Design of an Automated Power Sourcing Unit to Optimize the Operating Schedule of Industrial Loads

H P M Udayanga
Department of Physics and Electronics
University of Kelaniya
Kelaniya, Sri Lanka
madhumaludayanga@gmail.com

R T Seneviratne
Department of Physics and Electronics
University of Kelaniya
Kelaniya, Sri Lanka
seneviratneraveen@gmail.com

S A R Geethal
Department of Physics and Electronics
University of Kelaniya
Kelaniya, Sri Lanka
geethalsuraweera95@gmail.com

W V I U Kumara
Department of Physics and Electronics
University of Kelaniya
Kelaniya, Sri Lanka
indika258456@gmail.com

A L A K Ranaweera
Department of Physics and Electronics
University of Kelaniya
Kelaniya, Sri Lanka
arunaran@kln.ac.lk

S R D Kalingamudali
Department of Physics and Electronics
University of Kelaniya
Kelaniya, Sri Lanka
kalinga@kln.ac.lk

***Abstract* — This work proposes a novel methodology to automate a power sourcing unit. The main objective of the proposed power sourcing unit is to control the power supply for various loads connected to it by optimizing their operating schedule. This enhances the durability of the loads while reducing energy waste. The proposed power sourcing unit was tested by constructing a prototype model which controls four 3-Phase motors to maintain a constant pressure in a vacuum tank in an industrial plant. The implemented prototype consists of a microcontroller based switching scheme for controlling loads. In addition to the automated operating mode, the system consists of manual operating mode. In case of failure of the entire automated system, the process is allowed to be continued by switching into manual operating mode. It is believed that the proposed method will be very useful in modern factory automation.**

Keywords — Power Sourcing Unit, Factory Automation

I. Introduction

To bring about the 4th industrial revolution, rapid technological advances are needed to realize factory automation. Traditional automation systems are not capable of addressing the current market demands due to the rapidly changing products avenues [1]. The key challenge in modern factory automation is the development of reusable, maintainable and adaptable automation solutions [2].

An effective energy management for residential applications was realized by the appropriate modification of existing products for home automation using microcontrollers [3]. An autonomous and distributed demand-side energy management system for smart grid was realized by allowing users to optimize the daily schedules of their household appliances and loads minimizing the energy costs [4]. Study [5] improves the energy usage efficiency by eliminating waste through process optimization. An Arduino microcontroller that communicates with an Android application, wireless Zigbee and wired X10 technologies makes a cost-efficient hybrid system reducing the total energy consumed by some appliances [6]. An agent-based model is introduced, optimizing the load demand, through load prioritization, to improve the micro grids self-sustainability [7]. In [8], a generic optimal industrial load management (OILM) model for industrial energy hubs in smart grids was proposed. In another study, operating schedules for industrial units were optimized yielding a considerable reduction of energy costs by shifting processes with high power consumption to times with low energy prices [9]. A study [10], proposes a framework for optimizing the water distribution system operators and frequency regulation. A recent study suggests that manufactory load allocation can be used as an effective industrial demand response scheme to reduce operating costs for industrial multi-energy micro-grids [11]. But none of the studies on automating the power sourcing unit to optimizing the operating schedule of industrial loads were reported..

II. Objectives

In this study, an automated power sourcing unit for industrial use is proposed. A Prototype model of the proposed power sourcing unit is implemented to automate and optimize the operating schedule of four 3-Phase motors. The implemented prototype consists of a microcontroller based smart switching scheme for the industrial loads connected to it. The microcontroller can be reprogrammed to adapt the system into different operating conditions. In addition to the automated operating mode, the system consists of manual operating mode. In case of failure of the entire automated system, the process is allowed to be continued by switching into manual operating mode. The novelty of the proposed systems is its ability to adapt into various industrial environments and the cost effectiveness as compared to PLC based traditional control approaches.

III. Methodology

The prototype model of the proposed system is developed to control four 3-Phase motors in order to maintain a constant pressure level inside a vacuum tank. The reconfigurability in the design allowed it to be adapted to control any industrial load connected to it easily. The prototype model consists of three basic parts, sensor, microcontroller and operating (automated/manual) mode selection circuitry. Block diagram of the prototype model is illustrated in Fig.1.

The internal pressure of the vacuum tank is monitored by the pressure sensor and its output is fed into the microcontroller. Depending on the pressure sensed, the microcontroller controls the 3-Phase motors connected to it. Operating mode selection circuitry was developed to switch between automated and manual operating modes. This mode selection is a necessary requirement for assuring the process continuity of industrial plants. When the automated operating mode is selected, AC/DC power supply unit provides power to the microcontroller.

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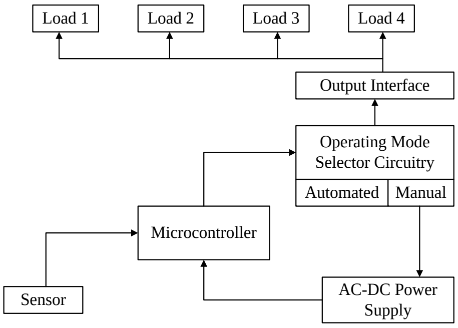

Fig.1. System Block Diagram

Fig. 2 depicts the operating mode selection circuitry and output interface for connecting various loads to the prototype model. Industrial loads (3-Phase motors) are connected to the output interface using the contactors and relays.

A. Automated Pressure Controlling System

In the operation of the proposed system, it is capable of indicating the status (Fig. 3) whether a particular load is connected with the power sourcing unit or not. In the automated mode, the microcontroller detects the number of industrial loads connected to the system through the output interface. This has been realized without using a current sensor as contrast to traditional methods.

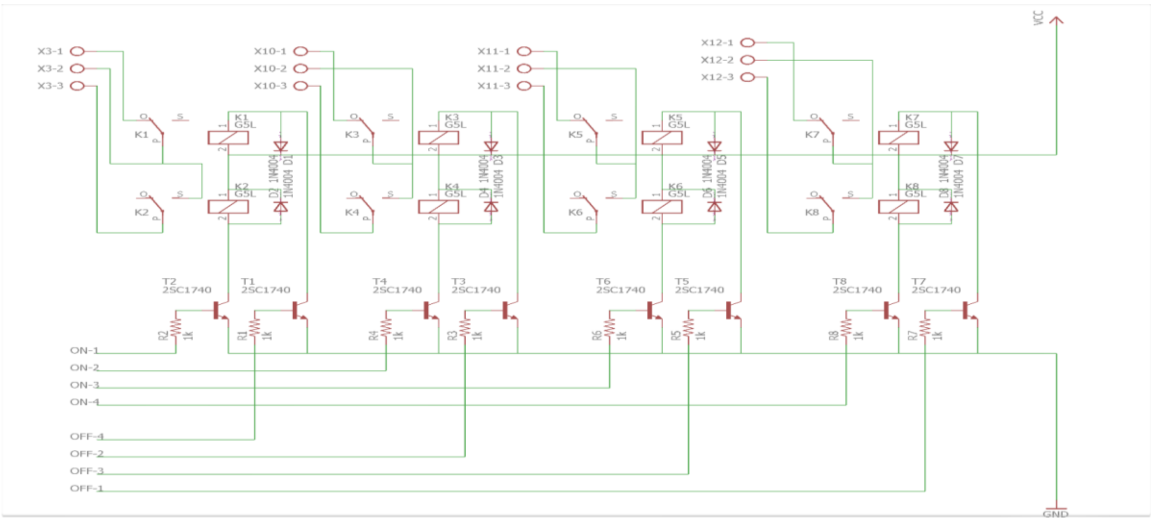

Fig. 2 Operation mode selection circuitry and output interface

If a current sensor is used, at the beginning, it is essential to flow a current through the sensor and wait for a certain time period for the loads to be powered. Therefore, the proposed system reduces the cost for current sensor, waiting time and risk of short circuit (3-Phase motor with neutral). This is a unique advantage of the proposed design.

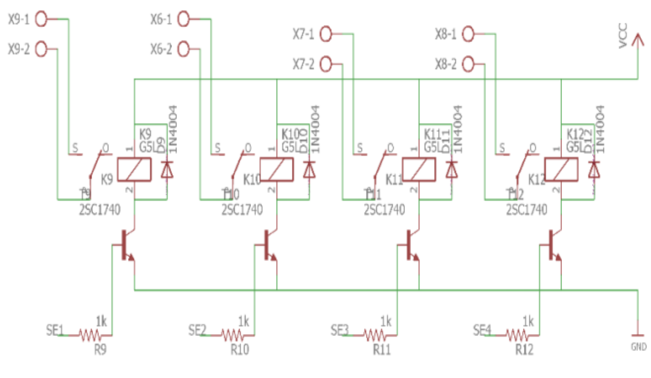

Fig.3.Circuitry for indicating the connectivity of the loads with the power sourcing unit

First, the microcontroller takes the count of industrial loads connected to the system. Secondly, it converts analog voltage input from the pressure sensor into digital and checks whether the value is smaller or greater than the reference value. The reference value is the digital value corresponding to the required constant pressure level to be maintained inside the vacuum tank. There are three possible conditions;(1) $P_i< P_r$ (2) $P_i> P_r$ and (3) $P_i= P_r$ where P_i is the internal pressure of the tank and Pr is the pressure required to be maintained.

The system is capable of controlling the switching ON/OFF the connected loads (3-Phase motors) and maintaining a constant pressure inside the vacuum tank. On the other hand, in each and every time of removing or adding a load to the system, it has the ability to identify the new condition and restart the system accordingly.Further, the designed system is able to switch the operating motors (Fig. 4) according to the pre-defined power sourcing time in the microcontrollers. EEPROM technology has been employed to record the number of hours that each motor was operated, and they were stored separately in the memory. Routine service requirements will be indicated with a RED colored warning light for the specific load and it will automatically be disconnected from the system. In addition, the system consists of an LCD panel which displays the operation periods of the connected loads together with the time left to the next service.

These additional features make the system more user-friendly, unique and efficient. The memory of the EEPROM is directly linked to the LCD panel and coded to display the number of days after the last service, and days left to the next service.

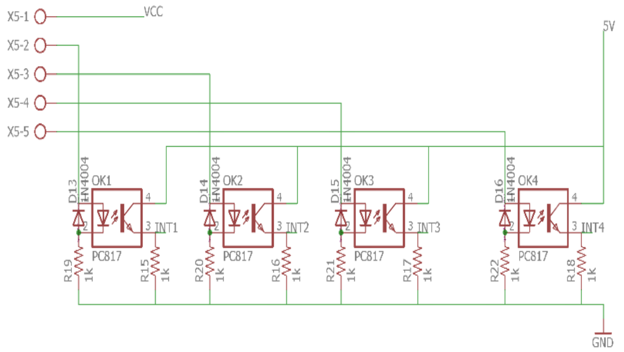

Fig.4.Circuitry for indicating the currently operating loads connected with the automated power sourcing unit.

B. *Secured Manual Operating Mode*

The manual operating mode is incorporated to assure the reliable and continuous operation of the loads if a fault occurred in the automated operating mode. Selector switches which are commonly used in the industry are utilized to indicate whether a particular load is working or not; by switching on the standard symbolic colors GREEN & RED respectively. Further, the use of the manual operating mode allows desired load(s) to be disconnected from the system without interfering with the entire process. To realize all the operations a novel algorithm was developed and implemented on microcontrollers. Further, the system is capable of connecting various types of loads and is controlled successfully.

IV. RESULTS AND DISCUSSION

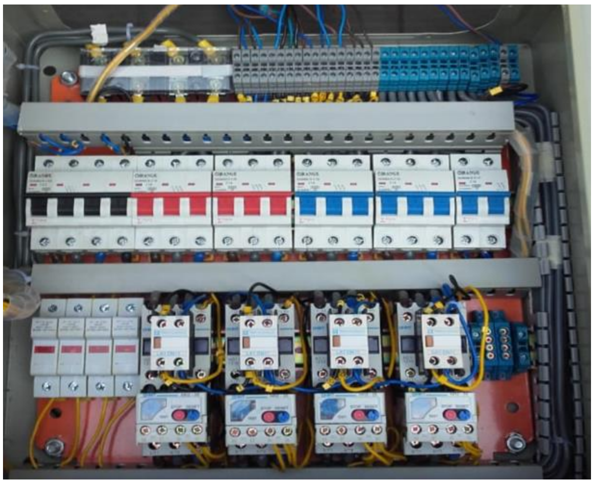

Fig. 5. Prototype of the developed model

The prototype of the proposed smart power sourcing unit was built successfully and tested to automate the vacuum pressure controlling system of an industrial plant. Image of the prototype model is shown in Fig. 5. The cost effectiveness of the power sourcing unit against the ordinary manual operating mode was highlighted due to the optimized switching schedule of the loads connected to the system. On the other hand, the ultimate safety towards the employment of the industry was guaranteed with the usage of the standard industrial switches. Checking the pressure inside the vacuum tank and switching the operation of motors with reference to the predefined pressure ranges, optimizes the number of operating loads. Therefore, the effective working hours per one particular service of a motor has been extended by significant numbers due to optimal usage of energy, providing sufficient rest for each motor equally and it's intelligence operation according to demand and supply. As a result of that, the cost for lubricants has been reduced drastically. Since the working time of each load has also been prioritized through the coding, the effective durability of each load has been increased. The in-built LCD panel gives the important details of each device to alert the management about the next service of the load and the RED light indicates the warning signal to the management if the specific load is out of service.

V. CONCLUSION

This particular automated power sourcing unit can be used in any field which is required to automate and optimize the operation of power consuming loads, in order to maintain a constant operating condition. This concept can be employed to sense any detectable physical parameter and automate the process smartly. Ultimately, it reduces the cost and energy waste compared to traditional approaches. The proposed automation concept can be connected together with the IOT, cloud computing, and Big Data in futuristic industrial automation.

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