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Application of Delta PLC on Battery Management System in AC/DC Microgrid

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ABSTRACT- To keep the energy balance and power quality in check, a proper controller must be made for all the parts of the microgrid to work together. The sizing of the microgrid is done by considering the distributed generators and their connected ACDC loads. The performance of DC will obtain according to the state of charge condition of the battery bank. So it is essential to operate the battery bank by observing the state of the charge condition. To maintain the voltage stability of the system the PLC (programmable logic controller) best switching controller is designed to operate the battery bank according to the distributed generators' demand. The main objective of the present work is to enhance the power conversion efficiency and maintain voltage stability during essential conditions which are fulfilled by the Battery storage and its controller. It must provide effective voltage support in a fault condition.

Keywords: Battery Bank, PLC, PV, Wind Farm

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1. INTRODUCTION

The establishment of inexhaustible sources (built microgrids) can be a feasible solution in many places to reduce power demand on utility grids. However, electrical power generation from a single renewable energy source cannot provide reliable power to the system due to the random changes in the availability of sources [1- 3]. Unfortunately, batteries require high maintenance and have a short life span (they need to be replaced repeatedly), which can lead to high operational costs in the long term. To overcome these issues, the electrolyzer and Fuel Cell (FC) set are considered to operate for a long time in the system, whereas the small-size batteries can maintain power balance during transient changes [4-8]. To keep the energy balance and power quality in check, though, a proper controller needs to be made for all the parts of the microgrid to work together [9-11]. This will be tuned at a particular instant or change of conditions; hence, the same gains cannot work properly for all conditions, especially in the microgrid where renewable energy sources, electrolyzers, fuel cells, batteries, and rapid changes in load are considered. The usage of batteries in autonomous PV, a wind-based hybrid system, is presented by the authors in [12], but the system is a DC microgrid and does not include an electrolyzer or fuel cell. A robust control strategy for a PV and wind-based hybrid islanding microgrid has been developed by authors in [13]. However, the authors have not included an electrolyzer, fuel cell, or energy management system. In [14], the authors talk about hybrid PV and wind power generation systems that work with the grid.

The isolated condition of microgrids can be a feasible solution in many places to reduce power demand on utility grids. However, electrical power generation from a single renewable energy source can't provide reliable power to the system due to the random changes in the availability of sources. Hence, two or more renewable energy sources need to be integrated to make the system more reliable. Apart from many generators, the permanent magnet synchronous generator B MSG is the most suitable for medium-sized applications to generate power from wind turbines. It seems it is directly coupled [15,18]. The primary use of an energy storage device is to maintain a continuous supply due to rapid changes in both solar irradiance and wind velocity. Therefore, many places integrate a battery into PV and wind-powered generation systems. Unfortunately, batteries require high maintenance and, because of their short lifespan, need to be replaced repeatedly, which can lead to a high operational cost over the long term. To overcome this issue, filters, an electrolyzer, and a fuel cell are considered to operate for a long time in the system, and a small battery can maintain a power balance during transient changes [20-23]. The power quality improvement is done with the increase in the penetration of wind energy in the microgrid, which gives effective voltage support during the fault condition however, to maintain proper energy balance and power quality, proper coordination control among all the components in the microgrid needs to be designed.

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In the manufacturing unit, there are more people who are working as operator engineers and so a number of the equipment is for better performance. it has been noticed that the execution time is showing a delay to get the desired output if the process is automated, a timer circuit is needed and fed to the controller. This vital role is done by the programmable logic controller.

There are various types of PLC manufactured for the automation process. The present controller is Delta PLC for tripping the battery banks in different loading conditions [23-25].

2. METHOD

At one time, the automatic system was controlled with relays. The relays are electromechanical devices and fail quickly as the mechanical parts were out and the electrical parts are destroyed. The electricity switch may burn away the contacts. In modern-day control terms, even so, a control system implementation in the relay was a big, complicated affair. So, it is essential to draw a logic control for making the system automated for safety reasons. The programmable logic controller (PLC) is an advanced technique to monitor and fast-acting programmes for the execution of the proposed Battery management system.

2.1 Programmable logic controller (PLC)

It is a computer control system which continuously monitors the state of input devices. It makes the decision depending on the customer program to control the output condition of the device.

The present work is based on the application of delta PLC which has eight inputs and six outputs. The input power source for the delta PLC is 24 Volt. The ladder diagram consists of two vertical lines called power rails and the circuits are connected in a horizontal line. In the latter programming, read can be done from left to right and from top to bottom.

2.2 Specification

MPU Points:14(8DI+6DO)
Max I/O points: 494(14+480)
The input and outputs are all identified by their address.

2.3 Coulomb Counting Method (CCM)

The state of charge is a crucial stage for battery management system. This coulomb counting method tracks its flow of charge from one battery bank to other during load demand.

SOC= (Capacity – Accumulated Discharge)/Capacity.

This state of charge ensures its proper operation and control of the battery bank system. The unit shall have powdered with external power supply 110Vdc to the dc grid. A contactor will be used to disconnect the Battery bank from the dc grid and connect to another bank. If there are overcharged, the contactor will turn off.

$$SOC\ (t) = \frac{Remaining\ Capacity}{Nominal\ Capacity} \tag{1}$$

Coulomb counting method is one of the best methods for estimation of charging condition of Battery. It is popularly known as Ampere –Hour counting method.

$$SOC\ (t) = SOC(0) \pm \frac{1}{C_n}\int_0^t i_b(r)dr \tag{2}$$

In this method, the SOC(t) of the battery can be manipulated by *equation (2)*. Where first term represents initial condition of SOC and the second term on the right side presents the variation of battery SOC over time.

$r \in [0,t], i_b(r)$ is current drawn from and/or supplied to the battery bank.
+ve sign indicates the charging mode.
–ve sign indicates the discharging mode.

$$SOC\ (k+1) = SOC(k) \pm \frac{I_b(k)\ X\ \Delta t}{C_n} \tag{3}$$

In order to implement this method in to delta PLC, it is essential to discretize *equation (2)*, by assuming $I_b(k)$ (Battery current) as function of Δt(Sampling time step).

The SOC estimation of battery by using PLC is described by *equation (3)* in both charging and discharging mode of operation.

3. BATTERY MONITORING SYSTEM

It will continuously monitor the two groups of battery banks which indicate the battery bank stayed up charges within a period of time. It displays the parameter such as voltage current consumed and pure hours and remaining hours. This system is capable to communicate the same information as the power management system.

The switching action of the battery bank is done by the controller's design of the Programmable logic controller which is automatically operated according to the load demand. In the programmed table, the left side is noted as the input source battery bank and the right-hand side is the connected load. The contactor plays a main role in opening and closing the interconnected link between the battery bank and the loads. Which is shown in *figure 1* and *figure 2*.

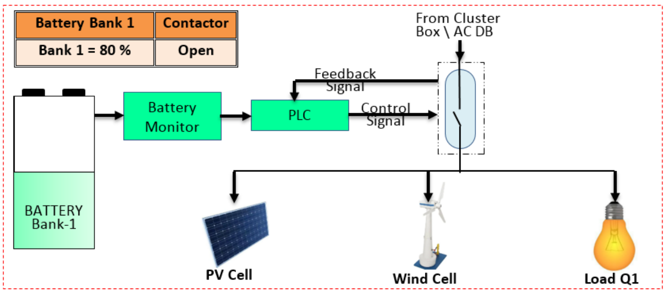

Figure 1: Schematic diagram of distributed generators with Battery Bank 1

There are six different types of loads connected to the Battery. When there is a deficit of Energy from the Distributed

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Generator, these two Battery banks compensate for the power by using a Programmable logic controller. The main objective of the proposed work is to operate the microgrid automatically depending on the load demand.

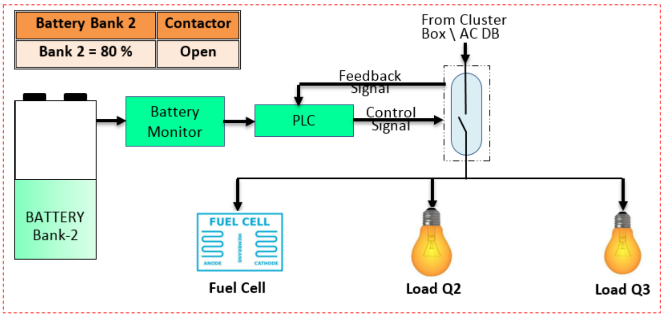


Figure 2: Schematic diagram of distributed generators with Battery Bank 2

The state of charge of battery banks will be monitored by the battery monitor when the battery SOC is less than 20%, this condition will be sensed by the PLC through the battery monitor. It sends the signal to the contactor to open and show that the connected generators and loads will be switched up until the next generators will be on. When the battery bank charge above 80% of SoC, the PLC will send a control signal to the contractor and the connected loads will be powered. The same condition is applied in battery bank two. The switching on and off of battery banks is done by using the PWM technique for charging the battery. This condition is implemented when there is a deficiency of power supply from a particular distributor generator to fulfil the low demand.

3.1 Flow Chart of PLC-Based Battery Management system:

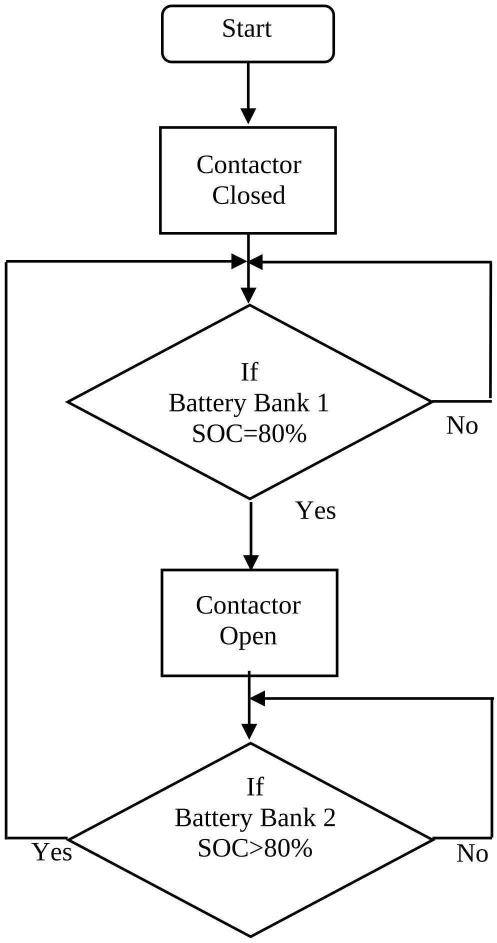
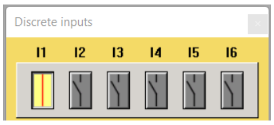
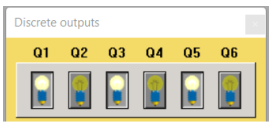
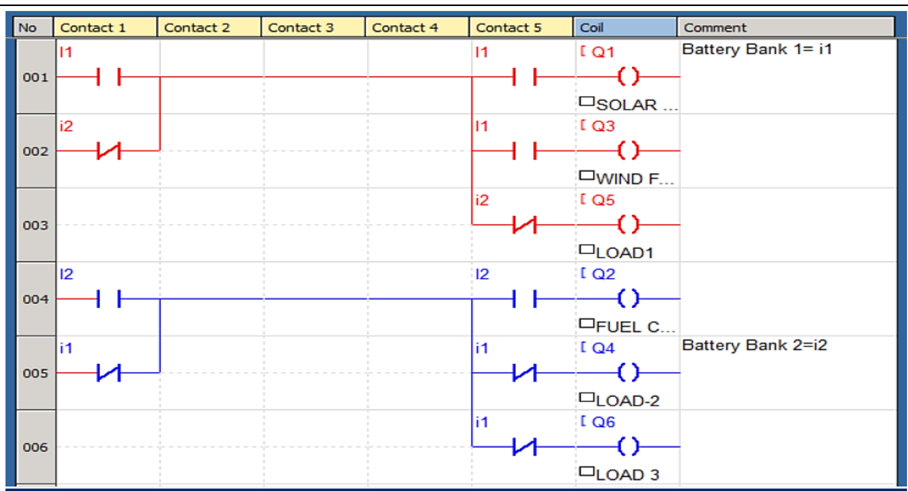


Table 1. Ladder Programme for Battery Management system with various loading condition

Condition	Input / Output	Lader
1	 Battery bank 1 is ON  Load 1, Load 3, Load 5 will operate	

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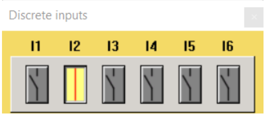
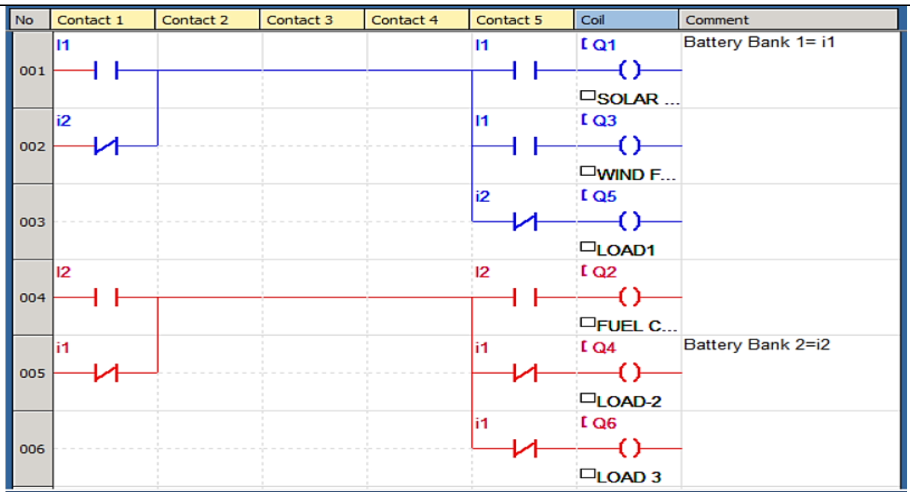
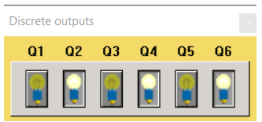
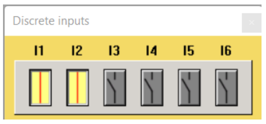
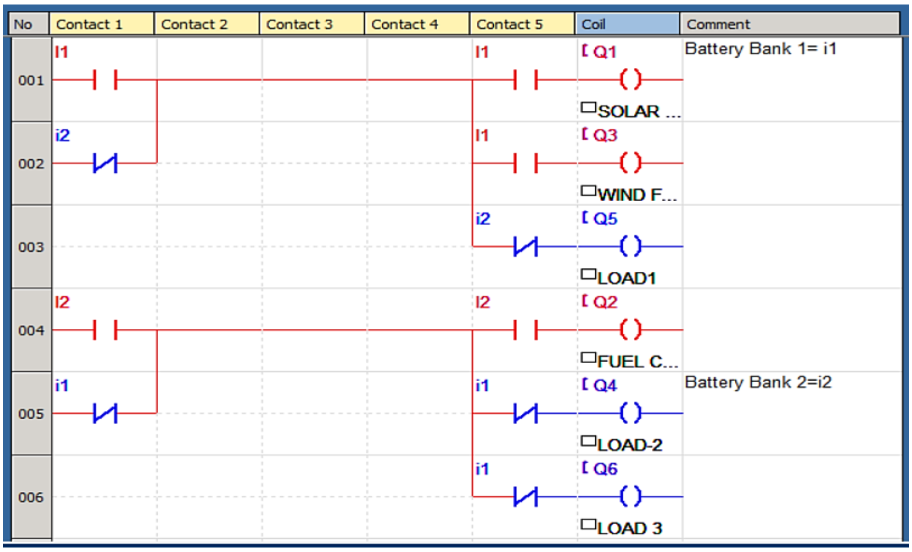
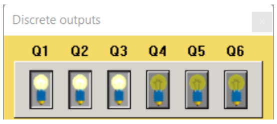
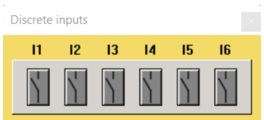
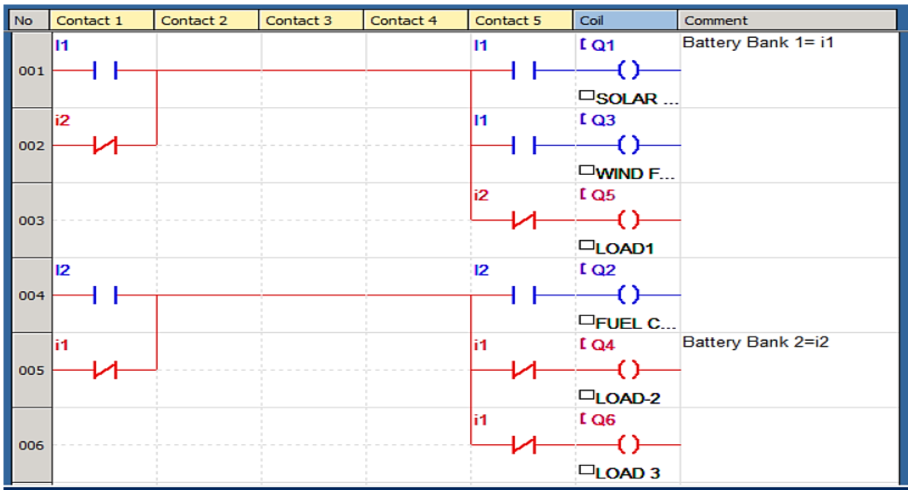
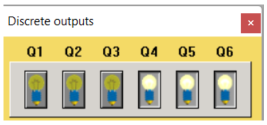
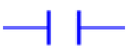
<table>
<tr><td rowspan="2">2</td><td>
Battery bank 2 is ON</td><td rowspan="2"></td></tr>
<tr><td>
Load 2, Load 4 Load 6 will operate</td></tr>
<tr><td rowspan="2">3</td><td>
Both Battery Banks
ON</td><td rowspan="2"></td></tr>
<tr><td>
Load 1, Load 2, Load 3 will operate</td></tr>
<tr><td rowspan="2">4</td><td>
Both Battery Banks OFF</td><td rowspan="2"></td></tr>
<tr><td>
Load 4, Loa 5, Load 6 will operate</td></tr>
</table>

	NO=NORMALLY OPEN
	NC=NORAMLLY CLOSED

The charging of battery banks is done separately by using the PV farm. During normal operation, the Battery bank gets charged by the Distributed Generators (DG) and when there is a deficient power supply from the sources, the battery banks are operated in weak grid conditions.

4. RESULTS AND DISCUSSION

This ladder program is running for six loads and two inputs model. The various conditions are applied to the to give supply to the OR even both odd and even number of loads. When there is an insufficient power supply from the distributed generators, the battery bank is coming to the pictures. The two groups of battery bank, switch on and off according to the customer paid programmer. It has been observed that the voltage maintained constant in spite of weak grid condition. The paper presents the automatic switching operation of battery according to the load conditions which is done by the delta PLC. The designed programmable logic controller (PLC) control and monitor the battery parameters (current, voltage, SOC and temperature). The result is obtained by using DELTA PLC which provide accurate SOC estimation for providing Power to the DC Micro grid. The Voc=f(SOC) is implemented into PLC based battery management system. Figure presents the operation sequence of push bottom switches.

There are four mode of operation occurs, depending on Load demand.

- Battery Bank 1 is on, accordingly load 1,3,5 is getting connected.
- Battery Bank 2 is on, accordingly load 2,4,6 is getting connected.
- Both Battery Banks are on, accordingly load 1,2,3 will be connected
- Both batteries off.

The charging period permits the SOC capacity of battery bank; accordingly, they are connected to the corresponding loads in DC micro grid.

TABLE II: Specifications of the battery used in Battery banks

Description	Value	Unit
Nominal Capacity (Battery)	3.4	Ah
Nominal Voltage (Battery)	3.7	V
Cut-off Voltage for Charging	4.2	V
Cut-off Voltage for Discharging	2.5	kV

5. CONCLUSION

The two groups of battery banks play a vital role in the operation of an ac/ dc hybrid microgrid with a 5 Km. distribution system. The main purpose of designing PLC based controller will shut down the loads and generators during emergency conditions. It protects the storage system from the deep discharge of the battery bank in absence of huge load demand.

REFERENCES

[1] Tomasz Klopot;Piotr Skupin;Patryk Grelewicz;Jacek Czeczot , "Practical PLC-Based Implementation of Adaptive Dynamic Matrix Controller for Energy-Efficient Control of Heat Sources", IEEE Transactions on Industrial Electronics, Year: 2021 | Volume: 68, Issue: 5, DOI: 10.1109/TIE.2020.2987272.

[2] Jaroslaw Tarnawski;Piotr Kudełka;Mateusz Korzeniowski,"Advanced Control With PLC—Code Generator for aMPC Controller Implementation and Cooperation With External Computational Server for Dealing With Multidimensionality, Constraints and LMI Based Robustness," IEEE Access, Year: 2022 | Volume: 10, DOI: 10.1109/ACCESS.2022.3142054.

[3] Shane Dominic;Yannik Löhr;Andreas Schwung;Steven X. Ding, "PLC-Based Real-Time Realization of Flatness-Based Feedforward Control for Industrial Compression Systems", IEEE Transactions on Industrial Electronics, Year: 2017 | Volume: 64, Issue: 2, DOI: 10.1109/TIE.2016.2612160.

[4] Borja Fernández Adiego;Dániel Darvas;Enrique Blanco Viñuela;Jean-Charles Tournier;Simon Bliudze;Jan Olaf Blech;Víctor Manuel González Suárez, "Applying Model Checking to Industrial-Sized PLC Programs," IEEE Transactions on Industrial Informatics, DOI: 10.1109/TII.2015.2489184.

[5] Arup Ghosh;Shiming Qin;Jooyeoun Lee;Gi-Nam Wang, "FBMTP: An Automated Fault and Behavioral Anomaly Detection and Isolation Tool for PLC-Controlled Manufacturing Systems", IEEE Transactions on Systems, Man, and Cybernetics: Systems, Year: 2017 | Volume: 47, Issue: 12, DOI: 10.1109/TSMC.2016.2633392.

[6] Patryk Grelewicz;Paweł Nowak;Jacek Czeczot;Jakub Musial, "Increment Count Method and Its PLC-Based Implementation for Autotuning of Reduced-Order ADRC With Smith Predictor", IEEE Transactions on Industrial Electronics, Year: 2021 | Volume: 68, Issue: 12, DOI: 10.1109/TIE.2020.3045696.

[7] Krzysztof Stebel;Jakub Pospiech;Witold Nocon;Jacek Czeczot;Piotr Skupin, "Boundary-Based Predictive Controller and Its Application to Control of Dissolved Oxygen Concentration in Activated Sludge Bioreactor" IEEE Transactions on Industrial Electronics. Year: 2022 | Volume: 69, Issue: 10, DOI: 10.1109/TIE.2021.3123629.

[8] Victor Ruiz Molledo;Jesus Enrique Sierra Garcia, "Simulation Tool for Hybrid AGVs based on IEC-61131", IEEE Latin America Transactions Year: 2022 | Volume: 20, Issue: 2, DOI: 10.1109/TLA.2022.9661472.

[9] Yameng An;Feiwei Qin;Baiping Chen;Rene Simon;Huifeng Wu, " OntoPLC: Semantic Model of PLC Programs for Code Exchange and Software Reuse", IEEE Transactions on Industrial Informatics, Year: 2021 | Volume: 17, Issue: 3, DOI: 10.1109/TII.2020.2997360

[10] Francisco J. Sánchez-Pacheco;Pedro Juan Sotorrío-Ruiz;Juan R. Heredia-Larrubia;Francisco Pérez-Hidalgo;Mariano Sidrach de Cardona, "PLC-Based PV Plants Smart Monitoring System: Field Measurements and Uncertainty Estimation", IEEE Transactions on Instrumentation and Measurement, Year: 2014 | Volume: 63, Issue: 9, DOI: 10.1109/TIM.2014.2308972

[11] Thiago Alves;Rishabh Das;Thomas Morris, "Embedding Encryption and Machine Learning Intrusion Prevention Systems on Programmable Logic Controllers", IEEE Embedded Systems Letters,Year: 2018 | Volume: 10, Issue: 3, DOI: 10.1109/LES.2018.2823906.

[12] Nan Zhou;Di Li, "Hybrid Synchronous–Asynchronous Execution of Reconfigurable PLC Programs in Edge Computing",IEEE Transactions on Industrial Informatics, Year: 2022 | Volume: 18, Issue: 3, DOI: 10.1109/TII.2021.3092741.

[13] Pablo Krupa;Daniel Limon;Teodoro Alamo, "Implementation of Model Predictive Control in Programmable Logic Controllers" IEEE Transactions on Control Systems Technology,Year: 2021 | Volume: 29, Issue: 3, DOI: 10.1109/TCST.2020.2992959.

[14] Poushali Pal;A. K. Parvathy;K. R. Devabalaji;S. Joseph Antony;Simon Ocheme;Thanikanti Sudhakar Babu;Hassan Haes Alhelou;T. Yuvaraj, "IoT-Based Real Time Energy Management of Virtual Power Plant Using PLC for Transactive Energy Framework", IEEE Access, Year: 2021 | Volume: 9, DOI: 10.1109/ACCESS.2021.3093111.

[15] Mohsen Salehi;Siavash Bayat-Sarmadi,"PLCDefender: Improving Remote Attestation Techniques for PLCs Using Physical Model", IEEE

Internet of Things Journal, Year: 2021 | Volume: 8, Issue: 9, DOI: 10.1109/JIOT.2020.3040237.

[16] Salvatore Cavalieri;Marco Giuseppe Salafia, "Asset Administration Shell for PLC Representation Based on IEC 61131–3", IEEE Access, Year: 2020 | Volume: 8, DOI: 10.1109/ACCESS.2020.3013890.

[17] Anais Guignard;Jean-Marc Faure;Gregory Faraut, "Model-Based Testing of PLC Programs With Appropriate Conformance Relations", IEEE Transactions on Industrial Informatics,Year: 2018 | Volume: 14, Issue: 1, DOI: 10.1109/TII.2017.2695370.

[18] Weiming Ba;Xin Dong;Abdelkhalick Mohammad;Mingfeng Wang;Dragos Axinte;Andy Norton "Design and Validation of a Novel Fuzzy-Logic-Based Static Feedback Controller for Tendon-Driven Continuum Robots" IEEE/ASME Transactions on Mechatronics, Year: 2021 | Volume: 26, Issue: 6, DOI: 10.1109/TMECH.2021.3050263.

[19] Guizhong Guo,"Design and Implementation of Smart Campus Automatic Settlement PLC Control System for Internet of Things" IEEE Access, Year: 2018 | Volume: 6, DOI: 10.1109/ACCESS.2018.2877023.

[20] Martin Obermeier;Steven Braun;Birgit Vogel-Heuser,"A Model-Driven Approach on Object-Oriented PLC Programming for Manufacturing Systems with Regard to Usability" IEEE Transactions on Industrial Informatics, Year: 2015 | Volume: 11, Issue: 3, DOI: 10.1109/TII.2014.2346133.

[21] Daniil Chivilikhin;Sandeep Patil;Konstantin Chukharev;Anthony Cordonnier;Valeriy Vyatkin "Automatic State Machine Reconstruction From Legacy Programmable Logic Controller Using Data Collection and SAT Solver" IEEE Transactions on Industrial Informatics, Year: 2020 | Volume: 16, Issue: 12, DOI: 10.1109/TII.2020.2992235.

[22] Moon Kyoung Choi;Chan Yeob Yeun;Poong Hyun Seong "A Novel Monitoring System for the Data Integrity of Reactor Protection System Using Blockchain Technology" IEEE Access, Year: 2020 | Volume: 8, DOI: 10.1109/ACCESS.2020.3005134.

[23] Luis González-Sotres;Carlos Mateo;Pablo Frías;Carlos Rodríguez-Morcillo;Javier Matanza "Replicability Analysis of PLC PRIME Networks for Smart Metering Applications" IEEE Transactions on Smart Grid, Year: 2018 | Volume: 9, Issue: 2, DOI: 10.1109/TSG.2016.2569487.

[24] Julien Provost;Jean-Marc Roussel;Jean-Marc Faure, "Generation of Single Input Change Test Sequences for Conformance Test of Programmable Logic Controllers", IEEE Transactions on Industrial Informatics, Year: 2014 | Volume: 10, Issue: 3, DOI: 10.1109/TII.2014.2315972.

[25] Peng Liu;Yifan Zhang;Huifeng Wu;Tingting Fu "Optimization of Edge-PLC-Based Fault Diagnosis With Random Forest in Industrial Internet of Things", IEEE Internet of Things Journal, Year: 2020 | Volume: 7, Issue: 10, DOI: 10.1109/JIOT.2020.2994200.

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