

DATABASE DESIGN FOR POWER QUALITY SURVEY

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Abstract

A power quality survey of nine electricity distributors was undertaken in 2000/2001. Some 500 Mb of data was collected and analysed. The database requirements for this survey is described together with an evaluation of the suitability of Microsoft® Access for this application. The design of the database is outlined including the inputs to and outputs from the database as well as the data processing required. The use of Visual Basic macros within Access is presented. Access was found to be operating close to its limit for large databases of this type.

1. INTRODUCTION

During 2000/2001, the Integral Energy Power Quality Centre at the University of Wollongong carried out a pilot power quality survey of the electrical distribution networks of eastern and central Australia. Nine electricity Distributors were involved, with eight 240/415 V sites from each being monitored for one week. Although similar surveys had been previously performed overseas [1], this was the first time that a study like this has been undertaken in Australia.

One of the major aims of the survey was to establish a survey methodology applicable to Australia that would meet the requirements of State Regulators for the provision of network power quality data in an appropriate format. Hence the issues of data collation, analysis and presentation were a major focus of the project.

Microsoft Access was chosen as the database program for the survey because of its widespread use and availability. It is part of the Microsoft Office suite of programs. The particular version used was Access 97. This paper describes the development of the power quality database used for the survey and assesses Access for its suitability for this application.

2. DATABASE REQUIREMENTS

During the survey, 72 sites were each monitored for one week leading to the collection of some 500 MB of data. The measured quantities can be divided into two groups, namely, those that were measured by logging and those that were captured as distinct events.

Logged quantities (continuous events):

1. Steady State Voltage.
2. Unbalance (3 phase sites only).
3. Harmonics.

Captured quantities (discrete events):

1. Sags/Interruptions.
2. Swells.
3. Transients.

In a survey of this type, it is important that the data gathered from the various measurement sites is accurate and consistent to allow comparisons. All survey measurements were undertaken with CHK Wireless Technologies [2] POWERmonic PM30 instruments. These instruments were chosen because they had both logging and event capture capabilities, measured or allow calculation of the selected power quality quantities, had battery-backed memory (4 MB), were rugged and weather proof, and were locally manufactured, being readily available and well supported. All instruments were calibrated prior to use at a NATA certified laboratory.

2.1 Inputs to the database

The voltage data from the monitoring instruments which was put into the database was of three main types:

- a. Trends, i.e. logged data, consisting of the 10-minute average line-neutral voltages of each phase, and the 10-minute average of the 3^d and 5th harmonic and Total Harmonic Distortion (THD).
- b. Sag/interruption/swell parameters obtained using the Table Capture feature of the instrument which stores the time of occurrence, maximum depth and duration of RMS events for each phase independently.
- c. Transients waveforms stored as 1 cycle pre-trigger and 5 cycles post-trigger (1368 points) for each phase independently.

2.2 Outputs from the database

The data from the survey was reported in two ways:

- a. Site data – the actual data collected from each site.
- b. Summary data – collation of key power quality parameters from all sites.

All sites were coded for confidentiality.

The data from each site was presented as:

- The RMS voltage trends over the survey period for each phase.
- The voltage unbalance trend over the survey period.
- Harmonic trends over the survey period for each phase for 3rd & 5th harmonic & THD.
- The sag/interruption/swell capture table.
- Captured transients waveforms.

This data was presented in the form of Microsoft Excel spreadsheets using the in-built charting functions.

The summary data was presented in the form of bar graphs where each bar was used to display the data from each site, the worst sites being located on the left of the graph. The graphs were divided into two sets based on Distributor Type (Average & Poor power quality sites) and Load Type (Commercial, Industrial, Residential, Rural & Remote sites). The key summary parameters presented were:

- 95% absolute deviation from nominal voltage.
- 95% voltage unbalance.
- 95% 3rd & 5th harmonic and THD.
- Number and duration of sags with depths to less than 80%, 60%, 40% & 10% (interruptions) of nominal voltage.
- Number and duration of swells greater than 120% of nominal voltage.
- Number of transients with magnitude greater than 120% of peak 50 Hz level.

The 95% cumulative probability value was used for the logged data to be consistent with the way national and international standards deal with variations of these quantities over time [3].

An example of how the results were graphed is shown in Figure 1 for the 95% absolute deviation from nominal voltage, using manufactured data.

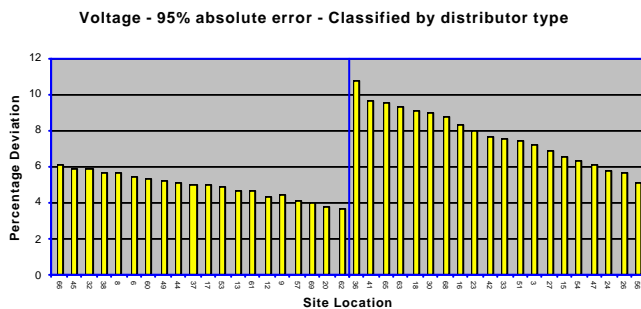


Figure 1: Example of graphical output.

2.3 Processes and calculations

Data was not able to be moved directly from the instrument database to Access. Trend data and Table

Capture data were temporarily moved to an Excel spreadsheet in order to strip off header information before being pasted into Access. Also, a special program had to be provided by CHK Wireless Technologies in order to get the Transients Waveforms data into a suitable form for Access to import. After manipulating the data, the results were moved to Excel for graphing. The graphing tools within Access were poor with limited flexibility compared to those of Excel especially with respect to labelling of graphs. The data handling process is shown diagrammatically in Figure 2.

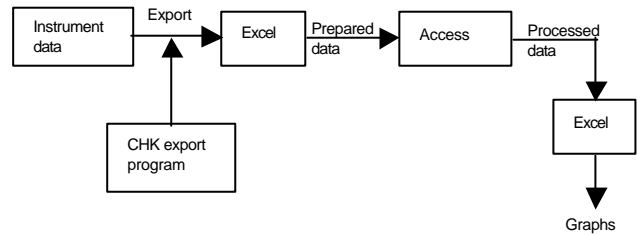


Figure 2: Data handling process.

The various summary quantities were processed for each site as follows:

- RMS voltage:** The 95% level of the absolute deviation from nominal voltage was determined for each phase and the maximum of these values assigned to the site. Short-term undervoltage events were removed from the data to prevent distortion of the results.
- Unbalance:** The 95% level of voltage unbalance was calculated from the phase-neutral RMS voltages which were assumed to be 120° apart with the effects of harmonics being negligible. This assumption led to a slight underestimate of the actual negative sequence unbalance. The phase-neutral voltages were used to calculate the phase-phase voltages and then the unbalance was calculated using the IEC formula [4]:

$$Unbalance = \frac{1 - \sqrt{3 - 6b}}{1 + \sqrt{3 - 6b}}$$

where
$$b = \frac{V_{AB}^4 + V_{BC}^4 + V_{CA}^4}{(V_{AB}^2 + V_{BC}^2 + V_{CA}^2)^2}$$

- Harmonics:** The 95% levels of 3rd & 5th harmonic and THD were determined as for RMS voltage.
- Sags/interruptions:** These were sorted according to depth and the number with depths to less than 80%, 60%, 40% & 10% (interruptions) of nominal voltage were determined. The minimum, average and

maximum duration of sags within these categories were then calculated.

- e. Swells: These were sorted according to height and the number above 120% of nominal voltage were counted. The minimum, average and maximum duration of these swells was then determined.
- f. Transients: Each transient waveform table (V vs t) was examined and the number of transients with magnitude greater than 120% of peak 50 Hz level were counted. This was the best that could be done with transients due to instrument limitations (voltages were clipped at 800 V and sampling speed of 11,413 samples/s did not allow fast transients to be resolved).

3. THE DATABASE

The Access database uses Structured Query Language (SQL) which is a commonly used and standardized database language. Access is a relational database which allows the defining of different search keys and primary keys. The primary key is defined within a Table and must be unique for every entry, allowing individual entries within a table to be uniquely identified. A Table within the Access database can be created either manually by entering data via cut and paste or by being generated using a macro (which uses Microsoft Visual Basic code and specially provided database functions that come with Access). All of the raw data was entered via cut and paste from Excel spreadsheets and Word documents, taking advantage of the linkages between the components within Microsoft Office components, namely, Object Linking and Embedding (OLE). All Tables are stored by the database along with the designed Queries, Forms and Visual Basic Macros. In order to allow analysis and filtering of data, a Dynaset is defined using Queries, and is basically a temporary storage area that exists only while the Query has been run and needs to be re-run at a later date if the analysis needs to be repeated or the Query is modified. Dynasets are not stored in the database as Tables are. Apart from this distinction, nearly anything that can be done to a Table can be done to a Dynaset. Dynasets can be used as inputs to other Queries which result in another Dynaset. Using this feature it was possible to filter, manipulate and calculate various statistics for this study.

To provide the required data for the analysis of the power quality data, it was necessary to first perform calculations on a phase by phase basis and then to do comparisons and select statistics between these phases. The coexistence in the study of single-phase and three-phase subsystems resulted in database Dynasets and Tables being of different lengths. This resulted in problems when statistics needed to be

calculated between phases, such as Unbalance and the minimum, maximum, average and 95 percentile values [5]. The methodology chosen to solve such problems was to develop Visual Basic modules which used the primary keys and secondary keys to identify similar records in Tables and Dynasets and then to do some statistical manipulation required for the statistical analysis. The following Section will give examples of the required macros and explain details of their design.

4. VISUAL BASIC MACROS

As mentioned above, the problem of Dynasets and Tables of different lengths was overcome by the use of Visual Basic macros. It was decided early in the study that the statistics minimum, maximum, average and 95% level would be calculated for every phase at a particular site, then all three phases would be compared and the maximum used as the value for that statistic at that site. Normally, if the Dynasets were of the same length (as for the case if all sites were three phase and no sites had a phase missing), it would have been simple to use a Query to produce the required information. In fact, only Phase A Dynasets had information on all sites since some sites were Single Wire Earth Return (SWER) sites and some phase information was missing from other sites.

The partial listing of the code used to combine different sized Dynasets in the study is shown in Figure 3. A flowchart of the full algorithm is shown in Figure 4. Looking at the example code provided in Figure 3, the Query or Recordset (another name for Dynaset in Access) called **RMSVoltsSelValidDataAveVStats1** is opened by the Access built in Visual Basic function **db.OpenRecordset()**. A line in the macro not shown in the Figure sets **db** to be the current database (`Set db = CurrentDb()`), and the argument passed to this function in inverted commas is the name of the Query/Dynaset that must be opened. The variable **RMSVoltsSelValidDataAveVStats1** is set to point to the Dynaset using the Set command. The same name is used as the Dynaset to show which Query is currently involved. The next command sets the pointer to the open Dynaset to the first record (`.MoveFirst`) in the Dynaset or Recordset. A Do Loop is then started. This Do Loop will continue until an End of File (.EOF) is encountered which in this context would be the Loop has checked all records in the Dynaset. Inside the Loop, a newly created Table is being populated with the values stored for Phase A (which this first Query is concerned with – as indicated in the use of 'AveVA' in the name of the Query). The name of this new Table, following the convention used for the Query or Dynaset is actually **RMSVoltsMaxMinAvgNomDevTable**. The first

command in the Loop uses ‘.AddNew’ which adds a new record to the Table. The Table needs to be predefined before this is done and opened in a similar way to the Query. Thus all elements of a record will be present in this new record of the Table but set to their default or NULL value. Some of the existing records element headings can be inferred from the code, for example the first two records set in the Loop set indicates that ‘SiteID’ is an element of the Tables record (in fact this is the primary key as it is unique for this Table) and ‘Max_of_RMS_Mins’ is another. Once the values have been changed in the record element of the new Table, the Table needs to be updated, so the ‘.Update’ command is used. Then the pointer to the Query needs to be moved along one record, hence the use of the Queries name with ‘.MoveNext’.

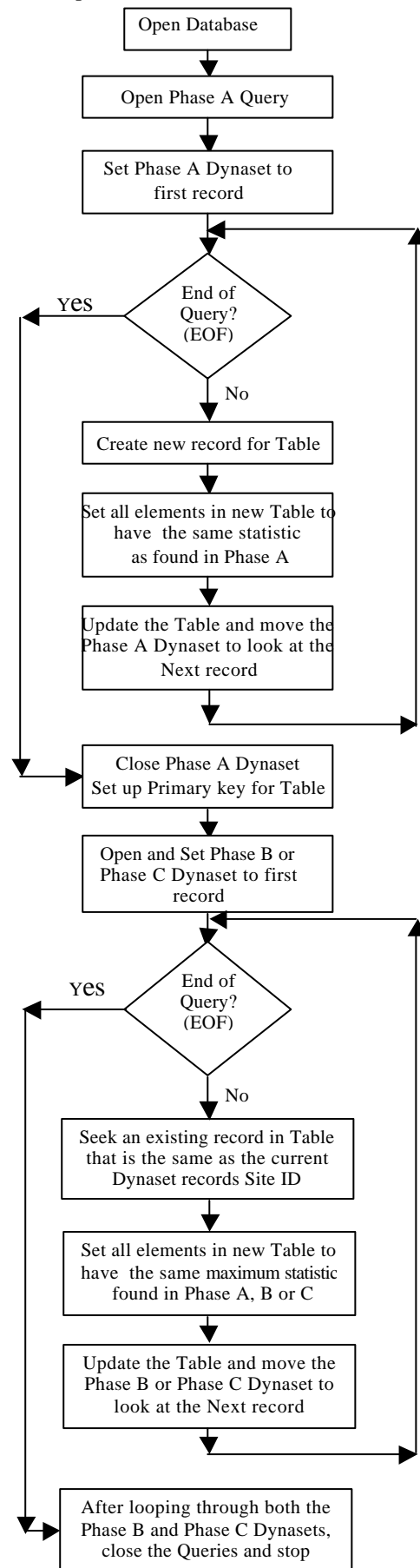
Figure 3: Partial Listing of Visual Basic code to formulate different sized Dynasets.

```

'Open the first query required
Set RMSVoltsSelValidDataAveVAstats1 =
db.OpenRecordset(
    "RMSVoltsSelValidDataAveVAstats1")
RMSVoltsSelValidDataAveVAstats1.MoveFirst
Do Until RMSVoltsSelValidDataAveVAstats1.EOF
    RMSVoltsMaxMinAvgNomDevTable.AddNew
    RMSVoltsMaxMinAvgNomDevTable.[SiteID] =
    RMSVoltsSelValidDataAveVAstats1.[SiteID]
    RMSVoltsMaxMinAvgNomDevTable.[Max_of_
    RMS_Mins]=
    RMSVoltsSelValidDataAveVAstats1.[MinOfNum
    SelAveVA]
    RMSVoltsMaxMinAvgNomDevTable.[Max_
    of_RMS_Maxs] =
    RMSVoltsSelValidDataAveVAstats1.[MaxOf
    NumSelAveVA]
    RMSVoltsMaxMinAvgNomDevTable.[Max_of_
    RMS_Avgs] =
    MSVoltsSelValidDataAveVAstats1.[AvgOfNum
    SelAveVA]
    RMSVoltsMaxMinAvgNomDevTable.Update
    RMSVoltsSelValidDataAveVAstats1.MoveNext
Loop
  
```

Clearly the code in Figure 3 only caters for the data associated with the Phase A voltage statistics. The code that follows closes the Dynaset and opens the Dynaset associated with Phase B and then Phase C. In these cases the SiteID needs to be searched to ensure that the correct elements of the record are compared and then the maximum of the corresponding value is stored in the new Table. In the case of single phase systems such as the SWER sites, there are no entries in the Phase B and Phase C Query sets, so the recorded data for these is simply the original data found in the Phase A Query/Dynaset. Figure 4 shows a flow chart illustrating the algorithm involved in developing one of the Tables used to provide the statistical data for the study.

Figure 4: Flow Chart of Algorithm used to provide a Table of statistics.



Visual Basic macros were used to also rank the values for Harmonics and average values after they had been entered into Tables within the Access database. From these rankings it was possible to locate the 95% points and report these in the study. While not impossible, it would have been harder to locate the values for these statistics without the use of Visual Basic macros inside the Forms designed for the Access database.

[7] G. Perry, "Visual Basic 5", QUE, 1997.

References [6] and [7] were used extensively during the design of the database.

5. CONCLUSION

The database requirements associated with a power quality survey of nine electricity distributors have been described. Inputs to and outputs from the database have been given together with a description of the data processing performed. The database used required the use of macros because after filtering the data it was found that the Dynasets that needed to be compared were of different lengths. Microsoft Access was used to process some 500 MB of data and was found wanting in several areas. The in-built graphing facilities were found to be inadequate necessitating the use of Excel for reporting purposes. Also, data processing was very slow even on a fast PC. Consequently, for more extensive power quality surveys in the future, further investigation should be pursued in choosing a different database program such as Oracle which may scale and perform better for such larger database applications.

6. REFERENCES

- [1] E.W. Gunther and H. Mehta, "A survey of distribution system power quality – Preliminary results", IEEE Trans. Power Delivery, Vol. 10, No. 1, January 1995, pp. 322-329.
- [2] <http://www.chk.com.au/>
- [3] CENELEC European Standard EN 50160, "Voltage characteristics of electricity supplied by public distribution systems", November 1994.
- [4] Robert, A. and Marquet, J., "Assessing voltage quality with relation to harmonics, flicker and unbalance", CIGRE 1992 Session, Paris, Paper 36-203.
- [5] V.J. Gosbell, V.W. Smith, R. Barr and B.S.P. Perera, "Methodology for a National Power Quality Survey of Distribution Networks", submitted to Distribution 2001.
- [6] C.N. Prague and M.R. Irwin, "Access 97 Bible", IDG Books, 1997.