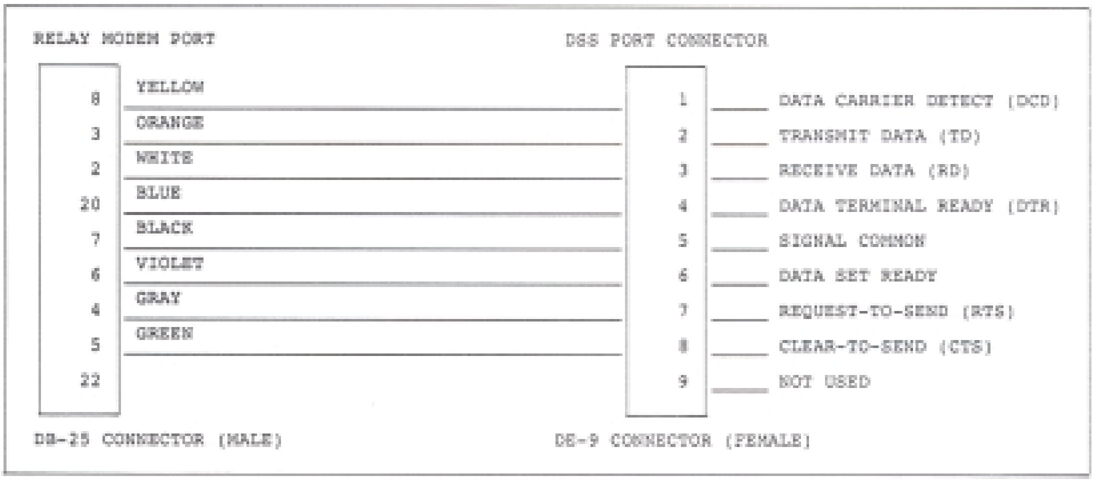

Figure 8. Cable configuration, DSS to Optimho/DLP Relay

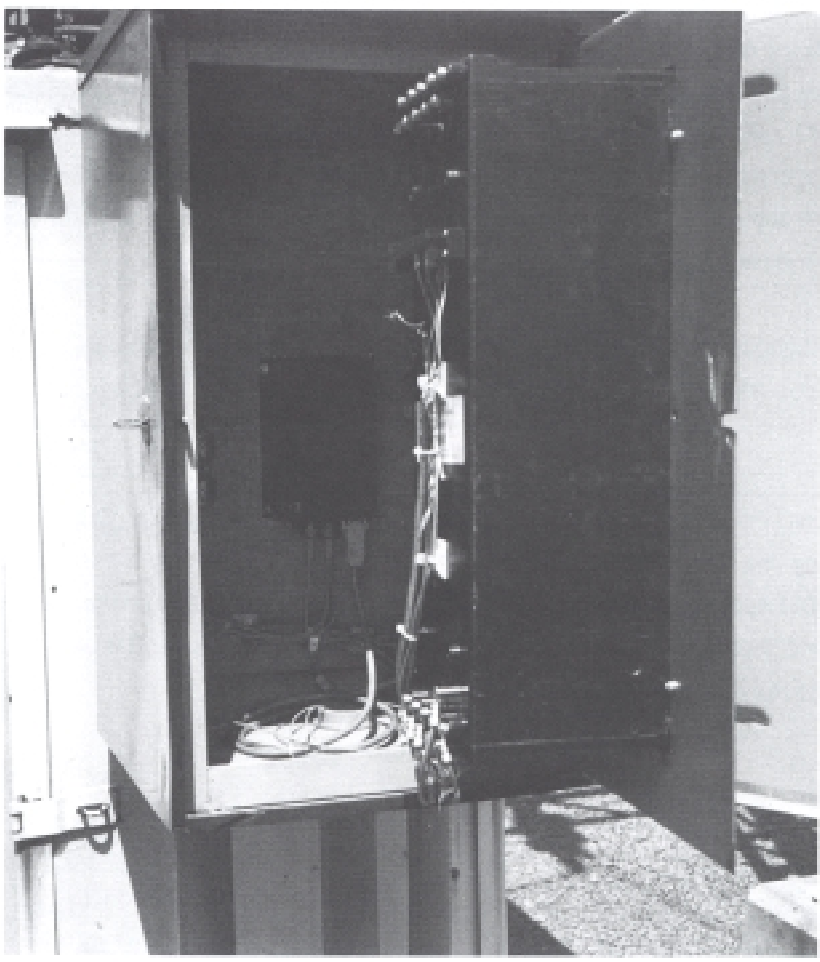

Figure 9. Fiber optic remote connected to DDP relay

Port Configuration

Each relay is assigned a port on the DSS. The DSS can accommodate 8, 16, 24, or 32 devices, depending on the number of port I/O modules installed. Figure 10 is a port information display obtained from the DSS that shows how the relays at Grange Road Substation are assigned. Other information on the display shows the type of flow control (Mode), active status of the DTR and RTS lines (when used), and whether device callout is enabled. This display is generated by the DSS in an ASCII format, so it can be viewed with a dumb terminal.

The device ports on the DSS are set to match the protocol requirements of the line relay or feeder relay attached to it. DDP relays require flow control, eight data bits, one stop bit, and no parity. Flow control on the Optimho relays is selectable on the relay itself; for simplicity, the same configuration as the GE relays was selected. Figures 11 and 12 show the port configuration settings used for the DDP and Optimho relays.

The only significant difference between the two relay port configurations is the use of a modem string. The data transferred between the DDP relay and the D-Link program requires that the DSS's internal modem ignore an XOFF command that is sent by the relay during some data transmissions. Because this is a condition that is only required by some devices, the port modem string is used to implement it. When a port is selected that contains a modem string, the internal modem will be re-configured; when the port is de-selected, the modem returns to its original configuration.

In the port configurations shown in Figures 11 and 12, the port number is followed by a "port label." When accessing the port from a remote terminal, either the port number or the label can be entered to select a device port.

Communications with Optimho relays takes place using a terminal program or GEC's Opticom software. When accessing the Optimho relay, Opticom sends the identifier listed in the software. When using Opticom, the DSS appears transparent. Opticom dials the station, sends the identifier, retrieves the desired information, and then logs out of the relay without hanging up the phone. This allows a user to access several Optimho relays at a single station with only one phone call.

```
Welcome to Grange Road
#  TYPE   LABEL            MODE   DTR    RTS    CallBack
-------------------------------------------------------------
1  RS232  Cherokee DLP      0      1      1      N
2  RS232  CH-OPT            0      1      0      N
3  RS232  Rossignol DLP     0      1      1      N
4  RS232  RO-OPT            0      1      0      N
5  RS232  Kraft 1 DLP       0      1      1      N
6  RS232  KR1-OPT           0      1      0      N
7  RS232  Kraft 2 DLP       0      1      1      N
8  RS232  KR2-OPT           0      1      0      N
28 Fiber  Feeder 5 DDP      0      0      0      N
29 Fiber  Feeder 4 DDP      0      0      0      N
30 Fiber  Feeder 3 DDP      0      0      0      N
31 Fiber  Feeder 2 DDP      0      0      0      N
32 Fiber  Feeder 1 DDP      0      0      0      N
```

Figure 10. Port information display

```
      Port# 1 (Cherokee DLP)
Interface        - RS232        Call Out         - Off
Baud Rate        - 2400         Call Request     - None
Data Bits        - 8            Call Priority    - 0
Parity           - None         Call String      -
Stop Bits        - 1            Remote String    -
Port Flow Ctrl   - None         Port String      -
Local Port DTR   - Off          Modem String     - \,+++\,AT\Q0\X0 O\N\,
Local Flow Ctrl  - Off          Port Password    -
```

Figure 11. Port parameter settings for DLP relay

```
      Port# 2 (CH-OPT)
Interface        - RS232        Call Out         - Off
Baud Rate        - 2400         Call Request     - None
Data Bits        - 8            Call Priority    - 0
Parity           - None         Call String      -
Stop Bits        - 1            Remote String    -
Port Flow Ctrl   - None         Port String      -
Local Port DTR   - On           Modem String     -
Local Flow Ctrl  - On           Port Password    -
```

Figure 12. Port parameter settings for Optimho relay

Software

The terminal emulator program in Microsoft Windows Version 3.1 has proven to be the most versatile software for communicating with the DSS. This program transmits and receives ASCII text, for communicating with the DSS and any relay that uses an ASCII format. Windows has a multi-tasking capability; this allows users to switch to a non-Windows application after the proper port is selected on the DSS. The procedure described in the relay communications manual used at Savannah Electric for communication with GE relays is as follows:

To Enter:

1. Dial DSS in Windows.
2. Select desired switch port.
3. Switch to D-Link.
4. Select relay.
5. Give Password and Unit ID.

To Exit:

1. Log out and then exit D-link.
2. Deselect port.
3. Switch to another device, or hang up and exit terminal.

At Savannah Electric, a program group in Windows has been created for each DSS user. There is an icon for each substation that runs the Terminal program with the phone number and settings needed for that substation. In the same group, there is an icon for D-Link and Opticom that runs these programs. The combination of a mouse and program icons makes switching between device programs fast and easy.

CONCLUSION

At the start of this venture, RFL Electronics Inc. and Savannah Electric had some very aggressive goals:

1. A transparent integrated device.

2. User-selectable password protection.

3. Positive verbose feedback for the user.

4. Compatible with off-the-shelf software (Microsoft Windows Version 3.1).

5. Programmable for all combinations of data parameters.

It was unclear whether a single device could meet all the requirements, and satisfy all the variables that can occur during RS-232 communications. The Digital Substation Switch (DSS) represents another example of an application made economically feasible by the microprocessor.

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"Windows" is a registered trademark of Microsoft, Inc.

The above trademark information is, to the best of our knowledge, accurate and complete.

RFL Electronics Inc.
353 Powerville Road
Boonton Township, NJ 07005-9151
Phone: (973) 334-3100
Fax: (973) 334-3863
www.rflelect.com
email:rflelect@nac.net