Vertical Turbine Pump Stations, Sizing and Pump Selection in General

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1. Pumps and Pump Stations:

Throughout the human history, settlements were placed where people could reach their needs as easy as possible. *Water is the most essential necessity for human life*. The first small villages becoming small towns and growing developed cities which were all near to enough, clean and easy attainable water sources. The increase in population as a result of the development, caused the near and easy attainable water sources became insufficient for the cities. This situation forced people to store the water from rains and to find solutions to carry or/to transform the drinking water from the longway sources to consumers. The developed technologies and solutions mainly based on gravity, as aqueducts, water channels, cisterns, water mills and similar fascinating monuments, which can be still seen in all developed historical cities.

The problem of dependence to altitude difference for water transfer were solved with development in pumps parallel to power solutions. So then, besides the open channels, closed conduit long pipelines were started to install. With the help of pumps, the distance and the elevations with the water sources and the cities were became unimportant. So the civilization and the water relationship were changed radically in the history of human. Pumps were also started to use in the city to distribute the water to the end user. The created waste water, after usage, was also started to send away again by pumps.

In addition to the urban water necessity, water is also transported by pumps to soils for the irrigation in agricultural purposes from very long distances. The other important purpose of pump usage is to remove uncontrolled waters from the cities or agricultural areas. The floods derived by rains, the overflowing of rivers threaten the agricultural fields and these unexpected and unrestrained waters are needed to be sent away. The pumping stations for purpose of protection and regulate the water, become more important because of unplanned urbanization and climate changes. Pumping systems are also critical in industry such as water cooling for power plants. There are other alternative applications in cooling systems worked with sea water or in fire fighting systems.

In all systems, pumps are not alone. They are used in a system composed of suction and discharge structure, energy and control units together.

2. Vertical Turbine Pump:

Vertical turbine pumps were designed according to compact serial pump solution to get the high heads in vertical multistage form to get the underground waters from narrow and deep wells (low dynamic water level) to the ground.

At the beginning, they were manufactured in nominal diameters (4”, 6”, 8”, 10”) due to restrictions related to well diameters.

In the following years, they were also started to be used in outside of the narrow wells, because of many advantageous with their special modular structures. Since if there is no limit for diameter on the application, they can be designed for high flow rates, the head can be reachable and changeable by stages, better suction conditions can be created by the usage in the water for their impellers with the working flexibility of different dynamic water levels.

It is understood that, these pumps have lots of advantages in the operation since they have a small assembly area on the ground and they do not need auxiliary equipments such as a vacuum pumps.

With the water pumping necessities, for high capacities and high heads, their diameters were increased for the capacity, the heads were arranged by the stages. Different motor speeds can create very flexible application areas to these pumps by changing column lengths in dynamic level fluctuations.

Nowadays, vertical turbine pumps have a wide usage area in very different application sites with its design characteristics.

3. Pump Stations and Related Structures with Equipments:

The structure of pump station can be defined like following;

- **Related Equipments or Structures**
  - Suction Lines or/and Suction Channels
  - Discharge Lines
  - Ventilation and Resting Tanks or Pools
  - Reservoirs
  - Channels
  - Energy Supply Units
- **Pump Station**
  - General
    - Strainers, screens etc.
    - Pits, suction holes etc.
    - Cranes, lifting equipments
    - Lighting
    - Air tanks, vessels
    - etc.
  - Pump Equipments
    - Main Parts
      - Pumps
      - Valves, dismantling peaces, check valves
      - Suction and discharge pipes
    - Driving Equipments
      - Main drivers (motors)
      - Starting Panels (Frequency converters, soft starters etc.)
      - Cables
    - Auxiliary Equipments
      - Pre-feeding or lubrication systems
      - Cooling systems (bearings or motors)
      - Vacuum pumps
      - Stuffing box lubricating systems
    - Power Sources
    - System Control Units (capacity, temperature, time, pressure sensors etc.)
  - Main Building
    - Suction structure
    - Pump holes or rooms
    - Vortex breakers
    - Reservoirs
  - Building Structure
    - Pump floor or room
    - Pump control room
    - Electrical control floor or room
    - etc.

4. Vertical Turbine Pump Stations:

Vertical turbine pumps are mainly used for sources having differences seasonally in dynamic water level. They are not preferred in the intermediate pump stations which don't have or need storage having constantly positive suction pressure but they can be used.

The first station in the waterlines having lots of pumping stations is the vertical turbine pump station in general. At the present time, they are preferred at the station far from source where there is a necessity of suction head instead of vacuum pump or horizontal pump needing high suction pressure. Because they give easiness in the operation owing to their start-stop features.

Vertical turbine pumps work in the water and power is transmitted from motor to pump shafts by lineshafts mounted into the column pipe. Single stage or multi stage impellers rotated by the pump shaft, fluid passes inside the impellers, fills the column pipe with high pressure and so fluid reaches the usage area on the surface.

The applications about pumping stations which are started to operate are represented in the following.

The first step for the vertical turbine pump station design starts with a basic question; “how much flow rate is pumped to how head?”. Theoretically, a designer for a vertical turbine pump station, has nearly infinite freedom to find a solution for answer to reach the desired performance values. If there is no any special restriction. Some examples for solution to the same answers can be as follows;

- Pumps can be designed as a single stage.
- Pump can be designed in different motor speeds
- Pumps can be designed as multi stages.
- Pumps can be thought that parallel pumping to a collector by increasing the number of them to get the total flow rate. That’s why, number of pumps can share the required flow rate.
- All of these can be thought together. Multi stage pumps, in different speed and different flow rates in different numbers.
- Or else, the pump which was designed before tried to adjust for new situations by increasing number of stages or the number of pumps, speeds.

Every performance value(s) cause a need of a new design. However, in reality the designer has no so much freedom. Two main reason gives the borders;

- To design or select the pump(s) for a built ready station
- Or to design the new station while selecting the pumps alternatively

4.1. The Selection or Design of Pumps for Built Stations

In general for this situation, the number of pumps and related structure are defined by previous works. Water levels were defined by the building. Since number of pump, suction conditions were defined, the designer is directed to limited speed and the diameter of the pumps. Mainly there is a maximum speed related to the water levels.

4.2. Designing a New Station Creating Pump Alternatives

As told before, in theory, designer has so much alternative approach to use them freely. But in practice, these alternatives becomes less or/else limited. Some limitations;

- According to the head and capacity related to system characteristics design is started.
- Mainly, the rotational speed is desired to be constant. The flow rate - time curve for the system (continuity curve) is tried to be guarantee with constant speed. If there are some special but limited time zone performance values, the pumps are varied. So that, different pumps are combined in the same stations for different performance values. Speeds selected rather than standard motor speed, needs different equipments such as frequency converters, gear heads etc, increasing the first investment. However, related with the system curve and continuity curve, sometimes, the use of these equipments can be more reliable for life cycle cost. This has to be analyzed.
- When it is talked about the standard speeds, it gives another limitation for power. In general, when the speed is high, motor powers becomes less.
- For the pumps, there are limitations for capacity related to the speed. When the speed is increased, the pump size decreases while increasing frictional losses and other hydraulic losses. This brings the other limitations related to hydraulic design. High speed also effects, the thrust bearings, shafts sizes and journal bearings related to total mechanical design.
- The pump(s) can be single or multistage. The pump size is generally defined, when the speeds were specified.
- When the pumps are defined alternatively, the general construction of the building related to suction conditions, site elevations can be analyzed in general.
- When the speed is high, the suction speed increases, increasing the submergence so the suction structure costs.
- Also, for the motors, when the speed is high, the cost is low. This can be also shared with the customer.
- When the speed is low, the submergence and the installation lengths decrease.

- When the speed is low, pump gets bigger and/else the stage number increases.
- Without decreasing the speed, number of pumps can be increased for the total capacity to decrease the suction installation lengths.

All of these has to be combined based on the need capacity and head, with each other, thinking about the investment and life cycle cost, availability of motors, manufacturing time and capacities, operational necessities, delivery time etc.

According to given explanations below variations, the pump station can be designed with different installing dimensions which can be changed from 3 m to 14 m, considering ;

- Constant head, constant capacity with different standard speed pumps
- Constant head, constant speed with different capacity pumps
- Multistage (1-2-3), constant head, constant speed, constant capacity pumps
- Multistage (1-2-3), constant head, different speed, constant capacity pumps
- Constant total capacity, constant head, constant speed, increasing the number of pumps (1-2-3)
- Constant total capacity, constant head, increasing the number of pumps (1-2-3) with different standard speed pumps

5. Results

There are many alternatives for a new design station. There are can be other important parameters for customer, such as efficiency so the designer can also work on specific speed for desired efficiency to limiting the alternatives. Frequency converters also can be added for different working conditions as explained before, different capacity pumps can be put on the same station for different working times etc.

Station has to designed optimizing all first investment, life cycle cost, time depended needs, power supply conditions, pump and building sizes, etc. So before starting the building project, customer or user has to be in contact with the pump manufactures to see the limitations and alternatives.

The other important point has to be kept in mind that, high capacity pumps are generally designed for a specific work. So, it is better to work the manufacturer directly at the planning steps, rather than work on their general catalogs. Because different tailor made solutions can be offered to the customer.