International Journal of Open Publication and Exploration (IJOPE), ISSN: ISSN: 3006-2853
Volume 10, Issue 2, July-December, 2022, Available online at: https://ijope.com

Testing Protocols for Battery Performance and Reliability Applications of Python in Battery Management Systems

Jayanth Kolli

Independent Researcher, USA

ABSTRACT

Lithium-ion batteries(LIBs) which are popular across electrical devices and gadgets such as products with EV charging and renewable energy systems such as EV charging systems. Despite that, the characteristics of batteries such as performance, reliability and cost are still problematic. Therefore, this report aims at examining how Python, together with Open Source tools, can be used in the testing and management of battery systems. It covers charge-discharge cycling, determination of capacity, and impedance techniques. Further, it discusses Python incorporation in the improvement of Battery Management Systems (BMS) for accurate monitoring of vital settings like voltage, current and temperature of batteries. In the low-cost battery testers, PVWPS, and BMS, modular designs, the report reveals how the use of Python can minimize costs and enhance the systems' dependability. Based on the results, solutions implemented with Python have versatility, low cost and expansiveness that is fundamental to guarantee sustainable power for electric automobiles and renewable energy storage systems. Some recommendations for future work are provided at the end of the report, such as machine learning integration and the creation of battery less embedded systems.

Keywords: Lithium-Ion Batteries, Battery Management Systems (BMS), Python Programming, Testing Protocols, Energy Storage Systems.

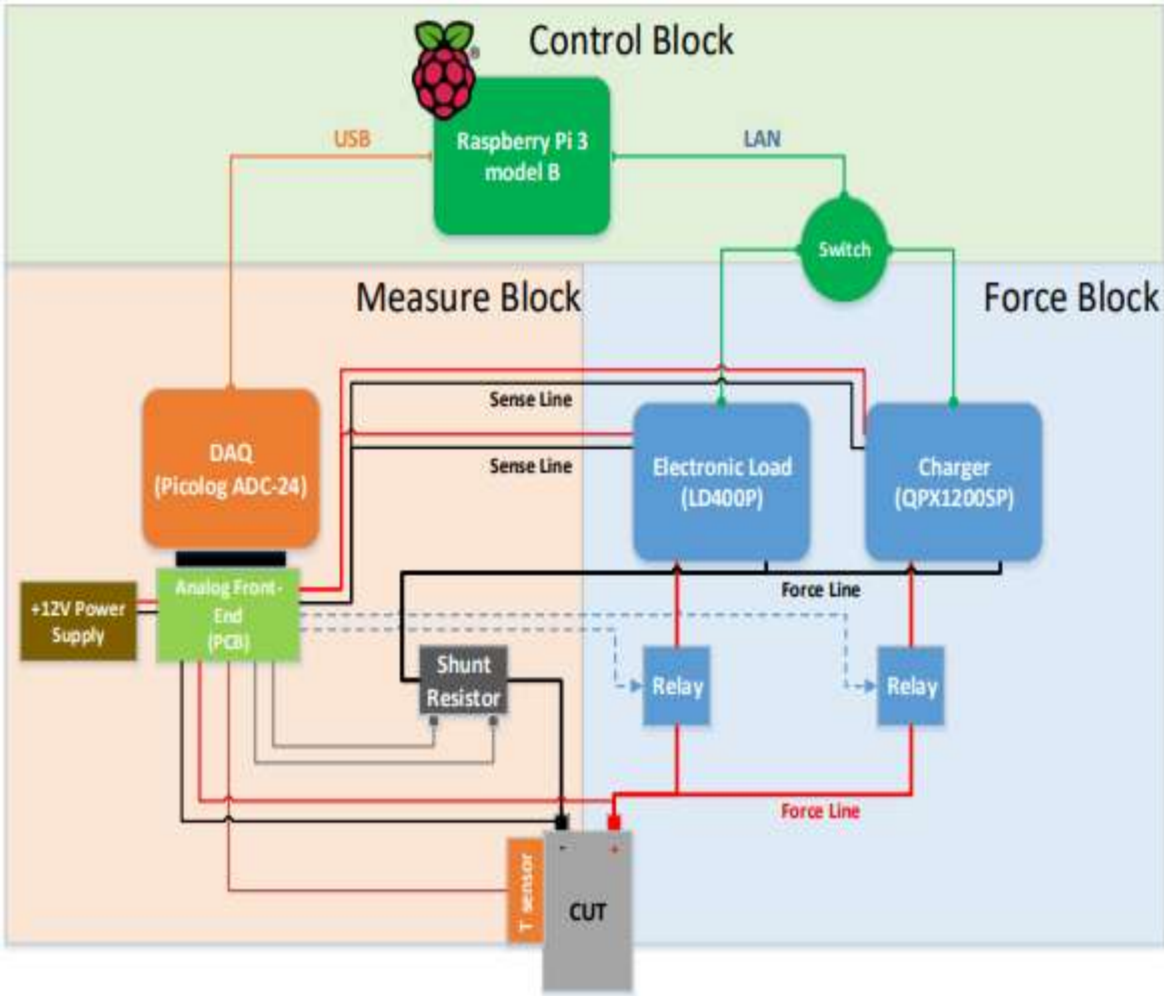
INTRODUCTION

Lithium-ion batteries (LIBs) have gained recognition in numerous applications resulting from their high energy density, long cycle life and efficiency. They are commonly applied in EVs, HEVs and renewable power systems including photovoltaic water pumping systems (PVWPS). Nevertheless, there is still the problem of implementation cost, performance, and battery issues associated with using lithium-ion batteries. The testing procedures of battery performance are critical to the efficiency and life cycle of LIBs in these applications. Open source Python tools and frameworks have become useful for empowering BMS developers to construct efficient and cost effective solutions for battery monitoring and controlling charging cycles. This paper discuss the present techniques relating to testing and analyze the adaptability of using Python for the enhancement of BMS for batteries in different applications such as electric vehicles and renewable energy storage.

LITERATURE REVIEW

Low-Cost Open-Source Battery Testing System for Lithium-Ion Cells in Electric Vehicles

According to the author (Carloni *et al*. 2018), Lithium-Ion Batteries (LIBs) are preferred more in high power application such as EVs and HEVs because they possess higher energy and power density compared to other types of batteries. For now, the cost of battery is still a challenge, especially for the medium power applications like E-scooters where the battery system accounts for a major component of the total bill. The paper unveils increasing attention towards convertibly powered battery pack designs in which one or a few of the degraded cells are replaceable instead of the entire pack thus extending the battery life and the costs of replacement. Since there is a deficit of cheap cell testing equipment, the authors suggest constructing a battery cell tester using a set of affordable commercial laboratory instruments with Python-controlled testing equipment based on a Raspberry Pi board (Faika *et al*., 2019). This configuration is more economical compared to the conventional PC-based system thus, it allows proper monitoring of vital features of battery, including voltage, current, as well as capacity. This paper makes use of this system to prove its feasibility through the accurate estimation of State of Health (SoH) of twenty 40 Ah LiFePO4 cells from an E-scooter battery pack. Based on the presented idea, the authors say that the advantages include the system's open-source approach that within the scope of its development in the future will be developed around the task, and the reduction in the total cost of electric vehicles due to lower maintenance costs.



(Source: Carloni *et al*. 2018)

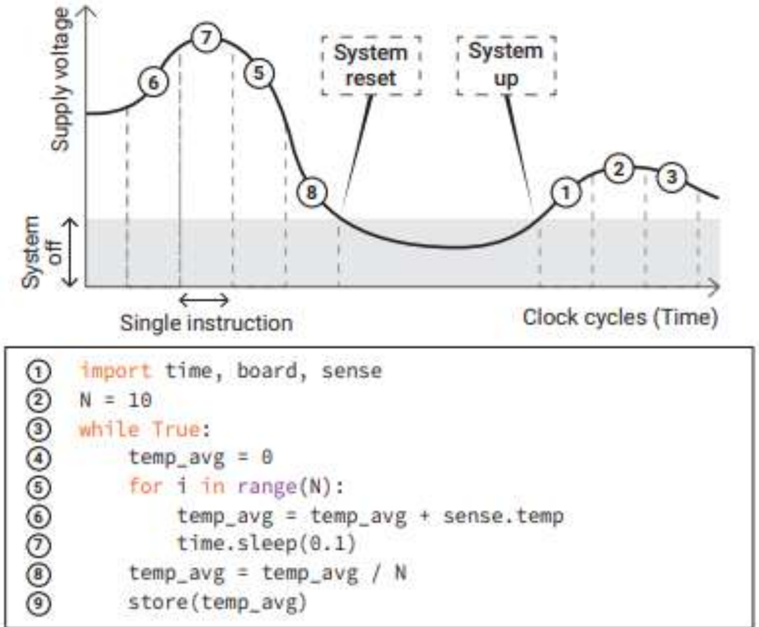
Figure 1: Hardware framework of the Cell Station Tester

Enabling Battery-Free Embedded Systems for Hobbyists: Power Failure Resilience and Python Integration

According to (Kortbeek*et al*. 2020), With the emergence of the maker and hobbyist culture, another audience has embraced computation and programming to build embedded systems such as temperature sensors, motion controlled-actuators and more broadly robotics platforms. With platforms such as Arduino, CircuitPython, Micro:bit, and others, new developers are now able to easily conceive, build and program elaborate embedded systems, making the entry point to create new applications less steep.

However, a new debate has been raised about energy consumption and the sustainability of these energy sources most notably battery-operated devices in WSNs and IoT by virtue of increasing number of devices as well as battery disposal (Mathew *et al*., 2018). To these worries, efforts are being made to adopt batteryless embedded systems that draw energy from environmental vibrations, lights or radio signals. These systems have indicated the benefits of reduced environmental footprint, lower costs, and longer deployment periods without subsequent maintenance. But, the creation of such battery-less applications is still a problem to most hobbyists as such systems experience problems due to energy inadequacy and power shutdowns.

To this end, the paper presents BFree, an end to end system to empower hobbyists construct battery free energy harvesting devices with Python for the vulnerability of embedded systems in power failure situations. These include the CircuitPython interpreter and support for power outage, general peripherals, and the basic hardware that allow for battery less operation on regular microcontroller boards and thus enabling those hobbyists build untethered battery less computing devices.

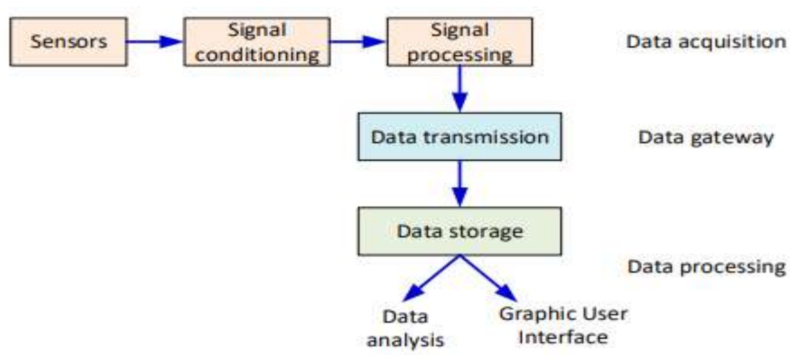


(Source: Kortbeek*et al*. 2020)

Figure 2: Power supply trace of a battery-free device executing a simple Python program

Monitoring Systems for Photovoltaic Water Pumping Systems (PVWPS) with Li-ion Battery Storage

According to (Gimeno *et al*. 2020), the global awareness of the climate change requires a shift in global energy model in which the REs and ESSs have critical roles to minimize emissions of greenhouse gases and the use of fossil fuels. Wind and photovoltaic (PV) systems are expected to lead this drive mainly on account of the added advantages of cost and environmental impacts. However, these sources are not continuous, due to this, ESSs such as the lithium-ion battery and pumped hydro storage are important in matching supply and consumption demands. The incorporation of ESSs in PV systems particularly PVWPSs is becoming popular as a cost effective means of providing water where electricity supply is unpredictable (Mian, 2018). This is a result of Battery Storage in PVWPSs meaning that any water pumped can be used at any time irrespective of the sun status. However, it is also noted that as the prices of LIBs fall further, cost of these systems should also come down. Maintaining, diagnosing and evaluating the efficiency of PVWPS, therefore, requires constant monitoring. Many monitoring systems were designed with simple decentralised analog metrics to the state-of-art IoT-based systems for tracking values such as solar irradiance, PV voltage and flow of water. (Gimeno *et al*2020) disclosed that incorporating a monitoring system that can pull from open-source software and IoT generates a more effective PVWPS that help in creating the sustainable development goals especially in the remote areas.



(Source: Gimeno *et al*. 2020)

Figure 3: Parts of a monitoring system

Methods

The approach used in assessing the efficiency and reliability of lithium-ion batteries for different companies can be divided into three, Testing procedures, Python integration, and BMS architecture.

Testing Protocols for Battery Performance

The standard test procedures for the evaluation of the lithium ion batteries comprise charge discharge cycling, impedance measurement, capacity determination, and thermal tests. The protocols often relates to international standards such as IEC 61960 and SAE J2464 that describes methods of estimating battery capacity, overall efficiency, and cycle life. Other particularities that are considered during tests encompass volt AC/DC, current, and temperature in different and variable loads and conditions (Moghaddam and Leon-Garcia, 2018). Furthermore, through SoH and SoC, predictions are made to understand the overall life and performance loss of the battery.

Python Integration in Battery Testing

Many situations include Python in battery testing because of its free and open-source reference model and expanded adaptability for automation and data processing. In this research, Python based software is used to control lab equipment including multimeters, electronic loads, battery analyzers, etc. Through Raspberry Pi or any microcontroller. The superficial use of Python makes it possible for controlling and even tracking certain parameters in batteries such as voltage, current and temperature among others in real time (Florea and Taralunga, 2020). Scripts for execution are functional, making it possible to achieve identical outcomes in successive testing cycles whilst making it easy to analyze results and develop graphical images.

Battery Management Systems (BMS) Design

The Battery Management Systems (BMS) are one of the pillars considered when it comes to battery performance and dependability. BMSs are employed to control and unavoidably, to monitor and control fundamental features such as charging /discharging rates, voltage fluctuations and temperature, and furthermore, to compensate the output of each cell of a battery coupled pack (Choi *et al*., 2019). The BMSs of the later proposed using Python can be further extended as compact and highly modular systems where different parts could be changed to support different types of batteries or usage patterns. Thus, such open-source frameworks make it possible to deliver BMSs that allow scaling, flexibility, and reasonable cost when creating devices for controlling the performance of batteries in electric vehicles and storage stations for renewable energy sources.

RESULT

Low-Cost Python-Based Battery Tester Performance

The use of the battery tester implemented in the Python programming language enabled identification of important characteristics of the battery such as voltage, current and capacity of the battery before and after numerous cycles of charging and discharging. This low cost system was found capability to find out the SoH of Li ion cells and was believed to offer solutions to main issues like, the degradation of offered capacity and loss of performance of individual cells of a battery pack (Valant *et al*., 2019). The findings corroborated the applicability of low-cost open-source systems based on Python for routine battery maintenance and monitoring, as compared to widespread expensive testing techniques. It also enables proper evaluation of battery efficiency over the period to make better decisions in as far as replacement and maintenance of these batteries is concerned.

Integration in Photovoltaic Water Pumping Systems (PVWPS)

Concerning PVWPSs, inclusion of the Python-based systems made it possible to monitor battery status and general working condition of the entire system in real-time under field conditions. Various critical parameters including solar irradiance, PV voltage, flow rate of water and battery voltage were measured using IoT devices. This monitoring was made possible with the help of software developed in Python, whereby real-time data acquisition was performed, and the operation of the systems was improved, especially in the otherwise isolated regions lacking physical connections to grid electricity. In addition, it supported the monitoring without physical access, enabled continuous fault detection, and provided an understanding of the system's status before potential faults resulted in systems' failures, making the PVWPS systems more reliable and sustainable in off-grid locations.

Modular Python-Based Battery Management System (BMS) Integration

The design of the Python-based Battery Management System (BMS) means that simple integration with many types of battery pack was possible, thus providing the means to effectively manage such critical tasks as balancing charges as well as controlling temperature. These critical processes are necessary for safety and reliability of EVs and other battery interface applications, such as home energy storage systems and electric public transport. The BMS that was developed using Python helped in getting real-time data concerning the battery's operations hence ensuring that battery life was well managed and that the system's performance was enhanced. Furthermore, it is able to incorporate the possible flexibility and modularity of the system that can fit almost any battery type sizes and other battery related complexities ranging from small stationary battery system to big complex system.

DISCUSSION

The incorporation of Python application in battery performance testing and BMS design has given significant input in the domain of battery management for several uses. Another important aspect of systems based on Python is that such systems are inexpensive, highly configurable, and portable between various platforms, which makes them attractive for use both in amateur radio and in professional projects. The examples like the use of Python in the experimental testing of lithium-ion cells from the E-scooter pack and IoT PVWPS solutions reflect quite a dramatic role played by Python in enhancing the battery performance monitoring and control (Horn, 2017). As a result, different challenges arise when implementing such systems. Software problems like plugging and playing, power issues, and the necessity to update every time new types of batteries come up, are some concerns that should be looked continuously. Furthermore, the openness of the solutions supports the development of new ideas, though there is a requirement for standardization and verification of Python-based testing protocols with respect to platforms and applications.

Future Directions

The innovative concepts of true portability, connectivity, modularity, and automation of battery testing and management are offering greater control and easy handling to battery testing and management systems in the near future. For instance, utilization of machine learning algorithms and data analytics within Python supported BMS can improve the means to predict battery failure with an appreciation of charging cycles. In addition, growth of new cloud based methods of remote tracking and real-time diagnosing of battery performance would increase with current capacities of systems making it feasible to better control energy storage systems in electric vehicles and renewable energy sources (Reindl *et al*., 2020). Moreover, activities in the direction of eliminating batteries from the embedded system and charging those batteries by using ambient energy sources like vibrations and light are other development line for future green energy management. Such systems would decrease the use of conventional batteries and improve the modularity and portability of embedded systems.

CONCLUSION

Integration of battery testing protocols and battery management systems that are built on Python programming language make this solution relatively cheap and easily scalable during its application in enhancing the energy density and cycle life of lithium-ion batteries. The inclusion of Python in BMS design is pleasant due to its high flexibility, simplicity, and user-friendly characteristics and may be a perfect solution for both, basic research and practical usage. Given the rising need for energy storage systems due to mobility and green energy, Python will increasingly be used in the improvement of battery control technology for the improvement of future energy solutions.

REFERENCE LIST

JOURNALS

[1]. Carloni, A., Baronti, F., Di Rienzo, R., Roncella, R. and Saletti, R., 2018. Open and flexible li-ion battery tester based on python language and raspberry pi. Electronics, 7(12), p.454.
[2]. Kortbeek, V., Bakar, A., Cruz, S., Yildirim, K.S., Pawełczak, P. and Hester, J., 2020. Bfree: Enabling battery-free sensor prototyping with python. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 4(4), pp.1-39.
[3]. Gimeno-Sales, F.J., Orts-Grau, S., Escribá-Aparisi, A., González-Altozano, P., Balbastre-Peralta, I., Martínez-Márquez, C.I., Gasque, M. and Seguí-Chilet, S., 2020. PV monitoring system for a water pumping scheme with a lithium-ion battery using free open-source software and IoT technologies. Sustainability, 12(24), p.10651.
[4]. Faika, T., Kim, T., Ochoa, J., Khan, M., Park, S.W. and Leung, C.S., 2019, September. A blockchain-based Internet of Things (IoT) network for security-enhanced wireless battery management systems. In 2019 IEEE industry applications society annual meeting (pp. 1-6). IEEE.
[5]. Mathew, M., Janhunen, S., Rashid, M., Long, F. and Fowler, M., 2018. Comparative analysis of lithium-ion battery resistance estimation techniques for battery management systems. Energies, 11(6), p.1490.

[6]. Mian, S., 2018. A novel battery management & charging solution for autonomous uav systems (Master's thesis, Arizona State University).

[7]. Moghaddam, M.H.Y. and Leon-Garcia, A., 2018. A fog-based internet of energy architecture for transactive energy management systems. IEEE Internet of Things Journal, 5(2), pp.1055-1069.

[8]. Reindl, A., Schneider, V., Meier, H. and Niemetz, M., 2020. Software update of a decentralized, intelligent battery management system based on multi-microcomputers. In Tagungsband 2. Symposium Elektronik und Systemintegration ESI 2020:" Intelligente Systeme und ihreKomponenten: Forschung und industrielleAnwendung" (pp. 8-19).

[9]. Florea, B.C. and Taralunga, D.D., 2020. Blockchain IoT for smart electric vehicles battery management. Sustainability, 12(10), p.3984.

[10]. Choi, Y., Ryu, S., Park, K. and Kim, H., 2019. Machine learning-based lithium-ion battery capacity estimation exploiting multi-channel charging profiles. Ieee Access, 7, pp.75143-75152.

[11]. Valant, C., Gaustad, G. and Nenadic, N., 2019. Characterizing large-scale, electric-vehicle lithium ion transportation batteries for secondary uses in grid applications. Batteries, 5(1), p.8.

[12]. Horn, B.V.W., 2017. The development of a 48V, 10kWh LiFePO4 battery management system for low voltage battery storage applications (Doctoral dissertation, Stellenbosch: Stellenbosch University).

[13]. Sai Krishna Shiramshetty, "Big Data Analytics in Civil Engineering : Use Cases and Techniques", International Journal of Scientific Research in Civil Engineering (IJSRCE), ISSN : 2456-6667, Volume 3, Issue 1, pp.39-46, January-February.2019
URL : https://ijsrce.com/IJSRCE19318

[14]. Sai Krishna Shiramshetty, " Data Integration Techniques for Cross-Platform Analytics, IInternational Journal of Scientific Research in Computer Science, Engineering and Information Technology(IJSRCSEIT), ISSN : 2456-3307, Volume 6, Issue 4, pp.593-599, July-August-2020. Available at doi : https://doi.org/10.32628/CSEIT2064139

[15]. Shiramshetty, S. K. (2021). SQL BI Optimization Strategies in Finance and Banking. *Integrated Journal for Research in Arts and Humanities*, *1*(1), 106–116. https://doi.org/10.55544/ijrah.1.1.15

[16]. Sai Krishna Shiramshetty. (2022). Predictive Analytics Using SQL for Operations Management. *Eduzone: International Peer Reviewed/Refereed Multidisciplinary Journal*, *11*(2), 433–448. Retrieved from
https://eduzonejournal.com/index.php/eiprmj/article/view/693

[17]. Harish Goud Kola. (2022). Best Practices for Data Transformation in Healthcare ETL. *Edu Journal of International Affairs and Research, ISSN: 2583-9993*, *1*(1), 57–73. Retrieved from
https://edupublications.com/index.php/ejiar/article/view/106

[18]. Kola, H. G. (2018). Data warehousing solutions for scalable ETL pipelines. *International Journal of Scientific Research in Science, Engineering and Technology, 4*(8), 762. https://doi.org/10.1.1.123.4567

[19]. Harish Goud Kola, " Building Robust ETL Systems for Data Analytics in Telecom ,IInternational Journal of Scientific Research in Computer Science, Engineering and Information Technology(IJSRCSEIT), ISSN : 2456-3307, Volume 5, Issue 3, pp.694-700, May-June-2019. Available at doi : https://doi.org/10.32628/CSEIT1952292

[20]. Kola, H. G. (2022). Data security in ETL processes for financial applications. *International Journal of Enhanced Research in Science, Technology & Engineering*, *11*(9), 55. https://ijsrcseit.com/CSEIT1952292.

[21]. Annam, S. N. (2020). Innovation in IT project management for banking systems. *International Journal of Enhanced Research in Science, Technology & Engineering*, *9*(10),
https://www.erpublications.com/uploaded_files/download/sri-nikhil-annam_gBNPz.pdf

[22]. Annam, S. N. (2018). Emerging trends in IT management for large corporations. *International Journal of Scientific Research in Science, Engineering and Technology*, *4*(8), 770.https://ijsrset.com/paper/12213.pdf

[23]. Sri Nikhil Annam, " IT Leadership Strategies for High-Performance Teams, IInternational Journal of Scientific Research in Computer Science, Engineering and Information Technology(IJSRCSEIT), ISSN : 2456-3307, Volume 7, Issue 1, pp.302-317, January-February-2021. Available at doi : https://doi.org/10.32628/CSEIT228127

[24]. Bussa, S. (2019). AI-driven test automation frameworks. *International Journal for Innovative Engineering and Management Research*, *8*(10), 68–87. Retrieved from
https://www.ijiemr.org/public/uploads/paper/427801732865437.pdf

[25]. Nama, P. (2021). Enhancing user experience in mobile applications through AI-driven personalization and adaptive learning algorithms. *World Journal of Advanced Engineering Technology and Sciences*, *3*(02), 083-094.

[26]. Nama, P. (2021). Leveraging machine learning for intelligent test automation: Enhancing efficiency and accuracy in software testing. *International Journal of Science and Research Archive*, *3*(01), 152-162.

[27]. Harish Goud Kola. (2022). Best Practices for Data Transformation in Healthcare ETL. *Edu Journal of International Affairs and Research, ISSN: 2583-9993*, *1*(1), 57–73. Retrieved from https://edupublications.com/index.php/ejiar/article/view/106

[28]. Nagarjuna, P., Arulkumaran, R., Pagidi, R. K., Singh, S. P., Kumar, S., & Jain, S. (2021). Transitioning legacy systems to cloud-native architectures: Best practices and challenges. *International Journal of Computer Science and Engineering (IJCSE)*, *10*(2), 269–294. https://www.researchgate.net/publication/387371765_TRANSITIONING_LEGACY_SYSTEMS_TO_CLOUD-NATIVE_ARCHITECTURES_BEST_PRACTICES_AND_CHALLENGES