Power Generation and Water

A multi-decade look at this important relationship

July 2016

SUNFLOWER ELECTRIC POWER CORPORATION

A Touchstone Energy® Cooperative

Early System Generation

Pre-1960

- Initial buildout of rural electric system
- Generating units were quite small (< 5 MW) and used natural gas or fuel oil
- Early units used once-through cooling systems
    - Water was pumped directly from wells through single-pass steam condensers and dumped to an effluent ditch
    - Untreated effluent water was used for area irrigation with excess water entering the Arkansas River
    - Some early designs even used this effluent water stream for food processing in Garden City's sugar mill
    - Warm effluent water was even a source of area recreation with many elder residents remembering winter swimming in the "steaming" warm waters
- No reliable records remain from this era, but pumping rates are estimated to have been in excess of 25,000 gallons per MWh of electric production

Early System Growth and Expansion Years

1960 to 1970

- Electricity available on a more widespread basis creating rapidly rising loads
- First unit constructed with an open-*loop* cooling system (cooling tower)
  - Water was continuously circulated between a condenser and cooling tower in a constant loop
  - Heat was exchanged between the water and air in the cooling tower
  - Make-up water compensated for system water losses (evaporation)
- Multiple small units in operation with multiple cooling configurations
- Units fueled with natural gas or fuel oil
- Typical annual station (GCS) gross generation was around 180,000 MWh
- Typical water pumping rate dropped measurably to approximately 22,250 gallons per MWh of electric production

Rapid Growth Period

1970 to 1980

- Rapidly growing electric loads made it difficult to build units fast enough to keep pace with electric demand
- Constructed first large-scale, steam unit (90 MW)
- Constructed first, large-scale, simple-cycle peaking units (50 MW each)
- Both designs were configured with open-loop cooling systems
  - Steam unit with a cooling tower
  - Gas turbine units with evaporative coolers
- Production shifted dramatically to the larger, more efficient units
- Most electric production during this period is produced with natural gas
- Congress passes the **Fuels Use Act** in 1976 prohibiting construction of baseload electric generators fueled by natural gas
- Typical annual station (GCS) gross generation in the 1970s more than tripled from 1960s levels to around 650,000 MWh
- Typical water pumping rate dropped dramatically to approximately 2,100 gallons per MWh of electric production

Garden City Station

Holcomb Facility

1980 to 1995

- Constructed Holcomb Station (350 MW) which entered service in 1983
- At that time, it was larger than all other system units combined
- Coal-fired with dry scrubber and fabric filter baghouse
- Designed with a "zero discharge" wastewater system
  - Re-cycles system liquid waste streams improving cycle water efficiency
  - This system effectively demonstrates large-scale, gray-water re-use
- Electric production shifts virtually exclusively to the new Holcomb unit
  - All other steam units are permanently retired *or* placed in long-term layup
  - Simple-cycle gas turbines still used for summer peak loads and for backup
- Typical annual station (HLS) gross generation in first ten years of operation was approximately 1,500,000 MWh
- Typical water pumping rate for electric generation reduced dramatically to approximately 460 gallons per MWh of electric production

Holcomb Station

Growing into System Resources

1995 through 2010

- Holcomb remained the system “workhorse” and unit production continued to grow as system load continued to grow
- Holcomb’s annual gross production peaks at more than 3,000,000 MWh
- Typical annual gross production through this period is approximately 2,600,000 MWh
- Sunflower made significant capital investment in water systems in the late 1990s
  - Holcomb’s splash-fill cooling tower replaced with an advanced film-fill design in 1997
  - S2 is brought out of long-term layup in 1999 and the existing cooling tower is replaced with an advanced, splash-film hybrid design
  - More than $6M in capital investment in cooling system upgrades alone
- New Holcomb cooling tower improves water efficiency modestly lowering pumping rate to approximately 450 gallons per MWh of electric production

Sunflower Helps Pioneer Gray-Water Use

- Sunflower implemented several agreements to use external sources of gray-water starting more than a decade ago
- Sunflower brings approximately 60 acre-ft of effluent gray-water annually from the city of Holcomb to Holcomb Station offsetting pumping needs
- Sunflower uses Wheatland for the S2 water supply including using city of Garden City effluent virtually exclusively for the unit's water needs
  - Contract between Wheatland and Garden City for return flow credits
  - When S2 is placed in service, initial system fill comes from water wells
  - Once unit is in operation, the entire unit's cooling water make-up is supplied from city of Garden City effluent, gray-water stream

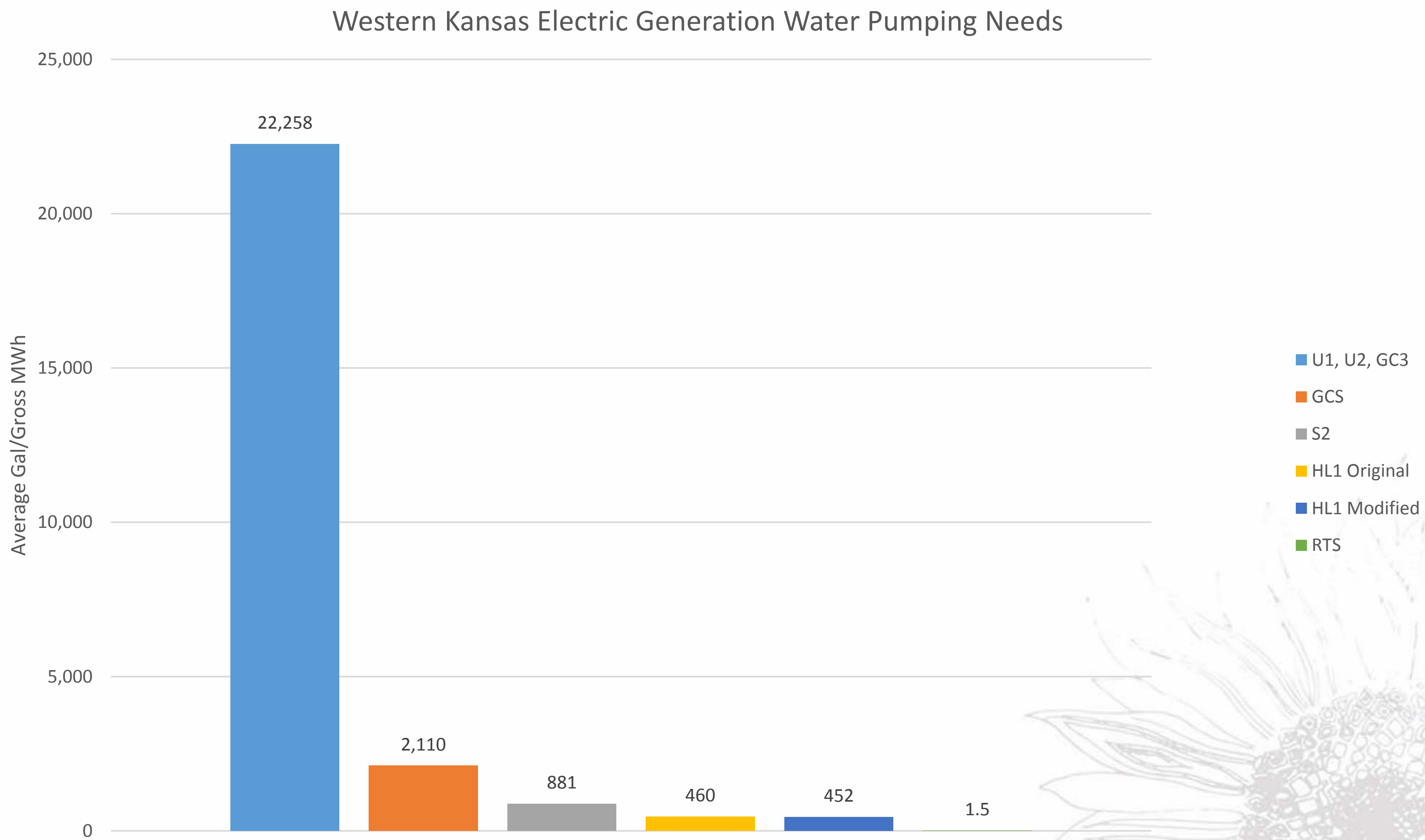
Latest System Generation

2010 to Present

- Rubart Station (100 MW) located in Grant County enters service in 2014
  - Design based on 12 Caterpillar G20CM34 engines
  - 20 cylinders per engine with ***each piston*** producing more horsepower than John Deere's biggest 4WD tractor (9620R/9620RX)
  - 12,500 horsepower per engine; 150,000 shaft horsepower total
  - Facility can go from fully stopped to full load in less than 10 minutes
- First generation facility constructed by the system in more than 30 years
- First generation facility based on ***closed***-loop cooling system design
- Natural gas fueled, highly flexible, ultra-low emissions, ultra-efficient facility
- Exceptionally low water usage with a design pumping rate of ***less than 2 gallons per MWh*** of electric production
- Sunflower and Mid-Kansas also currently hold contracts on 229 MW of wind projects representing generating resources with ***zero-water*** requirements

Rubart Station

Dramatic Water Need Changes Over Time



Policy Coordination Challenges

- Policies can create "tensions" between intended objectives
  - Environmental objectives vs. consumer costs
  - Conservation targets vs. economic benefits
  - Air conservation vs. water conservation
- Policies to incent construction of renewable resources
  - Currently no utility scale, commercially available electric storage technology
  - Intermittent generation behavior forces fossil units to operate inefficiently
  - Inefficient operation causes increases in fuel consumption rates, increases in emission rates, increases in water pumping rates, and higher total costs
  - The greater the intermittent generation "penetration" the greater the impact
- Very difficult to have effective "one size fits all" policies
  - What works for irrigation may not work for municipal or industrial
  - What works for water conservation may not work for economic benefit
  - The potential for unintended consequences is high

Summary

- The pumping rates to support electric generation from the 1960s to the 1970s was reduced by more than an order of magnitude (>90% reduction)
- When the Holcomb facility entered service, the system's electric generation water pumping rates dropped by a factor greater than 4:1 (>75% reduction)
- The latest system generation facilities require very little water to support operation representing a 225:1 reduction (99%) as compared to Holcomb
- From the system's first generation to the latest generation the required design pumping rate has changed by a factor of 12,500:1 (>99.98% reduction)
- The design of western Kansas' electric generators has evolved dramatically with the construction of each facility – especially with respect to water needs
  - Utility investments are complex, expensive, and result in long-lived assets
  - Once a design is constructed, there is little opportunity for substantial change

Facility production is a function of many variables including reliability, fuel availability, cost, location, system load, environmental compliance, and many other factors