ASR Energy Recovery
Pumps as Turbines (PAT)

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Pump/Motor Operation, Motoring or Generating

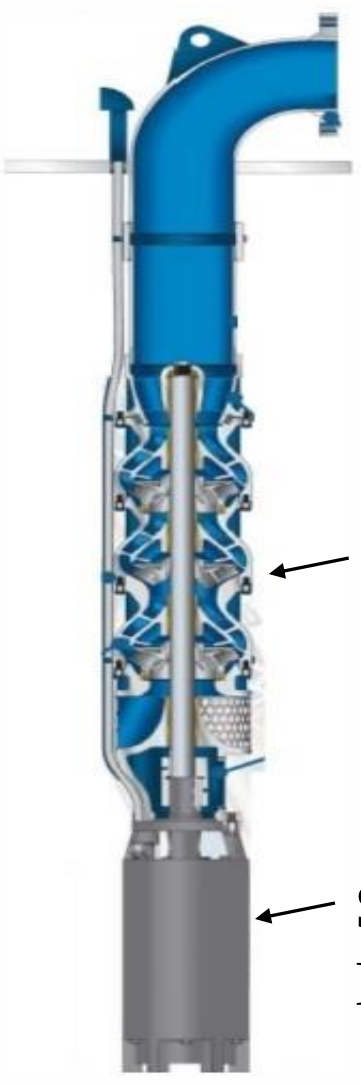
- **Groundwater ASR Systems are typically equipped with multistage centrifugal pumps that are powered by electrical induction motors, and these pump/motor combinations are normally used to extract (pump) groundwater with electrical power supplied by a utility.**

- **In some cases, those same centrifugal pumps can be fed injected recharge water which causes the pump/motor to rotate in reverse.**

- **If during this water injection process, the reverse pump/motor rotating speed is sufficient, the induction motor transitions from motoring (consuming power) to generating (producing power).**

Groundwater ASR Pumps and Motors

Vertical
Induction Motor

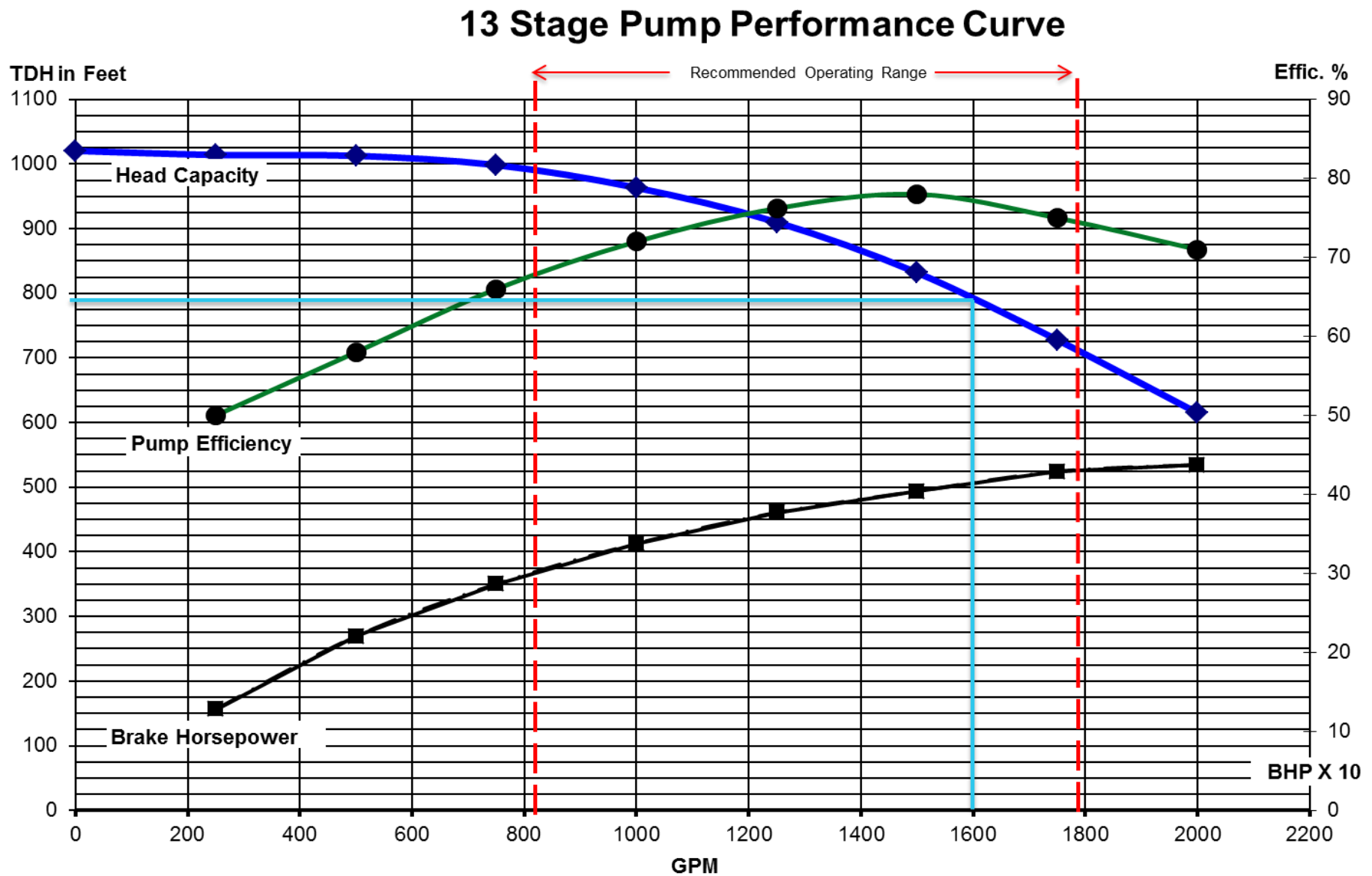


Submersible
Turbine Pump

Vertical
Turbine Pump

Submersible
Induction Motor

MULTISTAGE CENTRIFUGAL PUMP CURVE



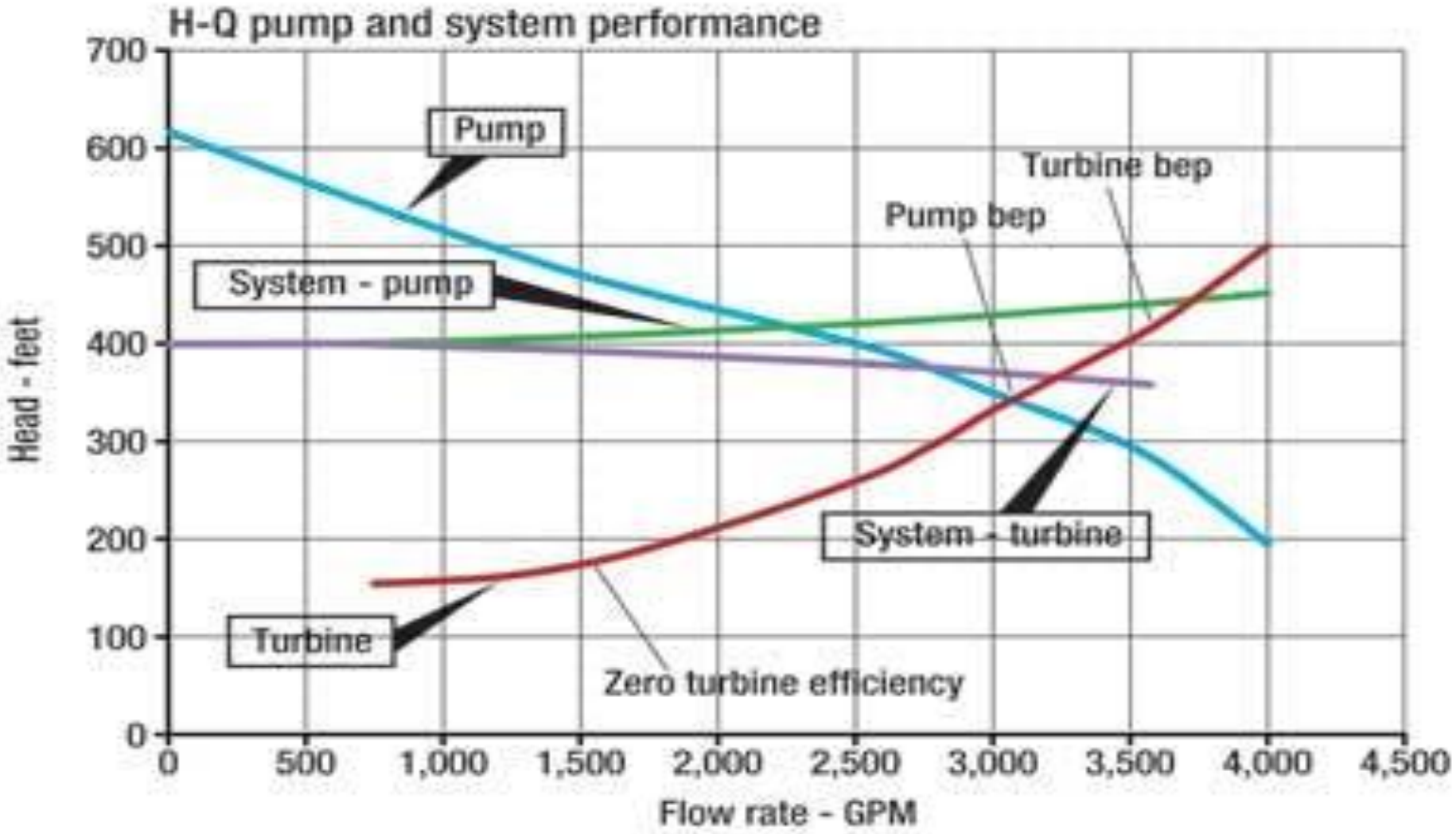
Induction Machines (Known as Motors)

- **Induction Machines (Known as Motors) can operate in a motoring mode where they consume electrical energy and create rotation (at less than synchronous speed) and that rotation can spin a centrifugal pump that then creates water flow and pressure. This type of operation is known as Motoring.**

- **That same Induction Machine (Motor) can operate in a generating mode where it can create electrical energy by being rotated by a pump that is driven by injection water flow, and rotating in a reverse rotation (at greater than synchronous speed). This type of operation is known as Generating.**

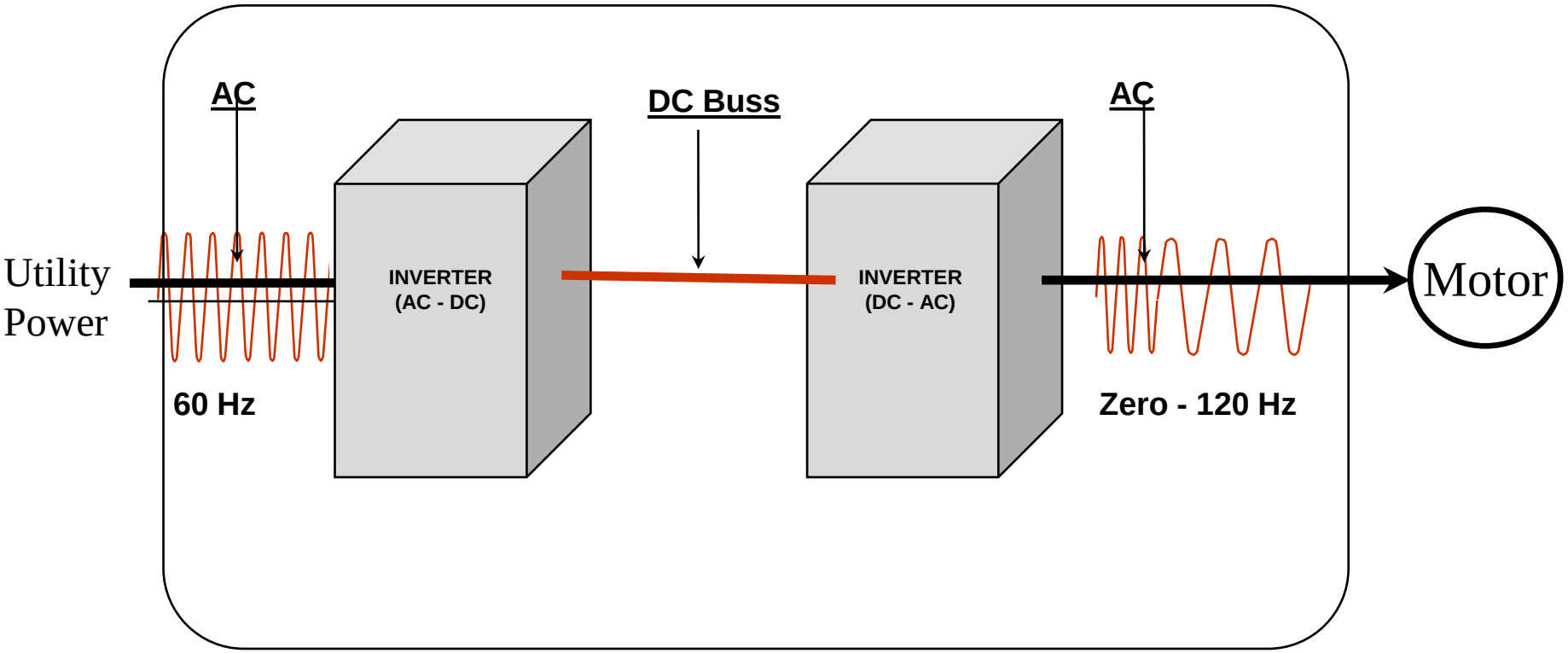
Pump as Turbine Performance Curves

Figure 3. Pump and Turbine Unit and System Performance



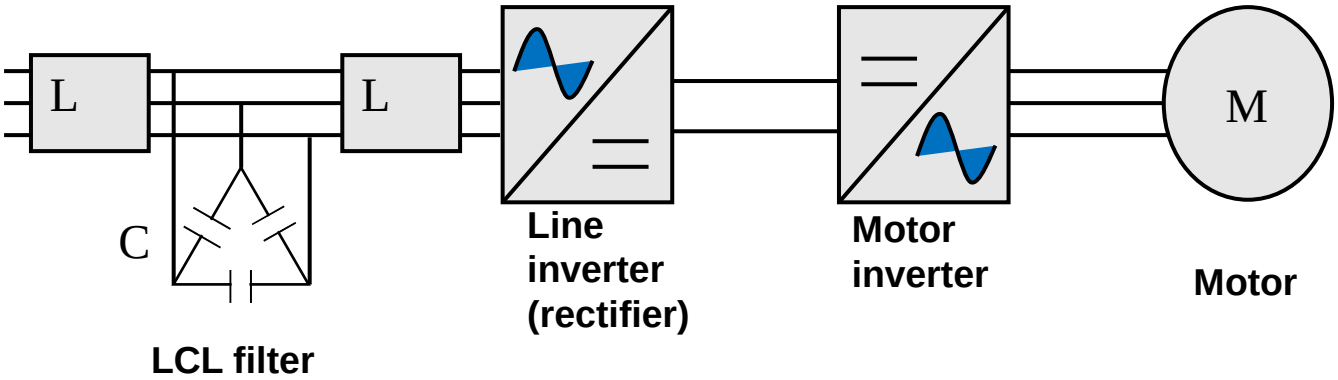
How to Capture Power From an Induction Machine

Certain Variable Frequency Drives (VFD) convert incoming AC 60 Hz utility power into DC, then convert that DC to a simulated variable voltage and variable frequency output. With the proper VFD design, power can flow from the utility to the motor, or from the motor to the utility.



Simplified Variable Frequency Drive Diagram

Active Filter Front End VFD with LCL Filter



- **Full regenerative capability**
- LCL Filter (Sine Filter) removes high frequencies >1 kHz. (Current and voltage)
- Full output voltage is available with 80% input voltage ($400V_{In} = 480V_{Out}$)
- No transformer required
- Not affected by line imbalance
- **UNITY POWER FACTOR ACROSS SPEED RANGE**

Challenges for ASR Energy Capture

1. **The proper selection, design, manufacture, factory testing of the Pump, Motor, VFD, and other components.**

   a. Few Pump and Motor Manufacturers can provide empirical Pump and/or Motor test data that enables accurate selection and application of a particular Pump as Turbine (PAT).

2. **Is your injection PAT flow rate greater than or equal to your pumping flow rate?**

   a. Is your injection total flow and total injection time sufficient to create a useful and/or commercial amount of electrical energy?

3. **Will your utility buy your ASR generated power at a price per kW/Hr that is workable?**

   a. Will your utility restrict your power generation due to "other" considerations?

Benefits for ASR Energy Capture

1. **Net energy cost savings for an ASR Well may help reduce the lifetime cost of the ASR operations, and thereby make the project more economically feasible.**
2. **Use of a Bidirectional VFD in the power generation will increase the Power Factor at the site, thereby reducing the Reactive Power required to be supplied by the power utility, thereby reducing the carbon footprint of the site electrical equipment.**
3. **Depending upon the PAT design, Variable Speed Power can be created at varying recharge flow rates, within limits.**
4. **Multistage Centrifugal Pump/Motors can perform reliably and well as generators with the correct design and application.**

400 HP Bi-directional Variable Frequency Drive

Joule Logix

ASR Energy Capture

- Questions?
- Comments?
- Thank you!