Feedforward on Temperature Control Systems

Fast Compensation for Disturbances

Arthur Holland, Holland Technical Skills

The tried and true PID controller can handle most processes, even those with tiresome long lags. Easy, right?
Not always. Some processes can give a regular PID controller a hard time; even make it impossible to do its job. **Feedforward** is a solution worth bearing in mind.
The operation of an outdoor thermostat is a simple example. It says "Hey it's getting cold out here, better turn up your heat in there. Why wait for that sluggish indoor thermostat."

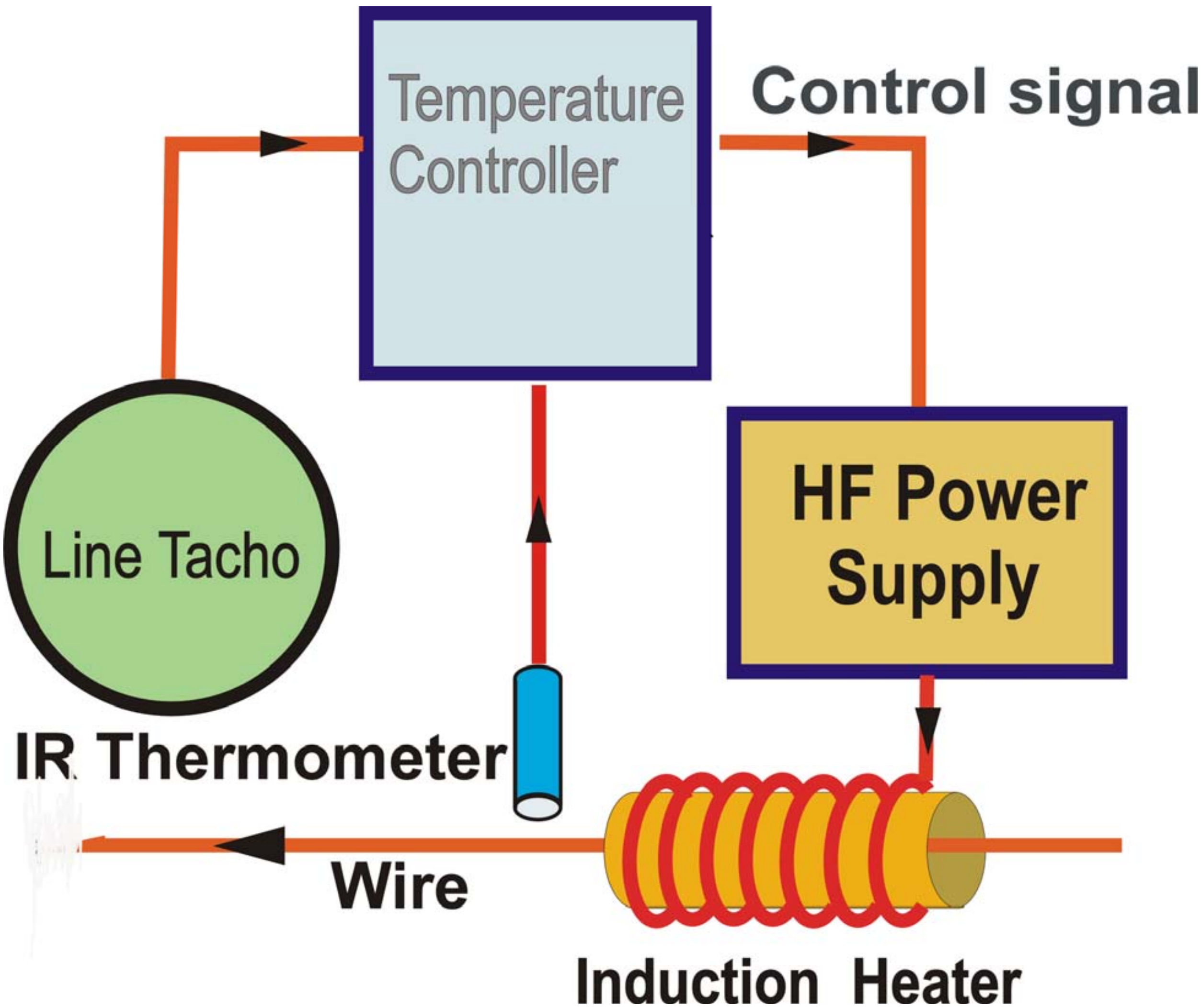

Fig 1. Process with Feedforward Control

Fig 1. shows such a process. A wire-covering line where a fast-moving copper wire is being wrapped with a plastic-impregnated fiberglas tape then passed through a high frequency

induction heater coil to bond the tape to the wire. The heat is delivered right to the copper by electromagnetic induction.
The wrapped wire temperature is sensed by an infrared thermometer and passed to the controller whose analog dc output drives the induction heater which brings the wire up to the desired temperature.
Problem. The line speed changes at startup, at shutdown and upon any disturbance to the motor drive during a run. The resulting variations in the mass/second of passing material demand immediate corresponding changes in heating power to keep the temperature on target.
Fast though they are, the sensor, controller and induction heater, acting one after the other, will be too late in catching and correcting for these temperature deviations. So the wire covering will suffer underheated (unbonded) and overheated (scorched) sections.

How to make the speed signal turn up the heat.
Let’s say you put the controller on **manual.** You could find and plot the controller’s manual input settings that produce the power required to hold the correct temperature for every speed in the range. That is assuming no other upsetting factors.

Since immediate knowledge of speed comes from the line-speed tachometer signal you can scale this signal and use it as the manual input to the controller. It passes immediately through to the induction heater and by turning up the power in proportion to speed you stand a fair chance of holding the desired temperature at all speeds. This is called **feedforward.**
You have now removed from the controller the burden of watching the temperature and chasing line speed disturbances.

Now put the controller in **automatic** mode but keep the speed signal’s contribution. Now the controller’s temperature feedback and automatic PID action superimpose the now relatively small corrections to control signal on top of that from the speed signal.
You can now optimise the controller’s PID settings to minimise deviations and off-spec product.

You may find that the temperature does not hold well enough with a linear speed signal calling up the power. This could overwork the PID temperature loop. You can insert a **signal conditioner** to shape the speed signal to yield smaller temperature deviations.
You will need a controller that can scale and add the feedforward signal to the regular PID output.

OTHER APPLICATIONS OF FEEDFORWARD.
Temperature control of gas or liquid flow where incoming product flow or temperature could vary.

- Use mass flow feedforward.

- Use temperature feedforward based on set point minus incoming temperature

Temperature control using electric heaters where line-voltage varies.
In a process having long lags it takes a long time for temperature feedback to recognise and correct for a line-voltage change. It is impractical and expensive to stabilise the line voltage.

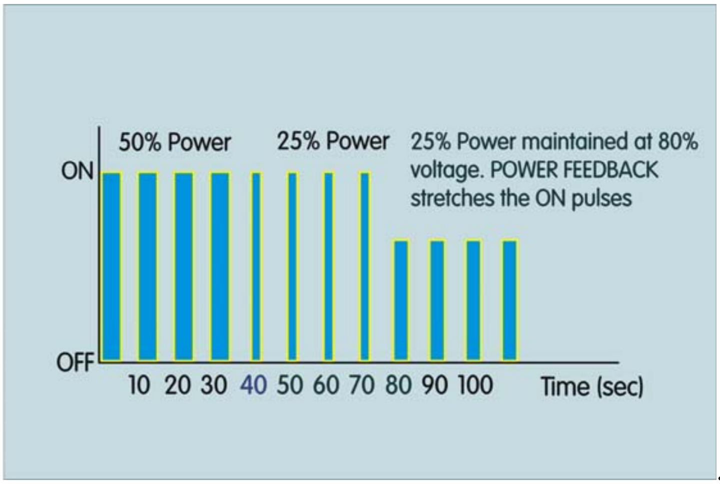

Fig 2. Correction for Line Voltage Variation

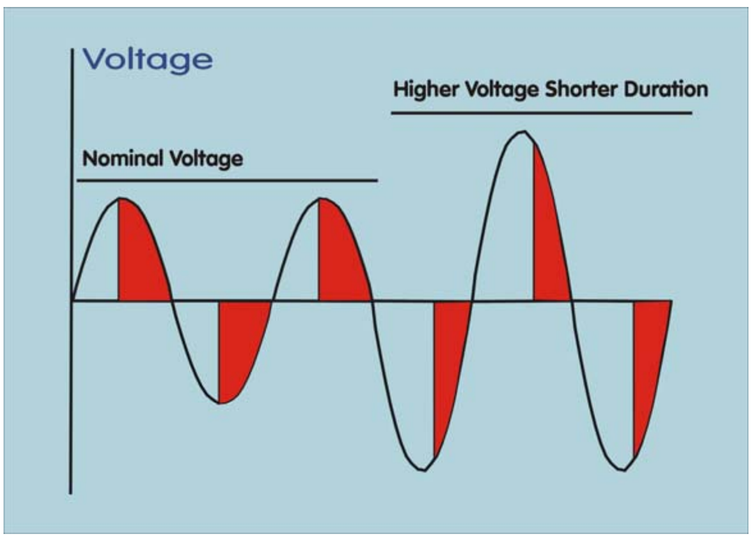

Fig 3. Correction for Line Voltage Variation

- Use a controller with a time proportioning output having a percentage ON time that varies as $1/V^2$ (sometimes called **power feedback** though it is an example of **feedforward. See Fig 2.**
- You can do the same with phase-angle control where the shark fin pulse width is reduced in response to a line-voltage increase. **See Fig 3.**
- With severely temperature dependent heater resistance (e.g. silicon carbide, tungsten molybdenum disilicide) use a phase-angle fired SCR where the controller signal calls up true power regardless of line voltage and heater resistance.