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Irrigation Pumping Plant Efficiency Testing

Determining the Cost of Electricity of a Natural Gas Generator

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As water well production declines across many parts of the Texas High Plains, many pumping plants currently using natural gas engines are becoming better suited for smaller submersible pumping units driven by electricity.

Infrastructure costs associated with delivering necessary electrical power from the grid often make this conversion to properly sized, efficient pumping plants an economic compromise. An alternative method for electrical power delivery in these scenarios is the installation of an on-site natural gas generator that can power multiple smaller electrical pumping plants.

Natural gas Caterpillar 3306TA driving a Marelli three-phase generator, providing power to three irrigation wells.

The following information contains a basic method for determining the fuel costs associated with producing electricity at an on-site natural gas generator. This cost can be directly compared to the market price of electricity purchased from a commercial provider.

To determine total costs associated with on-site power generation, operation and maintenance expenses and amortized capital expenses tied to the purchase of the natural gas generation unit also must be considered. For practical comparative evaluations, the capital expenses associated with on-site generation usually are similar to or less than the capital expenses related to delivering power from the existing commercial electrical grid to a pump location. Further, comprehensive maintenance costs associated with one natural gas generator typically are much less than the costs associated with multiple natural gas wells. Upgrade costs at individual pumping plants also will need to be included in a comprehensive economic evaluation related to this conversion.

Method of Calculating Costs

Measure the elapsed time in seconds for consumption of a specified volume of natural gas (the longer the interval is, the more accurate this measurement will be). This measurement is used to calculate the rate of natural gas consumption. As a note, most natural gas meters in the Texas High Plains require that a displayed reading is multiplied by a correction factor to account for local conditions (for example: gas temperature, altitude, pressure, etc.).

1 $$NG_{cons} = \frac{Vol_{NG}}{Time} * 3600$$

Where:

NG_{cons} = natural gas consumption in cubic feet per hour (ft^3/hour)
Vol_{NG} = volume of natural gas consumed during the specified time period (ft^3)
$Time$ = elapsed time (seconds)

Calculate the hourly fuel cost of the natural gas generator:

2 $$NG\ Cost = NG\ Cost_{unit} * NG_{cons.}/1000$$

Where:

$NG\ Cost$ = cost of natural gas consumed per hour of operation ($ / hour)
$NG\ Cost_{unit}$ = purchase price of natural gas per thousand cubic feet ($ / thousand cubic feet)
NG_{cons} = natural gas consumption in cubic feet per hour (ft^3/hour)

Measure the electrical production of the generator using a properly rated, true-rms digital clamp meter. The measurements necessary are AC volts and current in amps. It often is worthwhile to measure all three electrical legs to ensure balanced power production and use the average voltage and amperage readings. (These calculations are for three-phase power (the calculation for single-phase power does not include the square-root of three factor.)

> ### Exercise extreme caution when working around all agricultural electrical circuits!

Determine the power generated by the generator in kilowatt hours per hour (kwh / hour).

3 $$Power = \frac{V * I * PF * \sqrt{3}}{1000}$$

Where:

Power = kilowatt hours per hour generated (kwh / hour).
V = output voltage generated (AC volts)
I = output current generated (amps)
PF = power factor of the generator in decimals (typically 85 percent or .85)

Calculate the cost of power:

4 $$Elec\ Cost = \frac{NG\ Cost}{Power}$$

Where:

Elec Cost= unit electrical cost in dollars per kilowatt hour ($ / kwh)
NG Cost = natural gas cost per hour ($ / hour of NG)
Power = electrical power generation rate (kwh / hour)

Example

A natural gas generator set with an 85 percent power factor is generating 480 volts with a system current load of 120 amps from two pumping plants. Natural gas is purchased from an off-site supplier at $5 per thousand cubic feet. Measurements of natural gas show that 20 cubic feet are consumed in a 50-second period. Determine the unit electrical power cost associated with this generator set.

1 $$NG_{cons.} = \frac{Vol_{NG}}{Time} * 3600 = \frac{20\ ft^3}{50\ seconds} * 3600 = 1{,}440\ \frac{ft^3}{sec.}$$

2 $$NG\ Cost = NG\ Cost_{unit} * \frac{NG_{cons.}}{1000} = \$5.00 * \frac{1{,}440\ \frac{ft^3}{sec.}}{1000} = \$7.20\ /Hour$$

3 $$Power = \frac{V * I * PF * \sqrt{3}}{1000} = \frac{480V * 120Amps * .85 * \sqrt{3}}{1000} = 84.8\ KWH/Hour$$

4 $$Elec\ Cost = \frac{NG\ Cost}{Power} = \frac{\$7.20\ /Hour}{84.8\ KWH/Hour} = \$.0849/KWH$$

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