RECLAMATION

Managing Water in the West

Machine Condition/Vibration Monitoring

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Power O&M Workshop

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Portland, OR

U.S. Department of the Interior
Bureau of Reclamation

Russian Hydro Accident
August 17, 2009

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Details of Russian Hydro Accident

- Russia's largest hydroplant, the Sayano–Shushenskaya, broke apart violently, killing 75 people and leading to widespread power failure in the local area, and forcing all major users such as aluminum smelters to switch to diesel generators.
- Repairs are estimated at over one billion dollars.
- From what is known of this incident, high turbine vibration accelerated damage to improperly pretensioned headcover holddown studs, which lead to a catastrophic failure that flooded the plant.

What Could Have Prevented the Accident?

- **A condition monitoring system could have detected the onset of this vibration and alerted the operators that there was a problem before the failure occurred.**

- **In response to this incident, Reclamation published Power Equipment Bulletin 42, which includes a Category 2 recommendation for installation of vibration monitoring systems for all Reclamation's units.**

PEB 42 - Vibration Monitoring

- Proximity probe vibration monitoring systems (measuring the displacement of the shaft relative to a stationary component, such as the bearing housing) are usually the best suited for hydroelectric units.
- Accelerometer systems that measure the acceleration of the vibration of stationary components are usually not a good choice for hydroelectric units.
- Most accelerometers are not capable of effectively measuring vibration at the low frequencies that occur on hydroelectric units.

PEB 42 – Vibration Monitoring

- **A basic proximity probe vibration monitoring system consists of at least one proximity probe (preferably two, 90 degrees apart) mounted at each guide bearing elevation, connected to some type of monitor that can alarm when the peak-to-peak vibration levels reach a predetermined level.**

Vibration package meets the requirements of Power Equipment Bulletin No. 42

- **“All facilities shall install vibration monitoring on all units.**
- **The system must consist of proximity probes at each guide bearing elevation, with output data transmitted to a system that is capable of alarming on peak-to-peak vibration levels.”**

New Hydro Generator Condition Monitoring Equipment

- **The Hydropower Technical Services Group has been researching and evaluating various Commercial machine condition monitoring systems for use in Reclamation hydroplants over the past several years.**

- **The overall objectives of a hydrogenerator condition monitoring system are to reduce operation and maintenance costs, increase plant availability, and preserve Reclamation's infrastructure by providing current and relevant information on the present condition of plant equipment.**

New Hydro Generator Condition Monitoring Equipment

- Based on the results of this past research effort, it was decided to pursue a more generic data acquisition product, where Reclamation would own the rights to the source code.
- The main advantage of this approach is it allows for in-house expansion and customization of the software.
- The development of the core software for the Hydrogenerator Condition Monitoring system has been completed.
- The initial release is now available and focuses on vibration monitoring.

New Hydro Generator Condition Monitoring Equipment

- This system can & will be expanded in phases to include additional hydroplant monitoring features such as temperature trends, generator monitoring/analysis, and control system monitoring.

- Specialized monitoring system also can be implemented via this platform including air-gap monitoring, rough zone detection, or cavitation detection.

New Hydro Generator Condition Monitoring Equipment

- This software package has several advantages over commercially available software, including:
  - Open-source code
  - Free to Reclamation powerplants,
  - Expandable and adaptable to meet the end users changing needs, and
  - Plug In architecture
  - Works with a variety of data acquisition hardware.

Vibration Monitoring - Costs per Unit

Item	Qty	Price
10V M8 Proximity Probe	6	$1,008
Power Supply for Proximity Probes	1	$50
NI Compact DAQ Ethernet Backplane	1	$1,399
NI 9201 12-bit Analog Input Module	1	$379
Software ***(FREE)***	1	$0
	Total:	$2,900

- **Users will only need to purchase the hardware and probes**
- **Other Hydro MCM systems can cost up to $200,000 per generating unit**

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Open-source code

- **The source code is fully accessible and is available for *free.***
- **End users have the option to modify and expand the software to meet their needs. This is accomplished by writing new “plugins” for custom measurements, displays, calculations, alarms, etc., or changing the source code if necessary.**
- **The software is expandable. The initial basic vibration monitoring system can be expanded to a full hydro generator machine condition monitoring system.**

Plugin Architecture

- **The software can be expanded to communicate with virtually any existing or future hardware.**

- **Designed to work with a wide variety of plant equipment including off-the-shelf data acquisition systems, specialized monitoring systems, and other computer systems.**

- **Plugins can be reused once the code has been fully developed and the performance has been verified; while also providing the option to easily make changes to each plugin to add additional functionality later.**

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Hydroplant Machine Condition Monitoring System Core Measurements

Measurements	Sensor Locations	Output Displays
Rotation	Keyphasor	Bar Graph, Trend
Guide Bearing Vibration/Runout	Turbine Guide Bearing – X/Y Lower Guide Bearing – X/Y Upper Guide Bearing – X/Y	Waveform vs. Pole or 1/Rev Bar Graphs – Magnitude/Angle Orbit Plots, Trend, FFT, Waterfall
Guide Bearing Temperature	Turbine Guide RTD Lower Guide RTD Upper Guide RTD	Bar Graph, Trend
Thrust Bearing Temperature	Thrust Bearing RTD	Bar Graph, Trend
Stator Temperature	Stator RTDs	Bar Graph, Trend
Governor Status	Speed Changer Set Point, Wicket Gate Position	Bar Graph, Trend

Core Measurements

Measurements	Sensor Locations	Output Displays
Exciter Status	Field Current, Field Voltage, PSS Output	Bar Graph, Trend
Generator Status	Active Power, Reactive Power, Stator Current, Stator Voltage, Frequency, Air House Temperature	Bar Graph, Trend, Magnitude/Angle

Recommended Additional Measurements

Measurements	Sensor Locations	Output Displays
Rough Zone	Draft Tube Pressure	Waveform, Bar Graph, Trend
Governor Status	Oil Pump Running, Penstock Pressure	Bar Graph, Trend
Exciter Status	Voltage Regulator Set Point, Exciter Limiter Active, Field Breaker Operation	Bar Graph, Trend
Governor Status	Cooling Water Pressure, Cooling Water Flow, Cooling Water Inlet Temp, Cooling Water Outlet Temp, Bulkhead Oil Pump Running, Split Phase Current, Unit Breaker Operation, 86 Relay Operation	Bar Graph, Trend

Recommended Additional Measurements

Measurements	Sensor Locations	Output Displays
Plant Status	Fore Bay Elevation, Tail Bay Elevation, Air Compressor Running, Sump Pump Running, Motor (General) Running, Bus Voltage, Bus Current, Bus Breaker Operation, Plant Temp, Outside Temp	Bar Graph, Trend
Power Transformer Status	Oil Temperature, Gas Pressure, Cooling Fan Running	Bar Graph, Trend

Optional Measurements

Measurements	Sensor Locations	Output Displays
Thrust Bearing Oil Film Thickness	Bearing Shoes	Waveform vs. 1/Rev Bar Graphs – Magnitude/Angle Orbit Plots, Trend, FFT, Waterfall
Bearing Supports	Turbine Bearing Support - X/Y Upper Guide Bearing Support – X/Y Lower Guide Bearing Support – X/Y	Waveform vs. Pole, Orbit Plots, Trend, FFT, Waterfall
Wear Ring Clearance	Wear Ring	Waveform vs. Pole or 1/Rev, Trend, Gap Plot
Shaft Torque	Shaft – Z Bridge – Z Shaft Torque	Waveform vs. Pole or 1/Rev, Bar Graphs – Magnitude/Angle, Orbit Plots, Trend

Optional Measurements

Measurements	Sensor Locations	Output Displays
Cavitations	Draft Tube or Head Cover or Wicket Gate Shaft or Shaft	Trend, Bar Graphs
Shaft Voltage	Lower Guide Voltage	Waveform vs. Pole or 1/Rev, Bar Graph
Governor/ Turbine Status	Servo Motor Stroke Servo Motor Pressure Gate Limit Pilot Valve Stroke Servo System Friction	Trend, Bar Graphs, Waveform
Turbine Gate Leakage	Turbine or Penstock	Trend, Bar Graphs

Optional Measurements

Measurements	Sensor Locations	Output Displays
Generator Air Gap	Air Gap	Waveform vs. Pole or 1/Rev, Bar Graphs, Trend, Waterfall, Rotor Shape, Stator Shape, Airgap Plots
Air Gap Flux	Magnetic Flux	Waveform vs. Pole or 1/Rev
Generator Partial Discharge	Partial Discharge	Bar Graph, Trend
Generator Efficiency	Flow Measurement	Bar Graph
Condenser Operation	Makeup Air Valve Open	Trend

Optional Measurements

Measurements	Sensor Locations	Output Displays
Circuit Breaker	Trip Signal Bus Current	Time Delay Waveform

Other Measurements

- Stator Frame/Core Vibration
- Stator Bar Vibration
- Ground Relay Voltage
- Stator Core Temperature
- Shear Pin Monitor
- Stator End Winding Temperature
- Rotor Pole Temperature
- Cooling Air Analysis (CHx)
- Cooling Air Ozone
- Relay Fault Waveforms

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Customized Guide Bearing Display

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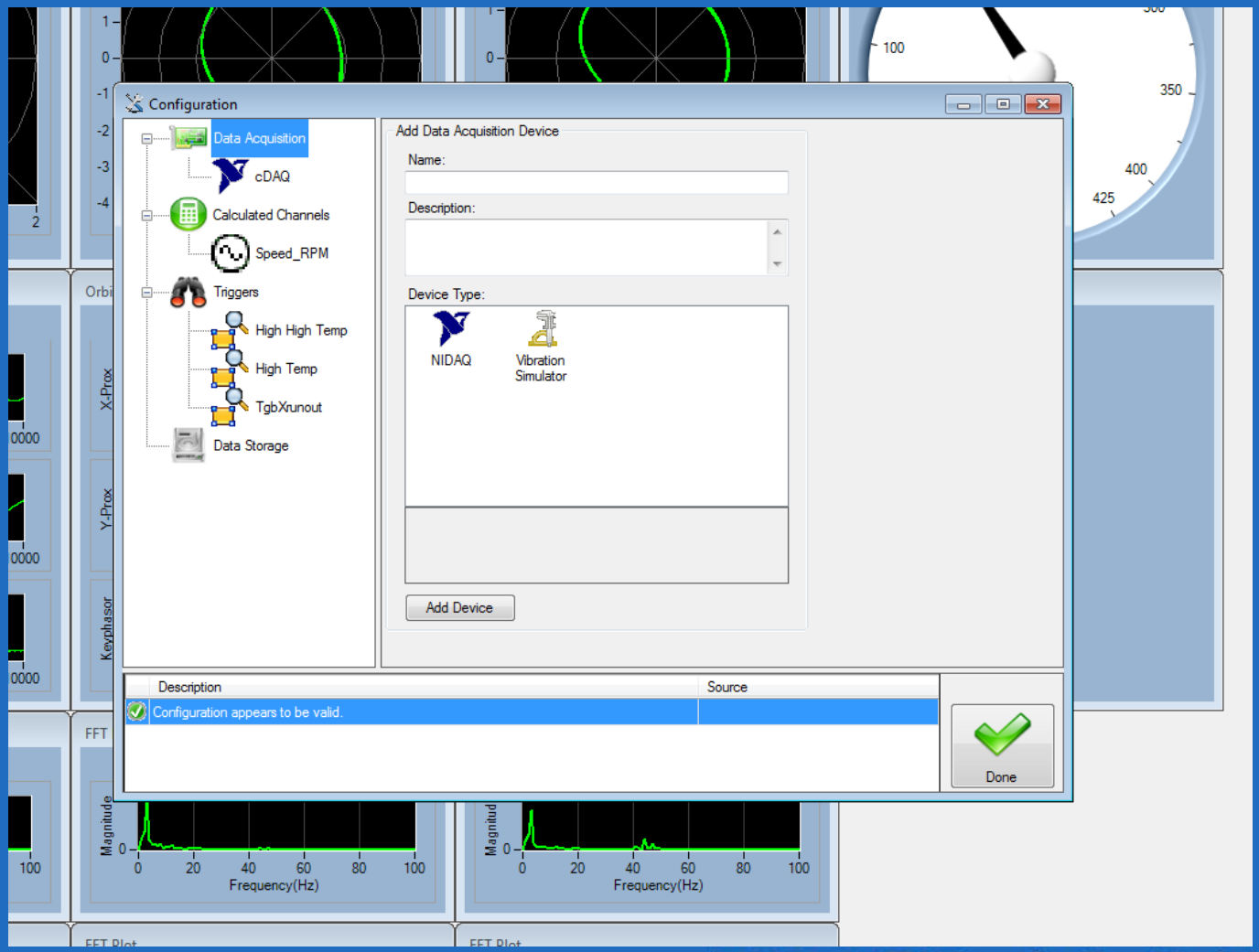
Works with Multiple Data Acquisition Devices



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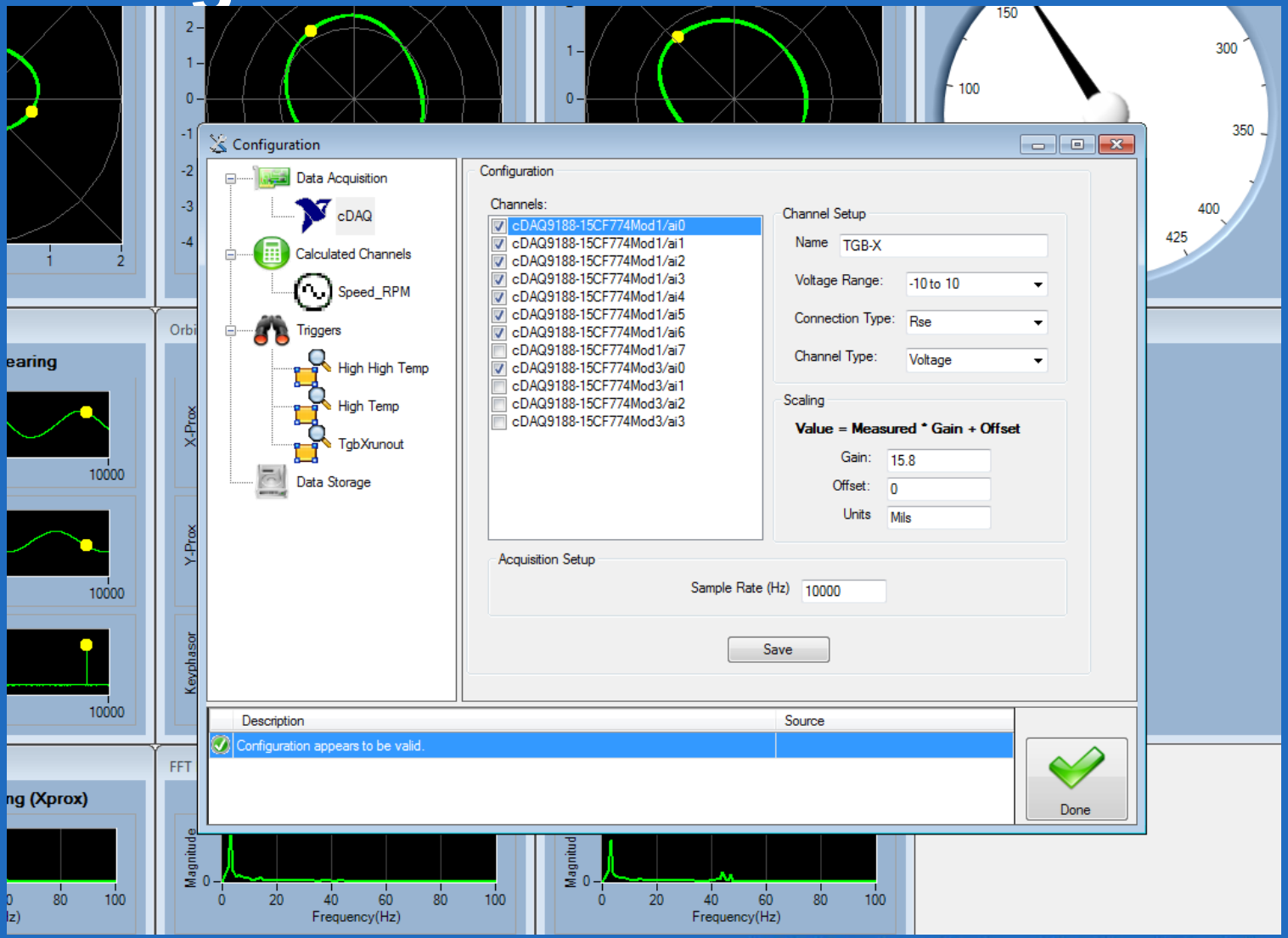
Configure Data Channel



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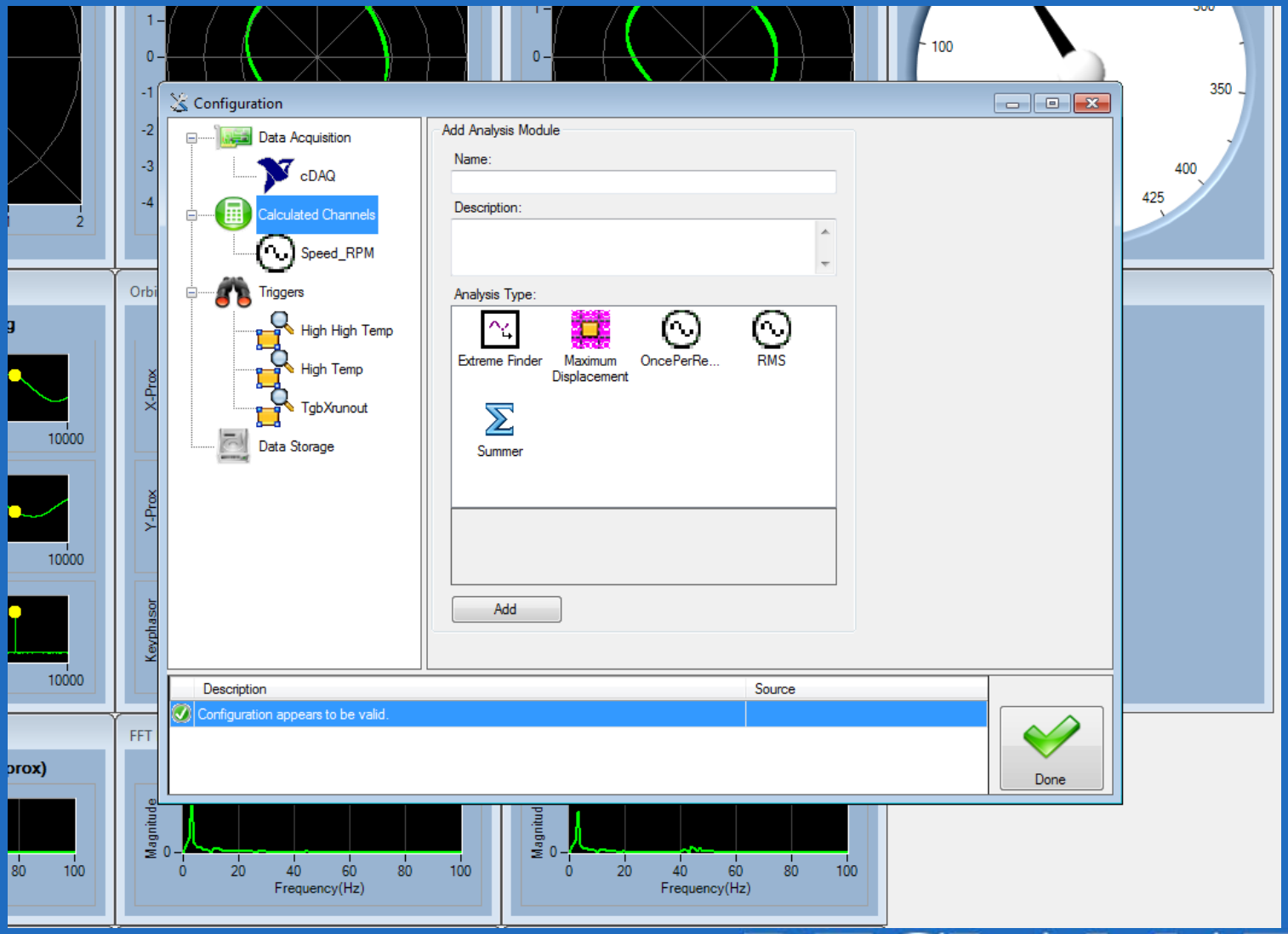
Calculate A New Data Channel



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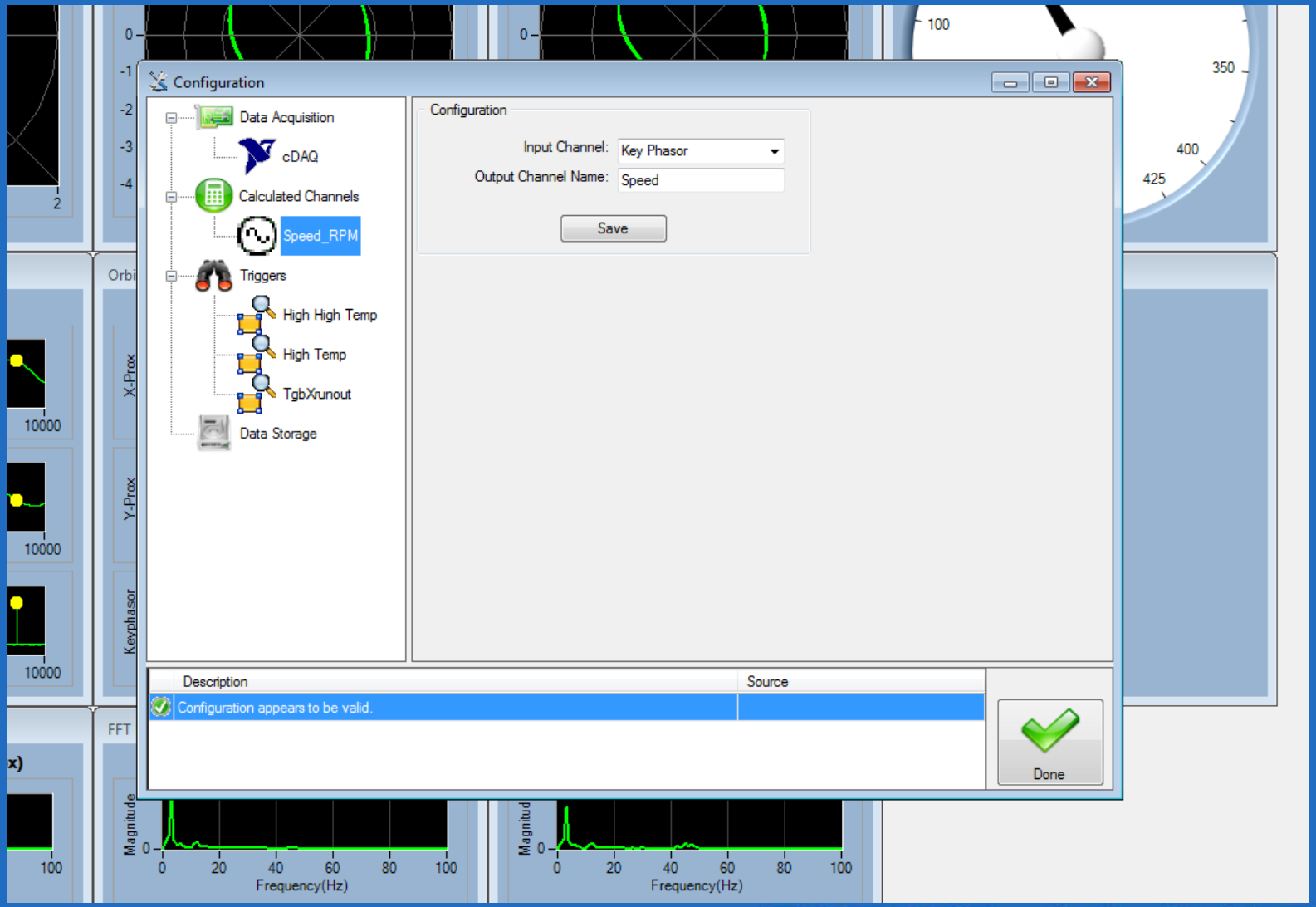
E.G. Calculate speed from 1/rev.



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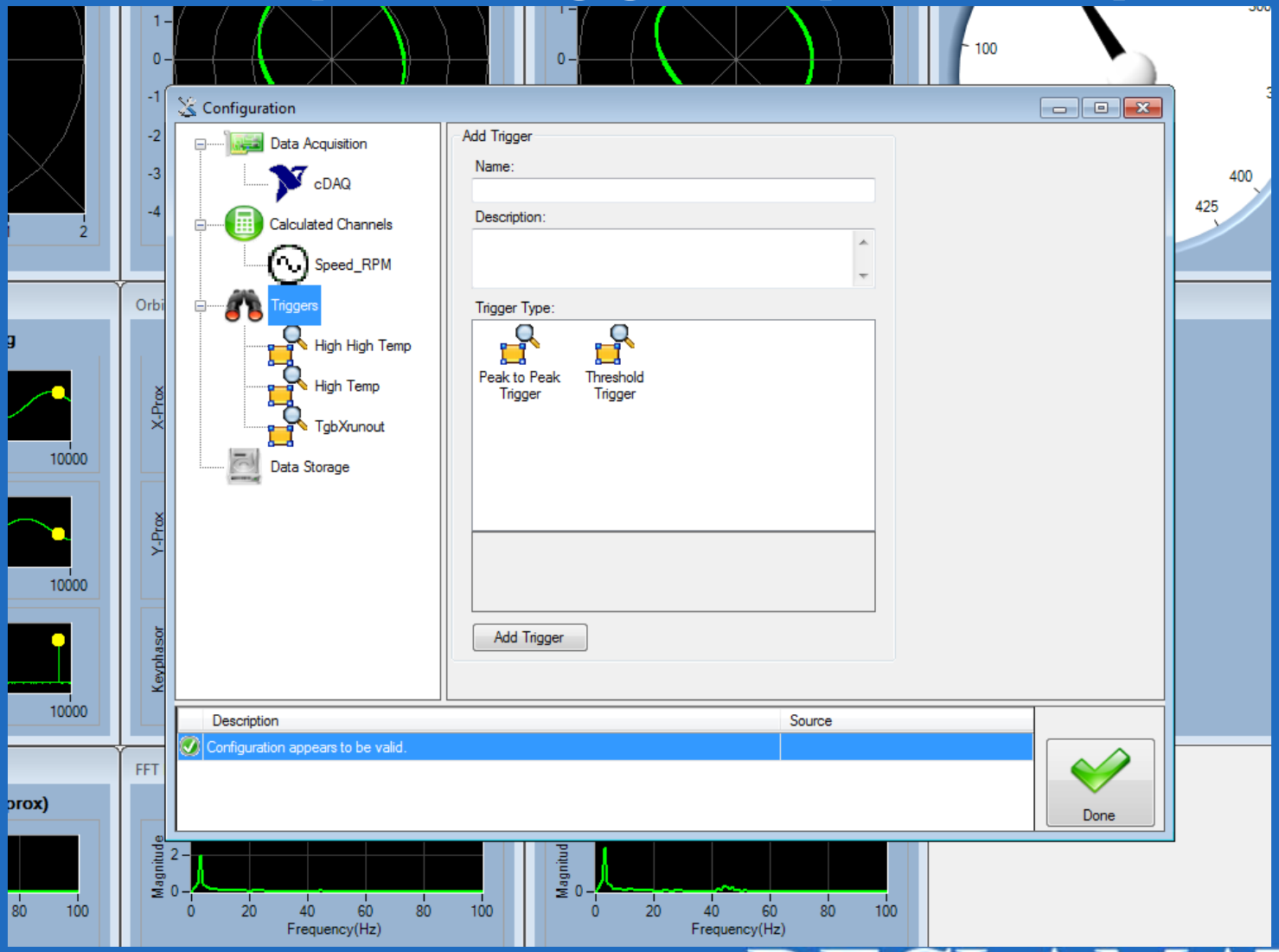
Set Multiple Triggers (Alarms)



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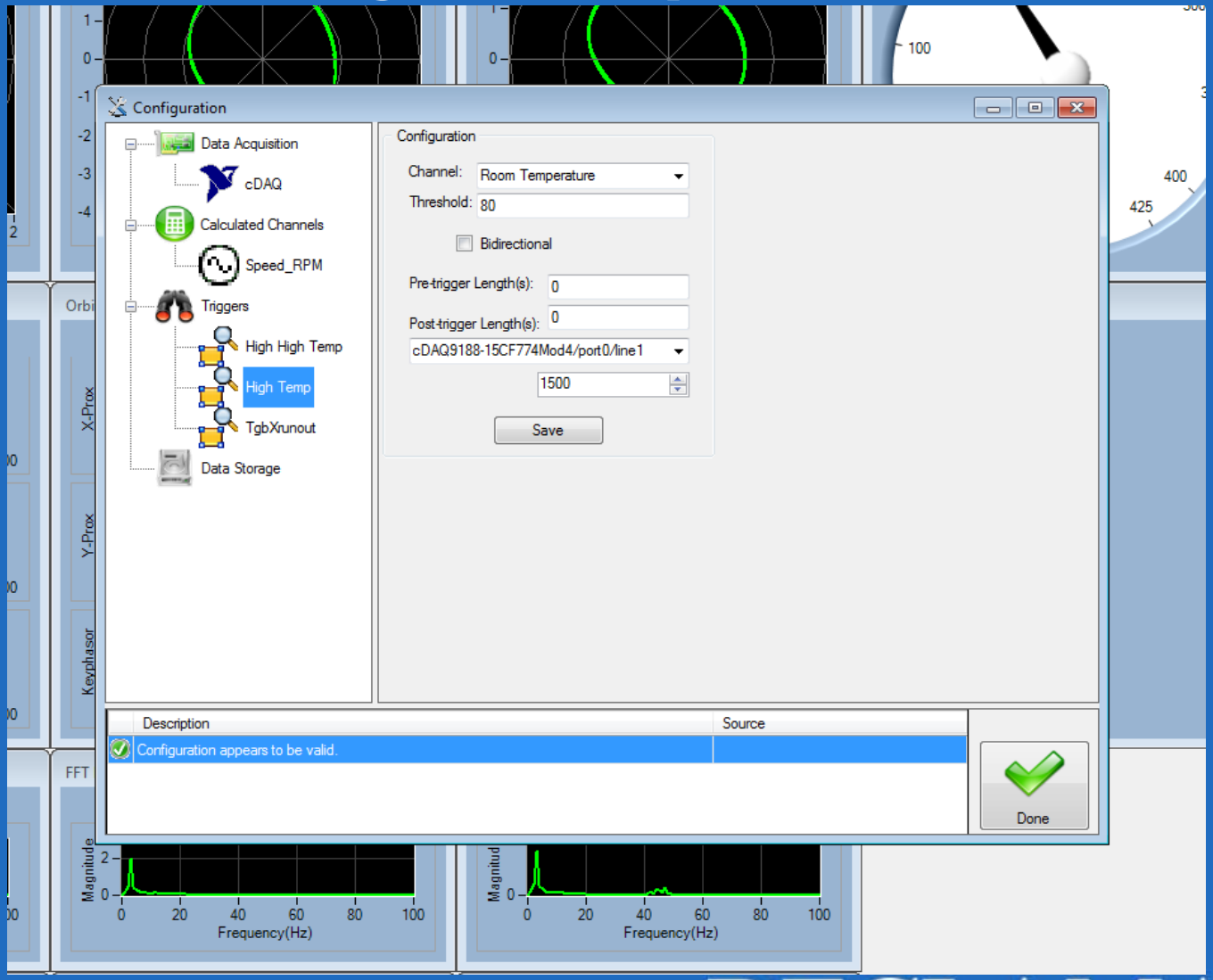
E.G. Set High Temp Alarm



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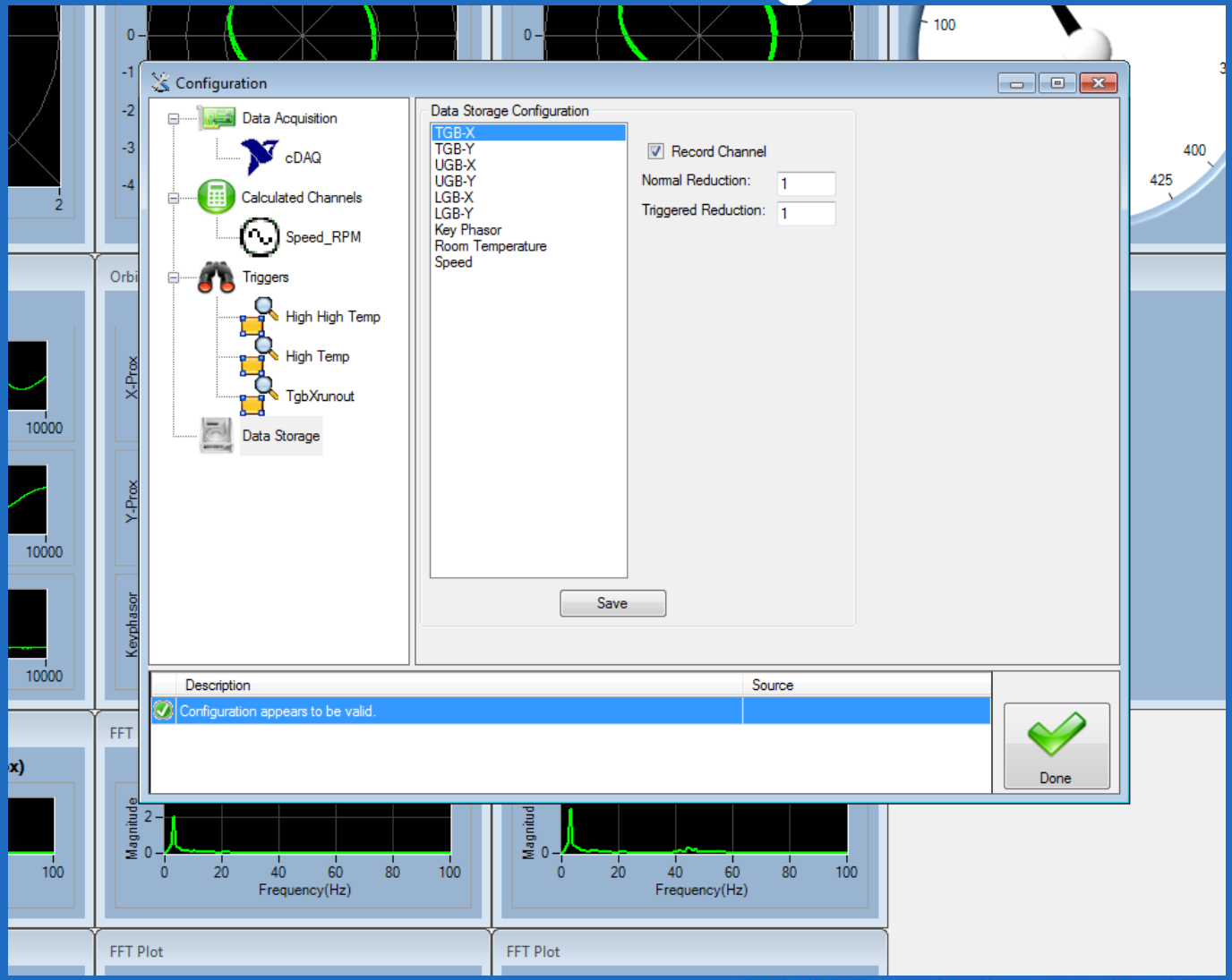
Select Data for Storage



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