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The Performance-Cost Effect of the SCADA System on Distribution Networks

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Abstract: *The central management systems that are established to see and control the parameters in Remote Terminal Units are called as SCADA (Supervisory Control and Data Acquisition) Systems. By using these systems, advantageous results are received in terms of time, number of personnel, and safety of life and property. For this purpose, an application study has been performed in a 36 KV electric distribution network with a SCADA Center (Master Terminal Unit-MTU) and 10 pieces of Remote Terminal Units-RTUs. The software used was C++, and the system with and without SCADA were compared in terms of the number of monthly and annual breakdowns, the duration of the cut-off and costs. It was observed that the SCADA System which was applied in the context of the study, increased efficiency by decreasing the number of the breakdowns and cut-off duration. In addition, the decrease in the cost in the establishment of the SCADA System, the decrease in maintenance costs in the first year, and the decrease in the cut-off duration made it possible to sell more energy and thus converted the system into a profitable one.*
Keywords: *grid monitoring and measurement; power system control; economic dispatch*

I. Introduction

SCADA System can be used in every field from energy automation to adjusting the water debit of the hydraulic power plant, from the efficient working of water distribution pump to thermal-fuel power plants or to the cars used in transportation, from the heating-cooling systems in buildings, and to works aimed to decrease the environmental influences of energy production and distribution [1-2].The purpose in SCADA System is transporting current, voltage, active-reactive load, power factor, harmonic frequency components parameters, and cutter-separator status and alarm information of the electricity distribution plants diffused to a wide area to the center, and remote-controlling this system. By doing so, collecting the signals and measurement values in the sub-stations in the command and control center, and saving time and staff will be possible. The measurement values like relay status information, bus voltage, feeder and transformer active-reactive power, feeder currents and transformer temperature may be obtained with SCADA system [3-7]. The cutter, separator, tap-changers, relay settings and feeder separators may be remotely controlled by observing the status of the breakdown sensors and separators on the feeders [8,9].

II. The Structure of the SCADA System

The SCADA System in electricity plants consists of three parts. These are MTU, RTU and Communication System. The sample chart of the SCADA System whose application has been performed is shown in Figure 1.

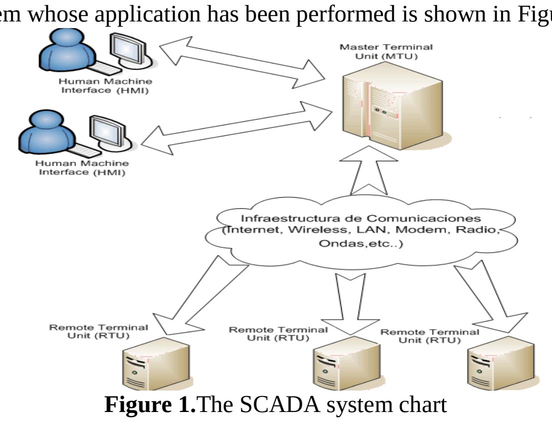

Figure 1. The SCADA system chart

2.1. Remote Terminal Unit

RTUs are the systems that constitute the data collection and control edge units. RTUs collect the data, alarms, status information and counter information needed in the centers they are connected to, and keep them in their memories. These data are kept for certain periods that are preset or until the MTU questions them. The data collection process is performed with certain periodical intervals, or when the values deviate from the adjusted values to record the new values [10]. The values like current, voltage, active and reactive power are received by using the measurement transformers and transducers that are isolated from the system. RTUs perform collecting and sending data by connecting in RS-232 or RS-485 serial form. This situation is a disadvantage for SCADA; however, it is preferred because it simplifies the data transfer. RTUs process the data collected through a pre-processor and convert these data into user defined ones. In other words, after some analogue data are converted into digital data, they are subjected to comparison with the limit values of these values or to mathematical calculation via a database formed in RTU. After these processes, it is revealed whether the data are worth sending to the control center or not. After the data are received and processed, they are sent to the MTU if necessary or stored in the RTU to be sent when questioned. These data stored are recorded to the database formed in the RTU according to the occurrence order. In addition, RTUs perform detection of breakdowns and isolation as well. RTU senses the breakdowns by using the Breakdown Interface module and the Breakdown Current Sensor Modules that are connected to it. RTU sends the necessary command to question all breakdown sensors via the Breakdown Interface. The interface communicates with the Breakdown Current Sensor Modules and learns the points where the breakdown current passes and sends it to RTU [11]. In the light of these data and the commands coming from the control center, RTU acts to isolate the breakdown area of the system, and sends the necessary commands to the Breakdown Current Sensor Modules, and thus, the breakdown isolation is completed.

It is known that finding the breakdown point and isolation of this takes hours with classical methods. Instead, breakdowns are detected and isolated in seconds with the SCADA System [12, 13]. This process takes 1-10 seconds. With this function, the SCADA System ensures important advantage for the user, and ensures that the detection of the breakdown point and the solution are solved in the most economical way.

2.2. Communication System

Communication systems ensure the mutual data communication from an area to another area. The obtaining of the data by communication channels and the speed of the data transfer speed influence the SCADA System. The success of the SCADA System depends on the communication system. Voltage lines, telephone lines, cable-TV lines, communication in radio frequency (radio, satellite), fiber optic, and special lines with metallic cables may be used as communication media in SCADA Systems.

The communication between the SCADA and the devices in the field may be performed via various ways. Communication may be ensured via serial communication port like RS232/RS485, Ethernet, GSM modem and Radio modem (wireless) [14-17]. The RS232/RS485 serial communication port was used in this study. The communication chart of the SCADA System is given in Figure 2.

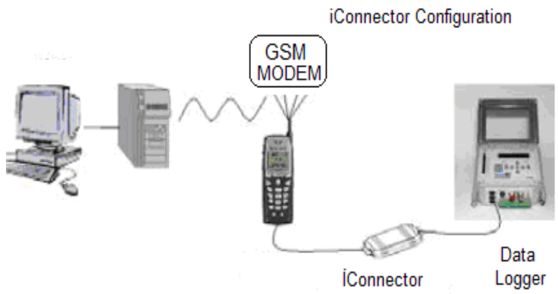

Figure 2.SCADA system communication chart.

2.3. Communication Protocols in SCADA Systems

The Remote Terminal Units ensure the communication via communication protocols in SCADA System. The data communication protocols are the sets of rules that define the communication between the control center and the RTU, or the communication among the RTUs. Different communication protocols may be used in the communication between the control centers and between the RTUs. It is possible that the control center communicates with different RTUs and the RTUs communicate with more than one control center with the help of these protocols. In addition, it is not necessary that these ports use the same communication protocols. Two different communication protocols may be used in two different ports. This advantage ensures us communicate with computer systems that use different protocols. However, it is necessary that the same protocol is used between an MTU and RTU that will communicate with each other. Many communication protocols may be used in communication systems. Today, IEC communication protocols are used commonly. IEC 870.6, which is one of the communication protocols of IEC, regulates the communication between the control centers, and the IEC 870.5 regulated the communication between the control centers and the RTU[14-17].

2.4. Master Terminal Unit

Master Terminal Unit is the center where the plants located in a wide area are controlled, monitored and managed with a computer-based structure remotely. The MTU collects the incoming data, processes them and sends them to the screen-printer. It is used to produce control commands and alarms, or sending the incoming alarms to the operator in the fastest manner. It records the events and data according to the sequence. It transfers the data to the MTU when asked to the RTU. The MTU arranges and visualizes these data in the form of graphics and tables. The communication between the MTU and the RTU is a two-way communication; however, the RTU cannot start communication. The operator was enabled to reach the system data with a password for security reasons in this study. If the operator does not have the password, only the graphics are visible for the operator, and the operator cannot intervene to the system. While it is possible for an operator to have higher authorization levels, another operator may be authorized in a limited manner to intervene to permitted functions. Serial protocols (IEC 60870-5-101, 102, 103) were used in this study for instant and fast communication in RTUs between the protection and measurement devices and the SCADA center[14-17].The software used and established in this study was performed with C++. Since the C++ software installed in the system supported Windows and communication protocols, and since it is easy to use, and may reply to the needs in the future by working in agreement with many databases with its high capacity.

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III. SCADA Application Circuit

3.1. SCADA Pack 32P

SCADAPack RTU is a programmable control device designed to be used in SCADA. SCADAPack 32P RTU is a device that works without the need for heater or cooler, between the -40°/70°C range, resistant to 95% humidity rate, works with Modbus RTU, Modbus ASCII, DF-1, DNP3.0 standard protocols, its protocol may be developed with C/C++, ensures the possibility of changing within the application while the application is working, fed by AC or DC, it has integrated power source, ensures high protection in physical inputs and outputs, and has store and forward property, enables remote programming, and has the property of upgrading software with integrated data logging function[14-17].The assembled visual of the SCADAPack 32P model RTU is given in Figure 3; and the properties of the SCADAPack 32P model RTU are given in Table 1.

Figure 3.SCADA Pack 32P assembled view

Table 1. Characteristics of SCADA Pack 32P[14-17].

SCADA PACK 32P	
Anolog Inputs	
On-Board	None
Expansion	128 Channels
Anolog Outputs	
On-Board	None
Expansion	64 Channels
Digital Inputs	
On-Board	3(24VAC / 30VDC, sharedwithcounterinputs), 1(30 V interruptinput)
Expansion	512 inputs
Digital Outputs	
On-Board	1(Controller Status Output)
Expansion	512 Outputs
Frequency Inputs	
On-Board	3 (0-5 KHz, sharedwith digital inputs) 1(0-500 Hz, interruptinput)
Expansion	64 inputs
Turbine inputs	None
Communication Ports	2, RS232
	1, RS232/RS485

3.2. iConnector

It is an adaptor that ensures loaded devices to connect to the Internet over the wireless modems using IC101 iConnector and data enabled phones, AMPS, CDMA, CDPD, GPRS, GSM, IDEN, and TDMA networks. iConnector ensures instant connection for the existing devices loaded without a change in hardware between the Internet and the main device. iConnector may store data and may be updated by connecting remotely. It is sufficient to load iConnector to the telephone in order to enable the Internet only with a device and a wireless modem. This eliminates the need for the change in the main application by connecting as a direct serial-Internet port server. IC101 is connected to the Serial Port of the main device with a DB-9 connector. The modem is connected over this DB-9 connector. iConnector may be connected for the main device with DB-9 connector pin 9 or with an external power supply [13-16]. The iConnector used in this application is shown in Figure 4.a. The performance and hardware properties of the iConnector are given in Table 2.

Table 2. Performance and hardware properties of iConnector[14-17].

iConnector Performance Specifications	
Host Data Rate	Upto 115,000 bps
Data Format	Asynchronous, character, serial, binary, 8 databits, noparity, 1 stopbit.
Standard Operating Mode	Fullduplex; autoredial, tone dialing.
Flow Control	Hardware (DTR, RTS, CTS, DCD) andsoftwareflowcontrol
iConnector Hardware Description	
Operating Humidity	90% maximum (non-condensing)
Commercial Temperature Range	0° to 70° C (32° to 158° F)
Industrial Temperature Range	-40° to 85°C (-40° to 185° F)
Power Supply Input	5-24 VDC
Power Consumption	0.4 W
Connectors	2 DB-9, 1.3 mm power jack
Host Interface	RS-232

3.3. Isolated Converter

IFD8500 RS-232 - RS485/422 Isolated Converter is advice that converts the RS-232 signals into RS-485/RS-422 signals in order to enable communication. This device enables communication only with a RS-232 interface device and a RS 485/RS-422 device without the need for hardware. The Feeding Voltage is within +9V and +35V DC range, power consumption is 1.2 W and isolation voltage is 3000V DC. The operating logic of isolated converter is as follows;

LED Display:

- If the device is with energy and there is no data transfer on the RS-485/422 data route, the Green LED is ON.
- If there is data transfer from RS-485/422 to RS-232, the Red LED is ON.
- If there is data transfer from RS-232 to RS-485/422, the Green LED is ON.
- Data transfer with RS-485:

RS-485 ensures the Half-Duplex communication of many receivers of senders over one single line[7-10].The visual of the isolated converter is given in Figure 4.b.

(a) (**b**)

Figure 4. View of iConnector and isolated converter: (**a**) iConnector view; (**b**) Isolated converter view [14-17].

3.4. Modem

A Siemens brand GSM Modem was used in this study. The Siemens terminal type modem has the following properties; dual-band GSM 900/1800 MHz, DB15 RS232 interface, SIM application toolkit, supply voltage range 5-24 V, temperature range normal operation -20°C to +55°C, data transmission up to 14.4 kbit/s, point-to-point SMS cell broadcast, mini-SIM card reader. The RTU panel that is produced for the SCADA System in this study is shown in Figure 5.

Figure 5.RTU SCADA board

IV. Working of the SCADA Systems

The working of the system may be monitored over the charts drawn, and the on/off positions of the swithes and cutters and the breakdown information may be monitored in relevant pages. On and off commands may be given to the switches and cutters by the operator. In the system with SCADA, sudden current changes are encountered within the day for each 3 phases, which is observed in Figure 6. During the day, sudden current changes were observed for 12 times, and the RTU steps in without waiting for the defined periodical time, and sends the feeder information to the MTU. In this application, in order for the RTU to send the information to the MTU without waiting for the periodical time, the then-present current must vary at a rate of 15% [18]. The cutters may be energized for two successive times with remote control against the breakdown in the system. However, if the breakdown in repeated for twice, the SCADA System does not energize [19]. In such a case, the action is defined by the operator. In other words, maintenance teams are guided by the operator for manual intervention. The daily sudden current changes for 3 phases are shown in Figure 6.

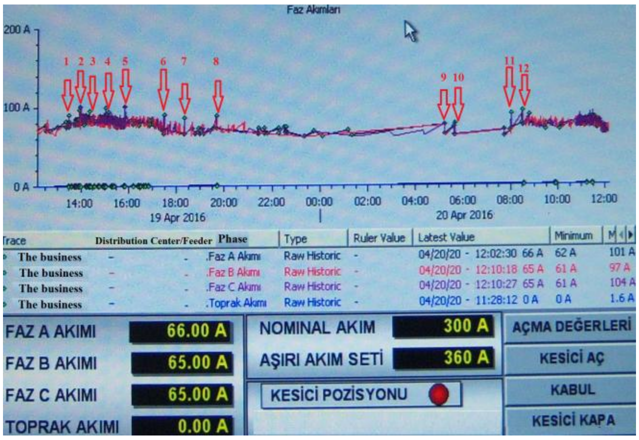

Figure 6. Daily sudden current changes for 3-phase

Please use this document as a "template" to prepare your manuscript. For submission guidelines, follow instructions on paper submission system as well as the Conference website. The MTU main control-command screen are shown in Figure 7.

Figure 7.MTU main control-command screen.

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.Materials and Methods should be described with sufficient details to allow others to replicate and build on published results. Please note that publication of your manuscript implicates that you must make all materials, data, computer code, and protocols associated with the publication available to readers. Please disclose at the submission stage any restrictions on the availability of materials or information. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited.Research manuscripts reporting large datasets that are deposited in a publicly available database should specify where the data have been deposited and provide the relevant accession numbers. If the accession numbers have not yet been obtained at the time of submission, please state that they will be provided during review. They must be provided prior to publication.Interventionary studies involving animals or humans, and other studies require ethical approval must list the authority that provided approval and the corresponding ethical approval code.

V. Discussion

The annual number of the breakdowns according to the months of the system with and without SCADA is shown in Figure 8.

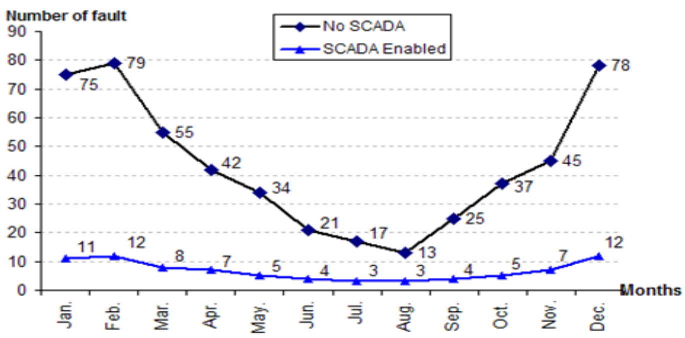

Figure 8. Annual number of the breakdowns according to the months

The annual number of the cut-off duration according to the monthly data of the system with and without SCADA is shown in Figure 9.

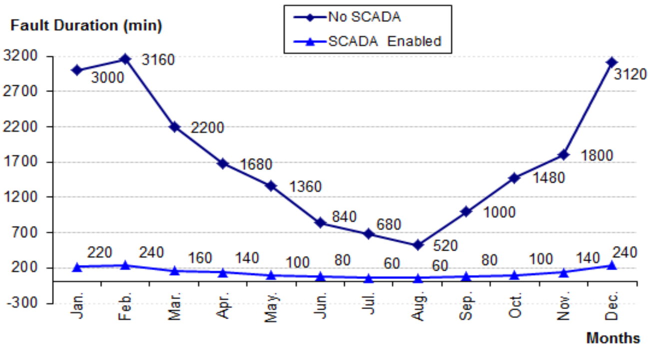

Figure 9. Annual total cut-off duration according to monthly data

The comparative analysis of the system with and without SCADA has been given in Table 3.

Table 3. The comparative analysis of the system with and without SCADA.

Event	System without SCADA	System with SCADA	Explanation
Number and Type of Breakdowns	521 permanent and temporary breakdowns	81 permanent breakdowns	440 temporary breakdowns were recovered with the help of SCADA. The number of breakdowns decreased at 84.45% with the help of SCADA.
Annual Total Cut-off Duration	20.840 minutes 320 hours	1.620 minutes 27 hours	Energy cannot be sold during cut-off. The duration of cut-off decreased at 84.37%. Energy sale increased and the profit increased.
Additional Cost	0 $	40.000 $	SCADA first establishment cost
Number of Subscribers	15.000	15.000	Number of Consumers based on RTUs

Since the energy parameters are continuously monitored, the consumption is kept under constant control. With the help of the automation systems, the distribution system is taken under control with few personnel. Instead of keeping personnel in each sub-station, the number of the personnel was decreased to the number of the personnel in one single center.The instant values of the parameters of the system may be monitored and the instant values have been reached. With the help of SCADA, the energy quality level has been reached. Since the whole of the system is monitored in one computer, the changes in the status in the system are informed instantly and the breakdown is either prevented or intervened instantly. Instant information is received about the place and reason of the breakdown, and all the system is under control from one single center.With the help of SCADA, the load levels of the transformers are checked, and the loads of the transformers with lower loads have been transferred to other transformers. Saving has been made due to the internal losses that previously used to work in vain.The chance has been created for running the current plants in an efficient manner, and cancelling the investments that were meant to be made in this field, and efficient plans for the future has been made possible.The managers have been provided with reliable, fast and economic system management.Some risks have been eliminated in terms of the safety of life and property. For example, the risks like the cutter being turned off against the ground, or the separator is prevented from being turned on under load, have been eliminated with the SCADA System.The automation system works according to the desires of the user, and it will command the field hardware, and therefore more reliable and safe working has been ensured when compared with the man-made control systems.

VI. Conclusions

As a result, one of the most efficient methods of ensuring that the energy is sustained and the system losses are kept at a minimum level in areas where electricity cut-off is frequent is the establishing of systems for the purpose of managing, controlling and monitoring all the stages of energy from production to consumption. There are few SCADA applications in Turkey. It is expected that there will be increases in the use of SCADA with the privatization in the energy sector. With privatization, the relevant distributions companies must start SCADA systems in order to decrease the investment and operation costs, and to increase the continuity and reliability of the system, and to ensure customer satisfaction. Otherwise, distribution companies will be faced with high penalty fines.

The number and the duration of the cut-off due to breakdowns decreased. The hourly energy cut-off durations are decreased to minutes. With the help of the automatic on/off, the network cut-off is reflected to the clients at the least level.The energy map of the plant has been drawn, and improvement works has been done for the energy saving (lost-faulty current) at dense consumption points thus increasing the efficiency. The status of some feeders consuming excessive current has been monitored on the screen, and the system has been intervened without opening the feeders with the help of the alarm system. The material fines caused by the cut-offs that exceeded the defined annual cut-off value are not paid. The sales of the electricity and the profitability have been increased.

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References

[1] Cengiz M.S., Mamiş M.S. Price-Efficiency Relationship for Photovoltaic Systems on a Global Basis,*International Journal of Photoenergy*, 2015(2015), Article ID 256101, 12 pages.

[2] Cengiz M.S., Mamiş M.S. Thermal Solar Energy Use and Turkey Analysis, *BitlisErenUniv J Sci&Technol*,5 (2), 2015, 88-91.

[3] Efe, S.B. Effects of Faults on Power-Flow Analysis for Microgrids, *8th International Ege Energy Symposium and Exhibition*,Afyon, 11-13 May 2016.

[4] Cengiz M.S. System Optimization On Smart Grid, *International Journal of Electrical and Electronics Engineering,* 2014, 1(8), 28-32.

[5] Cengiz M.S. Evaluation of Smart Grids and Turkey, *Global Advanced Research Journal Of Engineering Technology and Innovation*,2014, 3(7), 149-153.

[6] Cengiz M.S.,MamişM.S. Solution Offers For Efficiency and Savings in Industrial Plants, *BitlisErenUniv J Sci&Technol,* 5 (1), 2015, 24-28.

[7] Cengiz M.S., 2013. Smart Meter and Cost Experiment, *Przeglad Elektrotechniczny*,2013, 89(11), 206-209.

[8] Abdul-Rahman, K.H.; Shahidehpour, S.M. A Fuzzy-Based Optimal Reactive Power Control. *IEEE Transactions on Power Systems*, 1993, 8(2), 662-670, DOI 10.1109/59.260814.

[9] Handschin, E.; Dornemann, C. Bus Load Modelling and Forecasting. *IEEE Transactions on Power Systems,* 1988, 3(2), 627-633, DOI 10.1109/59.192915.

[10] Qiu, B.;Gooi, H.B.; Liu, Y.; Chan, E.K. Internet-based SCADA display system. *IEEE Computer Applications in Power*,2002, 15(1), 14–19, DOI 10.1109/67.976986.

[11] Ong, Y.S.;Gooi, H.B.; Lee, S.F. Java-based applications for accessing power system data via Intranet, extranet and Internet. *International Journal of Electrical Power & Energy Systems*, 2001, 23(1), 273–284, DOI 10.1016/S0142-0615(00)00057-0.

[12] Sefriti, S.;Boumhidi, J.;Naoual, R.;Boumhidi, I. Adaptive neural network sliding mode control for electrically-driven robot manipulators, *Journal of Control Engineering and Applied Informatics*, 2012, 14(4), 27-32.

[13] Ertuğrul, Ö.F. Forecasting electricity load by a novel recurrent extreme learning machines approach, *International Journal of Electrical Power & Energy Systems,* 2016, 78, 429-435.

[14] iConnector-iC101-Wireless Internet Adapter, IC101-FM-I-1-Connect-One-datasheet-11547993.pdf, (Publication Number 17-9100-04)

[15] SCADAPack 32-IEC 61131-3 Quick Start Guide, SCADAPack32_Quick_Start.pdf

[16] SCADAPack Controllers, SCADAPack Comparison Chart.pdf

[17] SCADAPack-Hardware Manual, SCADAPack 32P Controller.pdf

[18] Yao, A.W.L.; Ku, C.H. Developing a PC-based automated monitoring and control platform for electric power systems, *Electric Power Systems Research,* 64, 2003, 129–136.

[19] Wang, H.P.; A. Pintea, N.; Christov, P.; Borne, D. Modelling and recursive power control of horizontal variable speed, *Control Engineering and Applied Informatics,* 14(1), 2012, 34-41.

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