Interpretation of results measured by the Current and Voltage Monitor System on LV networks

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Abstract. This paper presents the results of research done on the measurement of Currents and Voltages measured on the Eskom LV network in the North Western Region (NWR). The NWR include areas of Gauteng, Free Sate and Northern Cape. The reason for this research is to identify areas with theft and to improve the quality of supply to our customers. A measurement device was developed that could be connected to pole mounted transformers in the urban areas (townships) without disconnecting the customers. The Current and Voltage Monitor System had to remotely connect to all measurement units in the field via GPRS and provide graphs that can be interpreted to the advantage of the performance of the system as well as the customers. The system should also provide instantaneous alarms and must be able to configure settings remotely. The energy consumption kWh and kVA of a transformer for a given period could also be calculated. This energy consumption data can then be verified with the billing department. The research described here forms part of an Eskom regional need where annual load profiles need to be taken for planning purposes.

Key Words. Remotely configure, Remotely connect, GPRS, CVM

INTRODUCTION

Eskom, North Western Region, has 35 948 pole mounted transformers installed. The failing rate of these transformers varies between 3 and 5 percent per annum. The reasons for the failures are most of the time unknown. Lightning do play a role but most of the time the reasons will be recorded as "cause unknown". The average cost to replace a pole mounted transformer in 2011 rand value will be about R44 000, commissioning included. Thus for a 5 percent failing rate per annum, the replacement cost will be R 71 896 000 for the NWR.

Factors that might influence the performance and life cycle of the pole mounted transformers are overloading, unbalancing, lightning, system faults and temperature control.

Additional to the technical performance of the pole mounted transformers the perceived quality of supply to the customer is for Eskom the number one priority.

1. THE CURRENT AND VOLTAGE MONITOR UNIT (CVM)

The Current and Voltage Monitor Unit consist of Clip-On CT's (20 A to 1000A), Voltage inputs (20V to 300V), 2 Gb memory card, and GSM/GPRS modem. The unit can also measure temperature and consist of a number of input and output contacts.

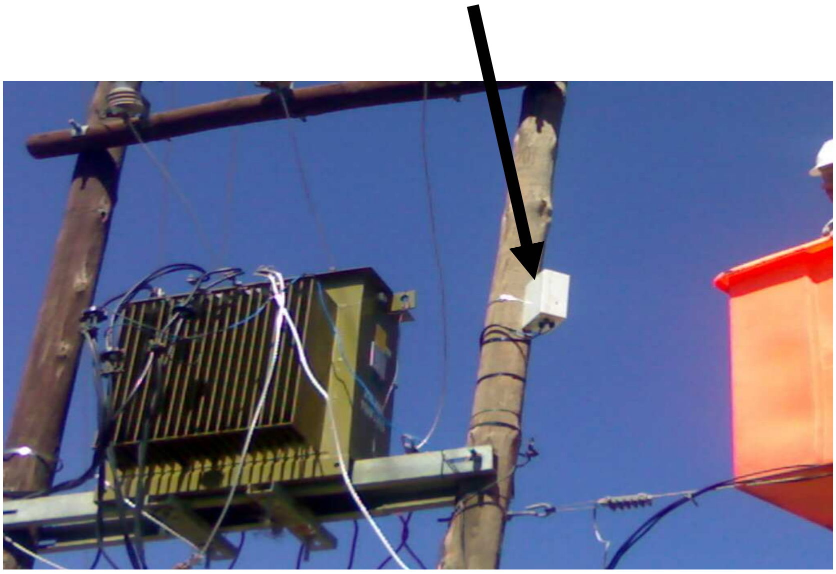

Figure 1: CVM installed at pole mounted trfr

The first three CVM’s were installed during 2007 as dial up units via GSM. To reduce operating costs GPRS were implemented thereafter.

The CVMs are fully programmable. With the default settings the CVM will log the Temperature, Current and Voltage values every 30 minutes. A preset dead band will be defined and as soon as the actual values exceed these values the unit will start to rapid log for example every minute. This will allow full visibility of the graph with minimum traffic on the communication channel. All units need to be tested prior to commissioning to ensure that the IP address is available from the APN (Application Point Node). A LAB and Commissioning procedure were compiled to ensure that all work done comply to a standard.

2. SERVER AND PROGRAM

The hardware consists of a normal desktop computer as well as a router. The software allows the CVM’s to be grouped according to the Eskom NWR geographical area, which is divided into six Field Service Areas, each with a number of Technical Service Areas.

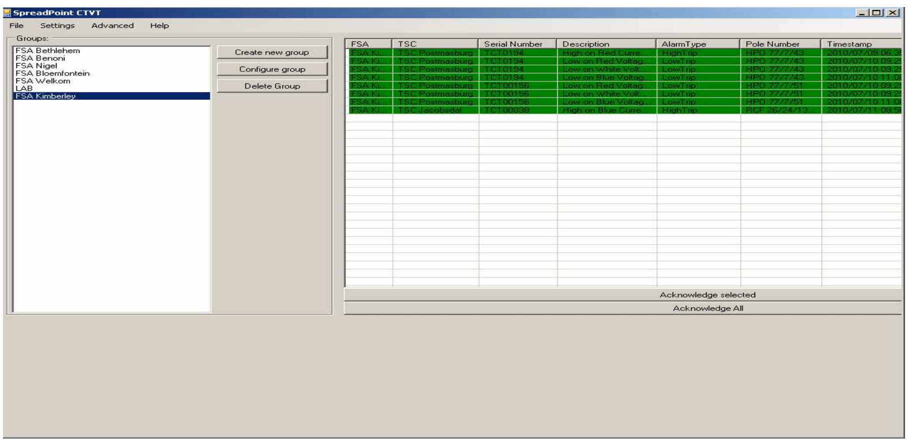

Figure 2: Six Field Service Areas

For each Technical Service Area the size of transformers can be grouped according to kVA ratings. This will allow down loading of settings to all 100 kVA transformers in that Technical Service Area.

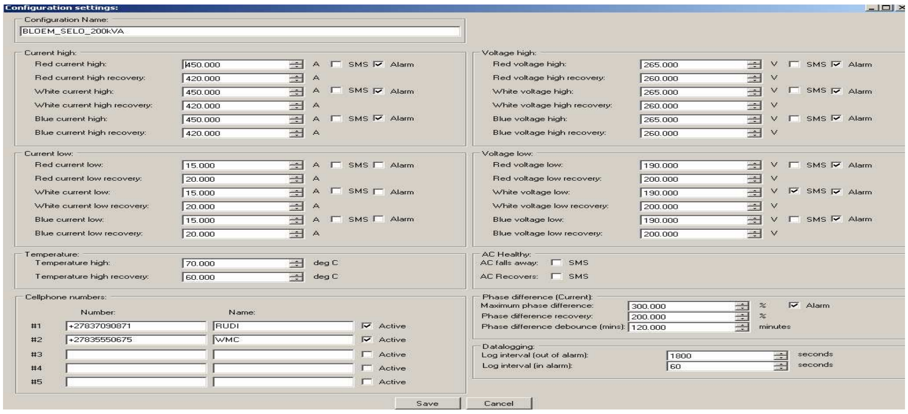

Figure 3: Settings sheet per kVA

To allow GPRS (General Packet Radio Switching) communication, it is imperative to ensure that each unit communicates to the server. The server can be set in solicited mode to pole the CVM's on a preprogrammed time. Instantaneous values can also be read directly from the program. For each CVM the GPS co-ordinates need to be recorded for RICA.

The program will default on the alarm panel to indicate the latest CVM's that went out of the dead band. For each CVM a graph will be available according to the time frame selected. The current and voltage graphs can be down loaded to an Excel spread sheet.

The kWh and kVA can also be selected per unit for a selected time period. The percentage unbalancing between Red, White and Blue phases can be set as well as the minimum duration before an alarm must trigger.

The following alarms can be selected for immediate action from the Control Centre or Contact Centre: Over Voltage, Low Voltage, Over Current, Low Current, Lost of supply, Unbalancing and Earth Fault detection.

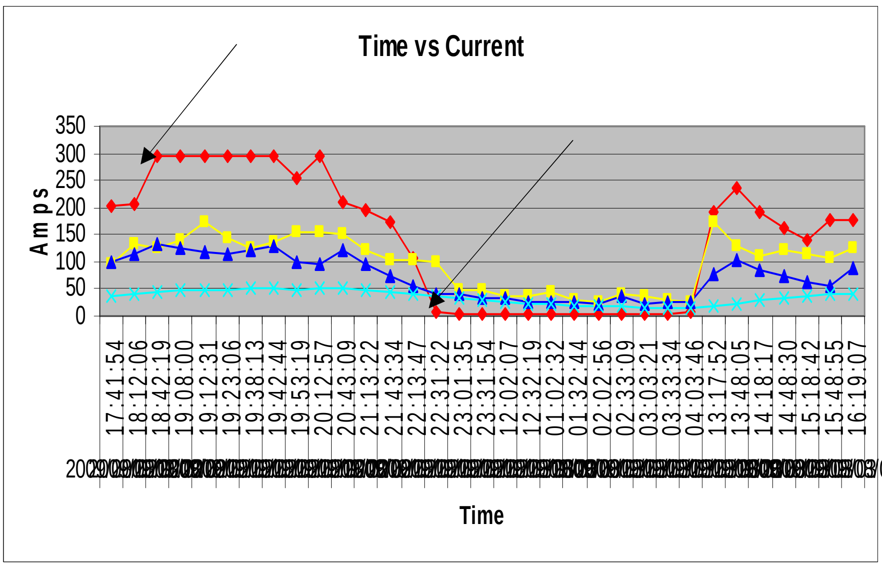

Figure 4 : Example of trigger points

The program will default on the alarm panel that will daily show the latest pole mounted transformers that went outside the dead bands. These alarms can be acknowledged and if the specific pole mounted transformer went back to its normal operating values, the alarm will disappear. If the situation is still abnormal the alarm will stay on, on the alarm panel but in yellow.

3. ACCURACY

The CVMs were not meant to be metering devices but was developed to provide load profiles to assist the planning department, energy balancing as well as to alarm abnormalities at the point of supply. During product evaluations the following errors were measured.

Current Input	Red Phase	Percentage error	Voltage Input	Red Phase	Percentage error	Eatrh Fault Current	Measured	Percentage error
0	0	#DIV/0!	70	70	0.00	0	0	#DIV/0!
5	4.9	-2.00	80	80	0.00	0.1	0	-100.00
10	10	0.00	90	90	0.00	1	0.905	-9.50
15	15.2	1.33	100	99.9	-0.10	2	1.9	-5.00
20	19.9	-0.50	110	109.9	-0.09	5	4.95	-1.00
30	29.9	-0.33	120	119.8	-0.17	10	10	0.00
40	39.9	-0.25	130	129.8	-0.15			
50	50	0.00	140	139.8	-0.14			
60	60	0.00	150	149.8	-0.13			
70	70.1	0.14	160	159.7	-0.19			
80	80.3	0.37	170	169.6	-0.24			
90	90.3	0.33	180	179.7	-0.17			
100	100.4	0.40	190	189.6	-0.21			
150	150.8	0.53	200	199.6	-0.20			
200	201.2	0.60	210	209.6	-0.19			
250	251.6	0.64	220	219.6	-0.18			
300	302.1	0.70	230	229.6	-0.17			
350	352.4	0.69	240	239.6	-0.17			
400	402.9	0.72	250	249.5	-0.20			
450	453.1	0.69	260	259.4	-0.23			
500	503.8	0.76	270	269.5	-0.19			
550	554.3	0.78	280	279.4	-0.21			
600	604	0.67						
650	652	0.31						
700	702.6	0.37						
750	753.2	0.43						

Figure 5 : Accuracy table

4. PRACTICAL RESEARCH RESULTS

Up to date there are more than 150 CVM’s installed. A few examples of graphs were selected to provide insight into the problems that Eskom are facing.

4.1 An example of low voltages on a transformer

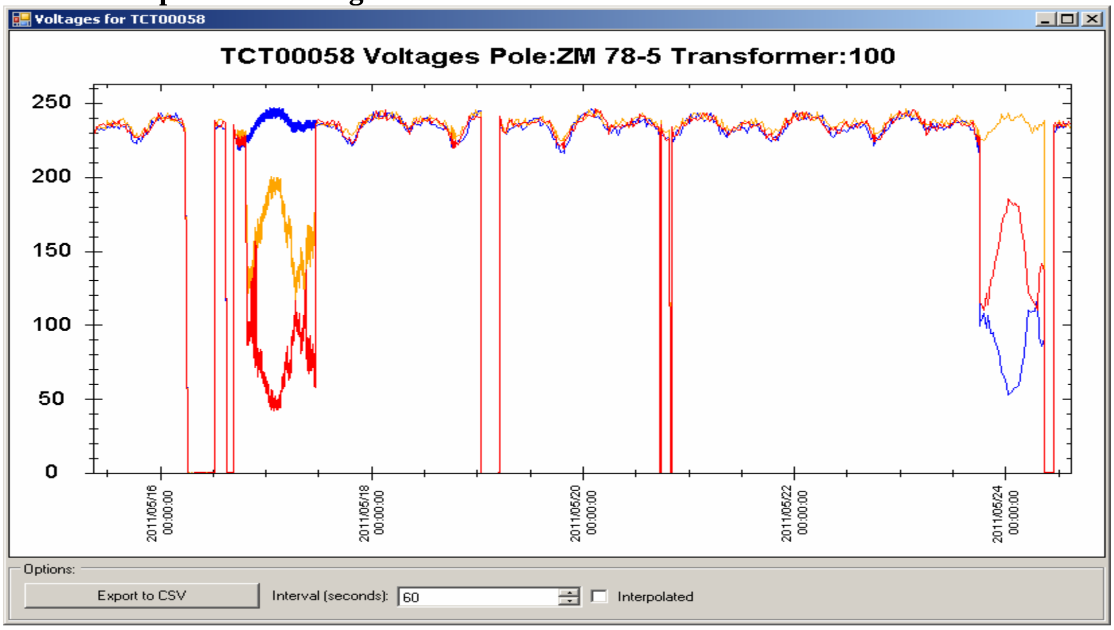

Figure 6: Over head conductor that burned off causes low voltages on the 400 V side

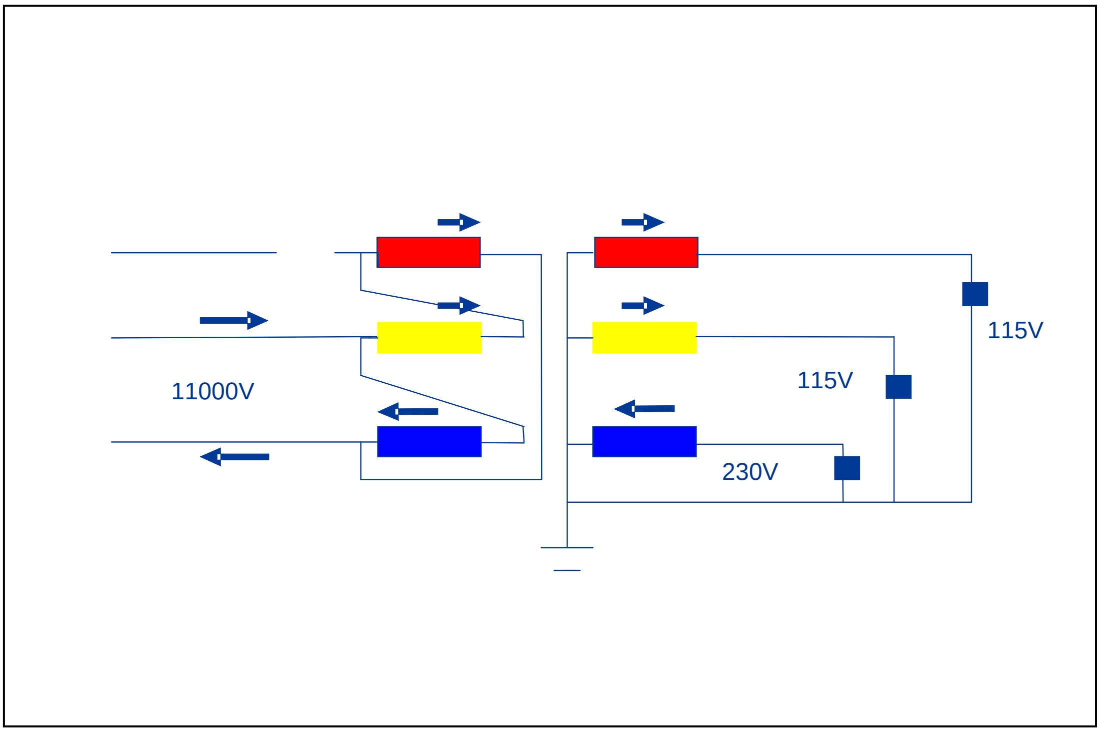

Figure 7: Red phase open conductor causes low voltages at customers (115V instead of 230V)

4.2 An example of an over loaded transformer

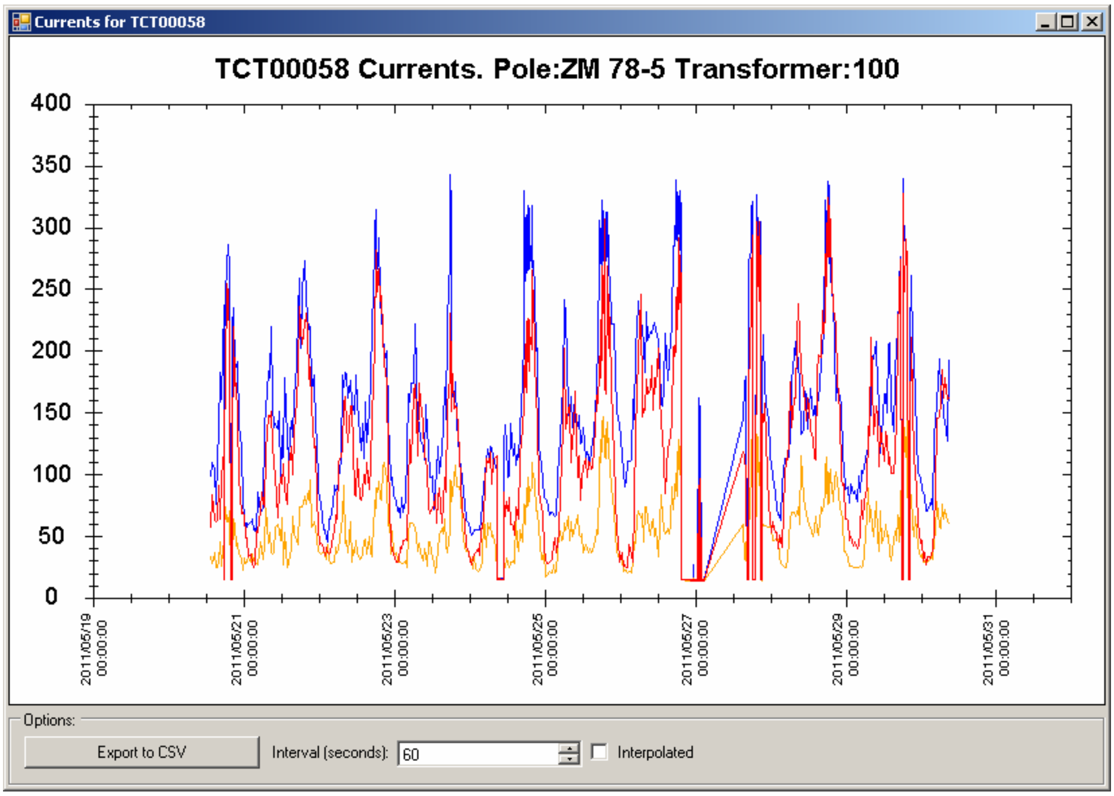

Figure 8: Pole Mounted Transformer exceeds full load of 150 Amps by 100%

The graph in figure 8 is a typical example of an overloaded transformer. The reason for the over loading might be illegal additional customers, an increase in appliances or a lack of correct data for proper planning.

4.3 An example of an over voltage situation

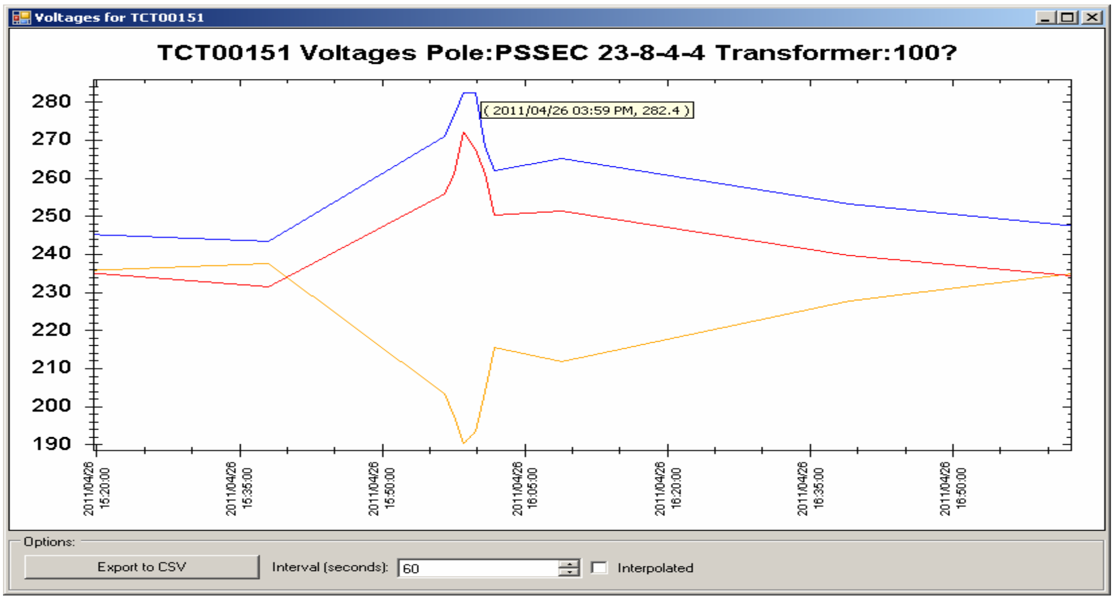

Figure 9: Loose Neutral connection on transformer. Some customers get over voltage and other low voltage

In figure 9 the phase to neutral voltage on the Red and Blue phase went up to 280 Volt. This is a typical example where the unbalanced current will flow through the neutral and the neutral connection will become so hot that it starts to lose its connection. The reason for the high voltage is because the reference point is now floating.

5. REVENUE COMPARISON

5.1 Methodology

As most of the customers in this energy usage category are pre-paid customers, it is not easy to compare revenue with the actual energy consumption. For this study the principle was used that an average revenue and energy consumption over a five month period will be used. Taking into account that the measuring equipment is not Class 0,2 accuracy, the results can only give an indication. The revenue and kWh per customer linked to a specific transformer were used and compared to the actual kWh and KVA measured at the transformer. Four Pole Mounted Transformers were selected for the exercise. See figure 10.

5.2 Actual Results for Pole Mounted Transformer 1 as an example:

Account	Revenue	Account	Revenue	Account	Revenue	Account	Revenue	Account	Revenue	
87	37	87	38	87	42	87	42	87	32	46
9774763678	9774763678	9774763678	9.77E+09	9774763678	9.77E+09	9774763678	9774763678	9774763678	5777256474	
8363800004	7571280705	8363800004	5.78E+09	8363800004	7.57E+09	8363800004	5777256474	8363800004	9770733910	1
9477511381	9770733910	9477511381	7.57E+09	9477511381	9.77E+09	9477511381	7571280705	9477511381	7144476577	1
9805229713	7032583213	9805229713	9.77E+09	9805229713	7.03E+09	9805229713	9770733910	9805229713	6378664327	
6074465385	7144476577	6074465385	7.03E+09	6074465385	7.14E+09	6074465385	7144476577	6074465385	7068223244	
7606832163	7983782972	7606832163	7.14E+09	7606832163	5.82E+09	7606832163	5819139626	7606832163	6564961867	1
5092873288	7566318295	5092873288	5.82E+09	5092873288	7.98E+09	5092873288	7983782972	5092873288	8359238068	
8985835288	7709223200	8985835288	7.57E+09	8985835288	7.57E+09	8985835288	7566318295	8985835288	8297124759	
5777256474	6378664327	5777256474	6.38E+09	5777256474	6.98E+09	5777256474	6378664327	5777256474	7922861481	
6102882052	7080996160	6102882052	7.07E+09	6102882052	6.38E+09	6102882052	5699461420	6102882052	7626939662	
5707213249	7068223244	5707213249	5.7E+09	5707213249	5.7E+09	5707213249	6564961867	5707213249	8769683043	
7388501655	5699461420	7388501655	8.77E+09	7388501655	8.77E+09	7388501655	8359238068	7388501655	5200420201	1
5951280312	8769683043	5951280312	5.2E+09	5951280312	5.2E+09	5951280312	7922861481	5951280312	6987040561	
6547074935	5200420201	6547074935	6.99E+09	6547074935	6.99E+09	6547074935	8769683043	6547074935	6964911875	
7926879279	6987040561	7926879279	6.96E+09	7926879279	6.96E+09	7926879279	5200420201	7926879279	5590959648	
6096255663	6964911875	6096255663	5.59E+09	6096255663	5.59E+09	6096255663	6987040561	6096255663	8985835288	1
5957110916	5590959648	5957110916	8.99E+09	5957110916	8.99E+09	5957110916	6964911875	5957110916	5092873288	1
7524938343	8985835288	7524938343	5.09E+09	7524938343	5.09E+09	7524938343	5590959648	7524938343	7356420704	1
5980308409	5092873288	5980308409	9.94E+09	5980308409	9.94E+09	5980308409	8985835288	5980308409	5755934941	1
6256732269	9941760844	6256732269	7.36E+09	6256732269	7.36E+09	6256732269	5092873288	6256732269	6074465385	1
7144476577	7356420704	7144476577	5.76E+09	7144476577	7.18E+09	7144476577	9941760844	7144476577	5707213249	
7136155015	5755934941	7136155015	6.1E+09	7136155015	5.76E+09	7136155015	7356420704	7136155015	6547074935	1
5889416476	6102882052	5889416476	6.07E+09	5889416476	6.1E+09	5889416476	7184954990	5889416476	5889416476	
6027762462	6074465385	6027762462	5.71E+09	6027762462	6.07E+09	6027762462	5755934941	6027762462	6027762462	
5755934941	5707213249	5755934941	6.55E+09	5755934941	5.71E+09	5755934941	6102882052	5755934941	7868286889	
5808296505	6547074935	5808296505	6.03E+09	5808296505	6.55E+09	5808296505	6074465385	5808296505	7926879279	1
5098091275	5889416476	5098091275	7.87E+09	5098091275	5.89E+09	5098091275	5707213249	5098091275	5951280312	1
8504392014	6027762462	8504392014	7.93E+09	8504392014	6.03E+09	8504392014	6547074935	8504392014	7915780164	1
6378664327	7926879279	6378664327	9.81E+09	6378664327	7.39E+09	6378664327	5889416476	6378664327	9710924042	
6958396068	5951280312	6958396068	5.95E+09	6958396068	7.93E+09	6958396068	6027762462	6958396068	7507411119	1
6346745076	7915780164	6346745076	8.76E+09	6346745076	9.81E+09	6346745076	7868286889	6346745076	8183269968	
6840366784	9710924042	6840366784	7.92E+09	6840366784	5.95E+09	6840366784	7926879279	6840366784	7818982458	1
7032583213	6346745076	7032583213	6.35E+09	7032583213	6.84E+09	7032583213	9805229713	7032583213		
5916233894	7507411119	5916233894	8.99E+09	5916233894	7.92E+09	5916233894	5951280312	5916233894		1
7566318295	7520394101	7566318295	7.51E+09	7566318295	9.71E+09	7566318295	7397313708	7566318295		
7184954990	7199443829	7184954990	7.52E+09	7184954990	6.35E+09	7184954990	7915780164	7184954990		1
8769683043	7818982458	8769683043	7.2E+09	8769683043	8.99E+09	8769683043	9710924042	8769683043		
6964911875		6964911875	7.82E+09	6964911875	7.51E+09	6964911875	6346745076	6964911875		
5701072815		5701072815		5701072815	7.52E+09	5701072815	7507411119	5701072815		1
7397313708		7397313708		7397313708	8.18E+09	7397313708	7520394101	7397313708		1
8763241175		8763241175		8763241175	7.2E+09	8763241175	8183269968	8763241175		1
7459587476		7459587476		7459587476	7.82E+09	7459587476	7199443829	7459587476		1
6983061214		6983061214		6983061214		6983061214		6983061214		1
5200420201		5200420201		5200420201		5200420201		5200420201		
6108695041		6108695041		6108695041		6108695041		6108695041		1
7868286889		7868286889		7868286889		7868286889		7868286889		
9227306074		9227306074		9227306074		9227306074		9227306074		1
7709223200		7709223200		7709223200		7709223200		7709223200		1
9941760844		9941760844		9941760844		9941760844		9941760844		
5699461420		5699461420		5699461420		5699461420		5699461420		
7626939662		7626939662		7626939662		7626939662		7626939662		1
6564961867		6564961867		6564961867		6564961867		6564961867		1
7058828499		7058828499		7058828499		7058828499		7058828499		1
7054361536		7054361536		7054361536		7054361536		7054361536		1
6155576931		6155576931		6155576931		6155576931		6155576931		1
8991492679		8991492679		8991492679		8991492679		8991492679		1
7068223244		7068223244		7068223244		7068223244		7068223244		
8297124759		8297124759		8297124759		8297124759		8297124759		1
5819139626		5819139626		5819139626		5819139626		5819139626		
7922861481		7922861481		7922861481		7922861481		7922861481		1
5794212011		5794212011		5794212011		5794212011		5794212011		1
7080996160		7080996160		7080996160		7080996160		7080996160		1
9381560932		9381560932		9381560932		9381560932		9381560932		1
6509768412		6509768412		6509768412		6509768412		6509768412		1
7818982458		7818982458		7818982458		7818982458		7818982458		
6298208357		6298208357		6298208357		6298208357		6298208357		1
7507411119		7507411119		7507411119		7507411119		7507411119		
7915780164		7915780164		7915780164		7915780164		7915780164		
7520394101		7520394101		7520394101		7520394101		7520394101		
7571280705		7571280705		7571280705		7571280705		7571280705		
8220579281		8220579281		8220579281		8220579281		8220579281		1
8183269968		8183269968		8183269968		8183269968		8183269968		
8230666090		8230666090		8230666090		8230666090		8230666090		1

Figure 10: Accounts vs Revenue.

From figure 10, the yellow colored figures indicate the Premises Account Numbers that has not received revenue for that month. For this study the assumption was made that if a Premises Account Number did not receive revenue for three months then that premises should be investigated

5.3 Results of four Pole Mounted Transformers investigated

		January 2011		February 2011		March 2011		April 2011		May 2011	
		kWh	Revenue	kWh	Revenue	kWh	Revenue	kWh	Revenue	kWh	Revenue
TEH 72-12-7-4	Totals	9904.9	6489.3	11033.4	7229.2	10600.5	6944.1	10927.9	7957.8	8627.6	6157
(92 Tot Cust)	Number of customers paying	75		76		79		82		82	
	Measued							9437	6182.75	10061	6591.571
	Percentage kWh diff							15.7		14.24	
	Average kWh per customer per day according to revenue	4.26		5.18		4.33		4.44		3.39	
	Average kWh per customer per day according to measurement							3.84		3.96	
TEH 72-2-13	Total			7033.3	4609.4	7344.7	4813.2	8060.9	5761.2	6103.1	4281
(92 Tot Cust)	Number of customers paying			72		72		75		73	
	Measured					9409	6166.358	10125	6635.601	10534	6903.647
	Percentage kWh diff					21.9		20.36		42	
	Average kWh per customer per day according to revenue			3.49		3.29		3.58		2.70	
	Average kWh per customer per day according to measurement					4.22		4.50		4.65	
PSSEC 23-6-2	Totals	25987.6	17032.5	22165.7	14528.4	23979.9	15718.2	20589	15790.6	15653.7	11864.4
(168 Tot Cust)	Number of customers paying	115		112		112		105		101	
	Measured			57918.65	37962.5	64505.85	42280.04	68296.98	44764.92	77145.3	50564.51
	Percentage kWh diff			61.7		62.8		69.8		79.7	
	Average kWh per customer per day according to revenue	7.29		7.07		6.91		6.54		5.00	
	Average kWh per customer per day according to measurement			18.47		18.58		21.68		24.64	
NT11-9	Totals	10990	7182	8435.1	5503.4	10263.5	6726	10507.7	8362	7213.7	5836
(87 Tot Cust)	Number of customers paying	37		38		42		42		32	
	Measured			51516		58995		67714	44014.1	82194	
	Percentage			83.6		82.6		84.4		91.2	
	Average kWh per customer per day according to revenue	9.58		7.93		7.88		8.34		7.27	
	Average kWh per customer per day according to measurement			48.42		45.31		53.74		82.86	

Figure 11: Summary of kWh measured vs kWh used according to revenue received.

In figure 11 the “Totals” row indicates the kWh and revenue received according to the billing system. The “Measured” row indicates the actual kWh for that month. The “Percentage kWh difference” indicates the percentage difference between the actual measured valued and the kWh received.

The Pole Transformer “NT 11-9” has a 91,2 percent difference in May. Actual revenue received for April was R 8 362 and the revenue that should have been received R 44 014. That results in a loss of R35 652. It is clear from figure 11 that outstanding revenue is not the only criteria but that some customers might only pay part of the electricity consumed.

6. CONCLUDING REMARKS

With the implementation of the CVM’s on the Eskom LV networks the quality of supply can be monitored and improved. The load profiles will indicate which Pole Mounted Transformers are due for upgrading. The line parameters as well as the source capacity can be pro-actively be evaluated. The real time alarms allow for speedy reaction time on power failures and thus quicker restoration of supply.

By comparing the measured kWh, with the kWh consumed according to the database, areas can be identified where possible theft or illegal connections are causing over loads. These points will have to be visited and corrected. With the capital outlay of new power substations it is critical that all South Africans should pay for the quantity of electricity used.

7. REFERENCES

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