Central Asian Journal
of Theoretical and Applied Sciences
Vol. 5 Issue 3 | pp. 80-89 | ISSN: 2660-5317
Available online @ https://cajotas.centralasianstudies.org/index.php

Low-Cost Arduino LoRa Transmitter for Monitoring PV Systems

May Adnan Falih[1*], Firas Mahdi. Salbi[1]

[1] Departement Communications, University of Babil, Engineering College, Babil, Iraq.
* Correspondence author email: mayf992002@gmail.com

Abstract: This study addresses the need for cost-effective supervisory control and data acquisition (SCADA) systems to monitor and control grid-connected inverter units and battery energy storage systems in remote photovoltaic (PV) plants. By leveraging Internet of Things (IoT) technology and open-source platforms, a novel SCADA model based on LoRa communication is proposed. This model integrates Arduino microcontrollers, LoRaWAN servers, and data visualization tools like Grafana to monitor and control PV system parameters. Through experimentation, it is demonstrated that the LoRa-based SCADA system achieves reliable long-range communication up to 15km with low power consumption. The system's effectiveness is validated by successfully collecting and analyzing data on PV and battery performance. Overall, this research presents a practical solution for affordable SCADA implementation in remote PV systems, addressing the growing demand for grid stability and energy cost optimization.

Keywords: SCADA system, Arduino, Internet of Things (IOT), Raspberry Pi, LoRa, Low Cost, Node-Red, Grafana.

Citation: May Adnan Falih, Firas Mahdi. Salbi. Low-Cost Arduino LoRa Transmitter for Monitoring PV Systems. Central Asian Journal of Theoretical and Applied Sciences 2024,5(3),80-89.

Received: 23 March 2024
Revised: 23 April 2024
Accepted: 7 May 2024
Published: 14 May 2024

1. Introduction

Power might be distinguished as the ultimate vital product when humanity forwarding to the modern life. The regular energy scheme has been worked to provide energy along a focal energy supply to dispersed shoppers. Later the expansion of bi-directional energy stream suppliers like power stockpiles and smaller than expected and micro-grid ideas, the energy model has become increasingly defenseless. To lessen the expense of power delivered also to act upon the nature of the power gave, power capacity systems are presented. This permits service organizations to minimize the expense of power by utilizing, predominantly environmentally friendly energy supplies. Utilizing more environmentally friendly power sources to supplant high fossil fuel byproduct age plants help to dial back the environmental variation whereas environmental alternation has turned towards the danger to everybody upon the planet [1-2].

As per the Global Energy Storage Database, 98% of power stockpiling schemes are hydro pumping scheme whereas BESS are turning out to be further well- known beside worked in highlights related against BESS [2]. Various advances are being utilized in power capacity rather than BESS with Pumping hydro. Fly wheels might being distinguished as part of the essential strategies which have been utilized as well as packed air schemes can likewise be thought of as another arising pattern [3]. With regards to the area of batteries power capacity systems (BESS), formative act that is finished to utilize dispersed BESS in families also close to every dispersion transformer unit[4]. Also, it is fsundamental to foster proper

energy converter devices particularly applied to be utilized against BESS with another power stockpiles.

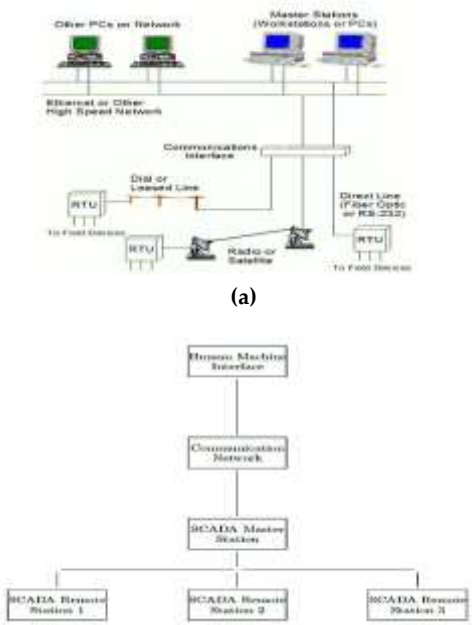
There are several benefits of incorporating power stockpiling gadgets to the energy structure. It empowers to lessen fossil fuel byproduct, yet in addition it will operate on the nature of the power provided by upgrading the unwavering quality of the power provided [3,4]. It will likewise lessen the expense of the power delivered by top shaving also enhancing the energy age. Those are a parts of the benefits that clients will be advanced by coordinating power stockpiling models towards the energy scheme. Along the service part, power capacity has been perceived as the secondary innovation against the ultimate critical voltage as a eventual income hotspot for services [5]. Numerous obstructions available whereas incorporating energy stockpiling towards the current energy plant. That would incorporates the measuring of the power stockpiling, the way of choosing the ideal content of the power stockpiling, whereas to introduce the power stockpiling, the way to conduct the power capacity to augment the benefit are not many obstructions out of them [2-5]. The compatibility of power stockpiling against another components in the shrewd grid is alternative Confrontation [6]. In particular, whereas incorporating various advancements to the current grid, there will be issues against conventions, equipment confounds, and so forth. Many issues should be addressed prior to coordinating power stockpiling schemes to the ongoing network. Above all summing an energy stockpiling towards the system wouldn't sum either benefit to the model as well it must be ideally controlled to obtain the ultimate extreme advantage out of it. Since the labor force isn't modest energy stockpiling should be checked and controlled remotely [3-5].

In the greater section of the issues, energy converting units are being utilized to incorporate power stockpiling structure in the energy scheme, against such inverters are utilized to infuse reversed DC energy towards the grid. DC energy created by Wind, Solar or part of another sustainable wellspring of power or put apart in a battery or some another power stockpiling gadget will be taken care of towards the grid. Recently, situation power infused by limited scope energy makers are not adjusted or checked by the service, yet it would end up being a prerequisite for the service whenever the limit surpasses as far as possible. Since there is a developing business sector for BESS as well another power stockpiling models rather that pumping hydro capacity schemes expected for controlling as well monitor of force inverters (converters) that likewise turn towards a necessity.

There are several kinds of force converters (inverters) that might become illustrated as in the market whereas top of the line significant expense inverters are accompanying inserted SCADA systems and minimal expense against similar proficiency inverters probably won't accompany such complicated highlights [7]. Normally, the greater section of the costly converters like SMA producing installed SCADA models. In any case, a large portion of the less end inverting devices with little converters don't offer SCADA scheme. Hence, there is a shortage of open source minimal expense SCADA for invention. For instance, SMA bright kid 10kW inverters expense near CAD 4*103 [4] as well the almost extreme proficiency is 98% and a minimal expense inverters might be exist at CAD 1*103 using a similar proficiency [8]. After ID of basic elements of a SCADA, such examination becomes directed to distinguish the favorite accessible open source structure so it is accessible to become utilized within an open source permit against the least expense which might being utilized for distant controlling with monitoring. Next, to foster a SCADA scheme for control with monitoring of a grid-associated inverters. Numerous advancements are being utilize to fulfill the ahead reason like Lab vie based models, Simulink devoted schemes, open source program dependent schemes and devote SCADA software [5-8]. Be that as it might, there are several inconveniences connected to each scheme that is talked about in the last pieces for here section. Hence, with such exploration, the condition of-workmanship innovation, Internet of Things (IoT) based design has been chosen to foster the SCADA.

Throughout the expanding need for power and reduced carbon discharge, expanded environmentally friendly power supply infiltration for power age like breeze, sun based and hydro is passing on. To achieve this, various age as well as capacity structures have been sent at various fields because of reasons like asset, accessibility of land region for establishment and additionally seclusion along fields of person residence. Such thing, hence intends that for nonstop commonly activity of the different sections, there should be a dependable

supervisory with controlling scheme. SCADA is an abbreviation for Supervisory Control as well Data Acquisition, that is an innovation designed for successful monitoring of various appropriated system at fields for standard employing [1-2]. This project is commonly achieved during information acquisition along the different distant schemes become checked against the utilization of sensing units with info sent to SCADA has for perceptions also conceivable control utilizing actuators [2-3]. Inferable along the path which almost of the schemes are situated in topographical fields against conceivable brutal weather and distant. Whereas, there might be a require of a nearby approach for resources activity the executives, it is likewise of indication to have a solid, adaptable, financially smart and hearty facilitated monitoring with control. Such capacity might become achieved utilizing a SCADA schemes [3]. Against a SCADA model in place, the demand for an application power to be positioned at the site is radically decreased. The essential elements of a SCADA units contain: Info acquisition, info move, info show and faraway supervisory controlling with monitoring [3]. The SCADA units fills such roles utilizing its essential elements [2-3]: Field instrumentation gadgets like the sensors with actuation devices, the Remote Terminal Units (RTU) like the microcontroller units, the Master Terminal Units (MTU) which equalized the info handling, illustrate also the communication medium that joins the RTUs to the MTUs [4]. SCADA models might either being exclusive or open source [3-4]. For restrictive SCADA, the significant sections are along a unique producer as well as thus the typical as well as coding for the appropriate activity of the SCADA units is the sole obligation of the producer that involves complete reliance upon the producer for investigating and fixes. The adaptability of the system is additionally in line as there might available several similarity issues. Next again, the open source SCADA schemes would become schemes created against the blend of various minimal expense parts along alternative producers against generally excellent similarity beside the capacity to accomplish secure also appropriate capacity. In the open-source systems, such capacities are accomplished for minimal price with best interoperability of sections [4]. For correspondence, SCADA systems in presence have involved different correspondence innovations for info travel inside the RTUs as well MTUs. The current correspondence systems incorporate Wi-Fi, Zigbee, internet or a mix of the previously mentioned. LoRa that stands Long Range correspondence is a correspondence model that is familiar for its Long Range and Low power utilization attributes. Such elements of LoRa deserves it the current adaptability it has procured in the IOT business. In here study, an open source LoRa based SCADA units is suggested. A typical structure of the SCADA unit scheme is shown in Figure1.



(a)

Figure 1. Typical SCADA unit system, (a) Schematic connection diagram, (b) block diagram

2. Methods

The suggested LoRa based correspondence model is an IoT path to deal against info travel within micro-grids as well as in which would contain the cooperation among LoRa specialized gadgets against sensing units that might being comparable against various sections of the micro-grid for monitoring and info travel. In here study, the sensing units are customized to obtain info along the checked nits, the information are treated and next transmitted via the LoRa hubs to the entryway, the door forwards such info needed to the servers for supervising, stockpiling, illustrates as well conceivable control. Fig 2 illustrates the complete setup of the suggested LoRa-based SCADA scheme. The essential aim of here study is to expand a little-cost SCADA for controlling as well a grid tie inverters monitoring. Figure 2 illustrates the construction of the structured proposed low coast SCADA system.

Figure 2. Inspection of the suggested model

The essential role is accomplished by verifying 4 further aims.

1) Aim 1 is to determine principal highlights of SCADA framework for controller of network associated inverters.
2) Aim 2 is to think about accessible minimal expense SCADA choices.
3) Aim 3 is to foster a minimal expense SCADA against highlights indicated in the Figure 2.
4) Aim 4 is to controlling the inverters associated with power stockpiling framework to expand the benefit.

The essential goal of here section is to exhibit the improvement of a minimal expense open source SCADA framework against complicated elements embraced along business SCADA frameworks for energy converters. Work illustrated in here section was illustrated at NESTnet yearly gathering [23]. As a piece of the examination, an overview has been done against respect to SCADA programming which is being utilized in WEICAN to figure out additional insights regarding monetarily accessible SCADA frameworks which might being utilized for observing as well as controlling of inverter devices. In the investigating organization, VTscada is utilized for checking wind turbines control using batteries power capacity framework. Recognizing the expense of the framework the primary expense of the framework incorporates 1*103 I/O label improvement Runtime bundle is around 5,595.00 Computer aided design. Also, for upkeep and crisis support 20% [24] of the yearly expense is charged along the underlying cost. The accompanying elements are being advertised:
It permits clients to log information for observing, Sends email cautions for characterized occurrences, Sees information in time stretches It provides moving information, Creates reports, Permits sending controlling boundaries

Here section examines IoT based method to deal against accomplish the essential target of an ordinary SCADA framework which is to broadcast against actuators with sensors also, beside the Internet against a different IP addresses whenever contrasted with a cloud. Such strategy is arranged based on IoT design as cloud helped SCADA frameworks. In particular, the decentralized methodology in IoT engineering permits sensing units what's more, actuators to communicate against one another and take their own choices, as well it provides independence to gadgets. Against regards to the complete scale image, IoT too

permits concentrated information the board for bigger networks wherein regular SCADA frameworks focal information taking care of is confounded. In research offices like WEIcan [25], they utilize a little SCADA frameworks that can't broadcast together, and that demands the association of a ton of human operating to gather information along single SCADA with feed a portion of those information to elsewhere. IoT assists against wiping out this issue totally whereas everything sensing units might take care of their information to the cloud, and the cloud stage does all the computations like AI, pattern estimations, and so on. Or, in every likelihood the thingspeak server might go about as a facilitator for another SCADA framework utilizing correspondence admits one another. Figure 3 demonstrates the flow chart bock diagram of the suggested SCADA model utilized for low cost applications based upon the Arduino LaRo Arduino LoRa Transmitter (ALT) scheme.

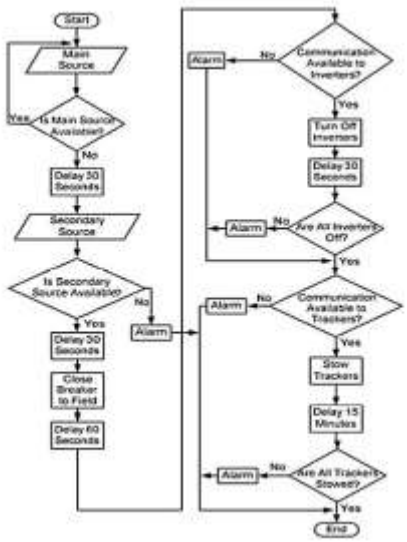


Figure 3. Flow chart of the suggested SCADA model utilized for low cost applications based upon the Arduino LaRo Arduino LoRa Transmitter (ALT) scheme.

Also, Figure 4 presents a bock diagram of the proposed SCADA model specified for low cost applications based upon the Arduino LaRo Arduino LoRa Transmitter (ALT) scheme.

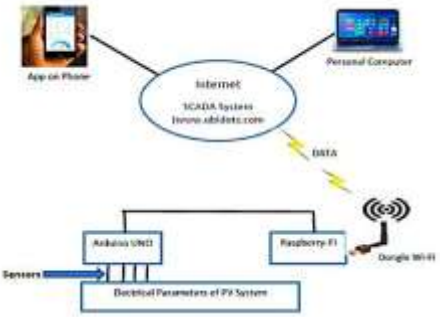


Figure 4. Block diagram of the suggested SCADA model utilized for low cost applications based upon the Arduino LaRo Arduino LoRa Transmitter (ALT) scheme [12].

Thingspeak is an IoT cloud stage which permits clients to transmit information in like clockwork for nothing. The client will actually want to immediately image as well investigate live information in the cloud. The primary benefit is that it permits integrating Mathworks report with the thingspeak one so the client will actually want to utilize elements like machine gaining stage from Matlab. According to engineers, thingspeak is an open source IoT implementation with API to save information along things utilizing HTTP convention. In this SCADA framework thingspeak neighborhood servers have been demonstrated in a X86 engineering based PC. For such situation, there is no recurrence limitations, as well as the

nearby servers permiting the client to transmit information although at a larger recurrence.

3. Result and Discussion

In this study, a minimal expense Arduino LoRa Transmitter (ALT) has been investegated almost a photovoltaic framework. ALT is utilized to principally gather the photovoltaic framework's information, that comprises of the voltage as well current of the photovoltaic (PV), and the voltage with current of the batteries. To gather the whole information, ALT is associated against certain sensor (e.g., 105 voltage as well current sensors) and a voltage source of 5Volt. ALT has a pin 5Volt that might be utilized as a energy sources. The perception chamber is situated around 1 km along the PV framework. ALT has been introduced here and is associated with a PC by means of a small scale USB. Clay, which is software that might without much of a stretch be summed to a PC, is utilized to present sequential COM-associated information on the observing screen. The program incorporates the choice to save information as a text record on a PC. Actually, for this test, ALT, ALR and the ongoing sensing units are the power shoppers. Table 1 represents the flows and potentials estimated by the multimeter for every unit.

Table 1. Demonstration of the voltage & current drown for the proposed low coast SCADA scheme

Equipment	Drown Voltage	Drown Current	Total Power
ALT	3.2	125mA	450mW
ALR	3.2	125mA	450mW
Current	4	10mA	60mW
Voltage	4	10mA	60mW
Overall power consumption			

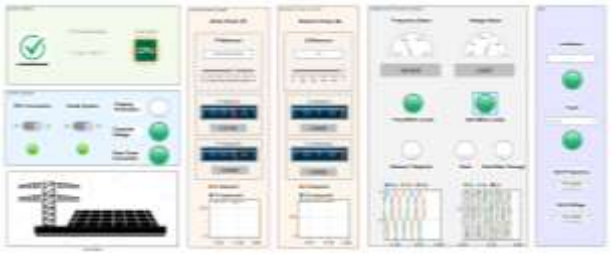


Figure 5. Simulation implementation of the Low Cost Solar_Station_with_Scada_System using MatLab2020b.

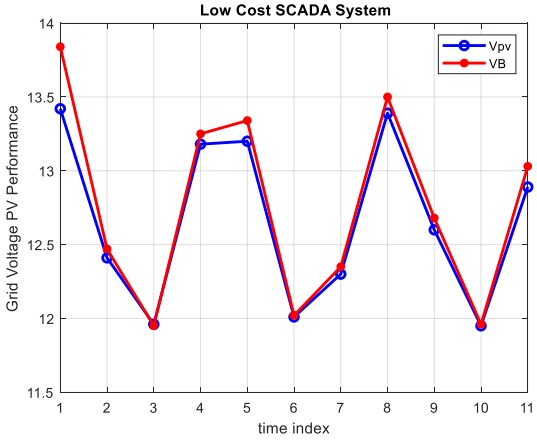


Figure 6. Voltage performance of the suggested SCADA model utilized for low cost applications.

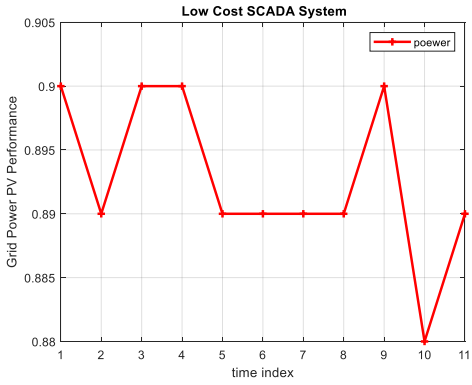


Figure 7. Power performance of the suggested SCADA model utilized for low cost applications

4. Conclusion

The fundamental point of this paper was to plan a minimal expense checking and information procurement framework utilizing Arduino LoRa. The plan was applied on a little PV framework to gather information relating to PV and battery current and voltage of PV as well as PV proficiency. ALT was introduced at a PVS area and effectively gathered information from the PV framework, while ALR was set in a control room found roughly 1 km from ALT. The reason of ALR was to get information and show these information on Putty's chronic screen. The information was then, at that point, saved money on the PC as a text record. Most extreme reach was found at 15Km. The all out cost of this framework was around CAD $150, which covers generally fundamental framework parts. The power utilization of the framework was determined to be around 1.125W.

REFERENCES:

[1.] E. Chemali, M. Preindl, P. Malysz, and A. Emadi, "Electrochemical and Electrostatic Energy Storage and Management Systems for Electric Drive Vehicles: State-of-the-Art Review and Future Trends," IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 4, no. 3, pp. 1117-1134, Sept. 2016.

[2.] NESTNet, "Themes," [Online]. Available: https://www.ryerson.ca/nestnet/themes/.

[3.] A. Ujvarosi, "Evolution of SCADA Systems," Bulletin of the Transilvania University of Brasov. Engineering Sciences. Series I, vol. 9, no. 1, pp. 63, 2016.

[4.] GoGreenSolar, "SMA SB 10000TLUS-10 Sunny Boy Grid-Tie Inverter 10000W with DC," [Online]. Available: https://www.gogreensolar.com/products/sma-sb-10000tlus-10-sunny-boy-gridtie-inverter-10000w-with-dc.

[5.] A. Sajid, H. Abbas, and K. Saleem, "Cloud-Assisted IoT-Based SCADA Systems Security: A Review of the State of the Art and Future Challenges," IEEE Access, vol. 4, pp. 1375-1384, 2016. doi: 10.1109/ACCESS.2016.2549047.

[6.] A. M. Grilo, J. Chen, M. Diaz, D. Garrido, and A. Casaca, "An Integrated WSAN and SCADA System for Monitoring a Critical Infrastructure," IEEE Transactions on Industrial Informatics, vol. 10, no. 3, 2014.

[7.] E. Andreescu, H. Gurban, and G. D., "SCADA Element Solutions Using Ethernet and Mobile Phone Network," in 2011 IEEE 9th International Symposium on Intelligent Systems and Informatics, 2011, pp. 303-308.

[8.] P. Zhang, T. Liu, Z. X. Yang, Y. Mou, Y. H. Wei, and D. Chen, "Design of Remote Control Plug," in 2015 IEEE International Conference on Applied Superconductivity and Electromagnetic Devices (ASEMD), 2015, pp. 29-30.

[9.] S. Sanap, R. Nawale, S. Kapse, A. Kale, and M. Korade, "Exact Virtualization of Industrial Environment on Web Using SCADA with Artificial Intelligence," in Green Computing and Internet of Things (ICGCIoT), 2015 International Conference on, Noida, 2015, pp. 99-103.

[10.] S. G. Hegde, S. R. Desai, D. R. Gajanan, S. B. Kowligi, and S. R. C. Ndustrial Instrumentation and Control (ICIC), "Implementation of SCADA in Industries Using Wireless Technologies," in 2015, Pune.

[11.] A. Soetedjo, Y. I. Nakhoda, and D. Suryadi, "Development of Data Acquisition System for Hybrid Power Plant," in QiR (Quality in Research), 2013 International Conference on, Yogyakarta, 2013, pp. 197-201.

[12.] J. L. Sarinda, T. Iqbal, and G. Mann, "Low-Cost and Open Source SCADA Options for Remote Control and Monitoring of Inverters," in 2017 IEEE 30th Canadian Conference on Electrical and Computer Engineering

(CCECE), Windsor, ON, 2017, pp. 1-4.

[13.] S. Blanch-Torn, F. Cores, and R. M. Chiral, "Agent-Based PKI for Distributed Control System," in World Congress on Industrial Control Systems Security (WCICSS-2015), 2015, pp. 28-35.

[14.] F. C., Y. C., and L. R., "Wireless Sensor System According to the Concept of IoT - Internet of Things," in 2014 International Conference on Computational Science and Computational Intelligence, 2014.

[15.] S. Pasha, "Thingspeak Based Sensing and Monitoring System for IoT with Matlab Analysis," International Journal of New Technology and Research (IJNTR), pp. 19-23, 2016.

[16.] B. Zhu, A. Joseph, and S. Sastry, "A Taxonomy of Cyber Attacks on SCADA Systems," in 2011 IEEE International Conferences on Internet of Things, and Cyber, Physical and Social Computing, 2011.

[17.] M. Hasan and H. T. Mouftah, "Optimal Trust System Placement in Smart Grid SCADA Networks," IEEE Access, pp. 99, 2016.

[18.] D. K. Maly and K. S. Kwan, "Optimal Battery Energy Storage System (BESS) Charge Scheduling with Dynamic Programming," IEE Proceedings - Science, Measurement and Technology, 1995.

[19.] C. H. Lo and M. D. Anderson, "Economic Dispatch and Optimal Sizing of Battery Energy Storage Systems in Utility Load-Leveling Operations," IEEE Transactions on Energy Conversion, 1999.

[20.] M. S. Habibi, "Model for Impact of Storage on Spinning Reserve Requirements and Distributed Generation," in Proceedings of the 33rd Southeastern Symposium on System Theory, 2001, pp. 161-165.

[21.] T. D. H. C. Kaye and R. J., "Multiple Distributed Energy Storage Scheduling Using Constructive Evolutionary Programming," in PICA 2001. Innovative Computing for Power - Electric Energy Meets the Market. 22nd IEEE Power Engineering Society. International Conference on Power Industry Computer Applications, Sydney, 2001, pp. 402-407.

[22.] L. C. C. Fung, "Combined Fuzzy-Logic and Genetic Algorithm Technique for the Scheduling of Remote Area Power System," in IEEE Power Engineering Society Winter Meeting, 2000, pp. 1069-1074.

[23.] T. Y. Lee, "Operating Schedule of Battery Energy Storage System in a Time-of-Use Rate Industrial User With Wind Turbine Generators: A Multipass Iteration Particle Swarm Optimization Approach," pp. 774-782, 2007.

[24.] S. Xu, R. Shao, and L. Chang, "Single-Phase Voltage Source Inverter with Voltage-Boosting and Power Decoupling Capabilities," in 2017 IEEE 8th International Symposium on Power Electronics for Distributed Generation Systems (PEDG), Florianopolis, 2017, pp. 1-8.

[25.] S. Jayasinghe, T. Iqbal, and G. Mann, "IoT Based Low-Cost SCADA System for an Inverter," presented at 25th IEEE NECEC Conference, 2016.

[26.] S. L. Jayasinghe,

[27.] T. Iqbal, and G. Mann, "Internet of Things (IoT) Based Open Source SCADA for Monitoring and Controlling of Inverters," Poster session presented at: NESTNet Technical Conference. 1st Annual conference, July 21-22, 2017; Toronto, ON.

[28.] S. Jayasinghe, T. Iqbal, and G. K. Mann, "An Internet of Things Based Open SCADA for Monitoring and Controlling of Inverters," IEEE Access, 2017.

[29.] S. Jayasinghe, T. Iqbal, and G. Mann, "Optimum Control of a Grid Connected Battery Energy Storage," presented at 26th IEEE NECEC Conference, 2017.

[30.] D. Watson, C. Hastie, and M. Rodgers, "Comparing Different Regulation Offerings from a Battery in a Wind RnD Park," IEEE Transactions on Power Systems, vol. PP, no. 99, pp. 1-1, 2017. doi: 10.1109/TPWRS.2017.2747517.

[31.] G. Giroux, "Data Topology," Wind Energy Institute of Canada, 2007.

[32.] "Core IEC Standards," May 15, 2007. Accessed: 2016. [Online]. Available: http://www.iec.ch/smartgrid/standards/.

[33.] Trihedral Engineering Limited, "SCADA Software Pricing," [Online]. Available: https://www.trihedral.com/scada-software-pricing.

[34.] M. N. Ashraf, S. A. B. Khalid, M. S. Ahmed, and A. Munir, "Implementation of Intranet-SCADA Using LabVIEW Based Data Acquisition and Management," in Computing, Engineering and Information, 2009 ICC '09. International Conference on, Fullerton, CA, 2009, pp. 244-249.

[35.] A. Ujvarosi, "Evolution of SCADA Systems," Bulletin of the Transilvania University of Brasov. Engineering Sciences. Series I, vol. 9, no. 1, pp. 63, 2016.

[36.] GoGreenSolar, "SMA SB 10000TLUS-10 Sunny Boy Grid-Tie Inverter 10000W with DC," [Online]. Available: https://www.gogreensolar.com/products/sma-sb-10000tlus-10-sunny-boy-gridtie-inverter-10000w-with-dc.

[37.] A. Sajid, H. Abbas, and K. Saleem, "Cloud-Assisted IoT-Based SCADA Systems Security: A Review of the State of the Art and Future Challenges," IEEE Access, vol. 4, pp. 1375-1384, 2016. doi: 10.1109/ACCESS.2016.2549047.

[38.] A. M. Grilo, J. Chen, M. Diaz, D. Garrido, and A. Casaca, "An Integrated WSAN and SCADA System for Monitoring a Critical Infrastructure," IEEE Transactions on Industrial Informatics, vol. 10, no. 3, 2014.

[39.] E. Andreescu, H. Gurban, and G. D., "SCADA Element Solutions Using Ethernet and Mobile Phone Network," in 2011 IEEE 9th International Symposium on Intelligent Systems and Informatics, 2011, pp. 303-308.

[40.] P. Zhang, T. Liu, Z. X. Yang, Y. Mou, Y. H. Wei, and D. Chen, "Design of Remote Control Plug," in 2015 IEEE International Conference on Applied Superconductivity and Electromagnetic Devices (ASEMD), 2015, pp. 29-30.

[41.] S. Sanap, R. Nawale, S. Kapse, A. Kale, and M. Korade, "Exact Virtualization of Industrial Environment on Web Using SCADA with Artificial Intelligence," in Green Computing and Internet of Things (ICGCIoT), 2015 International Conference on, Noida, 2015, pp. 99-103.

[42.] S. G. Hegde, S. R. Desai, D. R. Gajanan, S. B. Kowligi, and S. R. C. Ndustrial Instrumentation and Control (ICIC), "Implementation of SCADA in Industries Using Wireless Technologies," in 2015, Pune.

[43.] A. Soetedjo, Y. I. Nakhoda, and D. Suryadi, "Development of Data Acquisition System for Hybrid Power Plant," in QiR (Quality in Research), 2013 International Conference on, Yogyakarta, 2013, pp. 197-201.

[44.] J. L. Sarinda, T. Iqbal, and G. Mann, "Low-Cost and Open Source SCADA Options for Remote Control and Monitoring of Inverters," in 2017 IEEE 30th Canadian Conference on Electrical and Computer Engineering (CCECE), Windsor, ON, 2017, pp. 1-4.

[45.] S. Blanch-Torn, F. Cores, and R. M. Chiral, "Agent-Based PKI for Distributed Control System," in World Congress on Industrial Control Systems Security (WCICSS-2015), 2015, pp. 28-35.

[46.] F. C., Y. C., and L. R., "Wireless Sensor System According to the Concept of IoT - Internet of Things," in 2014 International Conference on Computational Science and Computational Intelligence, 2014.

[47.] S. Pasha, "Thingspeak Based Sensing and Monitoring System for IoT with Matlab Analysis," International Journal of New Technology and Research (IJNTR), pp. 19-23, 2016.

[48.] B. Zhu, A. Joseph, and S. Sastry, "A Taxonomy of Cyber Attacks on SCADA Systems," in 2011 IEEE International Conferences on Internet of Things, and Cyber, Physical and Social Computing, 2011.

[49.] M. Hasan and H. T. Mouftah, "Optimal Trust System Placement in Smart Grid SCADA Networks," IEEE Access, pp. 99, 2016.

[50.] D. K. Maly and K. S. Kwan, "Optimal Battery Energy Storage System (BESS) Charge Scheduling with Dynamic Programming," IEE Proceedings - Science, Measurement and Technology, 1995.

[51.] C. H. Lo and M. D. Anderson, "Economic Dispatch and Optimal Sizing of Battery Energy Storage Systems in Utility Load-Leveling Operations," IEEE Transactions on Energy Conversion, 1999.

[52.] M. S. Habibi, "Model for Impact of Storage on Spinning Reserve Requirements and Distributed Generation," in Proceedings of the 33rd Southeastern Symposium on System Theory, 2001, pp. 161-165.

[53.] T. D. H. C. Kaye and R. J., "Multiple Distributed Energy Storage Scheduling Using Constructive Evolutionary Programming," in PICA 2001. Innovative Computing for Power - Electric Energy Meets the Market. 22nd IEEE Power Engineering Society. International Conference on Power Industry Computer Applications, Sydney, 2001, pp. 402-407.

[54.] L. C. C. Fung, "Combined Fuzzy-Logic and Genetic Algorithm Technique for the Scheduling of Remote Area Power System," in IEEE Power Engineering Society Winter Meeting, 2000, pp. 1069-1074.

[55.] T. Y. Lee, "Operating Schedule of Battery Energy Storage System in a Time-of-Use Rate Industrial User With Wind Turbine Generators: A Multipass Iteration Particle Swarm Optimization Approach," pp. 774-782, 2007.

[56.] S. Xu, R. Shao, and L. Chang, "Single-Phase Voltage Source Inverter with Voltage-Boosting and Power Decoupling Capabilities," in 2017 IEEE 8th International Symposium on Power Electronics for Distributed Generation Systems (PEDG), Florianopolis, 2017, pp. 1-8.

[57.] S. Jayasinghe, T. Iqbal, and G. Mann, "IoT Based Low-Cost SCADA System for an Inverter," presented at 25th IEEE NECEC Conference, 2016.

[58.] S. L. Jayasinghe, T. Iqbal, and G. Mann, "Internet of Things (IoT) Based Open Source SCADA for Monitoring and Controlling of Inverters," Poster session presented at: NESTNet Technical Conference. 1st Annual conference, July 21-22, 2017; Toronto, ON.

[59.] S. Jayasinghe, T. Iqbal, and G. K. Mann, "An Internet of Things Based Open SCADA for Monitoring and Controlling of Inverters," IEEE Access, 2017.

[60.] S. Jayasinghe, T. Iqbal, and G. Mann, "Optimum Control of a Grid Connected Battery Energy Storage," presented at 26th IEEE NECEC Conference, 2017.

[61.] D. Watson, C. Hastie, and M. Rodgers, "Comparing Different Regulation Offerings from a Battery in a Wind RnD Park," IEEE Transactions on Power Systems, vol. PP, no. 99, pp. 1-1, 2017. doi: 10.1109/TPWRS.2017.2747517.

[62.] G. Giroux, "Data Topology," Wind Energy Institute of Canada, 2007.

[63.] "Core IEC Standards," May 15, 2007. Accessed: 2016. [Online]. Available: http://www.iec.ch/smartgrid/standards/.

[64.] Trihedral Engineering Limited, "SCADA Software Pricing," [Online]. Available: https://www.trihedral.com/scada-software-pricing.

[65.] M. N. Ashraf, S. A. B. Khalid, M. S. Ahmed, and A. Munir, "Implementation of Intranet-SCADA Using LabVIEW Based Data Acquisition and Management," in Computing, Engineering and Information, 2009 ICC '09. International Conference on, Fullerton, CA, 2009, pp. 244-249.