International Journal of Engineering Applied Sciences and Technology, 2017
Vol. 2, Issue 8, ISSN No. 2455-2143, Pages 9-14
Published Online December 2017 in IJEAST (http://www.ijeast.com)

PARAMETERS OPTIMIZATION OF SCADA OPERATION OF ATHENS TRAM LINE

C. Giannopoulou
Dept. of Automation Engineering,
PUAS, Athens, Greece

M. Papoutsidakis
Dept. of Automation Engineering,
PUAS, Athens, Greece

D. Tseles
Dept. of Automation Engineering,
PUAS, Athens, Greece

Abstract- **High industrial growth in recent years, automation and control of complex systems and applications, as well the introduction of innovative technologies have made it necessary to a direct and uninterrupted control for accurate operation and reliability in systems. The SCADA system collects data and visualizes the operation of the application system by utilizing supervisory control. SCADA is an acronym that stands for Supervisory Control and Data Acquisition. This paper is an introduction on how SCADA Systems are employed by Athens Tram Line for monitoring and control Catenary and Traction Substations, as well proposals for parameters optimization of the existing SCADA system. This paper highlights the benefits of SCADA system that accrue, such as reliability, safety and immediacy in operation level, cost effective and environmental performance ensuring the continuous improvement of the quality of the services provided.**

Keywords - SCADA Systems, tram, catenary, power traction, protocols

I. INTRODUCTION

Supervising industrial station, equipments and processes on a daily basis combinated with stations located in different places via a geographical aerie is an extremely arduous task. The need for constant Supervisory Control in Real Time and Data Acquisition led to SCADA Systems. A SCADA System could be defined as the technology that enables a user to collect data from one or more distant facilities and to send limited control instructions to those facilities. SCADA makes it unnecessary for an operator to be assigned to stay or visit frequently remote locations when those facilities are operating normally. SCADA systems are major used in industrial processes: e.g. power generation and distribution, water supply systems, gas and oil pipelines.

The basic structure of a SCADA system consists of the following components:

- Master Terminal Unit – MTU, is the host computer on which the SCADA software is installed
- Remote Telemetry Unit - RTU's
- Programmable Logic Controller - PLC's
- Intelligent Electronic Devices - IED's
- Human Machine Interface - HMI
- Communication Network and Telemetry

The MTU station through the communication network (e.g. Ethernet, profidus or wireless) communicates with the local units (PLC, IED & RTU) by adopting the master-slave architecture. The data are transferred from the local units to the MTU, where they are properly processed and recorded on computers with HMI software where the operator can manually check and supervise the processes. The operator, through the computer with HMI, monitors real-time data and information and with input devices, such as keyboard, mouse or touch screens, inserts its commands and controls into the system. It's customary for computers with HMI to connect with a printer as an output device for recording SCADA data and information, as well as an alarm to inform the operator of a change that requires attention. Automatic control signals produced in the MTU are sent back to the local units, which in turn trigger the conversion devices and the machine controllers. The SCADA system software includes a variety of ready and attached functions, making it easy for the user to expand or modify it without the need to stop data collection and recording, as well as eliminating the risk of storage data loss during the modifications. The security of the SCADA system is offered at many different access levels so that is locked against unauthorized access. The access rate of each user is determined through appropriate software from the System Administrator. The evolution of SCADA systems, although it's matured in the late 1970s, has been rapid the last few years. The swift

International Journal of Engineering Applied Sciences and Technology, 2017
Vol. 2, Issue 8, ISSN No. 2455-2143, Pages 9-14
Published Online December 2017 in IJEAST (http://www.ijeast.com)

evolution of computer, electronics, automation and electrical technology has contributed to this, as well as the implementation of innovative technologies in these areas. Their evolution is usually divided into four generations:

- First Generation- Monolithic
- Second Generation- Distributed
- Third Generation- Networked
- Fourth Generation – Internet of Thinks (IoT)

The main functions of a modern SCADA system can be described as follows:

- Data Acquisition
- Supervisory Control
- Information Display- analyze, process and save and data and represent them through graphs
- Alarm Management and Processing- the system through an audio or visual signal or even a combination of both, alerts the operator
- Information Storage and Reports of historical data file
- Sequence of Event Acquisition –data are transferred to other parts of the central information and management system
- Data calculation

The use of SCADA systems has been increased in recent years, mainly because of the benefits and advantages of that presents.

- Improved quality by making the most of the resources available to the fullest extent possible in terms of use of equipment
- Records and stores information about production and management
- Improved reliability, due to forecasting and diagnosing equipment failures and localization, to maximize availability
- Reduced operating costs due to optimal use of internal energy sources and lower labor costs
- Maintenance / Expansion of the customer base and provision of high value services due to the flexibility and adaptability of production under constantly changing market conditions
- System implementation reduced costs due to minimizing maintenance costs for infrastructure equipment (such as machines, peripherals)
- Improvement of safety conditions due to the minimization of the risk of accidents at work
- Minimize of human error

II. SCADA SYSTEM OPERATION FOR CATENARY AND TRACTION SUBSTATIONS OF ATHENS TRAM LINE

The rapid development of tram technology has led to tram being considered as urban eco-friendly transportation in the context of noise and exhaust gases, as well as comfort and service to passengers. The use of electricity for tram traffic was considered an eco-friendly mean, since it does not burden the atmosphere with additional exhaust gases. The Athens Tram Line (member of STA.SY.) uses electricity, which is fed to the train via a pantograph. The electrification system that applies in Athens Tram line is consists of two major components. The first one is the Traction Substation (Traction Power System-TPS) and the second is catenary or overhead line as is otherwise known. Due to the immense importance for the smooth functioning and credibility of the electrification system, the need for immediate and uninterrupted control is deemed necessary and is achieved through the implementation of a modern SCADA system.

The electrification system is constructed in a relative large geographic area, approximately 25 km. tramway and 50 km of catenary. The electrification of the TRAM line is supported by a total of 15 Traction Substations, of which 14 are installed along the urban fabric and the 15th at depot. The Traction Substations are responsible for supplying the necessary electricity to tram. Specifically they convert the supplied power and then feed the catenary, through which the tram receives the required contact energy. The TPS Substations are designed in a simple way and include one or two traction rectifiers and two or three output feeders with one power switch for each feeder. The catenary is electrically divided into segments, through appropriate intersection points (separators), which are usually located near TPS. Between the sides of the intersection points, the feeders of a TPS substation are connected to the contact wire on both overhead lines. Suitable bypass switches enable the "intersection" of the separators and merge the neighboring segments of the catenary.

The SCADA system applied to Athens Tram line is a modern, distributed system tailored to the needs of the company. It was set up from the beginning with the commencement of operation of Tram line in the city of Athens in 2004 by Emon Electric.

The purpose of the SCADA system is the centrally control of the operation and remote control of the TPS stations through real-time visualization of differences in variations, sizes and conditions of the

International Journal of Engineering Applied Sciences and Technology, 2017
Vol. 2, Issue 8, ISSN No. 2455-2143, Pages 9-14
Published Online December 2017 in IJEAST (http://www.ijeast.com)

equipment that are compiled by local computers via compatible of internationally recognized communication protocols and transmitted to the central computer station (MTU-Server) of the system at TRAM Line Control Center. Supervisor and control of the SCADA system for catenary and traction substations is performed by an engineer operator (Power Supervisor), situated at Operation Control Center OCC).Since for security reasons monitoring the system is required for 24 hours, the workstation in OCC is a 24 hour/7 days shift.

- *Description of the established SCADA system*

The model followed by the established SCADA system can be described as following: monitoring and controlling the Traction Substations (TPS) operation and as well the operation of the switches through a local computer system / data collection (Device Information Processor-DIP Client) and intermediate data collection and transfer nodes (Full Server), who in turn end up at the central computer station (MTU-Server), which is located in OCC. Each intermediate Full Server (3 in total), in addition being the local computer of the TPS on which it is installed, collects data from four other PCs communicating with it and sends them to the SCADA server and backwards. The SCADA system processes more than 6000 data from the15 TPS stations daily.

The SCADA system consists of 15 local computers, installed one on each TPS across the network, which are part of the system's peripheral units. The 3 of these computers are the intermediate nodes of data collection and transfer to MTU, located at OCC, where the engineer operator (Power Supervisor), via the HMI interfaces, it performs supervisory and control. The MTU server runs on a Windows Server 2000 / Service Pack 4 environment and are installed WIN CC V6.00 & SICAM PAS CC V5.01 applications from SIEMENS and implements OPC technology. Each local computer consists of a rack-type industrial computer with three basic communication cards installed:

- APPLICOM, PROFIBUS FMS PCU1500PFB
- SIEMENS PROFIBUS DP, CP5613
- MOXA CP-114IS

These local computers (DIP Client) collect all the signals and all the information about the state and position of the switches and various analog magnitudes of voltages and amperages. Local computers run on Windows XP Professional / Service Pack 2. The applications installed on them are based on SIEMENS SICAM PAS V5.00.26.In particular, on the three local computers that act as servers, the applications that are installed are:

- SICAM PAS FULL SERVER V5.00,
- SICAM PAS PROFIBUS DP MASTER,
- SICAM PAS IEC-103 MASTER
- SICAM PAS OPC Client

Rest of local computers (DIP Client) has:

- SICAM PAS DIP
- SICAM PAS Driver for PROFIBUS DP
- SICAM PAS Driver for IEC-103
- SICAM PAS OPC Client

The interface from the APPLICOM card to the DIP Client is via an OPC Client-Server link. If a local computer is shut down due to a fault or error, then remote monitoring, control and operation of the individual TPS is impossible, then for security reasons the computer is turned off until the problem is restored. However, until the local PC is switched off any data and information that exists in the devices and the systems of the TPS, these are not lost but transferred to the MTU via the local computer when it is restored, because the devices and the systems have memory logging for specific period.

On the communications network, all computers for SCADA System are located on an independent virtual LAN (VLAN) network of the metropolitan area network(MAN), entirely made of fiber, using Ethernet standards, and in particular Industrial Ethernet. The communication network can be divided into two sections. The first section concerns communication between local computers (DIP Client), and the interconnection nodes(Full Server), which in turn end up at the host computer (MTU-Server) using TCP / IP communication protocol.

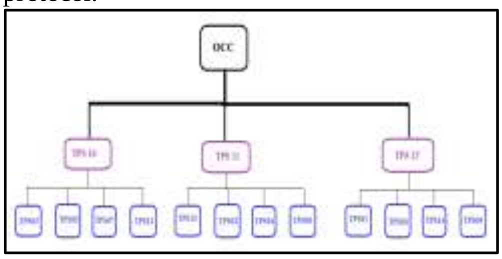

Figure 1 Architecture of Communication Network

The second part of the SCADA system communication network concerns the industrial level, the communication of the systems of the TPS substation with the local computer, for the supervisory of the operation of its equipment internally and externally with the catenary. This communication is established through the use of internationally recognized protocols Profibus DP, Profibus FMS and RS-485, which are linked to the local PC's communication cards and transfer the data to the MTU.

The basic functions and controls of the applied SCADA system are:

- Real-time (RT) display of the DC voltage and amperage of the feeders & incoming,
- Actual state of each Traction Substation
- Medium Voltage (MV) indications at the input of each TPS
  Energy consumption indications (active, reactive, total)
- Position indication (ON / OFF, Remote / Topical) for all DC circuit breakers (HSCB) and Medium Voltage switches
- Indication of the current state of the protective relays for MV and DC
- Color indication of the disconnectors positions of feeder and Bypass
- Over temperature alarm in Transformer windings,
  Fire alarm and fire system fault alarm
- Auxiliary rectifier fault
- Door open/closed

Figure 2 Real time Medium Voltage and Energy consumption for each TPS

SCADA's supervisory functions are result of intelligent devices including sensors and digital relays. For example at the MV field SIMEAS P metric device is responsible for MV indications at each station and energy consumptions.
Regarding the remote control of the existing SCADA system, it supports the manipulation of the switchgear of the Medium Voltage AC switches. Also supports ccircuit breaker and power switch (HSBC) of the incoming and feeder carriers as well as resetting the SEPCOS card of these carriers.

Figure 3 Screenshot of confirmation from user for remote control

The benefits of using SCADA system in Athens Tram line are:

- Optimal management of the equipment, materials and energy of the TPS station is ensured due to the endless monitoring of the system
- Reduced operating costs, instead of sending personnel for scans and measurements at scattered points, the entire system is controlled by the operator at OCC
- Improved reliability of the equipment and materials of a TPS station, the state of the catenary through real-time measurements over the entire network
- Diagnosing equipment failures and errors by the operator , in order to achieve procedures for solving problems by qualified personnel and to avoid incidents that may be detrimental

This can be considered the biggest advantage of using a SCADA system for Athens Tram Line, the safety. It is a mean of public transportation with basic guiding principle the safe transportation of passengers and employees. The intervention in emergency operations should be immediate and effective to avoid partial or total destruction of equipment, even human losses, which are offered to us through a SCADA system.

- *Proposals for Parameters Optimization of SCADA System Operation for Catenary and Traction Substations of Athens Tram Line*

STA.SY. and Athens Tram line as part of it is a modern company with rapid growth. The expansion of the Tram line has been approved and planned, ensuring at the same time the continuous improvement of the quality of the services that are provided. It is reasonable that main objectives with these extensions expected in the coming years, are the need to improve the level of service provided to the public and the environmental impact of the operation or installation of a tram system, as well as the more economical performance of the system. In the context of improvement, security and more cost-effective performance, the following proposals for parameters optimization of applied SCADA System operation for Catenary and Traction Substation Air Network and Traction Substations are propounded.

- Redundancy server

Because of the processes and activities in the current SCADA system are critical, and the cost of loss can be characterized high, a redundancy server must be built. As the master station MTU is a strategic part of the entire SCADA system, it is important the system reliability and availability .The best approach should be a hot standby configuration between the primary MTU and the secondary MTU [4]. A watchdog timer (WDT) could be used and activated if the primary CPU (of primary MTU) does not update or reset it within a given time period. Once the WDT is activated, a changeover is affected from the primary to the secondary CPU (secondary MTU) system. Although the installation of a redundancy Server has a high cost, the criticalness of the SCADA system's immediacy and reliability to ensure its proper function now and in the future due to the pending expansions consists an increase, of the supervisory control zones, addition of new Traction Substation, is deemed necessary.

- Remote control of disconnectors and Bypass switches

The proposal for remote control of disconnectors and Bypass switches arise from the day-to-day problems encountered during the operation of tram combined with the expansion of the tramway.

The catenary allows each part to be powered by 2 neighbouring TPS to ensure continuity of operation in the event of an error or loss of medium voltage from a TPS. In case that the second TPS is experiencing a power problem, then by adjusting the traffic load, this particular part of the catenary can be fed by the next one in the line of the system. In order to do this, local handling of the Bypass switch is required to merge, and then the unit to be fed by adjacent TPS. Until local handling is made, the tram traffic within this range is setting with a limitation, in order not to provoke a sudden increase in demand by causing a short circuit or exceeding the maximum allowable current of the feeder Due to the limitation of tram numbers within the scope of the feeder, it is reasonable to create time delays in the tram routes with direct consequence to the inconvenience of the passengers.The capability of remote control of Bypass switches, by the operator means direct merge of the TPS to provide sufficient supply to catenary without creating time delays as well as the risk of short circuit would be eliminated. The remote control of the disconnectors is clearly proposed for safety and protection reasons, since in case of fire there is no immediate isolation of the power supply to the catenary. The cost of activate the remote control of the disconnectors and Bypass switches s is low since there is already automatic control within the TPS which is not connected to the SCADA system. In SCADA system there is only the display of the switching positions.

- *Water level detection/flood water sensor or humidity sensor*

The cause of this proposal is deducted from changes in weather conditions that have been observed in recent years, such as heavy rainfall and in combination that some TPS are underground, has as result water inflow. The detection of water level or the increase of humidity through a suitable sensor in the interior of an underground TPS will inform the SCADA system via an audible alarm when it exceeds the maximum allowable limit, allowing the operator to intervene and protect peripheral units or update the technicians in time for pumping water or even actuating by remote control or automatically a water pump for pumping water. This proposal is basics a precautionary measure to ensure the proper operation of TPS equipment, as the problem of water flow in an underground TPS is currently addressed by sending the technicians to check the TPS state and in any case where the water level is high, the TPS is put out of service for safety reasons until the water is pumped.

Although, someone will consider the installation of this proposal a high cost, since through supervisory the proper operation and protection of the equipment is ensured, as well as a reduction cost after minimizing the movement of the technicians, its implementation over time will result in a cost reduction.

III. CONCLUSIONS

The demands of the times combined with the expansion of Athens tram line create needs for improvement of the services provided at the operational, financial and environmental level. The suggestions made in the previous chapter are aimed precisely at this. The installation of a redundancy server, the ability to remotely operate additional switches, and the implementation of intelligent devices (sensors), contribute to the most cost-effective system performance. Over time, the cost reduction will be evident due to more accurate control of the equipment by eliminating faults and errors which, through the information and data acquisition , will make it possible to predict them and thus to properly address them. At the environmental level, the data from the electricity (zero pollutants, low noise emissions)that is used is collected through the SCADA system, allowing with the assist of machine learning in the future, to train the system with the appropriate algorithm to make better use of energy and cost reduction with proper distribution of electricity.

ACKNOWLEDGEMENT

All authors would like to express their gratitude to the Post-Graduate Program of Studies "Automation of Productions and Services" of PUAS, for the financial support to undertake this research project

IV. REFERENCES

[1]. Boyer S.A., "SCADA: Supervisory Control and Data Acquisition" ISA- The Instrumentation, Systems and Automation Society, 3rd edition June 2004

[2]. Cartiman Iman, «These 3 SCADA Architectures below You Must Know Deeply», https://program-plc.blogspot, 18 September 2015

[3]. Kefalas G., Iliopoulos A, " Electrification System of Athens Tram line: Traction Substations", Athens, January 2006

[4]. National Communications System, "Supervisory Control and Data Acquisition (SCADA) Systems", Technical Information Bulletin 04-1, October 2004

[5]. Emon Electric SA Romania « Scada Operating & Maintenance manual, Modern Tramway in Greater Athens», volumes 1&2, October 2005

[6]. David Bailey and Edwin Wright, "Practical SCADA for Industry", IDC Technologies, 1st edition 2003

[7]. Gordon Clarke, Deon Reynders and Edwin Wright, "Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems", Newnes An imprint of Elsevier, 2004