Early Load Flow Application in Iraq

Harith Jameel

Al – Tirath university College

المستخلص

بدأ استخدام الحاسبة الالكترونية لتحليل سريان القدرة لمنظومات الطاقة الكهربائية في العراق في أوائل السبعينات من القرن الماضي. بعض التطبيقات المهمة والتي اجريت على حاسبة مصلحة الكهرباء الوطنية تعود إلى تلك الفترة. كانت تلك الدراسات بمنتهى الأهمية لاتخاذ القرارات التصميمية والمستقبلية. تتناول هذه الدراسة بعضا من تلك التطبيقات. كما تشير إلى بعض الآثار التي أدى إليها استخدام الحاسبة لهذا الغرض. تستند هذه الدراسة إلى ثلاث وثائق فنية تعود إلى تلك الفترة تتعلق بتطور الشبكة الوطنية العراقية للضغط العالي والفائق.

Summary

The use of digital computers for Power System Load Flow Analysis started in Iraq in the early 1970's. Some important applications go back to that period and were carried out at the National Electricity Administration Computer Centre. It was used for studies that were essential for making major design and futuristic studies. Some of these applications are discussed. The effect of this use on later developments is briefly discussed. The study is based on three documents concerned with the development of the Iraqi High Voltage National Grid and Supergrid.

Introduction

Electrical Power Systems undergo changes in a variety of ways. The initial construction requires numerous studies to determine the system components, their parameters and interconnection. As time passes, new load centres, changes in load concentration, industrial and other added demand for electricity dictate the continuous review of the system. Such a review is needed to decide on addition, extension, replacement and innovation of components to enable the system to meet the increasing demand in the best possible manner. Also

numerous studies need to be carried out to solve technical problems of design, operation, economy, faults and contingencies that are ever present in electrical networks and plant.

Load Flow Analysis is one important study that needs to be carried out in most aspects of power system development and review. It provides the basic parameters that indicate the state of the system. The study is concerned with the conditions in the system at a specific instant defined by a certain combination of load demand distribution, a set of power station output and a specific network connection. The study provides the operating conditions at the various stations mainly defined by the voltage profile, the transmission line loading and the losses in the transmission network. Such a study can be a stand-alone activity, to provide that information. It can be a step in a wider study such as transient stability. It can also be a part of a more detailed comparative study for decision making on design or extension.

Such studies were carried out for the Iraqi power system by consulting firms that were always employed whenever there was a need for any new project such as a power station or extension of the transmission network. In some cases, especially for transmission extension, such as adding new substations or limited transmission line extensions, no such detailed studies were carried out at all. In these cases "engineering sense" was used to make the decision. This would have been the case for the building of the Baghdad Ring, upgrading the Kerbala voltage network from 66kV to 132 kV, the connection of the single 132 kV line Qurna-Amara-Kut, the connection Shamiya-Samawa-Nassiriya with a 132 kV single line. The line Dibis-Samarra, designed for 220kV voltage was another such example. The decisions for the last two examples were made in the mid-sixties and put into operation around 1966 to form an interconnected National Grid for the first time.

The reason for not carrying out the necessary studies was the lack of the tools for calculation. Such studies were, at that time, carried out in industrialised countries by specially designed boards called Network Analysers. Also, digital computers were coming into use for these problems. Both means were not available in Iraq.

The Computer Centre of the National Electricity Administration (مصلحة الكهرباء الوطنية NEA) had the aim of developing the work on these problems. But it was only in the second half of 1969 that a specialized engineer was available to start this work. Working from experience gained in post-graduate study in the U.K., work started on developing two important applications: the Load Flow Analysis and the Unbalanced Short Circuit Study using the available computer [1].

Historical Development of the National Grid

Up to the early 1950's electrical power was provided by local generating stations in Baghdad and other cities and towns. The Development Board of Iraq employed the consulting firm J.G.White Engineering to study the future development of electric power in Iraq. The report recommended the development of a National Grid operating at 132 kV and 66kV instead of local generation. The first stage included building three regional power stations at Dibis, Baghdad and Basra. These regions would be interconnected by transmission lines in future. Figure 1 gives a visual description of the Northern scheme. The Kirkuk and Sulaimaniya voltages were planned to be 66 kV. Table 1 gives the geographical location of 132kV substations in the three regions. Each substation supplies its own local area. The actual implementation did not follow the plan exactly.

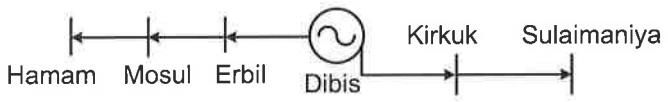

Figure 1 Northern System

Table 1: Locations of early 132kV substations

	North	Middle	South
Power Stations	Dibis 60MW	Baghdad BS 80MW Sar 52MW	Basra Naj 45MW
Substations	Kirkuk Sulaimaniya Erbil Mosul	Baquba Kut Shamiya	Qurna Nassiriya

The development of these separate networks did not need complex studies for their design. Experience and engineering sense was sufficient to decide their details. This was possible because of the low electricity consumption at that time. The targets for supply were the main population centres and the few industrial plant like the Cement factories in Hammam Al-Alil and Surchanar. Many major and small towns were not included.

During the 1960's a number of power transmission lines were added which finally connected the three regions into one National Grid working at 132 kV. The technical studies for these extensions were not extensive and were carried out by foreign consulting engineers. The Iraqi specialists were not involved in any way in these studies, they only discussed their recommendations and accepted them. No attempt was made to undertake or participate actively in any studies of deep nature by the Iraqi authorities and their staff.

The actual loading of the grid started in the 1970's with the increased industrial and other consumption of electricity. Problems had to be addressed, especially with the planned addition of large hydro-electric power stations.

Development of a Load Flow Program

The National Electricity Administration (NEA) had an NCR315 computer with the basic task of the billing for electricity consumers in Baghdad. It was oriented to commercial use rather than scientific applications.

It had a simple Fortran II compiler with cumbersome paper tape input and output was on paper tape or line printer. The line printer works mainly with the Arabic "barrel". The barrel needed to be changed when English text is needed.

There was no interactive communication with the computer. Program development was "blind" in the sense that handwritten code is punched on paper tape with no printed copy. It is only when the code is compiled that error messages indicate typing or syntax errors. The actual testing of the program is through studying the results and trying to explain any discrepancy. It took a large amount of man-hours of actual work and many weeks to produce the final correct code.

Another problem was the limited memory of the computer. It had only 20k "slabs". A slab was a memory unit that has 12 bits. The full program, together with its data, had to be present in memory at the same time. The main data item, power system Z-matrix, is a square matrix of complex numbers. The available memory would not be able to handle any matrix of practical size.

It was necessary to handle the matrix one row at a time in all the extensive complex calculations involved in the reading of data, forming the Z-matrix and calculating the system variables in the iterative process as well as producing the necessary output. The external storage medium was CRAM units* which needed to be set up every time the application was used. In fact the actual programming was by itself a formidable task.

The mathematical solution model was based on the System Nodal Z-matrix. The author had a good and tested program written in ***Algol*** for the Elliott 803A computer as part of the work of for his M.Sc. degree that formed the basis for development [21].

The expected number of major power stations and substations in Iraq was around eighty. It is not necessary to represent each substation explicitly. The developed program could handle 56 nodes which was sufficient when the proper engineering principles are deployed.

The basic steps of the program were organized for maximum efficiency in memory requirement which in the end served the purpose quite well.

The application was used for a number of years for various studies. The number of individual case studies was not documented and runs into scores of cases for the full Iraqi system with many more specific studies to deal with local sub-networks. A program run to produce results for a specific case study took about 30-40 minutes in addition to the compilation time of the program that took around 20 minutes with each run. There was no possibility of storing the object code for further runs. It will be appreciated that a run that may take about 10-20 seconds nowadays required about one hour, apart from the time for the manual operations of loading tape, changing printer barrel, loading CRAM cards, etc which added to the time cost of the run. Thus making three case studies would

* Abbreviated from Card Random Access Memory.

have taken much of a day's work time. It was necessary to spend time after work and sometimes on Fridays to carry out a set of runs for a case study.

Three examples of studies each involving numerous runs of alternative network strategies and their contingency conditions are briefly presented.

Case 1:Study of a Consultant's Report

This was the first large application of the Load Flow Program. In 1969, a European consulting firm* was given the task related to adding generating capacity of 150-200 MW in the South of Iraq. In the final report, they recommended the extension of Najibiya Power Station in Basrah. Their task also included the study of future power demand in Iraq and suggesting further development up to 1980. In fact this extra task was made because the studies required could not be made in Iraq, especially the required system Load Flow analysis.

The report related to this part had a number of flaws, not in the technical and scientific analysis, but in some of the assumptions and ideas on which the analysis was based. In particular there was a need for propping the transmission system somewhere in the Central Euphrates area. Also, no solution was presented for the difficult and problematic operating conditions in other places in the National Grid. This had to be addressed in some way.

Other major points were related to the interim time up to the completion of the Najibiya extension and many technical differences on the hydro-electric development at Dokan and Derbendikhan.

These points were tackled within the NEA Projects and Studies Engineering Department. A team of two engineers** carried out the study of the Iraqi system taking different alternative solutions into consideration.

The main tool for the study was the newly developed Load Flow Program. It was used to study all the alternatives with their special weak points and contingency conditions.

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* The consulting firm Verbund Plan, Austria..

** Eng. Sabeeh Kafil Husain was the other member.

As a result of these studies, clear conclusions were made as to the best course of action. Two new gas-turbine power stations at Hilla and Shuaiba were suggested to enter service in time to avoid the expected problems. This met with "great" resistance from important authorities only because it was not customary to criticize European Consultants by young Iraqi engineers. But the proposal was finally approved.

It took only two years to show that the problems that had been anticipated by the NEA team were real problems that were averted.

Case 2: The Hydro Development

The Dokan and Derbendikhan dams were built in the late 1950's. They were designed for flood control, irrigation and electrical power generation. The hydro-electric part was not implemented. In 1970 it was decided to develop these two resources for power generation. The original design was based on small capacities as suggested by the J.G.White report[3] which was the first and only comprehensive report on electrical power development in Iraq. No further studies had been made. The report of Verbund Plan Consultants suggested increasing the capacity and even suggested the possibility of building a large 400MW hydro PS at Derbendikhan without presenting any background studies.

In 1972, the Soviet firm Technopromexport was given the task of constructing the two hydro power stations. First they had to present a technical report on the design aspects of the two stations including the transmission facilities needed to carry the power to Baghdad with possibility of supplying the Northern Region as well.

The Soviet firms that made these studies were Hydro Project, for the power houses, and Energoset Project, for the transmission scheme.

An initial look at the report by a delegation of Iraqi engineers showed some flaws, mainly in relation to the transmission scheme. On returning the suggestion that a composite group of engineers study these reports when they

are presented with the possibility of making their own studies on the subject. A team of eleven engineers from five concerned authorities was formed*.

The Soviet consultants' reports were thoroughly analysed. Two specific technical studies were carried out by the NEA members: study of the optimum capacity at the two sites and a study of the transmission scheme alternatives.

The capacity study was based on the actual daily load curve and an empirical method of analysis was developed.

The Load Flow program was used extensively for the transmission part. The number of cases included in the committee's report was 30 case studies that were chosen from a larger set of results (see Fig. 2). The study showed flaws in the recommendations of the Energoset Project report and made major changes in connections and voltage level. The committee adopted these studies and their recommendations on both capacity and transmission scheme.

The committee report [4] was discussed and analysed at a special meeting for the committee with the Ministry of Planning experts. The recommendations were accepted as the basis for implementation.

Prior to that, at a meeting for the committee with the president of SOIDC and DG of NEA, the head of SOIDC, Eng. Adnan Al-Kindi expressed the idea that power projects should be handled by NEA implying that his organisation did not have the level of know how needed. Perhaps the decisive factor that led to that statement was the ability to deal with advanced technical analysis, which in turn was much influenced by the system studies made.

* Members from: State Organisation of Industrial Design and Construction (6), National Electricity Administration (2), GD of Dams and Reservoirs (1), GD of Irrigation (1), Ministry of Planning – Industrial Planning (1)

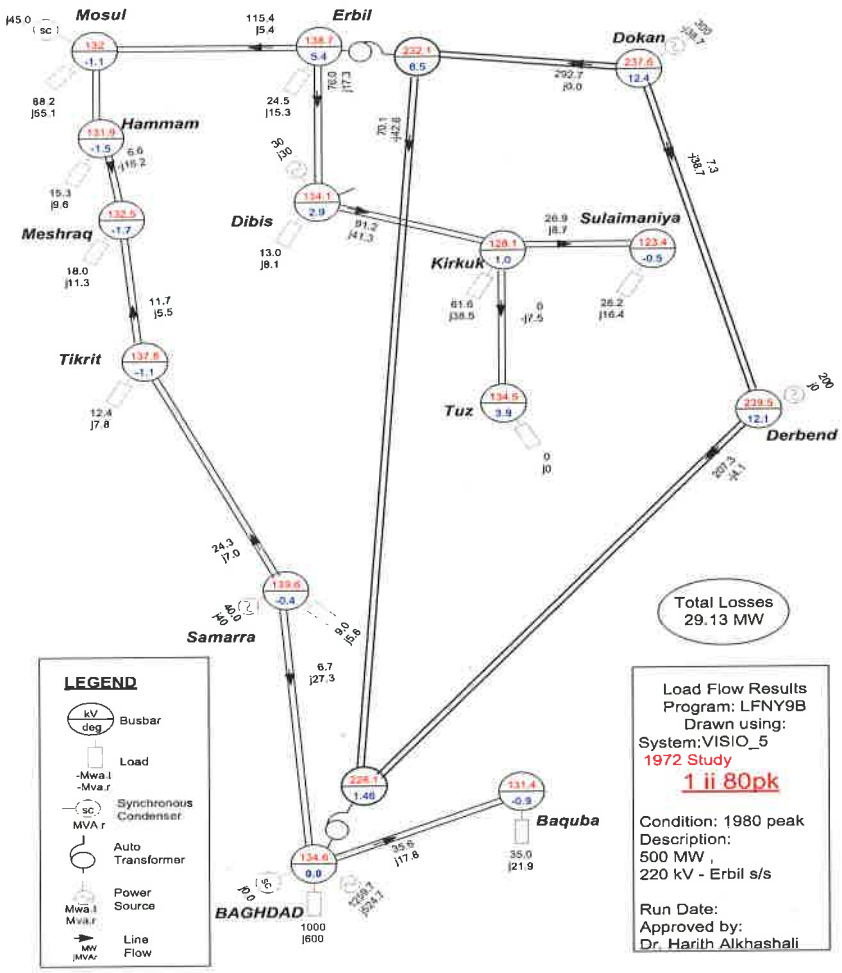

Fig. 2 Example of Load Flow Results of Case 2 (Redrawn)

Case 3: The Power Survey Report[5]

Immediately after the hydro report, it was suggested that the future of electric development in Iraq needs to be looked at in a more comprehensive manner. That would need a multi-purpose study that needs the necessary knowledge and a lot or ground work. It was suggested that a committee be formed within NEA for this purpose.

Studies of load development, transmission schemes, energy resources, possible future development for various alternative schemes were to be made.

The main result of the study was the decision on the next transmission voltage level. This dictated the study of the future system for five alternative voltage levels. It involved the extensive use of the Load Flow program to cover all the possible normal and contingency conditions for a future period of 15 years. Figures 3 & 4 are snapshots from the report.

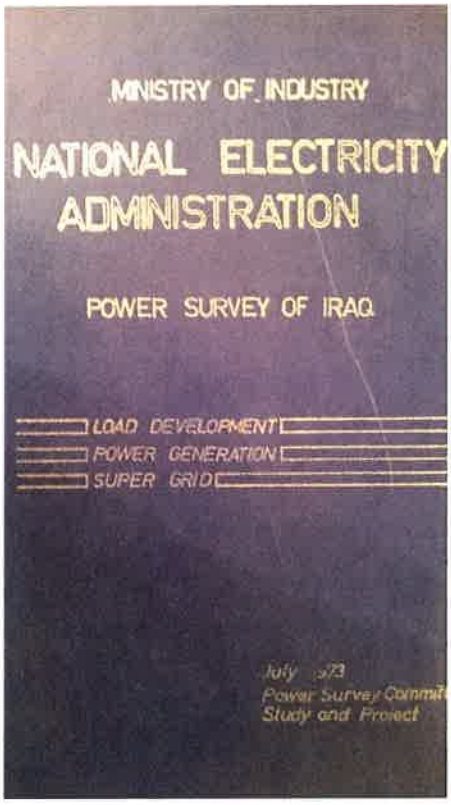

Figure 3 Outer Cover of report

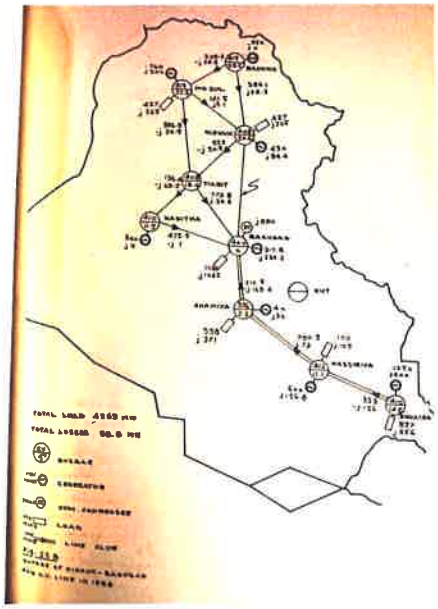

Figure 4 Results of a case study

The 400 kV transmission network, usually called the ***super-grid***, was designed and constructed as a result of this study. This provided a very strong back bone for power transmission. It makes it possible to build large economical power stations that provide energy anywhere in the country. It is still the main transmission network that is expected to serve that role for more decades.

Discussion: The Influence of Load Flow

There are many ways in which this particular type of study, i.e. the Load Flow, makes its impact which can be summarised as:

- it provides accurate values for the variables in a power system under different operating conditions specifically voltages, line flows and system losses.
- for power system operation it helps optimise the use of power and transmission resources especially under contingency conditions.
- it gives indication of possible problems such as overloading, excessive losses, over-voltage and under-voltage conditions.
- it gives indication of possible transient stability problems through the relative phase angles.
- it provides initial conditions when detailed Transient Stability analysis is required.
- It forms the basis for further studies such as optimisation studies
- In the special case of the early days of computer use for engineering problems in Iraq it had a special role. On the one hand it gave much self confidence in the ability to develop computer applications for various purposes. It also helped to create credibility and confidence in the recommendations of Iraqi specialists.

Conclusions

- The examples put forward in this study indicate the importance of the introduction of digital computers in Iraq. The first electronic computers started work in 1968[1]. It would have been impossible to carry out a study of practical size before that date. Nevertheless, they were not put to use immediately. Computers were mainly used for administrative tasks. There was no real program for the coordinated or planned use of computers. It was left to the experts who dealt with computers to initiate any useful work.
- It must be said that little is published about the use of computers in those early days, except for individual sources such as the First Iraqi

Conference on Computers[6]. Any engineering or scientific professional use was generally not published inside Iraq.

- A lot of work on the use of computers in Iraq has been done since those days. However, the fact remains that little is published about this use. In particular almost nothing is published about the impact of such use on decision making on technical, economical or other issues.
- There is need for making effort to collect and document such activities that would have been carried out by Iraqi specialists and experts. While this study has dealt with a single computer application in one aspect of engineering work, there are other fields that need to be searched and documented.
- There is need to encourage this kind of documentation on the level of university conferences, the Iraqi Engineers Union and other bodies.

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