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Review

Using SCADA System to Improve Electricity in Gaza Strip

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Power networks in Gaza Strip are complex systems that cannot be efficiently and securely operated without an energy management system. Electric power which is fed to Gaza Strip comes from three main sources: the Gaza Power Station, Israeli Electric Company, and Egyptian Power Company. In spite of the existence of these sources, the electric power in Gaza Strip is facing several problems: Non-optimal and unfair distribution of electric power to all consumers, the presence of significant losses on the distribution network, and the lack of monitoring and control systems that monitor the status of the network over the time. This paper proposes a new technique for the first time on the electric power network in Gaza Strip. This technique uses the Supervisory Control and Data Acquisition (SCADA) system that depends on the optimal power flow (OPF). The middle area of Gaza Strip is taken as a case study in this research to apply the proposed technique using SCADA. Then, a model is assembled and simulated and a comparison between mathematical and simulated result is performed where good results are obtained.

Keywords: SCADA System, Optimal Power Flow (OPF), Gaza Strip.

INTRODUCTION

Electricity plays a major role in modern society; moreover, its consumption rate is a valuable index in determining the standards of livings. Palestinians in the West Bank and Gaza Strip have been living under Israeli occupation since 1967. Gaza* Strip is one of highest overpopulated regions in the world; there are 1.6 million people in 360 km2. In addition, it suffers for poor and unstable electric power. Power networks in Gaza Strip are complex systems that cannot be efficiently and securely operated without an energy management system (Hassona, 2010).

Gaza Strip completely depended on Israel for their electricity supplies until 2002 when Gaza Power Generation Company was founded. This newly founded company was supposed to supply Gaza Strip with all of its power demands; however, it currently supplies 70MW out of the 300MW of total demands and the power generation company totally depends on fuel from Israel which leaves its operation under the mercy of the occupier. Currently, Israel supplies Gaza Strip with 120MW and Egypt adds another 19MW which leaves Gaza Strip with power shortage of about 90MW. Consumption numbers shows that average monthly electric energy consumption per capita in Gaza Strip is 57 KWh for 2011 compared to 594.425 KWh in Israel (Gedco, 2012).

This leaves Gaza Strip to suffer from daily scheduled electric power outages. Many of the 1.6 million Palestinians residing in the Gaza Strip must cope with scheduled electricity cuts of 6-8 hours daily due to the increment in annual demand growth where the rate of

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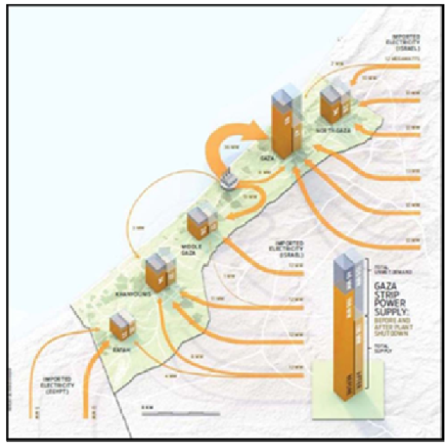

Figure 1: Power feeders of Gaza Strip, its demand.

electrical deficit reached 30 % in the year 2011 (PENRA, 2010). Due to the sage in Gaza Strip, measures to generate more electricity are not successful; thus, energy management measures are the only option left.

Gaza Power Generation Station was built using four turbines with combined cycle operation to provide Gaza Strip with 140MW with the ability to expand to produce 280MW and was designed to use natural gas or diesel as fuel (PENRA, 2010). After 2006 and Israel bombarding of the main substation, the power station was able to produce a maximum of 72MW (Weinberger, 2009). To meet the local demands with the limited power resources, the distribution company schedule daily power cuts for the whole Gaza Strip. Moreover, residents and companies in Gaza Strip went their own way to solve the power outage by buying small power generators that runs on either gas or diesel. These generators are disaster for the local environment with enormous heath consequences. Since the ability to produce more electric power is limited due to the sage on Gaza Strip that was imposed by Israel since 2006 (Weinberger, 2009), a power saving scheme is necessary in order to save energy and allow more power for distribution.

Electric distribution network is the final phase in the delivery of electricity to end users. A distribution system's network carries electricity from the transmission system and delivers it to consumers (Wikipedia, 2012). The electrical network in Gaza is considered radial (Gedco, 2012). A distribution network always involves interlaced radial feeders. Radial feeders are laid out in interlaced manner where two or more feeding alternate transformers into a secondary network (Willis, 2005). A radial network leaves the substation and passes through the network area with no normal connection to any other supply. This is typical of long rural lines with isolated load areas while an interconnected network is generally found in more urban areas and has multiple connections to other points of supply (Stott, 1974). These points of connection are normally open but allow various configurations by the operating utility with closing and opening switches. These switches may operate by remote control from a control center or by a lineman. The benefit of the interconnected model is that in the event of a fault or a required maintenance, a small area of network can be isolated and the remainder kept on supply (Willis, 2005). The main sources of electricity in Gaza are: Gaza Power Station, the Israeli Electricity Company, and the limited power line that comes from Egypt, which feeds the southern part of Gaza Strip (Weinberger, 2009), (Wikipedia, 2012).

Therefore, the resources of power in Gaza strip are limited. Poor mentoring and controlling systems to rationalize and to secure electric power characterize the existing situation; however, the infrastructure of power system in Gaza is not completed nor organized (Hassona, 2010). The limited power supply coupled with low quality of the supplied power and a growing power demands in Gaza Strip, necessitates performing research studies that aim to manage the current situation. Such studies involve cutting down losses, improving the voltage and current supplies, limiting the power outages hours and improving system's efficacy and reliability. This study uses a SCADA system to improve the power quality and to coordinate between power supplies by monitoring the current power supplies, balancing the three-phase lines, and controlling the quality of the supplies.

This paper is organized as follows: section 2 talks about the power systems in Gaza Strip, section 3 talks about optimal power flow problem and analysis in Gaza Strip, section 4 shows solution to the optimal power flow problem, section 5 presents design of a SCADA system based OPF, section 6 runs and tests the designed system, section 7 concludes this paper.

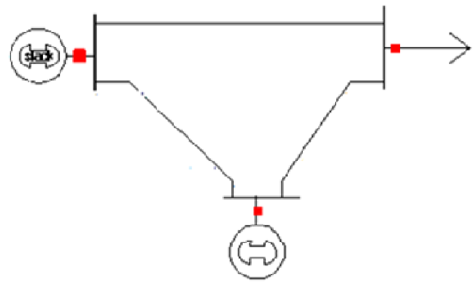

Figure 2: Three bus system in Middle region

POWER SYSTEMS IN GAZA STRIP

The situation in the Gaza Strip differs from the ideal one; the Gaza Strip depends on three different sources of energy as shown in Figure 1. It also includes a distribution networks for these sources without the presence of a real transmission networks due to various factors currently preventing the existence of such networks, in addition to an absence of coordination of supplies between these sources. The supplies are based on needed demands but supplies are always significantly less than demands.

The needs vary from season to season, time to time, and governorate to governorate. Most of the operations are performed manually; thus, resulting in many errors that adversely affect the efficient of the system and the energy that must reach consumers. From the viewpoint of system automation, Generating Unit Control is a complete closed-loop system and a lot of effort has been dedicated to improve the performance of the controllers in the last decade. The main problem with excitation control is that the control law is based on a linearized machine model and the control parameters are tuned to some nominal operating conditions. In case of a large disturbance, the system conditions will change in a highly non-linear manner and the controller parameters are no longer valid. In this case, the controller may even add a destabilizing effect to the disturbance by adding negative damping.

Gaza Strip relies on three main sources of power: Gaza Power Station, the Israeli Electricity Company, and the limited power line that comes from Egypt, which feeds the southern part of Gaza Strip. Gaza is fed with electricity as follows (Gedco, 2010):

- Ten Israeli lines, 12 MW for each line; a total of 120 megawatts divided as follows:
  - Gaza City: Dome line, Baghdad line, Sha'af line, and the sea line (shared between Gaza City and the north area).
  - North area: Jabalya line and Beit Lahiya line.
  - Central area: Line K7 and line 11 (shared between the Central area and Khan Younis).
  - Khan Younis: Line 8.
  - Rafah: Line 9 (joint between Khan Younis and Rafah).
- Two lines from Egypt 5 MW and 12 MW. It feeds Rafah area in the south.
- Gaza power plant with nominal capacity of each generator is 140 MW. The generators transformers were destroyed in 2006 as a result of the Zionist shelling. After a partial reform, the current production capacity of the generators is 78 MW (Weinberger, 2009).

OPTIMAL POWER FLOW PROBLEM & ANALYSIS IN GAZA STRIP

Optimal Power Flow (OPF), or load flow calculates a state of the power system and values of the control variables which minimize a given objective function (e.g. generation cost, network losses, etc.) and at the same time satisfy all constraints imposed on the problem (Willis, 2005), (Stott, 1974), (Lezhnuk et al, 2004). The objective here deals with network losses. OPF analysis is an important part of power system design procedures (system planning) (Stott, 1974). The OPF problem models the nonlinear relationships among bus power injections, power demands, and bus voltages and angles, with the network constants providing the circuit parameters (Stott, 1974). It is the heart of most system-planning studies and also the starting point for transient and dynamic stability studies. This section provides a formulation of the OPF problem and its associated solution strategies. Power flow is the name given to a network solution that shows currents, voltages, and real and reactive power flows at every bus in the system (Lezhnuk et al, 2000), (Saada, 2002).

This section uses the middle region in Gaza Strip as a case study, and utilizes several analysis methods to obtain Optimal Power Flow (OPF) solutions using MATLAB and PowerWord. The Middle region depends on two sources of power: the first source is from Gaza Power Station: with a feeder around 16 MW from lines (J1, J2, J4, J5, and J10), and the second source is Israeli Electricity Co. (IEC) with a feeder around 12 MW form line (F7) (Weinberger, 2009). The next step will be

Table 1: Line impedance and line charging data.

Bus #	Bus Voltage		Power Generated		Load	
	V(p.u)	*Θ(deg)*	*P(MW)*	*Q(MVAR)*	*P(MW)*	*Q(MVAR)*
1	1.05	0	NA	NA	0	0
2	1	0	0	0	96	62
3	1	0	0	0	35	14

Table (2): Bus voltages, power generated and load - initial data.

Line (bus to bus)	Impedance	Line charging (*Y*/2)
1-2	0.02 + *j*0.10	*j*0.030
2-3	0.04 + *j*0.20	*j*0.025
3-1	0.05 + *j*0.25	*j*0.020

Table 3: Bus voltages, power generated and load after load flow convergence.

Bus #	Bus Voltage		Power Generated		Load	
	V (p.u)	*Θ (deg)*	*P (MW)*	*Q (MVAR)*	*P (MW)*	*Q (MVAR)*
1	1	0	15	57.11	16	14
2	0.9826	-5.0124	0	0	26	45
3	0.9777	-7.1322	32	15.59	0	0

obtaining a single line diagram to expected needs for each region and, which represents three bus systems to shows the distribution lines in the Middle region and customers' needs. Buses are classified as (Saada, 2002):

1- Slack bus: or swing bus is taken as reference where the magnitude and phase angle of the voltage are specified. This bus makes up the difference between the scheduled loads and generated power that are caused by the losses in the network.

2- Load Bus: or P-Q bus is a bus where the active and reactive power is specified. The magnitude and phase angle of the bus voltage are unknown.

3- Regulated Buses or Generator Buses (Voltage-controlled buses): At these buses, the real power and voltage magnitude are specified. The phase angle of the voltage and the reactive power are to be detrained. The limits on value of the reactive power are also specified. These buses are called P-V buses.

OPTIMAL POWER FLOW SOLUTION

For Power flow case study, Guess-Seidel, and Newton-Raphson methods must be applied on Middle region. Comparison between the two investigated methods will be shown.

Assuming the Middle region system consist of a slack bus from Power Plant, Israeli P-V bus, and load bus in the Middle region as shown in Figure 2.

The line impedances and the line charging admittances are given in Table 1. The bus voltage magnitudes, their angles, the power generated and consumed at each bus are given in Table 2.

Using Gauss-Seidel and Newton-Raphson methods to calculate the bus parameters yielded the same result. However the Newton-Raphson method converged faster than the Gauss-Seidel method, where the NR gave results after 4 iterations, while the GS gave results after 10 iterations. The bus voltage magnitudes, angles of each bus along with power generated and consumed at each bus are given in Table 3.

This shows that OPF enables us to utilize numerical analysis tools to compute and estimate the bus parameters using Matlab and PowerWord.

OPF SCADA SYSTEM DESIGN

Before starting to design a SCADA system, we must know a functional description for a power system such as requirements, and specifications (Wood, 1996). This section defines a functional description, requirements, specifications, and SCADA framework. The power plant(s) supplies Gaza Strip with the generated the power that is needed and distributed through distribution networks to the customers. The main services and requirements that are needed for a SCADA system must be included:

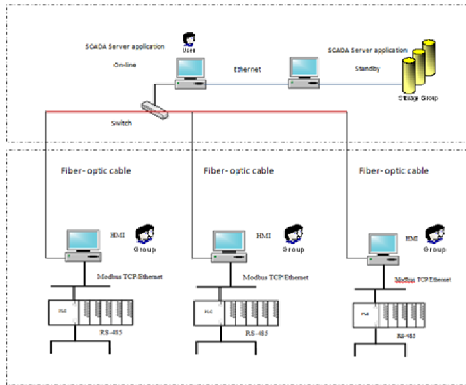

Figure 3: Proposed hardware designs

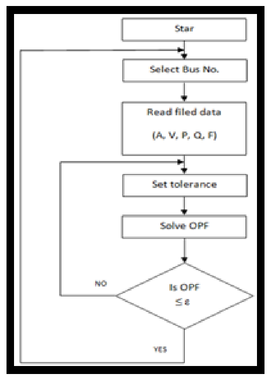

Figure 4: SCADA System Flow Chart

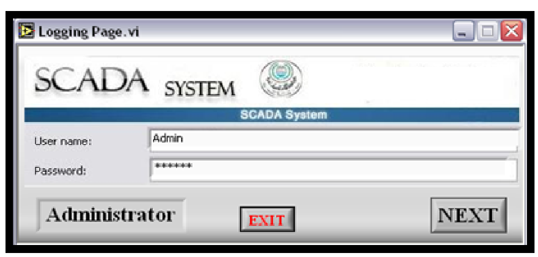

Figure 5: Admin Account.

1- Reading magnitude voltage from generation(s).
2- Reading phase angle voltage from generation(s).
3- Reading real and reactive power generation(s)
4- Investigating occurrence of optimal power flow for customers.
5- Providing previous data in real-time to help manger or operator in decision making.
6- Providing graphical representation and Human Machine Interface (HMI) of the actual power network in Gaza Strip.
7- Supplying data archive for all process in the network and mage it from any control room(s).
8- Collecting data from distributed area in Gaza Strip.

Designing a SCADA system that achieves the above requirements, fulfills specifications while minimizing costs and insuring long term system robustness, will be achieved using hardware and software components.

According to the previous functional discretion and the power system demand in Gaza Strip, the proposed SCADA system consists of three subsystems distributed in Gaza Strip based on power feeder's sources. The distributed system is interconnected by communication network. Figure 3 provides general layout of the

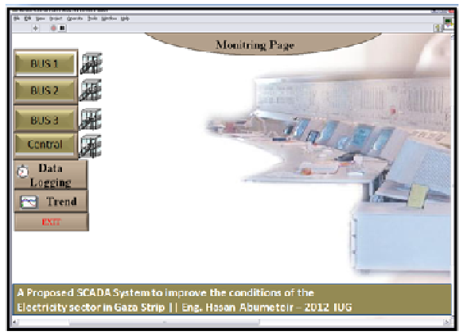

Figure 6: SCADA Main window

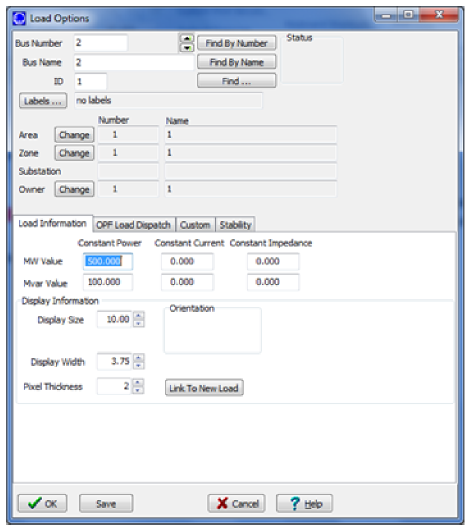

Figure 7: Bus 2 information

proposed SCADA system in Gaza Strip.

It is clear in Figure 3 that three PLCs which control the three subsystems are interconnected to allow communication between the subsystems. For this purpose, PLCs in each subsystem must have modules to deal with different signals (digital and analog). Also each PLC should have interface modules to control the network.

The proposed system design is based on constructing three subsystems in Middle of Gaza for power generation from Gaza Plant, South of Gaza for power generation from Egypt, and North of Gaza for power generation from the Israeli to collect the necessary data through PLCs. The collected data is sent to a SCADA center, which is proposed to be constructed in GEDCO, using fiber-optic communication because it has thousands of times the bandwidth of copper wire and can carry signals hundreds of times further before needing a repeater. It also gives them greater reliability and the opportunity to offer new services (VDV, 2011).

In filed data process collects the different measurements (analog and digital) by PLC through serial connection (RS232, RS422, or RS 485). RS232, RS422 and RS485 form the key element in transferring digital information between the RTUs or PLCs, and the modems.

SCADA software application is considered important to be integrated with the hardware design to achieve a good security in SCADA system. Many readily made SCADA packages are available such as LABVIEW, WinCC Filexble, Trace MODE, Industsoft, Wonderware, and Ifix (Saada, 2002). The process in SCADA application is illustrated in flow chart as show in Figure 4, and uses LabVIEW for implementation (LabVIEW, 2008).

When the operator or manger of the SCADA system runs SCADA application, it should select the bus number from overall system to read all data. Then, the manger sets the tolerance value ε to calculate the OPF according to this value. After that the SCADA application provides the manger in the network result to make a decision based on the result. The proposed flow chart is expected to result in the previous requirements when integrating the SCADA application with a hardware design.

RUNNING AND TESTING THE DESIGNED SYSTEM

Administrator Account: or SCADA slave/data server. The administrator account page is shown in Figure 5. After logging in the system, move to main page (Data server) as shown in Figure 6.

This window shows all regions included in SCADA system. On clicking on any buses, all information about this bus will appears. Figure 7 illustrates bus 2 information.

CONCLUSION

Studying power flow and distribution is important to cut loses and waste in power distribution networks. Finding an optimal power flow using the latest technology optimizes the available resources. This paper addressed the problem of the power distribution in Gaza Strip, which is fed with power from three different sources: the Gaza Power Station, Israeli Electric Company, and Egyptian Power Company. This study provided a novel approach for optimal power distribution by monitoring sources of nutrition, the network and the energy up to the consumer for sporadic periods.

A SCADA technology was utilized to collect data, monitor performance, and conduct control. A power flow analysis was performed using the optimized methods of Newton-Raphson and Gauss-Sidle. MATLAB-LABVIEW was used to perform the analysis and modeling of the system. PowerWord was also used to perform the analysis.

A comparison was performed between the results of the optimized OPF methods Newton-Raphson and Gauss-Sidle. The results showed Newton-Raphson was faster than Gauss-Sidle and more accurate. On the other hand, a comparison was performed between the results of the PowerWord and MATLAB-LABVIEW. The comparison showed that similar results were obtained using both methods. An infrastructure for SCADA system for Power network in Gaza Strip based on OPF was proposed.

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