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PLC BASED ELECTRICAL DEMAND MANAGEMENT IN SUGAR INDUSTRY

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ABSTRACT

Electrical energy is required for various purposes: for lighting, industrial drives, traction system and automation, etc. This is because of its cleanliness and abundant availability of various types of energy sources. Every industrial plant has its own electric power distribution system. Depending on the size of the power distribution system, layout of the plant, power source and operation, types of industry the power management may be more or less complex. This paper describes the Programmable Logic Controller (PLC) based electrical demand management system for a medium to large size industrial plant. The objective of this work is for the effective management of load demand with respect to available power in sugar industry under various conditions using PLC in order to maximize the flexibility and reliability of the electrical demand management.

Keywords: Power Demand, Management, Sugar industry, Programmable Logic Controller.

I. INTRODUCTION

Demand for electricity has increased with the advancement of technology and living standards. Most of the electric utilities throughout the world are facing difficulties in meeting the increasing demand from different consumer sectors, at all times. For example, the power system of India is experiencing an energy shortage of 9%, with a peak demand deficit of about 15.2%. As the electrical demand is widely varying, the utility must run generation units that are sufficiently rated to meet the demand. Especially during peak periods, the utility has to increase generation capacity and operate costly peak-generating units. Initiatives are usually introduced by the utilities to smooth the system load curve and thus delay (or avoid) the installation of extra capacity. Typically, customers are made aware of this either by means of price signal or through load shedding. Electricity costs can be minimized by taking advantage of incentives and favorable pricing offered by utilities in order to encourage consumers to use energy in such a way and at suitable times so as to enable the utility to manage load patterns. By making the best use of these incentives, it is possible to achieve significant savings in production costs, with no adverse effect on product quality and productivity [1].

Electrical demand management (ELM) is a specific method of controlling the peak load in the network in order to produce a constant demand. For applying ELM techniques to the industrial sector, a detailed modeling and optimization of the industrial loads is needed, including the complexities and constraints of the process. Industrial load management (ILM) activities are aimed at the economic reduction of an electric utility's demand during peak hours without affecting the specified production. ILM applications have been reported for utilities using interruptible load control schemes [1].

The set of options available for load management in industry includes process rescheduling or load shifting, machinery interruption/ restart cycle, energy storage, captive power, and automation. The choice of each option must be weighed against the rate system or financial agreement in effect and the technological constraints posed by the production process. The industrial sector consumes about 41% of the total electrical energy generated on a worldwide basis. Since industries consume a significant proportion of the total electrical energy generated, load management in the industrial sector assumes an important role in peak demand management. Load shifting, one of the simplest methods of load management, is to reduce customer demand during the peak period by shifting the use of appliances and equipment to partial-peak and off-peak periods. No loads are switched off but only shifted or rescheduled; hence, the total production is not affected [2].

II. METHODOLOGY PROPOSED

Fig. 1 below shows the block diagram of the proposed work.

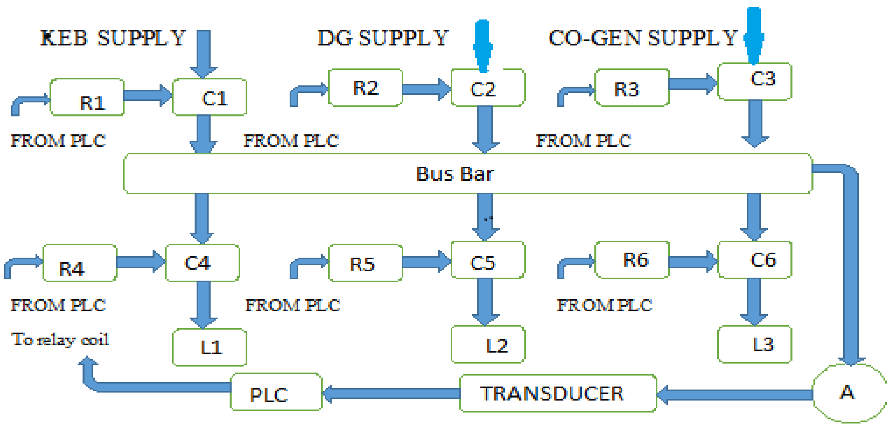

Fig. 1: Block Diagram of Load Management in Sugar Industry Using PLC

Where,

R1, R2, R3, R4, R5 & R6 are Relay coils

C1, C2, C3, C4, C5& C6 are Contactors

L1, L2 & L3 are Loads

A is AC ammeter (0-10A)

2.1. Components used

- MCB
- Contactors
- Relay coils

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- Transducer
- PLC-DVP14SS2
- Ammeter

2.2. Programmable Logic Controller

A programmable logic controller (PLC) is a special form of microprocessor-based controller that uses programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting, and arithmetic in order to control machines and processes (Fig. 2). It is designed to be operated by engineers with perhaps a limited knowledge of computers and computing languages. They are not designed so that only computer programmers can set up or change the programs. Thus, the designers of the PLC have preprogrammed it so that the control program can be entered using a simple, rather intuitive form of language. The term logic is used because programming is primarily concerned with implementing logic and switching operations; for example, if A or B occurs, switch on C; if A and B occurs, switch on D. Input devices (that is, sensors such as switches) and output devices (motors, valves, etc.) in the system being controlled are connected to the PLC. The operator then enters a sequence of instructions, a program, into the memory of the PLC. The controller then monitors the inputs and outputs according to this program and carries out the control rules for which it has been programmed.

PLCs have the great advantage that the same basic controller can be used with a wide range of control systems. To modify a control system and the rules that are to be used, all that is necessary is for an operator to key in a different set of instructions. There is no need to rewire. The result is a flexible, cost-effective system that can be used with control systems, which vary quite widely in their nature and complexity.

PLCs are similar to computers, but whereas computers are optimized for calculation and display tasks, PLCs are optimized for control tasks and the industrial environment. Thus PLCs:

• Are rugged and designed to withstand vibrations, temperature, humidity, and noise

• Have interfacing for inputs and outputs already inside the controller

• Are easily programmed and have an easily understood programming language that is primarily concerned with logic and switching operations.

The first PLC was developed in 1969. PLCs are now widely used and extend from small, self-contained units for use with perhaps 20 digital inputs/outputs to modular systems that can be used for large numbers of inputs/outputs, handle digital or analog inputs/outputs, and carry out proportional-integral-derivative control modes [3].

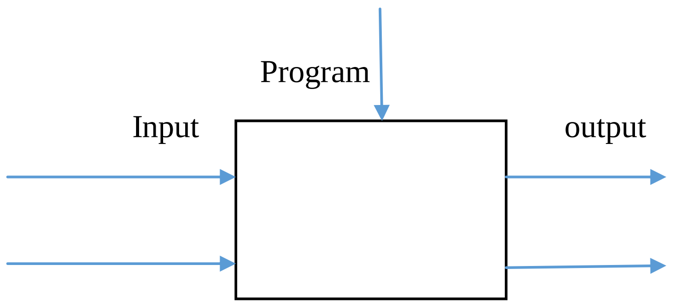

Fig. 2: Programmable Logic Controller.

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2.3. Hardware Development

Typically a PLC system has the basic functional components of processor unit, memory, power supply unit, input/output interface section, communications interface, and the programming device. Fig. 3 shows the basic arrangement.

• The processor unit or central processing unit (CPU) is the unit containing the Microprocessor. This unit interprets the input signals and carries out the control actions according to the program stored in its memory, communicating the decisions as action signals to the outputs.

• The power supply unit is needed to convert the mains AC voltage to the low DC voltage (5V) necessary for the processor and the circuits in the input and output interface modules.

• The programming device is used to enter the required program into the memory of the processor. The program is developed in the device and then transferred to the memory unit of the PLC.

• The memory unit is where the program containing the control actions to be exercised by the microprocessor is stored and where the data is stored from the input for processing and for the output.

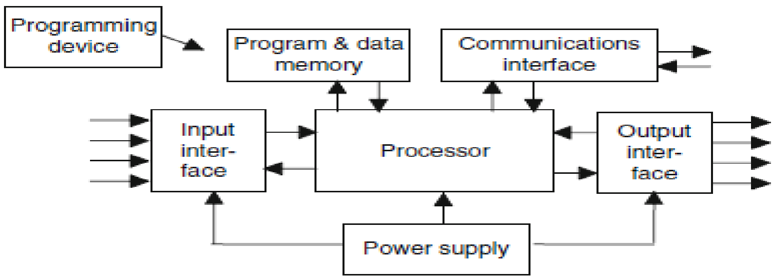

Fig. 3: The PLC System

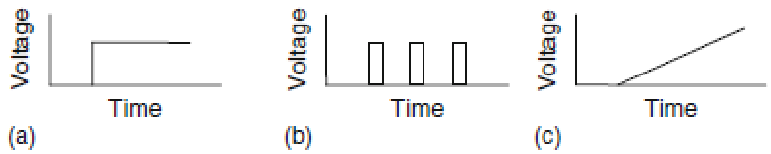

Fig. 3.1: Signals: (a) discrete, (b) digital, and (c) analog.

The input and output sections are where the processor receives information from external devices and communicates information to external devices. The inputs might thus be from switches, as illustrated in Fig. 3.1a with the automatic drill, or other sensors such as photoelectric cells, as in the counter mechanism in Fig. 3.1b, temperature sensors, flow sensors, or the like. The outputs might be to motor starter coils, solenoid valves, or similar things. Input and output devices can be classified as giving signals that are discrete, digital or analog.

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Devices giving discrete or digital signals are ones where the signals are either off or on. Thus a switch is a device giving a discrete signal, either no voltage or a voltage. Digital devices can be considered essentially as discrete devices that give a sequence of on/off signals. Fig. 3.1c analog devices give signals of which the size is proportional to the size of the Variable being monitored. For example, a temperature sensor may give a voltage Proportional to the temperature. The communications interface is used to receive and transmit data on communication networks from or to other remote PLCs. It is concerned with such actions as device verification, data acquisition, synchronization between user applications, and connection management [3].

2.4. Internal Architecture

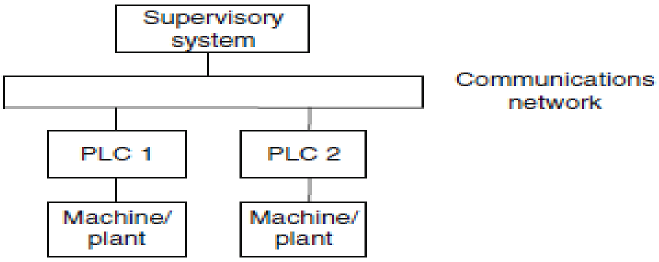

Fig. 3.2(a): Basic communication model.

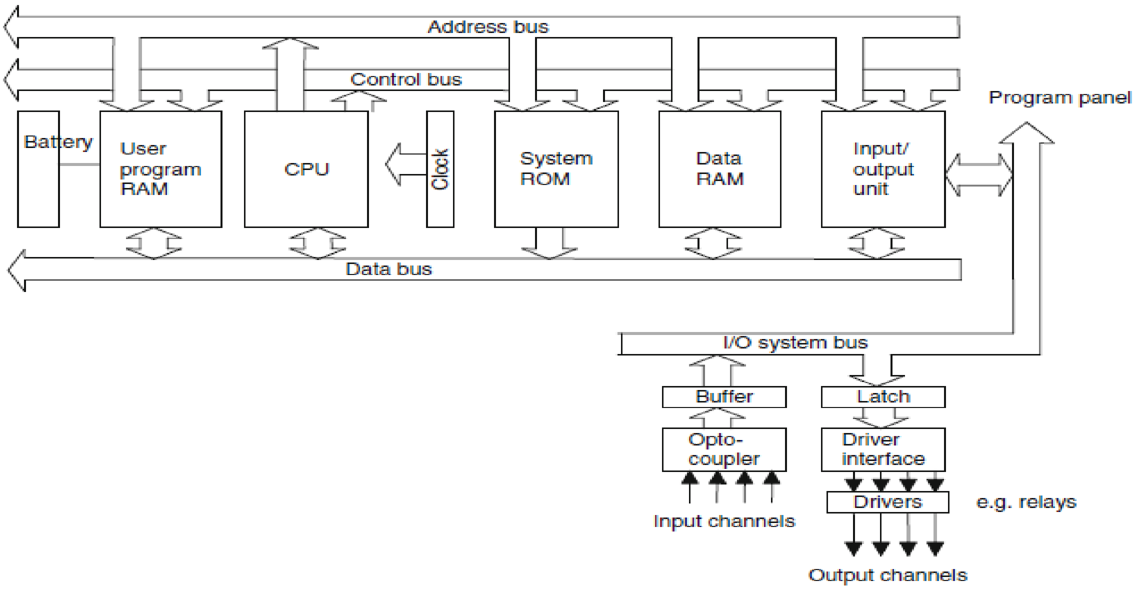

Fig. 3.2(b): Architecture of PLC.

Fig. 3.2(a) is the basic communication model and Fig. 3.2(b) shows internal architecture shows the basic internal architecture of a PLC. It consists of a central processing unit (CPU) containing the system microprocessor, memory, and input/output circuitry. The CPU controls and processes all the operations within the PLC. It is supplied with a clock that has a frequency of typically between 1 and 8MHz. This frequency determines the operating speed of the PLC and provides the timing and synchronization for all elements in the system.

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The information within the PLC is carried by means of digital signals. The internal paths along which digital signals flow are called buses. In the physical sense, a bus is just a number of conductors along which electrical signals can flow. It might be tracks on a printed circuit board or wires in a ribbon cable. The CPU uses the data bus for sending data between the constituent elements, the address bus to send the addresses of locations for accessing stored data, and the control bus for signals relating to internal control actions. The system bus is used for communications between the input/output ports and the input/output unit.

2.5. PLC Ladder Programming:

A very commonly used method of programming PLCs is based on the use of ladder diagrams. Writing a program is then equivalent to drawing a switching circuit. The ladder diagram consists of two vertical lines representing the power rails. Circuits are connected as horizontal lines, that is, the rungs of the ladder, between these two verticals. In drawing a ladder diagram, certain conventions are adopted:

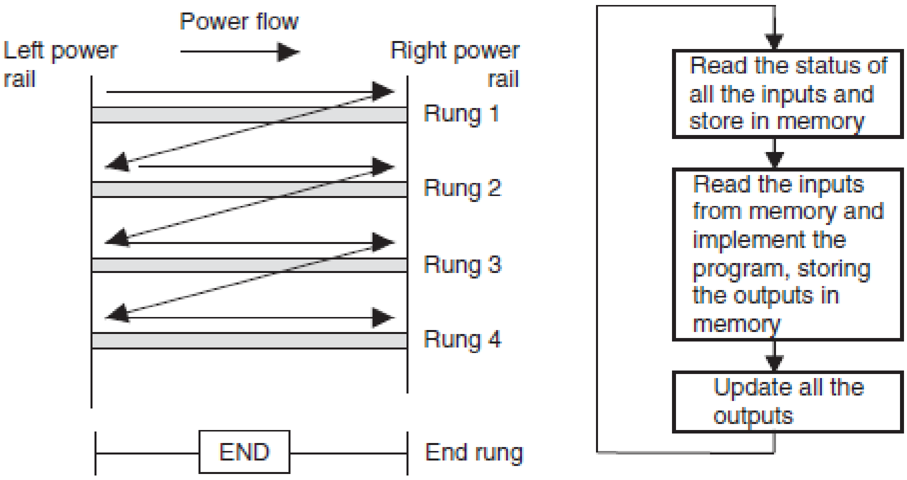

Fig. 4: Scanning the ladder program

The vertical lines of the diagram represent the power rails between which circuits are connected. The power flow is taken to be from the left-hand vertical across a rung.

• Each rung on the ladder defines one operation in the control process.

• A ladder diagram is read from left to right and from top to bottom. Fig. 4 shows the scanning motion employed by the PLC. The top rung is read from left to right. Then the second rung down is read from left to right and so on. When the PLC is in its run mode, it goes through the entire ladder program to the end, the end rung of the program being clearly denoted, and then promptly resumes at the start (Fig. 4). This procedure of going through all the rungs of the program is termed a cycle. The end rung might be indicated by a block with the word END or RET, for return, since the program promptly returns to its beginning. The scan time depends on the number of runs in the program, taking about 1ms per 1000 bytes of program and so typically ranging from about 10 ms up to 50ms.

• Each rung must start with an input or inputs and must end with at least one output. The term input is used for a control action, such as closing the contacts of a switch. The term output is used for a device connected to the

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output of a PLC, such as a motor. As the program is scanned, the outputs are not updated instantly, but the results stored in memory and all the outputs are updated simultaneously at the end of the program scan.

• Electrical devices are shown in their normal condition. Thus a switch that is normally open until some object closes it is shown as open on the ladder diagram. A switch that is normally closed is shown closed.

• A particular device can appear in more than one rung of a ladder. For example, we might have a relay that switches on one or more devices. The same letters and/or numbers are used to label the device in each situation.

• The inputs and outputs are all identified by their addresses; the notation used depends on the PLC manufacturer [3, 4].

III. LINE DIAGRAM OF THE PROPOSED WORK

Line diagram of hardware implementation in this work is as shown above in Fig. 5. MCB 1 is used for overall protection of hardware implemented, MCB 2 is for confirmation of availability of KEB supply, MCB 3 is for confirmation of availability of DG and MCB 4 is for confirmation of availability of co-gen supply. When MCB 1 gets supply then power is available at all MCB'S. The conformation of availability of KEB supply is done by switching on MCB 2. Similarly conformation of availability of DG supply and Co-gen supply is done by switching on MCB 3 and MCB 4 respectively. R1, R2 & R3 are the input relays and C1, C2 & C3 are the input contactors are used to know the availability of the supply. R4, R5 & R6 are the output relay coils and C4, C5 & C6 are the output contactors, which is operated according to the program implemented [5].

In order to fulfill the percentage load demand requirement we need to give DC voltage as input to the PLC but which is not available from the feedback, hence we are taking current as feedback from the load which is given to the I/V transducer of rating (0-5) / (0-10) V that means (0-5)A input transducer gives (0-10)V. This voltage is form input the PLC.

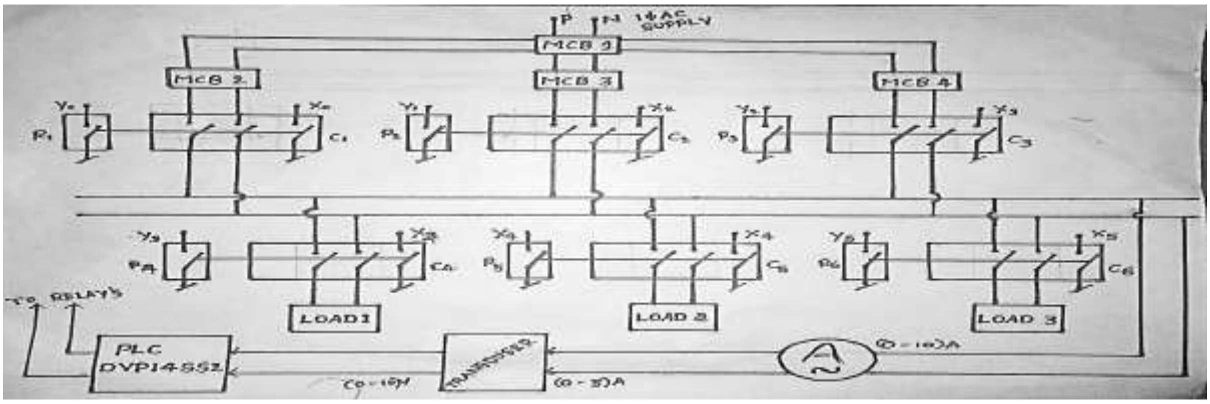

Fig. 5: Line diagram of proposed work

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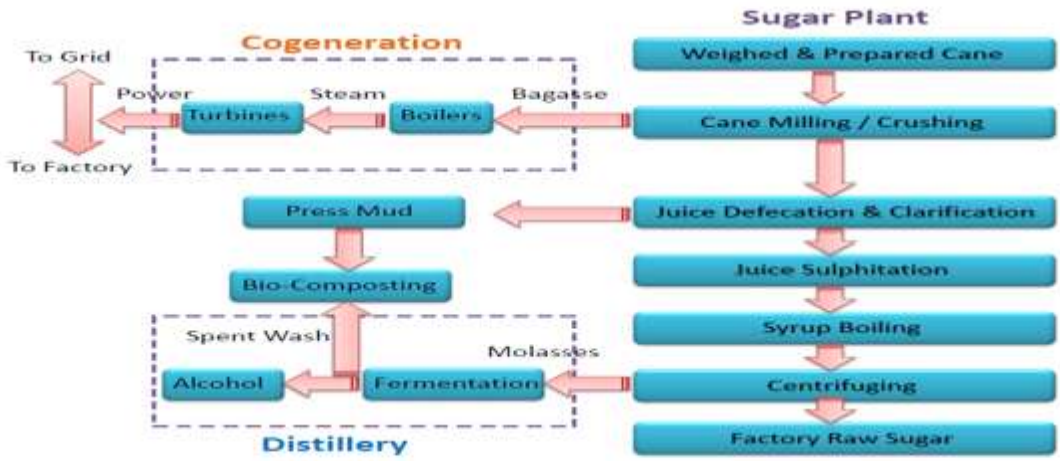
.1. Process Flow in Sugar Industry



The process flow in sugar industry is sown in Fig. 6.

Fig. 6: Process flow in sugar industry [4]

3.2. Load Prioritization in Sugar Industry

- High priority loads:

Sugar production: cane carrier, cane crusher, boiling house, syrup boiling, centrifuging, conveyors, cranes and hoists.

- Medium priority load:

1. Fuel- coal or bagasse, boilers, steam, turbine, power.
2. water- Demineralized water, boiler, turbine, condenser, power, recycle.

- Low priority load: Distillery unit, power required for advertise purpose.

IV. RESULTS AND DISCUSSION

4.1. Implementation of PLC based Demand Management

Case 1:

- When KEB supply is ON, all loads must be ON, i.e. load 1, load 2 and load 3 must be ON.
- When CO-GEN supply is ON, load 1 and load 2 must be ON.
- When DG supply is ON, only load1 must be ON.

When MCB 2 is on, power is available at contractor 1, we have programmed in such a way that when contractor 1 is on, which energies contractor 4, 5 and 6 which in turns switches on load 1, 2 and 3.

When MCB 3 is on, power is available at contractor 2, which energies contractor 4 and 5 then only load 1 and load 2 gets turn on.

When MCB 3 is on, only contractor 3 is energised then contractor 4 get energised so only load 1 gets turn on.

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Case 2:

The full load power is 1150 Watts.

- All loads (load 1, 2 and 3) must turn on when incoming power supply is more than 80%, i.e. 920Watts.
- When supply is greater than 60% and less than 80%

  Load 1 and 2 must be on.
- When power supply is less than 60% only load 1 should be on.

4.2. Ladder Diagram

To ensure the availability power supply from various sources ladder diagram is used. The ladder diagrams are as shown in Fig. 7 and 8, respectively.

It has been assumed that **Total Counts: 2000 = 5A = 10V.** The results of demand management in sugar industry for the different cases considered are given in **Table 1 and 2**, respectively.

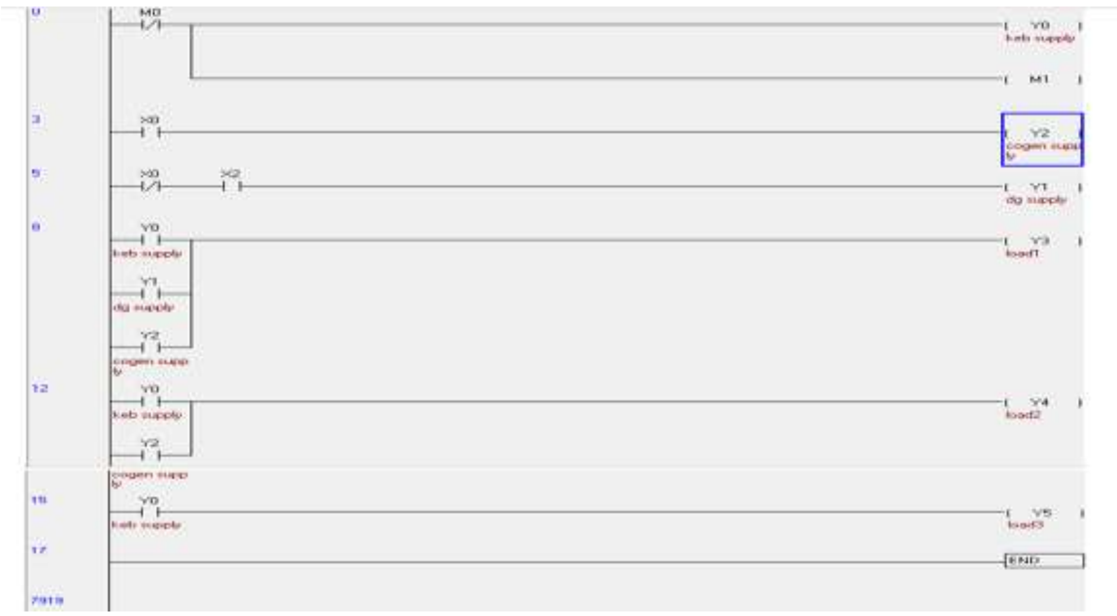

Fig. 7: Basic ladder program to check the availability of power supply

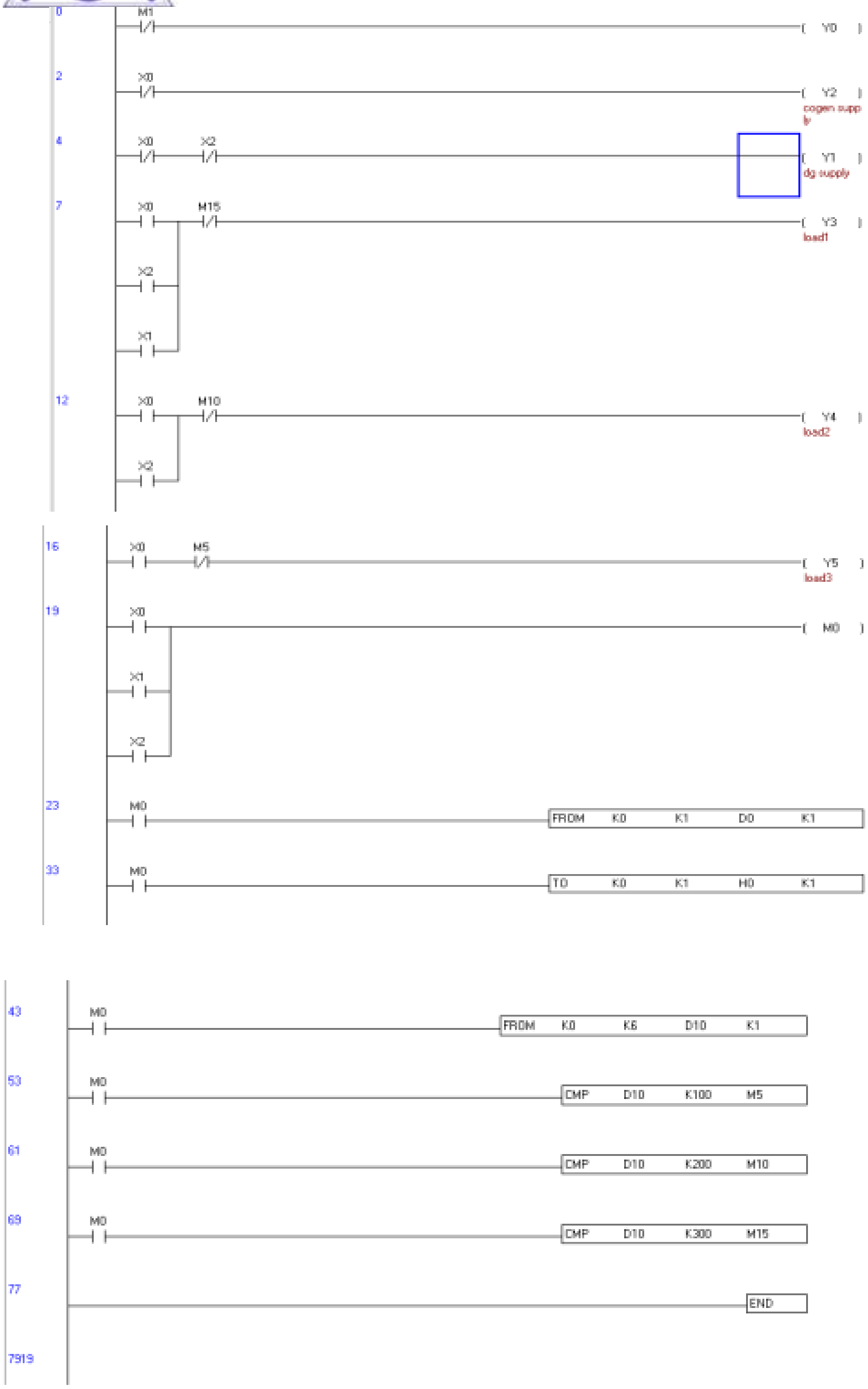

Fig. 8: Ladder diagram implementation based on percentage of power supply.

Table 1: TRAIL NO. 1

	Counts	Voltage(V)	Current(A)
When power supply is > 80%	1640	8.2V	4.1A
When power supply is >60% &<80%	1320	6.6V	3.3A
When power supply is < 60%	900	4.5V	2.2A

Table 2: TRAIL NO. 2

	Counts	Voltage(V)	Current(A)
When power supply is > 80%	1780	8.9V	4.45A
When power supply is >60% &<80%	1280	6.4V	3.2A
When power supply is < 60%	1100	5.5V	2.75A

V. CONCLUSION

For the validation of the developed hardware and software, the interfacing circuit has been tested under various operating conditions. This hardware and software developed has been coordinated very well to produce the desired output response. The result obtained from the developed system is matching with the input command specified. Advantages of this work are efficient use of power supply, better load management, high dynamic response, and long operating life. By incorporating additional equipment's such as Current Transformer, we can provide fault protection during overloading conditions to the system by isolating unhealthy section from healthy section. The presented work can be applied to any continuous process industry for implementing industrial load management by employing a load managing technique for electricity cost minimization.

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Biography

Dr. S. Gopiya Naik obtained the BE degree in Electrical and Electronics Engineering from MCE, Hassan, M.Tech in Power Systems from NIE, Mysore and Ph.D from IIT, Roorkee. He has got total 24 years of teaching experience and published many papers in the national and international journals of repute. At present he is working as an associate professor in the department of Electrical and Electronics Engineering at PESCE, Mandya, Karnataka. His research interest includes power distribution system planning, renewable energy systems and integration, micro grid.