Dual Media Filter Implementation for Water Treatment Plant using PLC

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***Abstract* — The paper is discusses treatment of contaminated water for making it useful for industrial and domestic purposes. In water treatment plant there are various filters available but dual media filter is used because of its simplicity and efficiency. The dual media filter has various different operations which makes it easy to use and operate thus making it user friendly. The programming is done in ladder format which enables the operator to change or alter the program according to different conditions required. The different operations of the Dual Media Filter (DMF) are controlled through control valves which in turn is controlled through automation. The water is stored at first in the storage tank which is then in turn pumped into the filter where the filtration process takes place. The filtered water is again stored in a storage tank from where it is used for the designated purpose**

***Index Terms*—DMF, Water Treatment plant, PLC**

I. INTRODUCTION

Programmable logic controllers (PLCs) are the control hubs that are used for various industrial and automation processes [1]. The PLCs consists multiple inputs and outputs that use transistors and other switches and relays to control equipment. They are programmable via software interfaced via standard computer and proprietary languages and network options [2]. The PLCs and conventional computers are similar in terms of hardware technology, the features are suitable for industrial purpose.

The main features of PLC are:

1. Solid-state components
2. Common programming languages
3. Industry grade, Heavy Duty
4. Simple connections
5. Communication with other components and controller
6. Easy troubleshooting

Supervisory control and data acquisition (SCADA) as the name suggests is a control system on supervisory level, it is purely a software package that is positioned on top of hardware which is interfaced via programmable logic controllers or other commercial hardware modules.

These SCADA systems can run on DOS, VMS and UNIX; Recently they have moved to NT. SCADA can presently be used on linux [3].

II. PROJECT BACKGROUND

Water treatment is the process of removing chemicals. Biological contaminants, suspended solids and gases from contaminated water. The goal is to produce water that's purified. The water purification is done in the DMF. The water is pumped into the storage tank which consists of two level switches for level low and level high. The water in this tank is controlled by the means of a proportional integrated derivative (PID) controller. This PID is responsible for connecting the two switches which is calibrated to the actual level of the tank. The DMF consists of six valves which perform the various operations. The operations performed are refill, rinse, and filtration. To increase the efficiency of filtration we have also performed the backwash operation which prevents the particle to get stuck in the filter thus increasing the life of the filter. The two backwash operations are backwash filtration and backwash rinse. The software used for developing the ladder is Simatic Manager. For implementation of Supervisory control and data acquisition (SCADA) we have used WinCC Explorer.

III. FILTRATION STAGES

A. *Storage tank*

The water before filtration is stored in the Tank_1.The water in this Tank_1 is pumped through with the help of Motor_1. Tank_1 consists of two level switches which maintain the level of water in Tank_1. The level switch here are LS_HIGH and LS_LOW. When the water reaches LS_HIGH the feedback is sent to the PID which Switches OFF the motor. Similarly when the water level reaches LS_LOW the feedback is sent again to the PID which turns ON the motor. Through this process the level of the tank_1 is kept constant.

B. *Dual Media Filter*

As the name suggests Dual Media Filter consists of two layers sand and anthracite layer which is primarily used for the removal of turbidity and suspended particles below 10-20microns. Dual media filters provide efficient particle removal under the conditions of high filtration rate. Inside a sand-anthracite filter is layered bed of filter media. Due to

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filter media the sand-anthracite is able to run for a longer time before the need of backwash occurs. The filter consists of two main parts:

1. A composite pressure valve with multiport valve
2. Graded beds of sand and anthracite

The dual media filter consists of an inlet distributor and a collecting system at the bottom. The filter is fitted with external pipes and valves which control the operations to be performed by the filter. Sand is responsible to remove the suspended particles in the water and the anthracite is used to remove the odor and color in the input water. Anthracite has a higher dirt holding capacity and so it can be operated at higher velocities. The largest sand particles are strained out by anthracite. The media in dual filter are arranged in such a way that water moves through media with progressively small pores. The sand and garnet trap the rest of the particulate matter through a combination of adhesion and straining. Since the particles are filtered out at various depths in dual media filter, it does not clog as quickly as all the particles are not caught by the top layer. Gravel and pebbles are used to support both the media that is Sand and anthracite. The flow of water in the dual media filter is periodically changed to enable the backwash operation in the filter.

Figure.1 Dual Media Filter

IV. IMPLEMENTATION

A. *Block Diagram*

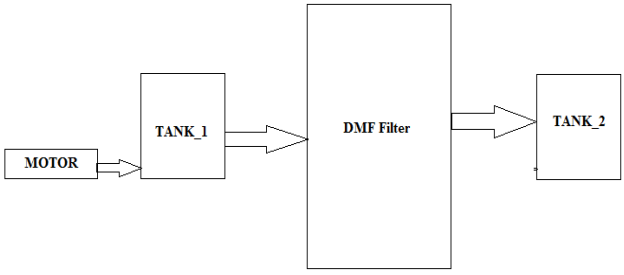

Figure.2 Block Diagram

The Figure 2. shows the block diagram of our water treatment plant. The motor is responsible to pump the water into the storage Tank_1. The tank_1 consists of two level switches which helps maintain the level of the water. The level switch is connected with the PID which is calibrated between 4-20mA so that we can determine the actual level of water.

The water is now given to the Dual Media Filter which implements the filtration operation. The dual media filter consists of six exterior valves which are assigned the operation respectively. Once the operation is completed the filtered water is given out to the storage tank_2. The water from storage tank_2 is used for different domestic and industrial purposes.

B. *Hardware used*

The hardware components used are:

1. Programmable logic controller (S7-314 2PN/DP)
2. Racks for modules
3. Power supply
4. Digital input modules
5. Digital output modules
6. Analog input modules
7. Network interface module
8. PC for SCADA
9. Cables

C. *Working*

The motor is used to pump the water into the Tank_1. The Tank_1 consists of two level switches LS_LOW and LS_HIGH. The switches used here are LT56029-01 and LT56029-03. These switches help maintain the water level in tank. When the water level drops below LS_LOW the motor is turned ON and the water is pumped into the tank, similarly when the water level reaches LS_HIGH the motor is turned OFF. The level switches are connected to the PID controller which is calibrated from 4-20mA.

The PID controller is given the feedback and the error signal is calculated with the set point. The PID controller tries to minimize the error by using one or all of the proportional, integral or derivative action.

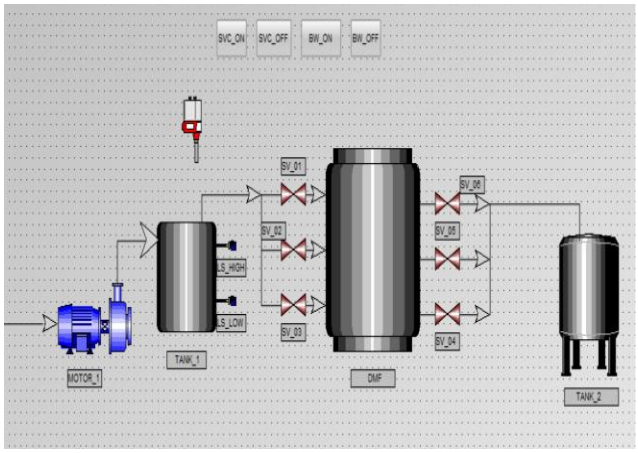

Figure.3 Screenshot from WinCC Explorer

The water from the Tank_1 is sent to the Dual Media Filter for the purification purpose. The dual media filter consists of 6 external valves which perform the operations.

The valves used here are:

1) XV-05921-27
2) XV-05921-30
3) XV-05921-29
4) XV-05921-28
5) XV-05921-31
6) XV-05921-32

The status of valves during the filter operations is shown in Table 1:

Filter operation	SVC IN	B/W OUT	B/W IN	SVC OUT	Rinse OUT	Air release
Refill	Open	Close	Close	Close	Close	Open
Rinse	Open	Close	Close	Close	Open	Close
Filtration	Close	Close	Close	Open	Close	Close
Backwash	Close	Open	Open	Close	Close	Close
B/W Rinse	Open	Close	Close	Close	Open	Close

1. XV-05921-27 valve is the SERVICE INLET valve. The water enters the filter through this valve. In the above figure it is denoted by SV_01.
2. XV-05921-30 valve is the SERVICE OUTLET valve. The water after the service operation is given out from this valve. In the above figure it is denoted by SV_04.
3. XV-05921-29 valve is the BACKWASH INLET valve. This valve is opened during the backwash operation. The water enters the filter through this valve during backwash operation. In the above figure it is denoted by SV_03.
4. XV-05921-28 valve is the BACKWASH OUTLET valve. This valve is the outlet after the backwash operation. After backwash is completed the water is given out of this valve. In the above figure it is denoted by SV_02.
5. XV-05921-31 valve is the RINSE OUT valve. This valve is opened up during the rinse operation. In the above figure it is denoted by SV_05.
6. XV-05921-32valve is the AIR RELEASE valve. This valve is opened up to release the air pressure in the filter. In the above figure it is denoted by SV_06 .

The different modes of operation of DMF are:

1. REFILL
2. RINSE
3. SERVICE
4. BACKWASH
5. BACKWASH RINSE
6. AIR RELEASE

REFILL: The refill operation is performed to fill the filter with the water. The Refill operation takes place in the following way.

- XV-05921-27(SV_01) Service inlet is OPEN.
- XV-05921-32(SV_06) Air release is OPEN.

RINSE: The rinse operation is performed to clear of the filter. It takes place in the following way:

- XV-05921-31(SV_05) Rinse out is OPEN.
- XV-05921-32(SV_06) Air release is CLOSED.

SERVICE: The filtration of the water takes place in this operation. The Service operation takes place in the following way.

- XV-05921-30(SV_04) Service out is OPEN.
- XV-05921-31(SV_05) Rinse out is CLOSED.

Once the Service is completed XV-05921-27(SV_01) and XV-05921-30(SV_04) are CLOSED.

BACKWASH:

Objective of backwash is to remove accumulated particles on the surface and within the filter medium. Backwash continues till the waste wash water is relatively clear.
During back washing, the flow of water through the filter is reversed, cleaning out trapped particles. Backwashing should begin slowly. The water can damage the under drain system, gravel bed, and media due to the high speed of the water. High speed backwash may also force air bound in the filter out, further damaging the filter.

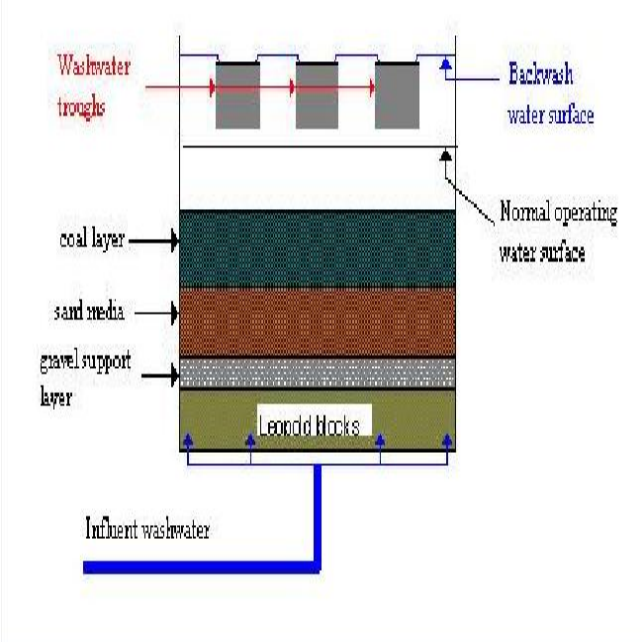

Figure.4 Backwash Diagram

The BACKWASH operation takes place in the following way:

- XV-05921-29(SV_03) Backwash in is OPEN.
- XV-05921-28(SV_02) Backwash out is OPEN.

The BACKWASH RINSE operation takes place in the following way:

- XV-05921-29(SV_03) Backwash in is CLOSE.
- XV-05921-28(SV_02) Backwash out is CLOSE.
- XV-05921-27(SV_01) Service inlet is OPEN.

- XV-05921-31(SV_05) Rinse out is OPEN.

Once the BACKWASH RINSE operation is completed XV-05921-27(SV_01) and XV-05921-31(SV_05) are CLOSED.

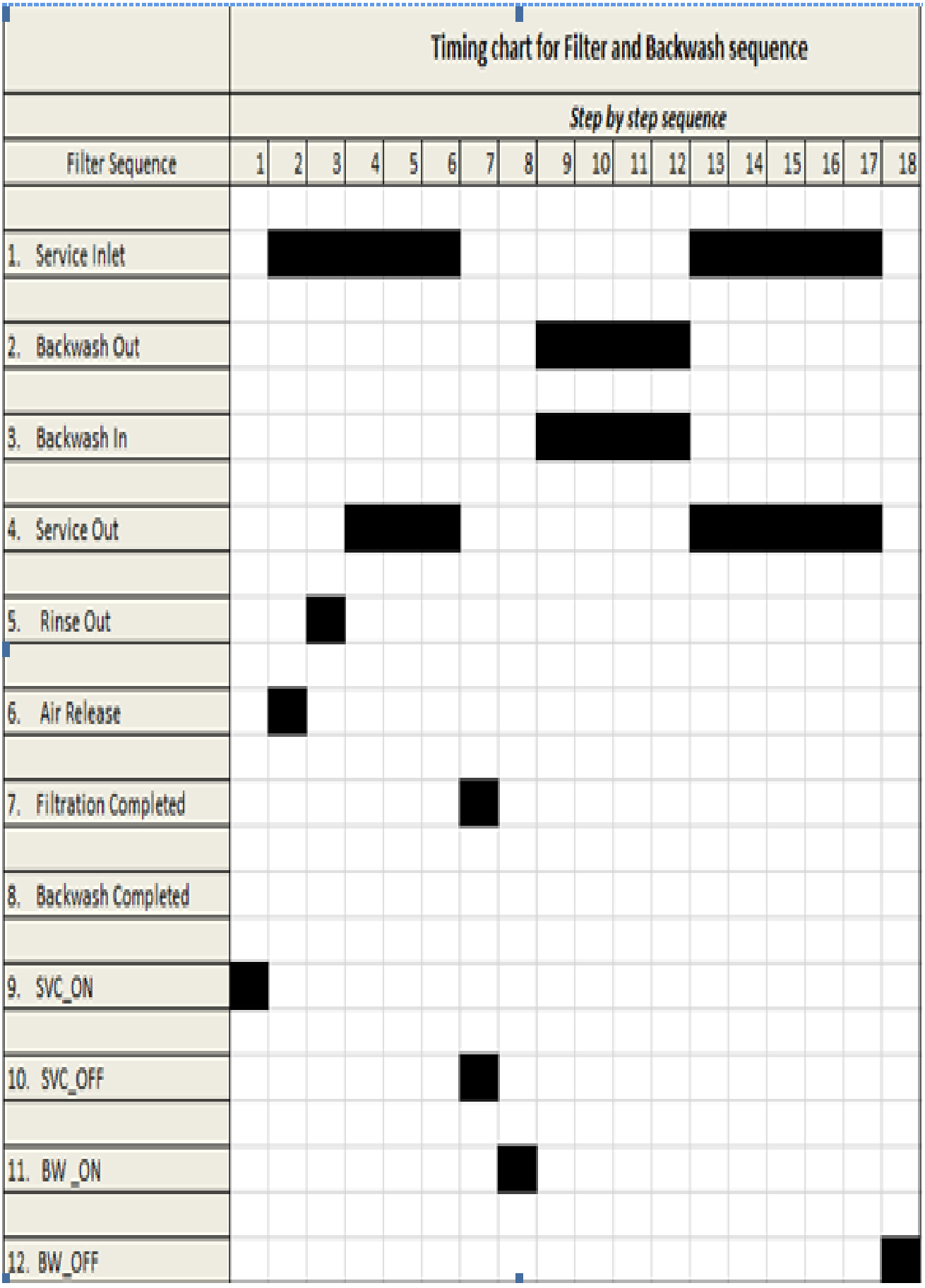

Figure 5. Timing chart for Filter operation

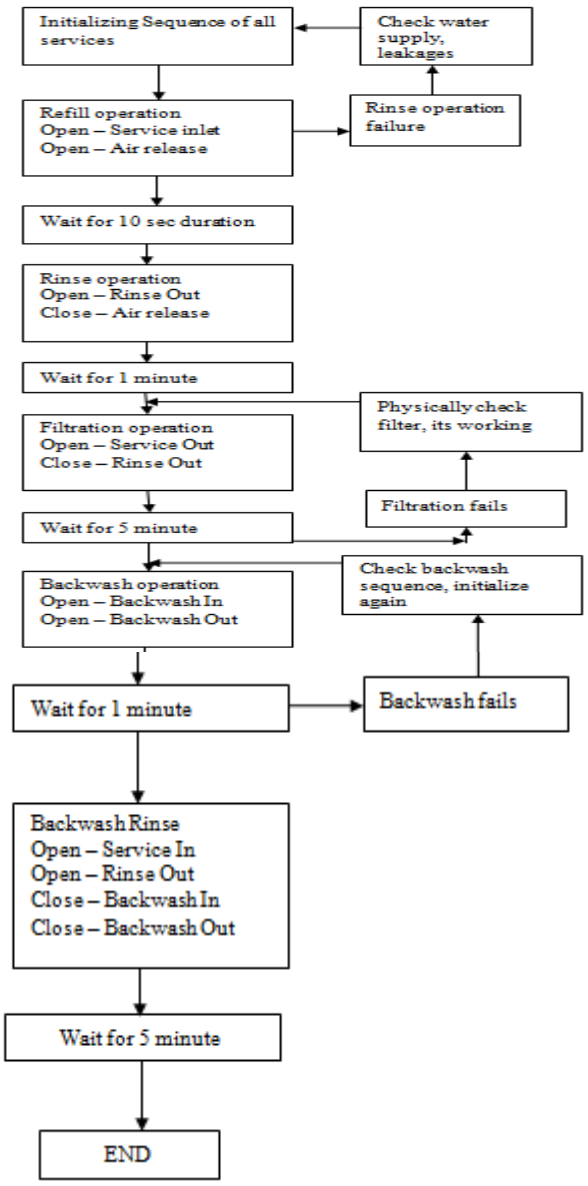

Figure 6. Flow Chart for filter operation

V. Conclusion

In this paper our goal was to develop a PLC based software for controlling the various filter operations. The reason of using PLC here because it's easily programmable instead of making the hardwired connections. The algorithm can be used for different filter operations.

Here PLC-SCADA based DMF filter is implemented. The use of PLC makes it cost effective, highly reliable. Communication between different hardware components is simpler. The SCADA system makes it convenient for observing the process in runtime thus helping in minimizing the errors.

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