Digital Twin (DT) of a Bottle Filling Control System

Emulation of the Physical System

The DT emulation of a simple bottle filling system is composed of a Programmable Logic Controller (PLC) controlling multiple industrial assets which includes a conveyor belt, a liquid pump, a discard push rod, and several switching mechanisms. Sensors are assumed to be in placed but remain inactive.

A bottle filling station conveyor system requires a PLC program that will detect and discard a bottle that is not filled to certain minimum level. There are two sensors: a proximity sensor and a liquid level sensor. The proximity sensor detects the presence of a bottle and liquid level sensor detects the liquid level of the bottle. The conveyor will keep on running as long as a bottle is detected or the main switch is turned-off. When the bottle fails to meet the minimum liquid level, a push rod is activated which, in turn, guides the bottle to a discard conveyor. Additionally, two Timer-On delay timers are used to control the pump that fills the bottle with liquid to a certain level. The first timer assumes a fill-up time of 3 seconds as indicated in the preset time (PT) initialization. Second timer assumes a lag time of 1 second for the bottle to arrive in position and thus, disabling the filler pump. Two up counters were introduced during the first enhancement of the system. The first counter enables the counting of the normally filled bottles while the second keeps track of the number of bottles that were discarded.

Table 1 depicts the control assets and variables. The ladder logic implementation for this application is shown in Figure 1.

Table 1. Control Assets and Variables of the DT

#	Name	Class	Type	Location	Initial Value	Option	Documentation
1	MainConveyor	Local	BOOL	%QX0.0			Main conveyor indicator lamp
2	MainSwitch	Local	BOOL	%QX0.6			Main switch
3	FillerLamp	Local	BOOL	%QX0.1			Filler indicator lamp
4	PushRod	Local	BOOL	%QX0.7			Fill Sensor Activated switch
5	DiscardLamp	Local	BOOL	%QX0.2			Discard Indicator lamp
6	NormalLamp	Local	BOOL	%QX0.3			Normal Level Indicator lamp
7	FillerOff	Local	BOOL	%QX0.4			Status of filler pump control
8	TON0	Local	TON				Timer for setting filler pump
9	TON1	Local	TON				Timer for resetting filler pump
10	NC	Local	CTU				Up Counter for normal fill
11	NC0	Local	INT	%QW0			Normal counter variable
12	DC0	Local	INT	%QW1			Discard counter variable
13	Reset	Local	BOOL	%QX0.5			Reset counter switch
14	DC	Local	CTU				Up Counter for discarded bottles

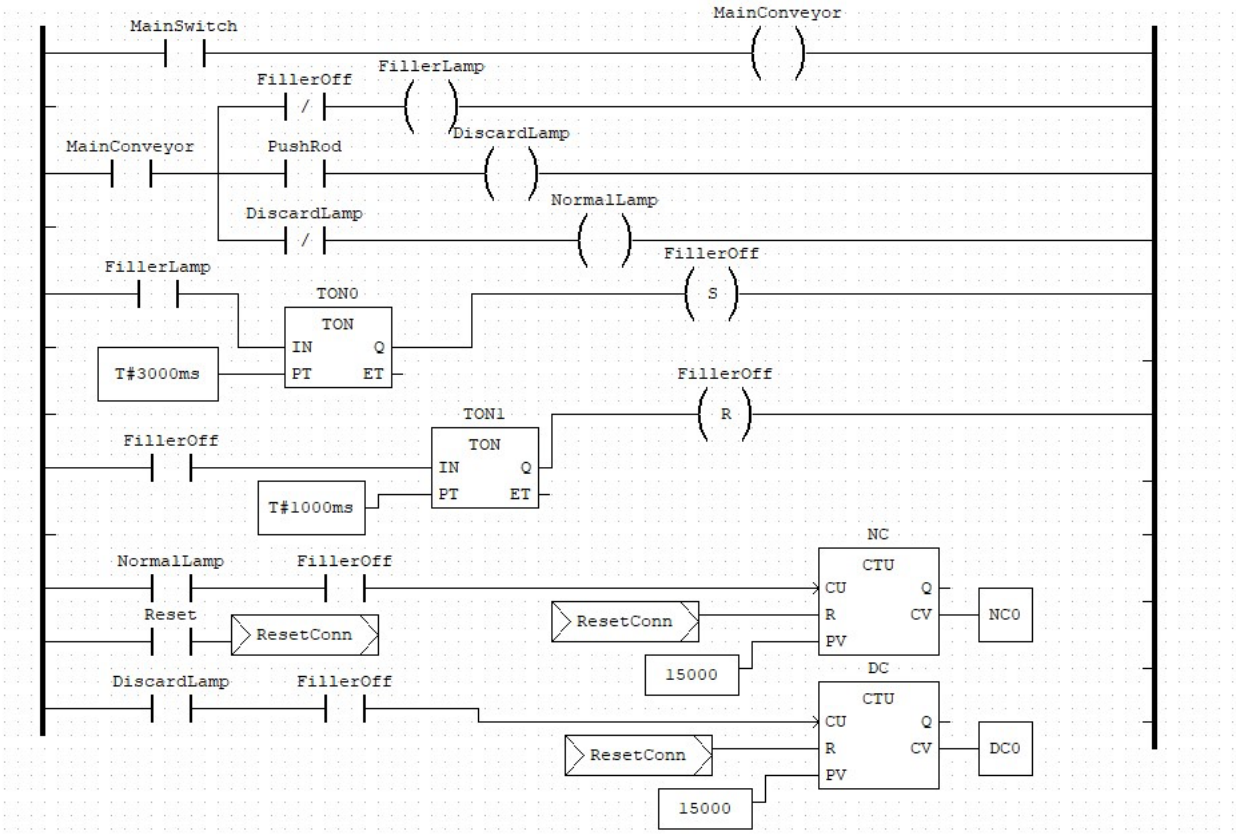

Figure 1. Ladder Logic Implementation

The Structured Text Program of the Ladder Logic Implementation

```
PROGRAM BFSystem
```

```
VAR
  MainConveyor AT %QX0.0 : BOOL;
  MainSwitch AT %QX0.6 : BOOL;
  FillerLamp AT %QX0.1 : BOOL;
  PushRod AT %QX0.7 : BOOL;
  DiscardLamp AT %QX0.2 : BOOL;
  NormalLamp AT %QX0.3 : BOOL;
  FillerOff AT %QX0.4 : BOOL;
END_VAR
VAR
  TON0 : TON;
  TON1 : TON;
  NC : CTU;
END_VAR
VAR
  NC0 AT %QW0 : INT;
  DC0 AT %QW1 : INT;
  Reset AT %QX0.5 : BOOL;
END_VAR
VAR
  DC : CTU;
  R_TRIG1 : R_TRIG;
  R_TRIG2 : R_TRIG;
END_VAR

MainConveyor := MainSwitch OR MainSwitch;
FillerLamp := NOT(FillerOff) AND MainConveyor;
DiscardLamp := PushRod AND MainConveyor;
NormalLamp := NOT(DiscardLamp) AND MainConveyor;
TON0(IN := FillerLamp, PT := T#3000ms);
IF TON0.Q THEN
  FillerOff := TRUE; (*set*)
END_IF;
TON1(IN := FillerOff, PT := T#1000ms);
```

```
  IF TON1.Q THEN
    FillerOff := FALSE; (*reset*)
  END_IF;
  R_TRIG1(CLK := FillerOff AND NormalLamp);
  NC(CU := R_TRIG1.Q, R := Reset, PV := 15000);
  NC0 := NC.CV;
  R_TRIG2(CLK := FillerOff AND DiscardLamp);
  DC(CU := R_TRIG2.Q, R := Reset, PV := 15000);
  DC0 := DC.CV;
END_PROGRAM



CONFIGURATION Config0

  RESOURCE Res0 ON PLC
    TASK task0(INTERVAL := T#20ms,PRIORITY := 0);
    PROGRAM instance0 WITH task0 : BFSystem;
  END_RESOURCE
END_CONFIGURATION
```

Human Machine Interface (HMI) of the Digital Twin of the Bottle Filling System

The HMI of the DT is implemented using Visual Studio IDE, C# and the AdvancedHMI libraries. The HMI interfaces with the Digital Twin running on the local machine. The implementation is designed to any instance of the DT

that is deployed on the local network or on the virtual network environment. A snapshot the HMI is depicted on Figure 2 below.

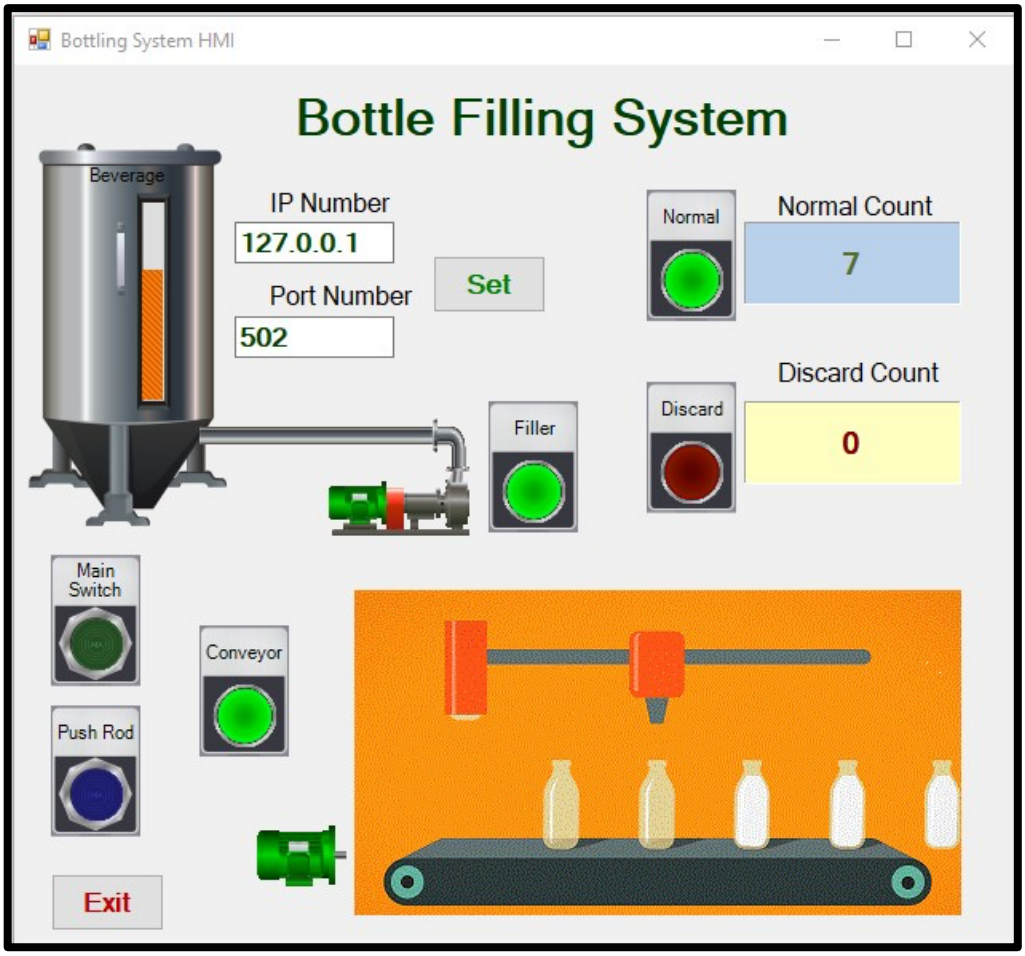

Figure 2. HMI of the Digital Twin