## Real Time Power System Simulation using F6000 Instruments

Real time digital simulation is a very sophisticated and powerful tool to evaluate the performance of protection. For critical and complex application, the performance evaluation of protection schemes can ensure unwanted surprises during service. The maloperation or failure to operate during service can be very catastrophic and expensive. To ensure correct operation of protection scheme, simulation of the power system condition is very important. Simulation is not straight forward as the tools used to calculate the power system condition are very complex. Such tools are now readily available and with proper understanding of system parameters, actual power system condition can be simulated on a PC. Once the power system simulation is done, the next step is to use the current and voltage amplifiers to simulate CTs and PTs. These signals can be applied to relays to evaluate the performance of the protection scheme. In the past, power system simulation software and appropriate current and voltage amplifiers were very expensive and hence were available only to relay manufacturers. Nowadays due to advances in digital technology such tools are available to all and are portable too. These tools are now very affordable and allow the protection users as well as the designers to evaluate and design the protection to suit their needs. This document describes such an application.

Typical application of a real time power system simulator is the simulation of the power system condition in real time. The block diagram below describes the typical application.

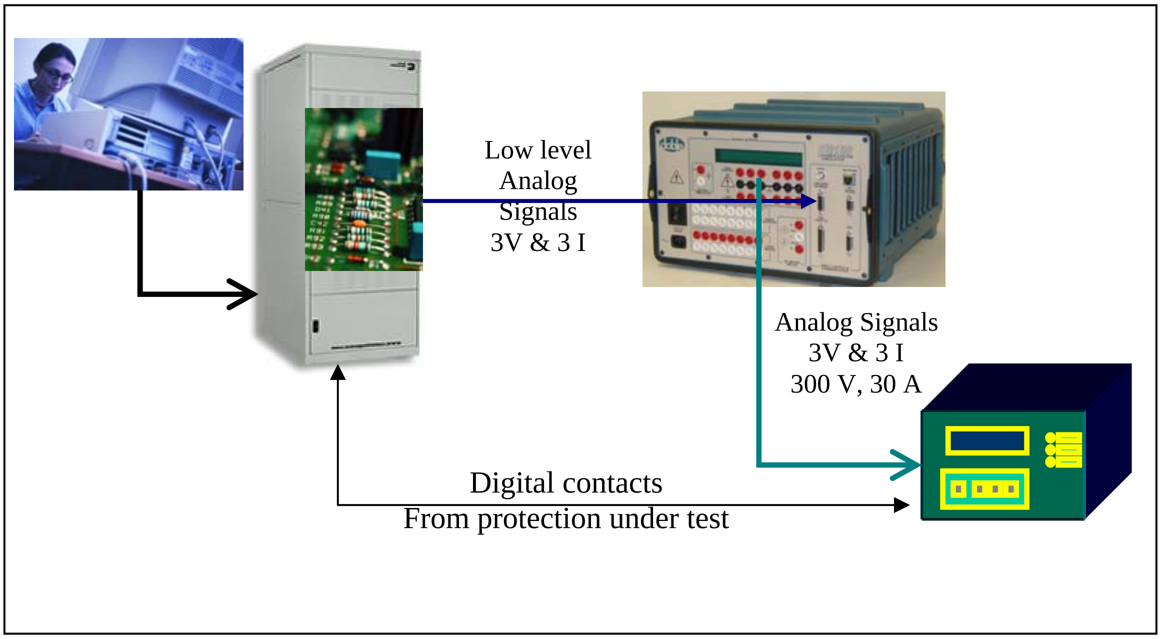


**Figure 1**

PC connected to RTDS (Real Time Digital Simulator) simulates the power system signal and converts digital signals to low level analog signals ready to be applied to F6350, which is a modified version of the Doble Power System Simulator F6150.

As shown in Figure 1, F6350 amplifies the low level analog signals and the amplified signals are applied to protection under test. The contact output from the protection under test is supplied to RTDS which interprets the protection response and generates the appropriate signals to simulate the power system condition based on the protection response. Similarly, the contact inputs on the protection under test can be controlled by signals from the RTDS to provide necessary permissive for the protection to implement specific schemes internally .

This application shows that F6350 is a very powerful tool to simulate the power system condition and evaluate the protection response.

The difference between F6150 and F6350 is:

In F6150 the built in signal processing algorithm internally generates the low level analog signals. These low level signals, provided to the current and voltage amplifiers located within F6150, are amplified and the amplified signals present themselves at the current and voltage terminals of F6150. There is no need to inject any low level signals from an external source and this constitutes a major difference between F6150 and F6350.

Standard F6150 can be converted to F6350 by replacing an analog I/O card with a special analog I/O card loaded with a special firmware. The F6350 allows the sources to be configured as is the case with F6150. There are many combinations that can be configured. For example, the user can choose 3 voltages and 3 currents (3V and 3I), six voltages and six currents (6V, 6I), etc. The user has to choose the range of these sources as well like one does in F6150. The range selection has the following impact. If for example the user selects 300V as the range for the voltage, a low level signal of 6.7 volts will correspond to 300V available at the voltage terminals of F6350 ready to be applied to the device under test. Hence the high end of the range selection corresponds to 6.7 volts. Any signal strength lower than 6.7 volts will be reduced proportionally. The 6.7 volts is the high end threshold value for the voltage amplifier.

Similarly, the high current source amplifier has a high end threshold of 3.4 volts that corresponds to the high end of the range. Hence, for ranges associated with the high current source namely, 7.5A, 15A or 30A, a low level signal of 3.4 V will correspond to the selected high end of the range. In other words if the user selects 30A as the range, a low level signal magnitude of 3.4 V will result in 30A being available at the current terminals of F6350.

The current amplifier has a high end threshold value of 6.8V for transient current output and this corresponds to a range of 15A, 30A, and 60A depending which range is selected by the user. Similarly, the low level current source of F6350 has a high-end threshold of 4.6V and hence equals to a range of 0.5A, 1A or 2A depending on which range is selected by the user.

Figure 2 below shows the arrangement where the range for voltage channel and current channel is set at 300Vand 30A respectively and the configuration selected is 3V and 3I.

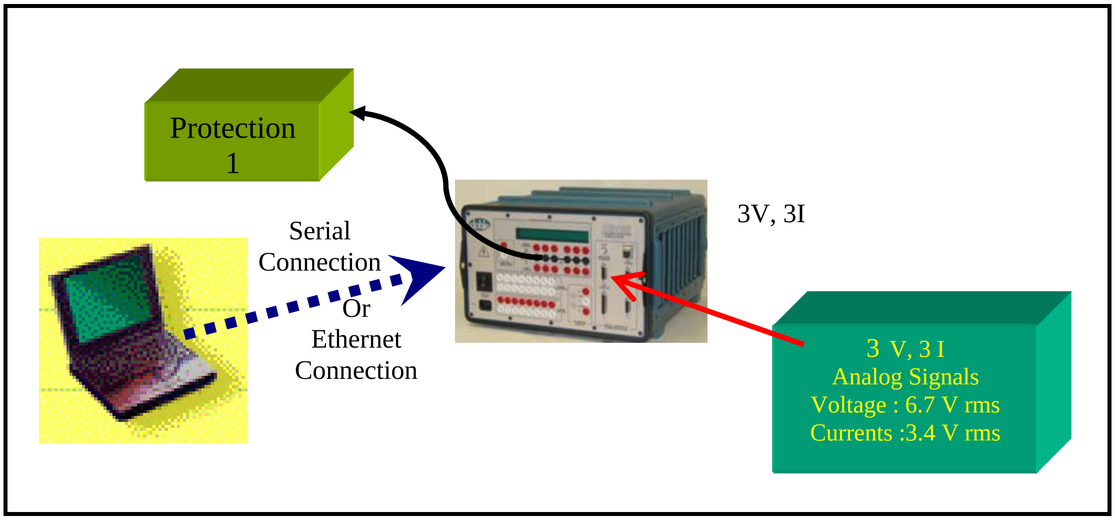


**Figure 2**

The user can make his selection for the source configuration and the range via a Control Panel User Interface.  Please refer to Figures 3 and 4 shown below for details.

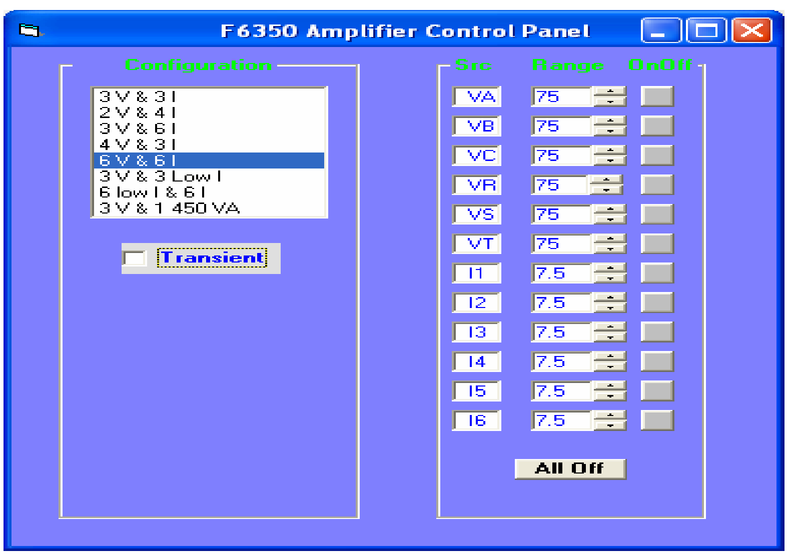


**Figure 3**

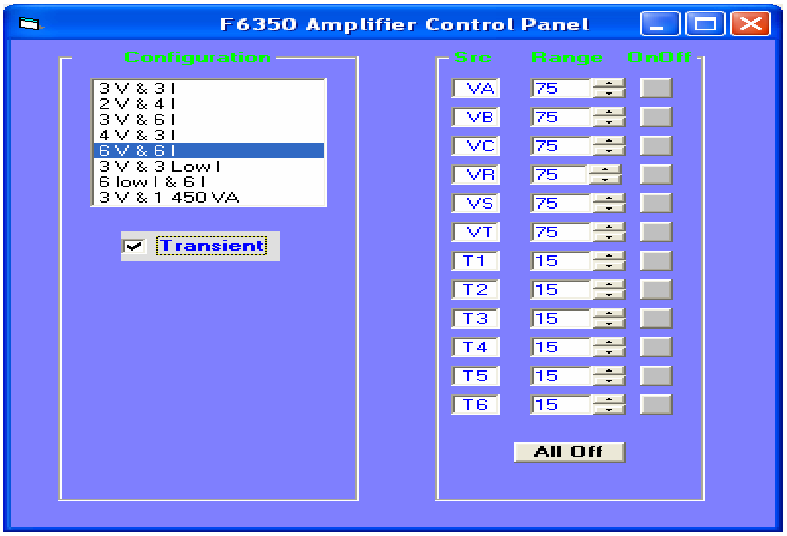


**Figure 4**

The process of configuring sources and its range is very simple. Power up the PC and open a Control Panel program supplied by Doble. Configure the sources (names, type and # of sources) and set the ranges for all the sources as shown in Figures 3 and 4.

The screen captures shown in Figure 5 shows the options that are available for setting up the communication between the Control Panel user interface and the F6350.
The user can select either Serial or Ethernet communication along with related communication port and IP address of F6350.

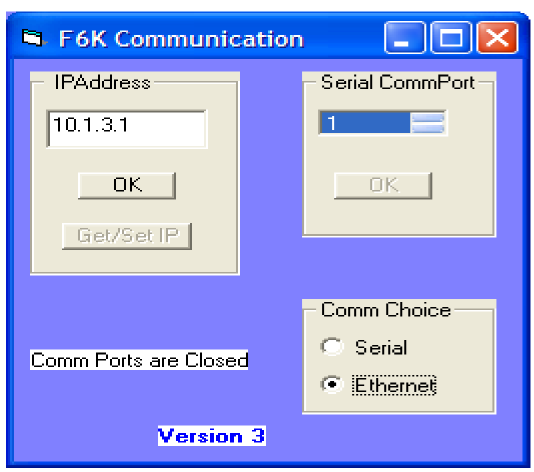


**Figure 5**

Figure 6 shows the setup for source configuration of 3V and 3I. If the range for the voltage is set at 300 Volts and current range is selected as 30 A, a low level signal of 6.7 Volts rms is applied at the low level signal input port for voltage channel, it will produce 300 Volts at the output terminal of F6350. Similarly for a low voltage input signal of 3.4 volts rms for current channel will produce 30 A at the current output of F6350.

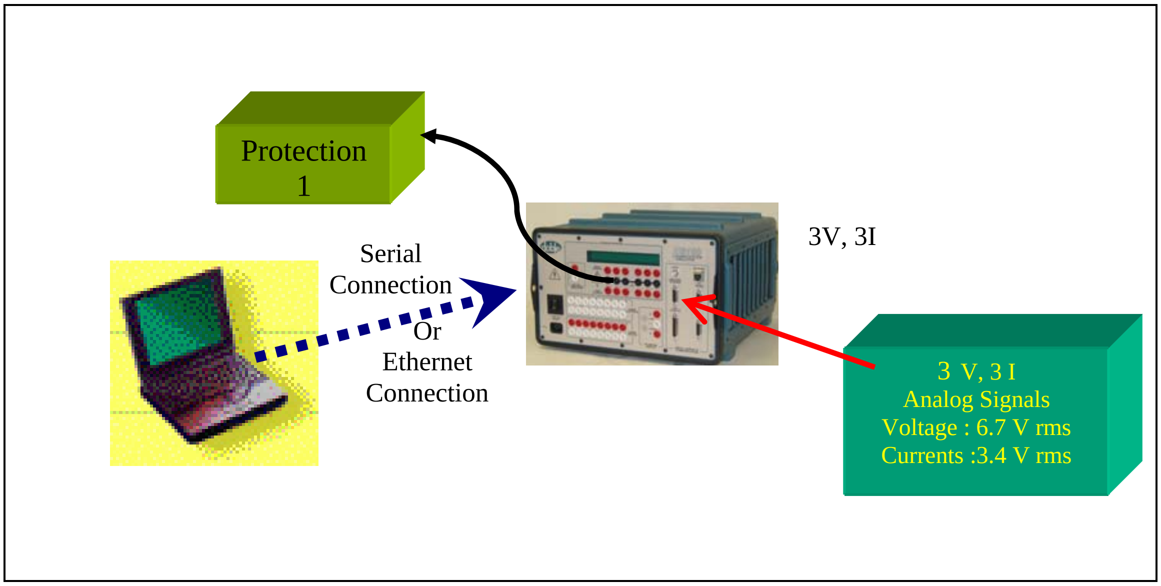


**Figure 6**

It is also possible to configure the sources as 3 V and 3 T sources. This will allow user to get 60 A for 1.5 seconds per phase for T sources. Please note that in this case the input signal requirement is twice that required for the full scale output. So as an example input signal of 6.8 V rms (instead of 3.4 V) is needed at the input for producing 60 A 225 VA for 1.5 seconds.

Total of 12 sources can be controlled externally. Maximum 6V and 6I can be selected using the source configuration.

Some of the possible source combinations along with cable details are listed in Appendix B.

As we can see there are many combinations of source configuration that can be obtained using the F6350. As shown in the table above we can also get 3 V and one I 450 VA source by paralleling the 3 currents. This will provide one 450 VA source that can deliver up to 90 A continuous current.

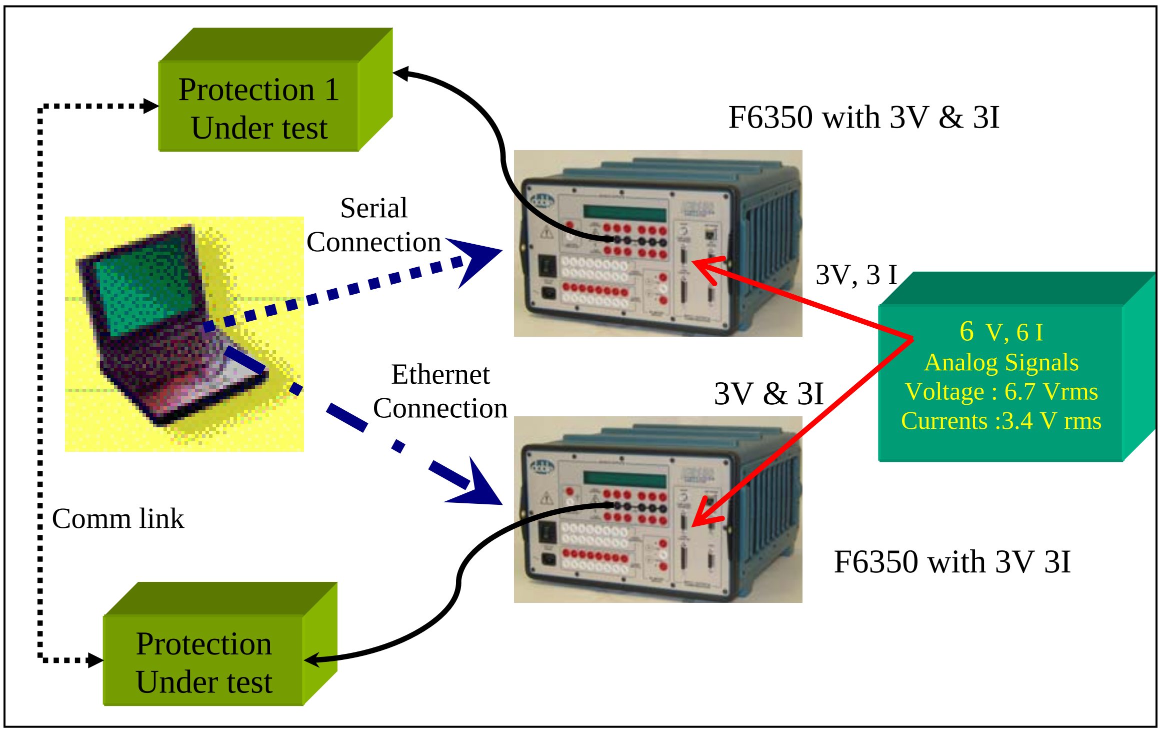


**Figure 7**

As shown in Figure 7, it is also possible to get 6 V and 6 I sources of 150 VA each by using two F6350 This setup will provide up to 300 V and 30 A continuous. This configuration can be very useful to check the complete system performance of two distance relays or line current differential relay in back to back connection in laboratory environment. This can be achieved by using one PC controlling two F6350 as shown in Figure 7.

In this application a PC opens up two instances of Control Panel and each configures the related F6350. By doing this and having a 6V and 6I low voltage sources you can test two protections back to back in a lab environments.

Another very interesting application that can be simulated is the application of 3V and 9 I. as shown in Figure 8. This setup is required to test 3 phase 3 winding transformer differential application.

To achieve this F6350 and modified F6300 (high current source) can be used. F6300 with a same low level analog I/O card used with F6350 can provide up to 3V and 9I as shown in Figure 8 below. If higher current is required the transient mode can be selected which will provide twice the current for 1.5 seconds.

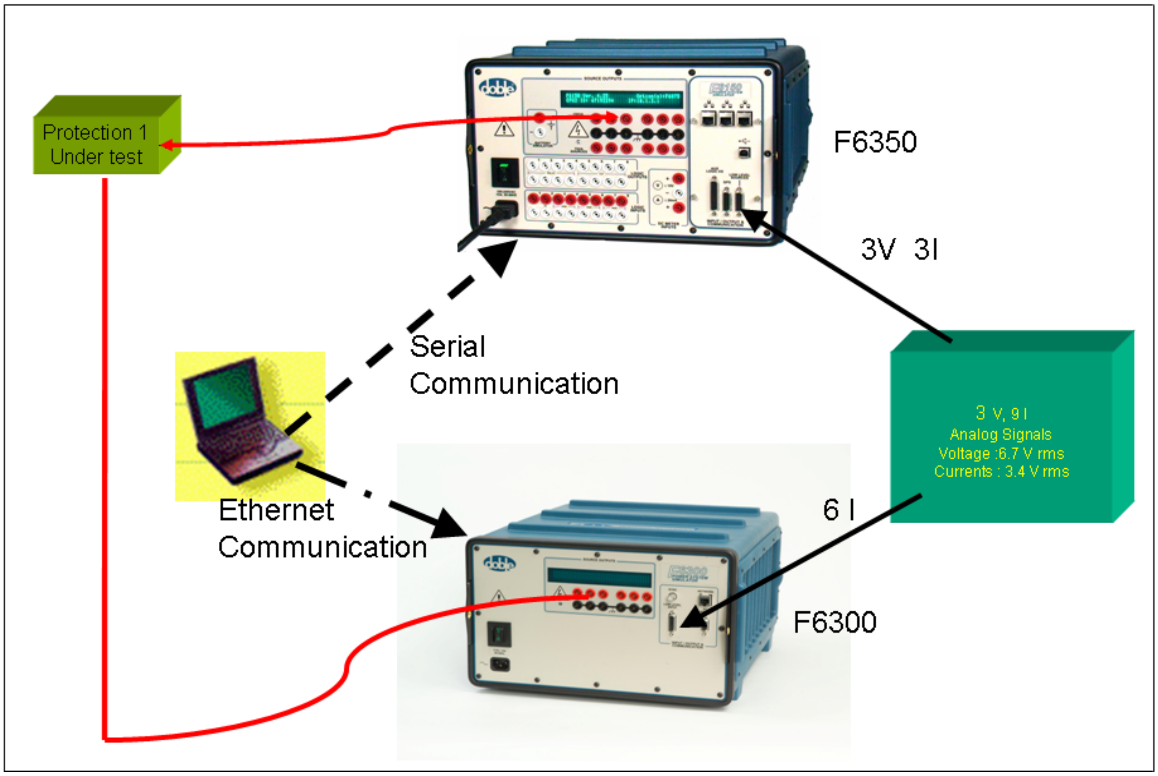


**Figure 8**

The combination of F6350 and F6300 can be used to provide 3 voltage sources and 3 current sources each capable of providing 90A continuously. This is helpful in testing the time over current characteristics of a three phase relay starting at low multiples and extending it to significantly higher multiples. The user can use these three high current sources for testing of other elements where significantly higher currents are required. The 3 current sources listed above each can provide 90 A continuously and 180 A each for 1.5 seconds. The setup for using the F6350 and a F6300 under such a setup is shown below in Figure 9.

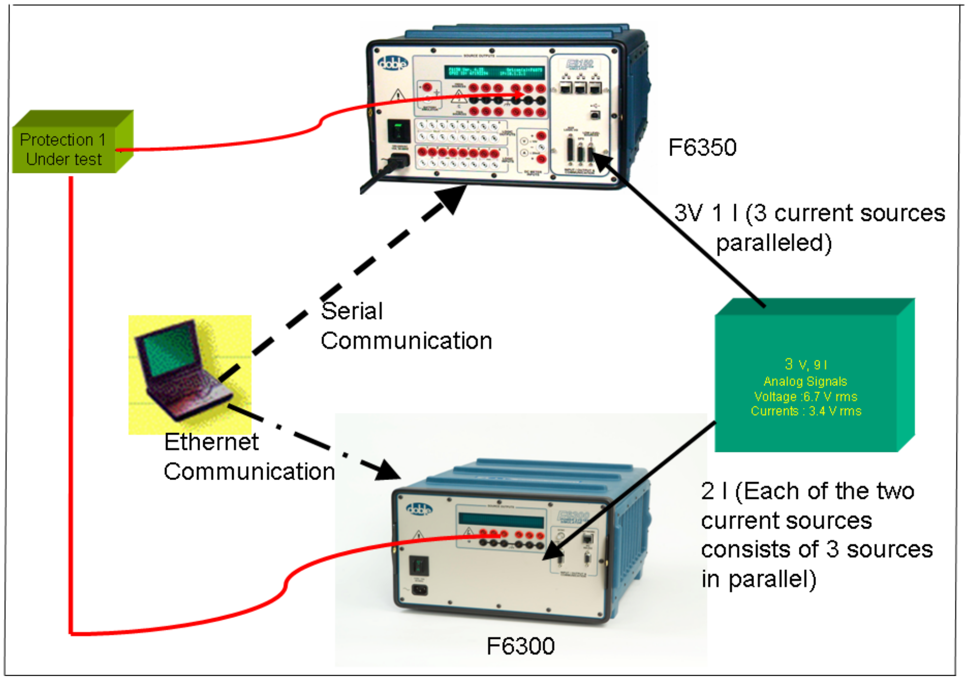


**Figure 9**

Using the special analog I/O card and with a special firmware and stand alone control panel, the power system simulation possibility is limitless. You can evaluate the performance of the complete system in the field or in your office for your system at affordable price. In the past this was only possible to achieve at the protection manufacturers premises.

The basic steps involved in converting the F6150 into a F6350 are listed in Appendix A below. Further details are available in the F6350 User Guide.

# APPENDIX A

When you purchase the F6350 conversion option, you will be provided the following:

Analog I/O board ( Doble Part Number 04S-0825-01)

A CD containing the firmware and the interface software

A cable for connecting the RTDS to the F6350

## Steps to install:

Your F6150 has an Analog I/O board in slot 4. This printed circuit board needs to be replaced by the one provided to you as part of the F6350 package.

The second step is to launch ProTest or F6Test or the F6 Control panel to upgrade the instrument firmware. The firmware is included in the CD that is provided to you. Once you install the firmware, the F6150 is converted into F6350.

Install the interface software on your PC.

Connect all the instruments involved as shown in diagrams listed earlier in this document including the relay under test.

Detailed instructions for loading the firmware, and interface software are included in the F6350 User Guide. The procedure to replace the printed circuit board is also explained in this guide.

**If you purchase a F6350 dedicated amplifier, you do not have to worry about replacing the Analog I/O card. In this case you will be supplied the F6350 equipped with the I/O card along with the interface cable (for connecting F6350 to the RTDS) and a CD.**

# APPENDIX B

### 3 V 3 I Configuration

| Source Name | Cable Pin Number | Cable Wire Color |
|---|---|---|
| VA | 12 | White/Yellow |
| VB | 13 | White/Green |
| VC | 14 | White/Blue |
| I1 | 9 | White/Brown |
| I2 | 10 | White/Red |
| I3 | 11 | White/Orange |

### 2 V 4 I Configuration

| Source Name | Cable Pin Number | Cable Wire Color |
|---|---|---|
| VA | 12 | White/Yellow |
| VB | 13 | White/Green |
| I1 | 9 | White/Brown |
| I2 | 10 | White/Red |
| I3 | 11 | White/orange |
| IN | 4 | Orange |

### 3 V 6 I Configuration

| Source Name | Cable Pin Number | Cable Wire Color |
|---|---|---|
| VA | 12 | White/Yellow |
| VB | 13 | White/Green |
| VC | 14 | White/Blue |
| I1 | 9 | White/Brown |
| I2 | 10 | White/Red |
| I3 | 11 | White/Orange |
| I4 | 2 | Brown |

| | | |
|---|---|---|
| I5 | 3 | Red |
| I6 | 4 | Orange |

**4 V 3 I Configuration**

| Source Name | Cable Pin Number | Cable Wire Color |
|---|---|---|
| VA | 12 | White/Yellow |
| VB | 13 | White/Green |
| VC | 14 | White/Blue |
| VN | 7 | Blue |
| I1 | 9 | Brown |
| I2 | 10 | Red |
| I3 | 11 | Orange |

**6 V 6 I Configuration**

| Source Name | Cable Pin Number | Cable Wire Color |
|---|---|---|
| **VA** | **12** | **White/Yellow** |
| **VB** | **13** | **White/Green** |
| **VC** | **14** | **White/Blue** |
| **VR** | **5** | **Yellow** |
| **VS** | **6** | **Green** |
| **VT** | **7** | **Blue** |
| **I1** | **9** | **Whiter/Brown** |
| **I2** | **10** | **White/Red** |
| **I3** | **11** | **White/Orange** |
| **I4** | **2** | **Brown** |
| **I5** | **3** | **Red** |
| **I6** | **4** | **Orange** |

3 V  3 Low I Configuration

| Source Name | Cable Pin Number | Cable Wire Color |
|---|---|---|
| VA | 12 | White/Yellow |
| VB | 13 | White/Green |
| VC | 14 | White/Blue |
| IA | 5 | Yellow |
| IB | 6 | Green |
| IC | 7 | Blue |

6 Low I  6 I Configuration

| Source Name | Cable Pin Number | Cable Wire Color |
|---|---|---|
| IA | 12 | White/Yellow |
| IB | 13 | White/Green |
| IC | 14 | White/Blue |
| IR | 5 | Yellow |
| IS | 6 | Green |
| IT | 7 | Blue |
| I1 | 9 | White/Brown |
| I2 | 10 | White/Red |
| I3 | 11 | White/Orange |
| I4 | 2 | Brown |
| I5 | 3 | Red |
| I6 | 4 | Orange |

3 V  1 450 VA I

| Source Name | Cable Pin Number | Cable Wire Color |
|---|---|---|
| VA | 12 | White/Yellow |
| VB | 13 | White/Green |
| VC | 14 | White/Blue |
| I1 | 9,10,11 | White/Brown, White /Red, |

| | | |
|---|---|---|
| | | **White/Orange, Red** |