Initialization of operator training simulator for Alexandria regional control center (application on load flow)

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In this paper a novel method for simulating power system dynamic performance to present solutions for some of the Alexandria regional control center problems is introduced. This simulation is based on the operation training simulator existing in control system centers. Field data from Alexandria regional control center in a conjunction of historical and future data are considered. This can be accomplished via dividing the system into sub-systems. This simulation is carried out without using the conventional telemetering of the feeder loads, meter placement and state estimators. The main purpose of this paper is to present suggestions and solutions for some of the Alexandria Regional Control Center (ARCC) problems for initializing the Operator Training Simulator (OTS) system from a data taken from the Historical and Future Data (HFD) sub-system, even in case of State Estimator (SE) absence, non-standard meter placement and not telemetering the feeders' load, to enable the OTS to solve load flow problems of Alexandria region.

تـم فـي هذا البحث اقتراح وتنفيذ عدد من التوصيات بهدف إعداد وتصحيح و أحيانا إضافة إلى قواعد البيانات الخاصة بالشركة المصـرية لنقل الكهرباء بالإسكندرية جهد ٢٢٠ ، ٦٦ ، ٣٣ ك.ف و اللازمة لتشغيل نظام محاكي الشبكة الكهربية وتنفيذ الحلول لمشـكلة مركـز الـتحكم الإقليمي بالإسكندرية وذلك حتى يصبح المحاكي قادرا على إيجاد قيم تدفق القدرة فى خطوط المنظومة الكهربـية نتـيجة بـيانات فعلية مأخوذة في لحظة معينة من النظام الفعلي والتي يتم تخزينها فى الأرشيف. تم تقسيم الحلول على ثـلاث مراحل:١- إدخال بعض البيانات التى لم تكن موجودة فى نظـام اكتسـاب المعـلومات و التحكـم عن بعـد. ٢- عمل طـريقة آلـية لـنقل البيانات من نظـام اكتسـاب المعـلومات و التحكـم عن بعـد الى نظام محاكي الشبكة الكهربية بعد عمل بعـض التغييرات عليها. ٣- إدخال هذه البيانات فى قاعدة البيانات الخاصة بنظام محاكي الشبكة الكهربية. ويتضمن أيضا إجراء مناقشة عامة على التعديلات التي تمت على قاعدة بيانات المحاكى الخاص بالشركة المصرية لنقل الكهرباء بالإسكندرية.

Keywords: Operator training simulator, Supervisory control and data acquisition system, Power system model, Control center model

1. Introduction

Egyptian Power Transmission company (EPT), is the main Egyptian utility company working in the Extra High voltages and High voltages power transmission. This includes 500 kV, 220 kV, 132 kV, 66kV and 33 kV networks. EPT is divided into seven small utilities, geographically distributed to meet the load demand for all of Egypt, named "Cairo", "Alexandria", "Canal", "South-Upper Egypt", "North-Upper Egypt", "West-Delta" and "Middle-Delta" utilities. EPT is controlling the power system through one National Energy Control Center (NECC) and other seven Regional Control Centers (RCCs). Out of the seven RCCs, there are two RCCs using Supervisory Control and Data Acquisition (SCADA) system and the other five RCCs are in the way of migration from manual control (using the phone, microwave, PLC or other types of voice communication facilities) to computerized control.

Alexandria Regional Control Center (ARCC) is one of the two RCCs that use Supervisory Control and Data Acquisition/Energy Management System (SCADA/EMS) system. It is in duty since December 2000. ARCC is controlling Alexandria Power System network (geographically from Abu-Kir to EL-Saloum). ARCC power system network consists of 56 stations (56 Remote Terminal Units (RTUs)), 6 of them are generation power stations and the rest of the 56 are substations (14 of them are 220/66/11 kV and the rest are 66/11 kV). The amount of data telemetered from the 56 RTUs is almost 9,150 telemetered points (7,500 digital signals e.g. circuit breaker, disconnect and protection relays, 1400 analogue signals e.g. MW, MVAR, kV, and frequency, and 250 Accumulator signals). The communication system scans the 56 RTUs at different periodicity, every 4 seconds, it scans the analogue signals, scan by exception for the digital signals and scan cycle of 15 min for the accumulator signals. This means that every 4 seconds there will be 1,400 telemetered analogue value that will be processed (compare the new value with the last scanned value, check the new values against their different limits, issuing alarms if it violates any of the limits, etc.).Calculate the system parameters from 5 to 9 times of that telemetered data for other purposes (e.g. MVA, Amp, Maximum, Minimum and Average values, etc.).

ARCC is mainly SCADA/EMS system without any On-Line power application or network application, that is due to the Egyptian Electricity Authority (EEA) policy of keeping the supervisory control of both the power stations and the 220kV side of the substations managed by the NECC. This means that all the power applications are executed in the NECC using SCADA/EMS, (Automatic Generation Control (AGC), Economic Dispatch (ED), etc.)

The Operator Training Simulator (OTS) has become an important tool for training power system control center operators/dispatchers because power systems have become increasingly complex and the requirements placed on operators/dispatchers in all phases of the system operations normal, emergency and restoration have increased correspondingly. OTS is also useful for the network and power application engineers to study power system behavior when subjected to any type of disturbances.

To simulate power system, its model should behave exactly like the actual real-time power system. This means that both the static and dynamic data should be the same as the real-time data.

Load flow study is one of the primary needs for the power system planning and operation. For the small utilities (less than 100 RTUs and do not have On-Line power or network applications), which is the case of ARCC, load flow study is performed using the OTS. For this purpose, the OTS should start load flow using actual data that is available from the actual power system network. The best way to get this data is taking a snapshot from the real time SCADA system, pass the snapshot to the State Estimator (SE) and start the OTS using the SE output. Without or with very little modifications the load flow solution will converge through 2-5 iterations. Due to economic reasons, ARCC did not only buy the State Estimator package but also reduced the number of telemetered analogue points.

This paper includes discussions of ARCC problems, suggestions and solutions that authors applied to make load flow converge for ARCC OTS system. The work required to solve the problem has been divided into three main portions:

1. In the Real-Time side of the SCADA/EMS system, pseudo database records will be added to hold estimated data required for load flow solution (some records for the external network and some for meter placement problems for the internal network).

2. In the OTS side, a mechanism has been developed to transfer data from the real-time side, convert it to the OTS data format and populate it into the OTS database, this mechanism called "Historical and Future Data (HFD) snapshot mechanism" which be done by the following steps:

- Take a snapshot from the SCADA/HFD subfunction.
- Initialize the OTS by this data.
- Restore this data into the OTS and check load flow solution.

3. In the OTS side also, the transformer readings are divided into feeders using a distribution factor (to help in load shedding study and smoothing the load changes for the transformer), since ARCC does NOT telemeter the feeders' meters (MW & MVAR).

2. OTS overview

Using the OTS [1-4], it becomes possible to expose both new and existing operators/dispatchers to emergencies and restoration procedures as part of refreshing training or after many changes in the actual power system topology (for example, adding a new station). The training includes for example the following situations [5]:

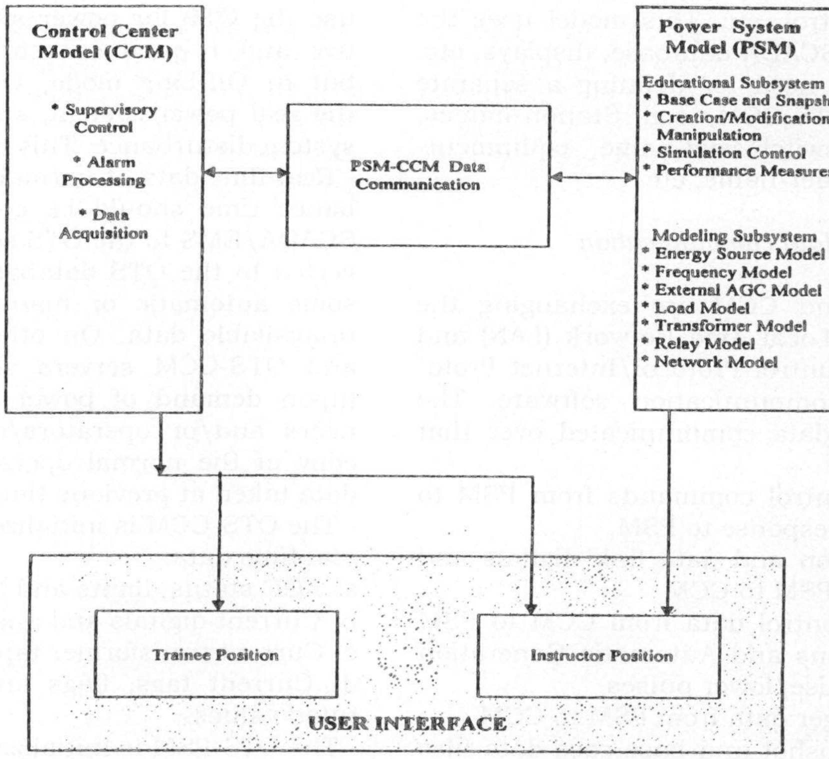


Fig. 1. Conceptual overview of OTS.

1-Normal steady state operation.
2- Heavy load
3-Light load
4-System disturbances
5-System islanding.
6-System blackout.
7-System restoration.
8-Emergency state operation.

The OTS is, also, used to study the response of the power system in case of a specific event for power system study. From the software point of view, as in fig. 1, the OTS consists of the following main components:

2.1. Power System Model (PSM)

- *Modeling system:* which simulates the dynamic behavior of the power system as seen by the system operators/dispatchers by the means of a real time SCADA/EMS. The models simulate data with the accuracy similar to that of the data generated by the instrumentation and telemetry of the real time SCADA system. It provides models of power system components such as generation units, transformers, transmission lines, relays, loads, etc., This model uses its own database, e.g. generators data, transformers data, transmission lines data, relays data, loads data, etc. These data is defined for OTS and not needed for the real time system. It is also simulating the remote sites in sending data to the Control Center Model (CCM) [6,7].

- *Educational sub-system:* consists of a set of software tools that help the instructor/trainer in the three phases of training activity: pre-session, session, post-session. The educational sub-system provides mechanisms to create, manipulate, and modify the training cases and the scenario events as part of the pre-session activities. During session activities, it provides simulation control, event creation, and event execution and trainee performance data collection. It summarizes the trainee performance and produces a performance report in the post-session phase.

2.2. Control center model

Control Center Model (CCM) is used for simulating the real time SCADA system functions, e.g. alarm acknowledge, curve tool, supervisory control, etc. This model uses the same real time SCADA database, displays, etc. So, there is no need for defining a separate database for OTS-CCM, e.g. Station-names, voltage-levels, switch-field-name, equipment-name, value-holder-name, etc.

2.3. *PSM-CCM data communication*

The PSM and CCM are exchanging the data using the Local Area Network (LAN) and Transmission Control Protocol/Internet Protocol (TCP/NP) communication software. The major types of data communicated over that link are:
- Simulation control commands from PSM to CCM and CCM response to PSM.
- Data acquisition and data link digitals and analogues from PSM to CCM.
- Supervisory control data from CCM to PSM for trainee actions and Automatic Generation Control (AGC) raise/lower pulses.
- Load tap changer data from PSM to CCM
- Real time snapshot and base case data files exchanged between PSM and CCM.

From the User Interface point of view, OTS consists of:
i) Instructor Position (IP), consists of one Man-Machine Interface (MMI) as an interface for both PSM and CCM, from which the instructor/trainer can design the test scenario by defining and scheduling of different event types and use it as regular MMI in training mode (off line) to see the reactions of the trainee.
ii) Trainee Position (TP), consists of one or more regular MMI, exactly like that used for On-Line, but in training mode (off line). These MMIs are used by the trainees (new/old dispatchers). From TP, the trainee can execute any activity; react to the power system events (created by the instructor) but Off-Line.

The PSM and CCM servers are connected to the real time SCADA system through the LAN. So, the servers have the ability to access all the real time and archived (both the Disturbance Data Collection (DDC) and HFD) data and database.

3. OTS initialization

In order to make it possible for the operators and other power system engineers to use the OTS for power system study alternative and re-produce real time disturbances, but in Off-Line mode, OTS should simulate the real power system, specially actual power system disturbance. This means that,
- Real time data at normal operation or disturbance time should be copied from real-time SCADA/EMS to the OTS server (Off-Line), converted to the OTS database format and make some automatic or manual changes for the unavailable data. On other words, OTS-PSM and OTS-CCM servers should be initialized (upon demand of power system study engineers and/or operators/dispatchers) from a copy of the normal operation or disturbance data taken at previous time.
- The OTS-CCM is initialized with the following real time data:
a- AGC status, limits and fuel data.
b- Current digitals and analogues.
c- Current transformer taps.
d- Current tags, flags and manually substituted values.
- The OTS-PSM is initialized from the real time data in the following manners:
a- Telemetered generation (Gross, Net, Auxiliary).
b- Telemetered loads which is not applicable in ARCC system, but transformer data will be used instead.
c- Telemetered circuit breakers and disconnects.
d- Not Telemetered loads, obtained from the company loads and load groups using the load distribution factors specified in OTS-PSM database.

OTS power flow solution should converge when starting from this data if it is taken from the State Estimator output.

4. State estimator and meter placement

Fig. 2 shows how SE and other power and network applications fit together in the control center. This figure shows the information flow between various functions to be performed in an SCADA/EMS system. The information has been broken down into digital (status) and analogue measurements. The analogue measurements of generator output are used directly by the AGC programs whereas all other data will be processed by the SE before being used by the other programs. In order to run the SE, the network topology must be known. Because changing of circuit breaker or disconnect in any station can cause a change in network topology, topology processor will read the status changes and re-construct the network topology after any change. The output of the SE consists of all bus voltage magnitudes and phase angles, transmission lines MW and MVAR flows, calculated from the bus voltage magnitudes and phase angles, and bus loads and generations calculated from the line flows. These quantities, together with the electric model developed by the topology processor provide the basis for the network applications and power applications [8]. In case of using the SE, the power system network should be observable under the normal network configuration and normal measurement availability. So, it is necessary to be sure that the metering system is adequate before start implementing SE. The placement of the meters has to take into account not only observablility but also the redundancy required for the best estimation. For N bus system, observablility requires a minimum of (2N-1) measurements and it is generally acceptable that at least 3N measurements are needed for adequate redundancy. But when talking about the minimum of (2N-1) measurements, it should be uniformly distributed over the buses and also to help in bad data detection. See fig. 3.

Since ARCC does not have SE, ARCC does not comply with the standard rules of meter placement.

5. Meter placement and telemetered data for ARCC

From the power system engineers' point of view, there seems to be no problem if all the available data in the remote sites have been telemetered to the master station (control center), but from the budget point of view, telemetering all the available data is not practical. This is limited by the following other factors:

a- Adaptation work in the substations and power stations to collect the information.
b- Size of the RTU.
c- Size of the SCADA computers and LAN traffic.
d- Communication links that will carry the information.
e- Scan rate, which is 4 seconds for ARCC.

MW and MVAR signals are telemetered only at one end of each overhead transmission line (O.H.L.) or cable in the 220 kV, 66 kV, and 33 kV networks. The choice, of which end is equipped, is based on the following principles:

a- For double circuit lines, the telemetering of active and reactive power are both taken together at one end of the circuit number 1, and the opposite end on the circuit number 2. The same rule applies for multiple circuit lines having an even number of circuits.
b- For single circuit lines, or the last circuit of lines with an odd number of circuits, the choice, of which end is to be telemetered, is the station where the RTU collects smallest number of information. So that in case of the failure of one RTU, minimum number of information is lost. Fig. 4 shows an illustrative example for ARCC meter placement.

6. ARCC problems and the solution

In ARCC starting the load flow solution (from an HFD snapshot) and making it converges was almost impossible due to absence of the SE package and lack of some measurements. In order to do this, SE functions should be performed manually, which include also checking the network model topology data, checking the mapping data between SCADA data and network model data for all measurements and supervisory control elements, prime mover data and protective relay data. This is the massive data required for OTS and it is very hard to do this checking and matching the data of the On-Line system to the Off- Line system manually.

The following are some problems and how ARCC gets around it:

6.1. Creating base case zero (BC 0)

Base Case 0 is a primary power system data that is created from the primary power system models data, this data is adequate for just solving the load flow. The load flow output could not be accurate, but it gives the network application engineer a primary checking for the power system model data (e.g. line data,

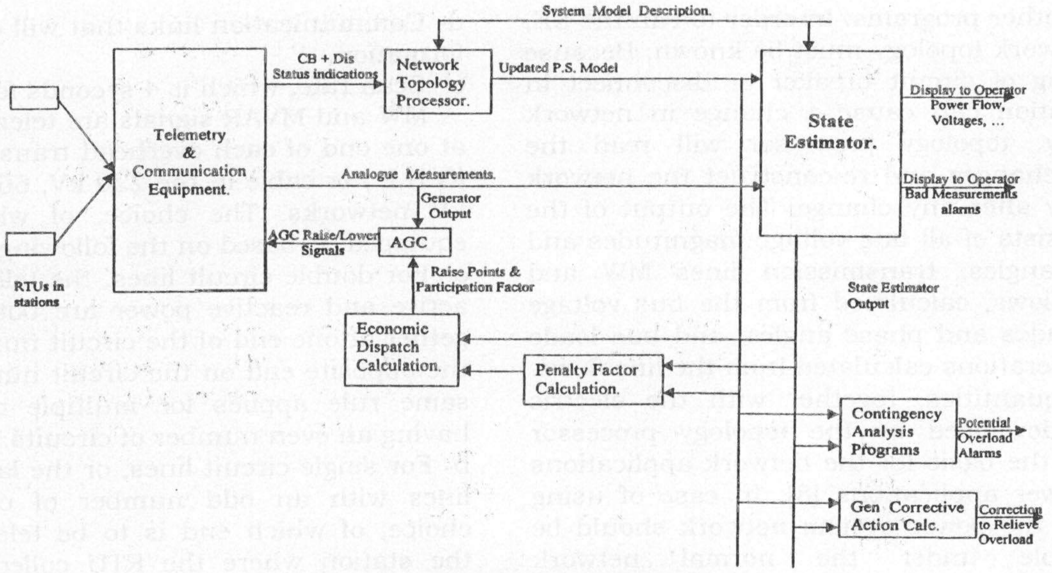


Fig. 2. EMS control center system.

generator data, AGC data, etc.) in addition to this, it gives the network application engineer an indication of how good the external model can be simulated.

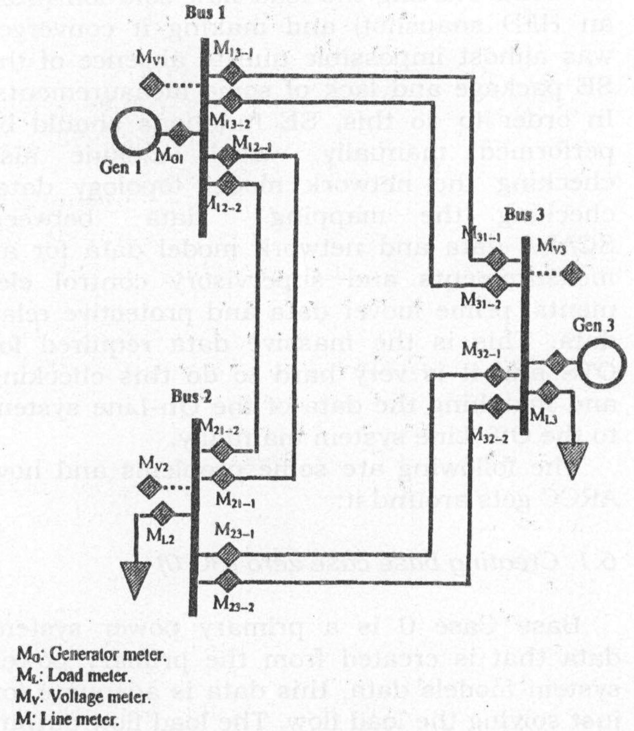


Fig. 3. Meter placement for estate estimator.

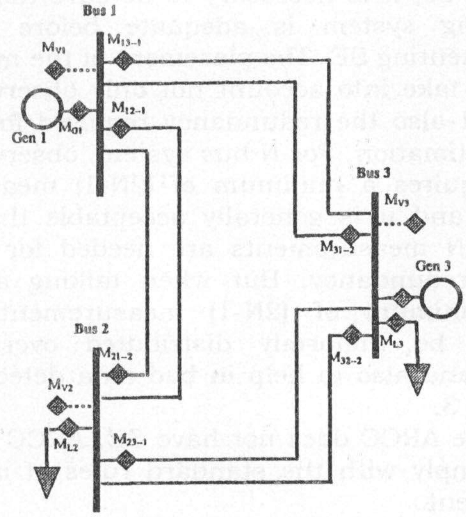


Fig. 4. Meter placement for ARCC.

The OTS-PSM database is defined in text files with specific format, this database includes:

a. Internal company load curve.
b. External company load curve.
c. Interchange schedule.
d. Network elements and connectivity (network topology configuration).
e. Line begin and line end.
f. Transformer data.
g. Transformer high side and low side tap changer data (Minimum, Maximum, step, normal position).
h. Switch field topology type.

i. Mapped data from real time SCADA/EMS system (when OTS is working in normal mode).
j. Load data.

The following steps are required to create BC 0 from the initial database. These steps are also shown in fig. 5:
a. The internal (observable) network, which consists of 56 stations, is divided into 5 groups, which are called "phases" or "stages", each phase consists of 7 to 15 stations according to the generation stations per phase.
b. Definition of the static database (data that does not change as a result of simulation) and quasi-static data (data that is static but can change due to factors such as data entered by the instructor) required to the phase's stations.
c. Definition of the primary dynamic database for the phase's stations. This data is called the "default values", which includes the status of the digital points (circuit breakers, line disconnects, bus bar disconnects, etc.) and values for analogue points (generation, loads, tap settings, etc.).
d. Populating the OTS-PSM database.
e. Check load flow solution, if it converges, then go to the next step, if it does not converge, modify the initial data base (default values) and repeat the previous steps again till the power flow converges. Sometimes an extra generation is needed to be add, extra loads or both of them, which are not actually part of the actual internal network.
f. Start the OTS in stand alone mode. In this mode the OTS-CCM sub-system will not be running and hence the power flow solution will not be mapped to the CCM side and the one line diagrams will not have the simulated power flow data. That is to shorten the time required for data processing, updating the graphics, and other SCADA activities because the OTS-CCM programs will not be ignited (started).
g. Repeat the previous steps for all the phases.
h. Repeat the previous steps for the external network model, which it divided into 4 phases.
i. Revise the primary data again by removing the extra generating units, extra loads or both of them.
j. Check load flow solution. If it converges, save this power flow solution as base case 0 which will be the base for all the next OTS work.

6.2. HFD snapshot

In the real-time SCADA/EMS, a snapshot from all the power system digitals, analogues is taken every 15 minutes and saved in the archiving system. If a SE exists, this snapshot is used as an input to SE, SE will do specific corrections to the data and the result is a data base capable of making the power flow solution converges. In the case of absence of the SE, a selected sets of data will be saved and used in power flow solution. Then the following sets have been identified:
a. For the analogue points instantaneous values are needed which exist in a specific data table called (MvMoment).
b. For the digital points, statuses that exist in data table called (Switches).
c. The tap position (actual tap setting), which exist in another data table called (Tappos).

To use that data for power flow solution, the following steps are followed:

6.2.1. Taking HFD snapshot

1. Check if there is data in the archiving subsystem at the required time. The data could be mounted from an external media.
2. Dump a snapshot, from the archiving subsystem at the needed time to simulate the power system at, to a directory in the HFD server.
3. Copying the Switches, MvMoment and Tappos data tables from the HFD server to the OTS-PSM server.

6.2.2. Restore HFD snapshot

1. Restore Base Case 0 or any other saved base case to be as measurement redundancy.
2. Load the HFD snapshot data into the OTS-PSM data tables. Using the mapping definitions in the OTS data base, assign the HFD snapshot data to valid network points, for example, Generation Unit (GU) status, GU mode, GU desired generation, GU regulated voltage, Load MW & MVAR, tap settings and switch statuses.
3. Do manual correction to the data if needed.

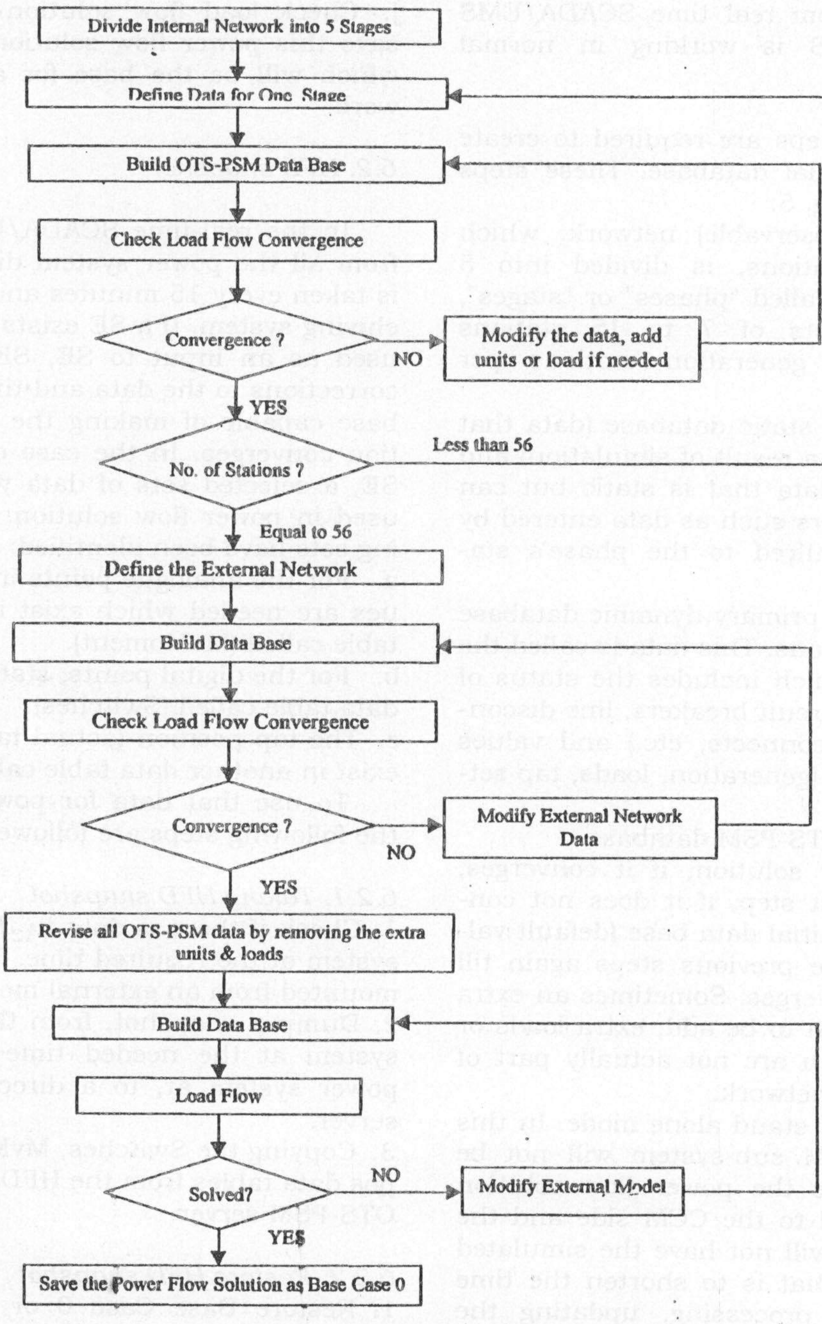


Fig. 5. Base case creation steps.

6.3.Telemetering data from one end of the transmission lines

This data caused the loss of the analogue values (MW and MVAR) redundancy, so, in the real time SCADA system it was defined a fake (pseudo) measurements in the other end of the transmission lines, P_{12-2}, Q_{12-2}, P_{21-1} and Q_{21-1} in fig. 6.

Where:

$P_{12-2}=P_{21-1}=(P_{12-1}+P_{21-2})/2$,

$Q_{12-2}=Q_{21-1}=(Q_{12-1}+Q_{21-2})/2$.

For more failure redundancy it could be done also as follows (not implemented yet): If P_{12-1} has a "Not Renewed" or "Invalid" quality code, then $P_{12-1}=P_{21-2}$.

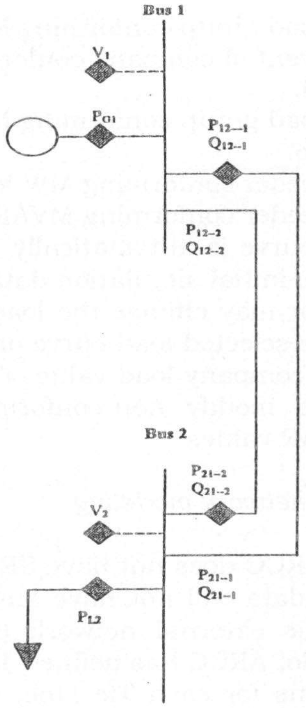


Fig. 6. Telemetering data from one end of T.L.

If P_{21-2} has a "Not Renewed" or "Invalid" quality code, then $P_{21-2}= P_{12-1}$.
If Q_{12-1} has a "Not Renewed" or "Invalid" quality code, then $Q_{12-1} =Q_{21-2}$.
If Q_{21-2} has a "Not Renewed" or "Invalid" quality code, then $Q_{21-2}= Q_{12-1}$.

This will be helpful in the case of loosing a single analogue point or loosing all the information from a specific remote site (RTU loss). From the accuracy point of view, P_{12-2}, Q_{12-2}, P_{21-1} and Q_{21-1} have deviation almost equal to the half of the line losses. But comparing with manually entering this data to the OTS-PSM model, this is more realistic, efficient and accurate.

6.4. RTU loss

In case of loosing RTU, all the information telemetered from that specific RTU would have a Not Renewed quality code. For the Transmission reading, the missing values will be gotten as explained before or it could be manually substituted in the real time before taking the snapshot. For the loads, which will be mapped to the low voltage side readings, could be manually substituted in the real time before taking the snapshot or it will be calculated from the load group, it belongs to, in the OTS-PSM database.

6.5. Bad or incorrect Circuit Breaker (CB) status

The status of telemetered circuit breakers is checked against a calculated status according to the Transmission line or transformer readings as follows:
If |MW| > 0, then CB status is indicated by red color (CLOSED).
If |MW| = 0 , then CB status is indicated by blue color (OPEN).

This has been implemented only for the Tie Lines to the external network model because this will affect the network coloring for the real time SCADA and will turn ON the generation unit connected to it for the external network model.

6.6. Distribution network (load) modeling

The simulation is partially driven by the load changes in the power system. Since the distribution network (feeders in 11 kV voltage level and below) belongs to "Alexandria Power Distribution" company, ARCC does not telemeter it. From the power flow point of view, this means that the loads are not telemetred and hence the load values are not available in the snapshot data, because the snapshot contains only the data available in the real time SCADA system. In order to override this problem, ARCC uses the transformer low side voltage telemetry as the load values, in OTS-PSM the load is modeled in special way to take the transformer low side voltage readings and divide it into some Feeders. Generally, ARCC Off-Line power system model is divided into two companies, ARCC as observable (internal) network and Egypt as unobservable (external network which consists of 18 Generators and loads). The loads in each company are grouped by load groups, each load (which is mapped to the transformer low side voltage active and reactive power) is divided into feeders. Through the load flow cycling, the load at each bus, at any given time, is calculated by the load model. This load is made up of three components and also is affected by bus voltage and island frequency.

The three components are called confirming, non-confirming and random noise portion of the busload.

The confirming portion is determined by subtracting the sum of the non-conforming loads from company total load, which is obtained from the company load curve. This load curve is stored as percentage of peak company load at intervals of 5 minutes and loads during the five minutes interval is obtained by linear interpolation on the curve. MVAR is calculated as a function of the busload MW using a set of MVAR/MW ratios.

The non-confirming portion of the bus load is a set of fixed MW and MVAR values which could be turned On or Off according to a time schedule. This is used to model special loads at particular buses, for example, furnaces and drag loads.

The random noise portion of the busload simulates the probabilistic load variation. This portion of load is a percentage of confirming load determined by a random function generator.

$$P_{CONFco} = P_{co} - \sum_{i \in co} P_{NONCfd_i} \cdot$$

Where:

P_{CONFco} = Company Conforming MW load.

P_{co} = MW load obtained from the company load curve by interpolation.

P_{NONCfd} = Feeder non-conforming MW load.

The company conforming load thus obtained is then distributed among the feeders through distribution factors. The feeder MW conforming load is given by:

$$P_{CONFfd} = F_{pfd} \times F_{pld} \times F_{plg} \times P_{CONFco},$$

and

$$Q_{CONFfd} = F_{Qfd} \times F_{Qld} \times F_{QPlg} \times F_{Plg} \times P_{CONFco}.$$

Where:

F_{pfd}, F_{Qfd} = Feeder conforming load in percent of individual load conforming component.

F_{pld}, F_{Qld} = Individual load conforming component in percent of load group conforming load.

F_{plg} = Load group conforming MW load in percent of company conforming MW load.

F_{QPlg} = Load group conforming MVAR/MW ratio.

P_{CONFfd} = Feeder conforming MW load.

Q_{CONFfd} = Feeder conforming MVAR load.

The load curve is automatically selected by specifying the initial simulation data and time. The instructor may change the load profile by modifying the selected load curve or by adjusting the peak company load value. The instructor may also modify non-conforming feeder MW and MVAR values.

6.7. External network modeling

Because ARCC does not have SE, OTS-PSM initialization data will not have any data that represents the external network (Generation and Loads). So, ARCC has defined 18 fictitious buses, one bus for each Tie Line, distributed through 4 fictitious large power stations, in both real time SCADA database and OTS-PSM database. Each bus is connected to the observable network through a Tie Line and has one fictitious generator (by default in AGC mode) and one factious lumped load. See fig. 7.

To get the MW and MVAR Generation values for the fictitious generators and loads, it has been developed a new algorithm to map the reading of the Tie lines from the ARCC side (P, Q in fig. 7) to the generator (P_G, Q_G) or to the load (P_L, Q_L). This according to the following criteria of P and Q values:

All the external network's CBs are CLOSED by default:

If $P > 0$, then $P_G = P$, $P_L = 0$ and open the load CB.

If $P <= 0$, then $P_L = P$, $P_G = 0$ and open the Generator CB.

If $Q > 0$, then $Q_G = Q$, $Q_L = 0$.

If $Q <= 0$, then $Q_L = Q$, Q_G = Minimum value (from the unit capability curve defined in the OTS-PSM database).

7. ARCC power flow solution results

"Output Busbar Voltage Magnitude and Angle" display shows samples of the power flow solution results. See fig. 8.

8. Summary and conclusions

This paper presented an overview of the Operator Training Simulator at Alexandria Regional Control Center. The Operator Training Simulator is or will be used to train new dispatchers, certify experienced dispatchers, perform realistic system restoration procedures, perform power system demonstrations and power system study by the network application engineers. A simulation for State Estimator functions has been developed and applied for Alexandria Regional Control Center Supervisory Control and Data Acquisition / Operator Training Simulator system. The simulation consists of the following portions:

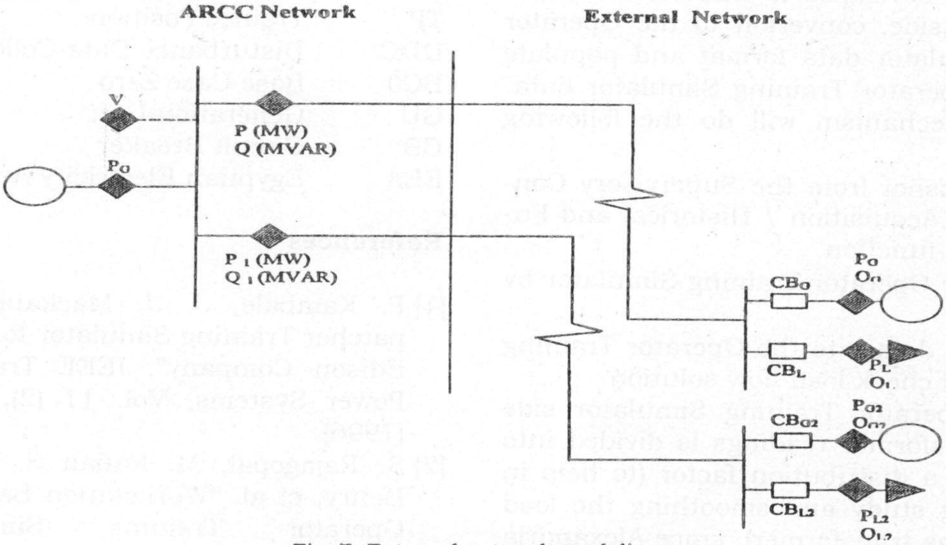
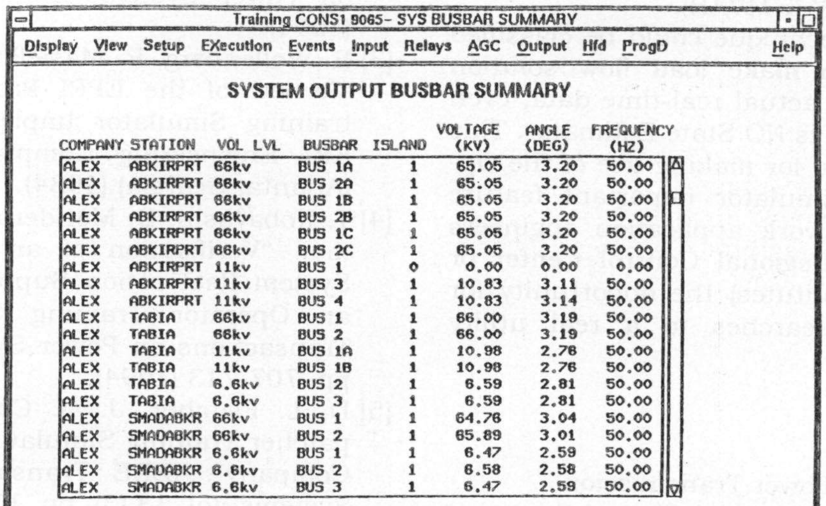


Fig. 7. External network modeling.



COMPANY	STATION	VOL LVL	BUSBAR	ISLAND	VOLTAGE (KV)	ANGLE (DEG)	FREQUENCY (HZ)
ALEX	ABKIRPRT	66kv	BUS 1A	1	65.05	3.20	50.00
ALEX	ABKIRPRT	66kv	BUS 2A	1	65.05	3.20	50.00
ALEX	ABKIRPRT	66kv	BUS 1B	1	65.05	3.20	50.00
ALEX	ABKIRPRT	66kv	BUS 2B	1	65.05	3.20	50.00
ALEX	ABKIRPRT	66kv	BUS 1C	1	65.05	3.20	50.00
ALEX	ABKIRPRT	66kv	BUS 2C	1	65.05	3.20	50.00
ALEX	ABKIRPRT	11kv	BUS 1	0	0.00	0.00	0.00
ALEX	ABKIRPRT	11kv	BUS 3	1	10.83	3.11	50.00
ALEX	ABKIRPRT	11kv	BUS 4	1	10.83	3.14	50.00
ALEX	TABIA	66kv	BUS 1	1	66.00	3.19	50.00
ALEX	TABIA	66kv	BUS 2	1	66.00	3.19	50.00
ALEX	TABIA	11kv	BUS 1A	1	10.98	2.76	50.00
ALEX	TABIA	11kv	BUS 1B	1	10.98	2.76	50.00
ALEX	TABIA	6.6kv	BUS 2	1	6.59	2.81	50.00
ALEX	TABIA	6.6kv	BUS 3	1	6.59	2.81	50.00
ALEX	SMADABKR	66kv	BUS 1	1	64.76	3.04	50.00
ALEX	SMADABKR	66kv	BUS 2	1	65.89	3.01	50.00
ALEX	SMADABKR	6.6kv	BUS 1	1	6.47	2.59	50.00
ALEX	SMADABKR	6.6kv	BUS 2	1	6.58	2.58	50.00
ALEX	SMADABKR	6.6kv	BUS 3	1	6.47	2.59	50.00

Fig. 8. Power flow solution results display.

1. In the Real-Time side of the Supervisory Control and Data Acquisition / Energy Management System, the pseudo database records is added to hold estimated data required for load flow solution (some records for the external network and some for meter placement problems for the internal network).
2. In the Operator Training Simulator side, a mechanism called Historical and Future Data mechanism is developed to transfer data from the real-time side, convert it to the Operator Training Simulator data format and populate it into the Operator Training Simulator database. This mechanism will do the following steps:
• Take a snapshot from the Supervisory Control and Data Acquisition / Historical and Future Data sub-function.
• Initialize the Operator Training Simulator by this data.
• Restore this data into the Operator Training Simulator and check load flow solution.
(3) In the Operator Training Simulator side also, the transformer readings is divided into feeders using a distribution factor (to help in load shedding study and smoothing the load changes for the transformer), since Alexandria Regional Control Center does not telemeter the feeders' meters (MW & MVAR).

The proposed technique could be classified as a vital tool to make load flow solution convergence using actual real-time data, even in case when there is NO State Estimator. This is potentially useful for making use of the Operator Training Simulator important feature and gives the network application engineers (from Alexandria Regional Control Center or other research institutes) the opportunity for applying their researches to a real utility power system.

Nomenclature

EPT	Egyptian Power Transmission
ARCC	Alexandria Regional Control Center
HFD	Historical and Future Data
SE	State Estimator
OTS	Operator Training Simulator
NECC	National Energy Control Center
RCC	Regional Control Center
SCADA	Supervisory Control and Data Acquisition
EMS	Energy Management System
AGC	Automatic Generation Control
ED	Economic Dispatch
CCM	Control System Model
LAN	Local Area Network
TCP/NP	Transmission Control Protocol /Internet Protocol
PSM	Power System Model
IP	Instructor Position
MMI	Man-Machine Interface
TP	Trainee Position
DDC	Disturbance Data Collection
BC0	Base Case Zero
GU	Generation Unit
CB	Circuit Breaker
EEA	Egyptian Electricity Authority

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