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PLC Based Intelligent Storm Drain Cleaning System

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Abstract - *PLC (Programmable Logic Controller) is considered as the central or main controlling unit of any operations present in any application, process or industry with efficiency and productivity. This paper briefly explains the need for PLCs when compared to other controller logic such as RLC (Relay and Contactor Logic) and highlights the advantages of PLC which is used in our application. The PLC based system increases the operation process speed by using automation and reduced human intervention which increases the system efficiency and reliability. Also, PLC along with DCS (Distributed Control System) and SCADA (Supervisory Control and Data Acquisition), which are the new application specific tools used with PLC, helps to increase the accessibility, flexibility and ease of use in the process control system.*

Key Words: **PLC, RLC, SCADA, DCS, HMI**

1.INTRODUCTION

The Intelligent Storm Drain Cleaner is designed to use automation to replace manual work in storm drain cleaning, which is critical in all industrial applications. This system aims mainly at drain pipes which are used for disposing of rain water off of the surface road. Storm Drain Cleaning system is used to remove the building up of silt in the drains and it uses an automated system that collects solid wastes if present to clean and control the flooding of road and water levels of drain.

1.1 Why does the storm drain cleaner designed?

A PLC based system is developed to achieve the requirements such as, to clean the storm drain and collect any solid wastes present. Since PLC controllers are used to control high voltage switching applications, PLC was suitable for the rotation of PMDC motors and also to control the trolley for collecting the accumulated wastes. A dashboard is created to monitor the working of the system and the details such as distance travelled, waste collected and the battery duration for working of the entire system.

1.2 History

A storm water drain is used to drain the excess rainwater present on the surfaces such as roads, car parks, footpaths, parking lots and sidewalks. The size of the storm drain varies depending on the dry wells or the large municipal systems. Older storm drains used to have open systems which caused a lot of problems such as health hazards, mosquito breeding or other parasites and caused air or water borne diseases and infections with bad odour. The open drain system usually requires regular cleaning service to remove solid wastes. Hence a closed drainage system with pores is created with concrete slabs to avoid these problems and also avoid any solid wastes from entering the drain channel which reduces the maintenance cost compared to the open drain systems. The health risk compared to open drain is far better in a closed drain system and the maintenance is less compared to an open drainage system.

1.3 Why automation is required

Manual work includes large margin of human error, inefficiency in manual cleaning up of open drainages and is causing huge rework with an additional cost, time and effort during heavy rains & flash floods. Water logging caused by plastic and metal deposited along storm drainage pipes promotes the growth of pests and diseases such as typhoid and malaria. This is dangerous to human life, which is why the idea of automating manual labour, which is essential in all industrial applications, was born. Automation helps us achieve work with better efficiency, less cost and more importantly without affecting the health of humans.

Automation provides the benefit of predictability, visibility, scalability and control, which determines exactly how each process is getting executed every time. It is able to combine processes which includes reduction in the number of steps involved and reducing the complexity of the task. More importantly, automating manual work helps to keep the data more secure. Any important information won't be visible to any other users.

1.4 Drawbacks of present manual method

There is no proper way for accountability of work done by manual labour which causes ambiguity in the labour expenses, also it is unable to keep the amount of work done per day and the availability of workers due to high wage are the drawbacks of manual labour and present problems.

Inefficiency of manual cleaning of storm drains and it causes huge rework with additional cost, time and effort during heavy rains and flash floods in urban or metropolitan areas.

2. LITERATURE REVIEW ON PLC BASED INTELLIGENT STORM DRAIN CLEANER

Sheng Qiang, X.Z. Gao [1] The application of PLC used in control and monitoring of fuel alcohol production. They are used for collecting data as well as controlling the sequence strategies using PID auto tuning. A HMI (Human Machine Interface) with WinCC software is used to monitor the fuel generation process. The analog data collected from the PLC such as temperature, pressure, liquid levels and flow must be monitored and measured every two seconds.

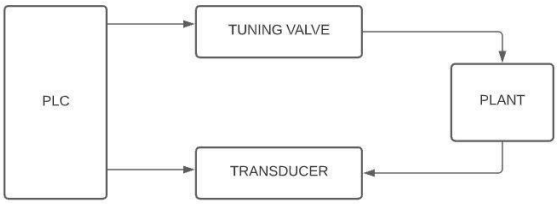

Figure 2.1 Process flow of monitoring and controlling of liquid level in the Plant

A transduction module converts the measured variable from the sensors into output voltage change which is in the range of 1-5V. This converted data from the module is sent to PLC for signal processing. Then this value is measured with a regulated level, which controls the tuning valve using either manual or auto mode to the desired levels. In this paper they have briefly explained about interfacing PLC with PID for motor direction and precision angle control and HMI to interface with the system, which helps us to incorporate it in our proposed work. The drawback of this system is that in auto mode the processing performance reduces since the sensor data has to be collected and processed every 2 seconds and doesn't allow other processes to be performed.

Maria G. Ioannides [2] The control and monitoring system for changing the induction motor's speed or RPM to the desired speed using a PLC controller. The PLC compares the desired speed with the actual measured speed, using a load current sensor with feedback and synchronizes the speed using a PWM rectifier and inverter for the 3-phase induction motor. It also consists of a thermal overload relay to shut down the motor if it is overheated. The induction motor is coupled to a DC generator with load R. The relay's output is connected to a voltage rectifier, which converts the three-phase voltage to DC and feeds it into an IGBT transistor-based inverter.

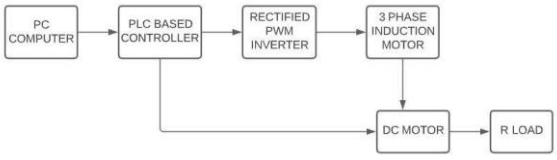

Figure 2.2 Induction Motor control system using PLC

The IGBT converts the normal DC to 3 phase voltage used to supply the stator of the induction motor. This paper helped us 6understand the concepts of how to correlate the operational variables to a desired speed and to adjust it accordingly. This helps us to increase the efficiency of the PLC control system. The drawbacks of this are in constant speed varying load operation at 1400 RPMs and load which is greater than 70%, the constant speed was not achieved.

Cosmina Illes, Gabriel Nicolae Popa and Ioan Filip [3] This paper discusses the design of a control system for water level monitoring, which is completely based on the PLC system which consists of converters, transceivers and an electrical motor to control the water pump. The dashboard consists of LEDs connected to PLC output which is used to indicate the water level. This system works by measuring the water level present in the tank. If the water is less than the minimum level the sensor detects and converts it to logic 1(1.2-2.6V) which is interrupted by PLC input.

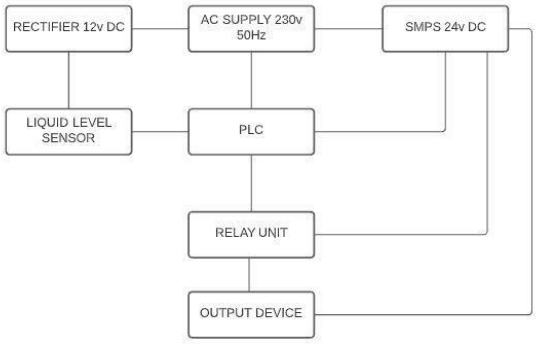

Figure 2.3 Water level control system

This is then displayed in the dashboard using the LED of minimum water level. When the water reaches the maximum level the sensor detects and converts it to logic 1 and it is sent to PLC. Another input of PLC is used to measure the proper working and speed of the motor used for the pump. A LED is used in the dashboard to indicate the proper functioning of the motor or if the motor has any fault. This paper helped us to interface wireless sensor nodes to PLC and how to control the actuator based on the signals from these sensors. The main disadvantage of this system is that the contactor used has reduced capacity for overloads and gets short circuited at full load operations.

Dong Yulin [4] They developed classical and robust PI controllers for PMDC motors. For Direct Current control of the system Siemens PLC is used and the system comprises two components, PLC based PI derived from PID controller which consists of both analog input and output module and the motor system. The system uses EM235 for including analog input and output pins which are not included in the PLC CPU of Siemens. During simulation the parameters of the PI controller for PMDC motor uses feedback motor control based on Internal Model Control (IMC) which is simulated in MATLAB/Simulink simulator.

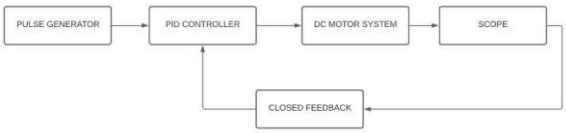

Figure. 2.4 PID based PMDC motor control

The PI controller method is difficult to use to control nonlinear systems because there is a lot of measurement noise and the torque on the motor shaft which has a big impact on the stability and control performance.

Ravi Mansad, Deepika Jadwani, Abhishek Sahu [5] DC motors are widely used because of fast performance and wide range of speed regulations. This is achieved by using PLC which reduces the size of the control panel, proper operations in worst cases and very low energy consumption. The speed of DC motors is regulated in this study using a PID controller and the powerful tool MATLAB/Simulink. A shaft encoder is used to monitor and transfer the DC motor speed to the PLC, where the (Proportional Integral Derivative) PID controller generates the control signals to achieve the desired speed.

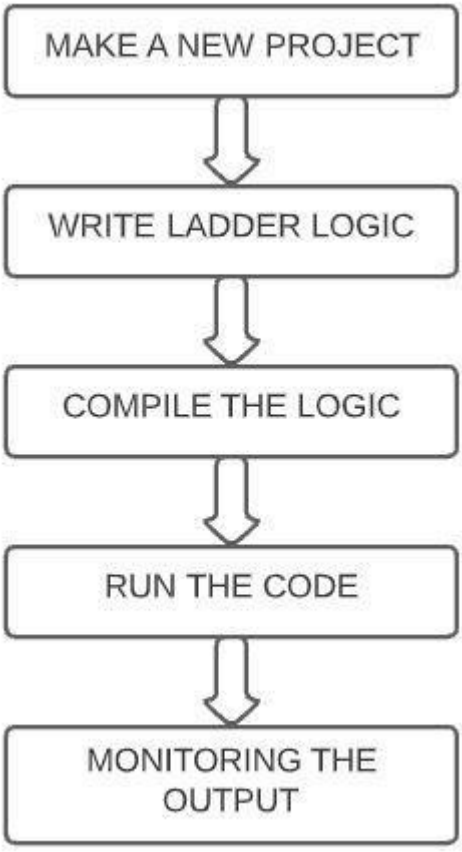

Figure 2.5 Process flow of PLC based speed control of DC motor

The analog signals are proportionally transmitted to the DC drive by the digital to analog module to maintain the required speed. The study's flaws include the fact that the temperature rise of the motor should be calculated using data such as load operation, motor efficiency, and thermal increasing coefficient to avoid DC motor operation at high temperatures, which causes velocity loss.

Parviz Amiri, Mahsa Bagheri, Shahid Rajaee [6] This paper discusses the various controller design methods for stabilization of DC motor speed. The third order system for measuring non linearities and stability considered by DC motors. This paper discusses three tuning methods for PID controllers. The first method is Adaptive Neuro-Fuzzy Inference System, second is Ziegler and Nichols and the third is Genetic Algorithm.

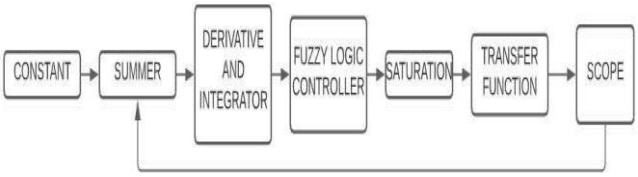

Figure 2.6 Process flow of AI based speed control of DC motor

This paper discusses more about Genetic Algorithm and its implementation. The Genetic Algorithm method is an efficient and effective technique to overcome problems based on optimization. Selection, Crossover, and Mutation are the three stages. This process is repeated for a number of iterations until the best solution to the problem is found. This paper uses the Genetic Algorithm method, which is much faster than the traditional method, we were able to reduce the settling time and increase the response time. The drawback of the proposed work is that if the system is more complex than the amount of time required to solve and optimize the problem it would take more time.

walaa M. Elsrogy, M. A. Fkirin, M.A. Moustafa [7] PID controllers have long dominated the way feedback control systems and industrial applications control process flow. Around 94% of all feedback loops are based on the PID controller, due to its capability to integrate windup and handle issues present in actuator saturation which is the major strength of PID controllers.

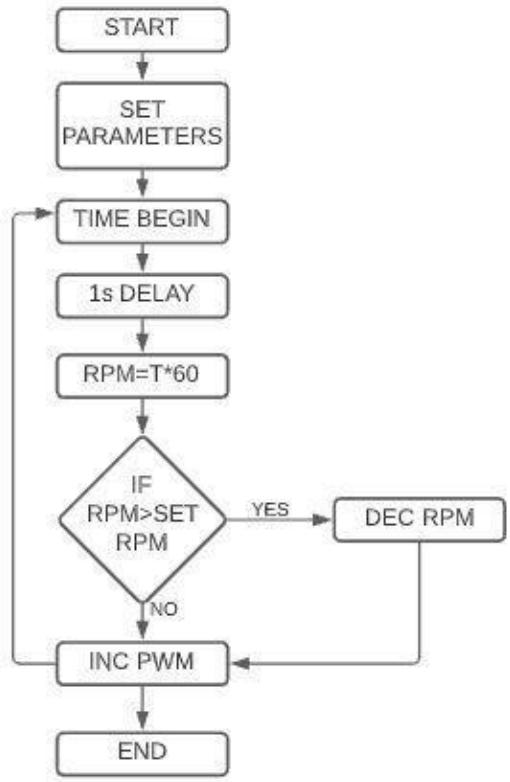

Figure 2.7 Process flow of speed control of DC motor using PIC controller

IR sensor is used to measure the speed of the PMDC motor, which is fed to the PLC to manipulate the process parameters to predetermined speed or RPM. The PWM technique is used to control the speed of the PIC microcontroller. To amplify the PIC controller output, the PMDC motor driver circuit uses a pre-amplifier circuit and a power transistor. The only disadvantage of this method is that when using a PMDC motor without feedback, the speed drops by 54% as the load increases, and the efficiency drops.

Upasana Sarma, P. K Bordoloi [8]The speed control motor uses a variable frequency based on PLC. This is one of the significant methods of three phase Asynchronous motors. A Variable Frequency Drive is a major tool used to convert high frequency AC into three phase AC, in which voltage and frequency are adjustable. The VFD is used for accurate speed control, reliable energy saving and easy to realize automatic control.

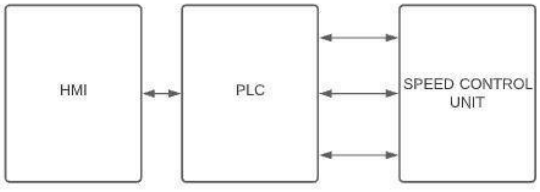

Figure 2.8 Variable Frequency Speed regulation of motor using PLC and HMI

Two speed stabilizing channels are used to control the PMDC motor, two photoelectric encoders and three motors which can be operated independently or in parallel. A smart measurement and control system method for the motor speed stabilizing by varying frequency. This makes the system more complex as per the design aspects and shaft currents induced by VFDs can lead to motor failures.

Xiaoming CUI, Bajin LI, zhiwei KOU, Yanjun QIAO [9] PLCs are used in Industrial Process Systems to improve the production rate of different products and services, overall time, price reduction and process optimization. The different parameters like reusability, flexibility, integrity and optimization are very important to adjust to a competitive market. The design for this is accomplished by XML or graphical technology. The graphical modelling tool helps us to interpret XML files from a programming tool or create a new project. The main drawback of this method is the redundancy in syntax of XML causes higher transportation costs and higher storage when the data volume is large. Another major drawback is currently there are only few tools that can import/export a project from an XML file which can be loaded directly, and thus it always makes use of API tools.

E. Estevez, M.Marcos, **N. Iriondo,D, Orive** [10]This paper discusses the software structure and PLC hardware which are required to build the SCADA (Supervisory Control and Data Acquisition) system of oil storage and transportation. SCADA systems supervise the different components running in the system and have functions like controlling equipment, collecting data from different devices, asking signals, detecting state and checking historical data. The system consists of a module of SRAM and two CPU modules of the same type which are configured by the system to send heat signals data of a dual CPU.

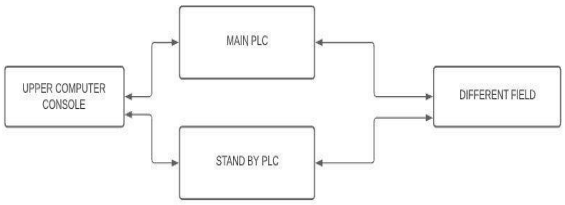

Figure 2.10 Monitoring of Oil storage and transportation using SCADA

The system consists of digital outputs and digital inputs which are used to collect parameters such as liquid level, flow, pressure, temperature and. The major drawbacks are the pipeline employed for petroleum transmission cannot perform switching ON and OFF reliably and also cannot monitor the behaviour of the external environments such as geothermal fields. So, to provide accurate and reliable test results it is required to build big in dimension and high automation.

LangFang and Li guohong [11] This paper discusses the efficient and lower cost method to mix asphalt, which is achieved using PLC and helps to boost its accuracy, efficiency and to lower the price. The system consists of an air compressor, ventilator, throttle to open the main circuit, blower, shaker, different belts to carry the asphalt and an elevator to carry out the process of mixing. If all the equipment is turned ON properly the PLC generates a signal to start the mixing process.

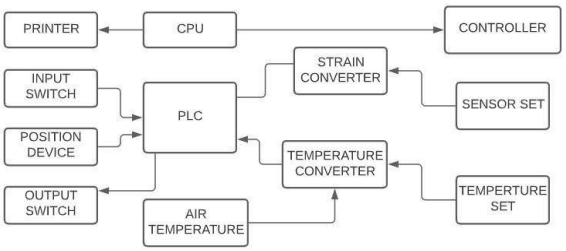

Figure 2.11 Process flow of Asphalt mixing

The computer is used to monitor the system and provides the user an interface with a working platform. The drawback of the system is if any of the equipment fails the entire system stops working.

Lianshe and Liu Baoguo [12] This study majorly emphasizes the importance for the PLC application in the elevator control system and renovating the old elevator system and technological upgrading PLC control systems are simple to program, reliable, strong at resisting interference and easy to maintain and hence it is more popularly used in elevator systems. The elevator system consists of two systems, an electrical control system for logic control and drive system for speed control. Using the input interface of the controller, the signal is passed to the controller which is PLC in this case and then this signal is processed by the PLC program present in the memory.

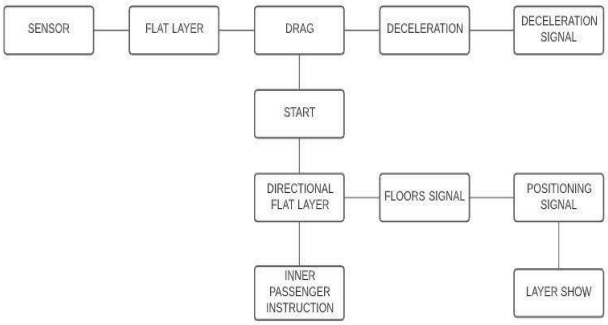

Figure 2.12 Elevator control system using PLC

With the help of the output interface, that is the drive system and the summon indicator the data is displayed and control signals are shown with automatic door switch, levelling and control dwell time. The drawback of the system is the cost of the PLC based elevator control system is relatively high compared to microcontroller-based systems. Since the work of using PLC in the elevator control system is in the initial stage, a lot more research and development is to be done.

Liu – Qiu [13] This paper examines smart/intelligent home technology that can assist a user in communicating via a GSM network using a mobile phone. The most crucial part of the automation process is the communication and interfaces between the cell phone and the controller. This methodology is implemented with the help of a PLC that is connected to a mobile phone. Between the user's cell phone and the PLC network, the GSM network provides a full duplex communication link. The PLC uses RS232 or Bluetooth to interface it to the GSM network and cell phone. When the PLC is connected to the GSM network, an SMS confirmation is sent.
The received commands are then processed, and the command is physically executed using digital input/output or digital to analogue converters, as well as adaptation circuits like relays, power amplifiers, and switches. After this the system is set to a waiting state until another command is received from the far end cell phone. Since GSM is an old technology the network speed and coverage is slow compared to recently evolved technologies like IoT and cloud computing and when the network is unavailable the system commands won't be processed properly. Since they are using GSM, multiple users share the same bandwidth. If users using the same bandwidth increases, transmission can encounter interference.

A. Alheraish, W. Alomar and M. Abu- AL- Ela [14] The main objective of the paper is to introduce Object Oriented Programming (OOP) concepts in industrial automation using PLC, features like encapsulation in Functional Blocks. The paper also discusses new modular and multilevel design to make PLC programs more flexible to get the advantages of OOPs like inheritance. In the physical model they have used relay-like components which have the same properties and perform the same functions in recent electrical cabinets.
The methodology is simple, a position sensor and two digital switches are connected to PLC, start and stop of axis movement can be achieved by using digital signals and analog signals are used to indicate the position of the axis. It has four output digital pins to start the movement and to indicate the forward and reverse direction. This paper helps us how one can make use of OOPs concepts in industrial automation to make processes more efficient and reliable.

Manuel Pineda Sanchez, Marina Perez Vazquez [15] This paper focuses on different approaches by utilizing redundant data along different sensors which enables fault detection and dynamic reconfiguration of a manufacturing unit while its operation. If there are any faults or failures in production, automation the control system appropriately reacts by turning down the system for debugging or maintenance or by bringing the device to a normal or stable state. This methodology uses a directed graph to represent the redundancy model of the automation system.

In the proposed redundancy model, every labelled node of directed graph represents a point to be measured and is associated with a real sensor or a soft sensor as a source. Each labelled node represents the quality value or the accuracy of the collected and measured value. The edges of the graph give analytical dependencies between nodes used to calculate sensor values during run time. The path or direction of an edge represents data or values and calculates a sensor which is retrieved.

Daniel Schutz, Andreas Wannagat [16] This paper reports the practical application of PLC and SCADA for controlling real time intelligent traffic lights, correspondingly a traffic junction was created with an intelligent traffic light control system. This uses monitors, dashboards, sensors and co-ordinates the operation of the entire system. This system works by detecting the changes in (Pyroelectric Infrared Radial) PIR sensor radiation spectrum i.e., change in temperature to detect motion.

If there is only one pedestrian present to cross the road and the red light is ON, the period of the red or stop light is reduced and when the green or go light is ON while a pedestrian is present the time of the green or go light is reduced. So due to this, the drawback of the system is that during the arrival of a pedestrian after half of the threshold time of the traffic light, the sensor will not be activated and the light will be ON till its entire duration, so the pedestrian will have to wait for a longer duration to cross the road.

Amel Toromon, Edin Mujcic [17] In this paper a fully automated test and development environment with electrical signals and pneumatic signals with gas or liquid is used for shaping different materials was proposed and designed. This proposed system consists of servo motor, Arduino, pneumatic controls and PLC-SCADA controller. The proposed work indicates a prototype for an electro and pneumatic based system for controlling valves, which consists of two cylinders where first is used to clamp the piece coming from the conveyer. This process is monitored and checked by the proximity sensor which is used for cutting using a PMDC motor.

Servo motors are precisely used to control the dimension of the product for cutting. The overall length of the product can be adjusted using the code of the Arduino. The drawbacks of this system is that the precise cutting of metal cannot be achieved as the resolution increases, since there are more efficient ways to get the job done, like laser cutting and it uses relay logic control, which requires more power and it cannot be switched ON and OFF rapidly.

Fahad Durrani, Muhammad Riaz, Muhammad Hamza Ahmad [18] This paper provides a method to control the stepper motor using any type of SEMs which is based on PLC. Using PLC, we can reduce the usage of electronic devices used in the drive circuit which results in minimising the cost and increasing the reliability of the system. This system uses Asynchronous Pulse Generator (APG) units to generate required pulses for phase of Stepper motor in each direction.

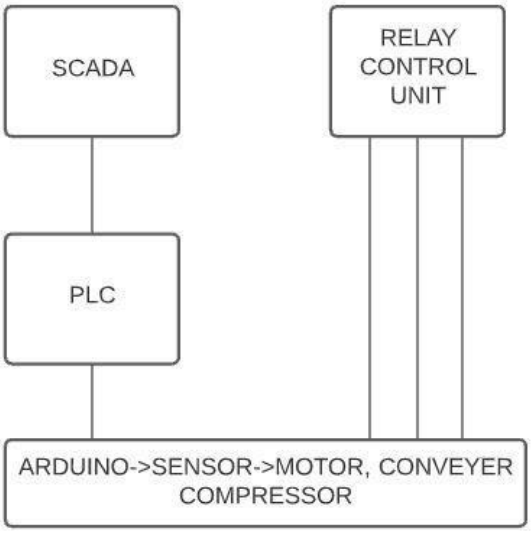

Figure 2.18 Multiple stepper motor excitation method

The speed of the motor can be adjusted by controlling pulse shape generated by APG. It also describes the different modes of excitation of stepper motors based on the winding such as Wave SEM, Full SEM and Half SEM. The drawback of the system is that at higher speeds the stepper motor becomes less stable and movement is less soft. So, the motor should be operated below the stable speed.

Omar Talal Mahmood and Noha abed-Al - Bary Al – Jawady [19] This paper briefly discusses present and past technologies of PLCs and explores its capabilities for different processes. The objective of the paper includes safety of operators, increased productivity and efficiency, integration of manufacturing process and reduced labour cost. The present PLC automation has evolved from different types of controllers such as Programmable Logic Controller (PLC) based on energizing contactors, RLC which is more power consuming, Supervisory Control and Data Acquisition (SCADA) and Distributed Control System (DCS). The RLC cost is low, bulky in size, operating speed is also slow and electrical noise and immunity is excellent. In PLC the cost is low, size is very small, electrical immunity and noise is good and operating speed is comparatively fast. But in SCADA the cost is high, overall size is compact, operating speed is very fast and electrical noise and immunity is good. So, based on the requirement of these parameters the appropriate controller can be selected.

Mallikarjun Hudedmani [20] This paper discusses the design of PLC based smart micro grid controllers to different challenges like power re-establishment to equipment and devices within a few minutes as soon as power outage of Distributed Energy Resources (DERs) occurs. The main

factor of this paper is to design a PLC based System Management Controller which helps to operate and control different power sources for switch and smooth load management, during normal or complete blackout scenarios.

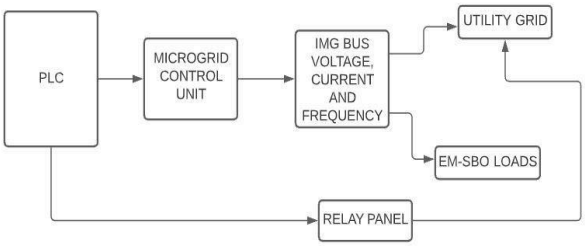

Figure 2.20 Power restoration using PLC during blackout

The proposed PLC module is designed for EDG applications used to handle multiple renewable energy based distributed systems to resolve complete blackout. It helps in reducing the power interruption time and the operation of restoring the power is faster compared to conventional methods. The disadvantage of the proposed model is that in case of blackout of the entire grid, classes 3 or 4 power supplies are not accessible. Rarely the power supply trips because of transient overloading, which causes power failures of the grid during blackout. During the use of a microcontroller unit, when it is directly connected to the local controllers, operations such as checking necessary parameters for fault detection, automatic synchronization, sequential load restarting and start of micro resources function are not possible.

Getachew Alemayehu and Ramesh Babu Nallamothu [21] Since the need for automation is increasing rapidly a PLC control system has to be designed to have flexibility, robustness, reliability, easy programming and cost effectiveness. This paper discusses applications of PLC based on automation in the current market such as engineering studies, monitoring of plants, energy research and industrial control applications. In PLC the term logic is used to indicate the implementation of switching operation and the logic of the design.

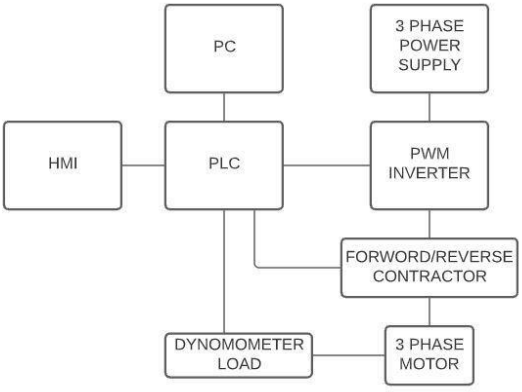

Figure 2.21 High power peripherals control using PLC

PLCs are used to replace the relay logic due to its simplicity and cost reduction. This paper helped us to choose the PLC controller for high power applications and the basics of PLC and its Ladder Logic for programming it. The drawback of the study is Personal computers are growing significantly, are inexpensive and are more capable of computing complex problems. Personal computers of the new generation with new features are available every quarter but development in PLC is not that fast. Even PCs are offering Terabyte memories but PLCs are Still living in MB and/or KB.

3. CONCLUSION

PLCs were first introduced in the early 70's and have been a major requirement and compulsory part in the role of controller for automation systems in almost all industries. They are fully adaptable to any industrial application, any research, monitoring application and control of advanced systems. They are also compatible with many other controllers such as microcontrollers, PIDs, PLA and PALs and coordinate with them to work accordingly which makes the production activity more efficient and profitable with PLC. The use of PLC in industrial automation definitely helps us to achieve greater performance and profit in the work. The setup time and the duration for complex operations can be greatly decreased by using the PLC based controller setup. The SCADA, Communication Systems and DCS integrate control, real time monitoring, analysis and protection, which increases the benefits of improved customer satisfaction and system performance. Programming in ladder logic using PLC is much beneficial and easy to interpret to users when compared to other types of programming language since even any person with any or no knowledge of programming is able to program and understand a system which is PLC based. Hence, we can conclude that PLCs can be applicable to any system either simple or advanced and will be used as a main controller in almost any field of research and development.

REFERENCES

1. Sheng Qiang, X. Z. Gao and Xianyi Zhuang, "PLC-based control systems for industrial production of fuel alcohol," 2002 IEEE International Conference on Industrial Technology, 2002. IEEE ICIT '02., 2002, pp. 827-832 vol.2, doi: 10.1109/ICIT.2002.1189274.
2. M. G. Ioannides, "Design and implementation of PLC-based monitoring control system for induction motor," in IEEE Transactions on Energy Conversion, vol. 19, no. 3, pp. 469-476, Sept. 2004, doi: 10.1109/TEC.2003.822303.
3. C. Illes, G. N. Popa and I. Filip, "Water level control system using PLC and wireless sensors," 2013 IEEE 9th International Conference on Computational Cybernetics (ICCC), 2013, pp. 195-199, doi: 10.1109/ICCCyb.2013.6617587.

4. Dong Yulin, "The analysis and implement of PLC-based PI control for the permanent magnet DC motor," 2010 Second International Conference on Communication Systems, Networks and Applications, 2010, pp. 448-451, doi: 10.1109/ICCSNA.2010.5588973.
5. Parviz Amiri , Mahsa Bagheri , "Speed Control of DC Motor by Programmable Logic Control with High Accuracy," Universal Journal of Control and Automation, Vol. 1, No. 4, pp. 91 - 97, 2013. DOI: 10.13189/ujca.2013.010401.
6. W. M. Elsrogy, M.A. Fkirin and M.A.M. Hassan, "Speed control of DC motor using PID controller based on artificial intelligence techniques," 2013 International Conference on Control, Decision and Information Technologies (CoDIT), 2013, pp. 196-201, doi: 10.1109/CoDIT.2013.6689543.
7. U. Sarma and P. K. Bordoloi, "Speed Control of A DC Motor Using PLC and PIC Microcontroller," 2017 14th IEEE India Council International Conference (INDICON), 2017, pp. 1-6, doi: 10.1109/INDICON.2017.8488046.
8. X. CUI, B. LI, Z. KOU and Y. QIAO, "Measurement and control system for variable-frequency speed regulating of motor based on PLC and HMI," 2019 IEEE 8th Joint International Information Technology and Artificial Intelligence Conference (ITAIC), 2019, pp. 1169-1173, doi: 10.1109/ITAIC.2019.8785791.
9. E. Estevez, M. Marcos, N. Iriondo and D. Orive, "Graphical Modeling of PLC-based Industrial Control Applications," 2007 American Control Conference, 2007, pp. 220-225, doi: 10.1109/ACC.2007.4282404.
10. Wang Xibin, Li Guohong and Wei Xuejie, "PLC-based SCADA system for oil storage and application," 2011 International Conference on Electric Information and Control Engineering, 2011, pp. 1539-1541, doi: 10.1109/ICEICE.2011.5777205.
11. L. Luo and B. Liu, "Research on PLC-Based Control System for Mixing," 2010 International Conference on E-Product E-Service and E-Entertainment, 2010, pp. 1-3, doi: 10.1109/ICEEE.2010.5661377.
12. L. Yong-Qiu, "Research on the PLC Technology Solutions in Four-Story Elevator Control and Renovation," 2015 8th International Conference on Intelligent Computation Technology and Automation (ICICTA), 2015, pp. 780-783, doi: 10.1109/ICICTA.2015.198.
13. A. Alheraish, W. Alomar and M. Abu-Al-Ela, "Programmable Logic Controller System for Controlling and Monitoring Home Application Using Mobile Network," 2006 IEEE Instrumentation and Measurement Technology Conference Proceedings, 2006, pp. 469-472, doi: 10.1109/IMTC.2006.328543.
14. M. Pineda-Sanchez et al., "Programmable Logic Controllers (PLC) in the packaging industry: An object-oriented approach for developing control programs," 2014 9th International Microsystems, Packaging, Assembly and Circuits Technology Conference (IMPACT), 2014, pp. 386-389, doi: 10.1109/IMPACT.2014.7048381.
15. D. Schütz, A. Wannagat, C. Legat and B. Vogel-Heuser, "Development of PLC-Based Software for Increasing the Dependability of Production Automation Systems," in IEEE Transactions on Industrial Informatics, vol. 9, no. 4, pp. 2397-2406, Nov. 2013, doi: 10.1109/TII.2012.2229285.
16. A. Toroman and E. Mujčić, "Application of industrial PLC for controlling intelligent traffic lights," 2017 25th Telecommunication Forum (TELFOR), 2017, pp. 1-4, doi: 10.1109/TELFOR.2017.8249411.
17. F. Durrani, M. Riaz, M. H. Ahmad, S. Durrani and H. Ali, "SCADA & PLC based fully automated pneumatic cutting machine: A test bench for industry and laboratory," 2018 International Conference on Engineering and Emerging Technologies (ICEET), 2018, pp. 1-6, doi: 10.1109/ICEET1.2018.8338634.
18. A. M. T. I. Alnaib, O. T. M. Altaee and N. A. Al-jawady, "PLC Controlled Multiple Stepper Motors Using Various Excitation Methods," 2018 International Conference on Engineering Technology and their Applications (IICETA), 2018, pp. 54-59, doi: 10.1109/IICETA.2018.8458097.
19. Hudedmani, Mallikarjun & Umayal, R & Kabberalli, Shiva & Hittalamani, Raghavendra. (2017). Programmable Logic Controller (PLC) in Automation. Advanced Journal of Graduate Research. 2. 37-45. 10.21467/ajgr.2.1.37-45. Alemayehu, Getachew & Nallamothu, Ramesh Babu. (2017). Programmable logic controller (PLC) application for hybrid electric vehicle (hev) simulator. International Journal of Mechanical Engineering and Technology. 8. 281-292.
20. Subhakanta Khatua, V. Mukherjee, Application of PLC based smart microgrid controller for sequential load restoration during station blackout of nuclear power plants, Annals of Nuclear Energy, Volume 151, 2021, 107899, ISSN 0306-4549, https://doi.org/10.1016/j.anucene.2020.107899.
21. Ephrem Ryan Alphonsus, Mohammad Omar Abdullah, A review on the applications of programmable logic controllers (PLCs), Renewable and Sustainable Energy Reviews, Volume 60, 2016, Pages 1185-1205, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2016.01.025.