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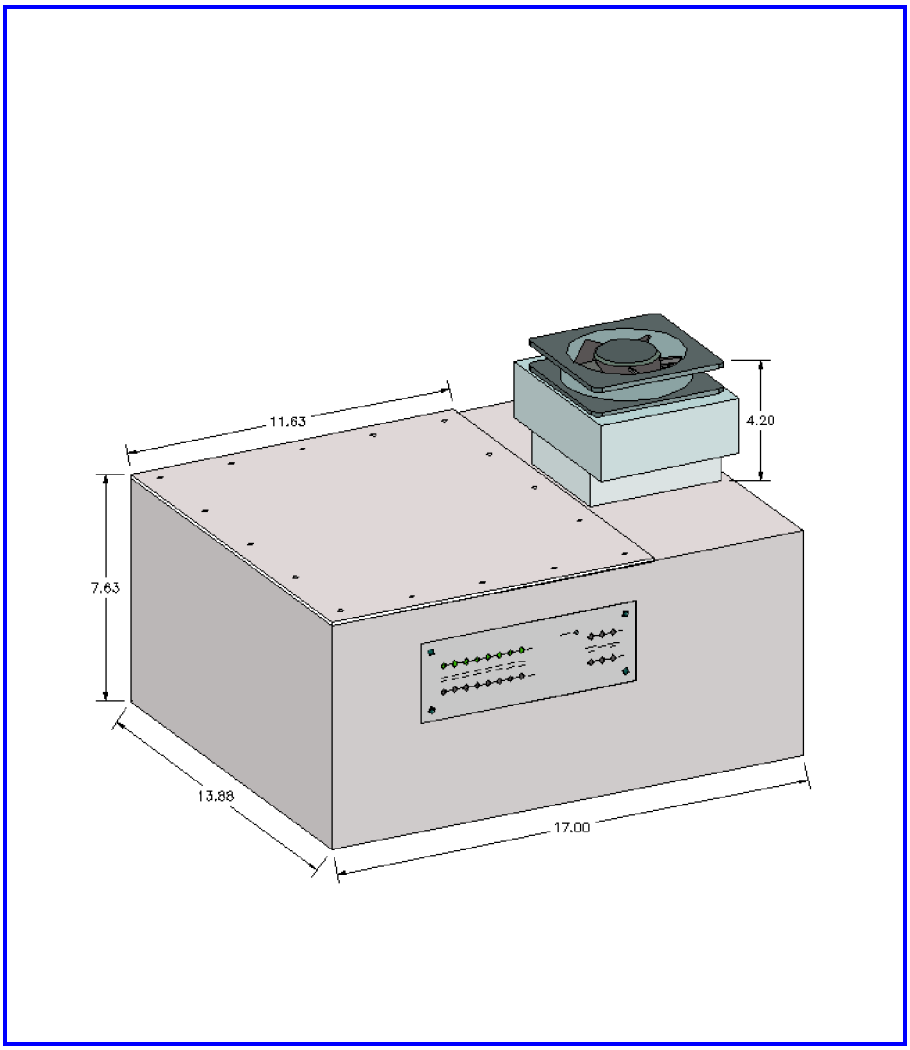
INTRODUCTION

The Lovejoy Controls Corporation (LCC) Series-2 Small Turbine Modular Governor is a state of the art PLC-interfacing or direct operated turbine electro-hydraulic control system designed to provide low maintenance and superior performance for small steam turbines.



Thermoelectrically Cooled Series-2 Governor Enclosure

The Series-2 Governor electronics are mounted in a nitrogen purged housing with redundant **Peltier thermoelectric cooling module**s which maintain operating internal electronic temperature in the optimum life range under ambient external temperatures **up to 175EF (80EC)**. With the flexibility enabled by solid state cooling, the governor housings may be mounted either wall or rail-mounted in proximity to the turbine units or in existing electronics cabinets. Virtually no further ventilation is required.

Series 2 Enclosure, 19" Rack-Mount

The application range of the Series-2 includes:

- **GENERATION TURBINES**
- **FEEDWATER PUMP DRIVE TURBINES**
- **FORCED DRAFT FAN TURBINES**
- **INDUCED DRAFT FAN TURBINES**
- **OTHER** small turbine applications of Westinghouse, General Electric, De Laval, Worthington, Seimans, ABB, Alsthom, both Mechanical and Generation drive.

Multiple Series-2 Governor configurations permit very cost-effective solutions to turbine control. Standard configurations can provide both PLC (Programmable Logic Controller) or DCS (Distributed Control System) serial interfacing along with dedicated operator control station options. An economical configuration can be found for each application which provides required interfaces and/or control stations without the

expense of additional unused equipment.

With a rich design heritage of governors controlling vital nuclear applications, LCC has applied a twenty-year experience in turbine control to the Series-2.

ARCHITECTURE

The electronic design architecture of the LCC Series-2 Governor can be summarized as *Parallel Microcontroller*. Just as advanced super-computer designers have learned that multiple, smaller computers dedicated to specific tasks operating simultaneously makes a much faster and more reliable computer, LCC has been applying parallel processing to electronic governors since 1986. LCC alone offers parallel processor control technology for small governor systems.

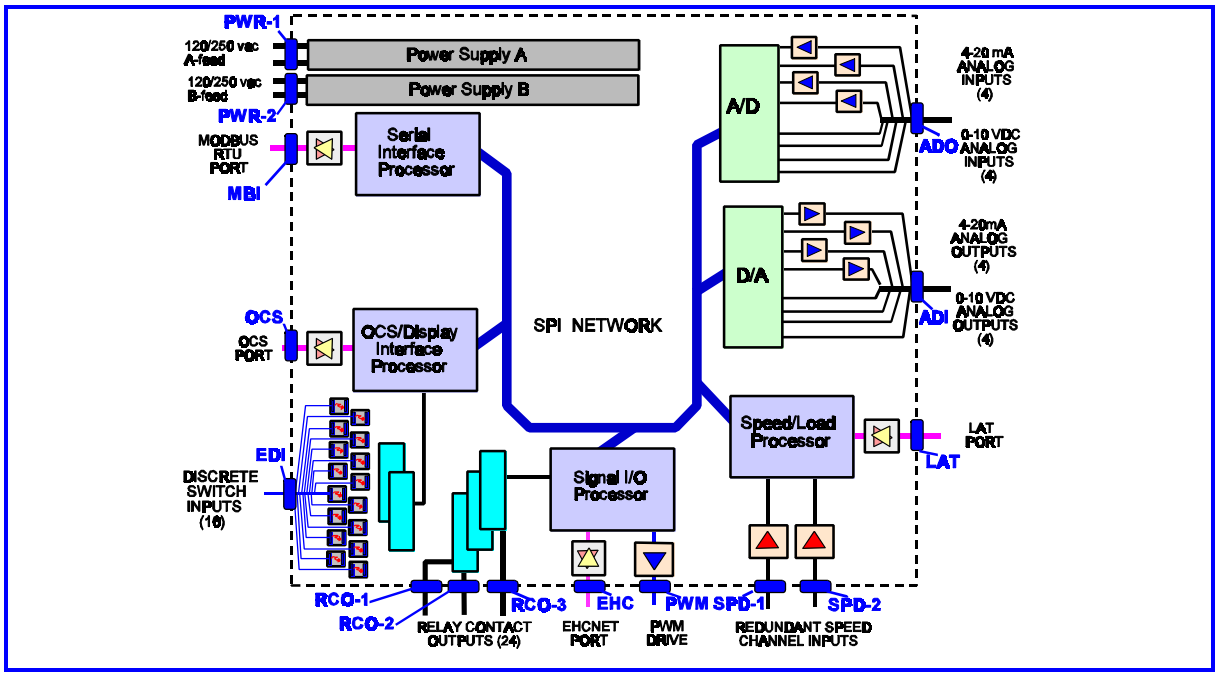
There are some excellent reasons for using a collection of small microcontrollers rather than a single exotic microcontroller:

- By assigning dedicated tasks to separate microcontrollers, the speed control loops are closed more quickly, improving governor response and turbine control.

- The microcontrollers used by LCC, the Motorola HC-11 (or Hitachi equivalent) are the standard automotive engine control computer used by American and Japanese automakers. It is therefore widely available, low cost, and most important of all guaranteed future availability for renewal parts. Lower volume production exotic microcontrollers can have production ceased overnight due to electronic market whims rendering designs immediately obsolete.

- An excellent library of turbine control algorithms, proven in hundreds of unit-operating years, has been developed by LCC for known bug-free operation. Manufacturers using trendy exotic processors must constantly develop new software with unproven validation and verification. LCC's algorithms have been accepted by the US nuclear plants for reliable, precise turbine control.

The Series-2 Governor Block Diagram is shown below.



SERIES-2 GOVERNOR ELECTRONIC BLOCK DIAGRAM

Combining the array of signal I/O and the library of associated LCC governor control algorithms, the Series-2 Governor provides a flexible turbine control package.

Field tuning and setup is performed by connecting a laptop personal computer operating a LCC-supplied *Configuration Program*. The serial communication link established allows adjustment of the Governor Characteristic Parameters (GCPs) for each unit.

The valve-positioning design architecture will vary with applications. For turbine applications requiring a servomotor pilot pressure to be generated, the LCC LPEHC (Low Pressure Electro-Hydraulic Converter) is optioned. In these applications the Pulse Width Modulated (PWM) drive output of the Series-2 Governor directly drives the LPEHC which in turn develops the pilot control oil pressure to position the governor servomotor.

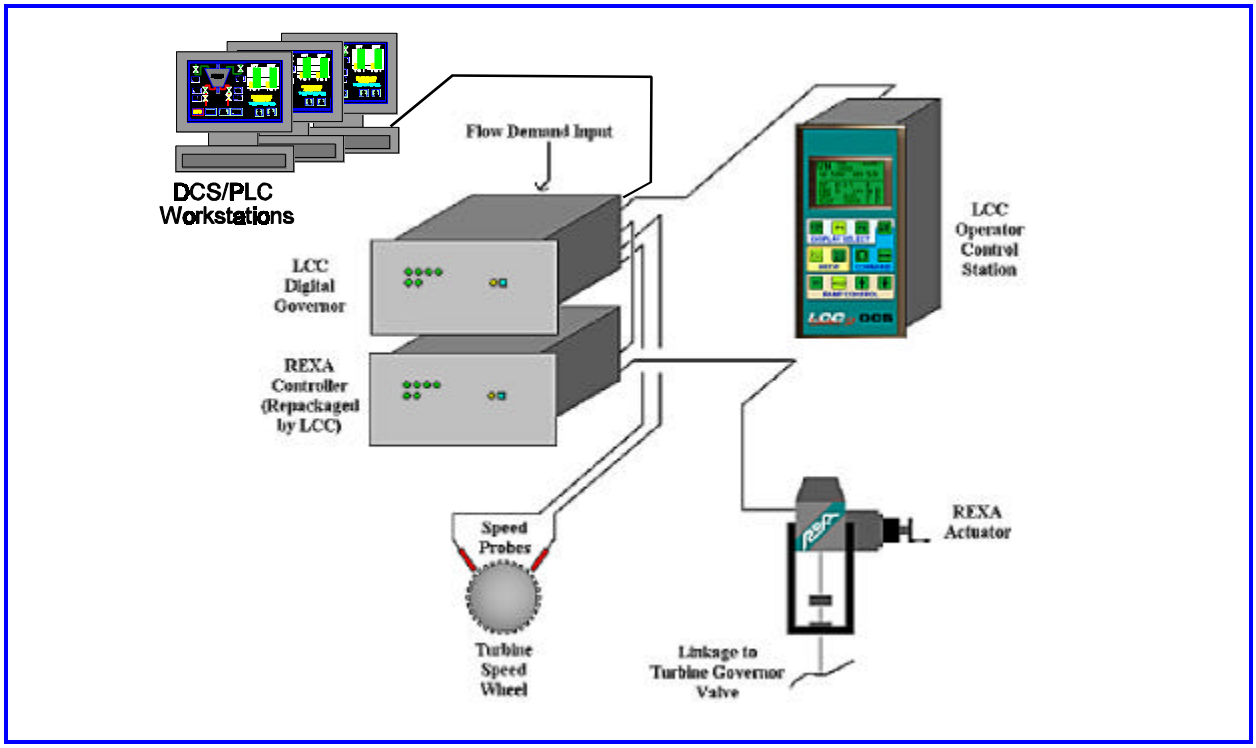
Other applications, Such as the REXA Type L Actuator, utilize the 4-20 mA drive output.

In addition, Series-2 Governors have configurable actuator feedbacks for precise positioning. Either pressure feedback or linear position (stroke) feedback may be implemented, optimized for the application.

Series-2 Governor speed feedback is accomplished by either simplex or duplex speed probes mounted in proximity to almost any size or tooth-count gear on the turbine shaft. RS-422 transmitters insure RFI/EMI-free speed feedback to the governor.

APPLICATION CONFIGURATION with REXA ACTUATOR

Configurations are determined by specifying *Demand Control*, *Positioner Drive/ Feedback*, and *Control Algorithm* options to perfectly fit the target steam turbine. When utilizing a REXA Actuator the interface is very straight-forward. The analog governor valve drive output (4-20 mA) of the Series 2 provides the REXA Controller position setpoint input. Further links between the REXA Actuator and the Series 2 Governor combine alarm and diagnostic information, making it available at the OCS and/or the DCS workstations. One such configuration is presented in the following figure.



TYPICAL SERIES-2 GOVERNOR SYSTEM CONFIGURATION DIAGRAM

1.0 Demand Control Options

1.1 Serial Interface

For applications where a plant (or OEM) PLC or DCS is present for coordinated systems control, the most logical design is to interface the turbine governor directly to the PLC or DCS as a distributed drop. The PLC/DCS operator control stations may then be utilized to provide manual or automatic speed/load demands to the Series-2 Governor. The serial interface may be:

1.1a. RS-485, RS-232, or priority Serial Ports

1.1b. Master/Slave or Networked

1.1c. Choice of Protocols, including but not limited to:

- ModBus™ RTU
- ModBus™ ASCII
- GE Fanuc GENIUS™ BUS

ModBus™ is a registered trademark of Modicon Corporation.
GENIUS™ BUS is a registered trademark of GE Fanuc Automation N.A.

The serial interface supports communication of demand setpoints, alarms, and special runbacks between the host PLC/DCS and the Series-2 Governor. Because the Series-2 Governor performs the high-speed loop closure of valve position and turbine speed (much too fast for PLCs or DCSs to control), it frees the host system to optimize demands and provide operator control stations or screens.

1.2 Operator Control Station

When required, the Series-2 Governor is fitted with an Operator Control Station (OCS) to provide a panel from which operators may input speed and load control commands. The OCS is typically opted when a PLC or DCS system is not resident in the plant or when a local hard-panel station is desired as a backup or turbine startup station.

Physically, the station consists of a dedicated pushbutton panel with

Typical OCS Layout

demand and real-time displays and status indicators. Pushbuttons are tactile ("clicking") and backlighted behind a membrane cover. Membrane identifications and legends may be printed in any language.

Multiple configurable digital displays, bar-graph displays, and indicators, allow simultaneous monitoring of both turbine speed/load and process parameters for knowledgeable operator control beyond conventional governor displays.

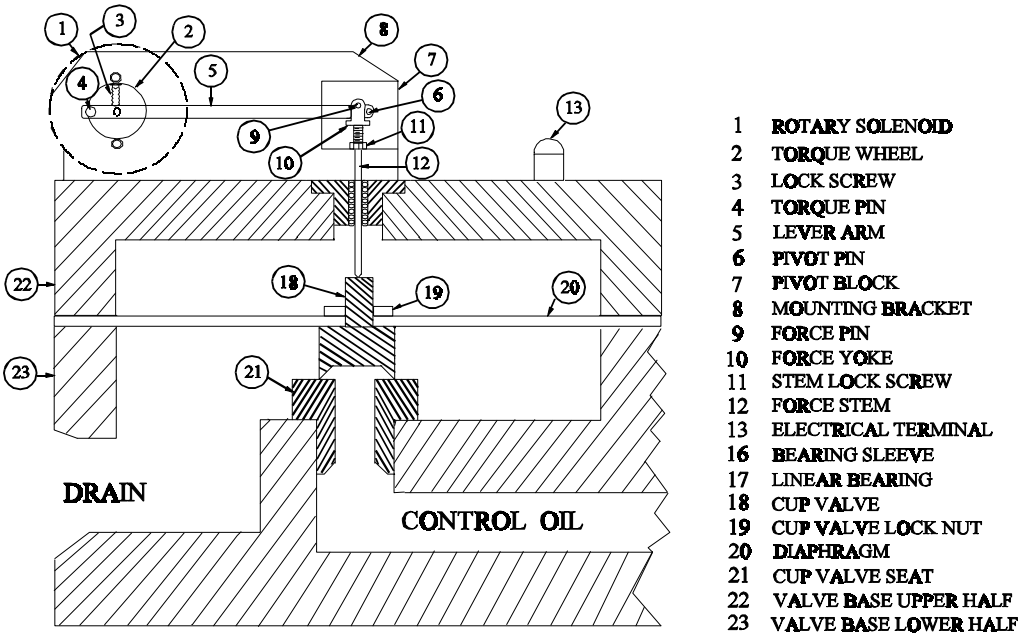
1.3 External Discreet Switch Control

On simple, basic installations using hard-wired control panels, external switches may be wired to the Series-2 Governor providing basic governor raise, lower, and emergency stop command inputs. When using this configuration, an external tachometer and/or process display must be available at the control switches' location for operator view.

When the existing displays exist and no "automatic" speed or load positioning is required, this eliminates the expense of an OCS.

2.0 Positioner Drive/Feedback Options

Positioners for turbines vary greatly both by manufacturer, type, and vintage. The Series-2 Governor may be configured to provide closed-loop positioner control of most designs of steam, gas, and hydro turbine inlet governing valves. The following configurations are most commonly utilized:



LPEHC CONVERTER CROSS-SECTIONAL VIEW

2.1 LCC LPEHC Converter for Servomotor Pilot Pressure Control

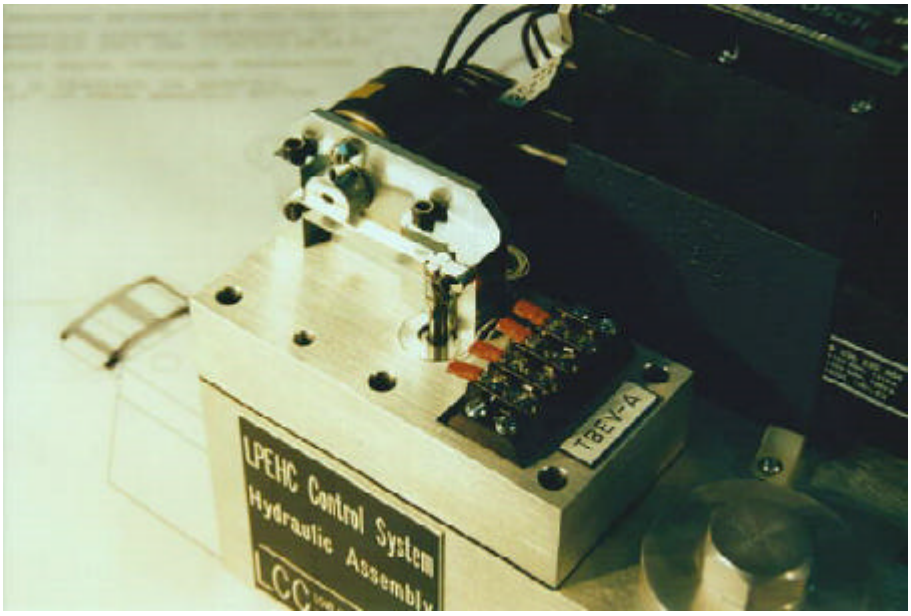
The Series-2 Governor produces a Pulse Width Modulated (PWM) drive output which drives the LCC Low Pressure Electro-Hydraulic Control Converter (LPEHC Converter). The LPEHC Converter is an advanced electronic to hydraulic pressure converter designed by LCC and currently employed on over one hundred turbines providing nuclear plant reactor and steam generator level control.

The LPEHC Converter produces a field-configurable linear pilot-positioning control oil pressure to precisely stroke steam and hydro turbine servomotors over their active range.

The figures on the following page depict the LPEHC Converter, which establishes a force balance between the torque of the rotary solenoid and the output control oil pressure working on the valve area. Existing lube oil supplies are tapped to feed the LPEHC Converter from dual inlets each protected with an orifice guard screen monitored for differential pressure and maintainable on-line.

LPEHC Converters are mounted in C-N-C machined hydraulic feed blocks. The Series-2 Governor LPEHC kit consists of one LPEHC Converter, two inlet guard screens with isolation valves and differential pressure switches, and fittings for connection to servomotor ports. The assembly mounts easily and provides leak-free connections.

Positioning feedback may be employed as LPEHC Converter pressure output (via pressure transmitter) or position feedback from an LVDT or linear potentiometer tracking the driven servomotor stroke. Each application is analyzed for optimum feedback method.



LPEHC CONVERTER

2.2 REXA Actuator (Analog 4-20 mA Positioner Drive)

On many turbine units, the existing oil supply system is not reliable or contains too much contamination to be used for control hydraulics. In these instances the REXA Actuator may directly (or through mechanical fulcrums) position the governor valves thus eliminating the oil system as a failure point.
LCC works closely with REXA for the best possible retrofit alignments.

3.0 CONTROL ALGORITHMS

According to the type of turbine, a set of control algorithms are provided which utilize Governor Characteristic Parameters (GCPs) to define the particular unit control functions. The laptop PC LAT may be used to change the GCPs at any time, even during turbine operation, due to bumpless transfer buffering. The following discussion covers basic control functions common to all types of applications.

3.1 Operating Modes

Three operating modes are supported:

MANUAL MODE employs demand speed or load control strictly on the basis of operator input commands, either from an Operator Control Station (in MANUAL MODE) or from discreet switch inputs enabled. This is a full-feedback closed loop control mode.

AUTO MODE uses an external demand signal for speed/load setpoint. The signal may be received from the PLC/DCS serial interface, a 4-20 mA analog input, or a pulse-coded input to the Series-2 Governor. This is a full-feedback closed loop control mode.

DIRECT VALVE POSITION MODE ignores all speed/load feedback and causes the operator input commands, either from an Operator Control Station (in DVP MODE) or from discreet switch inputs enabled, to induce immediate open or closed ramping of the inlet governor valve position.

The Series-2 Governor permits transfers between modes at all times without demand or speed "steps" due to complete bumpless transfer capability.

3.2 Intelligent Backup Control

In the event of a loss of an AUTOMATIC signal input, control is immediately transferred to MANUAL without speed or load loss. In the event of a loss of both speed feedback channels, control is immediately transferred to DIRECT VALVE POSITIONING MODE without speed or load loss.

LOVEJOY CONTROLS... A LONG USER LIST, A REPUTATION OF EXCELLENCE

LCC has manufactured and installed turbine governor systems at the following plants:

Arkansas Power & Light
White Bluff Plant

Baltimore Gas & Electric
Calvert Cliffs Nuclear Power Plant

Central Illinois Public Service
Newton Generating Station

Cincinnati Gas & Electric
East Bend Station

Cincinnati Gas & Electric
Miami Fort Station

Commonwealth Edison Company
Joliet Generating Station

Commonwealth Edison Company
Kincaid Generating Station

Commonwealth Edison Company
LaSalle Nuclear Generating Station

Commonwealth Edison Company
Will County Generating Station

Commonwealth Edison Company
Zion Nuclear Generating Station

Compania Sevillana de Electricidad
Estacion Bahia de Algeciras

Consolidated Edison Company
Indian Point 2 Nuclear Station

Dairyland Power Cooperative
Genoa 3 Generating Station

Duke Power Company
McGuire Nuclear Generating Station

Entergy Operations, Inc.
Arkansas Nuclear One

Mississippi Power & Light
Baxter Wilson Generating Station

Nebraska Public Power District
Cooper Nuclear Station

New York Power Authority
Indian Point 3 Nuclear Power Plant

New York Power Authority
Charles Poletti Generating Station

Northern Ireland Electricity
Kilroot Unit 2

Otter Trail Power Company
Big Stone Generating Station

PacifiCorp
Centralia Generating Station

Pacific Gas & Electric
Diablo Canyon Nuclear Power Plant

PSI Energy
Cayuga Generating Station

Tennessee Valley Authority
Shawnee Fossil Plant

Northwest Energy
Columbia Nuclear Plant