Review of SCADA systems for Photovoltaic Power Plants

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Abstract

Supervisory control and data acquisition (SCADA) is a control system architecture which makes use of computers, networked data communications and graphical user interfaces for high level process supervisory management, also uses other peripheral devices such as programmable logic controllers and discrete PID controllers to interface to the process plant or machinery. The operator interfaces which enables monitoring and the issuing of process commands, such as controller set point changes, are handled though the SCADA computer system. However the real time control logic or controller calculations are performed by networked modules which are connected to the field sensors and actuators. The proposed review paper provides an insight of SCADA systems for electrical and power systems. The review also provides a comparative analysis of various research methodologies that have been accomplished in the said area.

1. Introduction

SCADA systems are crucial for industrial organizations as it helps to maintain efficiency, processes data for smarter decisions, and communicate system issues to help mitigate downtime. SCADA basic architecture begins with programmable logic controllers (PLCs) or remote terminal units (RTUs). PLCs and RTUs are microcomputers that communicate with an array of objects such as factory machines, HMIs, sensors, and end devices, and then route the information from those objects to computers with SCADA software. The SCADA software processes, distributes, and displays the data, helping operators and other employees analyze the data and make important decisions.

2. SCADA COMPONENTS

There are many parts or components of a SCADA system, which include hardware (input and output), controllers, networks, user interface, communications equipment and software. All together, the term SCADA refers to the entire central system. The central system usually monitors data from various sensors that are either in close proximity or off site (sometimes miles away).

An industrial SCADA consisting of the following:

1) a central host or master station unit or, master terminal unit (MTU),
2) one or more field data gathering and control units or remotes (usually called remote stations, remote terminal units, or RTU's),
3) a collection of standard and/or custom software used to monitor and control remotely located field data elements.

Contemporary SCADA systems exhibit predominantly open-loop control characteristics and utilize predominantly long distance communications, although some elements of closed-loop control and/or short distance communications may also be present. Thus, a collection of equipment that is provide the operator at remote location with enough information to determine the status of particular piece of equipment or entire substation or a plant or a dynamic network and cause actions to take place regarding that equipment or network without being physically present. It is an arrangement for operator control and separation of remotely located apparatus using multiplexing techniques once a relatively small number of interconnecting channels.

2.1 Functions of SCADA

A SCADA system performs four functions:

1. Data acquisition
2. Networked data communication
3. Data presentation
4. Control

These functions are performed by four kinds of SCADA components:

- Sensors (either digital or analog) and control relays that directly interface with the managed system.
- Remote telemetry units (RTUs). These are small computerized units deployed in the field at specific sites and locations. RTUs serve as local collection points for gathering reports from sensors and delivering commands to control relays.
- SCADA master units. These are larger computer consoles that serve as the central processor for the SCADA system. Master units provide a human interface to the system and automatically regulate the managed system in response to sensor inputs.
- The communications network that connects the SCADA master unit to the RTUs in the field.

3. SCADA Role in Electrical System

Power system deals with generation, transmission and distribution sectors, the main aspect in all these is monitoring. . Electrical power generated at generating station is transmitted to the loads with the use of transmission and distribution substations. Most of the power distribution or utility companies rely on manual labor to perform the distribution tasks like interrupting the power to loads, hourly parameter checking, fault diagnosis etc.

3.1 Features of SCADA:

- Monitoring of substation parameter: With new transformer overload, phase imbalance and peak load reports, SCADA provides an affordable way for utilities to have real time monitoring. Thereby improves the reliability, efficiency, security and cost effectively power management.

- Controlling of electrical network components remotely: Remote monitoring and diagnostic capabilities provide many advantages for manufactures. It helps in keeping equipment running smoothly, extends operational lifespan and also increases overall production uptime. The first step towards capitalizing on technology is to understand the purpose and the benefits of remote monitoring.
- Safety tagging: It is one of the most effective means to reduce the risk of fire related to faulty electrical devices. The devices are defected sometimes or wear and tear happens, dust, dirt, moisture or movement can cause problems and malfunctions, therefore electrical testing and tagging can help to identify such issues, and could be addressed before fire occurs.
- High resolution time stamping: time stamping is an important function for tracking processes in some automation systems. This function is very helpful to identify process sequences in large and complex system and thereby help in improving overall system reliability.
- Demand side management: The goal of demand side management is to encourage the customer to use less energy during peak hours, which could be helpful to reduce the need for investments in network and power plants for meeting peak demands.
- Volt/VAR control: It is a fundamental operating requirement of all electric distribution system. It helps in managing system voltage levels and reactive power flow to achieve efficient distribution grid operation. It helps to reduce system losses, peak demand etc using various voltage reduction techniques.

- Preventive maintenance: It is regularly performed so as to avoid the equipment from failing. It is performed while the equipment is still working, so that it does not break down unexpectedly.
- Fault detection isolation and restoration: Whenever fault occurs in circuit, circuit breakers protect from further damage to circuit. Re-closers can restore power in the event of a transient power line fault.

3.2 Expected benefits of SCADA for Power System:

- Quality of service improvement.
- Reliability improvement.
- Operating costs reduction.
- Maintenance /Expansion of customer base.
- Ability to defer capacity addition projects.
- High value service providers.
- Improved information for engineering decision.
- Value added services.
- Flexible billing option.
- Customer information access improvement.
- System implementation costs reduction.
- Manpower requirements reduction

4. SCADA for Power Utility Network

Power network utilities (PNU) software aims to provide the electrical utility with tools which will enhance the operation of the system in a very cost effective way.in the present scenario of low budgets for power utilities to produce and distribute quality power at the minimum cost. This goal can be achieved by proper operation of the electrical network and at the same time having real time data about state of the network. This real time data can then be used for supervisory controlled changes of the network parameters with effective guidance from distribution automation tools. The PNU software utilizes the real time SCADA data the real time network topology network component details & user defined strategies to achieve the above mentioned goals[16][17][18][19][[20]. PNU uses a combination of mathematical and logical techniques to provide the user with a host of applications for the purpose of distribution automation.

4.1 Features of Power Network Utilities

- Component Modeling.
- State Estimation.
- Bad data suppression.
- Contingency analysis.
- Fault isolation/islanding.
- Load shedding.
- Volt/Var scheduling.
- Dispatcher power flow.
- Short circuit analysis.
- Network topology processor.

SCADA function in the power system network provides greater system reliability and stability for integrated grid operation. The applications for SCADA keep increasing day by day. Some of the applications are:

- Comprehensive operational planning and control.
- Fuel resource scheduling.
- Optimum power flow.
- Network security.
- Economic dispatch.
- Generation dispatch control

SCADA is widely used in different areas from gas, water, chemical, communications and power systems. Various applications of SCADA in other fields are as follows:

a) Electric power generation, transmission and distribution: Electric utilities use SCADA systems to detect flow of current and line voltage and to monitor the operation of circuit breakers.
b) Water, Waste Water Utilities and Sewage: SCADA is being used by state and municipal water utilities to monitor and regulate water flow, reservoir levels, pipe pressure and other factors.
c) Buildings, facilities and environments: Facility managers use SCADA to control HVAC, refrigeration units, lighting and entry systems.
d) Oil and Gas Transitions and Distributions.
e) Wind Power Generation
f) Communication Networks.
g) Industrial Plans and Process Control.
h) Manufacturing: SCADA systems manage parts inventories during manufacturing, regulate industrial automation and robots, and monitor process and quality control.
i) Mass transit and Railway Traction: Transit authorities use SCADA to regulate electricity to subways, trams and trolley buses; to automate traffic signals for rail systems; to track and locate trains and buses; and to control railroad crossing gates.
j) Traffic signals: Regulation of traffic lights and control of traffic flow is done by SCADA.

5. Literature survey

With the wide use of renewable energy resource (RES), traditional energy resource structure have been adjusted and modulated. In the recent years, supervisory control and data acquisition (SCADA) system has been applied in power system substation automation and became a focus of electric utility .A brief literature review related to SCADA is presented here:

Hu Guozhen, Cai tao, Chen Changsong, Duan Shanxu, "Solutions for SCADA system communication reliability in photovoltaic power plants",2009,has presented a paper in which main component of SCADA system in PV power plants was introduced. In order to enhance the security and reliability of the SCADA system in PV plants, this paper gave two effective solutions, strategy of security access control and mechanism of redundancy. The proposed strategy of security access control adopted some measures, such as authentication of security, data encryption, as well as role-based access control. These measures solved security issues related to communication between the remote terminal units (RTU) and configuration server of SCADA [1].

R. Palma-Behnke, D.Ortiz, L.Reyes, G.Jimenez-Estevez, N .Garrido, "Social SCADA and demand response for sustainable isolated microgrids" ,2011 gave a paper which proposed a composed solution that gave a combination of a social SCADA approach with a demand response program. Thus, resulted in minimum maintenance costs and a better covering. A social SCADA solution guaranteed the participation of the community through a procedure of proper communication and exchange of information, thereby allowed them to execute tasks associated to supervision and maintenance of the micro grid and various equipment repairing [2].

Vlad-Cristian Georgescu, "SCADA software used in dispatch centre for photovoltaic parks",2014, gave a paper which classified SCADA software as a base for implementing a center for dispatch for solar parks. Various technologies were implemented on SCADA software: drivers for electrical operators, industrial database which could be used for data collection [3].

Petru-Claudiu Pasc, Cristian-Dragos Dumitru, "SCADA system for solar MPPT controller monitoring", 2015, presented a paper which dealt with the simulation of a solar photovoltaic MPPT controller used for the supply of a power consumer. The power system consists of a photovoltaic generator, controllers of MPPT, batteries, power consumers and local grid connected to it. The solar photovoltaic MPPT controller could be implemented using the "perturb and observe"(P&O) algorithm that varied PV generator voltage and returned the peak power to power consumer. The intensity of solar radiation, the power load curve and the behavior of batteries could also be related with the solar photovoltaic MPPT controller [4].

Sajjad Durrani, Muhammad Riaz, Uzair Khan, "Development of SCADA automated 230V power house as a testing platform", 2016, gave a paper which worked on monitoring and control interface for a 230V power house using SCADA. This model provided a real time environment for the user related to the automation in a substation with respect to the accuracy and reliability in its control and monitoring. The presented model allowed the comparison of the efficiency of proposed system with existing systems[5].

XIAO Zhao xia, Guo Zhijun ,Josep M. Guerrero, Fang Hongwei, "SCADA system for islanded DC Microgrids", 2017 has presented a paper which developed a supervisory control and data acquisition (SCADA) system to monitor islanded DC micro grid including wind turbine, photovoltaics and battery units .The SCADA system based on King View 6.55 and established data communication between the host and the slave computers through intelligent modules and used different communication techniques . The developed SCADA system helped in monitoring real-time para meters such as voltages , currents ,powers and stored the important parameters into the database [6].

Ao Dong, Yingying Zhao, Xiwei Liu,Qi Liu, Dahai Kang , "Fault diagnosis and classification in photovoltaic systems using SCADA data", 2017 has presented a paper which presented fault diagnosis and classification techniques using the PV plant operational data collected from the supervisory control and data acquisition (SCADA). Specifically, the proposed solution consisted of three techniques: (1) a new statistical fault detection method; (2) a corrective performance ratio(CPR) which was based on fault isolation method; and (3) an anomaly degree index(ADI) based fault recoverability analysis and classification method [7].

Qi Liu, Yingying Zhao, Yawen Zhang ,Dahai Kang, Qin Lv, Li Shang , "Hierarchical context-aware anomaly diagnosis in large-scale PV systems using SCADA data",2017 has presented a cost-effective hierarchical context-aware method for string-level anomaly diagnosis in large -scale PV systems. The proposed approach was based on unsupervised techniques of machine learning and required no additional support of hardware beyond widely adopted supervisory control and data acquisition (SCADA) systems [8].

Hamzah Hilal, Anas Nangim, "Network security analysis SCADA system automation on industrial process",2017, has presented a paper in which building and designing SCADA infrastructure and analyzing vulnerability treated to SCADA network security was conducted. The result of this research was penetration of SCADA network using Kali Linux, which could be used to attack and make data traffic between programmable logic controller (PLC) with human machine interface (HMI) became solid, and resulted from penetration testing, SCADA system became down due to data traffic on a dense network, thereby indicated that SCADA networks were exposed to malware threats and attacks, the results of this study are recommendations and network security strategy SCADA system [9].

Braulio Barahona , Cyprien Hoelzl, Eleni Chatzi, "Applying design knowledge and machine learning to SCADA data for classification of wind turbine operating regimes",2017, presented a paper which proposed a method to classify the operating rule from coarse resolution data recorded by the turbine supervisory controller (i.e. data from the SCADA system). It relied on design knowledge and algorithms for dimensionality reduction and classification [10].

Luis Rosa , Tiago Cruz , Paulo Simoes, Edmundo Monteiro, Leonid Lev, "Attacking SCADA systems: a practical perspective", 2017, presented a paper which described the implementation of a group of attacks which targeted a SCADA hybrid testbed that produced an electrical grid for energy distribution (medium and high voltage) [11].

Sarinda Jayasinghe L, Tariq Iqbal, George Mann, "Low-cost and open source SCADA options for remote control and monitoring of inverters",2017, presented a paper to compare and document low cost open source SCADA options available for remote controlling and monitoring of inverters. An interface between inverter and the SCADA has been developed, so as to achieve the objective from the client side [12].

Abimael Rangel-Damian, Enrique Melgoza-Vazquez, H.Francisco Ruiz-Paredes, “Application of fault location methods in distribution circuits with SCADA”, 2017, presented a paper which showed a study case which was prepared using IEEE 34 node test feeder which showed the information available in the electrical equipment such as voltage and current measurements, could be introduced in an impedance based algorithm for fault location, improved performance when we considered equipment not only at the substation but along the mainline of the feeder [13].

M Lanzrath, C Adami, B Joerres, G Lubkowski, M Joester, M Suhrke, T Pusch, “HPEM vulnerability of smart grid substations coupling paths into typical SCADA devices”, 2017, presented a paper which showed the results of a test campaign which was to obtain coupling paths into a laboratory test setup of a power grid substation SCADA (supervisory control and data acquisition) electronics. The devices were tested for threats in a bulk current injection (BCI) setup and led the emission of threats inside a transverse electromagnetic (TEM) waveguide as well as with a near field TEM horn antenna [14].

6. Comparative Research

NO	Researchers	Title	Method	Tool
1	Hamzah Hilal et al[7]	Network security analysis SCADA system automation on industrial process	Analysis security attack and penetration normal/ abnormal	PLC, Omron, Wireshark, Kali linux
2	Hu Guozhen et al[1]	Solutions for SCADA system communication reliability in photovoltaic power plants	Analysis on security attack and redundancy mechanism	SCADA server
3	Sajjad Durani et al[3]	Development of SCADA automated 230V power house as a testing platform	Analysis on automation of a power system	WINCC SCADA, PLC, ladder logic
4	Xiao Zhaoxia et al[4]	SCADA system for islanded DC micogrids	Analysis on islanded DC microgrid	King view 6.55
5	Ao Dong et al[5]	Fault diagonosis and classification in photovoltaic systems using SCADA data	Analysis on fault detection method, corrective performance ratio and corrective performance index.	SCADA, Hampel identifier
6	Qi Liu et al[6]	Hierarchical context-aware anomaly diagnosis in large-scale PV systems using SCADA data	Analysis of string level anomaly diagonosis	LAI, SCADA
7	Abimael Rangel-Damain et al[11]	Application of fault location methods in distribution circuits with SCADA	Analysis on fault location	DNP3 protocol, open DSS, SCADA
8	Braulio Barahona et al[8]	Applying design knowledge and machine learning to SCADA data for classification of wind turbine operating regimes	Analysis on condition and structural health monitoring	SCADA
9	Luis Rosa et al[9]	Attacking SCADA systems: a practical perspective	Analysis on targeting SCADA system	IACS, SCADA
10	Sarinda Jayasinghe L et al[10]	Low cost and open source SCADA options for remote control and monitoring of inverters	Analysis on remote controlling and monitoring of inverters	ESP-12E, SCADA

7. Conclusion and Future Scope

Supervisory control and data acquisition (SCADA) provides a architecture which makes use of networked computers with a running GUI application connected to various programmable peripheral devices for efficient supervisory management. SCADA systems are crucial for any organizations in achieving efficiency, processes data for smarter decisions, and communicate system issues to help mitigate downtime. The SCADA provides a communication between the controllers (PLCs) with remote terminal units (RTUs). The data is collected from sensors and transmitted remotely to RTU where it gets stored and analyzed for efficient decision making. The proposed paper provides a review of various techniques and procedures that have been achieved in SCADA and provides a comparative analysis of these methodologies. It is observed that these mythologies regarding SCADA provide high efficiency and robustness when integrated in systems.

The research can be extended further validating the accuracy and robustness of the proposed methods against other approaches using more datasets. An anomaly classification process could be developed so as to provide more information for scheduling operation and maintenance activities and reducing safety risks in PV systems.

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