School of Electronic and Computing Systems (SECS)

University of Cincinnati

Smart Belt Transfer System Simulation Using Smart Metering Technology

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of the degree of
Bachelor of Science in Electrical Engineering Technology

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A. Introduction

The purpose of this report is to clearly define all aspects of the “Smart Belt Transfer System Utilizing Smart Metering Technology”. This report will include topic such as:

1) **The problem** - What is the problem that this project intends to resolve.
    a. The data – What data supports the fact that there is a problem.
    b. The significance – What is to be gained by this project.
2) **Solution/Methodology**
    a. Solution – How does the project solve the specific problem?
    b. Implementation – How can the project be implemented to solve the problem.
    c. Credibility – Authors expertise on the topic.
3) **Implementation**
    a. Timeline
        - Gant chart with scheduling
        - Scheduling and the effects on personal, and any limitations/inconveniences.
    b. Budget
        - BOM/Cost estimating table.
        - Explanation of the overall cost, effect on personal, and any limitations/inconveniences.
4) **Rationale/Benefits**
    a. Visualization of project advantages.
    b. Benefit of project.
    c. List of people who could potentially benefit from the project.
5) **Conclusion**
    a. Brief discussion on the overall benefit of the project.

The scope of this project encompasses three main areas:

1) Three phase power generation – Most manufacturing facilities rely on three phase power to control a majority of their automated equipment. Due to the limitations of the demonstration area, the project was limited to the standard 115VAC single phase power, which had to be improvised to produce three phase power. To accomplish this we used a combination of transformers, fuses, contactors, capacitors, and three phase motors to convert 115VAC single phase to 230VAC three phase. This new three phase voltage and current was used to power a variable frequency drive which ultimately controlled our three phase conveyor motor. The variable frequency drive gave us much more flexibility and control over our three phase motor. It allowed us to change the speed of the motor by simply varying the analog input signal from a range of 0 – 10 VDC. This could be done by either changing the speed on the HMI or tuning a potentiometer on the side of the enclosure. Another benefit of the VFD was the ability to change the direction of the motor on the fly. A dynamic braking resistor internal to the VFD allowed us to stop the motor within milliseconds and reverse the direction.

2) Automation and controls – The controls part of our project incorporated a PLC (Programmable Logic Controller) and an HMI (Human Machine Interface) to intelligently control processes based on real world inputs and outputs. This portion of the project utilized hardwired pushbuttons and selector switches, to control motor direction and run status. The hardwired momentary pushbuttons allowed the operator to jog the motor in either direction by simply pressing the appropriate button. Selector switches were used for continuous run operation in either direction. These devices were wired to PLC inputs that were manipulated by the PLC software that controlled outputs to the VFD. The HMI provided another means of machine control. Essentially the same hardwired features were duplicated using software which interfaced to the PLC over Ethernet using a communication driver.

3) Power Metering – Through the use of a SEL-735 Revenue Meter totalized power parameters from the “Smart Belt Transfer System.” The Schweitzer SEL-735 Revenue Meter allowed the user to monitor the simulated production costs and measure the power system quality. Through the use of the three phase power and the current transformers, (CTs and PTs) the SEL-735 calculated the current, voltage, phase angle, frequency, power factor,

total harmonic distortion, and transients. The meter was configured and programmed to the specifications of the parameters of the project. It utilized hardwiring from the current and potential circuits to calculate the data. The relay additionally was able to be configured one of two ways, the first from the front panel of the relay and the second, via an HMI through the use of an RS-232 connection. When connected to the human machine interface, it allowed for full analysis of the data as it would be connected to a computer.

Credibility

Having worked in industry for a combined 13 years Nate and I have gained tremendous experience in the fields of power, controls, and automation. Having started out as a basic CAD operator I spent a majority of my time drawing up other peoples design. This gave me great insight into how electronic components relate to one another. It also gave me a solid background in AutoCAD which is a useful tool in any engineering design. After 2 years as a CAD operator I jumped on the opportunity to add HMI designer to my title. Under this role I designed HMI screens and solution for various machine designs. I was also responsible for testing and implementing new HMI hardware and software. After about 5 years as CAD and HMI designer I was offered the role of new equipment electrical engineer. Under this role I was responsible for every aspect of the electrical engineering design. The process starts with conceptual drawings, and then moves into the scheduling phase. From there a BOM (bill of material) is generated which specs all the necessary components of the project. After the BOM phase is completed then the design and drawing phase begins. Once the BOM and drawing phases are complete then the test and debug phase begins. This is where a majority of the time is spent tweaking programs until they function as expected. Throughout this entire process each phase is continuously updated to reflect changes that occur along the way. One thing you will learn about engineering is that you must adapt to changes that occur throughout the build cycle.

Problem

There are three main problems our project will demonstrate to resolve. The first problem is to take standard 115VAC single phase house hold voltage and current and convert it into 3 phase voltage and current. Because most residential homes do not have access to 3 phase electric power it is often impossible for the average shop mechanic to run 3 phase electrical equipment. Many quality used industrial machines are available at attractive prices that require the use of 3 phase power.

With most residential homes having limited access to 3 phase electric power at a reasonable price, the average shop builder must come up with a creative solution to utilize this equipment.

The second problem our project attempts to resolve is to demonstrate how automation and modern controls can be used and implemented to increase manufacturing efficiency. Non automated tasks require human intervention which is often slow and prone to mistakes made by human error. Automation allows us to remove the human element from the equation and rely on machinery to do repetitive processes more quickly and reliably.

Automation refers to the use of computers and other automated machinery for the execution of tasks that a human laborer would otherwise perform. Companies automate for many reasons. Increased productivity is normally the primary reason for many companies desiring a competitive advantage. Other reasons to automate include the presence of a hazardous working environment and the high cost of human labor.

The third problem our project intends to resolve is to use smart metering technology to demonstrate the wide amounts of uses and functionality of smart metering. "Smart Grid" is a widely used industry term, but what exactly is it? To sum smart grid up into a sentence, it is a data acquisition tool used for metering and communication between devices. In the case of our project, we used the SEL-735 Revenue Meter to totalize the power parameters of the project. If the meter was in an industrial setting, as it is meant to be in, the data taken and calculated from the meter such as voltage and current, frequency, total harmonic distortion, system unbalance, sags, swells, and interruptions, flicker measurement, waveform capture and transients could be sent over a network to allow a user who is either in a local or remote location to monitor and check the system status. Also, another application of the SEL-735 Revenue Meter is to compare demand and power consumption with utility companies. Utilities bill their customers based on usage, and this meter will keep the utility companies honest by making sure they are being billed for the correct power consumption.

Solution/Methodology

The "Smart Belt Transfer System using Smart Metering Technology" intends to demonstrate how leading edge technology can increase production and efficiency through the use of automation and controls. The first obstacle to overcome was to generate our 3 phase power from a single phase source. To accomplish this we has to construct a rotary phase converter to convert 115vac single phase to 230vac three phase. The rotary phase converter provided current in all three phases and although not perfect, allowed us to provide all or nearly all of our motors rated horsepower. The current and phase angles of our 3 phase power were not exactly of a true three phase source, but we were able to slightly adjust the phase angles through the use of run capacitors to balance out the individual phases.

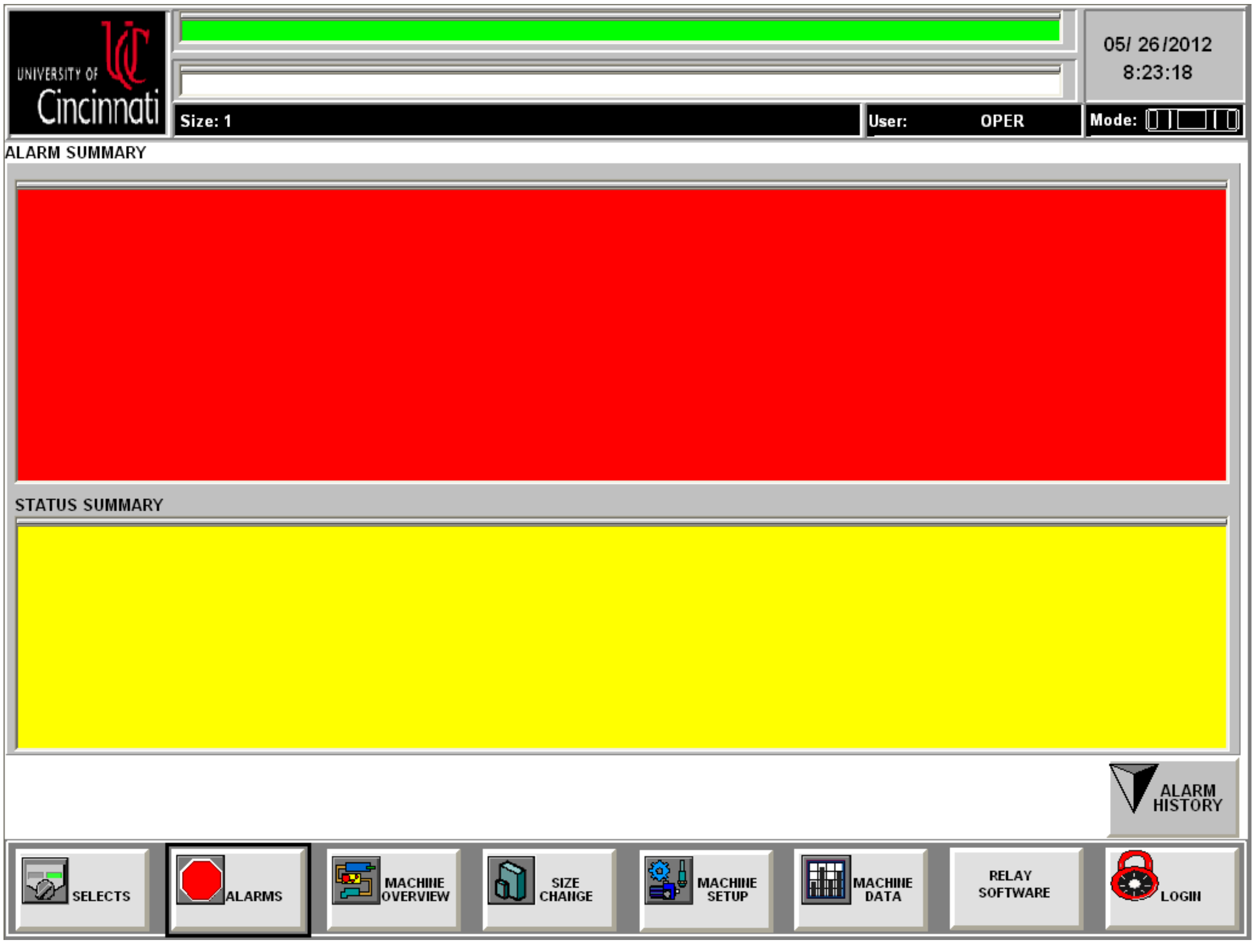
The rotary phase converter consists of a start contactor and capacitor which provides the initial boost of voltage and current to get the 3 phase generator motor spinning. Once the motor is up and running we rely on a run capacitor to balance out the three individual phases. This newly generated 3 phase power allowed us to control our VFD and conveyor motor.

The “Smart Belt Transfer System using Smart Metering Technology” demonstrates how to use automation as a means of process control. To simulate the automation process our project consisted of a PLC and HMI which manipulated hard wired input signals and controlled devices via outputs from the PLC. These hard wired input/output signals could be manipulated by the PLC software which could be programed to do various tasks.

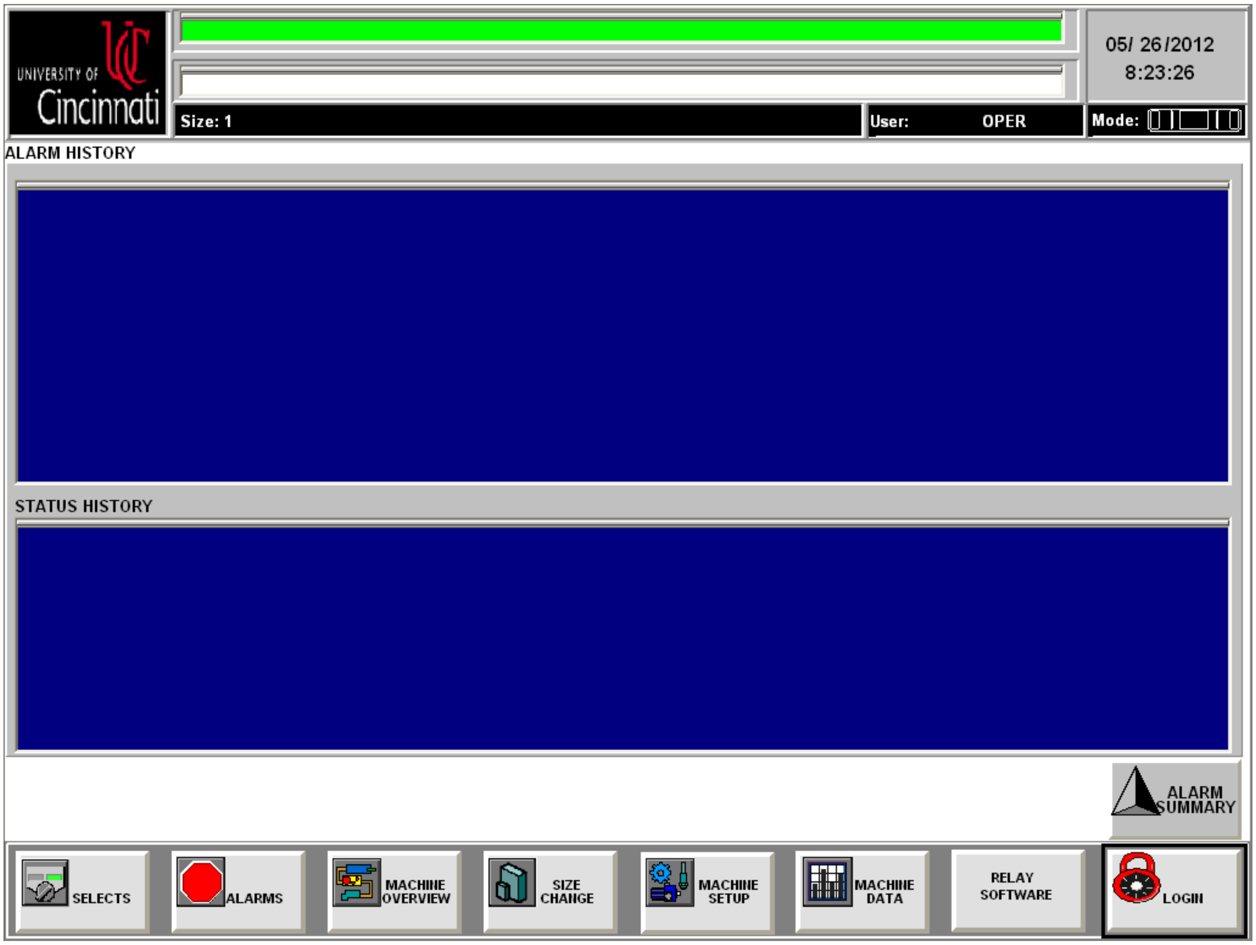
The use of a VFD (Variable Frequency Drive) gave us greater control of our 3 phase conveyor motor. The VFD allowed us to run the motor in both forward and reverse directions, allowed us to vary the speed of the motor, and allowed us to dynamically change the acceleration and deceleration rates of the motor.

The flexibility of the HMI allowed us to have a visual representation of what was going on with the machine operation and allowed us to totally control the machine operation through a touch screen PC. Below is a list of HMI screens and their purpose:

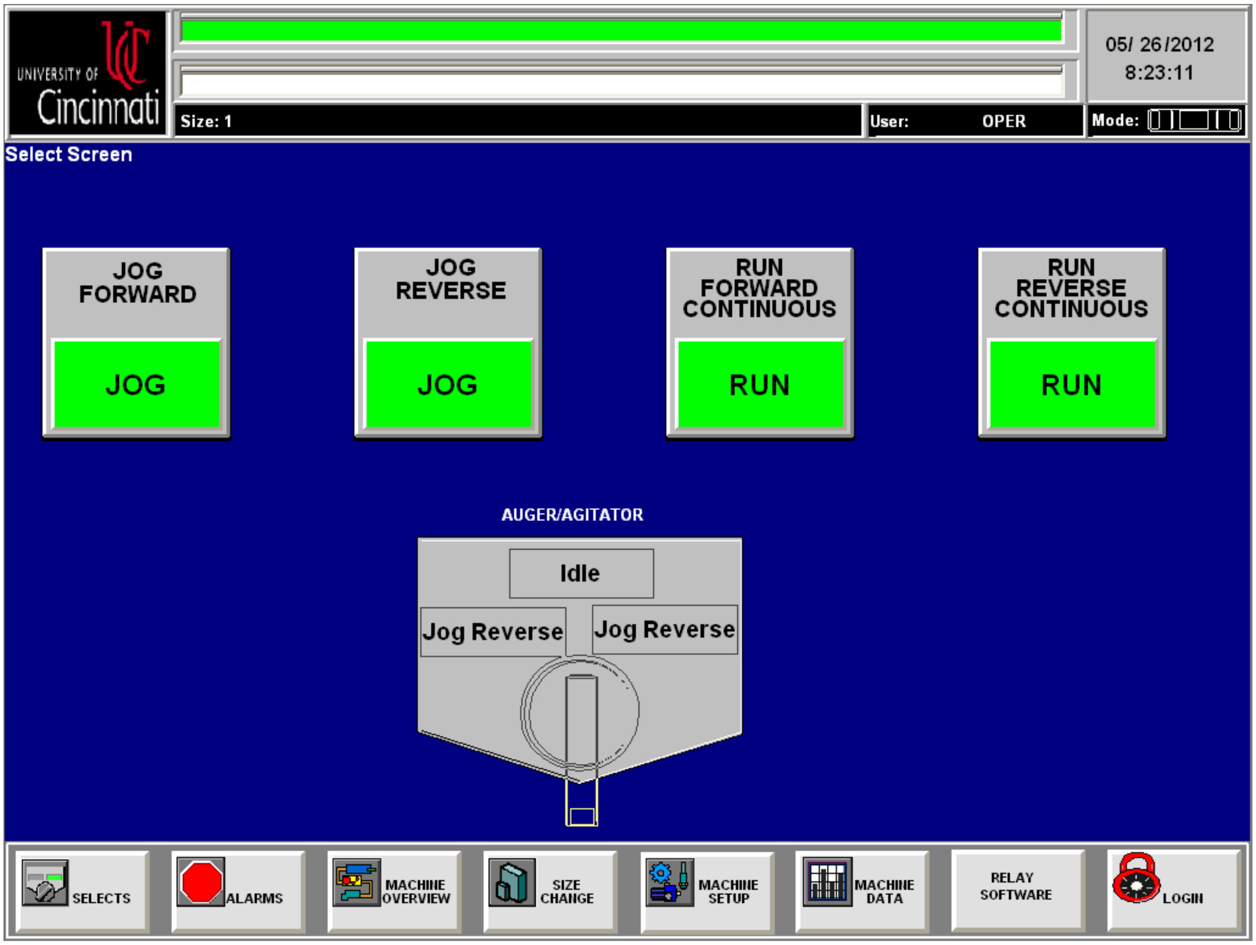
The alarm summary screen provides a list of current alarm and status messages present at any given time. Typically all alarms inhibit the machinery from operating, and must be remedied before operation can continue. Status messages on the other hand are warnings to the operator letting them know of upcoming problems. The very top banner displays the most recent alarm that has occurred. Alarms appearing in red are fault conditions, while a green banner represents no faults and the machine is ready to operate. Below the alarm banner is the status banner warning the operator of upcoming problems. The top banner also informs the operator as to which size he is running as well as the mode of operation.



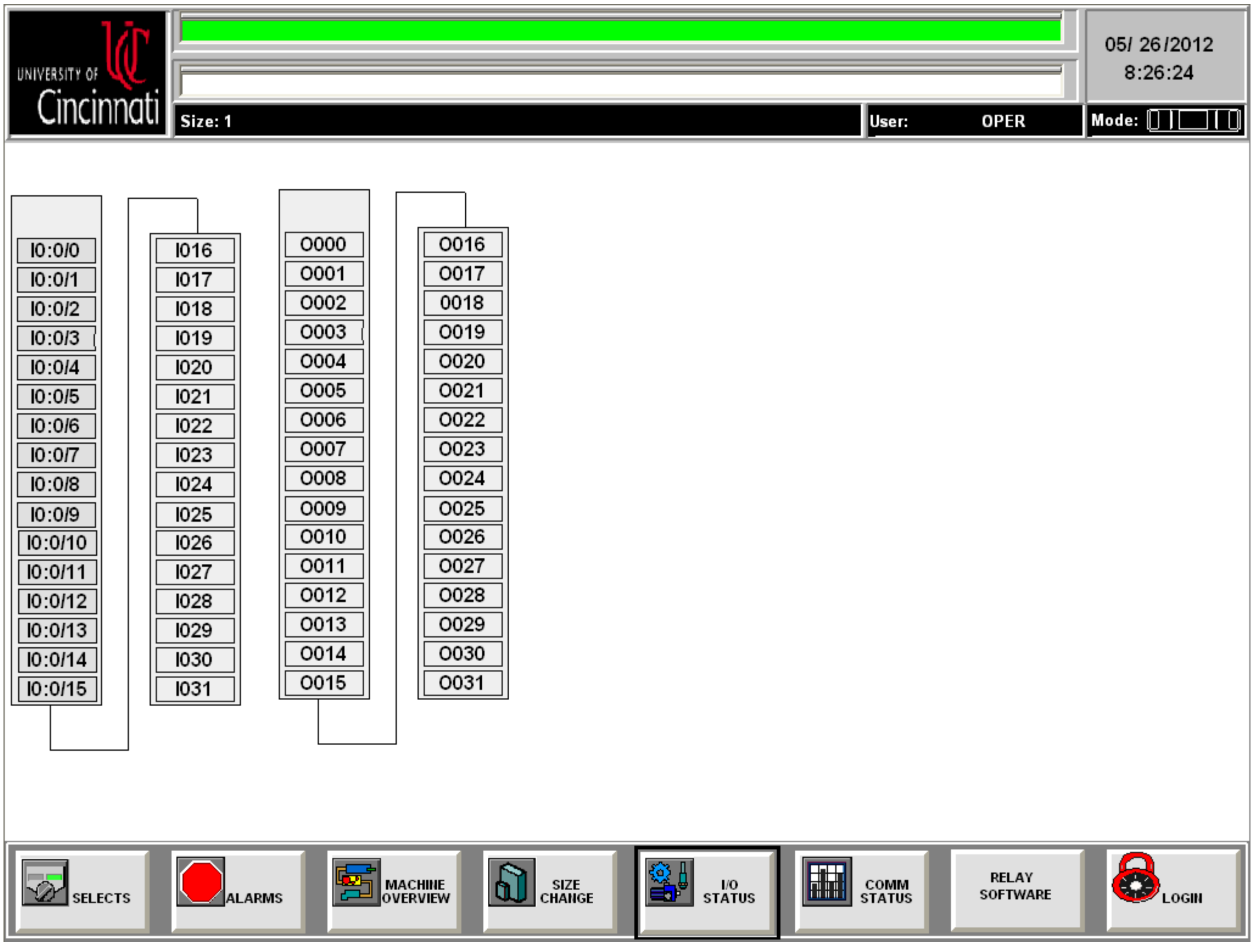
The alarm history screen is a historical representation of all alarms that have occurred within a specific time period set by the operator. This screen is useful for troubleshooting reoccurring fault conditions.



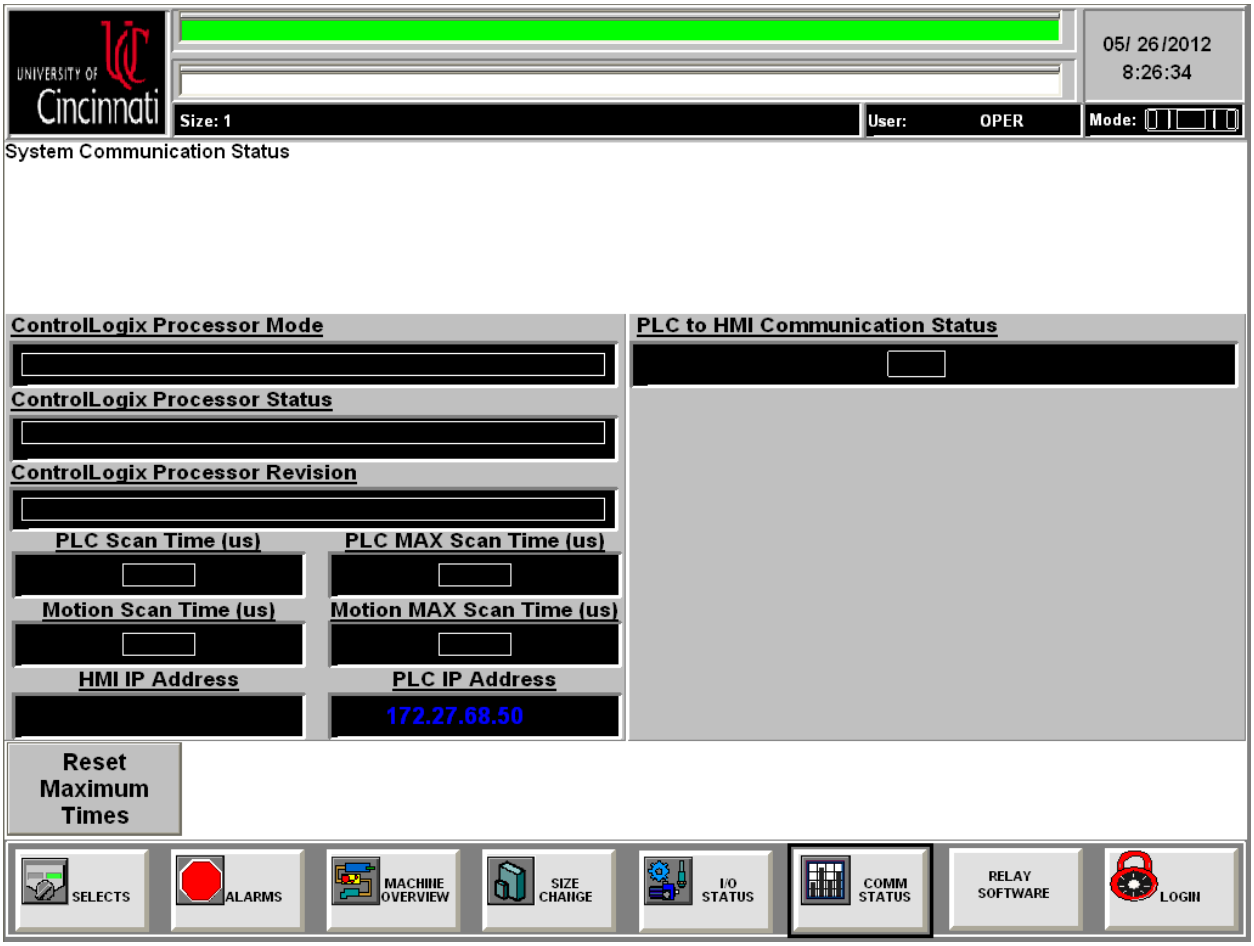
The selects screen provides the operator with a secondary means of control. From this screen the operator can jog the machine forwards or backwards and run the machine continuously in either direction.



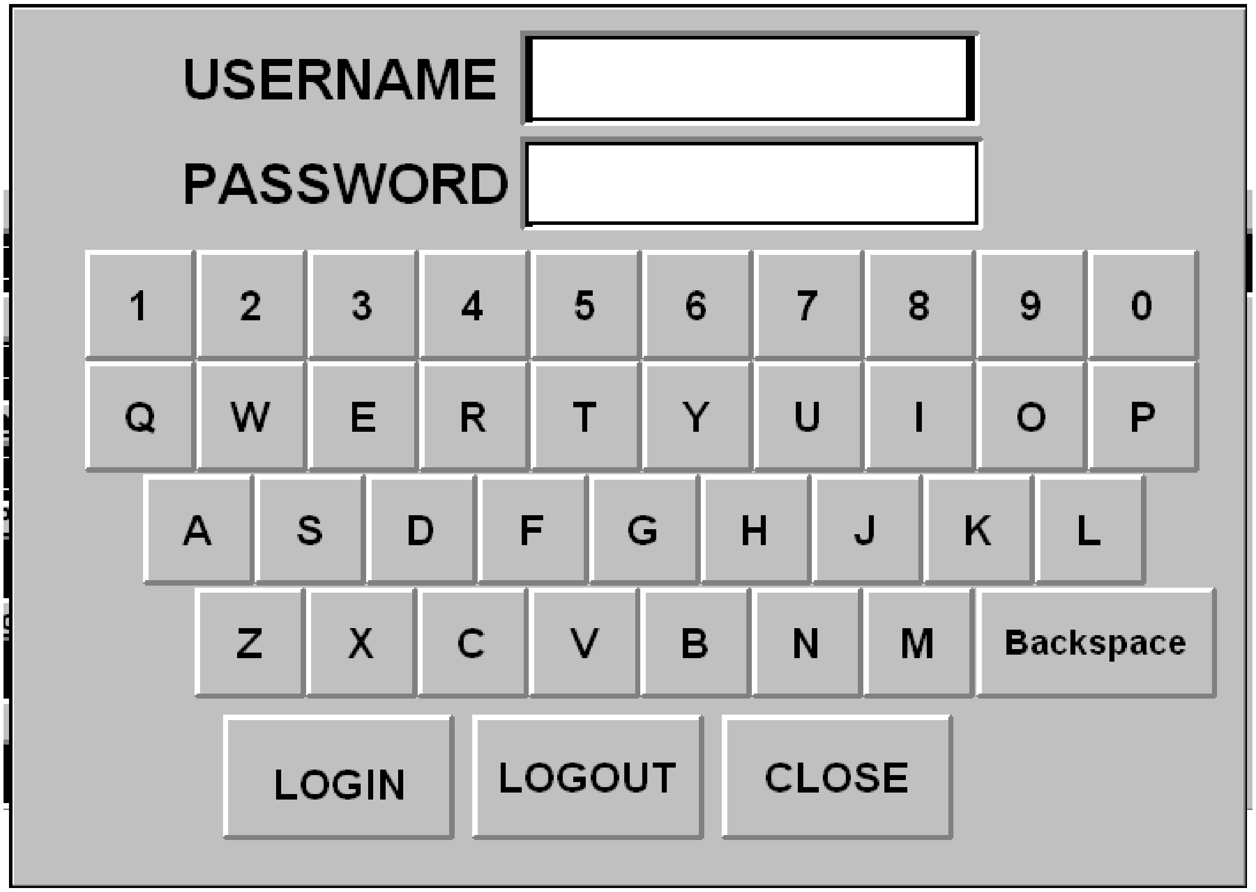
The input/output status screen indicates the status of all I/O at any given time. This screen is a useful troubleshooting tool to indicate to the operator if all I/O is functioning properly. If the input or output is ON then the indicator background will display green indicating the device is active. If the indicator background is grey then device is OFF.



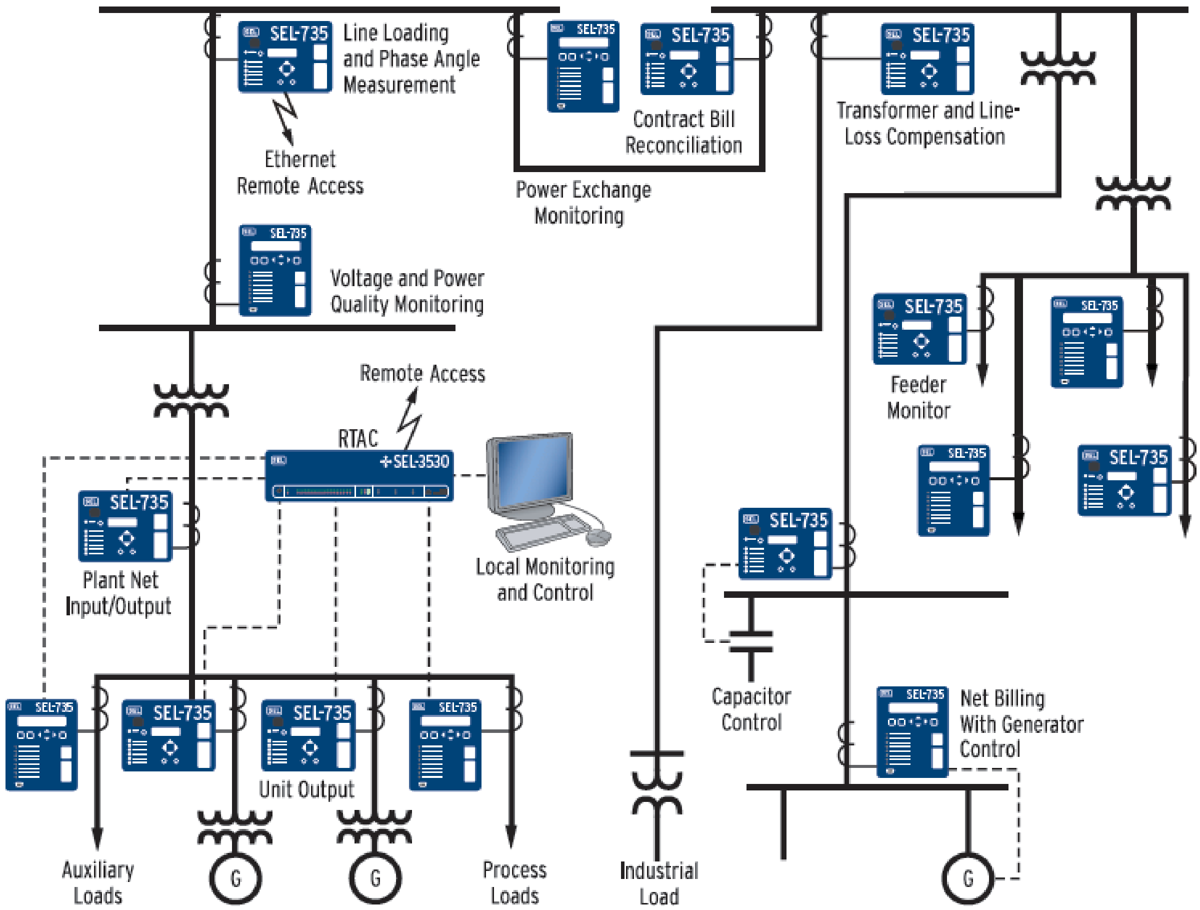
The communication status screen indicates to the operator the status of the PLC. Information such as processor mode, status, scan time, and HMI/PLC communication status can all be found on this screen. This information is useful to the plant engineer who monitors network traffic. Too much network traffic can bog down the scan time of the PLC causing a delayed response of the I/O effecting equipment performance.



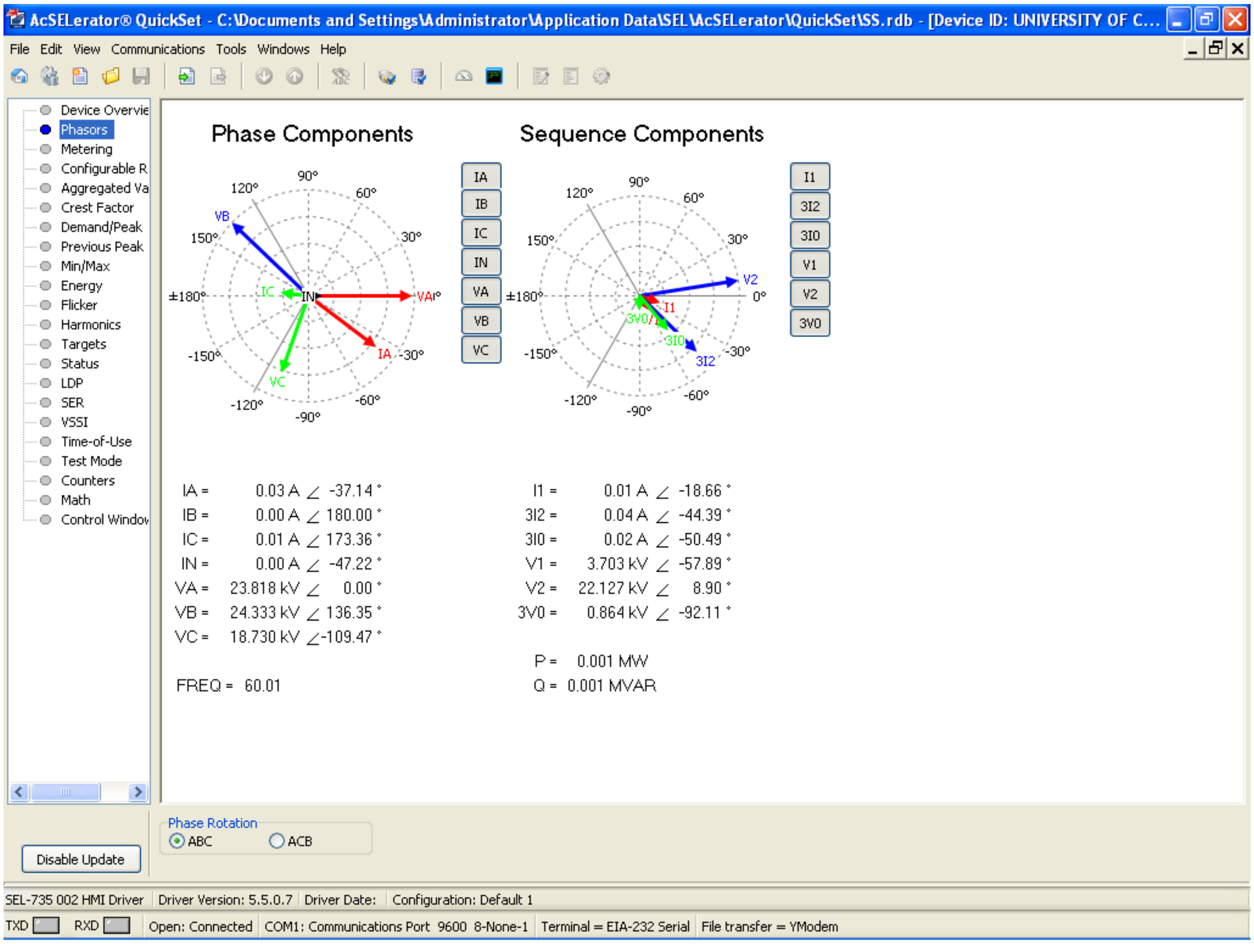
The security or login screen allows maintenance personal to access functions of the machine that may not be accessible to the operator. Important machine features can be hidden from the general user but accessible to plant technicians or engineers simply by entering a username and password.



Smart metering technology portions of our project demonstrate how smart relays solve the problem of data acquisition used for metering and communication between devices. In the case of out project, we used the meter in real time to display what the system power output was. Rather than tying the relays into several other relays as shown below, we tied the relay directly to a human machine interface (HMI) device to allow the users to display the real time values of the system.



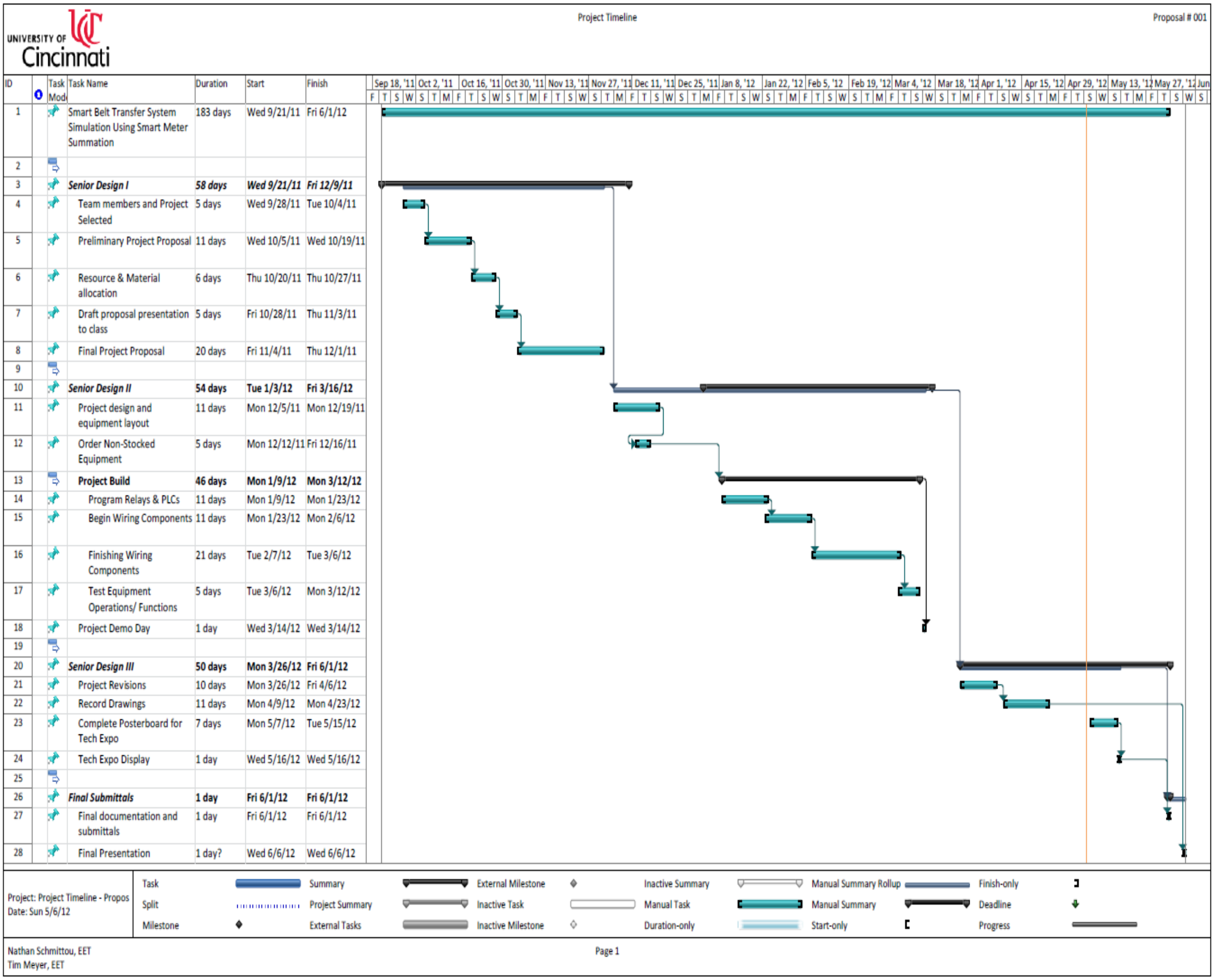
The phase and sequence components shown below are screen shots of the real time values of the system. To make the values more realistic, the relay program was given set points to portray these values. In addition to system analysis, the phasor diagrams allow the user to check for improper phase rotation, voltages and currents.



Implementation:

a. Time:

The schedule breaks down the individual tasks into four main categories. The first category is the task name. The task names are the individual milestones that we are striving to achieve. Each task name is clearly defined and organized in a top down



structure. The second category is the duration. The duration category simply states how many days we think each task will take to complete. The third category is the start date for each task. The start date is simply the date that we plan to start each task. The fourth and final category is the finish date. Much like the start date the finish date is simply the day we plan to complete each task. A graphical representation gives a pictorial view of each task and its duration from start to completion. Our schedule consists of 28 tasks and spans over 158 days from start to finish. The tasks break down as follows:

1) **Senior Design I. 58 days duration.**
    a. Team members and project selection. 5 days duration.
    b. Preliminary project proposal. 11 days duration.
    c. Resource and material allocation. 6 days duration.
    d. Draft proposal presentation to class. 5 days duration.
    e. Final project proposal. 20 days duration.

2) **Senior Design II. 54 days duration.**
    a. Project design and equipment layout. 11 days duration.
    b. Order non stocked equipment. 5 days duration.

3) **Project Build. 46 days duration.**
    a. Program equipment (HMI, PLC, Relays). 11 days duration.
    b. Begin wiring components. 11 days duration.
    c. Finish wiring components. 21 days duration.
    d. Test equipment operation and functionality. 5 days duration
    e. Project demonstration. 1 day duration.

4) **Senior Design III. 50 days duration.**
    a. Project revisions. 10 days duration.
    b. Record drawings. 11 days duration.
    c. Complete poster board for Tech Expo. 7 days.
    d. Tech Expo display. 1 day duration.

5) **Final Submittals. 1 day duration.**
    a. Final documentation and submittals. 1 day duration.
    b. Final presentation. 1 day duration.

During the build phase many issues impacted scheduling. Material allocation was big obstacle for our project. We relied heavily on our employers to provide the necessary equipment for the build phase. When we were unable to acquire the necessary equipment from our employers then we were forced to rely on our connections with vendors to provide the necessary equipment. Delays in acquiring all the necessary equipment for the project delayed the wiring phase which in turn delayed the test and debug phase. Scheduling was also impacted by the lack of individual time. With both of us working full time and taking nearly a full load of classes, available free time severely impacted scheduling.

c. Budget:

ITEM	DESCRIPTION	PART NUMBER	QTY.	UOM	ACT.Unit Price	Actual Total Price	Vendor	Requested Due Date
	Relays							
1	SEL-735 Revenue Meter	0735VB20916102XX	1	EA	$3,175.00	$3,175.00	SEL	01/02/12
	Wiring Equipment							
2	120-240/480V Step Up Transformer		1	EA	$65.00	$65.00	RB Sales	01/02/12
3	1/3 HP 3PH 460V Motors		3	EA	$105.00	$315.00	RB Sales	01/02/12
4	PLC (CONTROLLOGIX)	ABB1756-A7	1	EA	$255	$255	CBT	01/02/12
		ABB1756-L61/B	1	EA	########	$2,879.51	CBT	01/02/12
		ABB1756-PA75	1	EA	$569.72	$569.72	CBT	01/02/12
		ABB1756-ENBT	1	EA	$1,001	$1,001	CBT	01/02/12
		ABB1756-OB32	1	EA	$340.24	$340.24	CBT	01/02/12
		ABB1756-IB32	1	EA	$240.67	$240.67	CBT	01/02/12
		ABB1756-N2	4	EA	$14.39	$57.56	CBT	01/02/12
5	MOTOR CONTACTOR	ABB100S-C09DJ14C	2	EA	$71.60	$143.20	CBT	01/02/12
6	MOTOR PROTECTOR (MP1)	ABB140-MN-0400	1	EA	$91.73	$91.73	CBT	01/02/12
		ABB140-A11	1	EA	$12.53	$12.53	CBT	01/02/12
		ABB140-T10	1	EA	$11.78	$11.78	CBT	01/02/12
7	CONTROL RELAY	ABB700-HC22Z24-4	3	EA	9.91	$29.73	CBT	01/02/12
		ABB700-HN104	3	EA	6.88	$20.64	CBT	01/02/12
		ABB700-HN114	3	EA	0.48	$1.44	CBT	01/02/12
		ABB700-ADL1	3	EA	3.66	$10.98	CBT	01/02/12
8	24VDC POWER SUPPLY	ABB1606-XL240E-3	1	EA	255.91	$255.91		01/02/12
9	ETHERNET SWITCH	PHT2891929	1	EA	122.85	$122.85	Carlton Bates	01/02/12
10	VFD	ABB22B-D6P0N104	1	EA	637.81	$637.81	CBT	01/02/12
		ABB22-COMM-E	1	EA	308.25	$308.25	CBT	01/02/12
		ABB22B-CCB	1	EA	15.79	$15.79	CBT	01/02/12
11	FUSES	BUSLPJ-8SP	9	EA	6.31	$56.79	FDL	01/02/12
		BUSJTN60030	9	EA	10.06	$90.54	FDL	01/02/12
12	START PUSHBUTTON	ABB800T-A1AR	1	EA	28.39	$28.39	CBT	01/02/12

		ABB800T-XAR	1	EA	19.3	$19.30	CBT	01/02/12
		169317-232	1	EA	11.22	$11.22	CBT	01/02/12
13	STOP PUSHBUTTON	ABB800T-B6AR	1	EA	28.39	$28.39	CBT	01/02/12
		ABB800T-XAR	1	EA	19.3	$19.30	CBT	01/02/12
		169332-001	1	EA	11.22	$11.22	CBT	01/02/12
14	MISC. FUSES	BUSABC10	10	EA	$0.91	$9.10	CBT	01/02/12
		ABB1492-H4	10	EA	4.33	$43.30	CBT	01/02/12
		ABB1492-N37	10	EA	0.4	$4.00	CBT	01/02/12
15	HMI	ABB2711P-T15C4D6	1	EA	$5,091.00	$5,091.00	CBT	01/02/12
					Job Total:	**$15,973.89**		

The cost estimating worksheet or BOM is broken down into 5 main categories:

1) The first category is the device description. The device description briefly explains what the device is and touches on the device specifications.
2) The second category is the device part number. The part number is the specific part number used to order the device from the manufacturer.
3) The third category is the device quantity. The device quantity simply states how many of a particularly device is to be ordered.
4) The fourth category list the unit cost or the discounted OEM cost. Often times vendors will discount prices for OEM's based on the quantity of a particular device an OEM orders over the course of a year.
5) The fifth and final category lists the actual or total cost. The total cost is unit cost multiplied by the quantity to give an overall cost for a specific device.

Throughout the course of the build the BOM had to be updated frequently due to changes in the design and additions for project enhancements. Cost was a huge obstacle for our design. Many of the components used in our project cost several hundreds of dollars and even a few components cost several thousands of dollars. Fortunately we relied heavily on our employers to provide some of the high dollar devices. These high dollar devices were put on loan to us by our employers and some were on loan from vendors.

Rationale/Benefits:

Manufacturing companies rely on efficiency and keeping their production lines up and running to produce as much product as possible. Automating these systems and production lines is the most efficient and cost effective for these repetitive tasks. Automation is the process of integrating industrial machinery to automatically perform tasks such as: material handling, palletizing, dispensing, packaging, etc…Utilizing hardware and software, automation increases productivity, safety, and profitability. The "Smart Belt Transfer System" using "Smart Metering Technology" demonstrates how automation can be utilized to automate a specific process whether it is a conveyor system or an entire machine line.

Conclusion:

In conclusion, automation control and smart relaying will be the key to an efficient and effective growth in the industrial and utility industries in the future. With automation and control, factories will remove the aging existing equipment with modern capabilities, driving efficiency and profitability.