Product Data

Subject: VALVE SEQUENCING CONTROL WITH ADJUSTABLE SPEED PUMPING DRIVES

INTRODUCTION

Due to certain inherent characteristics of particular classes of pumps (centrifugal pumps, for example), it is necessary to apply some means to prevent reverse flow of liquid through the pump when the pump motor is de-energized. Generally, these means take the form of a simple gravity-operated check valve located on the discharge line of the pump. More complex hydraulic systems sometimes require motor-operated plug or cone valves to prevent pump backflow and to help prevent surge or "water hammer" effects.

Many times the control logic of a motor controller used to drive the pump must monitor the status of this valve, develop control signals for valve operation, detect any valve mis-operation, and take appropriate action in the case of failures.

Square D valve sequence control will provide all these functions when used with OMEGAPAK® or ECONOPAK® Adjustable Speed Drives. In addition, a novel feature is included in the valve control logic to minimize the effects of certain types of valve failures on pumping systems.

BACKGROUND

Since the pressure developed at the output of a pump can generally be varied by controlling the speed of the motor which drives the pump, variable speed motor drives are widely applied to pumping installations to provide continuous control of some process variables. Most pumps are equipped with some sort of valve arrangement attached to their discharge line. This valve arrangement is used to prevent backflow through the pump during the "off" periods of the pump motor and sometimes to prevent hydraulic pressure surges. These valves can either be passively or actively operated. Gravity-operated check valves are examples of passive valves which require no actuating signals from the pump motor controller. This type of valve will automatically open when the pump develops sufficient pressure to force the valve gate open and close anytime the flow through the valve attempts to reverse. Motor-operated valves are examples of active valves which require some sort of actuating signals to initiate opening and closing of the valve.

Occasionally, a valve may fail to operate correctly. One of the most common failure modes is that the valve would stick open when commanded to close. This is generally caused by debris catching in the valve body and not allowing the valve to seat.

The consequences of a valve sticking open once the pump motor is shut down are extremely serious. The pumped liquid will begin to run backward through the pump and cause the pump impeller to spin backward in a manner similar to the operation of a water turbine.

The motor, pump and drive shaft may be subjected to very high rotational speeds at this time. Since the motor is spinning in a reverse direction, applying power to the motor could cause severe torque and current surges which could damage the pump, motor, controller and drive shaft. In addition, a very serious hydraulic problem arises when the pump with the stuck valve is part of a group of pumps comprising a system such as shown in Figure 1. Three pumps are shown in the system schematic. All pumps discharge into a common manifold and draw liquid from a wetwell which is fed from a source of constantly varying inflow. As the flow into the wetwell increases, more pumps are started to keep the wetwell from overflowing. As the inflow decreases, fewer pumps are run to prevent the well from being pumped dry. Figure 2 represents, graphically, the operation of pump #1.

Normally, system operation is restrained to quadrant #1 by proper functioning of the valve. By varying the speed of the pump, the intersection point of the pump pressure vs. flow curve and the discharge line pressure vs. flow curve can be adjusted to vary the output flow of the pump between Q_1 to Q_2. Due to system considerations, Q_1 is very close to zero flow. The effect of operating additional pumps generates additional pump pressure vs. flow curves which intersect with the discharge line pressure vs. flow curve at flows greater than Q_2.

The problem which occurs with a valve stuck in the open position (while the associated pump motor is de-energized) is that the other pumps in the installation are effectively disabled, and the flow output of the station is nil. The reason for this situation is that, normally, a static head pressure exists between the pump discharge manifold and the pump suction line. When a pump is shut down, the valves maintain this head pressure. With a stuck valve, the liquid will flow from the discharge manifold, through the pump, and into the wetwell. Since the pressure drop across the reverse turbining pump is very low, the point of operation on the graph of Figure 1 shifts to the fourth quadrant — with the backward flow through the pump probably approaching Q_3. If additional pumps are started to make up for the lost capacity, their flow will take the path of least resistance and flow back through the pump with the stuck valve. Hence, if the discharge

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valve of pump #1 sticks open, pump #2 and #3 will be virtually "short-circuited" and unable to develop sufficient pressure to force liquid out the discharge line. The flow through the two operating pumps could be much greater than design rated flow and the pumps and motors would then rapidly overheat. Under these conditions, the wetwell will fill due to the combined flows from the pump discharge line and the inflow line. Usually, the wetwell fills so rapidly that only the fastest operator intervention can prevent flooding. Since many pump systems are unmanned, wetwell flooding under these conditions is unavoidable.

PRIOR ART

Many techniques have been developed to deal with the problems of stuck pump discharge valves. Most of the techniques were developed before adjustable speed drives became popular for use on pumps and, as a consequence, do not make use of the variable speed capability of pump drives.

The sequencing utilized on active valves (plug valves, cone valves, etc.) has been well developed. Generally, the sequences upon startup and shutdown are as follows:

Startup	Shutdown
1. Motor controller signaled to start.	1. Motor controller is signaled to stop.
2. Motor controller checks that valve is closed (using limit switch on valve).	2. Motor controller signals valve to close.
3. If valve is closed, motor is started and valve is commanded to open.	3. Once valve is closed, the drive is stopped by command from a limit switch mounted on the valve.

From the sequences, it can be seen that the pump motor cannot start unless the valve is closed and cannot stop unless the valve closes. This sequencing scheme deals well with the problem of the stuck valve. The only drawback is that if the valve sticks open, the well will probably be overpumped, since the pump runs continuously.

As a contrast, the sequencing utilized on passive valves is very poorly developed. The problem is that the pump motor must be shut down to close the valve. If the valve sticks open it is too late to do anything about it. Various schemes have been developed which utilize limit switches on passive valves, but these schemes only detect a valve failure and annunciate the condition. No corrective action is taken.

SQUARE D VALVE SEQUENCING SCHEME

By combining the capabilities of a variable speed drive along with special sequencing logic, the valve control scheme allows complete control of both active and passive valves. Figure 3 illustrates, in block diagram form, the sequencing strategy associated with the OMEGAPAK® and ECONOPAK® drive systems. A pair of limit switches are used at the valve to detect its position, and the toggle point of the contacts is arbitrarily set at "95% valve closed." The sequence upon startup for both active and passive valves is identical and occurs as follows:

Startup Sequence

1. Drive commanded to start.
2. Drive logic checks that valve is at least 95% closed before starting (using LS1 contact).
3. If valve is at least 95% closed, motor is started. If active valve is utilized, valve is commanded to open. Drive accelerates to speed called for by drive speed reference signal.

It can be seen that the startup sequence is practically the same as that traditionally used on active valves. However, the sequence upon shutdown for both active and passive valves is different and occurs as follows:

Shutdown Sequence

1. Drive commanded to stop.
2. Drive switches from regular speed reference signal to shutdown speed reference signal (R energizes). Shutdown speed has been adjusted so that the pump pressure vs. flow curve intersects the station discharge curve (reference Fig. 2) at the point where the flow through the pump is slightly reversed (i.e., approximately 10% rated flow in the reverse direction). This should cause a passive valve to close. If an active valve is used, the valve is also signaled to close at this time.
3. Motor is de-energized once pump valve is 95% closed (using LS2 contact). R relay also de-energizes at this time.

The advantages of the shutdown scheme are threefold.

First, since the drive is commanded to reduce the pump speed to a point which limits the reverse flow through the pump to a small valve, the reverse flow through the pump and into the wetwell is limited under valve failure conditions. Inherent speed regulation in both OMEGAPAK® and ECONOPAK® drives is used to maintain pump forward speed under reverse flow conditions. Hence, under valve failure conditions the pump maintains the difference in head between pump discharge and suction which the check valve would normally maintain.

Second, the pump is always spinning in the normal running direction until the valve closes and may be accelerated back to normal running speed at any time with no damage to the driving or driven equipment.

Third, since the valve action is positive even with passive valves, the scheme is highly immune from the effects of valve flutter sometimes noted on passive valves operated at low flow rates (a common problem on prior valve sequencing schemes).

The result of the sequencing scheme is that passive valves can be dealt with as reliably as active valves. With the scheme, the master process controllers maintain total control over the process variable, eliminating the need for operator intervention.

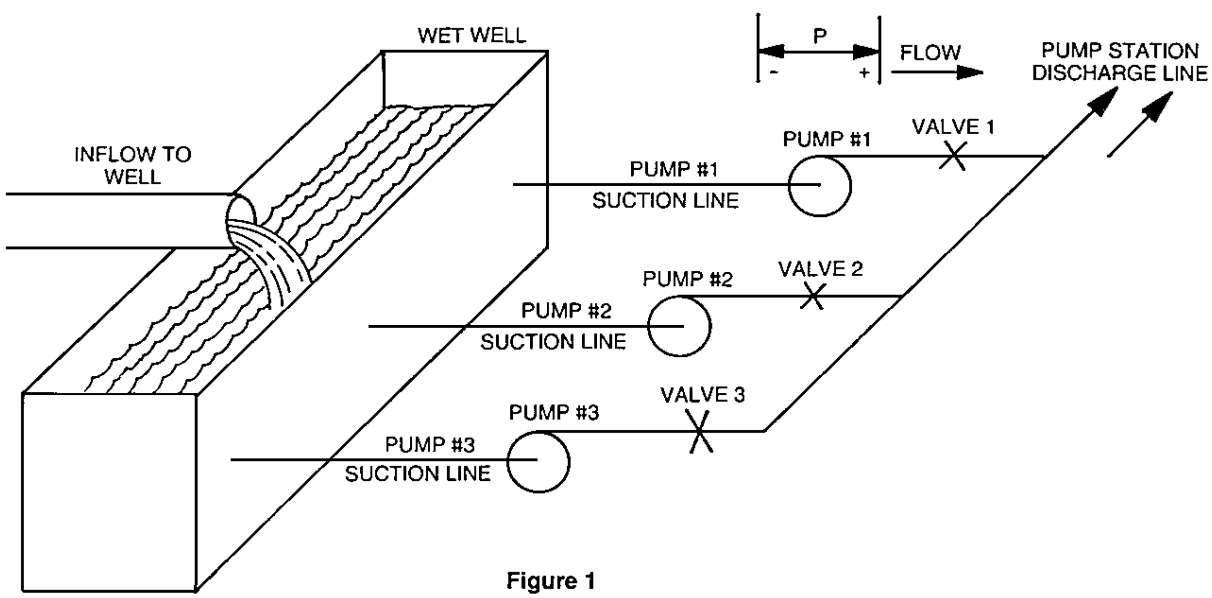

Figure 1

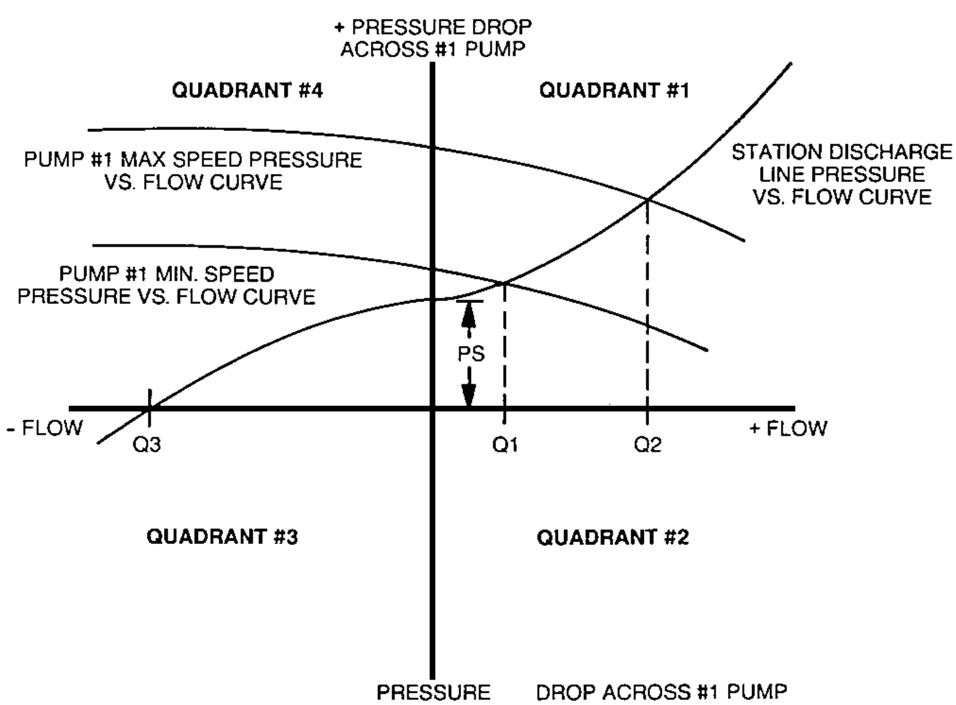

Figure 2

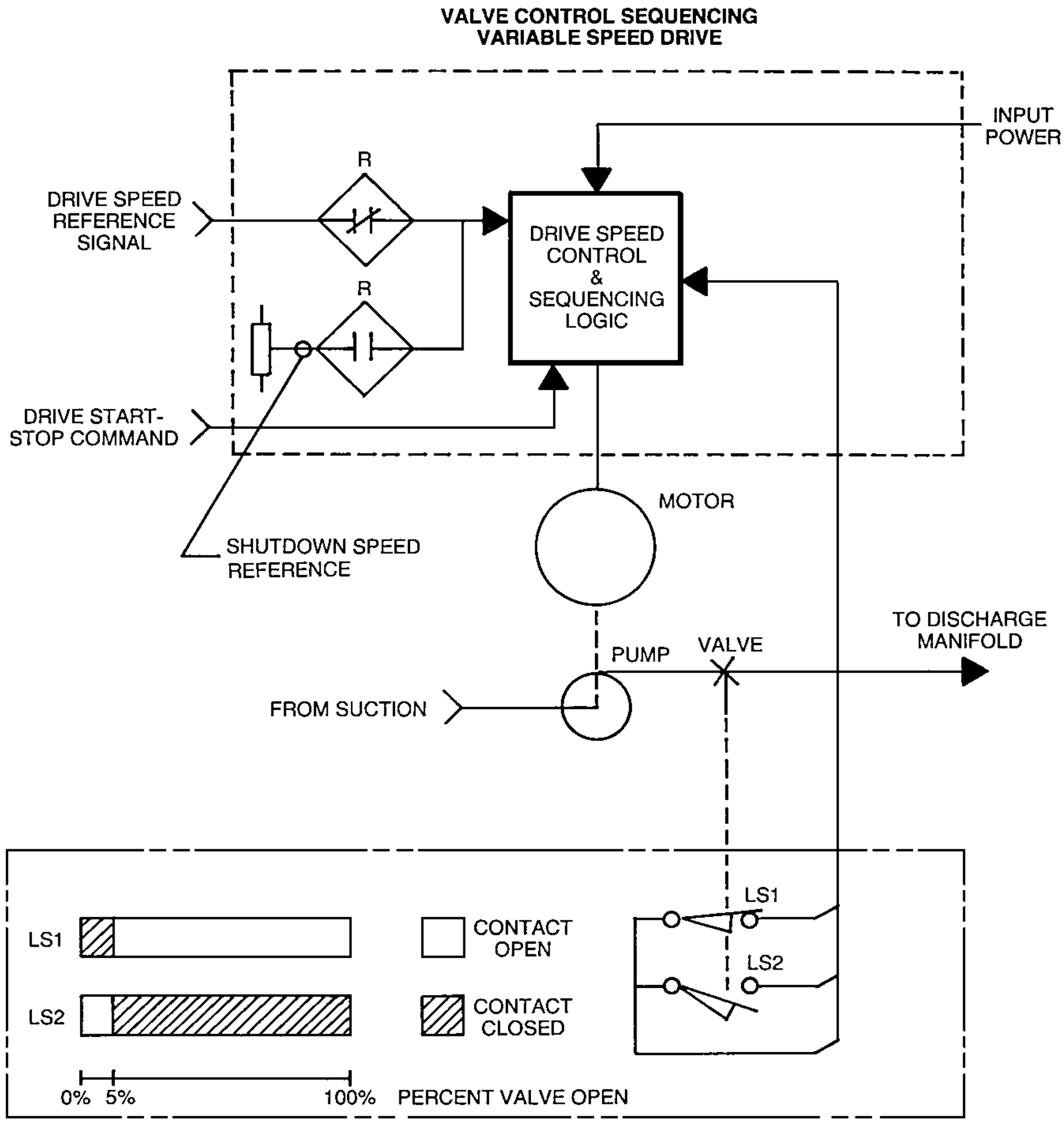
VALVE CONTROL SEQUENCING
VARIABLE SPEED DRIVE
INPUT POWER
R
DRIVE SPEED REFERENCE SIGNAL
DRIVE SPEED CONTROL & SEQUENCING LOGIC
R
DRIVE START-STOP COMMAND
MOTOR
SHUTDOWN SPEED REFERENCE
TO DISCHARGE MANIFOLD
PUMP
VALVE
FROM SUCTION
LS1
LS1
CONTACT OPEN
LS2
LS2
CONTACT CLOSED
0%
5%
100%
PERCENT VALVE OPEN

Figure 3