Loss minimisation using islanding technique for district of Klang, Malaysia

H. Shaibon
A.A. Mohd. Zin
Y.S. Lim
K.L. Lo

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Abstract: Distribution system loss reduction has been grossly neglected by most electricity utilities even though it contributes to no less than 75 per cent of the total system losses. Existing methods of loss reduction involve enormous capital cost and extensive rehabilitation to the existing distribution reticulation and are hence not very practical, compounded with the problem of coping with the high and dynamic load growth in most developing countries. The paper looks into techniques of selecting and operating the distribution system, with minimum or no physical change in the present distribution reticulation to reduce losses. It proposes that the existing distribution network be operated in 'island groups' by paralleling selected feeders into an island

1 Introduction

It is a well established fact in any power system that there is discrepancy between the energy sent out of the generation plants and the energy consumed [1, 2]. The discrepancy, which is termed as loss, can be attributed to technical and nontechnical reasons. The nontechnical losses are caused by theft, meter reading and metering errors. The technical losses can be broadly categorised into 'fixed' and 'variable' losses. The fixed losses such as transformer iron losses and dielectric losses of cables are mainly voltage-dependent. The variable loses are due to currents flowing in the resistive component of the plants. Since current varies with load demand, the losses vary accordingly.

This paper is concerned with technical losses in the distribution system in Tenaga National Berhad. The components of a distribution system are conductors, transformers, voltage regulars, and switchgears. When current flows through the components, heating occurs due to the presence of resistance (R) causing power loss given (I^2R). Transformer and regulator iron losses are generally constant due to a little variation in the voltage. Therefore it will not be affected by the variation in current due to the load demands.

The TNB is responsible for the generation, transmission and distribution of electrical energy. The voltage levels currently being used in the TNB system are 275 kV, 132 kV. 66 kV, 33 kV, 22 kV, 11 kV, 6.6 kV and 0.415 kV. Although there are very few consumers being supplied at transmission HV voltages of 275 kV, 132 kV and 66 kV, it is normally understood that distribution is mainly concerned with system outage including and below 33 kV. Tenaga National Berhad's annual system loses for the last 16 years are shown in Fig. 1. It can be seen that the amount of losses increase from 1056.82 GWh in 1978 to 4179.73 GWh in 1993.*

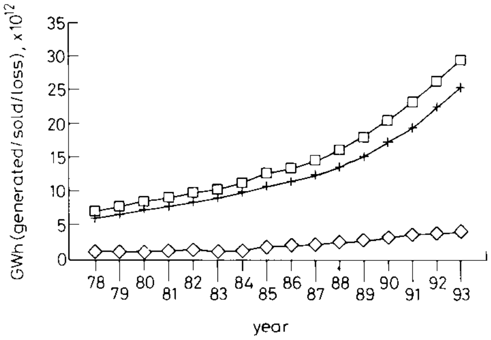

Fig. 1 *TNB's annual energy scenario*

□ units generated
+ units sold
◇ units lost

2 Methodology of islanding in distribution network

In the operation of the transmission system (132 and 275 kV network), the whole network is synchronised (paralleled) into a grid system. The system is designed to break and operate as islands, only in contingencies/emergies to prevent cascade trippings, which may lead to total system collapse. Elaborate and expensive protection schemes are used to achieve this, which are not economically viable or justifiable for the distribution system, where the connected loads are significantly smaller, and the equipment used is very much cheaper.

The present distribution system, especially on 11 kV, cannot be operated as for the transmission system due to

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H. Shaibon and A.A. Mohd. Zin are with the Faculty of Electrical Engineering, University Teknologi Malaysia, Malaysia

Y.S. Lim is with the Area Protection Department, Tenaga National Berhad, Kuala Lumpur, Malaysia

K.L. Lo is with the University of Strathclyde, Glasgow, United Kingdom

* Laporan Tahunan LLN and TNB, 1978–1993

the type of cheap switchgears and cheap protection system in use. To change the present design by rehabilitating it will be too costly and enormous a task. Nevertheless, it should be continuously pursued at a pace where we can afford to do so with respect to funds and manpower available without hampering new demands required for dynamic economic growth.

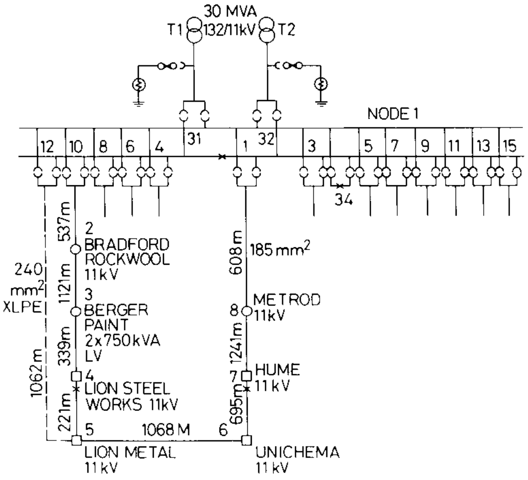

Fig. 2 *Case study network*

Table 1: Monthly recorded maximum demand at consumer's meter, October 1993

Sub-station (nodes)	Maximum demand		Units consumed	
	KW	kVAr*	kWh†	kVAh
1	Swing	Swing	Swing	Swing
2	2031	1195	760410	447260
3	500	129	156500	40477
4	668	215	228214	73286
5	1000	364	270667	130667
6‡	0	0	0	0
7	600	542	143900	130100
8	4080	2492	2199000	1343400
Total	8879	4937	3758691	2165190

* calculate value
† total peak + non-peak consumption, where applicable
‡ node 6, Unichema S/S converted to 33 kV consumer

Table 2: Maximum hourly load readings in amperes taken at Bukit Raja main intake (132/11 kV) for October 1993

Feeder	Maximum demand		
	Amperes	kW*	kW†
1	240	4024	4680
10	160	2683	3199
12	30	503	1000
Total	440	7210	8879

* calculated using average power factor = 0.88
† total MD of individual consumers connected to feeder

One possible solution is to operate the existing distribution network in 'island groups' by paralleling selected feeders into an island (in essence, mini or macro grids, where possible). The objectives of operating it in this format are to:

(*a*) reduce losses on the feeders as compared with open point operation

(*b*) minimise load loss when a selection of the feeders in the group is faulty

(*c*) reduce restoration time by simplifying fault sectionalisation

(*d*) improve reliability by having the ability to sustain a first fault.

The main disadvantage of operating it in such a manner will be an increase in fault levels on the 11 kV network and the secondary distribution network. Nevertheless, this will stiffen the system slightly and hence reduce flicker.

3 Feeder selection

The selection of feeders to form an island are subjected to the following constraints.

3.1 Loading criteria and load flow

The islands are selected in such a configuration where the total maximum demand of the group (feeders) in the island is less than the summation of the maximum loading (thermal) capacities of all the individual feeders making up the island minus the largest feeder capacity forming the island. This will prevent total loss of load for the island should a first leg fault occur on any of the feeders making up the island in most cases, i.e.

$$\sum_{i=1}^{N} I_{md_i} < \sum_{l=1}^{N} I_{c_i} - I_{c_{largest}} \qquad (1)$$

where:

N = number of feeders connected in parallel to form the island
I = current
c = current carrying capacity
md = maximum demand on feeder
$largest$ = the largest feeder/cable (current capacity).

A load flow study is done after the above desk-top selection of the feeders to form a particular island. This will ensure that no excessive overloading (load violations) will exist in the island to be formed which may trip the IDMTL relay on overcurrent, due to extremely long lengths or variation in sizes of cables used.

3.2 Fault-level violations

Fault levels will increase due to the reduction in impedance caused by the paralleling of feeders as seen by the source breakers of the feeders making the island. As such, a new fault-level study will be required. This is to ensure that the fault levels do not exceed the switchgear rating and are not too excessive as compared with open point operation. If the calculated fault levels on the 11 kV buses are excessive as compared with open point operation, further study of fault levels on the secondary busbars (LVDD/FP) may be required. The increase in fault level on the secondary (415 V) network will not be much of a problem because of the large impedance of the 11/0.415 kV step-down transformer.

3.3 Voltage violations

The possibility of voltage violations is unlikely except in very exceptional cases. The flow studies in Section 3.1 will have shown up such a problem. In adition, the on-load tap changer (OLT) on the primary side (132 or 33 kV) of the source bus will be able to adjust for slight variations caused by operating the circuit in island formation as is the case for open point operation. It is obvious that a better voltage regulation is obtained using an island formation operation. Moreover, the no-load tap changer on the 11 kV side of the step-down transformer (11/0.415 kV) may be adjusted to allow for voltage drop due to the distance from the source, as in open point operation.

3.4 Other constraints

Some other constraints that must be ensured before paralleling the circuits into an island are:

(*a*) Vector groups of the source transformers of the feeders used to form a particular island must be of the same group.

(*b*) Voltage (transformation ratio) of the source transformers should be approximately the same.

(*c*) Phasing out must be done just prior to paralleling to form the island, to ensure correct phasing.

4 Case study

A real network consisting of three feeders (feeders 1, 10 and 12, Bukit Raja M/I, Klang district) was used. The three feeders are made up of two sizes of cables, 185 mm^2, PILCDSTA (feeders 1 and 10) and 240 mm^2, XLPE (feeder 12); see Fig. 2. The measurement data shown in Tables 1 and 2 are used as inputs to the software called CADPAW (computer-aided distribution planning analysis workstation). This software is capable of doing load flow study, short-circuit/fault calculation and meter start/restart analysis as well as checking for voltage violations. It is also capable of evaluating the capital cost of a particular network and the amount of losses.

5 Discussion

From Table 3 it is obvious that the current (load) flow for an islanded network follows the path of least resistance.

Table 3: Load flow

Sub-station (nodes)	Open point operation			Island operation		
	Amps	kW	kVAr	Amps	kW	kVAr
1 to 2	183	3180	1426	157	2670	1346
1 to 5	57	1014	362	121	2040	1082
1 to 8	285	4624	2838	267	4340	2635
2 to 3	62	1145	297	31	588	98
3 to 4	35	631	178	4	77	−13
5 to 4	3	51	39	34	600	232
5 to 6	3	50	6	35	467	482
6 to 7	3	50	29	36	475	493
8 to 7	38	543	458	8	139	64

Notes:
Status of 'Off-points' are as for Table 2.
The results of the load flow study for both open and island operations are as shown by Table 3.

It may be possible sometimes, by using the above studies, to find an optimum off-point for open operation which may have slightly fewer losses for a particular demand, but this will not cater for dynamic load changes as demanded by the consumers.

It can be seen from Table 4 that the voltage fluctuations are much lower for island operation than for open points, i.e. island operation improves the voltage regulation slightly. The main disadvantage of island operation is the increase in fault level, as shown in Table 5. Nevertheless, we could limit the fault level by reducing the number of feeders in an island group so that it will not violate the fault rating of the equipment in use. The advantage of a higher fault level is that it will stiffen the network and hence reduce flicker.

Island operation reduces losses in cables, as can be seen in Table 6 (column 7), where savings of US$938 have been obtained. The capital cost for island operation is US$16, more than for open operation because of the two additional 5 m lengths of cable used to model the switches which were removed for open operation simulation. From Table 7 it can be seen that less load is lost for similar faulty cable sections. In addition, the number of sections that need to be tested to pinpoint the faulty section is reduced, thereby reducing the time required to isolate/sectionalise the fault and subsequently the feedback of the supply.

Table 4: Voltage violations

Substation (nodes)	Voltage (p.u.) (open point)	Voltage (p.u.) (island)
1	1.0000	1.0000
2	0.9967	0.9972
3	0.9944	0.9960
4	0.9940	0.9960
5	0.9983	0.9962
6	0.9982	0.9951
7	0.9928	0.9943
8	0.9942	0.9946

Notes:
1 p.u. = 11 kV and status 'off-points' are as for Table 2.
The system losses and costs for open point operation and for island operation are as shown in Table 6.

Table 5: Short-circuit analysis

Sub-station (nodes)	Max. fault level (open point operation)		Max. fault level (island operation)	
	Amperes	MVA	Amperes	MVA
1	14 857	283	14 857	283
2	13 569	259	14 139	269
3	9 285	177	12 587	240
4	8 416	160	12 984	247
5	11 686	223	13 514	257
6	8 390	160	11 327	216
7	8 792	168	11 254	214
8	13 194	251	13 665	260

Notes:
Bus/node 1 = swing bus
A prefault voltage of 11 000 V $(1.0 + j0.0)$ p.u. and a fault impedance of $(0.1 + j0.1)$ ohms was used in addition to the data above.
The results of the short-circuit analysis are as shown in Table 5.

Table 6: System losses and costs

Operation mode	System losses			System costs		
	Demand losses		Energy losses	Equipment	Losses	Total
	Real	Reactive				
	kW	kVAR	kWh/yr	US$/yr	US$/yr	US$/yr
Open	45.6	−128.15	163 572	11 584	20 787	32 371
Island	43.5	−128.05	156 062	11 600	19 833	31 433
Diff.	2.1	−0.1	7 510	−16	954	938

Table 7: Load loss and outage time

Fault between sub-stations (nodes)	Load loss (kW MD)		No. of sections affected (needs to be tested)	
	Open	Island	Open	Island
1 to 2	3199	2531	3	3
1 to 5	1000	0	4	1
1 to 8	4680	4080	2	2
2 to 3	3199	2531	3	3
3 to 4	3199	2531	3	3
4 to 5	0	0	1	1
5 to 6	0	0	1	1
6 to 7	0	0	1	1
7 to 8	4680	4080	2	2

Note:
Status of 'off-points' are as for Table 2.

For a right busbar fault at the intake, the reliability of the network for the case study is enhanced since the supply to all loads except to Metrod will not be disrupted and Metrod will only be disrupted for the time taken to identify and isolate the fault and subsequently the feedback. Should the island be formed using three different sources (main intakes), the loss of an intake will have much less impact than in open operation.

The cable between nodes 1 and 8 was changed from 185 mm^2 PILCDSTA to 240 mm^2 XLPE, and the results obtained are as in Table 8. The results show that US$1618 was saved between the two methods. In addition, if we compare Tables 6 and 8, there is a difference of loss amounting to US$1764 for open point and US$2444/yr for island operation, the cost for such a change being only US$247/yr.

Table 8: Cost comparison after the 185 mm^2 cable is change to 240 mm^2 (between node 1 (M/I) and node 8 (Metrod S/S))

Operation mode	System losses			System costs		
	Demand losses		Energy losses	Equipment	Losses	Total
	Real	Reactive				
	kW	kVAR	kWh/yr	US$/yr	US$/yr	US$/yr
Open	41.7	−1240	149 693	11 831	19 023	30 954
Island	38.1	−125.1	136 839	11 847	17 389	29 236
Diff.	3.6	−1.1	12 854	−16	1 634	1 618

6 Conclusions

The results show that the islanding technique could be used to reduce losses. In the authors' opinion, the distribution network loss minimisation using the islanding technique should have been adopted long ago since it is not something which is really new nor does it require great technical expertise.

7 References

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